EFFECTS OF RICE HUSK ASH ON GEOTECHNICAL PROPERTIES OF LATERITIC SOIL

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Summary

This paper gives the results of a series of laboratory tests carried out to examine the influence of well burnt rice husk ash on geotechnical properties of lateritic soil. The results of these tests indicate that the liquid limit, plastic limit, optimum moisture content, unconfined compressive strength, California bearing ratio value, cohesion, angle of internal friction as well as shear strength of the lateritic soil increase with increase of rice husk ash content. The maximum dry density and plasticity index decrease with increase of rice husk ash content. The unconfined compressive strength, California bearing ratio and shear strength parameters are highest at around 17% rice husk ash. These results indicate that 17% rice husk ash is the optimum binder required to stabilize the soil economically for sub-base materials in highway construction.

INTRODUCTION

This research work deals with lateritic soil. Many research works have been carried out on lateritic soils in many different countires over the years and detailed reviews of available literature have already been presented by Bawa (1957), Maignien (1966), Little (1969), Lyon Associates (1971), and Gidigasu (1976). This investigation has used local terminology to define lateritic soils. Lateritic soils include all products of tropical weathering with red, reddish brown or dark brown colour, with or without nodules or concretions and are generally found below hardened ferruginous crusts or hard pan. Ola (1978) also worked with laterite.

The chemical composition of rice husk ash was given by Korisa (1958) and Lazaro & Moh (1970) shown in Table 1. There are some minor differences in composition except in silicon dioxide. It is noted that silicon dioxide is somewhat more than 93% of the fully burnt rice husk ash.

The properties of the ash depend greatly on whether the husks had undergone complete destructive distillation or had only been partially burnt in the presence of adequate air (Houstin 1972). He had also classified ash into (1) high-carbon char, (2) low carbon (gray) ash, and (3) carbon-free (pink or white) ash.

Rice husk and rice husk ash had found many uses in civil engineering applications although none of these uses had developed to a commercial scale. Grist (1965) remarked that rice husks had been used as building materials in India. Light-weight concrete briquettes were partly made from rice husks. Insulating bricks were also made with cement and rice husk ash which resisted very high temperatures and were suitable for use in furnace. Korisa (1958) remarked that treated husks act as inert and suitable aggregate and which had been used in pressed insulating boards, high quality cement tiles and cement blocks. These blocks are said not only to have good heat and sound insulation but also are rat proof and not damaged by water nor subject to shrinkage or warping. Lime-rice husk ash mixtures was suited as stabilizer with deltaic clays by Lazaro and Moh (1970). The purpose of this research work is to find the effects of rice husk ash on various geotechnical properties such as liquid limit, plastic limit, plasticity index, maximum dry density, optimum moisture content, unconfined compressive strength, California bearing ratio and undrained shear strength parameters of lateritic A-7-6 group soil and also to find the optimum amount of rice husk ash to stabilize the soil successfully for construction purposes.

Description of soil samples

All soil samples used in this work were obtained from University of Ife campus, Ile-Ife, Nigeria. Soil samples were reddish brown in colour. General properties of original soil were determined by various laboratory tests and are shown in Table 2. These tests were carried out in accordance with British Standard Specifications (B.S. 1377:1975).

This soil was classified into A-7-6 group according to American Association of State Highway Officials (AASHO) method of classification. Wet sieving method and hydrometer method were carried out to determine the grain size distribution of original soil. Grain size distribution curve is shown in Fig. 2.

Description of Rice husk ash

The rice husks utilized in this work were collected from Ekpoma, Bendel State, Nigeria. The moisture content of rice husks was 6% on a dry weight basis at $105^{\circ}C$. After burning at $800^{\circ}C$, the percentage of ash was approximately 19.3.

Simple combustion chamber was used to burn the rice husks shown in Fig. 1. Combustion chamber consists of drum, circular pipe and gauge. The drum was 0.60m in diameter and 0.80m high. Compressed air was fed into a circular pipe with 0.30cm diameter holes which was fixed in the lower part of the drum. The rice husks were placed on a gauge about 5cm above this pipe. The rice husks were ignited by a match and then compressed air was supplied until the combustion was finished. Whitish carbon free ash was obtained. Rice husks burnt at $800^{\circ}C$ showed that the remaining organic content was less than 3%. Specific gravity of ash was measured and it was 2.35. Rice husk ash passed through 0.15mm sieve size was only used. 74.1 percent of rice husk ash particles were finer than 0.07mm. Moreover, ash was compacted with soil in the mould. Obviously, during compaction ash became much more finer than 0.075mm. It is not unlikely that it would be as fine and reactive as fly ash. Cook, et al (1976) have indicated that ash obtained from the controlled burning of rice husks has pozzolanic properties.

