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The Use of Rice Husk Ash as a Stabilizing Agent in Lateritic Clay Soil

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***Abstract*—**Rice Husk (RH) is the major byproduct in the processing of paddy rice. The management of this waste has become a big challenge to some of the rice producers, some of these wastes are left in open dumps while some are burn in the open space, and these two actions have been contributing to environmental pollution. This study evaluates an alternative waste management of this agricultural product for use as a civil engineering material. The RH was burn in a controlled environment to form Rice Husk Ash (RHA). The RHA was mix with lateritic clay at 0, 2, 4, 6, 8, and 10% proportion by weight. Chemical test was conducted on the open burn and controlled burn RHA with the lateritic clay. Physical test such as particle size distribution, Atterberg limits test, and density test were carried out on the mix material. The chemical composition obtained for the RHA showed that the total percentage compositions of Fe_2O_3, SiO_2 and Al_2O_3 were found to be above 70% (class "F" pozzolan) which qualifies it as a very good pozzolan. The coefficient of uniformity (C_u) was 8 and coefficient of curvature (C_c) was 2 for the soil sample. The Plasticity Index (PI) for the 0, 2, 4, 6, 8. 10% was 21.0, 18.8, 16.7, 14.4, 12.4 and 10.7 respectively. The work concluded that RHA can be effectively used in hydraulic barriers and as a stabilizing agent in soil stabilization.

***Keywords*—**Rice husk ash, pozzolans, paddy rice, lateritic clay.

I. Introduction

THE need to improve the engineering properties of soil has been in existence for many centuries, during the Romans Empire, roads and buildings were constructed for the use of the citizens, and various techniques were adopted to improve the soil quality. In the modern day, the era of soil stabilizations started in the early 1960's in the United State, since then the technology and materials been used to improve the stability of soil has greatly improved.

Makusa [1] states that soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two [2]. Soil stabilization can also be simply define as the transformation of soil index properties by adding chemicals such as cement, fly ash, lime, or a combination of these.

The simplest stabilization processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils [3]. Another common method of soil stabilization is the chemical method, in which materials like cement, lime, fly ash, bitumen or the combination of these materials are added to soil in certain proportion. There are two primary mechanisms by which chemicals alter the soil into a stable subgrade: (i) Increase in particle size by cementation, internal friction among the agglomerates, greater shear strength, reduction in the plasticity index, and reduced shrink/swell potential. (ii) Absorption and chemical binding of moisture that will facilitate compaction [4].

The criterion for chemical selection for soil stabilization and modification based on index properties of the soil was suggested by the office of the Geotechnical Engineering, Indianapolis as follows:

1) Chemical Selection for Stabilization.
a. Lime: If PI > 10 and clay content (2μ) > 10%.
b. Cement: If PI ≤ 10 and < 20% passing No. 200.
The Lime shall be quicklime only.
2) Chemical Selection for Modification
a. Lime: PI ≥ 5 and > 35 % Passing No. 200
b. Fly ash and lime fly ash blends: 5 < PI < 20 and > 35 % passing No. 200
c. Cement and/ or Fly ash: PI < 5 and ≤ 35 % Passing No. 200

Fly ash shall be class C only. Lime Kiln Dust (LKD) shall not be used in blends. Appropriate tests showing the improvements are essential for the exceptions listed.

The following chemicals are commonly used in soil stabilization:

i. Blast furnace slag; these are the by-product in pig iron production. The chemical compositions are similar to that of cement. It is however, not a cementitious compound by itself, but it possesses latent hydraulic properties which upon addition of lime or alkaline material the hydraulic properties can develop [2], [5].
ii. Lime; it reacts with medium, moderately fine and fine-grained soils to produce decreased plasticity, increased workability, reduced swelling, and increased strength. [4].
iii. Fly Ash: it is formed by the combustion of solid fuel such as coal and discharged as air born emission, or recovered as a byproduct for various commercial uses. There are two classes of fly ash, C and F, class C is produced from

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burning sub-bituminous coal and lignite, and it is rarely cementitious when mix with water alone. While class F is produced from the burning of anthracite or bituminous coal [6].

