ISSN: 2141 – 3290

EVALUATION OF GEOTECHNICAL PROPERTIES OF LATERITE SOILS IN ASA-DAM AREA, ILORIN, SOUTHWESTERN NIGERIA

OMOTOSO, O. A., MAMODU, M. O., AND OJO, O. J.*

Department of Geology and Mineral Sciences,
University of Ilorin, Ilorin
**Corresponding author; E mail – solafoluk@yahoo.com*

ABSTRACT: Two lateritic soils (ASA1 and ASA2) were examined for their suitability as construction materials based on their geotechnical properties and permeability. The samples were collected from a road cut at depths of 2.0m and 2.5m respectively along Asa-dam/Offa garage road in Ilorin metropolis, southwestern Nigeria. The grain size analysis shows that the sample ASA1 is silty-clayey sand (reddish brown lateritic soil) with 45% sand, 24% clay, 21% silt and 10% gravel while ASA2 is clayey sandy (brown lateritic soil) with 47% sand, 35% clay, 13% silt and 5% gravel and both are above the activity (A) line in the zone of intermediate plasticity clays (CI). Sample ASA1 contains normal clay (activity=1.15) while sample ASA2 contains inactive clay (activity= 0.6), which suggests that there is negligible or no swelling of the soils while chosen as construction materials. Analysis of samples ASA1 and ASA2 shows the following values; 27.6% and 22.6% for plasticity index; 8.6% and 9.2% for linear shrinkage; 44% and 46% for liquid limit; 16.4% and 23.4% for plastic limit; 2.61mm/sec and 2.72mm/sec for permeability respectively. The CBR values for soaked and unsoaked standard proctor and modified proctor range from 2% to 4%. The shear box tests give angle of internal friction of 31^0 and 33^0 with cohesions of 59kPa and 70kPa respectively. Based on the values obtained from the Atterberge consistency limit tests, grain size tests, permeability test, CBR tests, compaction tests and shear box tests, the soils are good for sub-grade materials in road construction, could support a moderately steep slope to a great height, could be used in dam and embankment construction and could also support the construction of drainage. Furthermore, the results show that the soils are not problematic as construction materials in most cases.

INTRODUCTION

The rate at which structures, most especially buildings and roads fail today calls for quick attention and lasting solution. The role of Engineering Geologists in providing solution cannot be over emphasized, especially when it comes to foundation construction. The geotechnical properties of soils on which a superstructure is to be constructed must be well understood in order to avoid superstructure and foundation failures.

The investigated area is based along Asa-Dam-Airport road within Ilorin, southwestern Nigeria where road expansion construction is mostly going on. It is situated within latitude 08^{o}26’22’’N and 08^{o}27’29’’N and longitude 04^{o}33’30’’E and 04^{o}34’60’’E (Fig 1). Because of the heterogeneous nature of some basement complex, there is the need to study the geotechnical characteristics of lateritic soils so as to know whether they could be useful as construction materials or not. It has been discovered that parent rock factors, geochemical and mineralogical factors influenced both engineering, index and geotechnical properties of lateritic soils (Little, 1971). Climatic features such as temperature variation, rainfall and transpiration influence geotechnical characteristics of soil. Correla, (1969) presented that parent rock, rock horizons and weathering conditions determine particulates constituents of lateritic soils. The failure of Lagos-Ibadan expressway in the southwestern Nigeria has been attributed to in-proportionate in its base and sub-grade materials (Adeyemi and Oyeyemi, 2000). The results of their investigation show that the sub-grade soils below the stable sections have a higher maximum dry density, unsoaked CBR and uncured, unconfined compressive strength than those below unstable sections. Permeability and grain-size distribution tests were also carried out. These tests enable the study of residual soils in relation to foundation condition (Idowu et al., 2010).

