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Study of Mechanical Properties of Stabilized Lateritic Soil with Additives.

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***Abstract*—*The overdependence on the usage of industrially manufactured soil improved or conventional additives have resulted in unaffordable cost of construction of better infrastructure in Third World and poor countries which are mostly agriculturally dependent across Globe. This study is aimed at studying the mechanical properties of lateritic soil stabilized with mixture of conventional and locally available additives. Soil samples collected from the study area were subjected to laboratory tests (i.e. Grain Size and Atterberg Limits tests) after stabilized with cement, ESA and RHA additives at proportion of 2% to 10% by sample weight. It is observed that the LL, PL and PI values varied from 30.1% to 35.5%, 9.9% to 12.5% and 20.1% to 23.2% respectively for sample A. While LL, PL and PI values varied from 35.2% to 41.5%, 10.8% to 14.5% and 24.4% to 27.1% respectively for sample B. It could be generally observed that PI values reduced while PL values increased for the soil samples after increase in addition of cement additive from 6% to 8%. All the LL, PL and PI values also reduced as the percentage of RHA additive added increased. Soil sample A has group classifications of A – 2 – 6 while soil sample B has A – 7 and tend towards A – 2 - 6 and A - 6 after stabilization. The stabilization process using local additives as partial replacement of conventional one generally improved the soils Engineering properties. Though it is more felt in ESA than RHA. Further research work should be carried out.*

Keywords*—*Atterberg Limits, Grain Size Analysis, Mechanical Properties, Soil, Stabilization.

I. INTRODUCTION

As necessity is mother of all inventions, there is need for local alternative materials (i.e. local additives) to be used as partial or total replacement to conventional ones as stabilizing agents in order to cut or reduce cost of construction in Third World countries like Nigeria. Cement and lime have been the two main materials used for stabilizing soils for many years and have rapidly increase in prices due to the sudden increase in energy cost since almost half of a century. The over dependence on the usage of industrially manufactured soil improved or conventional additives (cement, lime, etc.) have resulted in rise in construction cost of roads and structures. This has continue to act as barrier for the Third World and poor countries across Globe to have access to good or better infrastructural amenities such roads and safe structures. Though, these countries are mostly agriculturally dependent ([3]).

Since all structures are built on soil for stability, thus Soil stabilization is a significance aspect of Civil Engineering practices. Any deficiencies in soil characteristics will make it unsuitable for structure to be built on it – thus the need to either excavate the soil or improve its Engineering properties for maximum use. Excavation / replacement of soil is expensive and requires the use of heavy equipment. While Soil stabilization which has to do with improvement of Engineering properties of soil could be carried out through stabilizing agents / additives usage. Locally available additives such as Rice Husk Ash (RHA) and Egg Shell Ash (ESA) in partial replacement of Cement could be used. The overall cost of improving Engineering properties of soil using complete conventional additives (i.e. cement) in stabilization process could be high and unaffordable, but if partially replaced with locally available additives and are found suitable for stabilizing soil, this will reduce the cost of improving the Engineering properties of soil. These locally available additives could be agricultural wastes, industrial wastes, domestic wastes etc. Most of these wastes are hazardous to man and environment. Even burning them can deplete the ozone layer ([5]).

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]).

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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]).

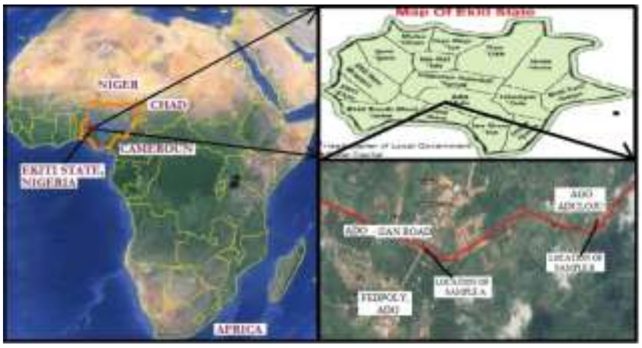

Fig. 1: Location of the Study area – Ado Ekiti, Ekiti State, Nigeria ([10]).

Past research works of many authors on locally available additives such as Sawdust Ash (SDA), Palm Kernel Shell Ash (PKSA), Rice Husk Ash (RHA), 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), Egg Shell Ash (ESA) 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], [4], [5], [6], [12], [13]).