iv. Pozzolanas are siliceous and aluminous materials, which in itself possess little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [1]. Pozzolanas are categorized into two major classes (C and F). The class C pozzolanas has total percentage compositions of Fe_2O_3, SiO_2 and Al_2O_3 to be below 70% while class F pozzolanas has over 70% composition of these chemicals, and thus classified as the best. . Clay minerals such as kaolinite, montmorillonite, mica and illite are pozzolanic in nature. Artificial pozzolanas such as ashes are products obtained by heat treatment of natural materials containing pozzolanas such as clays, shales and certain silicious rocks. Plants when burnt, silica taken from soils as nutrients remains behind in the ashes contributing to pozzolanic element [1], [2].

Rice husk is a by-product from agriculture produce when it is harvested, the outermost layer of the paddy grain is the rice husk, also called rice hull. It is separated from the brown rice in rice milling. Burning rice husk produced rice husk ash (RHA), so for every 1000 kg of paddy milled, about 220kg (22 %) of husk is produced and when this husk is burnt in the boilers, about 55kg (25%) of RHA is generated, if the burning process is incomplete, carbonized rice husk (CRH) is produced. The husk surrounding the kernel of rice accounts for approximately 20% by weight of the harvested grain (paddy). The exterior of rice husks are composed of dentate rectangular elements, which themselves are composed mostly of silica coated with a thick cuticle and surface hairs. The mid region and inner epidermis contains little silica, [7].

The use and disposal of rice husks has frequently proved difficult because of the tough, woody, abrasive nature of the husk, their low nutritive properties, and resistance to weather, great bulk and ash content. In fact in South East Asia, the accumulating heaps of rice husk have become significant problems [8]. Figs. 1 and 2 showed unburnt and burnt rice husk dump in Gboko, which is a major rice producing towns in Nigeria. The aim of this study is to examine the possibility of introducing rice husk ash as a stabilizing agent in lateritic clay that is commonly used for civil engineering construction.

Fig. 1 Unburnt rice husk deposit in Gboko, Nigeria

Fig. 2 Burnt rice husk deposit in Gboko, Nigeria

II. Materials and Methods

A. Soil Samples

Soil samples for this study were collected from a laterite deposit in Buruku at Gboko West Local Government Area of Benue State of Nigeria. A pit of 1m deep was excavated and samples of the soil were taken for laboratory analysis.

B. Rice Husk Ash

The rice husk used for this study was collected from a rice mill in Benue State Nigeria. The Husk was stacked in heaps near the Mill. Samples were collected from different spot at the heap site, some sample were openly burnt, while the remaining samples were burnt in a controlled incinerator.

Tests performed on the natural samples of the soil and on samples mixed with various percentage of the Rice Husk Ash (0%, 2%, 4%, 6%, 8% and 10%) are; Chemical analyses of the lateritic soil and Rice husk ash of controlled and uncontrolled burning, Natural Moisture determination, Grain Size Analysis, Atterberg Limit Test, Specific Gravity Test, Compaction Test and Bulk Density Test.

C. Chemical Analysis of Rice Husk Ash

A sample of 10g was weighed using digital weighing equipment (Mettler weighing balance), the samples were placed into a metal disc with four number grind aid tablets, and this was to aid the grinding process. The disc was now taken into a machine where it was grind into a very fine powder, to confirm the fines, it was passed through 0 to 425 µm digital sieve apparatus, the residue was now collected and converted into pellet by placing it into a steel ring of dimension 14mm x 40mm wide after which it was subjected to an hydraulic machine with a pressure of 40 N. The Rice husks were now converted to solid cylindrical mass which was finally taken into the X–ray florescence machine for analysis. (XRF: ARL 9900, OHASIS). The analyses of the samples were displayed on the monitor of the desktop computer linked to it. The same process used in detecting the chemical composition of the rice husk was applied on the lateritic clay soil.

D. Particle Size Analysis

This is to determine the particle size distribution of grain sizes in the soil mass. This test is a fundamental requirement for the identification and for specification compliance testing for coarse soils [9]. These tests were conducted according to specification in British Standards [10]. The test was carried out on the natural sand only (without mixing with RHA).