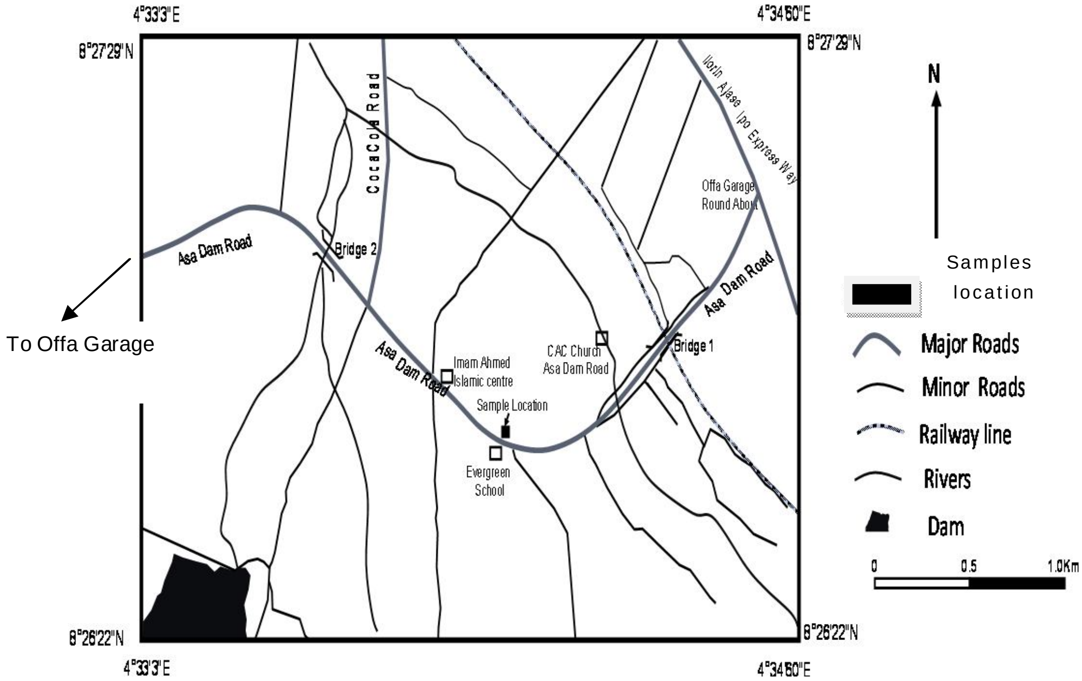

Figure 1: Sample location map showing sample locality

In this paper we examine the geotechnical properties of lateritic soils as well as their usefulness in engineering works in the study area.

MATERIALS AND METHODS

The lateritic soils sampled were collected from a road-cut vertical section, (2.70m deep) along Asa-dam/Offa garage road, Asa-dam area of Ilorin, Southwestern Nigeria (precisely longitude 08°26'50''N and latitude 04°33'60''E, (Fig.1). Three distinct horizons were identified and lateritic soil samples were collected from depth of 2.00m and 2.50m respectively, (Fig 2). The first horizon is the top soil which is composed of sand to gravel materials. The second is the lateritic horizon which is reddish brown in colour. The last horizon is the mottled zone.

The samples were subjected to the following tests: permeability, grain size distribution test, atterberg consistency limits test, California Bearing Ratio (CBR) test and shear box test.

The basic index properties were determined according to the Extended Unified Soil Classification System to Lateritic Soils, (Vallerga et al, 1969). The constant-head test was used to obtain the coefficient of permeability of the soil samples. Standard and modified proctor compaction tests were performed using the 10cm by 5cm diameter mould (volume = $1000cm^3$), number of layers =3/5, number of blows/ layer = 25/55, weight of rammer = 2.5kg, height of rammer =11.5cm, energy = 0.594N/M and 2.686N/M respectively.

Geology of the study area

The rocks in the study area are dominantly granite gneiss and banded gneiss. The gneisses are foliated with light and dark bands, and the main minerals are suspected to be quartz, feldspar and mica as observed from the petrographic analysis of the rock samples. There are quartzite veins which cut across one another. The main features observed on the rocks include: lineations, foliations, joints, fractures and folds (Figures 3a-d). The gneiss generally trend northeast direction and dip west.

