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Geotechnical Evaluation of Selected Lateritic Soils for Road Construction

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ABSTRACT

Lateritic soils are in great use for road construction. Therefore, it becomes necessary to investigate their geotechnical properties and suitability as sub-grade, sub-base and base materials for road construction. This study therefore undertook a geotechnical evaluation of selected soils in Ife North Local Government Area, Osun State, Southwestern Nigeria. This was with a view to providing a guide for road construction works in the study area. To achieve this aim, soil samples were collected from identified locations in the study area. Preliminary, index and engineering property tests were conducted on the selected soil samples, using standard procedures. The laboratory results were evaluated and the soil samples were classified for appropriate engineering purposes. The results showed that specific gravity of the soil samples ranged from 2.17 to 2.84; percentage passing sieve number 200 BS sieve ranged from 5.1 % to 17.8 %; liquid limits and plasticity index ranged from 32 % to 74 % and 11 % to 30 % respectively; maximum dry densities (MDD) lied between 1325 kg/m^3 and 1825 kg/m^3; the optimum moisture contents (OMC) lied between 15.2 % and 30.7 %; unsoaked California bearing ratio (CBR) values ranged from 6 % to 18 %. The soil classification falls within A-2-6 and A-2-7 (AASHTO classification); and CH, CL, MH and ML categories (USCS classification). It was concluded that the tested soil samples are good for fill and sub-grade in road construction.

Keywords: Geotechnical evaluation, Lateritic soil, Road construction, Subbase, Subgrade

1. INTRODUCTION

Lateritic soil is well known in many countries, including some Asian and African countries, as a building material for more than 1000 years. They are the most common reddish colour weathered pedogenic surface deposits occurring in the tropical and subtropical regions of the world. They are the most common materials for the construction of earth dams, highways, embankments, airfields as well as foundation materials to support structures in these areas. (Gidigasu, 1976; Owolabi and Aderinola, 2014).

Many factors influence the formation of laterite. They include: climate (precipitation, leaching, capillary rise and temperature, topography (drainage), vegetation, parent rock (iron-rich rocks) and time. In addition, lateritic soils are formed in hot, wet tropical regions with an annual rainfall between 750 mm and 3000 mm (usually in area with a significant dry season) on a variety of different types of rocks with high iron content. Therefore, the locations on earth that meet the condition for the formation of laterite fall between latitudes 35ºN and 35ºS (Gillot, 1968). The mineralogical composition of the lateritic soil also has an influence on its geotechnical parameters such as specific gravity, shear strength, swelling potential, Atterberg limits, bearing capacity and petrograpic properties (Amadi *et al*, 2012).

Because they are easy to manipulate on the road surface and have natural stable grading with a suitable proportion to act as binders lateritic soils are widely utilised as fill materials and flexible pavement foundations in road construction projects. Wrong application of road construction materials, especially

laterite as base and sub base material by construction workers lead to bad roads, which in turn constitutes a major cause of road accidents (Oke *et al*., 2009a; Nwankwoala *et al*., 2014; Layade and Ogunkoya, 2018). The understanding of soil behaviour in solving engineering and environmental issues, especially in lateritic soils, that can cause significant damage to road construction and other engineering applications is the sole aim of geotechnical engineering (Oke and Amadi, 2008). The characteristics and durability of any construction material is a function of its efficiency in response to the load applied on it (Oke *et al*, 2009b; Nwankwoala and Amadi, 2013). Therefore, the choice of any material(s) as either sub base or base course depends on its strength in transmitting the axle load to the sub-soil and or sub grade. It is of uttermost importance to have a good understandings of the basement soil on which highways and other transportation facilities are constructed.

According to Salter (1988), the performance of a highway pavement is influenced to a very considerable extent by the sub grade material. The construction of foundations of most engineering structures, including roads, requires that adequate information about the engineering properties of the soil and sub soil condition of the area are known. This is necessary for the engineering planning, design and construction of such foundations to be based on sound geotechnical parameters. This is more important especially in the design and construction of highways, where there is need for a good and sound knowledge of the geotechnical and engineering properties of the subgrade and, more importantly, the construction materials' properties for sound engineering decisions to be taken. Such geotechnical properties include the strength, the maximum dry density (MDD), the amount of fines (clay and silts) as well as the compaction performance of the proposed highway construction materials (Habeeb *et al*, 2012).

