

Potentials of Rice Husk Ash for Soil Stabilization

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Abstract

Soil sample collected from Maikunkele area of Minna, classified as an A-7-6 lateritic soil on AASHTO classification was stabilized with 2-12% rice husk ash (RHA) by weight of the dry soil. Using British standard light (BSL) compaction energy level, performance of the soil-RHA was investigated with respect to compaction characteristics, California bearing ratio (CBR) and unconfined compressive strength (UCS) tests. The results obtained, indicates a general decrease in the maximum dry density (MDD) and increase in optimum moisture content (OMC) with increase in RHA content. There was also slight improvement in the CBR and UCS with increase in the RHA content. The peak UCS values were recorded at between 6-8% RHA, indicating a little potential of using 6-8% RHA for strength improvement of A-7-6 lateritic soil.

Keywords: RHA, laterite, MDD, OMC, CBR and UCS.

Introduction

Geotechnically, soil improvement could either be by modification or stabilization, or both. Soil modification is the addition of a modifier (cement, lime, etc) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification.

A lot of laterite gravels and pisoliths, which are good for gravel roads, occur in tropical countries of the world, including Nigeria (Osinubi and Bajeh 1994). There are instances where a laterite may contain a substantial amount of clay minerals that its strength and stability cannot be guaranteed under load especially in the presences of moisture. These types of laterites are also common in many tropical regions including Nigeria where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available soil to meet the desired objective (Mustapha 2005). Over the times, cement and lime are the two main materials used for stabilizing soils. These materials have rapidly increased in price due to

the sharp increase in the cost of energy since 1970s (Neville 2000).

The over dependent on the utilization of industrially manufactured soil improving additives (cement, lime etc), have kept the cost of construction of stabilized road financially high. This hitherto have continued to deter the underdeveloped and poor nations of the world from providing accessible roads to their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. Thus the use of agricultural waste (such as rice husk ash - RHA) will considerably reduce the cost of construction and as well reducing the environmental hazards they causes. It has also been shown by Sear (2005) that Portland cement, by the nature of its chemistry, produces large quantities of CO₂ for every ton of its final product. Therefore, replacing proportions of the Portland cement in soil stabilization with a secondary cementitious material like RHA will reduce the overall environmental impact of the stabilization process.

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, while in Niger state, about 96,600 tons of rice grains is produced in 2000 (Oyetola and Abdullahi 2006). Meanwhile, the ash has been categorized under pozzolana, with about 67-70% silica and about 4.9 and 0.95% aluminum and iron oxides, respectively (Oyetola and Abdullahi 2006). The silica is substantially contained in amorphous form, which can react with the CaOH librated during the hardening of cement to further form cementitious compounds. This will go a long way in actualizing the dreams of the Federal Ministry of works in Nigeria of scouting for readily cheap construction materials. The World Bank too has been spending substantial amount of money on research aimed at harnessing industrial waste products for further usage.

Location of Study Area

The soil sample used for this study was collected from Maikunkele area of Minna (latitude 9°36'N and longitude 6°30'E) in Northern Nigeria at a depth of between 1.5m to 2.5m Using the method of disturbed sampling. A study of the geological map (Akintola 1982) and soil map (Areola 1982) of Nigeria shows that the sample taken belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.

Methods of Testing

The laboratory tests carried out on the natural soil include particle size distribution, Atterberg limits, compaction, CBR and UCS. The geotechnical properties of the soil were determined in accordance with British Standard Institute (1990a) while the stabilization tests were performed in accordance with British Standard Institute (BSI 1990b). Specimens for unconfined compressive strength (UCS) and California bearing ratio (CBR) tests were prepared at the optimum moisture contents (OMC) and maximum dry densities (MDD) – British standard light of the soil – rice husk ash (RHA) mixtures. The CBR tests were conducted as specified by the Nigeria General Specifications (1997) for road and bridge

works, where the compacted specimens were cured for six days and soaked for one day before testing at a constant loading rate. The RHA was grounded and sieved through B.S. sieve No 200 (75µm) before usage.

Test Results and Discussion

Identification of Soil and RHA

The geotechnical index properties of the laterite before addition of stabilizers are shown in Table 1. The particle size distribution of the natural soil is shown in Fig. 1. The overall geotechnical properties of the soil classified as A-7-6 in the AASHTO (1986) classification system, shows that it falls below the standards recommended for most geotechnical construction works and would therefore require stabilization.

