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INFLUENCE OF RICE HUSK ASH SOURCE VARIABILITY ON ROAD SUBGRADE PROPERTIES

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ABSTRACT
This study presents the influence of variability of Rice Husk Ash (RHA) on the geotechnical properties of subgrade. The subgrade soil classified as A–7–6 (Clayey soil) in the AASHTO Classification system or CL in the USCS was used. The RHA materials were obtained from Ebonyi, Enugu and Cross River States of Nigeria, respectively. The geotechnical properties investigated included consistency limits, compaction and the California Bearing Ratio (CBR) of the soil for varying RHA contents for the three different RHA sources. There was significant variability in the chemical composition of RHA, with samples from Cross River, Ebonyi and Enugu States having Silica contents of 84.55%, 76.30% and 70.12% respectively. The results obtained showed that there was a general increase in the Optimum Moisture Content (OMC) and CBR values of the soil with increase in RHA content. However, the plasticity and Maximum Dry Density (MDD) decreased with increase in RHA.

Keywords: *California Bearing Ratio; Consistency indices; Lateritic soil; Maximum Dry Density; Optimum Moisture Content; Rice Husk Ash; Sub-grade.*

1. INTRODUCTION
The milling of rice produces tons of rice husk, which, when burnt yields rice husk ash (RHA) with pozzolanic properties. RHA abound in rice mills across Nigeria, posing waste disposal problems to the environment. Researchers have carried out studies on the applicability of this agro waste in stabilization of soils. Comparison of use of Fly Ash and Rice Husk Ash as stabilizing agents to Black Cotton Soil was reported in [1]. While the addition of RHA resulted in an increase in optimum moisture content with decrease in dry density, the California Bearing Ratio (CBR) and Unconfined Compression Strength showed improvement. The study concluded with 12% and 9% as optimum amount of FA and RHA respectively. Also, investigation on the effect of RHA on Cement Stabilized Laterite in Minna, Niger State of Nigeria was carried out [2]. The study concluded with a decrease in Maximum Dry Density (MDD) and increase in Optimum Moisture Content (OMC) with improvement in the CBR and UCS. The potentials of RHA for Soil Stabilization were reported by [3], it was concluded that RHA alone as a stabilizer showed little improvement to the geotechnical properties of the laterite used. Cement or lime combination with RHA was recommended. This is in consonance with previous conclusions by [4, 5], that due to lack of cementitious properties, RHA cannot be used alone in soil stabilization.

In another study on the Improvement of the Index Properties and Compaction Characteristics of Lime Stabilized Tropical Lateritic Clays with Rice Husk Ash (RHA) Admixtures, [6], reduction in soil plasticity dry density was reported. The CBR however, showed remarkable improvement. A reduction in soil deformability with the addition of lime and RHA to clayey soil, however, shear strength and CBR values increased was reported in [7].

The consolidation properties of compacted lateritic soil treated with rice husk ash was reported in [8]. Results revealed reductions in compression index and swell index with increased RHA content, while, the co-efficient of consolidation showed no observable trend with addition of RHA. The effect of rice husk ash (RHA) on the properties of Ibaji burnt clay bricks was studied by [9]. An optimal value of 2% RHA resulted in decrease of plasticity with increase in compressive strength and water adsorption. The Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive

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Soil was demonstrated by [10]. The addition of RHA with lower specific weight resulted in decrease in dry density and increase in moisture content with reduction in free swelling and compressibility. However, the unconfined compressive strength and shear strength of soil showed improvement. [11] reported on the use of sugar cane bagasse ash, rice husk ash and groundnut shell ash to stabilize weak subgrade soil. The study concluded improvements on the CBR values of the subgrade by all the stabilizers. The Engineering Properties of Clay-Rice Husk Ash Composites were studied by [12]. The addition of RHA to clay improved shrinkage, plasticity and cracking of the clay bricks but reduces the compressive strength. Some geotechnical properties of soil treated with RHA were altered in a study carried out by [13] who reported that increase in RHA content resulted in reduced plasticity while volume stability as well as the strength of the soil increased. An optimal 10% RHA content was recommended by the study. In another study by [14], RHA was found to decrease liquid limit, free swell index (FSI) and undrained cohesion of the natural soil while, shrinkage, internal friction, dry density and California bearing ratio were improved. An optimal percentage of 5 for both RHA and Portland cement stabilization of subgrade using the California Bearing Ratio Test was established in [15].

