Assessment of Engineering Properties of Cement Modified Lateritic Soil Stabilized with Rice Husk Ash

Michael O. Dada
Department of Civil Engineering, the Federal Polytechnic, Ado – Ekiti, Nigeria

Abstract–**This study assessed effects of locally available additive (Rice Husk Ash - RHA) in partial replacement of conventional one (Cement) on the geotechnical properties of Ado-Ekiti to Ikere-Ekiti road lateritic soil. Two soil samples were taken from the study area and some laboratory tests (Atterberg Limit, California Bearing Ratio (CBR), Compaction and Grain size distribution tests) conducted on them at their natural and stabilized states. The soil samples were initially modified with 6 % Cement before being stabilized with RHA additive at proportion of 0, 2, 4, 6 and 8 % by soil weight. Results showed that the natural soil samples were generally and grouply classified as silt – clayey and A – 7 materials respectively with significant constituent of clayey materials. Their general rating as subgrade is fair to poor. These portrayed that the samples require stabilization.LL, PL, PI, MDD, CBR and OMC values of the stabilized soil sample A varied from 28.3 to 42 %, 18.2 to 38.2 %, 3.8 to 12.9 %, 1635 to 2089 Kg/m^3, 8.5 to 35.0 % and 13.4 to 3.6 % respectively. While for stabilized soil sample B, LL, PL, PI, MDD, CBR and OMC values varied from 28.8 to 38 %, 18.6 to 33.2 %, 4.8 to 11.4 % , 1545 to 2547 Kg/m^3, 8.0 to 34.0 % and 10.1 to 4.3 % respectively. As RHA content increased, LL, PL, MDD and CBR values increased, while PI and OMC values decreased. Conclusively, it can be deduced that stabilization took place and improved the soil's Engineering properties by reducing their moisture contents, increasing CBR and MDD. Thus makes the soil suitable as subgrade, subbase and base filling materials.**

Keywords **–Atterberg Limit, California Bearing Ratio (CBR), Compaction, Lateritic Soil, Moisture Content, Stabilization.**

I. INTRODUCTION

Roads are indispensable in the development of any country due to its significant role in the transportation of people, goods and services from one location to another especially from rural to urban areas. It is usually achieved through major connection of roads between rural and urban areas. Barriers to achievement of adequate roads especially in the third world countries are attributed to the high cost of roads' construction and rehabilitation due to lack of good road construction materials within the vicinity of most road projects (among other factors) [1].

Lateritic soil, which is a sedimentary rock deposit due to weathering of rocks, is very common and affordable road construction material found locally in a third world country like Nigeria. It is defined as the products of tropical weathering with red, reddish brown, and dark brown colour, with or without nodules or concreting and generally (but not exclusively) found below hardened ferruginous crust or hard pan. Low bearing capacity and strength due to high content of clay and its minerals are part of their characteristics at natural states. Whenlateritic soil has high amount of clay materials, its strength and stability cannot be guaranteed under load especially in the presence of water. A lateritic soil with high clay and its minerals has ability of causing cracks and damage on roads, building and any other Civil Engineering structures [1], [2], [3].

Thoughlateritic soils are used as road subgrade, subbase and base layers in construction of low cost roads, the problem of clay and its minerals have to be overcome. Thus, the need for the soil improvement.

Soil improvement has to do with soil modification and stabilization. Soil modification has to do with improvement of soilwithin short term, during or immediately after mixing. It enhances the consistency strength of soil to required levels. There is generally measurable strength improvement as a result of change in texture during consistency improvements. Soil modification is carried out through addition of different type of modifiers e.g. cement, lime, etc.[3], [4], [5].

While soil stabilization is a method of alteration of geotechnical parameters of soil to meet Engineering requirements. It occurs when an important longer-term reaction occur as a result of hydration of calcium silicates and aluminates in Portland cement,Class C fly ash or pozzolanic reactivity between the free lime and soil pozzolan. The idea of soil stabilization is very significant in Civil Engineering projects because some soils in their natural states usually have poor Engineering properties, which may result in damage of the Civil Engineering works [3], [4], [7], [8].

The mostly used stabilizers for changing the soil's properties are Cement and Lime. The previous studies of[3], [4], [5], [7], [8], [9] and [10] among othersportray the use of agricultural waste materials like Rice Husk Ash (RHA) for soil stabilization by means of full or partial replacement of cement or lime.

