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Assessment of Performance Properties of Stabilized Lateritic Soil for Road Construction in Ekiti State.

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***Abstract*—*Soil Stabilization usually enhances performance properties of soil. This can foster waste to wealth policy in country like Nigeria. The aim of this study is to assess performance properties of a stabilized lateritic soil with a view to obtain a cheap and more effective additive. Soil samples were collected from the study area and subjected to Compaction and California Bearing Ratio (CBR) laboratory tests with the addition of 2%, 4%, 6%, 8% and 10% Rice Husk Ash (RHA) and Egg Shell Ash (ESA). Results showed that MDD, OMC and CBR values varied from 1575Kg/m3 to 1930Kg/m3, 7.55% to 18.50% and 20% to 131% respectively for sample A. And 1566Kg/m3 to 1896Kg/m3, 7.53% to 16.90% and 16% to 98% respectively for sample B. The MDD values decrease with increase in the additives contents due to the replacement of soil by the additives in the mixture, coating of the soil by additives which resulted in large particles with larger voids and density; and addition of the additives which decreased the quality of free silt, clay fraction and coarse materials with large surface areas formed. OMC values also increase as the additives increase, though, that of RHA increases more than that of ESA. This is due to the increase in additives which resulted to increase in the amount of water required in the system to adequately lubricate all the particles in the mixture equally increase. Generally, CBR values also increase with increase in the additives contents. This could be attributed to gradual formation of cementitious compound between the additives and Calcium Hydroxide (Ca(OH)2) present in the soil, thus increase in coarse particles of the soil through cementation.*

Keywords*—*California Bearing Ratio, Compaction, Lateritic Soil, Moisture Content, Soil, Performance Properties, Stabilization.

I. INTRODUCTION

Wherever there is deficiency in properties of soil or expansive soil is encountered, it is usually accompanied by awkward problems in Civil Engineering works. Greater part of expansive or problematic soil properties could be improved through soil stabilization processes. The main reason for Soil Stabilization is to enhance mechanical and performance properties of the soil e.g. Strength, stability, water resistance etc. Soil Stabilization has been in existence for long time and is of different processes. Though, its usage is not so common in developing world. The use of Stabilization in Third World Countries like Nigeria will assist in maximization of "Waste to Wealth Policy". Therefore help in proper waste disposal and management and rise of standard of living. This will also serve as source of job opportunities ([1]).

The condition of any Civil Engineering structures greatly depends on the soil underneath its substructure. Almost all the soil within some significant Civil Engineering structures are not suitable for their construction purpose, thus cut to spoil. The end result is acquisition of borrow pit materials which are always costly at the end of the day. Most often, stabilization process could also be very expensive when engaged in this kind of situation. Whereas, waste materials are lying fallow within our vicinity waiting for its management and disposal. These materials could be used as replacement and serve the purpose (s) of expensive / imported materials such as Cement and Lime that are being used as stabilization agents in unsuitable soil. When the waste materials are being recycled or reused as stabilized materials, it would help a lot in construction industries and thus, improve the standard of living of people. The taste for imported materials in Third World countries is very high and one of the reasons the poor countries remains poorer. Waste recycling or reusing has been a great means of fame to many First World countries of the world ([2]).

[12] Expressed that though soil stabilization techniques were used for road construction in most parts of the world, the conditions and purposes of stabilization vary greatly from one place to another. In developed world, the need for aggregates has become issue of profound conflict between agricultural and environmental interests. While in developing world, availability of good aggregates of persistent quality and cheap prices may not be available.

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The above stated cases usually results in escalation in costs of aggregates and maintenance. The upgrading by stabilization of materials thus comes up as an attractive option, which will help in actualizing the dreams of the Federal Government of Nigeria at long term in scouting for already available cheap construction materials.

The study area is along Ado Ekiti – Ijan road, Ado – Ekiti Local Government Area (LGA), Ekiti State as shown in Fig. 1 - a state in western Nigeria declared as a state on 1st 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. One of these sixteen LGAs is Ado – Ekiti LGA. Ado - Ekiti is surrounded by Irepodun / Ifelodun LGA in the North, Gbonyin LGA in the East, Ekiti Southwest / Ikere LGAs in the West and Ise / Orun LGA in the South. The City itself is the Capital of Ekiti State and headquarters of Ado-Ekiti LGA ([9], [15]).

