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An Investigation on Geotechnical Properties of Subgrades in Oyo East Local Government Area, South-West, Nigeria

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Abstract:- In Nigeria, several billions of naira have been spent on road reconstruction and rehabilitation. Despite this, the roads fail almost immediately after the project is commissioned or even before. This phenomenon might be due to inadequate information about the subgrade properties of the roads. Hence, this study researches the behaviour of the subgrade soils under various conditions and classification of the soils. Laterite soil samples were collected from side-cuts along 5 roads (Ajagba Road, Akinmorin, Ajeigbe Afonja, Idi-Igba and Powerline Road) within Oyo East LGA. The study tests carried out include engineering soil classification tests and soil engineering strength tests. The result showed the liquid limit ranges from 10.39 to 65.27 percent, plastic limit falls within the range of 0 to 43.5 percent. The percentage passing the sieve No 200, ranged between 10 and 67 percent. The specific gravity of the samples was between 2.11 and 2.51, while the soil samples have soaked CBR values ranging between 3 and 42.7 percent. The MDD recorded ranged from 1.45 to 2.14 g/m^3 and the OMC for the samples ranged from 6.3 to 18.22 percent. Thus, this study concludes that some of the samples satisfy the condition for subgrade soil, while some did not.

Keywords:- *CBR, Side-Cuts, Subgrade, Engineering Soil Classification, Laterite.*

I. INTRODUCTION

In Nigeria, there have been several attempts in the development of roads and highways infrastructures, with the construction of over 20,000 km of road network throughout the six geopolitical zones. Despite these developments, several billions of naira has been spent on continuous reconstruction or rehabilitation of roads and highways but fails almost immediately after the project is commissioned or even before. Only little or no adequate efforts have been channeled to implementing the solutions to these short performance life and continuous failure of roads and highways. Therefore, this research study was carried out to be able to determine the behaviour of the subgrade soils under various conditions and classification of the soils in accordance with standard specification. And also to provide the geotechnical data necessary for the purpose of planning, designing, construction and maintenance works in the study area.

A. Location and Description of Study Area

Oyo East local government area is one of the thirty-three (33) local government areas of Oyo state, has a land area of about 144 km² and a population of 123,846 at the 2006 census [1]. It can be found around a coordinate of 7.68 °N – 7.87 °N and 3.97 °E - 4.0213 °E [2]. The study area experiences two distinct seasons; wet and dry seasons. The wet season is between the month of March and April and last till October while the dry season spans from November to March. The mean annual rainfall is about 1600 mm with its peak around July. The diurnal temperature is often between 25 ºC and 35 ºC with little variations in most times of the year. The relative humidity could be as high as 80 to 90 % in August [3]. Oyo State is not particularly rich in prominent minerals but is endowed with a wide distribution of the simple but easy to utilize sedimentary and metamorphic groups of minerals, namely, marble, red clay, sand, gravel, granite, limestone and talc. [3]

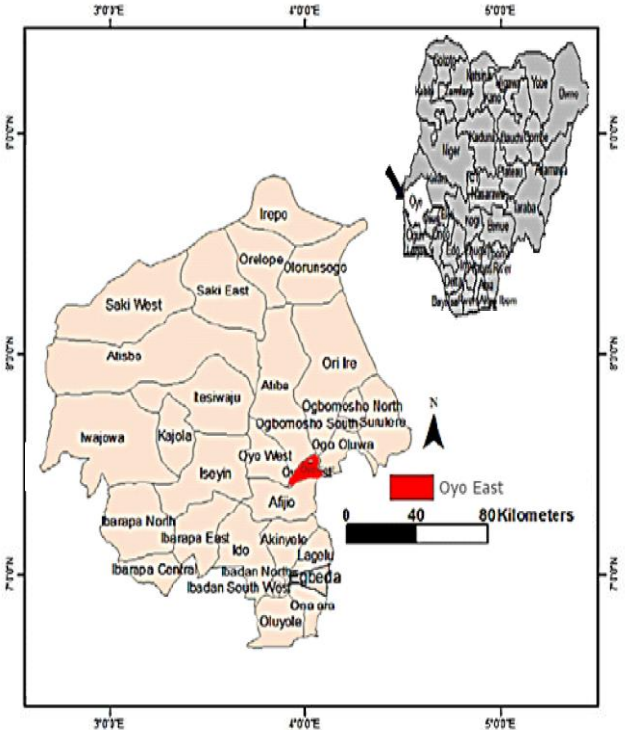

Fig. 1: Map of Oyo State Showing The Study Area, Oyo East (Oyedotun, 2012).