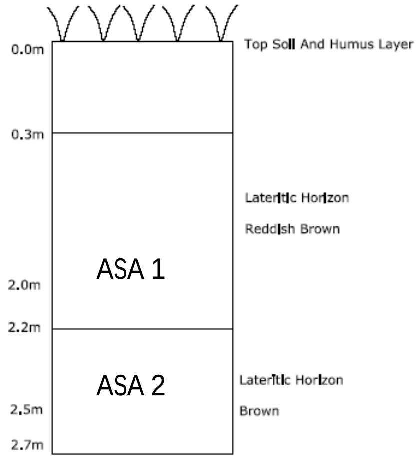

Figure 2: soil profile sample showing horizons and depths

Geotechnical Properties

Specific Gravity:

The results of the specific gravity analysis of both soil samples ASA1 and ASA2 are 2.67 and 2.64 respectively. Comparing these specific gravity values to some common soil types from Lambe, 1969 (Table 1), soil specimen ASA1 can be described as being a sand while soil specimen ASA2 can be said to be an inorganic soil which may or may not contain mica or iron. However, comparing these specific gravity values to that of Bowels, 1979 (Table 2), the two soils ASA1 and ASA2 can be described as sand.

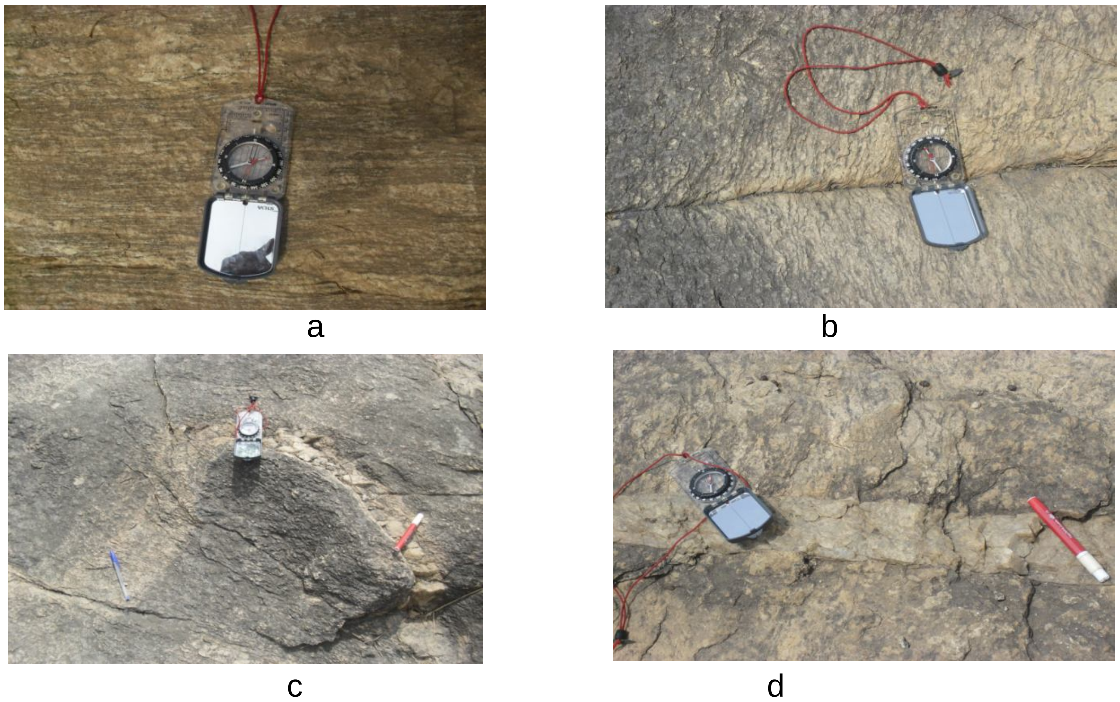

Fig 3. (a). A granite gneiss showing lineation. (b). A joint structure in granite gneiss; (c). An anticlinal fold in granite gneiss; (d). A quartzite vein in granite gneiss

Table 1: Typical values of specific gravity of soil sample (Lambe, 1969)

SOIL TYPES	SPECIFIC GRAVITY
Sand	2.65 – 2.67
Silty sand	2.67 – 2.70
Inorganic soil	2.70 – 2.80
Soil with mica or iron	2.75 – 3.00
Organic	Variable but may be under 2.0