Many researchers (Omotoso, 2010; Balogun, 1984; Ogunsanwo, 1989; Oglesby and Kicks, 1992; 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; Bello, 2007; Bello *et al*., 2007; Bello and Adegoke, 2010; Tijani *et al*., 2017) have studied the characteristics of lateritic soils, their improvement/stabilisation and their usage in road construction. Okoye *et al*. (2017) evaluated the suitability of Ihiala laterites, southwestern Southeastern Nigeria, as subgrade material in road construction. They concluded that seven of the tested soil samples were good or fair as subgrade material, while the remaining three could be stabilized for subgrade fill. Adunoye *et al*. (2018) investigated the geotechnical properties of lateritic soils in parts of Ife central Local Government, Osun State, Southwestern Nigeria. The study concluded that the soils were good for fill and subgrade in road construction. Relationships also existed between the engineering properties and Atterberg limits of the soils.

Layade *et al.* (2018) investigated the geotechnical properties of lateritic soil as subgrade and base material for road construction in Abeokuta, Southwestern Nigeria. They found that the geotechnical properties of the tested soils were fairly within the regulatory standards of Nigeria; and therefore concluded that lateritic soil present throughout the study area is suitable for use as subbase and base materials. Adeyemi *et al.* (2014) studied the geotechnical properties of subgrade soils along sections of the Ibadan–Ife expressway, Southwestern Nigeria. They reported that the observed nature of the pavement was due mainly to the weakening influence of groundwater on subgrade soils.

Owolabi and Aderinola (2014) evaluated the geotechnical properties of some lateritic soils in Akure South, Southwestern Nigeria. The study concluded that only one, out of the six samples tested, was not suitable for construction. Amadi *et al*. (2015) undertook an assessment of the geotechnical properties of lateritic soils in Minna, North Central Nigeria for road design and construction. They found that the lateritic soils fell within the class of A-3, A-2-4 and A-2-6; and concluded that the soils were suitable for subgrade fill, sub-base and base courses. Adebisi *et al.* (2015) studied the index and strength characteristics of sleeted

residual lateritic soils from Abeokuta and Ibadan, Southwestern Nigeria. They found that the tested lateritic soils were predominantly well-graded silty, clayey sands. They concluded that fairly strong inverse relationship existed between undrained cohesion and flow index, implying that the rate of loss of shearing stress of the soils is comparatively a function of increase in their moisture content.

It has since been established that the index properties of residual soils vary from region to region due to the heterogeneous nature and highly variable degree of weathering controlled by regional climatic and topographic conditions, and the nature of bedrock (Nnadi, 1988; Okoye *et al*., 2017). Also, there are no available data on the geotechnical properties of soils in the study area. This study therefore aimed at carrying out an evaluation of the geotechnical properties of selected lateritic soils in Ife-North Local Government Area, Osun State. This is to add to the body of knowledge and provide useful aid for engineers and contractors in the selection of suitable materials for engineering projects, especially road works.

1.1 Description and geology of the study area

The study area is Ife-North Local Government Area in Osun State, Southwestern Nigeria (see Figure 1). Its headquarters is at Ipetumodu town. The Loral Government covers an area of about 889 km^2 and has a density of about 237.5/km^2 (National Bureau of Statistics, 2019). The study area falls within the basement complex of Southwestern Nigeria (Figure 2). It forms part of the African crystalline shield which consists predominantly of migmatised and undifferentiated gneisses and quartzite (Akintola, 1982; Areola, 1982; Adunoye and Agbede, 2013).

