

EFFECTS OF RICE HUSK ASH ON SOME GEOTECHNICAL PROPERTIES OF LATERITIC SOIL

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ABSTRACT

The study is an investigation into the effect of rice husk ash (RHA) on some geotechnical properties of a lateritic soil classified as A-2-6 (0) or SW for sub-grade purposes. The investigation includes evaluation of properties such as compaction, consistency limits and strength of the soil with RHA content of 5%, 7.5%, 10% and 12.5% by weight of the dry soil. The results obtained show that the increase in RHA content increased the optimum moisture content but decreased the maximum dry density. It was also observed that increase in RHA content, reduced plasticity and increased volume stability as well as the strength of the soil. 10% RHA content was also observed to be the optimum content.

Keywords: Rice Husk Ash (RHA), Lateritic soil, Sub-grade, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR) and Consistency indices.

1.0 INTRODUCTION

In countries of the tropics and subtropics, lateritic soils are encountered in various engineering projects. In the precambian times, Nigeria consisted of uplifted continental landmass made up of basement sediments [1]. This resulted in the formation of lateritic soils which are of relatively good quality for road construction works.

Rice husk is an agricultural waste obtained from milling of rice. About 10⁸ tons of rice husk is generated annually in the world. In Nigeria, about 2.0 million tons of rice is produced annually [2]. Rice husk ash has so much been utilized in the past for upgrading of soils [2-6]. In most cases the RHA was used an admixture and a stabilizing agent (cement or lime) included

to increase the cementitious property of the stabilized matrix. It was discovered that both cement and RHA reduced the plasticity of soils and maximum dry density but increased optimum moisture content [4]. Results have indicated that cement and RHA used as overall binder system for stabilized/solidified lead-contaminated soils is more favourable in reducing leachability of lead from the treated samples than a binder system of only cement [3]. RHA was also used on a Malaysian soil with cement and lime as stabilizing agents [5]. The results showed that based on the strength development, it seems that lime is the more effective stabilizing agent. It was also clearly stated that the RHA can only be used as a partial replacement for the more expensive stabilizing agents (cement/lime) because it has inadequate cementitious

property required to bind the material to a satisfactory durability [5].

However, the previous works with RHA have shown that it has promising potentials of improving the engineering properties of soils for sub-grade purposes. Thus, this work focused on investigating the effect of RHA on some geotechnical properties of lateritic soil which are relevant for evaluating the performance of sub-grade soils.

1.2 MATERIAL AND METHODS

The soil sample used for this study was collected from Obukpa in Nsukka Local Government Area of Enugu state in Nigeria, using the method of disturbed sampling. The RHA was ground and sieved through 75 μ m aperture before use. The oxide composition of RHA is shown in table 1.

Table1: Oxide Composition of Rice Husk Ash [2].

Constituents	Composition (%)
Al ₂ O ₃	4.9
SiO ₂	67.3
Fe ₂ O ₃	0.95
CaO	1.36
MgO	1.81
Loss on Ignition (LOI)	17.78

The tests for identification of the lateritic soil and determination of the geotechnical properties of the lateritic soil treated with RHA were carried out in accordance with the BS 1377 [7]. The standard Proctor was used for compaction test which was also used to determine the moisture content for the California Bearing Ratio (CBR) specimens. The RHA was thoroughly mixed with pulverized lateritic soil and then with distilled water. The clay

mineral identification was done using plasticity chart developed by Casagrande data in [8]. The properties and grading curve of the lateritic soil are shown in table 2 and figure 1 respectively.

Table 2: Properties of the Lateritic Soil

Soil property	Test results
Specific gravity	2.50
Liquid limit, LL (%)	35.20
Plastic limit, PL (%)	18.13
Plasticity index, PI (%)	17.07
Linear shrinkage	13.08
Maximum Dry Density (kg/m ³)	2040
Optimum Moisture Content (%)	13.80
Percent passing BS NO 200 sieve	1.5
California Bearing Ratio (CBR)	22.05
AASHTO (9)/ USC classifications (10)	A-2-6(0)/SW
Major clay mineral	Illite

1.3 RESULTS AND DISCUSSION

Compaction characteristics

The relationship between the maximum dry density (MDD) and RHA contents is shown in figure 2. The results indicated that between 0% and 12.5% RHA contents, the MDD reduced from 2040 kg/m³ to 1689 kg/m³ respectively. The reduction may be attributed to the replacement of soil by RHA in the mixture which has relatively lower specific gravity of 2.25 compared to that of the soil which is 2.50. It may also be attributed to the coating of the soil by the RHA which results to large particles with larger voids and hence less density [11].