Table 2: Typical values of specific gravity of soil samples (After Bowles, 1979)

SOIL	SPECIFIC GRAVITY
Sand	2.65 – 2.68
Gravel	2.65 - 2.68
Clay (Organic)	2.52 – 2.66
Clay (Inorganic)	2.68 – 2.72
Silt	2.68 – 2.68

RESULTS AND DISCUSSION

Grain Size Analysis

The graphical representation of the results of the grain size analysis of soil sample ASA1 gave an indication of sand, silt and clay to be higher than gravel, but sand predominates with percentage composition of 45%, clay of 24%, silt of 21% and gravel making up 10% each and thus is silty-clayey sand, while sample ASA 2 is clayey sand, being composed of 47% sand, 35% clay, 13% silt and 5% gravel. This shows that each sample have sand to be predominant in its soil specimen (Figs. 4a and 4b). Interestingly, these values closely compared with Ogunsanwo (1989) in his evaluation of some properties of Laterite soil as engineering construction material in the western part of the country. Sand has the greatest percentage with appreciable amount of clay making it suitable for the description.

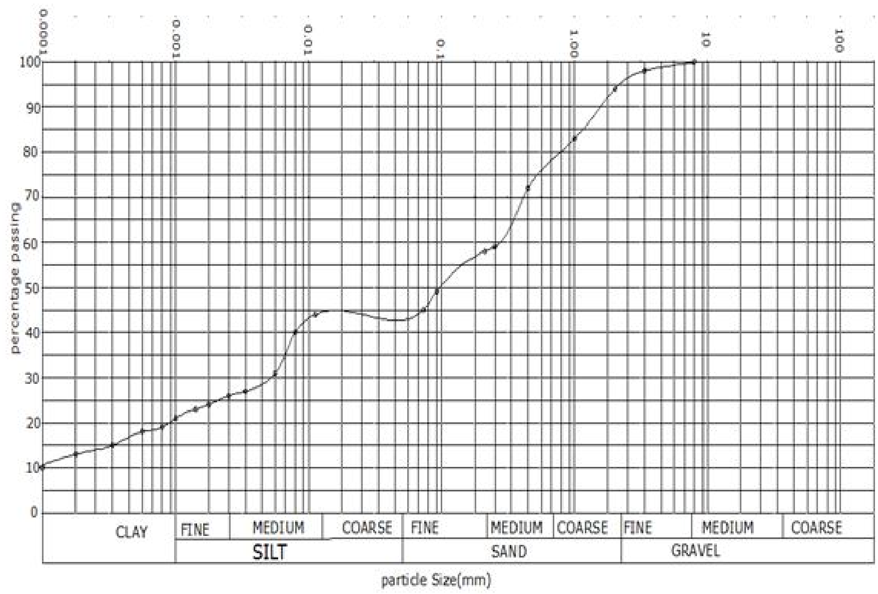

Figure 4a: Particle size distribution curve for sample ASA 1

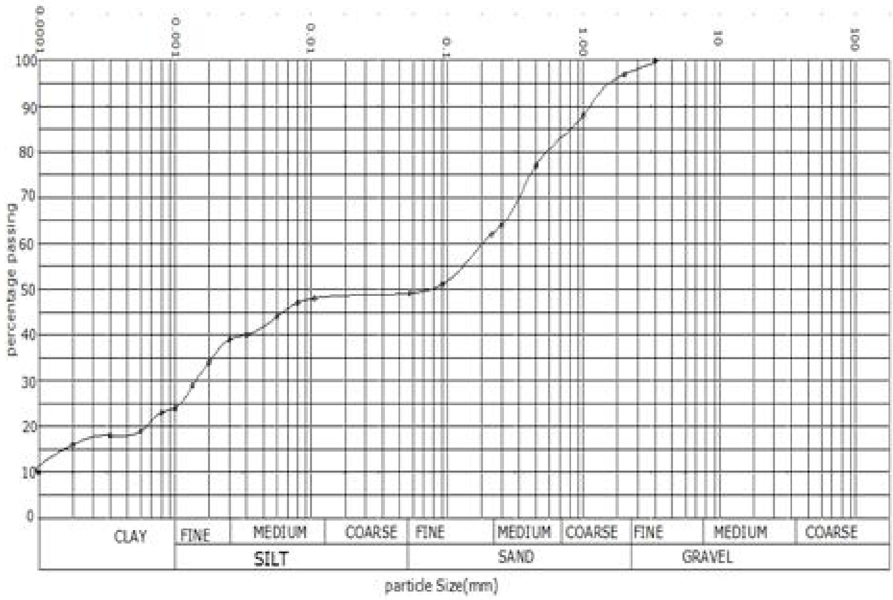

Figure 4b: Particle size distribution curve for sample ASA 2

The various percentage compositions of the grain sizes in samples ASA 1 and ASA 2 show that the grain sizes are not evenly distributed and this suggests a poor grading. On the engineering chart, samples ASA 1 and ASA 2 have a group symbol of SC, they are impervious, have good to fair shearing strength when they are compacted and saturated, low compressibility when compacted and saturated, and has a good workability as construction material which could resist erosion. The two samples according to the following results suggest that they can be used in the construction of earth dams.

Atterberg Limit Determination