Ado – Ekiti is located between latitude 7^0 15'N and 8^0 51'N; and longitude 4^0 51'E and 5^0 45'E. Its landscape consists of ancient plains broken by steep sided outcropping dome rocks situated within tropical climate of Nigeria. Geologically, the study area is underlain by metamorphic rocks of the Precambrian basement complex of Southwestern part of Nigeria, the great majority of which are very ancient in age. These basement complex rocks show great variations in grain size and in mineral composition. The rocks are quartz gneisses and schists consisting essentially of quartz with small amounts of white mizageous minerals. In grain size and structure, the rocks vary from very coarse-grained pegmatite to medium-grained gneisses. The rocks are strongly foliated and occur as outcrops. The soils derived from the basement complex rock are mostly well drained, having medium to coarse in texture. The geological nature of the study area and its increased urbanization make it more vulnerable and of public health concern when it comes to water quality. The study area is mainly an upland zone, rising over 250 meters above sea level. It lies on an area underlain by metamorphic rock ([1], [2], [9], [15]). The State is within tropical climate of South-western Nigeria with two distinct seasons namely rainy season (April–October) and dry season (November–March). Its Temperature is 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 (([9], [15]).

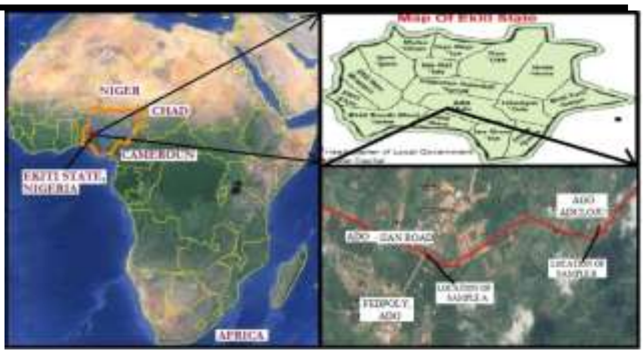

Fig. 1: Location of the Study area – Ado Ekiti, Ekiti State, Nigeria ([10]).

Previous studies of authors such as [1], [2], [3], [4], [5], [6], [12], [13], [14] etc looked into stabilisation of soil through the use of locally available additives made from agricultural and environmental wastes such as Eggshell, Rice Husk, Palm Kernel Shell, Sawdust etc. According to [4], previous studies have proved that Chicken Eggshell is an aviculture by-product that has been worldly known as one of the worst environmental problems, especially in those countries where the egg production and consumption is very high. [12] expressed that efforts in the application of conversion of Eggshells to important use is an idea worth embracing in the ever increasing efforts of "Waste to Wealth Policy".

Generally, egg shell structure is a protein lined interconnected with mineral crystals, commonly of a calcium compound like calcium carbonate. It is cheap, lightweight and has low load-bearing composite. It is a biomaterial which has 95% calcium carbonate by weight (in form of calcite) and 5% organic materials (i.e. Al2O3, SiO2, S, Cl, P, Cr2O3 and MnO). It is agricultural waste materials generated from domestic sources such as chick hatcheries, poultry, bakeries, fast food restaurants etc which can litter environment and thus result in environmental pollution without proper disposition and management. Scientifically, eggshell majorly comprised of calcium compounds that is very similar to that of cement ([3], [4], [5], [12]. According to [3], the quality of lime in eggshell waste is majorly affected by its degree of exposure to sunlight, raw water and harsh weather circumstances.

Rice Husk is surrounds of paddy grains; a rice by-product generated from rice milling. Rice Husk is made up of 22% of paddy while the rest percentage is rice. It is used as fuel in the rice mills for generation of steam for the purpose of boiling process. During heating process, Rice Husk is usually converted to approximately 75% organic volatile matter and 25% Ash (of its weight). This Ash is called Rice Husk Ash (RHA). RHA usually comprises of 85% - 90% amorphous silica and poses serious environmental threat ([14]).

In this study, assessment of performance properties of lateritic soil stabilized with Cement, Egg Shell Ash (ESA) and Rice Husk Ash (RHA) would be conducted. This entails looking into changes in the Engineering properties of the Soil due to addition of these additives; thus foster availability and affordability of construction materials in developing world like Nigeria especially Ekiti State.

II. MATERIALS AND METHODS

2.1 Performance Properties

These are properties of soil that have to do with Compaction and California Bearing Ratio (CBR) tests of the soil. It is an indirect measure of strength. Compaction test comprises of Dry density and Moisture content ([8]).