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II. METHODOLOGY

The study was executed in two main stages. The first stage was the fieldwork which involved reconnaissance survey of the selected roads and collection of samples at a depth 1.2 m below the road surface level. The selected roads are Ajagba Road, Akinmorin Road, Ajeigbe Afonja Road, Idi-Igba Road and Powerline Road; As shown in figure 2. The second stage was laboratory analysis of the samples and making comprehensive inference in terms of data records. The study tests carried out include Moisture content test, Grain size distribution, Atterberg limits, Specific gravity and the California bearing ratio in compliance to the BS 1377. And the Compaction characteristics (MDD and OMC) were carried out using the West African Compaction Standard.

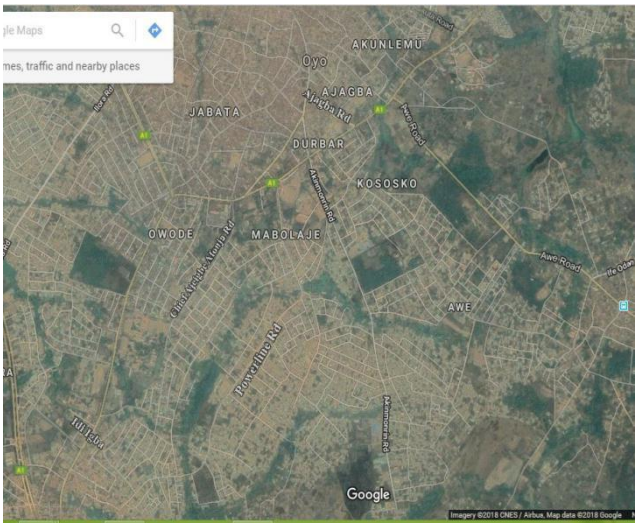


Fig. 2: Map Showing Data Collection Points.

III. RESULTS AND DISCUSSION

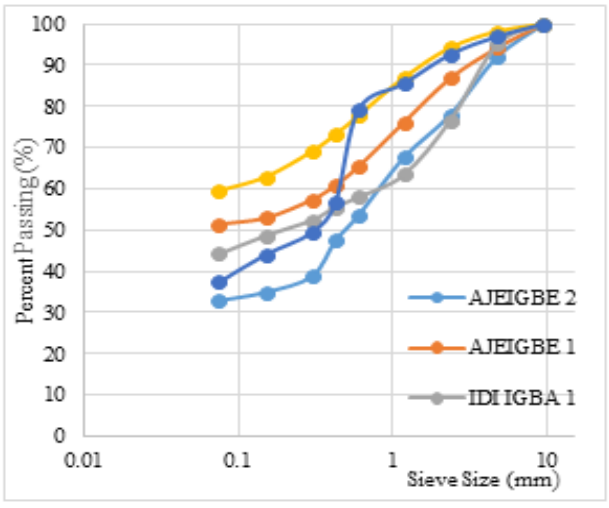
Natural moisture content is one of the most common soil parameters, low moisture content indicates the soil is a dry one, while high amount of moisture content indicates a wet soil. Table 1 shows soils in the study area have moisture content ranging from 7.2 % – 16.1 %. Samples with high moisture content might not be suitable for road construction, because that is an indication of either high affinity for water or the groundwater level is closer to the surface in that location. Soil with high affinity for water should be avoided. Samples from the study area possess a reasonable low value of natural moisture content with the highest value of 16.1 %. Other factors should be considered to determine the suitability of the soil samples for construction purposes.

From Table 2, the liquid limit of the soils ranges from 10.72 % – 60.9 % and the plastic limit ranges from 0 % to 43.52 %. The liquid limit varies widely but it must be noted that the values of 40 % to 60 % and above are typical for clay soils, such as samples AA_1, AK_1, II_1, II_2, PL_1, and PL_2 and values of 25 % to 50 % can be expected for Silty soils as in the case of samples AJ_1, AK_1, AK_2, and II_2 as outlined in BS 1377 of 1990.

