Comparative Analyses of Mechanical Properties of Ekiti State Soil, Nigeria

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***Abstract* — In Civil Engineering construction all over the World, soil is indispensable as it forms foundation of everything. Thus there is need for proper study / analysis of its properties especially mechanical ones. This study is aimed at investigating the mechanical properties of some Ekiti State soil. Soil samples collected from the study area were subjected to laboratory tests (i.e. Grain Size Analysis and Atterberg Limits tests) in its untreated states. The results of the tests carried out on the untreated soil samples indicated that Efon Alaaye, Gbonyin, Ido – Osi, Ijero and Oye LGAs soils were generally classified as Granular soil material with mainly Silty – Clayey Gravel and Sand Constituent materials. Oye LGA also has some Stone Fragments. Ido – Osi LGA has group classifications of A-1-a, A – 2 – 4 and A – 4 while Oye LGA has group classifications of A-1-b and A-2-4. Efon – Alaaye, Emure and Ise-Orun LGAs have group classifications of A-2-6, A – 6 and A – 7; Gbonyin LGA has group classification of A-2-4 while Ijero LGA has group classifications of A-2-4, A-2-6, A-4 and A-6. The general rating as sub-grade materials of most of Efon Alaaye, Ido-Osi, Gbonyin, Ijero and Oye LGAs were excellent to good while that of Emure, Ise-Orun and some parts of Ido-Osi and Ijero LGAs were fair to poor. The best soil materials (i.e. A-1-a and A-1-b) could be found in Ido – Osi and Oye LGAs. While the worst soil materials could be found in Ido – Osi and Ijero LGAs. Further research work could be done on this study in other to ascertain any other suitable hidden properties of the soil.**

Keywords—Atterberg Limits; Civil Engineering; Grain Size Analysis; Mechanical properties; Soil.

I. INTRODUCTION

In the world over today, soil cannot be assessed without considering its mechanical properties. In any Civil Engineering construction, foundation is of great importance. It must be firm enough to carry the whole structure. Soil underneath and surrounding any foundation must play important role for it to be able to perform its functions effectively. Therefore, there is need to acquire knowledge about the soils' properties (especially mechanical properties) and their behavioural factors ([8], [10]).

The present and future states of any Civil Engineering structures lie majorly on the soil beneath its foundation. Most of the soils that are readily available within our vicinity do not contain all the nutrients needed to make them suitable for some important Civil Engineering structures, hence they are being discarded. This usually results in seeking for expensive materials from far away burrow pit. At times, huge amount of money is used in stabilization process of the available soil in other to suit the construction purpose ([9]).

It is hard to overlook the importance(s) of soil in construction of structures and other aspect of Civil Engineering practices. All structures are built on soil for stability. If there is any deficiencies in the properties of soil that makes it unfit for structure to be built on it, there is need to either excavate the soil or improve its Engineering performance for optimum use. The formal is expensive and requires the use of heavy equipment. The latter which is improvement of Engineering performance of soil could be done through the use of stabilizing agents / additives ([11]).

The locally available additives such as PKSA and SDA can be used. The overall cost of improving soil properties with the use of conventional additives could be high and unaffordable, but if locally available additives are found suitable for stabilizing soil, this will reduce the cost of improving the soil properties. These locally available additives could be agricultural wastes, industrial wastes, domestical wastes etc. Most of these wastes are hazardous to man and environment. Even burning them can deplete the ozone layer ([11]).

Past research works of many authors on these locally available additives such as Sawdust Ash (SDA), Palm Kernel Shell Ash (PKSA), Rice Husk Ash (RSA), Coconut Shell Ash (CSA), Maize Cobs, Cassava Peel Ash (CPA), Cocoa Pod Ash, Pulverized Fuel Ash (PFA), Locust Beans Ash (LBA), Fly Ash, Groundnut Shell Ash (GSA), etc. which were usually products of milling stations, thermal power stations, waste treatment plants, breweries etc. showed that they have been found to be useful in most cases for stabilization of soil ([3], [8], [9], [11], [12], [13], [14], [15], [16], [17]).

In this study, comparative analyses of some Ekiti State soil mechanical properties would be assessed. These would help in laying hands on Engineering information / data of Ekiti State soil and in establishing the most suitable one (s) for different construction purposes.

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STUDY AREA - the study area is Ekiti State as shown in fig 1 - a state in western Nigeria, declared a state on 1 October 1996 alongside five others by the military under the dictatorship of General Sani Abacha. The state, carved out of the territory of old Ondo State, covers the former twelve local government areas that made up the Ekiti Zone of old Ondo State. On creation, it had sixteen Local Government Areas (LGAs), having had an additional four carved out of the old ones. Ekiti State is one of the thirty-six states that constitute Nigeria ([1], [2]).