From the above review, it can be concluded that due to the inadequacy of the desirable cementation property in Rice Husk Ash (RHA), it should only be used as a partial replacement for the more conventional cement and lime stabilizing agents. Soil stabilization is better achieved with a combination of cement and RHA stabilizers, rather than only cement or RHA. A Study by [16] has shown that lead-polluted soils are better stabilized against leach capability when cement and RHA are used as stabilizers than when only cement is used. Rice husk ash has displayed promising potentials in improving soil engineering properties for construction purposes. Variability in the pozzolanic properties of RHA from Seven different sources in Nigeria was revealed in [17]. However, the influence of variability of RHA on the geotechnical properties of pavement materials have not been given serious attention by researchers. Hence, the need for this study to investigate the influence of RHA variability on subgrade properties.

2. MATERIALS AND METHODS

The Rice Husk Ash samples were collected from Cross River, Enugu and Ebonyi States of Nigeria. A chemical analysis of each sample was conducted to determine the following oxides: ZnO, SiO_2, CaO, Fe_2O_3, K_2O, MnO, MgO and Na_2O. Table 1 shows the chemical composition of the rice husk ash and cement used for the study.

The soil sample used for this study was obtained along a proposed road within the premises of the Cross River University of Technology (CRUTECH), Calabar, at depth 1.0 m. Sampling was done using a posthole hand auger. Disturbed samples were roughly classified in the field before taking to the Soil Mechanics Laboratory for testing. The laboratory tests carried out on the natural soil included determination of Natural Moisture Content, Atterberg limits, Particle Size Distribution, Specific Gravity, Compaction, and California Bearing Ratio (CBR) tests. The tests were conducted in accordance with [18]. Table 2 shows the index properties of the subgrade soil used for the investigation. The soil could generally be classified as clayey soil under the Unified Soil Classification System (USCS) or A–7–6 under the AASTHO system. The testing program on the clayey soil sample stabilized with 0 - 50% of rice husk ash included consistency limits tests, compaction and California Bearing Ratio (CBR) tests.

3. RESULTS AND DISCUSSIONS

3.1 Rice Husk Ash Variability.

As shown in Table 1, Silica is the main component of the ash that makes it a pozzolanic and a good replacement for cement in soil stabilization. The analysis revealed that RHA obtained from Ogoja, Cross River State, had the highest concentration of silica (84.55%), followed by those from Ebonyi and Enugu States with 76.30% and 70.12% respectively. The reasons for these variabilities could be due to soil conditions where the rice are grown, species of rice and the temperature to which the husk was subjected to during burning.

Table 1: Chemical composition of RHA and cement used

SN	Sample/location	Elements and Composition (%)							
		ZnO	SiO_2	CaO	Fe_2O_3	K_2O	MnO	MgO	Na_2O
1	RHA-Adani, Enugu	0.60	70.12	0.20	0.05	0.66	0.57	0.45	0.52
2	RHA-Ogoja, CRS	0.75	84.55	0.30	0.25	0.69	0.43	0.45	0.51
3	RHA-Abakaliki, Ebonyi	0.20	76.30	0.25	0.09	0.27	0.20	0.03	0.16
4	Portland limestone cement	0.12	23.5	65.2	3.4	0.4	0.18	1.35	0.30

Table 2: Properties of the natural soil before stabilization

PROPERTY	VALUE
Natural moisture content (%)	26.7
Percent passing No. 200 Sieve (0.075mm)	
Percent passing No. 200 Sieve (0.075mm)	45.3
Liquid Limit (%)	43.5
Plastic Limit (%)	27.2
Plasticity Index (%)	16.3
Shrinkage limit (%)	7.1
Maximum Dry Density (Mg/m^3)	1.72
Optimum Moisture Content (%)	18.3
California Bearing Ratio (%):	
Unsoaked	7.39
Soaked	6.89
Specific Gravity	2.81
Colour	Brown
AASHTO Classification:	
General Classification	Clayey soil
Group classification	A–7–6
Unified Soil Classification System (USCS)	CL

3.2 Influence of RHA on Atterberg Limits

Results of the Atterberg Limit tests conducted on the subgrade stabilized with varying percentages of RHA are shown in Figure 1. It is observed that there is a general decrease in Liquid limit with increasing RHA content. This could be attributed to the non-plastic nature of the ash. As the RHA content increases, the soil loses plasticity.

The influence of RHA on the plastic limit is shown in Figure 2. There is a general increase in plastic limit with increasing RHA content. The results agree with [12] and [19] who found out that plastic limit increases with increasing lime and rice husk ash content.

Figure 3 shows the influence of RHA on the plasticity index of the soil. The plasticity index decreases with increasing rice husk content at all percentages for all soil-rice husks stabilized samples. RHA is a non-plastic stabilizer which reduces soil plasticity.

