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Characterizations of Various Lateritic Soils for Flexible Pavement in Rivers State

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***Abstract*-- Several designed and construction of roads in the study have been experiencing failure without observing the detailed cause of the problem, most roads failed without reaching the optimum lifespan due to the problem of lateritic soil application in road construction in the study area, the study expressed the physical properties of lateritic soil applied as sub base in construction of flexible pavement, the evaluation shows various physical properties of lateritic soil at different location, but the classifications expressed A-2-7 and A-2-6 to be predominant in the study area, these soil deposit clayish content thus not good for application in road construction in the study area, the study is imperative because it has evaluated the physical properties of lateritic soil, this has identified the type of soil using ASSTHO classification in the study area, the lateritic soil must be modified with any addictive to increase its strength in other to maintained the required designed life span of flexible pavement in the study area.**

***Keywords*-- characterization, Lateritic soil, Classification, physical properties and flexible pavement**

I. INTRODUCTION

Lateritic soils are found virtually in all part of Rivers state located in southern part of Nigeria has resulted in its continual use in road construction. Lateritic soil is enriched with aluminum phyllosillicate, aluminum oxide, iron oxides and hydroxides. Concern for the effect of these elements to the geotechnical properties is suggestive of the importance in the study of characterization of this soil type. Soil characterization is envisioned to identify the soil properties, its predictability, and responses to varying stress conditions. An understanding of the engineering characteristics of lateritic soils is necessary for engineers in the tropics, for the proper application of this soil to engineering works.

Soil structure, generally, refers to both the geometric arrangement of the soil particles and the inter-particle forces which may act between these particles (Day, 1999). Accordingly, the structure of soil provides for soil integrity and its response to externally applied and internally induced forces (Yong and Warkentin, 1975).

The actions of weathering and erosion in the tropics steadily alter the properties of residual soils, thus making it difficult to relate the soil structure to the stress history (Vaughan and Kwan, 1984). Therefore, the origin of the soil determines the micro fabric of the clay soils (Osipov and Sokolov, 1978), and the microstructure is strongly related to its environment of formation and consequent transformation during compaction (Malomo, 1989, Motos,2009; Manasseh and Edeh, 2015). Lateritic soils derived from different rock types in the tropics vary in different locations. Consequently, the soil structure differs for the diverse rock types. Residual soil formation involves some form of complex weathering process which is likely to cause the variability in the intermediate and final structures. Accordingly, studies in some lateritic soils reveal that they possess a porous granular structure consisting of iron impregnated clayey material in minute spherical aggregations (Hamilton, 1964). The aggregations derive its strength from the thin film found within the micro-joints of the elementary clay particles, which in addition coats the particles (Gidigasu, and Kuma 1987, Gidigasu and kuma 1972; Gidigasu1970).

The chemical composition and mineralogy of laterite soils is derived from the constituents of the parent rocks through the formation process. The constituent clay minerals are bound together by the oxides and hydroxides of iron and aluminum. The cementation forms a coating for the clayey constituents of the soil and further bound them into coarser aggregations which suppress the normal behavior of clay (Townsend et al., 1973), and determines the resistance to degradation of the soil grains (Malomo, 1989). Laterite soil chemistry and mineralogy is shown by studies to greatly influence the geotechnical properties, and in certain circumstances, significantly affects the economic potential in the construction industry (Ogunsanwo, 1995).

Generally, residual soils are composed of Silica (SiO_2), Aluminum Oxide (Al_2O_3), Iron-III-Oxide (Fe_2O_3), Tin oxide (TiO_2), Magnesium Oxide (MgO), Calcium Oxide (CaO), Sodium Oxide (Na_2O), Potassium Oxide (K_2O), and Copper (Cu).

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Others are Feldspar, Quartz, Kaolinite, Muscovite, Goethite, Montmorillonite and traces of other clay minerals as may be found in the parent rock underlining the lateritic soil formation. However, the proportions of these elements vary vertically and horizontally in any given formation, as while as, from region to region (Nnadi, 1988).