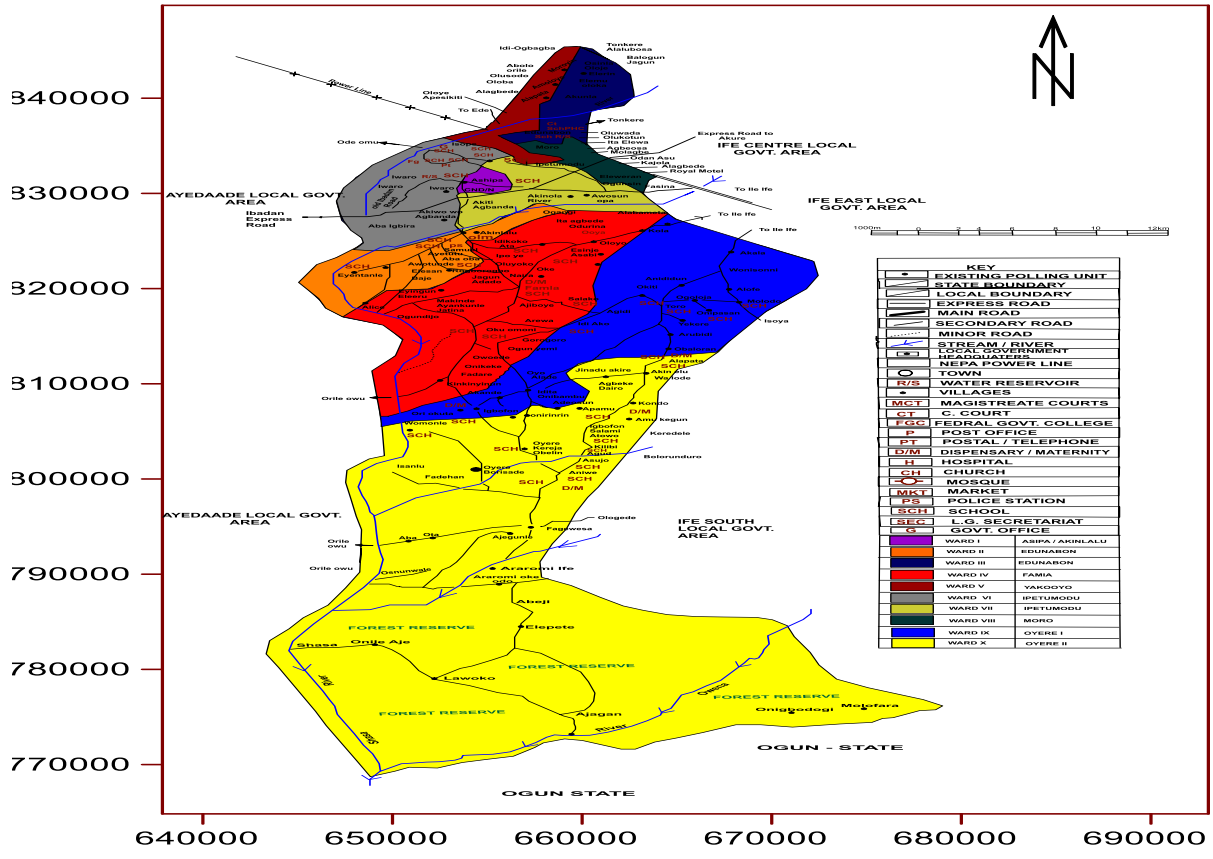

Figure 1: Map of Ife North Local Government Area (Ife North LGA, 2018)

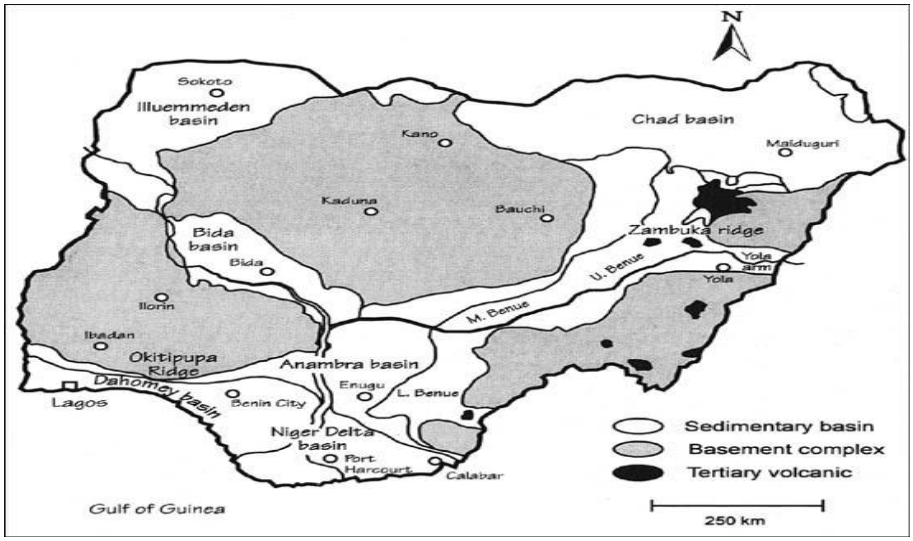

Figure 2: Map of the Major Geological Formations of Nigeria (Anukam, 1997)

2. METHODOLOGY

2.1 Materials and equipment

The main material used was lateritic soil samples obtained from ten (10) identified locations within the study area. Table 1 presents a description of the sampling points, while the list of equipment used for the various analyses/tests are contained in Table 2. All the equipment were available in the Geotechnical Laboratory of Obafemi Awolowo University, Ile-Ife.