The variation of optimum moisture content (OMC) with RHA content is shown in figure 3. The result shows that the OMC increased with increase in RHA content. This trend may be attributed to the addition of RHA which decreased the quantity of

free silt and clay fraction and forming coarser materials with larger surface areas (these processes need water to take place). This implies also that more water was needed in order to compact the soil-RHA mixtures [12].

Consistency limits

The relationship between liquid limit and RHA content is shown in figure 4. The liquid limit decreased from 35.20% to 24.80% with increase in RHA content from 0% to 7.5% respectively. This can be considered to be as a result of the replacement of the soil fines by RHA. The later which has less affinity for water, caused the drop in liquid limit. As the RHA was further increased from 7.5% to 10%, the liquid limit increased from 24.80% to 29.85% respectively. At this stage the RHA quantity increased to the extent that more water will be required to turn the soil-RHA mix to fluid.

The relationship between plastic limit and RHA content is shown in figure 5. The trend is similar to that of the liquid limit. The reasons for the variation of liquid limit with RHA content are also similar to that of the variation of plastic limit with RHA content.

Plasticity Index and RHA content relationship is shown in figure 6, the plasticity index decreased from 17.07% to 10.02% with increase in RHA content from 0% to 12.5%. This trend may be attributed to the replacement of the finer soil particles by the RHA with consequent reduction in the clay content and plasticity index. It was also observed that plasticity index of a soil increased as the amount clay fraction increased and vice versa [13].

In figure 7, the linear shrinkage decreased from 14.60% to 10.00% with

increase in RHA content from 0% to 12.5%. This may be attributed to the usual replacement of the soil fines by RHA. The later is less in activity with changes in moisture content and therefore, reduced the linear shrinkage of the soil-RHA mix. This enhances volume stability of the soil.

Strength characteristics

The relationship between California Bearing Ratio (CBR) and RHA content is shown in figure 8. The result shows that the CBR increased from 22.05% to 80.14% with increase in RHA content from 0% to 10% respectively and subsequently reduced with further addition of RHA. The reason for increment in CBR may be because of the gradual formation of cementitious compounds in the soil by the reaction between the RHA and some amounts of CaOH present in the soil. The decrease in CBR above 10% RHA content may be due to extra RHA that could not be mobilized for the reaction which consequently occupies spaces within the sample. This reduced the bond in the soil-RHA mixture. The CBR is a measure of the strength of the sub-grade and 10% RHA content gave the highest improvement of the CBR of the soil and hence would appear to be the optimum RHA content.

Conclusions

The following conclusions may be drawn from the study:

- i. The soil was classified to be A-2-6(0) or well-graded sand (SW)
- ii. RHA increased the OMC but decreased the MDD of the soil.
- iii. The increase in RHA content decreased the plasticity index of the soil. This confirms that the activity of the mixture reduced with the addition of RHA.

- iv. The addition of RHA increased the volume stability of the soil.
- v. The addition of RHA improved the strength property (CBR) of the soil.
- vi. 10% RHA content was observed to be the optimum content for the lateritic soil.
- vii. From the foregoing investigation it would appear that RHA perform satisfactorily as a cheap stabilizing agent for lateritic soil and is recommended for the stabilization of sub-grade soils in road construction.