II. Materials And Method

The atomic absorption spectro-photometer was used to determine the chemical composition of the lateritic soil samples see Table 3.1.

The particle size analysis test was carried out in accordance with BS 1377; 1990 Part 2. c. A weighed amount of each sample was used for grain size analysis using sieves with standardized openings. The percent by weight of soil passing each opening was then plotted as a function of the grain diameter (corresponding to a sieve number).

Most soil classification systems used in construction classify soils based upon grain-size distribution and Atterberg limits. These limits divide four different "states" of consistency. If a soil is heavily saturated with water and then is dried out, it will move from a liquid state to a plastic state to a semisolid state and then to a solid state. The values of these limits are affected by the interaction of the soil particles and the water present in the sample. Because other properties such as compressibility or permeability depend on the interaction of soil particles and water, the Atterberg limits can be related to these other properties. For this work, the liquid and plastic limits were determined. Most commonly Liquid Limit and Plastic Limit are an integral part of several engineering classification systems to characterize soils. The liquid limit is determined based on the number of blows required to cause a groove to close in a sample. This is determined using the apparatus of Casagrande. It is a brass cup with a cranking arrangement by means of which the cup can be lifted and dropped under standardized conditions. The liquid limit tests was carried out according to BS 1377 (1990).The soil was first dried and sieved and only the fraction < 425μm used. About 200g of the sample was soaked with distilled water and left for about 24hours. After ripening, the sample was then spread on a porcelain plate with distilled water added if it was too dry. After homogenizing, the soil was evenly spread out in the cup and a grooving tool used to make a 40mm long and 2mm wide groove which divides the sample in the cup into 2 equal parts. The cup was then lifted and dropped until the groove closed. The number of times N the cup was dropped was noted.

A small amount of the sample was taken and its moisture content determined. The remaining sample was then put back on the porcelain plate and the process continued until we had about 4 values which occur at different moisture contents. Using semi-logarithmic paper, water content was plotted against log N. The water content corresponding with N equals 25 is the liquid limit. Table 3.2 shows the liquid limit for the various samples. The plastic limit is determined as the water content at which a thread of soil of size about 2-3mm begins to crumble when rolled. The plastic limit test was carried out according to BS 1377 (1990**).** About 2g of the ripened soil was rolled on a porcelain plate using the hand to sizes of about 2-3mm without it breaking or sticking. When it developed cracks and could crumble, a little amount was taken and tested for water content. Table 3.2 shows the plastic limit for the various samples. The plasticity index is the difference in moisture content between the liquid and plastic limits. A high Plasticity Index indicates that the material has significant clay content; it is more plastic and compressible and has greater volume change characteristics. The plasticity index has proven to be one of the most useful of all soil indices and is essential to the description of a cohesive soil. Table 3.2 shows plasticity index for the various samples.

The compaction test determines the ranges of moisture content at which maximum compaction at optimum void content can be achieved. Provided this range of moisture content is not exceeded, stability of the layer ensured. The compaction test ensures that further deformation of the layer by consolidation shall not occur provided the imposed load does not exceed the value used in the test (Emesiobi F.C., 2000). The compaction test therefore is used to determine the optimum moisture content at which the given soil has to be compacted in order to attain maximum dry density. The compaction tests were carried out according to BS 1377 (1990). 3kg of the soil/soil-admixture sample were mixed thoroughly with 5% of water (and water is added at 5% for each of the compactions). The sample was then compacted into the 1000 cm^3 (of mass m1); in three layers of approximately equal mass with each layer receiving 25 blows of 2.5kg rammer falling through a height of 300mm. The blows were uniformly distributed over the surface of each layer. The collar was then removed and the compacted sample leveled off at the top of the mould with a straight edge. The mould containing the leveled sample was then weighed to the nearest 1g; m^2. Two small samples were then taken from the compacted soil for the determination of moisture content.