Rice husk is around 30% of the gross weight of a rice kernel and usually contains 80 and 20 % of organic and inorganic substances. It is created in many tons per year as agricultural wastes. RHA is usually obtained after burning in an open air or furnace. The main component of RHA, which makes up its pozzolanic reactivity is Silica [5], [11].

The overdependence on the use of industrially manufactured soil improving additives (cement, lime etc.) has kept the cost of construction of stabilized road financially high. This has continuedto hinder the Third world countries from providing accessible roads to their rural dwellers that constitute the higher percentage of their population and are mostly agriculturally dependent. Thus, the use of agricultural waste materials (i.e. RHA), which could result in environmental pollution if not properly managed will reduces the construction cost and the environmental problems they cause.

This piece of study aimed at assessment of effects of the locally available additive (RHA) in partial replacement of conventional one (Cement) on the geotechnical properties of Ado-Ekiti to Ikere-Ekiti road lateritic soil. This will help in assessment of the suitability of the additive (at mixed proportion) in soil stabilization processes for construction purpose.

The study area, which is Ado Ekiti – Ikere Ekiti road connected Ado – Ekiti and Ikere – Ekiti Local Government Areas (LGAs) together. It is about 14.4 km and lies within Latitude 7^{0} $30^{1}7.500^{0}$ N and Longitude 5^{0} 14^{1} 5.233^{0} E as shown in Fig. 1.

Geologically, its landscape consists of ancient plains broken by steep sided outcropping dome rocks situated within tropical climate of Nigeria and underlain by metamorphic rocks of the Precambrian basement complex of Southwestern Nigeria, which are very ancient in age as shown in Fig. 2. These basement complex rocks showed 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 mediumgrained 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 urbanisation make it more vulnerable and of public health concern when it comes to water quality [11].