Laboratory tests and their procedures

A series of laboratory tests were carried out on lateritic A-7-6 soil with different percentages of rice husk ash. The percentages of ash were 4, 8, 12, 16, 20 and 24. Laboratory tests were on liquid limit, plastic limit, standard Proctor compaction, unconfined compression, California bearing ratio and unconsolidated undrained triaxial compression. These tests were performed in the laboratory in accordance with British Standard Specifications (B.S. 1377:1975).

Rice husk ash was thoroughly mixed with soil in a large tray. Mixing was carried out by hand. All soil-ash samples used in unconfined compression, California bearing ratio and unconsolidated undrained triaxial compression tests were compacted at optimum moisture contents.

Large specimens for unconfined compression and unconsolidated undrained triaxial tests were moulded with the same compaction effort and mould used in the standard Proctor compaction test. Smaller cylindrical specimens were prepared from the moulded sample with the help of wire saw and soil lathe. Specimens were air-cured at room temperature for 7 days before being loaded in compression. The room temperature was low and humidity was very high.

A length-diameter ratio of 2.0 was utilized for all test specimens in unconfined compression tests. Samples were shared by strain-controlled test and the rate of strain was 1.14mm/min.

Penetration testing in California bearing ratio tests was carried out in a compression machine using a strain rate of 1.27mm/min. The CBR value was based on the load ratio for a penetration of 2.54mm, since this was always greater than the value obtained at a penetration of 5.08mm.

The sizes of the specimens used in unconsolidated undrained triaxial tests were 39mm in diameter and 78mm in length. Strain-controlled tests were carried out and the rate of strain was 1.14mm/min.

RESULTS AND DISCUSSION

Atterberg limits tests

Summary of the results of Atterberg limits of lateritic soils with various percentages of ash contents are shown in Table 3. The changes in the liquid limits, plastic limits and plasticity indices of lateritic soil with ash contents are presented in Fig. 3. The liquid limit and plastic limit increase linearly as the percentage of ash content increases. But, the plasticity index decreases linearly with increase in ash content. It is the opinion of the author that when ash is mixed with fine-grained cohesive soils, it causes flocculation of the soil which decreases the plasticity index of the soil.

Standard Proctor compaction tests

The results of the standard Proctor compaction tests on lateritic soil with various percentages of ash contents are shown in Table 3. The trend of changes in the maximum dry densities and optimum moisture contents of lateritic soil with ash content are presented in Fig. 3. The maximum dry density of lateritic soil decreases from 1.563t/m^3 at 0% ash to 1.390t/m^3 at 16% ash content and then it remains fairly constant. The decrease in maximum dry density is due to three reasons. Firstly, the specific gravity of the rice husk ash is lower. Secondly, ash raises enclosed air bubbles when mixed with soil. Thirdly, the ash content coats the soil to form larger aggregates which consequently results larger voids in the soils. The voids between the larger soil particles can be filled up with ash, if optimum percent of ash is mixed with soils and it will compensate some degree in dry density.

The optimum moisture content of lateritic soil increases from 22.80% at 0% ash to 25.7% at 16% ash and after that it remains fairly constant. This increase is due to the pozzolanic reaction of the ash with the soil constituents which tends to increase the optimum moisture content.

Unconfined compression tests

The results of unconfined compression tests on lateritic soil with various percentages of ash contents are shown in Table 4. The trend of the changes in unconfined compressive strengths with ash contents are presented in Fig. 4. The unconfined compressive strength of lateritic soil increases almost linearly from 211.13 kN/m^2 at 0% ash content to 416.01 kN/m^2 at 20% ash content. After reaching 20% ash content unconfined compressive strength starts to decrease. This increase in compressive strength indicates the increase in cohesion of the lateritic soil with increase in ash content.

California bearing ratio tests

The results of california bearing ratio tests on lateritic soil with various percentages of ash contents are shown in Table 4. The variation of CBR value with ash contents are presented in Fig. 4. CBR value of lateritic soil increases almost linearly from 7.73% at 0% ash content to 76.06% at 16% ash content. CBR value remains fairly constant after reaching 16% ash contents. This increase in CBR value indicates the improvement of the lateritic soil due to the addition of rice husk of rice husk ash and it also indicates the required amount of ash content to stabilize the soil successfully is about 16% for sub-base materials in highway construction.

