Evaluation of Geotechnical Properties of Ilesha East Southwestern Nigeria's Lateritic Soil.

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ABSTRACT

This paper aims at presenting the geotechnical properties of lateritic soil found within Ilesha East Local Government Area, Southwestern Nigeria and environs. For this to be achieved, the following laboratory soil tests were carried out during the course of research viz: particle size analysis test, Atterberg limit test, British standard light compaction test, specific gravity, and California bearing ratio in accordance with British Standard 1377 (1990) and Head (1992).

Grain size analysis shows that the percentages passing No. 200 BS sieve are 69%, 51%, 33%, 34%, 56%, 32%, 50%, and 64% for samples P1, P2, P3, P4, P5, P6, P7, and P8, respectively. The liquid limit ranges between 15.5% and 48.6%, plastic limit ranges between 4.66% and 25.60%, and the plasticity index ranges between 7.17% and 23%. California bearing ratio (unsoaked) ranges between 37% and 85%. The specific gravity ranges between 2.61 and 2.80 while the maximum dry density ranges between 2.3Mg/m3 and 2.62Mg/m3 with their optimum moisture contents ranging between 14.5 to 28.0%.

According to USCS soil classification, samples P3, P4, and P6 can be classified as well-graded soil thus be considered as good for subgrade and subbase materials. Sample P7 (Ilerin) is considered as a very poor soil thus should not be used as highway construction materials while others are properly graded thus be used as filling materials.

(Keywords: particle size analysis test, Atterberg limit test, British standard light compaction test, specific gravity, California bearing ratio, soil classification, geotechnical properties)

INTRODUCTION

The definition of latenite which had wide acceptance among authors state that 'laterite is a highly weathered material, rich in secondary oxides of iron, aluminum, or both. It is void or nearly void of bases primary silicates, but it may contain large amounts of quartz and kaolinite' (Alexandra and Cady, 1962).

Another definition categorized lateritic soils into laterite, lateritic, and non-lateritic soils, depending on the silica (SiO_2) to sesquioxide ratios (Fe_2O_3, Al_2O_3) less than 1.33 are indicative of laterites, those between 1.33 and 2.00 show laterite and those greater than 2.00 of non-lateritic types(Bell,1993). This definition is not convenient from an engineering point of view especially where there is lack of adequate laboratory facilities.

For the purpose of this investigation, the definition that is adopted defines laterite as products of tropical weathering with red, reddish brown, or dark brown color, with or without nodules or concreting and generally (but not exclusively) found below hardened ferruginous crust or hard pan (Ola,1983) .

Latentic soils are formed in hot, wet tropical regions with an annual rainfall between 750mm to 3000mm (usually in area with a significant dry season) on a variety of different types of rocks with high iron content. The locations on the earth that characterized the condition fall in between latitudes 35^{o}S and 35^{o}N and. Laterite formation factors include climate (precipitations, leaching, capillary rise, and temperature) to topography (drainage), vegetation, parent rock (iron – rich rocks) and time. Of all these primary factors, climate is considered the most important (Gillot,1968).

Laterite profiles are generally of three types, those in which the crust is derived from (i) the overlaying soil (downward transport), (ii) the underlying weathered rock (upward transport), and (iii) those in which the crust forming material is deterital (i.e., transported and deposited and/or precipitated).

The laterite profiles that develop *in-situ* have a number of horizons. The horizons vary in thickness, hardness, and colors depending upon the degree of development and preservation of the profile. Laterites may occur as surface deposits of unhardened clayey soils, gravels, and as hard pans (Fookes, 1997). Thus, genesis and pedological factors (parent materials, climate, vegetation, topography, weathering period), degree or weathering (decomposition, sesguioxide enrichment, clay–size content, degree of leaching), position in the topographic site and depth of soil in the profile have great influence on the geotechnical properties, characteristics and field performance of lateritic soil (Gidigasu, 1976).