2.2 Compaction Test

This is type of test(s) conducted on soil sample in other to determine its Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).This test measures the dry density of the compacted soil in relationship to moisture content depending on the manner of the compactive effort. Compaction influences the shear strength and compressibility of the soil and is frequently used in earthworks and road construction. It is primarily used as a rapid test to determine the moisture suitability of earthwork materials at the construction phase. Calibration lines are usually determined through a range of moisture contents in the laboratory. The Moisture Content Value (MCV) is used to quantify the compactive effort to produce near full compaction and can be correlated with shear strength and CBR value. It is also used for the evaluation of subgrade strength in road design. The test measures the load required to cause a plunger to penetrate a specimen of soil ([8]).

2.3 California Bearing Ratio (CBR)

is a test of penetration for the purpose of acquiring relative value(s) of shearing resistance of materials of road pavement layers. It is a dimensionless exponent carried out in a standard laboratory or on the field during construction. It is always serves purpose of soil evaluation for pavement design particularly in tropical and subtropical nations ([8]).

2.4 Sample Collection and Analysis

Soil samples were collected from pits dug within the study area (Sample A – front of the Federal Polytechnic, Ado-ekiti and Sample B – Ago Aduloju as shown in Fig. 1) at depth between 1.50m and 2.5m after topsoil removal using method of disturbed sampling. 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. Some Additives were then added to the soil samples (i.e. Cement, Rice Husk Ash (RHA) and Egg Shell Ash (ESA)) at varying proportions between 2% and 8%. The Cement Additive was added at 6% and 8% by soil sample weight. While the RHA and ESA additives were added at 2%, 4%, 6% and 8% by soil sample weight. Then soil samples and additives were thoroughly mixed to ensure homogeneous samples. Moulding of test specimens was started as soon as possible after completion of identification. All tests were performed to standards as in [8]. 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 [7] and [11].

2.5 Egg Shell Ashes (ESA)

The collected Eggshells were oven dried at 110^{O}C and further heated in a furnace to 450^{O}C at Civil Engineering laboratory, the Federal Polytechnic, Ado – Ekiti, Nigeria. The product is Egg Shell Ash (ESA) that was used for this piece of study.

2.6 Rice Husk Ashes (RHA)

The collected Rice Husks were oven dried at 110^{O}C and further heated in a furnace to 700^{O}C at Civil Engineering laboratory, the Federal Polytechnic, Ado – Ekiti, Nigeria. The product is Rice Husk Ash (RHA) that was used for this piece of study.

III. RESULTS AND DISCUSSION

From Table 1, the results showed that all the soil samples stabilized with RHA have Maximum Dry Density (MDD) values varied from 1650Kg/m3 to 1930Kg/m3 and 1566Kg/m3 to 1896Kg/m3 for soil samples A and B respectively. While from table 2, the results showed that all the soil samples stabilized with ESA have Maximum Dry Density (MDD) values varied from 1541Kg/m3 to 1930Kg/m3 and 1637Kg/m3 to 1896Kg/m3 for soil samples A and B respectively.

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Table 1: Compaction Test Results for the Stabilized Soil Samples (RHA)

ADDITIVE (%)	ADDITION OF 6% CEMENT				ADDITION OF 8% CEMENT			
	MDD (Kg/m3)		OMC (%)		MDD (Kg/m3)		OMC (%)	
	MP LE A	MP LE B	MP LE A	MP LE B	MP LE A	MP LE B	MP LE A	MP LE B
0	1930	1930	14.1	13.1	1930	1930	14.1	13.1
2	1650	1575	14.4	15.6	1905	1600	11	11.85
4	1765	1847	14.3	7.53	1847	1700	7.55	12.92
6	1575	1720	15.7	9	1675	1709	10.1	9
8	1840	1699	17.95	16.9	1900	1799	18.5	13.2
10	1650	1566	13.22	14.93	1759	1601	10.1	15.05

The results from table 1 also showed that all the soil samples stabilized with RHA have Optimum Moisture Content (OMC) values varied from 7.55% to 18.50% and 7.53% to 16.90% for soil samples A and B respectively.

While from table 2, the results showed that all the soil samples stabilized with ESA have Optimum Moisture Content (OMC) values varied from 7.60% to 14.10% and 6.70% to 13.10% for soil samples A and B respectively.