E. Bulk Density

The compacted and un-compacted bulk densities of the materials were determined in conformity with ASTM [11].

F. Specific Gravity Test

The test was carried out to know the general method of obtaining the specific gravity of the mass of any type of materials composed of small particles which has a specific gravity greater than 1,000. This is in accordance with ASTM [12].

G. Index Properties

Index properties of soil–mixture were determined in accordance with the procedures outlined in British Standard [10]. The atterberg limits test and the test involving the moisture–density relationship and volumetric shrinkage were carried out using air –dried soil crushed and passed through sieve BS No. (4.75 mm opening) mixed with 0, 2, 4, 6, 8 & 10% rice husk ash by weight of dry soil making use of the controlled burning and the open burning.

III. Results and Discussions

A. Chemical Composition of Samples

Table I shows the chemical composition of burnt rice husk ash and the lateritic clay. The total percentage composition of iron oxide (Fe_2O_3=0.95%), Silicon dioxide (SiO_2 = 67.27%) and Aluminium Oxide (Al_2O_3=4.90%) was found to be 73.12% for the controlled burnt rice husk ash. The ashes obtained at 500^0C to 700^0C were dark in colour indicating the presence of little unburnt carbon.

TABLE I
Chemical Composition of R. H. A. and Laterite

S/N	Element	Chemical composition of Unburnt Rice Husk	Chemical composition of Burnt Rice Husk (Controlled)	Chemical composition of Burnt Rice Husk (Open Burning)	Chemical composition of Lateritic Clay soil	Unit
1	$Si0_2$	43.37	67.27	58.75	29.11	%
2	AL_20_3	10.65	4.9	11.58	31.44	%
3	Fe_20_3	2.68	0.95	3.35	12.56	%
4	Ca0	1.74	1.36	2.57	7.55	%
5	Mg0	0.41	1.9	1.75	3.96	%
6	Na_20	0.04	-	-	0.16	%
7	K_20	0.51	-	-	0.08	%
8	$S0_3$	0.26	-	-	-	%
9	L.O.I		17.86	12.55		

The chemical composition result for rice husk ash in Table I is within the required value of 70% minimum for pozzolanas as recommended by [13] which qualifies it as a class "F" pozzolan, this means that it is a good pozzolan. The loss on ignition obtained was 17.86%. This value is slightly more than 12% maximum as required for pozzolanas. It means that the RHA contains little un- burnt carbon and this reduces the pozzolanic activity of the ash. The un-burnt carbon it-self is not pozzolanic and its presence serves as filler to the mixture. The value obtained is higher than 3.30% and as such the pozzolana is less effective. The magnesium oxide content was 1.9%; this satisfies the required value of 4 per cent maximum. From the chemical analysis of open burning of RHA collected from the Mill site, the sum of SiO_2, Al_2O_3 and Fe_2O_3 gave 74.05%. This equally satisfies the minimum percentage of 70% requirement for class "F" pozzolana. And the loss of ignition was 12.55% which is almost equal to the value required for a pozzolan. This result has revealed that the open burn rice husk ash has a better pozolanic property than the controlled sample, which contains unburnt carbon in it.

B. Sieve Analysis of Clay Soil

Fig. 3 showed the result obtained from the sieve and hydrometer test, it was established that the soil is well graded and could be described as clay silt sand with clay having the highest composition followed by silt and the least being sand in composition. The percentage of the soil particle passing through B.S number 200 was 56.83 [10]. The coefficient of uniformity (C_u) obtained from calculation was 8, while the coefficient of curvature (C_c) was 2, and based on ASTM D2487, [14] the soil can be classified as a well graded sand with silt. A well graded material is made up of optimal ranges of different sized particles, while a uniformly graded or poorly graded are made up of individual particle of almost the same size. The addition of the Rice husk ash caused an increased in particle size and reduction in voids within the natural clay soil, and this is a good property of a well graded soil.