However, investigations on geotechnical and engineering properties of lateritic soils have been researched into in northern, eastern, and southwestern Nigeria (Ola, 1983; Gidigasu and Kuma 1987; Alao, 1980; Arumala and Akpokodje, 1987; Ogunsanwo, 1989; Agbede, 1992; Adeyemi, 2002; Oladeji and Raheem 2002; Adewoye et al., 2004; Agbede and Osuolale, 2005 and Bello, 2007; Bello et al., 2007). Hence there are no available data on the geotechnical and engineering properties of lateritic soil within the study area. This scenario has therefore prompted the need of this research work. Hence, the main aim of this investigation is to obtain geotechnical characteristics of lateritic soil in the study area to assess its suitability for highway construction and providing data for engineers, planners, designers and contractors.

LOCATION AND GEOLOGY OF THE STUDY AREA

The soil samples used in this study were obtained from borrow pits in Ilesha within longitude $4^0$45'E – $4^0$49'E and latitude $7^0$35'N - $7^0$40'N (Figure 1) using the method of disturbed sampling. The areas include Ikesa, Imo, Kajola, Iroko, Ijofin, Bolorunduro, Ilerin, and Ilesha Farm Institute as shown on Figure 2. Geologically, the study area falls within the basement complex of southwestern Nigeria. It forms part of the African crystalline shield which consists predominantly of migmatised and undifferentiated gneisses and quartzite (Akintola, 1982 and Areola, 1982). The precipitation is moderate from May to October each year. The rain decreases in both frequency and intensity from south to north. The area has an average precipitation of 200mm. The vegetation is mostly guinea savannah, with its characteristics grass cover together with shrubs and medium-sized tress. The major mineral resources is gold, which is found a at Iperindo schist belt (Awogboro, 2007).

MATERIALS AND METHODS

Preparation of Specimens: Samples and specimens were prepared in accordance with BS1377 of 1990 and Head (1992). Prior to preparing the test specimens, the materials were air-dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

Test Procedures: The following tests viz; sieve analysis, Atterberg limit, compaction, California bearing ratio, specific gravity, and unconfined compressive strength were carried out on each of the disturbed samples. The procedures of these tests are as follows:

Sieve Analysis: Representative sample of approximately 500g was used for the test after washing and oven-dried. The sieving was done by mechanical method using an automatic shakers and a set of sieves.

Liquid Limit Determination: Soil sample passing through 425μm sieve, weighing 200g was mixed with water to form a think homogeneous paste. The paste was collected inside the Casangrade's apparatus cup with a grove created and the number of blows to close it was recorded. Also, moisture contents were determined.

Plastic limit determination: Soil sample weighing 200g was taken from the material passing the 425μm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball. The ball of soil was rolled on a glass plate until the thread cracks at approximately 3mm diameter. Therefore, the moisture contents were determined.