Table 2: Compaction Test Results for the Stabilized Soil Samples (ESA)

ADDITIVE (%)	ADDITION OF 6% CEMENT				ADDITION OF 8% CEMENT			
	MDD (Kg/m3)		OMC (%)		MDD (Kg/m3)		OMC (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	1930	1896	14.1	13.1	1896	1896	14.1	13.1
2	1775	1785	10.95	10.1	1578	1769	8.1	6.7
4	1670	1760	7.6	6.8	1921	1705	7.85	12.2
6	1800	1637	9.75	10.7	1800	1775	11	11.4
8	1785	1719	13.15	12.7	1839	1761	13.1	12.7
10	1740	1750	12.6	10.91	1541	1910	10.95	12.8

Figure 2 and 3 graphs were plotted from tables 1 and 2 results. From figure 2, it could be observed that MDD values decrease as Additives Contents increases for all the soil samples of RHA and ESA except soil sample B (8% Cement – ESA). This is due to the replacement of soil by the additives in the mixture. It could also be due to coating of the soil by the additives which resulted in large particles with larger voids and density. And addition of the additives also decreased the quality of free silt, clay fraction and coarse materials with large surface areas formed ([1]). These soil samples did not meet the required specification for subgrade course materials (i.e. MDD > 1760kg/m3), base and subbase course materials (i.e. MDD > 2000kg/m3) after stabilization process ([7], [11]). From figure 3, it could be observed that OMC increases as Additives Contents increases for all the soil samples of RHA and ESA. Though, that of RHA increases more than that of ESA. These portrayed that the increase in Additives Contents resulted to increase in the amount of water required in the stabilization process which will adequately lubricate all the particles in the mixture. Though the moisture content in the study area remains very high compared to required values, however the stabilization process improved the soil properties by reducing its moisture content ([1], [7], [11]).

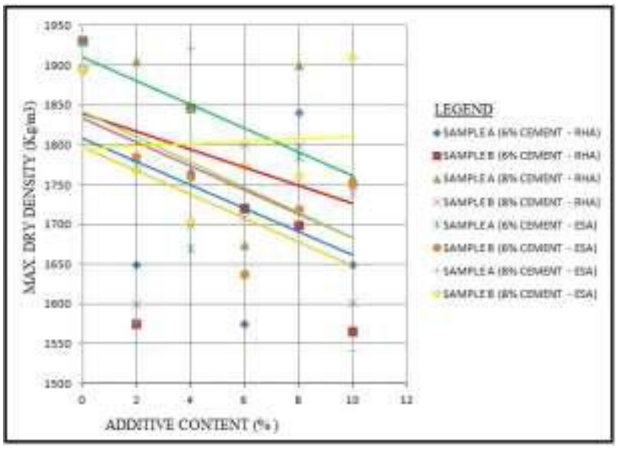

Fig.2: Graphs of Maximum Dry Density (MDD) for the Stabilized Soil Samples

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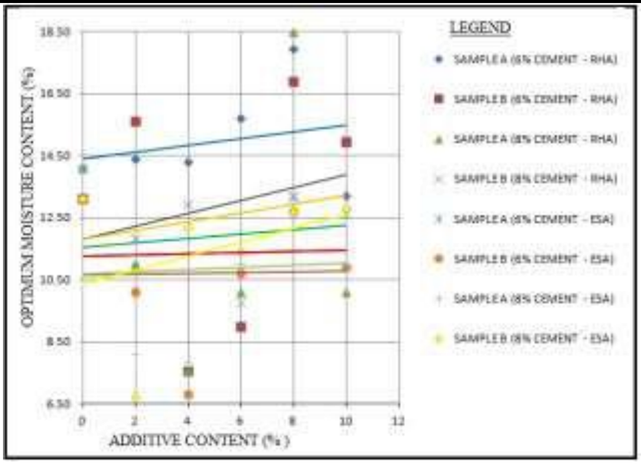

Fig.1: Graphs of Optimum Moisture Contents (OMC) for the Stabilized Soil Samples

From table 3, the results showed that all the soil samples stabilized with RHA have California Bearing Ratio (CBR) values varied from 20% to 131% and 16% to 98% for soil samples A and B respectively.