The results of Atterberg consistency limits carried out on sample ASA1 and ASA2 gave plasticity index of 27.6% and 22.6%; linear shrinkage of 8.6% and 9.2% respectively. The results therefore classified ASA1 and ASA2 as having a low volume change potential. Sample ASA1 has liquid limit of 44%, plastic limit of 16.4%, and sample ASA 2 has liquid limit of 46.0% and plastic limit of 23.4%. Sample ASA 1 has activity value of 1.15 which is therefore classified as containing a normal clay type, sample ASA 2 is also classified as containing an inactive clay type based on its activity value which is 0.65 (Das, 2006). These values together with the shrinkage limits exhibited by the soil samples suggest that they have very little potential to swell or shrink. They are therefore expected to show minimum shrinkage when dry, thus lowering the risk of the soil to fail when used as sub-grade materials in construction. Also, the Atterberg values obtained could be compared with the values obtained by Ogunsanwo (1988) who concluded that 'the soil should be good engineering construction materials when compacted'.

The plot of the results of plasticity index against water content show both samples ASA 1 and ASA 2 are above the activity (A) line in the zone of intermediate plasticity clays (CI), which, means that they are inorganic soils (Figure 5). According to the engineering use chart, both soil samples ASA 1and ASA 2 are impervious and inorganic clays which can thus be used as erosion resistance in canal construction. They can also be used as a homogenous embankment in rolled earth dams because of their: good to fair workability as construction materials, medium compressibility when compacted and saturated and their fair shearing strength when compacted and saturated (Wagner, 1957).

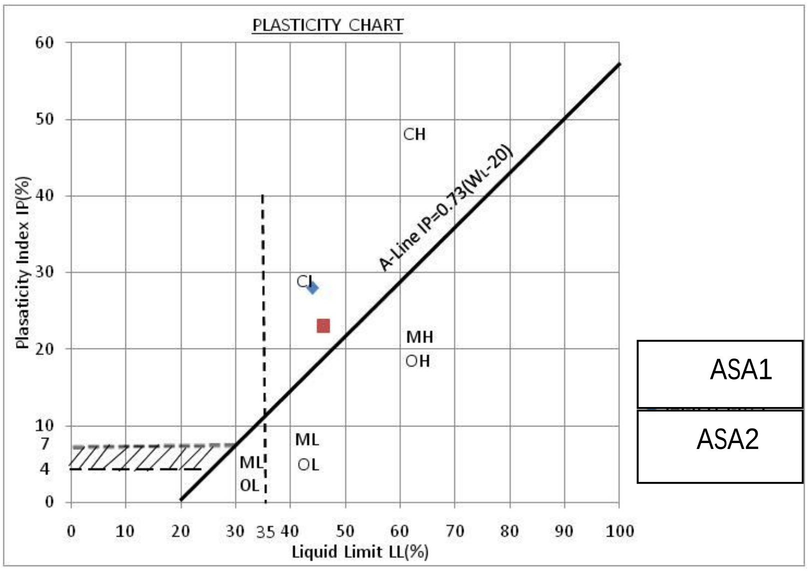

Figure 5: Plots of soil samples ASA 1 and ASA 2 on the plasticity chart.