Unconsolidated undrained triaxial compression tests

The summary of the results of unconsolidated undrained triaxial compression tests on lateritic soil with various percentages of ash contents are shown in Table 4. The trend of changes in shear strength parameters cohesion and angle of internal friction of lateritic soil with ash contents are presented in Fig. 4. The cohesion of the soil increases almost linearly from 123 KN/m^2 at 0% ash content to 360 KN/m^2 at 16% ash content and then it remains fairly constant. On the other hand angle of internal friction increases linearly form 12.8° at 0% ash content to 20.5° at 20% ash content. This increase in the value of shear strength parameters indicates the increase in shear strength of the lateritic soil due to the addition or rice husk ash. The required amount of ash content to stabilize the soil is 17%.

CONCLUSION

The experimental results clearly indicate that well burnt rice husk ash has appreciable effects on the geotechnical properties of the lateritic soil tested. The liquid limit and plastic limit increase with increase of rice husk ash, but, the plasticity index decreases. The maximum dry density decreases with increase in ash content, while, the optimum moisture content increases. The unconfined compressive strength and California bearing ratio increase with increase in ash content. The undrained shear strength parameters cohesion as well as angle of internal friction also increase with increase in ash content.

The unconfined compressive strength, California bearing ratio and shear strength parameters are found to be highest at around 17% rice husk ash and this is the optimum amount of ash required to stabilize the tested lateritic A-7-6 soil for sub-base materials in highway construction. Strength and other physical properties of lateritic soil can be improved efficiently by well burnt rice husk ash as inexpensive stabilizer. This is specially important for developing countries in the tropics where lateritic soils exist in abundance and their effective utilization can be widened and extended to other fields of construction purposes.

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Table 1. Chemical composition of rice husk ash given by Korisa (1958) and Lazaro & Moh (1970)

Composition	Korisa		Lazaro
	1	2	& Moh
Silicon dioxide (SiO_2)	94.5	93.5	88.66
Calcium oxide (CaO)	0.25	2.28	0.75
Magnesium oxide (MgO)	0.23	—	3.53
Sodium oxide (Na_2O)	0.78	—	—
Potassium oxide (K_2O)	1.10	3.15	—
Ferric oxide (Fe_2O_3)	Traces	1.01	0.35
Phosphorus oxide (P_2O_5)	0.53	—	—
Aluminium oxide (Al_2O_3)	Traces	Traces	1.48
Manganese oxide (MnO_2)	Traces	Traces	—
Carbon dioxide (CO_2)	—	—	0.51
Loss on Ignition	—	—	3.80

Table 2. General properties of lateritic soil used with rice husk ash

Tests	Results
Natural moisture content, %	8.02
Liquid limit, %	49.8
Plastic limit, %	22.6
Plasticity Index, %	27.2
Specific gravity	2.64
% passing No. 200 BS sieve	45.3
Group index	7.73

Table 3. Effects of rice husk ash on Atterberg limits, maximum dry density and optimum moisture content of lateritic soil.

Rice husk ash content %	Liquid limit %	Plastic limit %	Plasticity index (%)	Maximum dry density (t/m^3)	Optimum moisture content (%)
0	49.8	22.6	27.2	1.563	22.80
4	51.4	26.1	25.3	1.490	25.20
8	52.2	29.5	22.7	1.440	25.60
12	52.6	31.9	20.7	1.410	25.67
16	53.4	35.2	18.2	1.390	25.70
20	54.3	38.6	15.7	1.385	25.70
24	—	—	—	1.386	25.60

Table 4. Effects of rice husk ash on unconfined compressive strength, California bearing ratio, cohesion and angle of internal firction of lateritic soil.

Rice husk ash content %	Unconfined compressive strength (KN/m^2)	California bearing ratio %	Cohesion (KN/m^2)	Angle of internal friction (deg.)
0	211.23	7.73	123	12.8
4	216.99	11.96	155	13.0
8	250.23	22.03	200	14.5
12	303.20	44.82	295	16.0
16	371.61	76.06	360	18.5
20	416.01	77.68	370	20.5
24	348.51	—	—	—