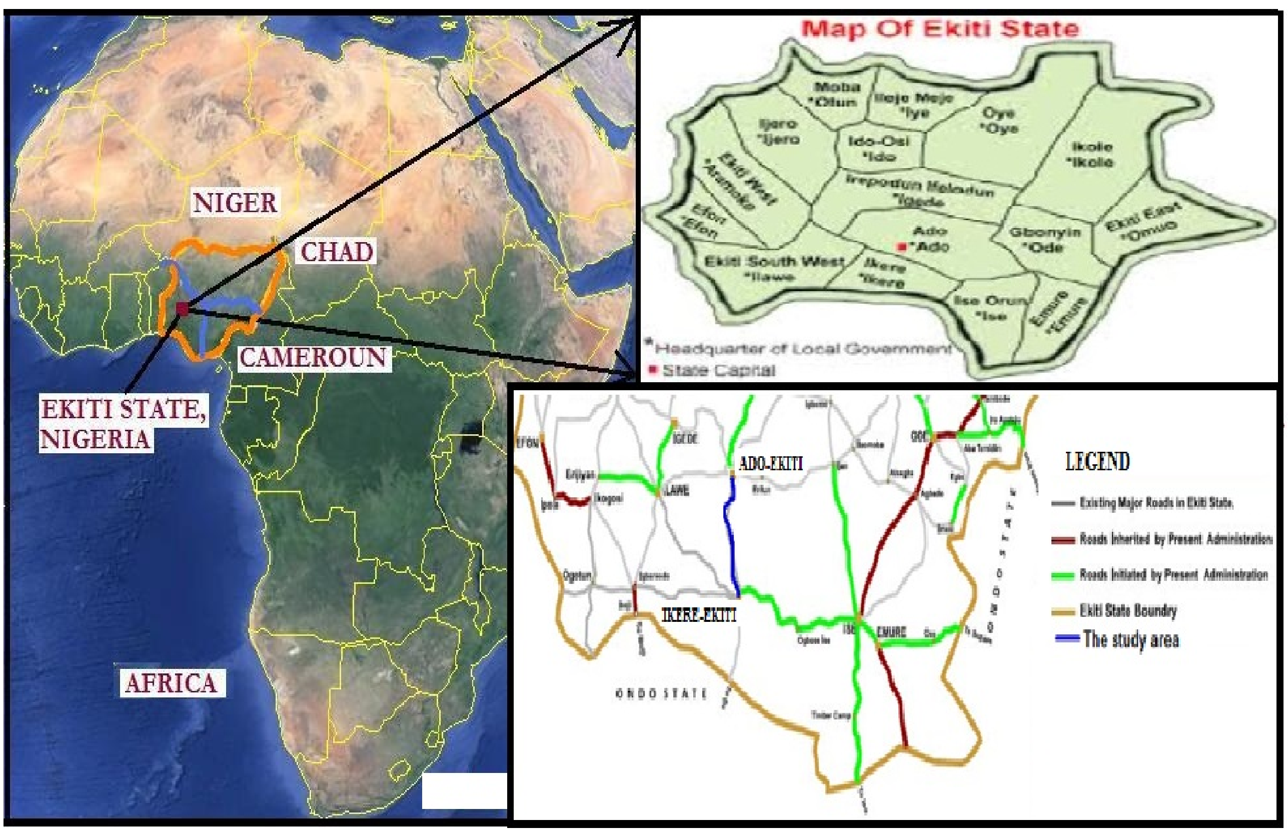

Fig.1: Location of the Study Area (i.e. Ado – Ikere road)

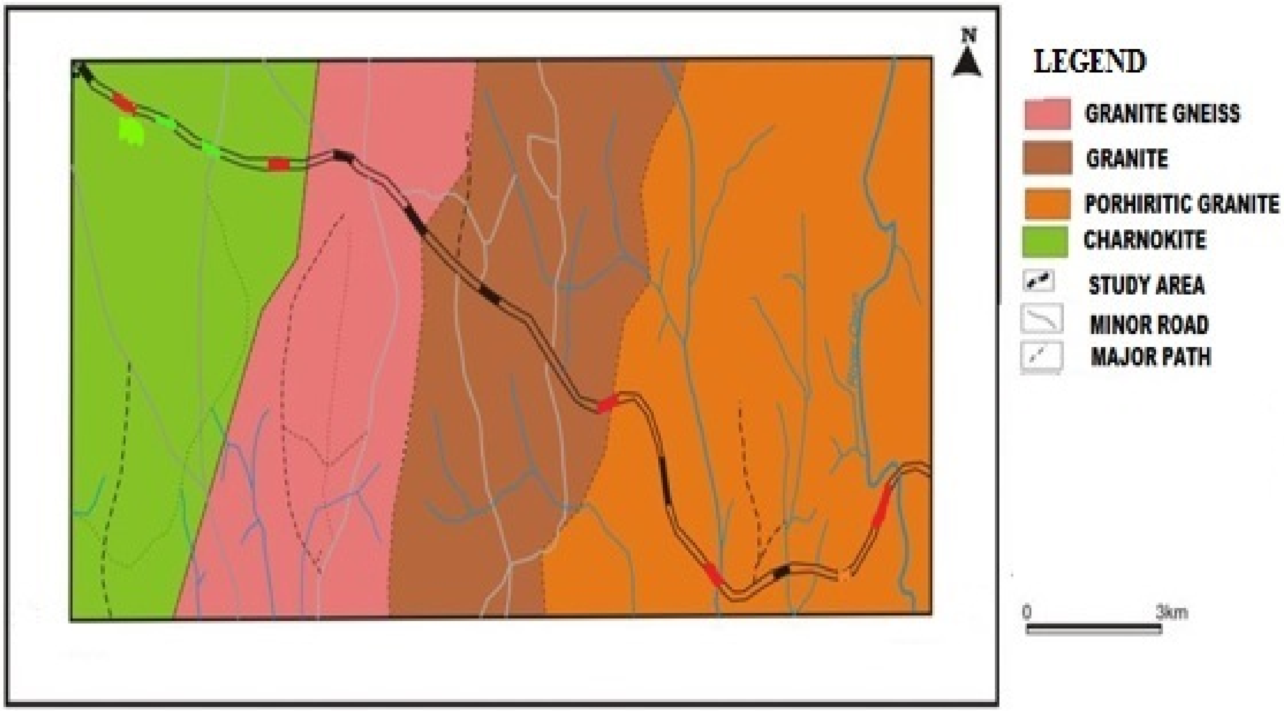

Fig. 2: Geology of the Study Area

II. MATERIALS AND METHODS

A. Materials

Cement: Lime, silica, alumina and iron oxide (Cao, SiO_2, Al_2O_3 and Fe_2O_3) are main raw materials involved in the manufacture of cement. These oxides interact with one another to form major complex compound known as Tricalcium silicate, Dicalcium silicate, Tricalcium aluminate and Tetracalcium alumina ferrite. The Ordinary Portland Cement (OPC) used for this study was purchased from the open market in Ado - Ekiti.