Permeability
Using constant-head test, the coefficient of permeability determined for ASA1 and ASA2 are: 2.61mm/sec and 2.72mm/sec respectively which could be classified as soil of intermediate permeability which is however better for drainage construction.

California Bearing Ratio, CBR
The CBR values of the samples are stated in Table 3 and Table 4 shows the general rating of soil materials based on the CBR values of the materials. Soils meet the requirements better when they are classified based on the CBR values of the soaked materials. For sample ASA1, CBR values indicates a very poor general rating based on its CBR values, which thus means that it can only be used as sub-grade material in road construction. Sample ASA 2 also have a very poor general rating based on its soaked CBR values which means it is also only good for sub-grade material in road construction. The unsoaked CBR test results shows that ASA1 can be used as a sub-base material in road construction and ASA 2 can also be used as sub-base material in road construction based on the modified unsoaked CBR values of both samples which are 4% and 5%.

Table 3: CBR values for ASA1 and ASA2

DEPTH OF PENETRATION	**UNSOAKED STANDARD PROCTOR**		**UNSOAKED MODIFIED PROTOR**		**SOAKED STANDARD PROCTOR**		**SOAKED MODIFIED PROTOR**	
	ASA1	ASA2	ASA1	ASA2	ASA1	ASA2	ASA1	ASA2
CBR at 2.5mm	4%	4%	4%	5%	2%	3%	3%	3%
CBR at 5.0mm	3%	3%	3%	4%	2%	2%	2%	2%

Table 4: General rating for soil based on CBR values (After Asphalt Institute 1962)

CBR NO	**GENERAL RATING**	**USES**	**CLASSIFICATION UNIFIED**	**SYSTEM AASHTO**
0 -3	Very poor	Sub – grade	OH, CH, MH, OL	A5, A6, A7
3 -7	Poor-fair	Sub – base	OH, CH,MH,OL	A4, A5, A6, A7
7 -20	Fair	Base	OL, CL, ML, SC, SM, SP.	A2, A4, A6. A7
20–50	Good	Asphalt material	GM, GL, SIN, SM, SP, GP, W, GM	Aib, A2 – 5, A3, Ala, A2 – 4, A3

Shear Box Test

Shear box results obtained for sample ASA1 at compacted energy of standard Proctor and modified Proctor gave angle of internal friction of 31^0 and 30^0 respectively, cohesion of 59kPa and 72kPa respectively for standard and modified Proctor compacted soil samples. For soil sample ASA2, the angles of internal friction are 33^0 and 29^0 for the standard Proctor and the modified Proctor respectively, with cohesion of 70kPa and 90kPa under the same conditions. According to the Unified Soil Classification, the results obtained from the shear box test are used to classify soils according to their angle of internal friction. A soil having angle of internal friction less than 20^0 are classified as soft, between $20\text{-}35^0$ are classified as hard and above or greater than 35^0 are classified as stiff. The shear box test shows that the soils are of high strength (Figures 6a-6d). The results obtained favourably compare with Alao (2011), that is, they fall within the same range.

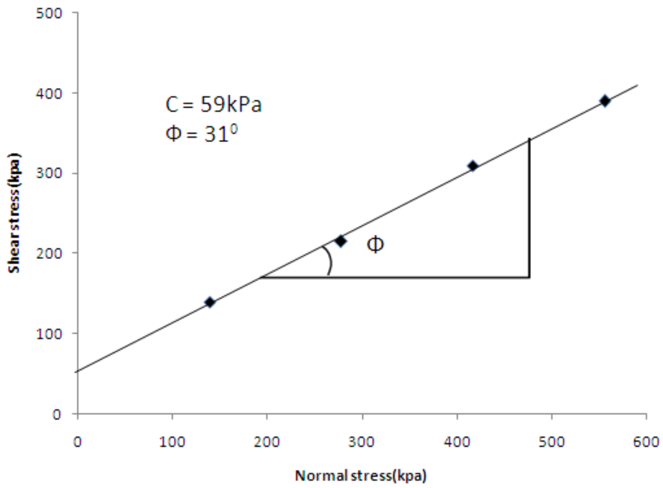

Figure 6a: Shear stress (KPa) against normal stress (KPa) for standard proctor compacted soil ASA 1.