Table 1. Properties of the natural soil before stabilization.

Characteristics	Description
Natural moisture content (%)	22.27
Percent passing B.S Sieve NO 200	77
Liquid Limit (%)	49.5
Plastic Limit (%)	24.4
Plasticity Index (%)	25.1
Group Index	20
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m ³)	1.482
Optimum Moisture Content (%)	18.38
Unconfined Compressive Strength (kN/m ²)	290
California Bearing Ratio (%)	
Unsoaked	8.5
Soaked	5.55
Specific Gravity	2.69
Colour	Reddish-brown

The oxide composition of RHA is shown in Table 2. The combine percent composition of silica, Al₂O₃ and Fe₂O₃ is more than 70. This shows that, it is a good pozzolana that could help mobilize the CaOH in the soil for the formation of cementitious compounds.

Table 2. Oxide composition of RHA (after Oyetola and Abdullahi 2006).

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

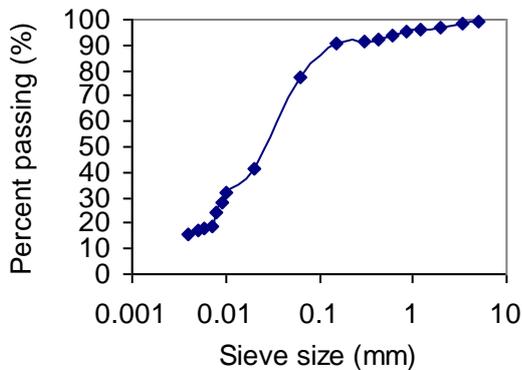


Fig.1. Particle size distribution for the natural soil.

Effect of Treatment with RHA

Compaction Characteristics

The variations of MDD and OMC with stabilizers contents are shown in Fig.2. The MDD decreased while the OMC increased with increase in the RHA content.

The decrease in the MDD can be attributed to the replacement of soil and by the RHA in the mixture which have relatively lower specific gravity (2.25) compared to that of the soil which is 2.69 (Ola 1975; Osinubi and Katte 1997). It may also be attributed to coating of the soil by the RHA which result to large particles with larger voids and hence less density (Osula 1991). The decrease in the MDD may also be explained by considering the RHA as filler (with lower specific gravity) in the soil voids.

There was increase in OMC with increase RHA contents. The trend is in line with Ola (1975), Gidigas (1976) and Osinubi (1999). The increase was due to the addition of RHA, which decreased the quantity of free silt and clay fraction and coarser materials with larger

surface areas were formed (these processes need water to take place). This implies also that more water was needed in order to compact the soil-RHA mixtures (Osinubi 1999).

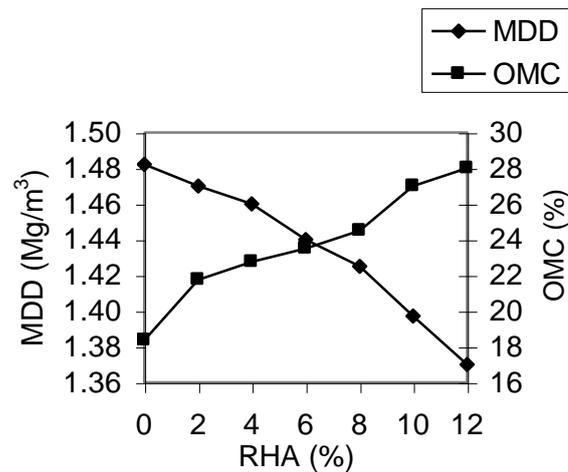


Fig. 2. Variation of MDD and OMC with RHA content.

California Bearing Ratio

As an indicator of compacted soil strength and bearing capacity, it is widely used in the design of base and sub-base material for pavement. It is also one of the common tests used to evaluate the strength of stabilized soils.

The variation of CBR with increase in RHA from 0 to 12% is shown in Fig.3. For unsoaked samples, CBR values initially dropped with the addition of 2% RHA, after which the values rises to its peak at 6% RHA.