Rice Husk Ash (RHA)–Rice husk was obtained from a rice mill factory in Igbemo – Ekiti, Ekiti State. RHA was generated after the rice husk was ashed at 700^{O}C for 6 hours in muttle furnace at the Civil Engineering laboratory, the Federal Polytechnic, Ado-Ekiti, Ekiti State. Then, the ash was sieved with 90 micrometer in order to increase its fineness.

Lateritic Soil: Lateritic soil samples were collected from two burrow pits dug along the study area at depth of approximately 1.5m 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 deleterious materials were removed.

B. Methods

Soil Samples and Source Materials Analyses: The samples (A and B) were air dried, pulverized and large particles were removed. Chemical analyses werethen conducted on the Cement and RHA. The Cement was used to modify the lateritic soil samples at 6 % by soil sample weight. Then the RHA additive was added to the cement modified soil samples at varying proportions between 0 and 8% at 2 % interval by soil sample weight. The 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 [6]. Their features were also examined. The tests carried out on both natural and stabilized soil samples were Atterberg limits, California Bearing Ratio (CBR), Compaction and Grain Size Distribution tests. The results were compared to the standard specified values and grouped in accordance with [12] and [13].

Chemical Analysis: It was performed on the Cement and RHA using AAS Buck scientific 210VGP and Flame Photometer FP 902GP at Chemistry Department of AfeBabalola University, Ado-Ekiti. Nigeria. This was carried out in accordance with [14] in order to determine the amount of silicon and alumina oxides present in the source materials.

Atterberg Limits Tests: These consist 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 natural and stabilized soil samples in order to analyze the samples natural reactions with water [9], [11]. The results were compared with acceptable standards specified values in [12] and [13]. These tests were carried out at the Civil Engineering Department, Federal Polytechnic, Ado-Ekiti, Nigeria.

California Bearing Ratio (CBR) Test: 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 [10]. It was also carried out at the Civil Engineering Department, Federal Polytechnic, Ado-Ekiti, Nigeria.

Compaction Test: This is type of test(s) conducted on soil sample in order 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 [10]. It was done at the Civil Engineering Department, Federal Polytechnic, Ado-Ekiti, Nigeria.

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 [12] ([9], [11]).

III. RESULTS AND DISCUSSION

A. Chemical Analysis of Source Materials

The total amount of Alumina, Iron and Silicon oxides present in RHA and Cement was 86.09 and 72.78 % respectively as shown in Table 1. This showed that RHA is a good pozzolana that could help mobilized the $Ca(OH)_2$ in the lateritic soil for the formation of cementitious compound.

Table 1: Result of Chemical Analysis for Source Materials

Source Material	AL_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	(AL_2O_3 + SiO_2 + $_2O_3$) (%)
RHA	17.78	67.36	0.95	86.09
Cement	17.12	51.56	4.10	72.78

B. Geotechnical Index Properties of the Natural Soil Samples

The geotechnical index properties of the lateritic soil samples before stabilization were shown in Table 2.In accordance with [12], the soil samples were generally and grouply classified as Silt – Clayey and A – 7 materials respectively. They have significant clayey constituent materials with general rating as Subgrade of "Fair to poor". These results showed that the samples require stabilization.

Table 2: Geotechnical Index Properties of the Natural Soil Samples

Characteristics	Sample A	Sample B
Natural Moisture Content (%)	22.27	21.15
Percentage passing B.S Sieve No. 200 (%)	46.20	44.35
Liquid limit (%)	48.50	46.40
Plastic limit (%)	25.40	22.00
Plastic Index (%)	23.10	24.40
AASHTO classification	A-7-6	A-7-6
MDD (Kg/m^3)	1,482	1,235
OMC (%)	18.45	16.32
CBR (%)	8.7	5.6
Specific gravity	2.96	2.45
Colour	Reddish-brown	Reddish-brown

C. Grain Size Distribution of the Natural Soil Samples

Table 3 showed Grain size analysis test results for the natural soil samples. It is observed that both soil samples A and B have percentages finer than 0.075mm fractions greater than 35% (i.e. > 35%), which were46.2 and 4.35 % respectively. The average percentages of sand and gravel were 43.8 and 45.25 % respectively. These results implied that the soil has large content of clay materials. It could also be seen that values of sand (i.e. 0.15 –2.36 mm) were within the specified limits (i.e. 43 – 54 %), while values of gravel (i.e. 4.25 – 9.50mm) were lesser than specified limits for both soil samples. These implied that the soil samples have too much clay and required sand, but have lesser gravel than required.