The State is mainly an upland zone, rising over 250 meters above sea level. It lies on an area underlain by metamorphic rock. It is generally undulating country with a characteristic landscape that consists of old plains broken by step-sided out-crops that may occur singularly or in groups or ridges. Such rocks out-crops exist mainly at Aramoko, Efon-Alaaye, Ikere-Ekiti,Igbara-odo- ekiti and Okemesi-Ekiti. The State is dotted with rugged hills, notable ones being Ikere-Ekiti Hills in the south, Efon-Alaaye Hills on the western boundary and Ado-Ekiti Hills in the centre ([1], [2]).

The State enjoys tropical climate with two distinct seasons. These are the rainy season (April–October) and the dry season (November–March). Temperature ranges between 21° and 28 °C with high humidity. The south westerly wind and the northeast trade winds blow in the rainy and dry (Harmattan) seasons respectively. Tropical forest exists in the south, while savannah occupies the northern peripheries ([1], [2]).

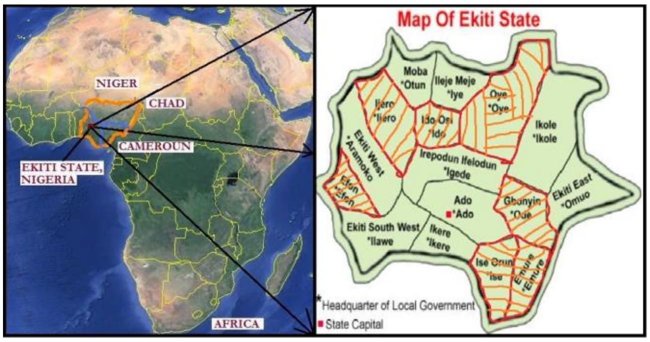

Fig. 1: Location of the Study area – Ekiti State [4]

II. MATERIALS AND METHODS

SOIL SAMPLE COLLECTION AND ANALYSIS - Soil samples were collected from pits dug within the study area (from seven different LGAs namely Efon Alaaye, Emure, Gbonyin, Ido / Osi, Ijero, Ise-Orun and Oye – Ekiti as shown in Fig. 1) at depth of 0.75 - 1.2m in its disturbed state. The soil samples collected were stored in polythene bag to maintain its natural moisture contents. The samples were then taken to the laboratory where the deleterious materials such as roots were removed.

The samples were air dried, pulverized and large particles were removed. Moulding of test specimens was started as soon as possible after completion of identification. All tests were performed to standards as in [5]. Their features were also examined. The tests carried out on the samples were Grain Size Distribution and Atterberg limits. The results were compared to the standard specified values and grouped in accordance with [6] and [7].

ATTERBERG LIMITS - These tests are also called CONSISTENCY LIMIT TESTS and consist of Liquid Limits (LL), Plastic Limit (PL), Plasticity Index (PI) and Shrinkage Limit tests. They are carried out on the soil sample(s) in other to assess the samples natural interactions with water. The results were then compared with [6] and [7] standard specified values as earlier mentioned ([8], [9], [12]).

GRAIN SIZE DISTRIBUTION – This test is used in assessing particles / grains distribution, grouping of the particles into sizes and relative proportion by mass of soil samples (i.e. clay, sand and gravel fraction). The results would then be grouped in accordance with [6] ([8], [9], [12]).

III. RESULTS AND DISCUSSION

Table 1: Summary of Test Results for the Natural Soil Samples of Emure and Ise-Orun LGAs

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	< 75μmm (%)	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)
A	12.2	48.2	39.6	55.31	23.15	32.16
B	16.2	34.2	49.6	57.99	22.85	35.14
C	12.2	47.2	40.6	59.73	24.35	35.38
D	17.2	39.6	43.2	62.31	26.70	35.61
E	22.2	35.2	42.6	48.36	19.80	28.56
F	18.0	42.0	40.0	62.89	26.40	39.49
G	15.8	41.8	42.4	57.01	22.76	35.14
H	17.0	42.8	40.2	62.24	26.70	35.54
I	18.2	40.8	41.0	51.38	22.45	28.93
J	20.0	31.6	48.4	57.02	24.10	32.92

Table 1 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Emure and Ise-Orun LGAs. The results showed that all the soil samples had very high percentages finer than 0.0075 fractions (i.e. >35%), which varied between 39.6% and 49.6%. Hence, general rating as sub-grade in accordance with [6] is fair to poor materials. They have significant constituent materials of mainly clayey soils while some are silty or clayey gravel and sand.

It is also observed that the Liquid Limit (LL) and Plasticity Index (PI) values varied from 51.38% to 62.89% and 28.56% to 35.54% respectively. These soil samples met the required specification for subgrade course materials (i.e. LL ≤ 80%, PI ≤ 55% and MDD > 1760kg/m3) but did not met specification for base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12%). Thus, they could be suitable for subgrade course materials and are grouped into A-2-6, A-6 and A-7 (A-7-5 or A-7-6) in [6].