It slightly dropped at 8% RHA and remains constant to 12% RHA. The initial decrease in the CBR is due to the reduction in the silt and clay content of the soil, which reduces the cohesion of the samples. The increment in the CBR after 2% RHA can be attributed to the gradual formation of cementitious compounds between the RHA and CaOH contained in the soil. The gradual decrease in the CBR after 6% RHA may be due to excess RHA that was not mobilized in the reaction, which consequently occupies spaces within the sample and therefore reducing bond in the soil-RHA mixtures.

The trend of the soaked CBR was similar to the unsoaked CBR only that, even after the addition of 6% RHA, the CBR kept increasing. This trend shows that the presence of water (moisture) helps to further the formation of the

cementitious compounds between the soil's CaOH and the pozzolanic RHA.

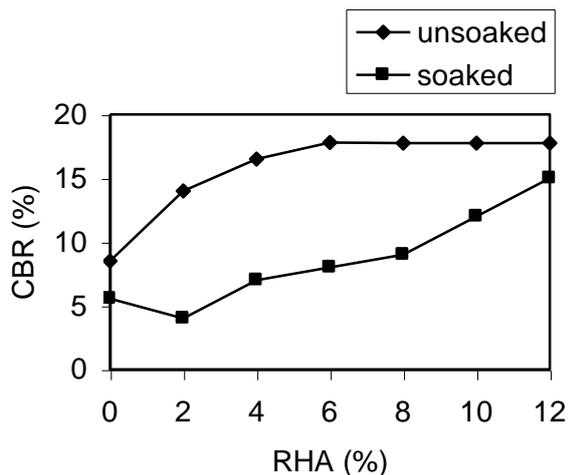


Fig.3. Variation of CBR with RHA content.

Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil (Singh and Singh 1991). Variation of UCS with increase in RHA from 0% to 12% at British Standard Light energy level and for 7 days, 14 days and 28 days curing period were investigated and the results for the three curing periods are shown in Fig. 4. There was a sharp initial decrease in the UCS with addition of RHA to the natural soil when compared with the UCS value of 290kN/m² recorded for the natural soil. This decrease may be due to earlier reason given in the case of CBR.

The UCS values increase with subsequent addition of RHA to its maximum at between 6-8% RHA after which it dropped from 10-12% RHA. The subsequent increase in the UCS is attributed to the formation of cementitious compounds between the CaOH present in the soil and RHA and the pozzolans present in the RHA. This decrease in the UCS values after the addition of 8% RHA may be due to the excess RHA introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed.

The maximum UCS value recorded was 293 and 295kN/m² at 6 and 8% RHA contents respectively, after 28 days curing period. These

values are slightly higher than the natural soil UCS of 290kN/m².

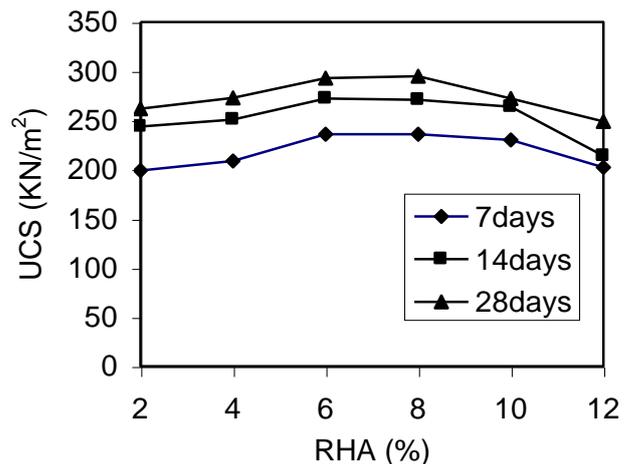


Fig. 4. Variation of UCS with RHA content.

Conclusion

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

1. The laterite was identified to be an A-7-6 soil on AASHTO (1986) classification system. It is also clay of high plasticity (CH) according to unified system of classification (USC).
2. Treatment with RHA showed a general decrease in the MDD and increase in OMC with increase in the RHA content.
3. There was also an improvement in the unsoaked CBR (18.5% at 6% RHA content) compared with the CBR of the natural soil (8.5%). The soaked CBR also improved.
4. A similar trend of the CBR was obtained for UCS. The UCS values were at their peak at 6-8% RHA. The UCS of the mixes also increased with curing age.

Recommendation

Since the result of the study shows little potentials of using RHA only for soil improvement, it is recommended that it should be employed more with cement or lime for the formation of secondary cementitious compounds with the CaOH produced from the hydration of cement or when in use with lime (CaOH).

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