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The sample was then removed from the mould, crushed, additional water added and the same procedure was repeated until minimum of five sets of samples were taken for moisture content determination. The values of the dry densities as were plotted against their respective moisture contents and the maximum dry density (MDD) were deduced as the maximum point on the resulting curves.

The corresponding values of moisture contents at MDD, deduced from the graph of dry density against moisture contents, gives the optimum moisture contents (OMC). Table 3.2 shows the MDD and OMC for the various samples.

III. Results And Discussions

Table 3.1:
Chemical Analysis of lateritic soils

Sample	Location (Local Govt. Area)	Composition									
		CaO	Fe_2O_3	SiO_2	Al2O3	MgO	SO_3	MnO	Na_2O	K_2O	Cl
1	Khana	0.16	0.26	0.082	0.059	0.045	0.17	0.148	0.045	0.025	0.006
2	Gokana	0.14	0.25	0.075	0.057	0.032	0.23	0.146	0.027	0.034	0.009
3	Eleme	0.16	0.25	0.074	0.071	0.043	0.18	0.152	0.03	0.028	0.012
4	Emohua	0.17	0.26	0.074	0.058	0.028	0.21	0.135	0.028	0.027	0.01
5	Etche	0.18	0.23	0.084	0.062	0.034	0.18	0.131	0.062	0.028	0.009
6	Ikwerre	0.16	0.27	0.069	0.074	0.044	0.14	0.146	0.064	0.025	0.008
7	Obio-Akpor	0.17	0.29	0.08	0.064	0.029	0.15	0.134	0.048	0.026	0.009
8	Ahoada East	0.16	0.24	0.076	0.07	0.035	0.17	0.154	0.049	0.034	0.012
9	Ogba-Egbema-Ndoni	0.15	0.21	0.088	0.068	0.042	0.18	0.156	0.061	0.037	0.008
10	Port Harcourt	0.17	0.21	0.081	0.076	0.045	0.16	0.155	0.063	0.031	0.009

Table 3.2:
Physical properties of lateritic soil

Sample	Location (Local Govt. Area)	Properties						
		%age Passing Sieve No. 200	LL (%)	PL (%)	PI (%)	MDD Kg/m^3	OMC (%)	AASHTO Classification
1	Khana	46.7	38	17.2	20.8	1866	19.2	A-6
2	Gokana	41.3	46	23.7	22.3	1662	23.6	A-2-7
3	Eleme	40.5	40	28.1	11.9	1677	20.2	A-2-6
4	Emohua	34.7	45	24.5	20.5	1567	25.3	A-2-7
5	Etche	53.3	49	31.3	17.7	1671	18.6	A-2-7
6	Ikwerre	36.7	43	26.5	16.5	1690	17.9	A-2-6
7	Obio-Akpor	33.6	28	18.9	9.1	1983	14.0	A-2-5
8	Ahoada East	41.0	32	19.5	12.5	1795	17.2	A-2-6
9	Ogba-Egbema-Ndoni	47.1	43	29.8	13.2	1492	27.1	A-2-7
10	Port Harcourt	36.0	44	29.1	14.9	1749	17.9	A-2-7

The atomic absorption spectro-photometer was used to determine the chemical composition of the lateritic soil samples see Table 3.1. It was observed that the samples were predominantly made up of iron-III-oxide (Fe_2O_3), quartz (silicon oxide) and calcium oxide (CaO). They also contain silica (SiO_2), aluminum oxide (Al_2O_3), manganese oxide (MnO_2), Magnesium oxide (MgO), sodium oxide (Na_2O), and potassium oxide (K_2O)

The chemical and physical process of lateritic soil in the study area has been expressed, the study shows different rate of various parameters thus engineering properties of lateritic soil, and these were characterized in different location in the study area.

The physical properties of lateritic soil considered were particle size distribution, liquid limit, plastic limit, plastic index, optimum moisture content and maximum dry density.