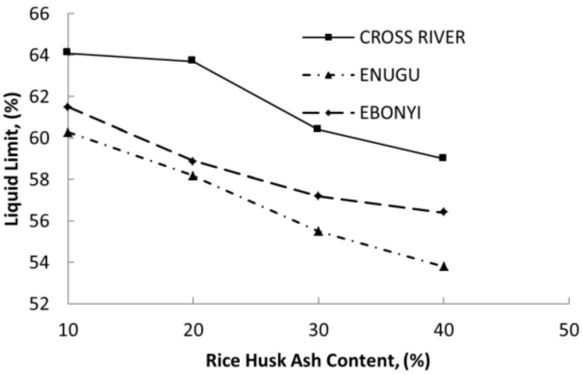

Figure 1: Variation of liquid limit with RHA content

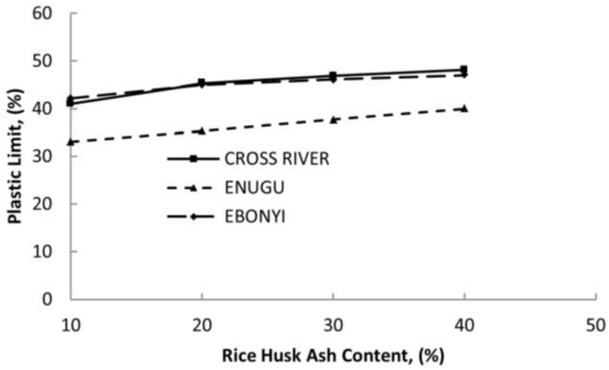

Figure 2: Variation of plastic limit with RHA content

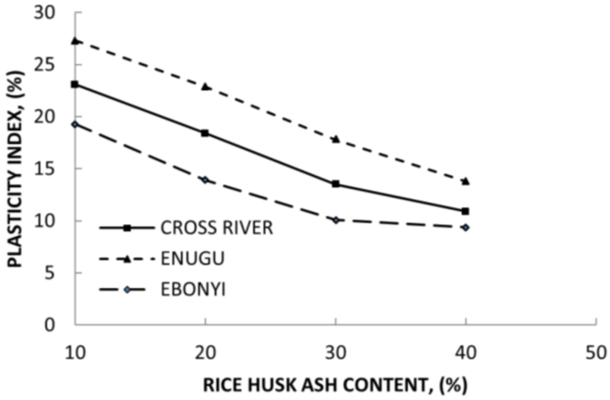

Figure. 3: Variation of plasticity index with RHA content

3.3 Influence of RHA on Maximum Dry Density (MDD)

A trend of decrease in MDD with increase in RHA content was observed from the compaction tests conducted with the three different Rice Husk Ash sources as shown in Figure 4. For example, treatment of the subgrade with Cross River RHA sample shows a decrease in MDD from $1.72kg/m^3$ to $1.28kg/m^3$ when the RHA content increases from 0 - 20%. Similarly, with Enugu and Ebonyi RHA samples there were decreases in MDD from $1.72kg/m^3$ to $1.31kg/m^3$ and $1.72kg/m^3$ to $1.26kg/m^3$ respectively. This agrees with [2] who opined that the particle size and specific gravity of the soil and stabilizer are what could cause the decrease in dry density. Decreasing dry density indicates that it needs low compactive energy (CE) to attain its MDD. As a result, the cost of compaction becomes economical [3]. The decrease in the maximum dry unit weight can therefore be attributed to the replacement of soil by the RHA in the mixture which has relatively lower specific gravity compared to that of the soil [6, 8]. It may also be attributed to coating of the soil by the RHA which results to large particles with larger voids and hence less density [9]. The decrease in the maximum dry unit weight may also be explained by considering the RHA as filler (with lower specific gravity) in the soil voids.