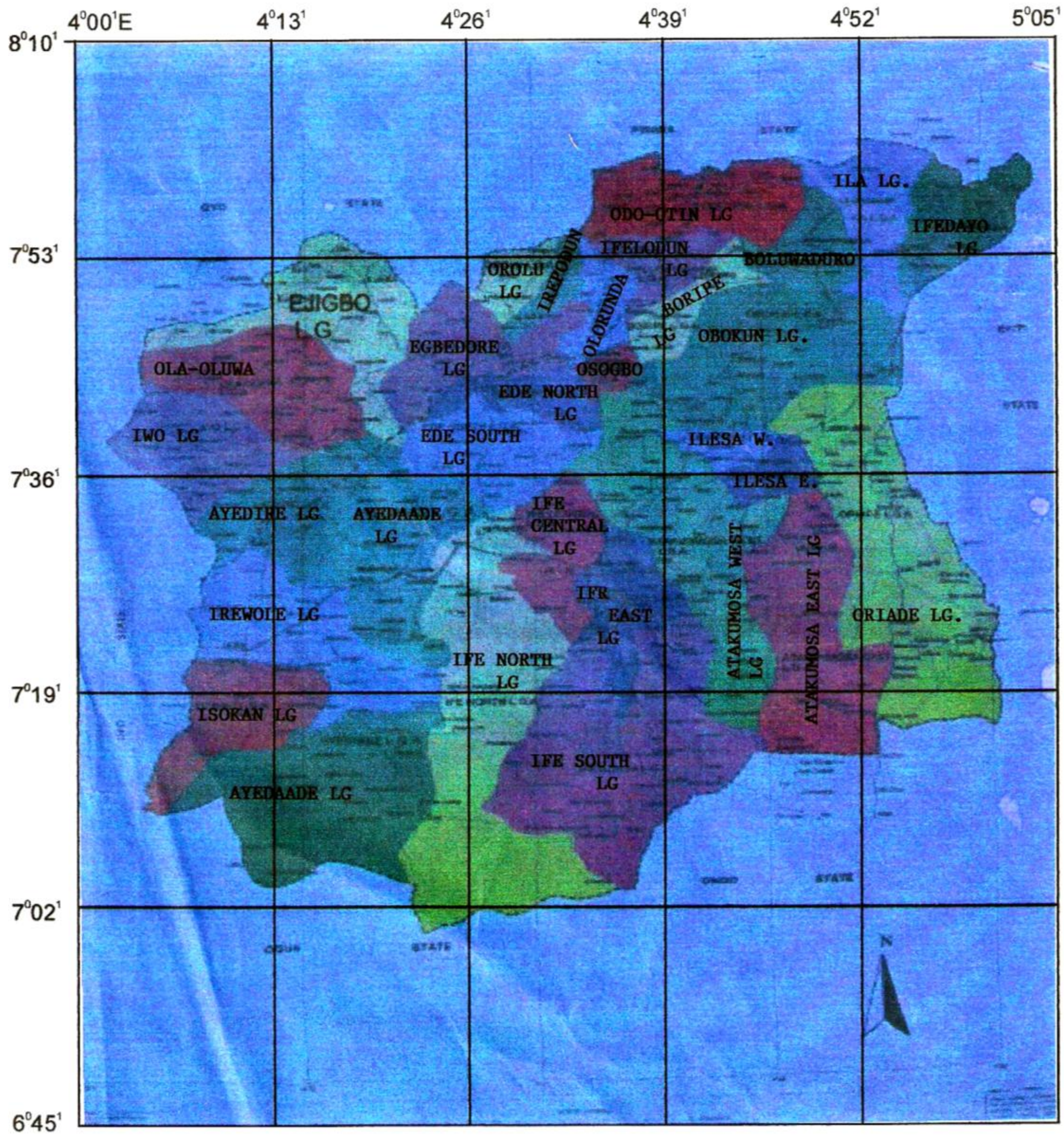

Figure 1: Local Government Map of Osun State.

California Bearing Ratio (CBR) test: Air-dried soil was mixed with about 5% of its weight of water. This was put in C.B.R mould in 3 layers with each layer compacted with 55 blows using 2.5kg hammer at drop of 450mm (standard proctor test). The compacted soil and the mould was weighed and placed under C.B.R machine and a seating load of approximately 4.5kg was applied. Load was recorded at penetration of 0.625, 1.9, 2.25, 6.25, 7.5, 10 and 12.5mm. The moisture content of the compacted soil was determined.

Natural moisture content, specific gravity and shrinkage limit: The determination of specific gravity, shrinkage limit and natural moisture content tests followed the standard as outlined in BS 1377 of 1990.

RESULTS AND DISCUSSION

Particle size distribution: The percentage of material passing through No.200 BS sieve ranges between 30-80%, which implies that the soil samples are in between coarse–grained and fined-grained soils according to USC systems.