Table 3.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	100	100	100			
9.5	97.9	93.8	87	97	7.9	4.2	GRAVEL
4.25	52.4	82	65	82			
2.36	90.0	89.6	50	65	43.8	45.25	SAND
1.18	86.3	64.5	36	51			
0.6	82.8	59.6	26	40			
0.3	78.3	52.6	18	30			
0.15	58.9	45.5	13	24			
0.075	46.2	44.35	7	14	46.2	44.35	SILT/CLAY

D. Atterberg Limits Tests Results of Stabilized Soil Samples

Table 4 showed Atterberg Limits tests results for the Cement modified soil samples stabilized with RHA. It is observed that the LL, PL and PI values varied from 28.3 to 42 %, 18.2 to 38.2 % and 3.8 to 12.9 % respectively for sample A. While LL, PL and PI values varied from 28.8 to 38 %, 18.6 to 33.2 % and 4.8 to 11.4 % respectively for sample B. All the LL and PL values for both samples decreased after 6 % Cement modification, then increased with increase in RHA content. While PI values initially increased up to 2 % then reduced with increase in RHA content. Though, it reduced after 6 % Cement modification for both samples.These indicated that the additives have effects of reducing the quantities of fine particles in the soil samples. And as the RHA additive was being increased, the cementation process of the particles of the soil samples was being increased. It also showed that the percentages of finer particles of 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 [9], [11] and [15].

Table 4.Atterberg Limit Tests Results for the Cement Modified Soil Samples Stabilized with RHA

RHA (%)	ADDITION OF 6% CEMENT					
	LL (%)		PL (%)		PI (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	28.3	28.8	18.2	18.6	10.1	10.2
2	34	30	21.1	18.6	12.9	11.4
4	36	33	28.7	24.2	7.3	8.8
6	40	35	35.3	29.3	4.7	5.7
8	42	38	38.2	33.2	3.8	4.8

E. Compaction and CBR Tests Results of Stabilized Soil Samples

Compaction and CBR tests results for the Cement modified soil samples stabilized with RHA is shown in Table 5. The results showed that MDD values varied from 1635 to 2089 Kg/m^{3}and 1545 to 2547 Kg/m^3. OMC values varied from 13.4 to 3.6 % and 10.1 to 4.3 %. While CBR values varied from 8.5 to 35.0 % and 8.0 to 34.0 % for soil samples A and B respectively.

It is observed that MDD and CBR values increase as RHAcontent increases for both soil samples. Though MDD of soil sample A reached optimum at 6 % RHA. While OMC values decrease as RHA content increases for both soil samples. These aredue to coating and replacement of soil by the additives contents in the mixture, which resulted in large particles with larger voids and density.

The addition of Cement and RHA contents also decreased the quality of free silt, clay fraction and coarse materials with large surface areas formed [10], [16].

The increase in MDD, CBR and consequent decrease in OMC values is also 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 [10], [16].

Generally, the soil samples tend towards meeting the required specification for subgrade (i.e. LL ≤ 80%, PI ≤ 55% and MDD > 1760kg/m^3), subbase and base course materials (i.e. LL ≤ 35%, PI ≤ 12% and MDD > 2000kg/m^3)as the percentage of the added RHA additive increases, Thus, they could be suitable for subgrade, subbase and base course materials after stabilization process even at 2 % RHA content [9], [10], [12], [13].

Table 5. CBR Tests Results for the Cement Modified Soil Samples Stabilized with RHA

RHA (%)	ADDITION OF 6% CEMENT					
	MDD (Kg/m3)		OMC (%)		CBR - 5.0mm (%)	
	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B	SAMPLE A	SAMPLE B
0	1635	1545	13.4	10.1	8.5	8.0
2	2151	2261	6.3	5.9	12.5	12.2
4	2283	2268	5.6	7.1	16.8	15.8
6	2283	2575	5.1	6.3	20.7	21.0
8	2089	2547	3.6	4.3	35.0	34.0

IV. CONCLUSION

The following conclusions were drawn from the above study:

1. The general rating as subgrade materials of both soil samples at their natural states was fair to poor. They were generally and grouply classified as silt – clayey and A – 7 materials respectively with mainly silty - clayey constituent materials.
2. The stabilization process improved the soils' Engineering properties by reducing their moisture contents, increasing CBR and MDD. Thus makes the soils suitable as subgrade, subbase and base filling materials
3. The stabilization process using RHA locally available additive as partial replacement of conventional Cement generally improved the soils engineering properties.

A further study on this piece of work is hereby recommended.

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