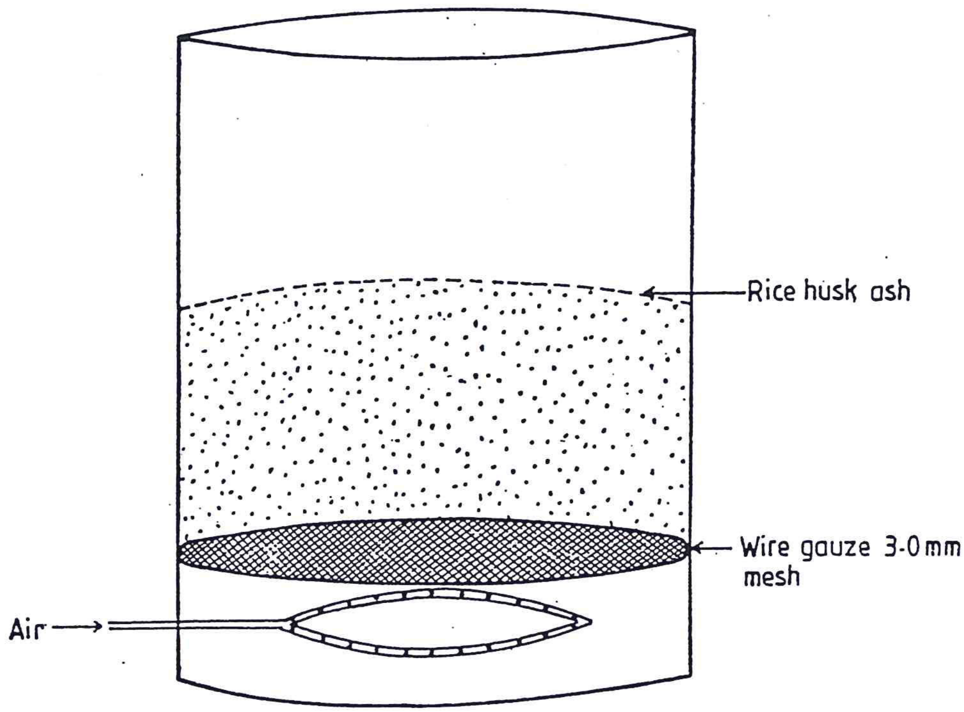

FIG. 1. Combustion chamber for preparation of rice husk ash

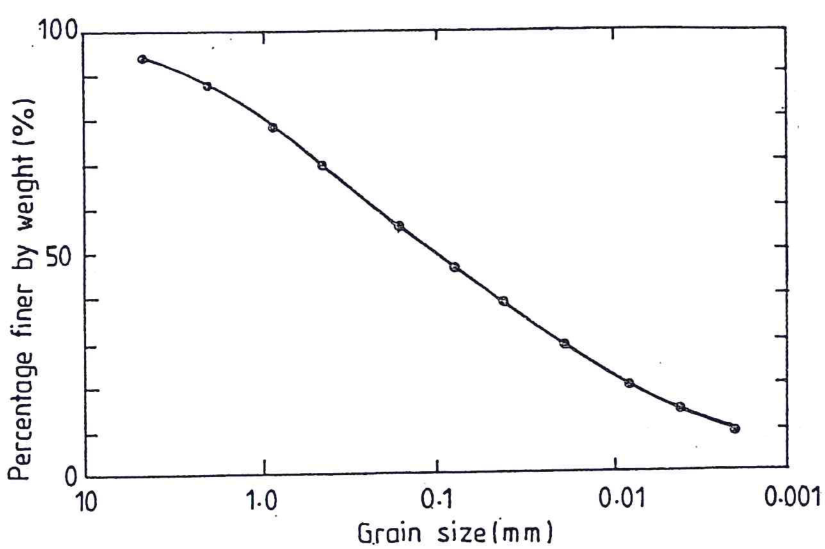

FIG: 2. Grain size distribution curve for original A-7-6 group lateritic soil.