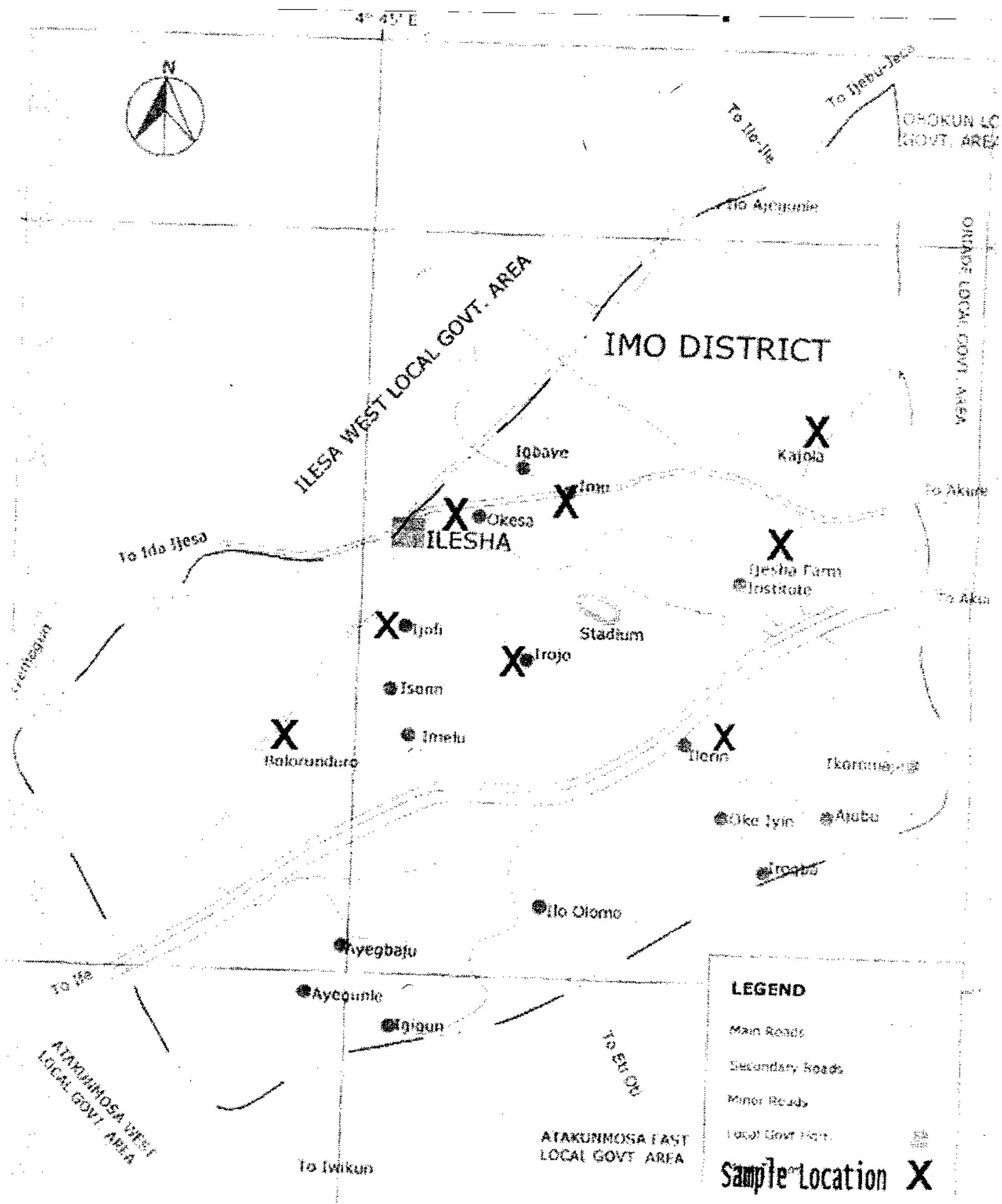

Figure 2: Ilesha East LGA Map indicating the Sample Locations.

The percentage of samples passing through No. 200 BS sieve for samples P1, P2, P3, P4, P5, P6, P7, and P8 are 69%, 51%, 34%, 33%, 56%, 32%, 80%, and 64%, respectively. Therefore samples P3, P4, and P6 can be classified as good-graded sample, while sample P1, P2, P5, and P8 are fair and sample P7 is poorly-graded. This according to Federal Ministry of Works and Housing (1972) specification, only sample P6 can be deduced as suitable for subgrade, subbase, and base materials as the percentage by weight finer than No.200 BS test sieve is less than 35%.

Atterberg limits, the liquid limits value, ranges between 15.5 to 48.6% while the plastic limits range between 4.7 and 25.6%. Plasticity index ranges between 7.2 to 23.0%. Federal Ministry of Works and Housing (1972) for road works recommend liquid limits of 50% maximum for subbase and base materials. All the studies soil samples fall within this specification, thus making them suitable for subbase and base materials.