These parameters generated the following results percentage passing obtained the highest at [47.1%], lowest [36%]; liquid limit the highest at [49%], lowest [28%]; plastic limit obtained [29.8%] while the lowest [17.2%]; plastic index produced the maximum at [22.3%] while the minimum was [9.1%]; the laboratory result of optimum moisture content obtained was [27.1%] while [14%] was the lowest; maximum dry density of [1983kg/m^3] was obtained while the lowest was [1492kg/m^3].
Using the American Association of State Highway and Transportation Officials (AASHTO) classifications system, the results from various location of the state shows that A-2-7 and A-2-6 soils are predominant, these express the soil structure in terms of sub base application for construction of flexible pavement in the study area. According to the AASTHO specification, it implies that the lateritic soil must be modified if it must be used as sub base material for flexible pavement construction in the study area. Also lateritic soil deposit in some location show low content of clay depositions predominated with silty sand formation that should be better off in subgrade applications.

IV. Conclusion

Characterization of lateritic soil in various location of Rivers State were carried to evaluate the chemical and physical properties of lateritic soil for application of standard construction of flexible pavement in the study area, the study thoroughly assessed various physical properties of soil in other to classified the soil in various location of the state, these evaluation will assist Highway Engineers to select the best location of obtaining lateritic soil for road construction, the examination shows that the A-2-7 and A-2-6 where predominant in various location, which is classified as soil with clayish content, these implies that those soil must be modified before it can be applied for road construction, the study is imperative because several designed and construction has been developing serious crises due to negligence of these aspect of evaluation in the study area, experts will definitely apply these study to determine the best option in applying lateritic soil in the study area.

REFERENCES

[1] Collins, K., and McGowan, A., (1974). The form and function of microfabric features in a variety of natural soils. Geotechnique, vol. 24, 2: 223 – 254.

[2] Day, R.W., (1999). *Geotechnical and foundation engineering: design and construction*. McGraw-Hill, New York.

[3] Gidigasu, M. D., and Kuma, D. O. K., (1972). Mode of formation and geomechanical characteristics of laterite materials of Ghana in relation to soil forming factor. *Engineering Geology*, 6: 79 – 150.

[4] Gidigasu, M. D., and Kuma, D. O. K., (1987). Engineering significance of lateritization and profile development processes. *Regional Conference for Africa on Soil Mechanics and Foundation Engineering*, 9th, Lagos, 3 – 20.

[5] Gidigasu, M. D., (1970). The engineering characteristics of laterite soils (literature review). Build. Road Res. Inst. Kumasi, Ghana, Proj. Rep. 7, pp. 31

[6] Hamilton, R., (1964). Microscopic studies of laterite formation in Ghana. In: A Jungerious (Editor): Soil Micromorphology, Elsevier, Amsterdam, 269 – 278.

[7] Lambe, T.W., (1958). The engineering behaviour of compacted clay. *Journal of the Soil Mechanics and Foundations Division, ASCE*, vol. 84, No. SM2. Proceedings Paper 1655.

[8] Malomo, S., (1989). Microstructural investigation on laterite soils. *International Association of Engineering Geology, Bulletin*, 39: 105 – 109.

[9] Manasseh J. and Edeh J. E., (2015). Comparative Analysis of Cement and Lime Modification of Ikpayongo Laterite for Effective and Economic Stabilization. *Journal of Emerging Trends in Engineering and Applied Sciences* (JETEAS) 6(1): 49- 56

[10] Matos, G., (2009). "Use of Minerals and Materials in the United States From 1900 Through 2006," Fact Sheet 2009-3008. U.S. Geological Survey, Reston, VA.

[11] Nnadi, G., (1987). Geotechnical properties of tropical residual soils. *Luleå University of Technology, Research Report, Tulea*.

[12] Vaughan, P. R., and Kwan, C.W., (1984). Weathering, structural and in-situ stress in residual soils. Geotechnique vol. 34, 1: 43 – 59.

[13] Yong, R. N. and Warkentin, B. P., (1975). *Soil properties and behaviour*. Elsevier Scientific, Publishing Company, Amsterdam, Chapter 3.