Table 2 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Efon – Alaaye LGA. The results showed that all the soil samples had less percentages finer than 0.0075 fractions (i.e. <35%), which varied between 10% and 22%. Hence, general rating as sub-grade in accordance with [6] is excellent to good materials.

They have significant constituent materials of mainly silty or clayey gravel and sand.

Table 2: Summary of Test Results for the Natural Soil Samples of Efon - Alaaye LGA

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	< 75μmm (%)	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)
A	6.0	76.0	18.0	25.0	16.03	8.97
B	4.0	74.0	22.0	24.0	14.60	9.40
C	10.0	80.0	10.0	22.0	13.50	8.50
D	4.0	77.0	19.0	23.0	11.60	11.40
E	7.0	74.0	19.0	15.2	11.30	3.90
F	4.0	76.0	20.0	16.5	10.30	6.20

It is also observed that the LL and PI values varied from 15.20% to 25.00% and 3.90% to 11.40% respectively. These soil samples met the required specifications for subgrade course materials (i.e. LL ≤ 80% and PI ≤ 55%). All the soil samples except A and B did not meet specifications for base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12%). Thus, they could be suitable for subgrade course materials and are grouped into A-2-6, A-6 and A-7 (A-7-5 or A-7-6) in [6]. Soil samples A and B could also be suitable for subbase and base course materials.

Table 3: Summary of Test Results for the Natural Soil Samples of Ido - Osi LGA

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	<75μmm (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
A1	10.00	26.00	63.20	15.30	11.50	3.80
A2	17.20	47.60	32.80	14.30	9.30	5.00
B1	12.60	48.00	35.00	13.90	10.10	3.80
B2	13.80	58.60	22.00	16.10	9.10	7.00
C1	12.80	49.00	33.60	10.80	5.20	5.60
C2	15.40	70.40	8.20	14.70	7.30	7.40
D1	15.80	67.40	10.40	13.90	5.10	8.80
D2	15.40	70.60	8.20	11.30	6.10	5.20

Table 3 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Ido - Osi LGA. The results showed that all the soil samples had percentages finer passing through 0.075mm fractions varied between 8.2% and 63.2% - All the soil samples have their percentages finer passing through 0.075mm fractions as 35% and below except that of A1 which is 63.2%. The untreated soil samples B2 – D2 could be generally classified as Granular soil materials while untreated soil sample A1 could be generally classified as Silt – Clay soil materials.

With reference to [6], the untreated soil samples A1 fell under group classification of A–4, A2, B1, C1, C2, and D1 fell under group classification of A – 2 - 4 while D2 fell under group classification of A – 1 - a. The untreated soil sample A1 has significant constituent materials of mainly silty soil. The untreated soil samples A2 to D1 have significant constituent materials of mainly silty or clayey gravel and sand. While D2 has significant constituent materials of stone fragments, gravel and sand.

The general rating of all the untreated soil samples (except A1) as sub-grade materials is excellent to good. Though that of D2 (i.e. A – 1 – a) is the best. While that of sample A1 is fair to poor and the worst. All the soil samples met the required specifications for subgrade (i.e. LL ≤ 80% and PI ≤ 55%), subbase and base (i.e. LL ≤ 35% and PI ≤ 12%) course materials.

Table 4: Summary of Test Results for the Natural Soil Samples of Gbonyin LGA

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	<75μmm (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
1	30.80	48.80	20.40	22.90	16.60	6.30
2	17.60	52.40	30.00	22.50	17.50	5.00
3	20.60	53.00	26.40	22.50	22.00	0.50
4	26.00	49.80	24.20	18.00	14.00	4.00
5	24.00	47.80	28.20	22.00	18.40	3.60
6	22.00	48.00	30.00	21.00	20.00	1.00
7	18.40	49.20	32.40	18.00	14.00	4.00
8	27.40	48.80	23.80	23.50	17.00	6.50

Table 4 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Gbonyin LGA. The results showed that all the soil samples had less percentages finer than 0.0075 fractions (i.e. <35%), which varied between 20% and 32%. Hence, general rating as sub-grade in accordance with [6] is excellent to good materials. They have significant constituent materials of mainly silty or clayey gravel and sand. It is also observed that the LL and PI values varied from 18.00% to 23.50% and 0.50% to 6.30% respectively.

These soil samples met the required specifications for subgrade course materials (i.e. LL ≤ 80% and PI ≤ 55%). None of the soil samples meet specifications for base and sub base course materials (i.e. LL ≤ 35% and PI ≤ 12%). Thus, they could be suitable for subgrade course materials and are grouped into A-2-4 in [6].