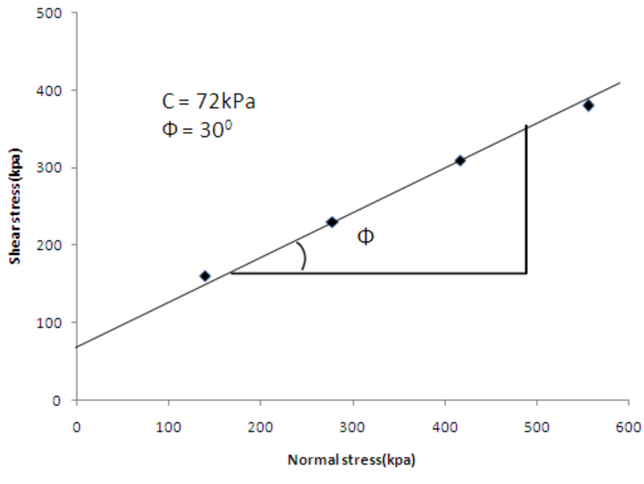

Figure 6b: Shear stress (KPa) against normal stress (KPa) for modified proctor compacted soil ASA 1

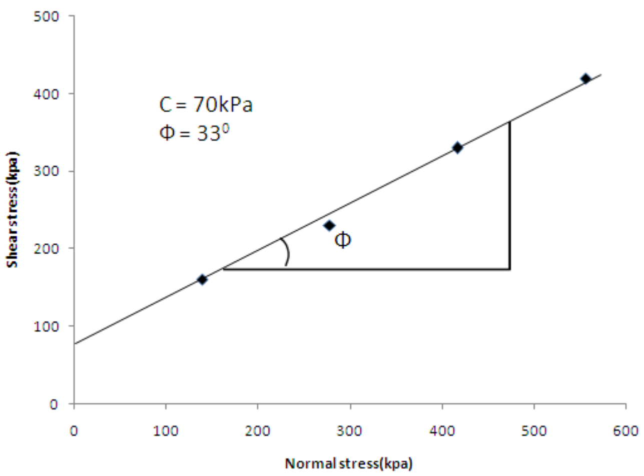

Figure 6c: Shear stress (KPa) against normal stress (KPa) for standard proctor compacted soil ASA 2

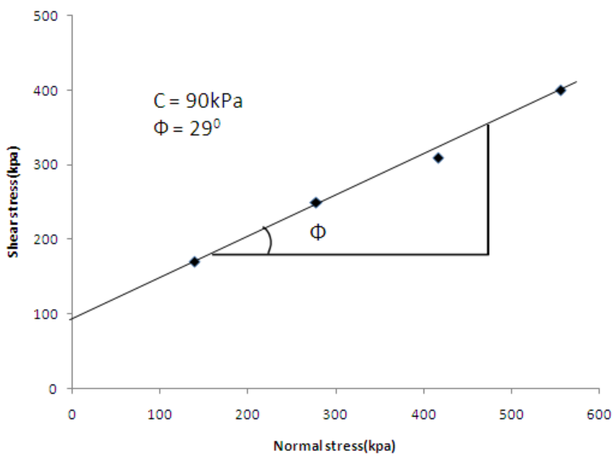

Figure 6d: Shear stress (KPa) against normal stress (KPa) for modified proctor compacted soil ASA 2

Also, Das (1990) provided typical values of angles of internal friction for lateritic soils ranging from 26-45^0, it can be deduced from the results of the test that the soil sample ASA1 and ASA2, have a medium angle of internal friction. Therefore, the soil samples can be classified as hard, according to the above references. This therefore implies that the foundation design for the area will be a shallow foundation; the values also indicate that the soil samples ASA1 and ASA2 can support a moderately steep slope to a greater height.

