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Evaluation of Rice Husk Ash Stabilized Lateritic Soil as Sub-base in Road Construction

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Authors' contributions

This work was carried out in collaboration between all authors. Author ABA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors ABA, AOO and AOA managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Laboratory experiments were conducted and the results were analyzed for rice husk ash (RHA) stabilization of laterite soils for utilization as sub base materials in road construction. The index properties classified the soils as (A-7) under the AASHTO soil classification scheme. The soils were stabilized with 2.5% increment between 5 - 12.5% of rice husk ash (RHA) by dry weight of soil. Performance of the soil-RHA was investigated with respect to compaction characteristics, California bearing ratio (CBR) and unconfined compressive strength (UCS) tests. Addition of RHA decreased the maximum dry density while it increased the optimum moisture content at 5% RHA; the values of maximum dry density (MDD) and optimum moisture content (OMC) were 1962 kg/m^3 and 24% respectively. California Bearing Ratio results showed that the peak CBR (soaked) value was 135.5% (for 7.5% RHA stabilization) which indicates 92.44% increase over the CBR value obtained for the laterite soils in their natural form. The lowest CBR (soaked) value occurred at 12.5% RHA stabilization. The unconfined compressive strength test results showed that the strength for natural soil was 107.32N/mm^2 and the highest UCS value for the stabilized soil was 68.82% (the value obtained for 5% stabilization using RHA). This gives 40.5% decrease in the UCS of the natural soil. This research shows little potentials of using RHA only for soil improvement, it is

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recommended that 5% of RHA be added to soil samples for field stabilization for the purpose of improving the soil engineering properties of the laterite soil for pavement sub-base construction. To achieve high pozzolanic behavior, it is recommended that RHA intended for use in stabilization are calcined burnt between 600ºC and 700ºC temperature [1].

Keywords: Compaction; California bearing ratio; strength, pavement; pozzolanic.

1. INTRODUCTION

The quest to reduce the cost of waste disposal and the attendant growing cost of soil stabilizers has led to intense global research utilizing for more economic materials such as agricultural wastes for engineering purposes [2]. Laterite soil is used for road construction as it occurs in tropical countries of the world, including Nigeria. There are instances where a laterite may contain substantial amount of clay minerals which impair its strength and stability as well as the ability to withstand intended traffic load.

The reaction of the laterite soil to loading in the presence of moisture is also of great concern in prospecting the soil for road, construction and rehabilitation. In most cases sourcing for alternative soil may prove uneconomical; hence we can improve the available soil to meet the desired objective. Stabilization of the laterite soils (with deficient properties) is done in order to improve their properties so as to possess the ability to carry anticipated load without failure.

Soil improvement can either be by modification or stabilization or both. Soil modification is the addition of a modifier (cement, lime and others) 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 [3]. Over the years, 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 and the high demand for them in the market. Cement as a stabilizer can be used to make up for the strength of laterite by addition of 0.5 – 7.5% of cement to the laterite soil (Adeboje et al, 2013).

Overdependence on the utilization of industrially manufactured soil improving additives (such as cement and lime) has kept the cost of construction of stabilized road high. This hitherto, has continued to deter the underdeveloped and poor nations of the world (which Nigeria is one) from providing accessible roads to a larger percentage of their population, especially their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. The use of agricultural waste (such as RHA) will considerably reduce the cost of construction and also reduce the environmental hazards they cause. According to Mustapha [4], “Portland cement, by the nature of its chemistry, produces large quantities of CO_2 for every tonne of its final product”. Therefore, replacing proportions of the Portland cement in soil stabilization with a secondary cementitious material like Rice Husk Ash (RHA) will reduce the overall environmental impact of the stabilization process.

1.1 Rice Husks

Rice husks are the natural sheaths that form on rice grains during their growth.

They can however be made useful through a variety of thermo chemical conversion process. The major compounds from rice husks are silica and cellulose which yield carbon when thermally decomposed (Adylov et al., 2003).

Rice Husk is an agricultural waste obtained from milling of rice. About 100,000,000 tons of rice husks are 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 were produced in 2000 [5].