2.2 Sample collection and preparation

In each of the identified sampling points, test pits were dug and excavated with the aid of digger and shovel. The depth of sample collection was 0.5 m – 1 m (Arora, 1988; Roy and Das, 2014). 20 - 25 kg of each sample was collected into a polythene bag, sealed and immediately taken to the Geotechnical Laboratory of the Department of Civil Engineering, Obafemi Awolowo University (OAU), Ile-Ife, for analyses. After determining the initial moisture content, the samples were prepared for subsequent laboratory analyses by air-drying and grinding to pass 2 mm sieve (Adunoye *et al*., 2018).

Table 1: The description of sample locations

Sample ID	Longitude (E)	Latitude (N)
S1	$4^0$27’92”	$7^0$32’33”
S2	$4^0$27’80”	$7^0$32’20”
S3	$4^0$26’43”	$7^0$30’19”
S4	$4^0$26’29”	$7^0$30’37”
S5	$4^0$26’57”	$7^0$29’42”
S6	$4^0$26’68”	$7^0$29’72”
S7	$4^0$24’24”	$7^0$29’70”
S8	$4^0$27’55”	$7^0$33’20”
S9	$4^0$26’29”	$7^0$30’45”
S10	$4^0$25’32”	$7^0$29’88”

Table 2: List of equipment

Equipment	Purpose
Set of Sieves (4.5mm to 0.06mm)	Particle size analysis (coarse grain)
Sieve Shaker	Shaking of soil sieves
Hydrometer Bulb	Particle size analysis (fine grain)
Specific Gravity Bottle	Specific gravity determination
Atterberg Apparatus	Plastic and liquid limits determination
Electric Oven (Temp 105^{o}C to 110^{o}C)	Drying of moist soil sample
Weighing balance	Weighing of soil
Measuring Cans	Measurement
Compaction Moulds and Rammers	Compaction test
CBR Machine	Determination of CBR

2.3 Methods

The following tests were conducted on the soil samples, using standard procedures as outlined in BS 1377 (1990): natural moisture content determination; particle size analysis; specific gravity; plastic limit; liquid limit; compaction and California bearing ratio (CBR). The compaction method adopted was Standard Proctor.

3. RESULTS AND DISCUSSION

3.1 Preliminary and index property tests

The results of preliminary and index property tests are shown in Table 3 and discussed as follows.

Natural moisture content: The natural moisture content of any soil varies from season to season, being highest during raining season and lowest during dry season. Emesiobi (2000) opined that natural moisture content in soil may range from below 5 % to 50 % in gravel and sand. The moisture content of the tested soil samples ranged from 16% to 31% (Table 3). Samples S3 has the lowest moisture content and this was as a result of the hot weather condition of the area when the sample was collected. Sample S6 has the highest moisture content and this is because the sample was collected immediately after rainfall.

Specific gravity: In addition to the use of specific gravity as the basis for identification of laterite soils, it has also been found as a useful identification and evaluation index of laterite aggregates for pavements construction, since it correlates well with mechanical strength of soil. These findings have made specific gravity an important parameter in evaluation of soils as subgrade materials, most especially in determining the degree of laterization (Adeyemi *et al*., 2014). Soils with specific gravity of between 2.60 and 3.40 have been classified by De Graft-Johnson (1969) as laterite soils. Wright (1986) also stated 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. The specific gravity of the lateritic soils obtained varied between 2.17 and 2.84. Samples S1, S2, S4, S5, S8, S9 and S10 could be said to be coarse; while samples S3, S6 and S7 could be described as fine-grained soils.