References

1. Kogbe C.A.; "Preliminary Interpretation of Gravity Measurements in the Middle Niger Basin Area, Nigeria." *Geology of Nigeria*, the Elizabethan publishing Ltd., 1975.
2. Oyetola E.B. and Abdullahi M.; "The use of Rice Husk Ash in Low-cost Sandcrete Block Production." *Leonardo Electronic Journal of Practical Technology*, Romania, Vol. 8, 2006, pp. 58-70.
3. Yin Chun-Yang; Mahmud H.B. and Shaaban M.G. "Stabilization / Solidification of Lead - Contaminated Soil Using Cement and Rice Husk Ash." *Journal of Hazardous Materials*, Elsevier, Amsterdam, Vol. 137, No.3, 2006, pp.1758-1764.
4. Basha E. A., Hashim R., Mahmud H. B. and Muntohar A. S.; "Stabilization of Residual Soil with Rice Husk Ash and Cement." *Construction and Building Materials*, 2005.
5. Haji Ali F., Adnan A. and Chew Kam Choy; "Geotechnical Properties of a Chemically Stabilized Soil from Malaysia with Rice Husk Ash as an Additive." *Journal of Geotechnical and Geological Engineering*, Springer Netherlands, Vol. 10 No. 2, 1992, pp. 117-134.
6. Al-Khalaf M. N. and Yousif H. A.; "Use of Rice Husk Ash in Concrete." *The International Journal of Cement Composites and Light-weight Concrete*, Vol. 6, No. 4, 1984, pp.241-248.
7. BS 1377: "Methods of Testing Soils for Engineering Purpose." *British Standard Institute*, London, U K., 1990.
8. Mitchell J. K.; "Fundamentals of Soil Behaviour." *John Wiley & Sons, Inc.*, New York, USA, 1976.
9. AASHTO: "Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 14th Edition." *American Association of State Highway and Transportation Officials*, Washington D. C., USA, 1986.
10. ASTM: "Soil and Rock: Dimension Stone: Geosynthetics." *Annual Book of ASTM Standards*, ASTM, Philadelphia, USA, 1993.
11. Osula D.O.A.; "Lime Modification of Problem Laterite." *Engineering Geology*, Vol. 30, 1991, pp. 141-149.
12. Osinubi K. J.; "Evaluation of Admixture Stabilization of Nigerian Black Cotton Soil." *Nigeria society of Engineers, Technical Transactions*, Vol. 34, No. 3, 1999, pp. 88-96.
13. Arora K. R.; "Soil Mechanics and Foundation Engineering (Geotechnical Engineering)." *Standard Publishers Distributors*, Delhi-110006, India, 2008.