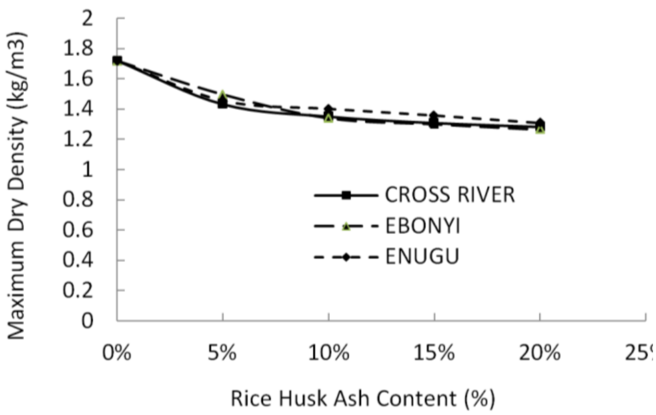

Figure 4– Variation of Maximum Dry Density with Rice Husk Ash Content

3.4 Influence of RHA on Optimum Moisture Content (OMC)

On the other hand, from Figure 5, a trend of increase in OMC with increase in RHA content was observed for all dry density tests conducted. For sample stabilized with Cross River RHA, OMC increased from 18.3% to 21.63%, for Enugu sample OMC increased from 18.3% to 21.63% and for Ebonyi sample, OMC increased from 18.3% to 23.06%. The trend of increase in OMC with increase in RHA contents is in line with [6], [10] and [11]. The increase is due to the addition of RHA which decreases the quantity of free silt and clay fraction forming coarser materials with larger surface areas which requires more water for proper mixing to occur. This also means that for better compaction of the soil and RHA mixture, there would be need for more water [11, 12]. Also, as reported in [13] the increase in OMC is probably a consequence of two reasons: (1) the additional water held with the flocculants soil structure resulting from cement interaction, and (2) exceeding water absorption by RHA because of *increase in porosity*.

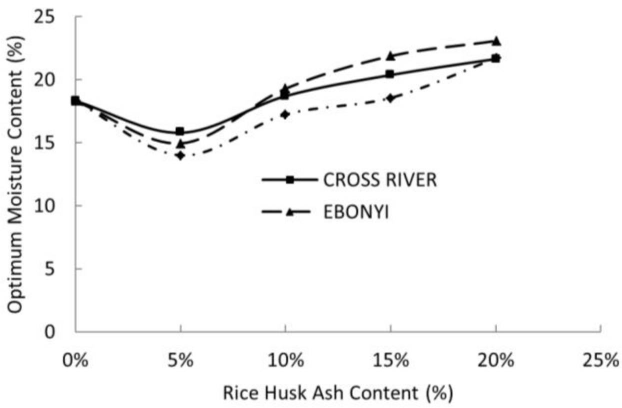

Figure 5 - Variation of Optimum Moisture Content with Rice Husk Ash Content

3.5 Influence of RHA on California Bearing Ratio

California Bearing Ratio is a common test used to evaluate the strength of subgrade. Figure 6 shows the results of the influence of RHA on the CBR of the stabilized subgrade. All the RHA samples improved the CBR values of the subgrade [7, 14]. The percentage improvement of 63.43%, 20.03% and 14.51% were observed for sample stabilized with Cross River, Ebonyi and Enugu RHA respectively at 10% optimum RHA value. The high improvement in the CBR value using the Cross River RHA is due to the high silica contents of this RHA source. It is however observed that the CBR values generally decline with the addition of RHA beyond 10%. This indicates that RHA alone is not suitable as stabilizer; instead a combination between RHA and cement will yield a significant enhancement of strength as well as CBR.

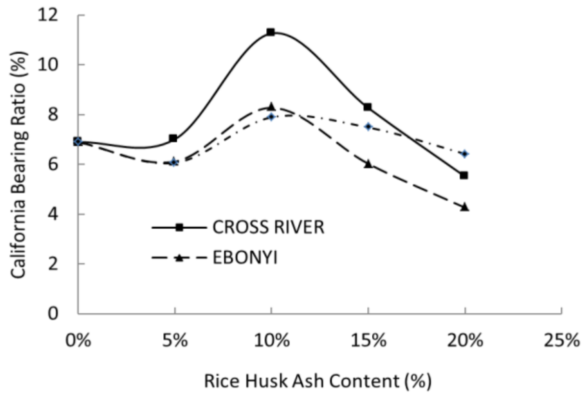

Figure 6 – Variation of California Bearing Ratio with Rice Husk Ash Content

The reason for the increment in CBR may be due to the gradual formation of cementitious compounds in the soil by the reaction between the RHA and some amounts of CaOH present in the soil and cement. The decrease in CBR with more RHA may be due to the extra RHA that could not be mobilized for the reaction which consequently occupies spaces in the sample. This reduces the bond in the soil-RHA mixture [16].

4. CONCLUSION

From the results of this study, the following conclusions can be drawn:

1. The subgrade used is identified to be soft clay of high plasticity. It has low (soaked) CBR value (6.89%).
2. There is variability in the rice husk ash properties from different locations in Southern Nigeria. The species of rice and other factors could be responsible for this variability. The RHA materials from Cross River and Ebonyi States were

relatively better as stabilizers than that from Enugu State, which has the lowest silica content.

3. Subgrade stabilization using RHA shows a general decrease in the maximum dry density (MDD) and increase in optimum moisture content (OMC).
4. There was also an all-round improvement in the California Bearing Ratio (CBR) of the RHA-Cement stabilized soil compared to the unstabilized soil.
5. The influence of the RHA materials on the geotechnical properties of the subgrade may largely depend on their unique chemical properties, particularly silica content, as demonstrated by the different RHA samples from the study.

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