Table 5: Summary of Test Results for the Natural Soil Samples of Ijero LGA

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	<75μmm (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
1	4.40	19.20	76.40	20.90	16.60	4.30
2	1.70	10.20	88.10	21.50	17.50	4.00
3	6.40	57.20	36.40	20.50	17.40	3.10
4	1.60	70.80	27.60	19.30	14.00	5.30
5	19.20	49.60	31.20	23.00	18.40	4.60
6	4.80	46.40	48.80	20.00	17.25	2.75

Table 5 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Ijero LGA. The results showed that all the soil samples had percentages finer passing through 0.075mm fractions varied between 27.6% and 88.1% - Soil samples 4 & 5 have their percentages finer passing through 0.075mm fractions less than 35% while that of remaining soil samples were greater than 35%. Thus, the untreated soil samples 4 & 5 could be generally classified as Granular soil materials while the untreated soil samples 1, 2, 3 & 6 could be generally classified as Silt – Clay soil materials.

Using [6] Classification system, the untreated soil samples 1, 2 and 3 fell under group classification of A–4; untreated soil sample 4 fell under group classification of A – 2 – 4; untreated soil sample 5 fell under group classification of A – 2 – 6; while untreated soil sample 6 fell under group classification of A - 6.

Table 6: Summary of Test Results for the Natural Soil Samples of Oye LGA

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS		
	> 4.25mm (%)	4.25 - 75μmm (%)	<75μmm (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
A	18.00	48.60	33.40	10.95	7.90	3.05
B	29.80	38.40	31.80	12.59	8.50	4.09
C	29.60	51.20	19.20	15.42	9.70	5.72
D	26.80	51.60	21.60	13.77	9.10	4.67

Table 6 showed results of Grain size Analysis and Atterberg Limits tests for the natural soil samples of Oye LGA. The results showed that all the soil samples had less percentages finer than 0.0075 fractions (i.e. <35%), which varied between 7.00% and 33.40%. The untreated soil samples could be generally classified as granular soils. Soil samples A and B fell under group classification of A - 2 – 4 while soil samples C and D fell under group classification of A – 1 - b. Hence, general rating as sub-grade in accordance with [6] is excellent to good materials.

Though that of C and D (i.e. A – 1 – b) were better than that of A and B (A – 2 – 4). Soil samples A and B have significant constituent materials of Silty or Clayey Gravel and sand while soil samples C and D have significant constituent materials of Stone Fragments, Gravel and Sand. These soil samples met the required specifications for subgrade (i.e. LL ≤ 80% and PI ≤ 55%), base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12%).

The untreated soil samples 1, 2 and 3 have significant constituent materials of mainly silty soil. Though from Table 3, it could be observed that untreated soil sample 3 has significant constituent materials of mainly silty, gravel and sand. The untreated soil samples 4 and 5 have significant constituent materials of mainly silty or clayey, gravel and sand. While untreated soil sample 6 has significant constituent materials of mainly clayey soil. Generally, betterment of the untreated soil samples could be arranged in ascending order of 4 > 5 > 3 > 1 > 2 > 6.

The general rating of the untreated soil samples 4 and 5 as sub-grade materials is excellent to good. Though that of untreated soil sample 4 (i.e. A – 2 – 4) is the best. While that of untreated soil sample 1, 2, 3 and 6 is fair to poor and untreated soil sample 6 is the worst. All the untreated soil samples met the required specifications for subgrade (i.e. LL ≤ 80% and PI ≤ 55%); while only untreated soil sample 4 met the required specifications for subbase and base (i.e. LL ≤ 35% and PI ≤ 12%) course materials.

IV. CONCLUSION

From the results of the study shown above, the following conclusions were drawn:

1. The Natural soils of Efon Alaaye, Gbonyin, Ido – Osi, Ijero, and Oye LGAs were generally classified as Granular soil material with mainly Silty – Clayey Gravel and Sand Constituent materials. Oye LGA also has some Stone Fragments.
2. Ido – Osi LGA has group classifications of A-1-a, A – 2 – 4 and A – 4 while Oye LGA has group classifications of A-1-b and A-2-4.
3. Efon – Alaaye, Emure and Ise-Orun LGAs have group classifications of A-2-6, A – 6 and A – 7; Gbonyin LGA has group classification of A-2-4 while Ijero LGA has group classifications of A-2-4, A-2-6, A-4 and A-6.
4. The general rating as sub-grade materials of most of Efon Alaaye, Ido-Osi, Gbonyin, Ijero and Oye LGAs were excellent to good while that of Emure, Ise-Orun and some parts of Ido-Osi and Ijero LGAs were fair to poor.
5. The study showed that the best soil materials (i.e. A-1-a and A-1-b) could be found in Ido – Osi and Oye LGAs. While the worst soil materials could be found in Ido – Osi and Ijero LGAs.

Further research work could be done on this study in other to ascertain any other suitable hidden properties of the soil especially Performance properties.

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