California bearing ratio: The unsoaked California bearing ratio value for the lateritic soil sample range from 37% to 85%. Federal Ministry subgrade, subbase, and base soils be less than or equal to10%, 30%, and 80%, respectively. Thus all the samples satisfy the condition of subgrade and subbase while sample P4 can be used as excellent base materials.

Compaction: The maximum dry density for the soil samples varied between 2.30Mg/m^3 and 2.62Mg/m^3 while that of optimum moisture content ranged between 14.50% and 28.0%. According to O'Flaherty (1988) the range of values that may be anticipated when using the standard proctor test methods are: for clay, maximum dry density (MDD) may fall before 1.44Mg/m^3 and 1.685Mg/ m^3 and optimum moisture content (OMC) may fall between 20-30%. For silty clay MDD is usually between 1.6 and 1.845Mg/m^3 and OMC ranged between 15-25%. For sandy clay, MDD usually ranged between 1.76 and 2.165Mg/m^3 and OMC between 8 and 15%. Thus, looking at the results of the soil samples, it could be noticed that they are sandy clay.

Specific gravity: The specific gravity of the tested samples lies between 2.60 and 2.80. These values are suitable in accordance with Wright (1986) which states that the standard range of values of specific gravity of soils lies between 2.60 and 2.80. Lower specific gravity values indicate a coarse soil, while higher values indicate a fine grained soil (BS1377, 1990).

Physical properties of soil samples are presented in Table 1. Particle size and compaction results for the soil samples are illustrated in Figures 3 and 4, respectively.

CONCLUSION

The geotechnical properties of Ilesha-east Local Government Area southwestern Nigeria has been carried out in compliance with BS 1377 (1997) and head of (1990) methods of soil testing for Civil engineers. The result showed that the studied soil samples are classified as sandy clay, incompressible, easily compactable with good drainage.

Table 1: Physical Properties of Soil Samples.

Samples	P1	P2	P3	P4	P5	P6	P7	P8
% Passing 0.075µm	69.22	51.0	33.0	34.0	56.0	32.0	80.0	64.0
Liquid limit (%)	33.3	48.6	15.5	22.5	27.0	30.2	35.0	30.7
Plastic limit (%)	18.40	25.6	8.33	4.66	15.5	18.6	17.8	20.0
Plastic index (%)	15.0	23.0	7.17	17.84	11.5	11.6	17.2	10.7
Maximum dry density (Mg/m^3)	2.60	2.50	2.55	2.62	2.30	2.45	2.62	2.56
Optimum moisture content (%)	14.5	17.0	18.0	15.0	28.0	23.0	10.4	16.5
CBR (unsoaked %)	66	60	65	85	64	50	37	58
AASHTO classification	A–6	A–6	A–2-4	A-2-6	A-6	A-2-6	A-6	A-6
USCS	CL	CL	SM	SW	CL	SP	ML	CL
Specific gravity	2.67	2.65	2.61	2.78	2.79	2.65	2.66	2.80