Particle size distribution: The results of the particle size analysis on the soil samples (Table 3) show that soil samples are predominantly granular materials. Adeyemi *et al*. (2014) posited that, with other factors being constant, a soil largely made up of fines (clay and silt size particles) is likely to have worse geotechnical properties as highway subgrade or subbase than a soil largely made up of coarse particles

(particles greater than 63 μm) According Federal Ministry of Works and Housing (1997), for any soil to be used as sub-grade, sub base or base material, the percentage by weight passing the No.200 sieve (0.075mm) shall be less than 35%; and if the percentage passing sieve no. 200 for a lateritic soil is greater than 35%, there is no need for further tests, the material is rejected. Therefore, by this consideration alone, all the tested lateritic soil samples qualified to be used as subgrade/fill, sub base and base materials.

Table 3: Results of preliminary and classification tests

Sample ID	NMC (%)	Specific Gravity	% Passing sieve 200	LL (%)	PL (%)	PI (%)	AASHTO Classification	USCS Classification
S!	21	2.3	9	74	50	24	A-2-7	CL
S2	21	2.17	9.1	64	34	30	A-2-7	MH
S3	16	2.84	8.6	40	27	13	A-2-6	MH
S4	17	2.5	10.5	32	21	11	A-2-6	CL
S5	28	2.19	17.5	50	35	15	A-2-7	ML
S6	31	2.79	17.8	60	37	23	A-2-7	ML
S7	30	2.81	6.1	39	22	17	A-2-6	CH
S8	28	2.42	5.6	41	23	19	A-2-7	CL
S9	22	2.43	7.1	48	29	19	A-2-7	MH
S10	27	2.55	5.1	43	24	19	A-2-7	CH

Atterberg limits

Kahl (1979) investigated Nigerian lateritic soils and obtained figures ranging from as low as 26.9 % for sand stone to 63.7 % as values of liquid limit for granite. The liquid limit of the tested lateritic soil samples ranged from 32 % to 74 % (Table 3). This falls within the range of the value specified by Federal Ministry of Works and Housing (1997), which is that, liquid limit should not be greater than 80% for sub-grade and not greater than 35% for sub-base and base course. The standards also provides that plasticity index should not be greater than 55% for sub-grade and not greater than 12% for both sub-base and base. Therefore with the exception of sample S4, which is suitable for sub-base and base courses, all the soil samples are suitable as subgrade/fill materials. Considering the values of the plasticity index (ranging between 11 % and 30 %), the soil samples could also be described as having medium to high plasticity (Das, 2006).

3.2 Engineering tests

The results of the engineering tests conducted on the soil samples are presented in Table 4 and discussed as follows.

Compaction test: The maximum dry density (MDD) for the soil samples varied between 1325 kg/m^3 and 1825 kg/m^3; while the optimum moisture content (OMC) ranged from 15.2 % to 30.7 % (Table 4). O'Flaherty (1988) suggested the range of values that may be anticipated when using the standard proctor method for compaction as follows: for clay, MDD falls between 1440 kg/m^3 and 1685 kg/m^3 and OMC may fall between 20 % and 30 %; for silty clay, MDD is between 1600 kg/m^3 and 1845 kg/m^3 and OMC ranges between 15 % and 25 %; for sandy clay, MDD is between 1750 kg/m^3 and 2165 kg/m^3 and OMC ranges between 8 % and 15 %. Therefore, the tested lateritic soils fall between clay and silty clay.

California bearing ratio (CBR): As presented in Table 4, the values of unoaked CBR ranged between 6 % and 18 %. Federal Ministry of Works and Housing (1997) recommends that soaked CBR for sub-grade and sub-base soils should not be less than 5 % and 30 % respectively; while the unoaked CBR value for base course should not be less than 80 %. Therefore considering the values of the unsoaked CBR, all the soil samples are good for subgrade/fill.

Table 4: Results of engineering tests

Sample ID	MDD (kg/m^3)	OMC (%)	CBR (%)
S1	1501	24.2	9
S2	1651	15.2	18
S3	1761	16.7	9
S4	1825	21.4	17
S5	1519	23.8	5
S6	1341	26.3	7
S7	1327	23.8	13
S8	1342	30.7	7
S9	1647	15.8	13
S10	1325	24.6	7

4. CONCLUSION

In the investigation of the suitability of selected lateritic soils from Ife North Local Government for road construction, preliminary and index property tests were conducted on the selected samples. Engineering tests (compaction and CBR) were also conducted on the samples. The results were compared with the standards for materials for road construction in Nigeria. All the soil samples could be used as sub-grade and fill materials in road construction.

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