According to [5], the soil samples can be classified based on the plasticity index as follows: Non plastic for PI equal to 0, Slightly Plastic for PI between 1 and 5, Low Plasticity for PI between 5 and 10, Medium Plasticity for PI within the range of 10 to 20, High Plasticity for PI between 20 and 40, and very High Plasticity for PI greater than 40. As a result of this, soil sample AJ_1 exhibits low plasticity with value of 7.36. While samples AJ_2, AA_2, AK_1, AK_2, II_1 and PL_2 exhibit medium plasticity with the values of 11.22, 10.72, 17.62, 18.90, 16.16 and 15.96 respectively. And samples AA_1, II_2 and PL_1 with PI values of 20.61, 20.47 and 27.78 respectively exhibit a high plasticity property. However, samples AJ_2 and AA_2 possess Zero plasticity values but have a liquid limit, this could be as a result of the presence of organic materials. The specification according to the Federal Ministry of Works and Housing (1972) recommends liquid limits of 50 % maximum, plastic limit of 30 % maximum and plasticity index of 20 % maximum for sub-base and base materials. From the foregoing, most of the soil samples, based on its liquid limit and plastic limit met the required specification except samples AA_1, II_1, PL_1 and PL_2 which are below the specification range.

From the Figure 3, which shows the distribution curves of all the particles, the percentage of sample passing through No. 200 BS (0.075µm) sieves for samples AJ_1, AJ_2, AK_1, AK_2, AA_1, AA_2, II_1, II_2, PL_1 and PL_2 are 18, 10, 51, 24, 37, 33, 44, 60, 63 and 67 respectively. This result indicates that samples AJ_1, AJ_2, AK_2 and AA_2 can be deduced as good subgrade, subbase and base materials as the percentage passing the BS 200 sieve is less than 35% while the other samples do not meet the specification. According to the [6], (General specifications for Roads and Bridges, VOL II.) none of these samples, except AJ_2, qualifies to be a stone base material because the percentage passing BS 200 sieve is greater than 15% for the samples.

The specific gravity of the samples ranged between 2.11 – 2.45, a typical value for halloysite mineral [7]. Lower specific gravity values indicate a coarse soil, while higher values indicate a fine grained soil [8].



(a)

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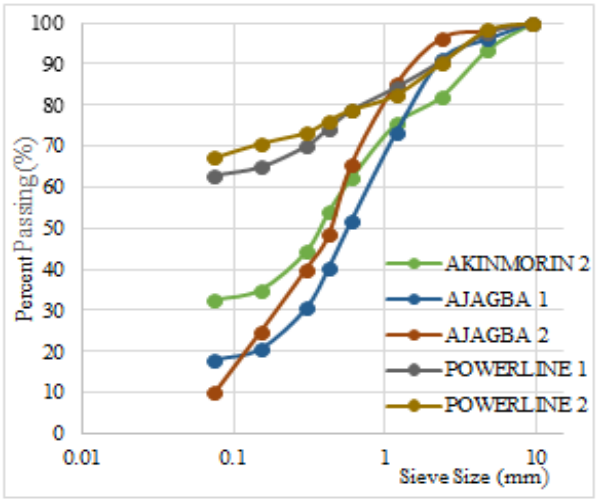


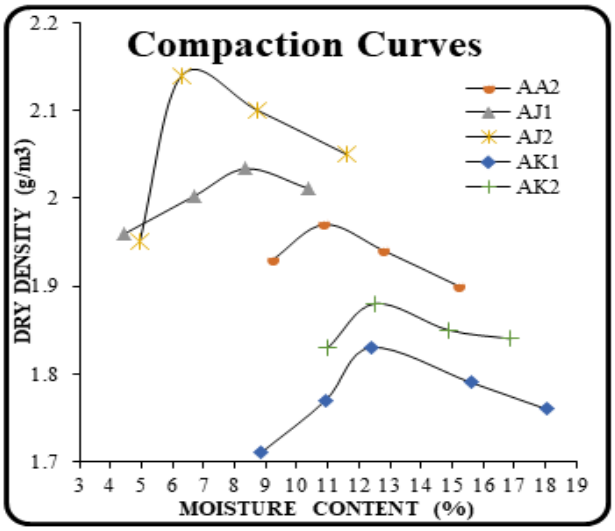
(b)

Fig. 3(a) & (b): Grain Size Distribution Curves of Samples.