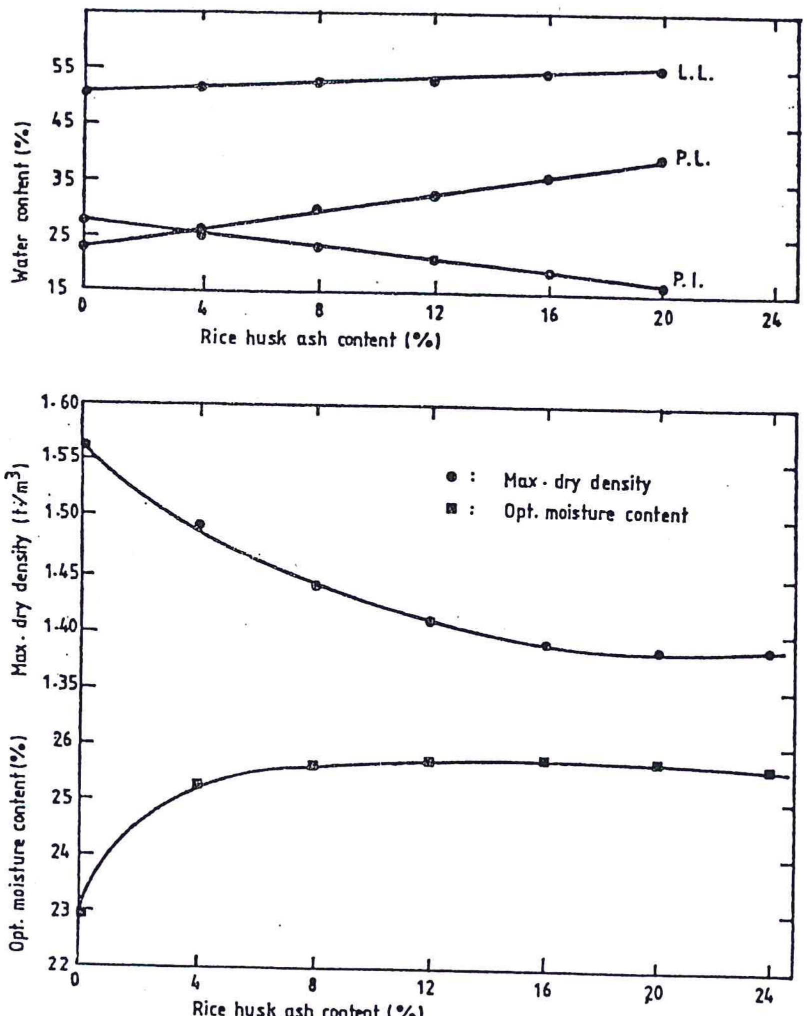

FIG. 3. Variation of Liquid limit, Plastic limit, Plasticity index, Maximum dry density and optimum moisture content of lateritic soil with percentage of rice husk ash contents

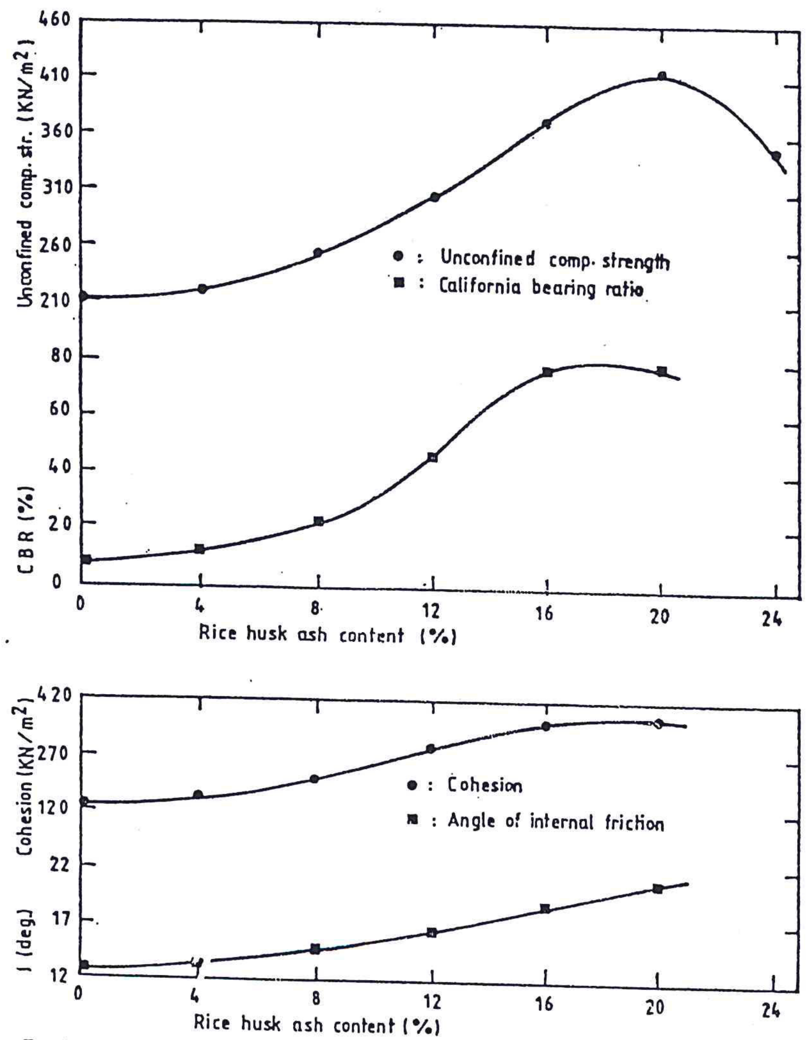

FIG. 4. Variation of Unconfined compressive strength, california bearing ratio, cohesion and angle of internal friction of lateritic soil with rice husk ash contents