Therefore, the use of agricultural waste materials such as RHA and ESA which could result in environmental pollution if mismanaged will seriously reduce the cost of construction as well as reducing the environmental problems they cause. The aim of this research work is to study effects of the locally available additives in partial replacement of the conventional one on the mechanical properties of the stabilized lateritic soil. This will help in assessment of the suitability of the additives (at mixed proportion) in soil stabilization processes for construction purpose. It will also help in provision of data for Engineers, Planners, Designers and Contractors.

II. MATERIALS AND METHODS

2.1 Atterberg Limits Tests

These comprises of Liquid Limits (LL), Plastic Limit (PL), Plasticity Index (PI) and Shrinkage Limit tests. Another name for these set of tests is *Consistency Limits Tests*. They were carried out on the soil sample(s) in other to analyze the samples spontaneous reactions with water ([6]). The results were compared with notable standards specified values such as [7] and [11] standards specified values.

2.2 Grain Size Distribution Test

It is used in analyzing particles or grains distribution, grouping of the particles into sizes and relative proportion by mass of soil types for the samples (i.e. clay, sand and gravel fraction). The results are always classified according to [7] ([6]).

2.3 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

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Distribution and Atterberg limits. The results were compared to the standard specified values and grouped in accordance with [7] and [11].

III. RESULTS AND DISCUSSION

Table 1 showed Grain size analysis test results for the natural soil samples. From Table 1, the results showed that soil sample A has percentages finer than 0.075mm fractions less than 35% (i.e. < 35%), which is 27.1%. Hence, general rating as sub-grade in accordance with [7] is excellent to good materials. The average percentages of sand and gravel were 16.7% and 56.2% respectively. These results implied that the soil has large content of granular materials. It is likely to have significant constituent materials of silty / clayey gravel and sand soils. While soil sample B has percentages finer than 0.075mm fractions greater than 35% (i.e. > 35%), which is 40.8%. Hence, general rating as sub-grade in accordance with [7] is fair to poor materials. The average percentages of sand and gravel were 29.6% and 29.6% respectively. These results implied that the soil has large content of clay materials. It is likely to have significant constituent materials of mainly silty / clayey soils.

Table 1: Grain Size Analysis Test Results for the Natural Soil Samples

SIEVE No. (mm)	% PASSING		LIMITS		SOIL CLASSN.		SOIL TYPE
	SAMPLE A	SAMPLE B	LOWER	UPPER	SAMPLE A	SAMPLE B	
12.5	100.0	100.0	100.0	100.0			
9.5	77.9	94.9	87.0	97.0	34.1	24.5	GRAVEL
4.25	52.4	82.0	65.0	82.0			
2.36	43.8	70.4	50.0	65.0	16.7	29.6	SAND
1.18	40.1	64.5	36.0	51.0			
0.60	36.6	59.6	26.0	40.0			
0.30	32.1	52.6	18.0	30.0			
0.15	28.9	45.5	13.0	24.0			
0.075	27.1	40.8	7.0	14.0	27.1	40.8	SILT/CLAY

It could also be seen that values of fine sand (i.e. 0.075 - 0.60mm) were within the specified limits, while values of coarse sand (i.e. 0.60 – 2.36mm) and gravel (i.e. 2.36 – 9.50mm) were lesser than lower specified limits for soil sample A. These implied that the soil sample has required fine sand, but have lesser coarse sand and gravel than required. For the soil sample B, values of fine sand (i.e. 0.075 - 0.60mm) and coarse sand (i.e. 0.60 – 2.36mm) were greater than the specified limits, while values of gravel (i.e. 2.36 – 9.50mm) were within the specified limits for soil sample B. These implied that the soil sample has more fine and coarse sands than required with required gravel.

Table 2 showed Atterberg Limits tests results for the soil samples stabilized with RHA. From Table 2, it is observed that the Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) values varied from 30.1% to 35.5%, 9.9% to 12.5% and 20.1% to 23.2% respectively for sample A. While LL, PL and PI values varied from 35.2% to 41.5%, 10.8% to 14.5% and 24.4% to 27.1% respectively for sample B. It could be generally observed that PI values reduced while PL values increased for the soil samples after increase in addition of cement additive from 6% to 8%. All the LL, PL and PI values also reduced as the percentage of RHA additive added increased.

These portrayed that the additives have effects of reducing the quantities of fine particles in the soil samples. And as the additives were being increased, the cementation process of the particles of the soil samples was being increased. It also showed that the percentages of finer particles than 0.075mm of the soil samples have reduced and cohesive qualities of the binder resulting from the clay or fine contents which make the soil samples better as explained by [14]. As the percentage of additive added increases, the soil samples tends towards meeting the required specification for subgrade course materials (i.e. LL ≤ 80% and PI ≤ 55%), base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12%). Thus, they could be suitable for subgrade course materials. Generally, soil sample A can be grouped as A-2-6 even after stabilization process, while soil sample B can initially be grouped as A-7 and later metamorphosed into A-6 and tends towards A – 2 - 6 in accordance with [7] classification system.