Table 3: California Bearing Ratio (CBR) Test Results for the Stabilized Soil Samples (RHA)

ADDITTIVE (%)	ADDITION OF 6% CEMENT				ADDITION OF 8% CEMENT			
	CBR - 2.5mm (%)		CBR - 5.0mm (%)		CBR - 2.5mm (%)		CBR - 5.0mm (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	89	43	91	49	89	43	91	49
2	87	77	84	86	20	16	20	24
4	43	73	64	74	26	36	33	22
6	91	83	131	80	79	65	97	20
8	107	98	90	97	63	46	78	76
10	69	75	86	80	52	18	56	53

While from table 4, the results showed that all the soil samples stabilized with ESA have CBR values varied from 24% to 98% and 16% to 97% for soil samples A and B respectively.

Table 4: California Bearing Ratio (CBR) Test Results for the Stabilized Soil Samples (ESA)

ADDITTIVE (%)	ADDITION OF 6% CEMENT				ADDITION OF 8% CEMENT			
	CBR - 2.5mm (%)		CBR - 5.0mm (%)		CBR - 2.5mm (%)		CBR - 5.0mm (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	89	43	91	49	89	43	91	49
2	26	18	34	24	24	20	26	24
4	31	17	36	27	24	24	32	26
6	26	16	79	36	39	20	26	24
8	91	97	83	70	86	90	98	87
10	59	48	63	64	57	47	54	26

Figures 4 and 5 graphs were plotted from tables 3 and 4 results. From figure 4 and 5, it could be observed that CBR values increase as Additives Contents increases for all the soil samples of RHA and ESA. This is due to gradual formation of cementitious compound between the additives and Calcium Hydroxide ($Ca(OH)2$) present in the soil, thus increase in coarse particles of the soil through cementation ([1]).

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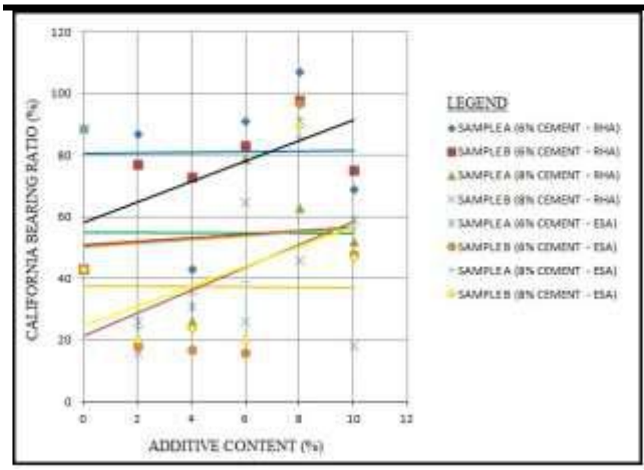

Fig.2: Graphs of California Bearing Ratio (CBR – 2.5%) for the Stabilized Soil Samples

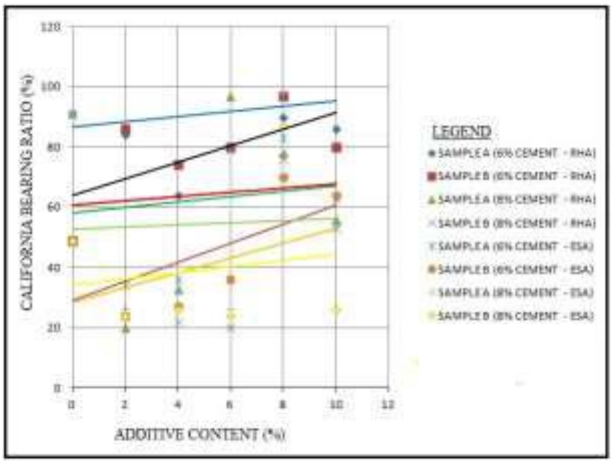

Fig.3: Graphs of California Bearing Ratio (CBR – 5%) for the Stabilized Soil Samples

IV. CONCLUSION

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

- The CBR and OMC values of the soil samples increase with increase in additives contents; while MDD value decrease with increase in additives contents.
- The decrease in MDD values is due to the replacement of soil by the additives in the mixture. It could also be due to coating of the soil by the additives which resulted in large particles with larger voids and density.
- Addition of the additives also decreased the quality of free silt, clay fraction and coarse materials with large surface areas formed.
- Increase in OMC values is due to increase in amount of water required in the system and to lubricate the mixture.
- Increase in CBR values is due to gradual formation of cementitious compound between the additives and Calcium Hydroxide ($Ca(OH)_2$) present in the soil, thus increase in coarse particles of the soil through cementation
- The additives (i.e. mixture of Cement and RHA/ESA) stabilized the soil.

Moreover, there is need for further research on this study.

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