1.2 Rice Husk Ash

Rice husk ash is a pozzolanic material that could be potentially used in Nigeria, though it is moderately produced and readily available. When rice husk is burnt under controlled temperature, ash is produced and about 17 - 25% of rice husk’s weight remains ash. The predominant component of the ash is silica with traces of other minerals [6].

The silica is substantially contained in amorphous form, which can react with the CaOH librated during the hardening of cement to further form cementations 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 [7]. From the majority of rice producing countries much of the husks produced from the processing of rice is either burnt or dumped as a waste.

1.3 Stabilization

The term 'stabilization' is the process whereby the natural strength and durability of a soil or granular material is increased by the addition of a stabilizing agent. In addition, it may provide a greater resistance to the ingress of water. There are many types of stabilizer that can be used, each with its own advantages and disadvantages. The type and quantity of stabilizer added depends mainly on the strength and performance that needs to be achieved.

Soil stabilization, in the broadest sense, is the alteration of any property of a soil to improve its engineering performance. It also comprises ~~of~~ any process which increases or maintains the natural strength of the soil. In this sense, it includes compaction, drainage and sowing of grass and planting the tree on banks (Cassie, 1969). Stabilization techniques could be mechanical or chemical (addition of cementitous additives).

1.4 Modification

Process of reducing plasticity and improving the texture of a soil is called soil modification [8].

The specific objectives of this study is to evaluate the effect of RHA on CBR, Compaction, Atterberg limits and UCS on lateritic soil as well as making deficient soil useful to meet geotechnical engineering requirements.

2. MATERIALS AND METHODOLOGY

2.1 Materials

The samples of lateritic soil (disturbed samples) used for this research were obtained from a borrow pit being used for an on-going rehabilitation of Ibese road by Arab Contractor at Egbe village along Igbogbo - Ikorodu road, Lagos State. The Rice Husk was obtained from a central Rice mill at Nguru, Mokwa, Niger State and Wasimi, Ogun State while the Ordinary Portland Cement (OPC) was procured from the open market and stored in a cool place.

2.2 Rice Husk Ash

The Rice Husk Ash used in this work was made in the laboratory by burning the husk using a ferro cement furnace with incinerating temperature not exceeding 650ºC for 60 minutes. During the burning process, the carbon content was burnt off and all that remains was the silica content, only fractions passing British Standard (BS) sieve No. 200 (75 µm) was used throughout the test without additional treatment. The RHA was ground (using mortar and pestle) and sieved through BS sieve No 200 (75 µm) before use. The investigation included evaluation of properties such as compaction, consistency limits and strength of the soil with Rice Husk Ash (RHA) content of 5 - 12.5% with increase of 2.5% by weight of dry soil.

2.3 Soil Index Properties

200 g of dry, well pulverized soil was passed through a stack of a selected set of sieves with a pan at the bottom. The amount of soil retained on each sieve was measured and the cumulative percentage of soil passing through each was determined. This percentage is generally referred to as percent finer. Particle size distribution was determined in accordance with BS 1377-2 (1990). Laboratory tests were conducted to determine the index properties of the natural soil and soil-rice husk ash mixtures (stabilized soil) in accordance with BS 1377-2 (1990) and BS 1924 (1990) respectively.

2.4 Compaction Test

The compaction test were carried out in compliance with standard laboratory test used to evaluate dry unit weight and optimum moisture content of the soil samples (natural and stabilized) are the Standard Proctor test (ASTM D698; AASHTO T-99) and the Modified Proctor test (ASTM D-1557; AASHTO T-180).

Moisture Content (%) = (weight of water/weight of dry sample) x 100 ------------------ (i)

Dry density = (wet density/ (100 + weight of dry sample) x 100 ------------------------ (ii)

2.5 California Bearing Ratio Test

California bearing ratio (CBR) was carried out using both natural and stabilized soil sample in compliance with the specifications of ASTM D1557.

2.6 Unconfined Compressive Strength (UCS) Test

Unconfined compressive strength (UCS) is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil [9].

3. RESULTS AND DISCUSSION

3.1 Index Properties and Sieve Analysis

The Atterberg limit tests results revealed that the liquid limit was 48.1% and the Plastic Limit was 16.9% respectively, while the plasticity index was 31.2% (Table 1).