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Table 2: Atterberg Limit Tests Results for the Stabilized Soil Samples (RHA)

ADDITTIVE (%)	ADDITION OF 6% CEMENT						ADDITION OF 8% CEMENT					
	LL (%)		PL (%)		PI (%)		LL (%)		PL (%)		PI (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	35.5	41.5	12.3	14.4	23.2	27.1	35.5	41.5	12.5	14.5	23	27
2	34.9	40.3	11.8	13.2	23.1	27.1	33.8	39.5	12	12.8	21.8	26.7
4	33	39.5	11	12.5	22	27	32.9	38.4	11.8	12.1	21.1	26.3
6	32.9	38.9	10.3	11.8	22.6	27.1	32.8	36.4	11	11.8	21.8	24.6
8	31.8	37.8	10	11.3	21.8	26.5	31.8	36.3	10.5	11.3	21.3	25
10	30.9	36.5	9.9	10.9	21	25.6	30.1	35.2	10	10.8	20.1	24.4

Table 3 showed Atterberg Limits tests results for the soil samples stabilized with ESA. From Table 3, it is observed that the Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) values varied from 28.8% to 35.5%, 9.7% to 12.3% and 19.1% to 23.2% respectively for sample A. While LL, PL and PI values varied from 33.8% to 41.5%, 9.5% to 13.4% and 19.1% to 29.4% respectively for sample B. It could be generally observed that PI and PL values reduced for the soil samples after increase in addition of cement additive from 6% to 8%. All the LL, PL and PI values also reduced as the percentage of ESA additive added increased.

Table 3: Atterberg Limit Tests Results for the Stabilized Soil Samples (ESA)

ADDITTIVE (%)	ADDITION OF 6% CEMENT						ADDITION OF 8% CEMENT					
	LL (%)		PL (%)		PI (%)		LL (%)		PL (%)		PI (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	35.5	41.5	12.3	13.4	23.2	28.1	35.5	41.5	12.3	12.1	23.2	29.4
2	34	39.4	11.5	12.6	22.5	26.8	32.9	39.7	11.2	11.4	21.7	28.3
4	33.6	38.6	10.4	12	23.2	26.6	31.1	38.7	10.5	11	20.6	27.7
6	32.5	37.7	10.1	11.4	22.4	26.3	30	36.4	10	10.9	20	25.5
8	31.5	36.9	10	10.8	21.5	26.1	29.8	34.9	9.9	10.5	19.9	24.4
10	30.8	35.8	9.8	9.5	21	26.3	28.8	33.8	9.7	9.7	19.1	24.1

These portrayed that the additives have effects of reducing the quantities of fine particles in the soil samples. And as the additives were being increased, the cementation process of the particles of the soil samples was being increased. It also showed that the percentages of finer particles than 0.075mm of the soil samples have reduced and cohesive qualities of the binder resulting from the clay or fine contents which make the soil samples better as explained [14]. As the percentage of additive added increases, the soil samples tends towards meeting the required specification for subgrade course materials (i.e. LL ≤ 80% and PI ≤ 55%), base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12%). Thus, they could be suitable for subgrade course materials. Generally, soil sample A can be grouped as A-2-6 even after stabilization process, while soil sample B can initially be grouped as A-7 and later metamorphosed into A-6 or A-2-6 after stabilization in accordance with [7] classification system.

Generally, from comparative analyses of effects of the additives (i.e. cement, RHA and ESA) on the soil samples, it could be observed that the addition of cement additive + ESA is more effective than addition of cement + RHA. Though it appears that of RHA is more effective at initial stage (i.e. from 6% to 8% cement).

IV. CONCLUSION

From the results of the above study, it could be concluded that:

- The soil sample A was generally classified as granular soil material with mainly silty / clayey gravel and sand constituent materials with some stone fragments. While soil sample B was generally classified as clay material with mainly silty / clayey constituent materials.
- Soil sample A has group classifications of A – 2 – 6 while soil sample B has A – 7 and tend towards A – 2 - 6 and A - 6 after stabilization.

- The general rating as sub-grade materials of soil sample A is excellent to good while that of soil sample B is fair to poor.
- The stabilization process using local additives as partial replacement of conventional one generally improved the soils Engineering properties. Though it is more felt in ESA than RHA.

Further research work should be carried out on this study at large scale. This will help in ascertaining it as one of the means of waste to wealth policy.

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