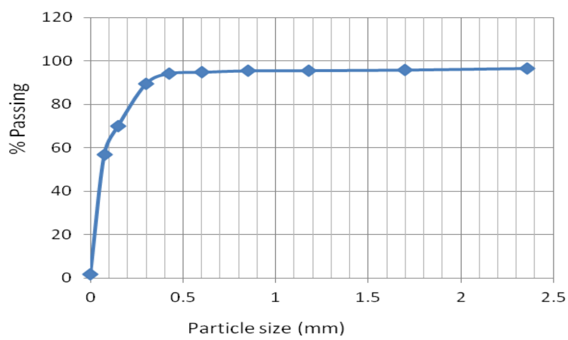

Fig. 3 Particle size distribution of untreated lateritic soil

C. Specific Gravity Results

The specific gravity of the sand was 2.65, while that of RHA was 2.37, this value is within the range for pulverized fuel ash (pfa), which is between 1.9 and 2.4. These values indicate that the specific gravity of RHA is location oriented and harvest-time dependent. It can be observed from Fig. 4 that as more RHA was mixed with the soil sample the specific gravity was reducing. This reduction could be attributed to the light weight property of the RHA particles, which generally react to reduce the overall specific gravity of the mixture.

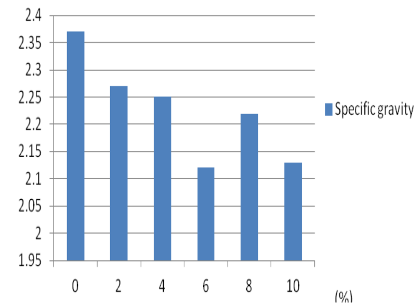

Fig. 4 Specific gravity against percentage replacement

D. Bulk Density

The compacted and un-compacted bulk density of rice husk ash was found to be 530kg/m^3 and 460kg/m^3 respectively. Test result indicates that the material is a lightweight material. Bulk density depends on how densely the practices are packed. The silica in pozzolana can only combine with calcium hydroxide when it is in a finely divided state. Pozzolana in this state have uniform particles which cannot be packed very closely consequently leading to a low compact bulk density.

E. Plastic Index Properties of Soils

The values in Table II showed that the liquid limit ranged from 34 to 41.5%, the plastic limit ranges from 13-28%, thus resulting in the decrease of the plasticity index (PI) values from 21-10.7%, a decrease in plasticity index is a sign of improvement of the soil quality. As a general guide, treated soils should increase in particle size with cementation, reduction in plasticity, increased in internal friction among the agglomerates, increased shear strength, and increased workability due to the textural change from plastic clay to friable, sand like material. [4]

The liner shrinkage decreasing as the ash content is added to the mixture up to 10%. The overall index properties of the soil without the RHA shows that the soils can be classified as low plasticity clay (CL) under unified soil classification system (ASTM, D2487), the addition of the RHA move the sample to the intermediate plasticity range which is between 35 and 50%. Atterberg limit are indices of the quantity of clay sized particles and their mineralogical composition. Typically, higher liquid limit and plasticity indices are associated with soils having a greater quantity of clay particles or particle having higher surface activity. Soils having higher liquid limit or plasticity would have lower hydraulic conductivities [15]. However, [16] suggested that material with plasticity index (PI) greater or equal to 7% would be suitable for hydraulic barrier.

TABLE II
INDEX PROPERTIES OF THE SOIL AND RICE HUSK CONTENT

Property	Rice Husk Ash content (%)					
	0	2	4	6	8	10
Liquid Limit (%)	34.4	36.0	37.6	39.4	40.8	41.5
Plastic Limit (%)	13.4	17.2	20.9	25.0	28.4	30.7
Plasticity Index (%)	21.0	18.8	16.7	14.4	12.4	10.7
Linear Shrinkage (%)	11.4	10.7	10.0	9.3	8.6	7.7
Moisture content (%)	13.4	17.2	20.9	25	27.9	27.95

IV. CONCLUSION

The addition of RHA to lateritic clay improved the index property and particle size distribution of the soil and this qualifies the RHA as a good stabilizing agent, for sub grade in road construction and for back filling in retaining wall, but the mix should be controlled not to exceed 10%. Also the various soils-ash mixes used in this study are suitable materials for hydraulic barriers.

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