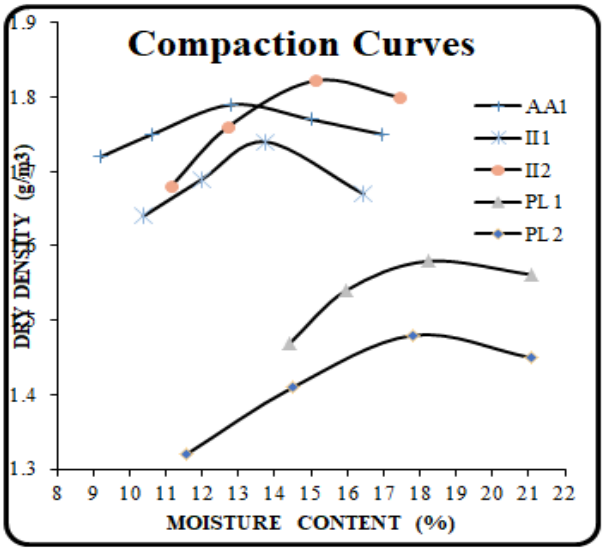
From figures 4a and 4b, the maximum dry density of the soil samples ranges between 1.48 g/m^3 and 2.14 g/m^3, while the optimum moisture contents range from 6.3 % to 18.22 % which is typical for materials within the range of silty clay to sandy soil. According to [9], samples characterized with high value of maximum dry density and low optimum moisture content are best suitable as subbase and subgrade materials. Also, [10] specified OMC should be less than 18 % for both subbase and subgrade materials. All the soil samples possess OMC values less than 18 %, except sample PL_1 with a value of 18.22 %.

The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soil, sub-base and the base course materials for use in road and airfield pavement design [11]. AS shown on Table 1, The results therefore showed the strength of the samples in terms of their load bearing capacity. The CBR values for the soaked soil samples ranged from 3.0 to 45.4 %. Soil Sample PL_1 has the least strength while sample AA_2 has the highest strength. The Highway Design Manual, Federal Ministry of Works and Housing specification of soil characteristics for flexible pavement design specifies a minimum CBR value of 10 %, 30 %, and 80 % for subgrade, subbase and base soil materials respectively. Only soil samples AA_1, PL_1 and PL_2 fall below 10 % and therefore not suitable for subgrade. AJ_1, AJ_2 and AA_2 have values above 30 % are suitable subbase materials.

From the AASHTO soil classification of the soil samples for highway, A-1 and A-2 soils are Excellent and Good soils for highway while A-3 to A-7 soils are fair to poor soils. Based on this, sample AJ_1 can be class into A-1-b (0), which are generally rated excellent to good subgrade material, AJ_2 is classed as A-3 indicating the presence of fine sand. Samples AA_2 and AK_2 belong to the A-2-6 subgroup, with a group indexes 0 and 2 respectively, indicating the presence of silty or clayey gravel and sand. AA_1, II_1 and PL_2 can be classified into A-7-5 groups with group index 12, 11 and 27 respectively. Samples AK_1, II_2 and PL_1 are classified under the A-7-6 group with group index 3, 15 and 20 respectively. These soil samples classified under A-7-5 and A-7-6 are clayey soils and are rated as poor subgrade materials which fall below the standards recommended for most geotechnical construction works and could cause instability of the roads.



(a)



(b)

Fig. 4:(a) Compaction Curve of Samples (AA_2, AJ_1, AJ_2, AK_1, and AK_2) (b) Compaction Curve of Samples (AA_1, II_1, II_2, PL_1, and PL_2).

The USCS classifies soils into two broad categories, the coarse grained soils and fine grained soils. The coarse grained soils are mainly gravelly and sandy in nature, i.e. with less than 50 % of the sample passing through the 0.075 mm sieve. While the fine grained soils are silt and clay, in which more than 50 % 0f the soil sample passes through the 0.075 mm sieve. The peat, silt and clay at times might be organic in nature. The liquid limits also play important roles in classifying the soil. Sequel to this, the soil sample AJ_1, AJ_2, AK_1, AK_2, AA_2, II_1, have a common group symbol SC and group name Clayey Sand. AA_1, PL_1 and PL_2 possess group symbol MH, with group name Elastic Silt, while II_2 possesses the group symbol CL and a group name Lean Clay.