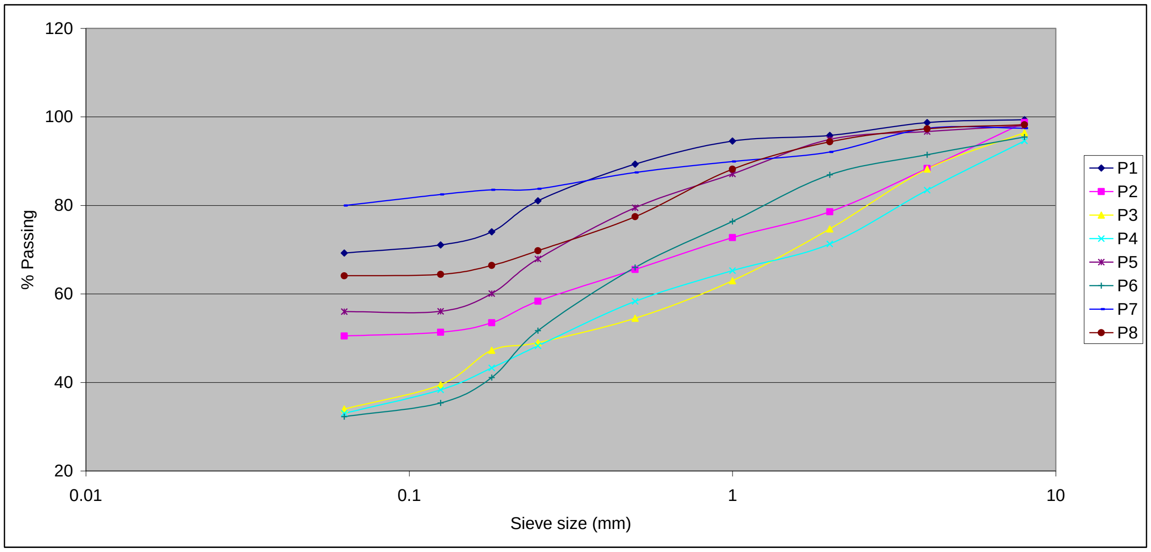

Figure 3: Particle Size Distribution of Ilesha East Local Government Lateritic Soil.

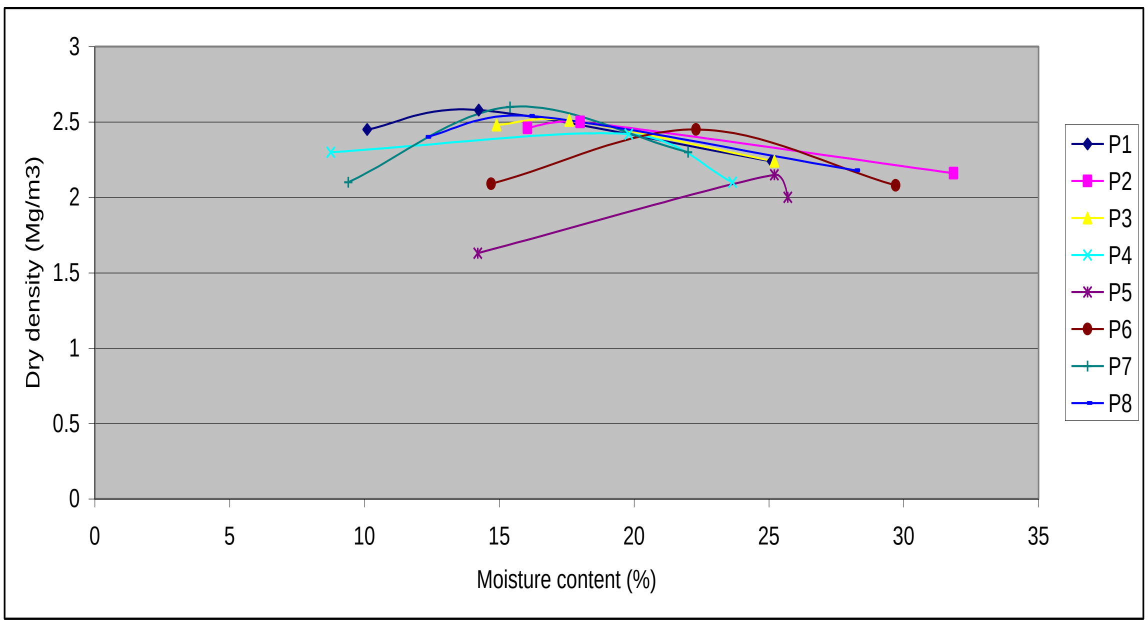

Figure 4: Compaction Values for Ilesha East Local Government Lateritic Soil.

Samples P3, P4, and P6 belong to A-2-6 subgroup classification; samples P1, P5, and P8 belong to A-6 group; while samples P2 and P4 belong to A-7 group classification, respectively. They are rated as good to fair subgrade materials. Thus samples P3, P4, and P6 can be rated as excellent material for road works having satisfied all the conditions for constructing subgrade and subbase materials while P4 can also be used as excellent base materials.

It is recommended that soil samples can be collected at various depths in trial pit to compare the geotechnical characteristics of the samples at various depths because of the anisotropic nature of soil. Also, samples P1, P2, P5, P7, and P8 should be properly investigated for liners properties became of the high percentage clay and fine particles.