The shear box text reveals that the soils are of high strength having cohesion values 59kPa and 72kPa with angles of internal friction of 31^0 and 30^0. The plots of shear stress against normal stress for the samples are shown in Figures 6a-6d.

CONCLUSION

The grain size analysis shows that the sample ASA1 is silty-clayey sand (reddish brown lateritic soil) with 45% sand, 24% clay, 21% silt and 10% gravel while ASA2 is clayey sandy (brown lateritic soil) with 47% sand, 35% clay, 13% silt and 5% gravel. The soil samples are above the activity (A) line in the zone of intermediate plasticity clays (CI). Sample ASA1 contains normal clay (activity=1.15) while sample ASA2 contains inactive clay (activity= 0.6), which suggests that there is negligible or no swelling of the soils while chosen as construction materials. The soil samples' coefficients of permeability are 2.61mm/sec and 2.27mm/sec respectively. The CBR values fall within the range of 0-3 and 3-7 for both ASA1 and ASA2, as a deduction from the results of the soaked CBR values of soil samples ASA1 and ASA2, they could be used as sub-grade materials in high way or road constructions. The results from the uniaxial shear box tests shows that both ASA1 and ASA2 have a medium angle of internal friction which ranges from 29^0-33^0 with cohesion of 59KPa-90KPa, this means that the foundation design of the area will be shallow foundation and could support moderately steep slopes to a great height. The petrography analysis shows that the dominant minerals are quartz, feldspars and micas. These minerals are commonly found in igneous and metamorphic rocks such as granite and gneiss. This is indicative of the parent rock of the lateritic soils, they could be granite gneiss derived.

REFERENCES

Adeyemi, G.O. and Oyeyemi, F.: (2000). Geotechnical basis for failure of sections of the Lagos-Ibadan expressway, southwestern Nigeria. Bulletin of the Engineering Geology and environment, Springer Verlag. (59): Pp 39-45.

Alao, D. A. and Opaleye, S. T. (2011). Geotechnical analysis of slope failure of a Kaolin Quarry at Kurra, Jos North-central. Inter Jour. of Scientific Research . (1) 1 87-102.

Bowels, J. E. (1979). Physical and geotechnical properties of soil. Mcgraw-hills incorporation 2^{nd}

Correla, F.G. (1969). Engineering geology and geo-technics. Text. 2^{nd} ed, Macmillian.pp115.

Das, B.M. (2006) Principles of geotechnical engineering. Stamford, CT: Thomson Learning College, edition,pp 418.

Das, M. D. (1990). The importance of soil genesis in the engineering classification of Ghana soils. Engineering Geology, 5(2), 117–161.

Idowu, S.O., Adeyemi, G.O. and Dada, S.S. (2010). Permeability and grain-size characteristics of Shagamu and Ibadan-Toll-Gate Lateritic soils in southwestern Nigeria. Journal of Environmental Sciences and Resources Management (2). Pp 86-94.

Kogbe, C. A. (1989). Geology of Nigeria, 2nd edition, pp 538.

Lambe, T. W., and Wihtman, R.V. (1969). Soil Mechanics, J. Wiley and Sons, New York, pp 165.

Little, A.A. (1971). The engineering classification of residual tropical soils. Proc.Sec.Sess. Laetritc soils Int. Conf. Soil meh. /Founation Engineering. 7^{th} ed, Mexico, (1), 186p.

Ogunsanwo, O (1989). Basic Geotechnical properties, Chemistry and Mineralogy of some Lateritic soils from south-western Nigeria. Bulletin of the International Association of Engineering Geology. Paris, No37, p.135.

Vallerga, B.A., Schuster, J.A., Love, A.L. and Van TIL, C.J. (1969). Engineering study of Laterite and Lateritic soils in connection with construction of Roads, Highways and airfields. USAID, Report AID/CSD, 1810.

Wagner, A.A. (1957). The use of the Unified soil classification system by the Bureau of Reclamation. Proc. 4^{th} ICSMFE, London, 1: 125.

ACKNOWLEDGEMENTS

Authors are grateful to staff of the Civil Engineering Department Laboratory of the University of Ilorin, Nigeria, for their technical assistance during the laboratory aspect of the work.