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Table 1: Summary of The Geotechnical Properties of Soil Samples from Oyo East LGA

LOCATION	% finer No. 200	MDD (g/m^3)	OMC (%)	CBR (%)
AJ 1	18	2.03	8.36	41.5
AJ 2	10	2.14	6.3	42.7
AJ 3	21	2.1	8.73	36.2
AA 1	51	1.79	12.81	10.7
AA 2	33	1.97	10.88	32.7
AA 3	46	1.67	11.41	17.5
AA 4	50	1.89	13.09	28.5
AA 5	38	1.75	12.47	25
AK 1	37	1.83	12.39	23.2
AK 2	33	1.88	12.51	21.1
AK 3	39	1.8	12.43	20.9
AK 4	36	1.79	10.08	21.2
AK 5	38	1.84	15.34	22.7
II 1	44	1.74	13.74	13.3
II 2	60	1.82	15.11	21.1
II 3	47	1.5	14.7	17.2
II 4	51	1.7	15.94	13
II 5	58	1.6	15.36	20.5
PL 1	63	1.58	18.22	3
PL 2	67	1.48	17.81	6.3
PL 3	51	1.49	16.38	3.8
PL 4	54	1.46	15.75	5.7
PL 5	57	1.45	17.89	6.8

Table 2: Summary of The Geotechnical Properties of Soil Samples from Oyo East LGA

LOCATION	LL (%)	PL (%)	PI	Gs
AJ 1	26.34	19.34	7	2.27
AJ 2	11.51	NP	NP	2.43
AJ 3	23.55	15.52	8.04	2.43
AA 1	52.92	32.38	20.54	2.19
AA 2	10.39	NP	NP	2.23
AA 3	44.15	22.8	21.35	2.21
AA 4	11.11	NP	NP	2.19
AA 5	45.86	19.47	26.38	2.24
AK 1	40.93	23.64	17.29	2.39
AK 2	31.2	12.48	18.72	2.26
AK 3	19.21	7.86	11.35	2.39
AK 4	27.49	19.28	8.2	2.27
AK 5	35.18	21.51	13.67	2.25
II 1	54.23	38.15	16.08	2.17
II 2	48.98	28.75	20.23	2.51
II 3	50.44	31.46	18.99	2.48
II 4	51.42	23.72	27.7	2.27
II 5	51.42	27.45	23.97	2.25
PL 1	60.8	33.12	27.67	2.15
PL 2	62.26	43.52	18.74	2.11
PL 3	60.98	41.58	19.4	2.13
PL 4	62.61	36.26	26.35	2.12
PL 5	63.27	42.7	20.58	2.14

IV. CONCLUSION

The result showed that the studied soil samples have soaked CBR values ranging between 3 % and 45.4 %. Soil sample AA_1 which has a value of 9.2 %, falls between the subgrade classification S4 (8 - 14 % CBR) according to [12]. Thus, all of the samples satisfy the condition for subgrade soil, except the soil samples obtained from Powerline road, with the CBR values of 3 % and 6.3 %, which are below the minimum 10 %, specified for subgrade by the [6]. This is probably the major cause of the incessant failure of the road. While samples like AJ_1, AJ_2 and AA_2 have a bearing capacity of 41.5 %, 42.7 % and 45.4 % respectively, a specification suitable for subbase coarse material. Some of the soils possess high clay content which is indicative of fair to poor highway subgrade and sub-base soils. Soil sample AJ_1 can be class into A-1-b (0), which can be generally rated excellent to good subgrade material, AJ_2 is classed as A-3 indicating the presence of fine sand. Samples AA_2 and AK_2 belong to the A-2-6 subgroup, with group indexes 0 and 2 respectively, indicating the presence of silty or clayey gravel and sand. The other samples are classified under the A-7-5 and A-7-6 groups which are clayey soils and are rated as poor subgrade materials which fall below the standards recommended for most geotechnical construction works and could cause instability of the roads. Soil samples AJ_1, AJ_2, AK_1, AK_2, AA_2, II_1, have a common group symbol SC and group name Clayey Sand. AA_1, PL_1 and PL_2 possess group symbol MH, with group name Elastic Silt, while II_2 possesses the group symbol CL and a group name Lean Clay. The soil samples from the study area, despite having suitable bearing capacities, fall below the recommendation for most geotechnical construction works and could be the cause of instability of the roads.

Geophysical investigations such as electrical resistivity should be carried out in order to determine depth of water table which in the long run will complement geotechnical techniques. Likewise, we should consider the effects of adequate drainage on the performance of these roads in future research. More academic research should be carried out on geotechnical mapping of Oyo East Local Government Area. Also, similar investigations should be extended to subgrade soils in as many local government areas as possible in southwestern Nigeria and the country at large.

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