REFERENCES

1. AASHTO. 1986. *Standard Specification for Transportation Materials and Methods of Sampling and Testing, 14th Edition.* American Association of State Highway and Transportation Officials: Washington, D.C.

2. Adeyemi, O.A. 2002. “Geotechnical Properties of Lateritic Soil Development over Quartz Schist in Ishara Area Southwestern Nigeria”. *Journal of Mining and Geology*. 38(1):57 – 63.

3. 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.

4. Agbede, O.A. 1992. “Characteristic of Tropical Red Soils as Foundation Materials”. Nigeria. J. of Science. 26: 237-242.

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

6. Akintola, F.A. 1982. “Geology and Geomophology”. *Nigeria in Maps*. R.M. Barbours, Editors. Hodder and Stoughton: London, UK.

7. Alao, D.A. 1983. “Geology and Engineering Properties of Laterites from Ilorin, Nigeria”. *Eng. Geol.* 19:111-118.

8. Alexander, L.T. and Cady, F.G. 1962. “Genesis and Hardening of Laterite in Soils”. Technical Bulletin 1282. US Department of Agriculture, Washington, D.C. 90pp.

9. Areola, O. 1982. “Soil”. In: Barbours K.M. (Editor). *Nigeria in Maps*. Hodder and Stoughton: London, UK.

10. Arumala, J.O and Akpokodje, E.G. 1987. “Soil Properties and Pavement Performance in the Niger Delta”. *Quarterly Journal of Engineering Geology*. London. 20:287.

11. Awogboro, S. 2007. “Geotechnical Evaluation of Laterites in Ila Local Government Southwestern, Nigeria”. Unpublished B. Tech Thesis. Ladoke Akintola University of Technology: Ogbomoso, Nigeria.

12. Bell, F.G. 1993. *Engineering Geology*. Blackwell Scientific Publication: London, UK.

13. Bello, A.A. 2007. “Geotechnical Evaluation of some Lateritic Soils as Foundation Materials in Ogbomoso North Local Government Area Southwestern Nigeria”. *Science Focus*. 12(2): 70-75.

14. Bello, A.A., Ige, J.A., and Tajudeen, S. 2007. “Geotechnical Characterization of Lateritic Soils in parts of Ejigbo Local Government Area, Southwestern Nigeria”. *LAUTECH Journal of Engineering and Technology*. 4(2):34-38.

15. British Standard Institution.1990. “Methods of Test for Soils for Civil Engineering Properties (BS 1377)”. British Standard Institution: London, UK. 143.

16. Federal Ministry of Works and Housing. 1997. “General Specifications for Roads and Bridges”., Volume II.145-284. Federal Highway Department: Lagos, Nigeria.

17. Fookes, G. 1997. “Tropical Residual Soils: A Geology Society Engineering Group Working Party Revised Report”. Geology Society: Tulsa, OK.

18. Gidigasu, M.D. 1976. “Laterite Soil Engineering: Pedogenesis and Engineering Principles”. *Development in Geotechnical Engineering*. 9:554.

19. Gidigasu, M.D. and Kuma, D.O.K. 1987. “Engineering Significance of Laterisation and Profile Development Processes.” *Proc, 9th Regional Conf. for Africa on Soil Mechanics and Foundation Engineering*. Lagos, Nigeria. 3-20.

20. Gillot, J.E. 1969. *Clay in Engineering Geology*. Elsevier Publishing: Amsterdam, The Netherlands.

21. Head, K.H. 1992. “Manual of Soil Laboratory Testing”. *Soil specification and Compaction Tests. 2nd edition*. Vol. 1. Pentech Press: London, UK.

22. O’Flaherty, C.A. 1988. *Highway Engineering, Vol.2.* Edward Arnold Publishers, London, UK.

23. Ogunsanwo, O. 1989. “CRB and Shear Strengths of Compacted Laterites Soils from Southwestern Nigeria”. *Quarterly Journal Engineering Geology*. London. 22:317 – 328.

24. Ola, S.A. 1983. “Geotechnical Properties of an Attapulgite Clay Shale in Northwestern Nigeria”. *Engineering Geology*.19:1-13.

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

26. Wright, P.H. 1986. *Highway Engineering, Sixth Edition*. John Willey and Sons: New York, NY.

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