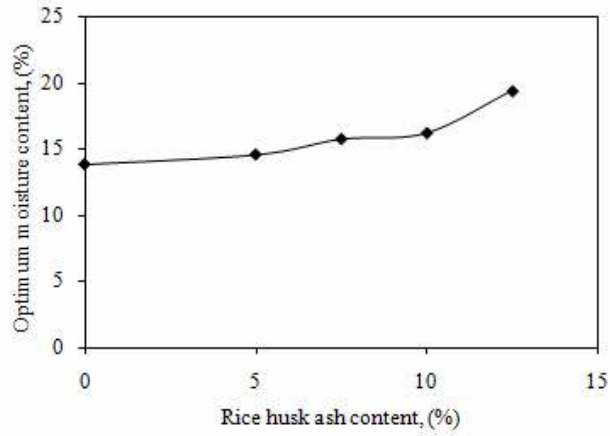


Figure 3: Variation of Optimum Moisture Content with Rice Husk Ash Content

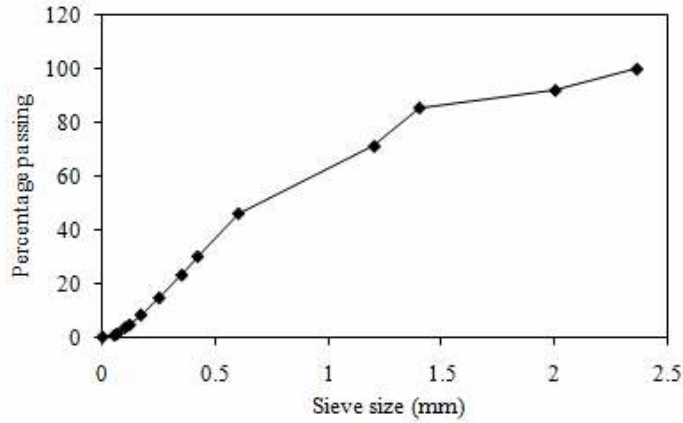


Figure 1: Grading Curve for the Lateritic Soil

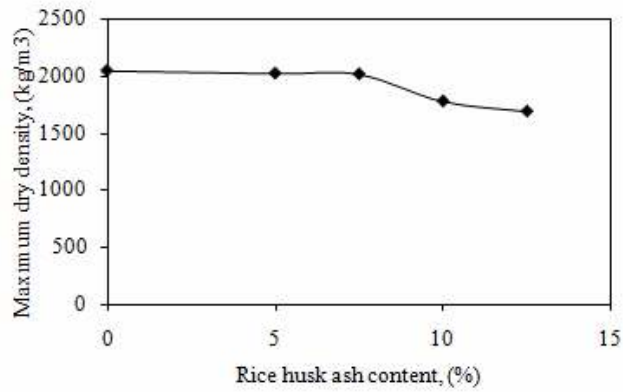


Figure 2: Variation of Maximum Dry Density with Rice Husk Ash Content

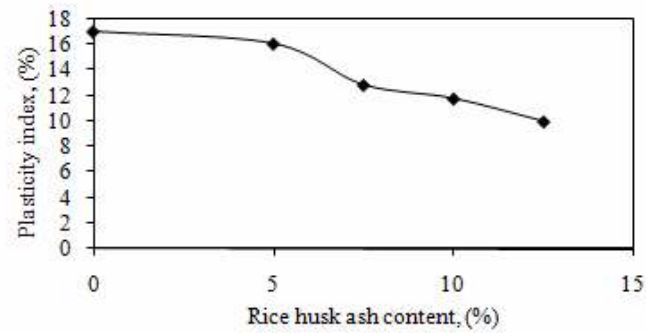


Figure 6: Variation of Plasticity Index with Rice Husk Ash Content

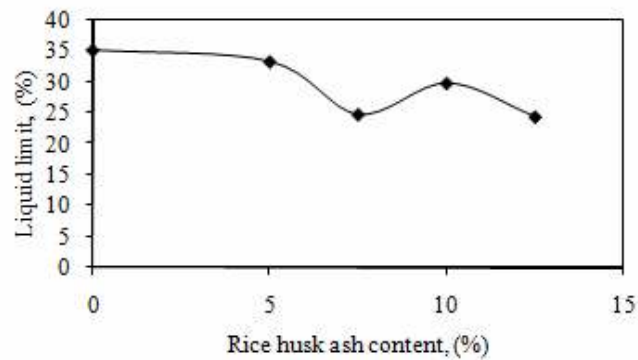


Figure 4: Variation of Liquid Limit with Rice Husk Ash Content

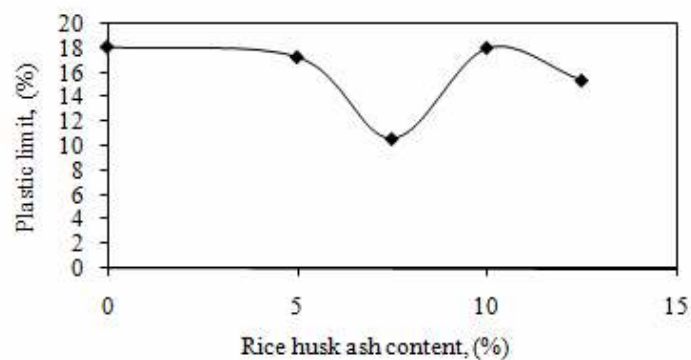


Figure 5: Variation of Plastic Limit with Rice Husk Ash Content

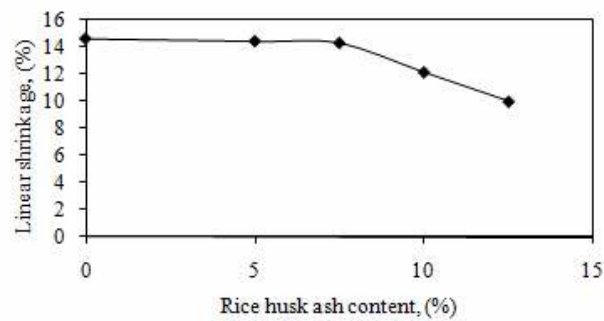


Figure 7: Variation of Linear Shrinkage with Rice Husk Ash Content

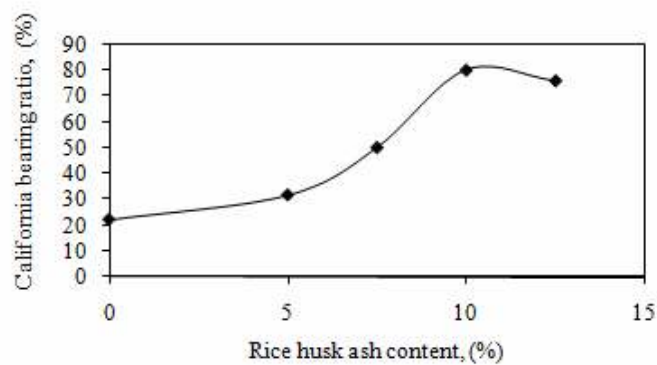


Figure 8: Variation of California Bearing Ratio with Rice Husk Ash Content