Table 1. Mechanical analysis result of natural soil

Property	Value
Liquid limit	48.10%
Plastic limit	16.9
Plasticity index	31.2
Shrinkage limit	9.40%
Specific gravity	2.62
AASHTO classification	A7
212 micron	6.6
150 micron	3.9
63 micron	3.6

According to Whitlow [10], liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. This shows that samples used have intermediate plasticity

The oxide composition of RHA is shown in Table 2.

Table 2. Chemical composition of rice husk ash (RHA)

Constituent	Composition (%)
Fe_2O_3	0.95
SiO_2	67.3
Al_2O_3	1.36
CaO	4.9
M_gO	1.81
Loss of ignition	23.68

3.2 Compaction Test Results

Compaction is an effort to increase the density of soil mass by r content [11].

The results obtained from the experiments revealed that the MDD and OMC for the natural soil sample were 2068 kg/m^2 and 21% respectively. Addition of RHA stabilizer increased the value of OMC steadily; the initial increment could have been as a result of increasing demand for water by various cations and the clay mineral particles to undergo hydration reaction [12,13,14]. However, addition of RHA was seen to have reduced the density of compacted soil [17]. The initial decrease in the MDD can be attributed to the replacement of the soil by the RHA which has lower specific gravity compared to that of the soil [15,16], it may also be attributed to coating of the soil by the ash content which result to large particles with larger voids and hence less density [18,19]. This is also confirmed by the reduction in MDD from the result obtained as shown in Table 3.

3.3 California Bearing Ratio Test Results

The California bearing ratio value is an indicator of soil strength and bearing capacity and it is used in the design of base and sub-base course for pavements.

Table 3. Experimental results for compaction

% stabilizer	Rice husk ash (RHA)			
	MDD (Kg/m³)		OMC (%)	
	Unsoaked	Soaked	Unsoaked	Soaked
0%	2068	1734	21	19
5%	1962	1583	24	20
7.5%	1964	1582	24.3	20
10%	1964	1568	24.8	21
12.5%	1905	1529	25	22

The results obtained from the California Bearing ratio Test carried out on both the stabilized and unstabilized natural soil sample with respect to their various percentages (%) of stabilization are shown in Table 4 and Fig. 1.

Table 4. Experimental results for California bearing ratio

% stabilizer	Rice husk ash (RHA)	
	CBR (%)	
	Unsoaked	Soaked
0%	12.3	10.25
5%	162.3	135.5
7.50%	157.2	121.7
10%	153.9	111.2
12.50%	136.8	105.5

The highest soaked CBR value was 135.5% (for 5% RHA stabilization) which indicates 92.44% increase over the CBR value gotten for the natural soil sample (control). The lowest soaked CBR value occurred at 12.5% RHA stabilization. The soaked CBR values of the treated soil increased from 10.25% for the natural soil to 135.5% for the soil treated with 5% RHA. In the other hand, the improved soaked CBR of up to 135.5% is a very stable material for sub-grade and acceptable for sub-base according to Emesiobi [20].

Also, the highest unsoaked CBR value which is 162.3% occurred at 5% RHA stabilization and the minimum unsoaked CBR value which is 136.8% occurred at 12.5% RHA stabilization.

The increment in the CBR at 5% RHA may be attributed to the gradual formation of cementitious compounds between the RHA and Calcium hydroxide contained in the soil. The gradual decrease in the CBR between 7.5 - 12.5% 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.

3.4 Unconfined Compressive Strength Test (UCS)

Unconfined compressive strength (UCS) is the most common and adaptable method for evaluating the strength of stabilized soil. UCS is the main test recommended for the determination of the required amount of additive to be used in the stabilization of soils [21].

The Unconfined compressive strength test results showed that the unconfined compressive strength for natural soil is 107.32 N/mm² and the highest UCS value for the stabilized soil was 68.82 N/mm² (i.e. the value obtained for 5% stabilization using RHA).

There is 40.5% reduction in the UCS tests obtained for the natural soil sample. The lowest UCS occurred at 12.5% stabilization using RHA which is 23.83%. The UCS values decrease with subsequent addition of RHA. This decrease in the UCS values after the addition of 7.5 - 12.5%

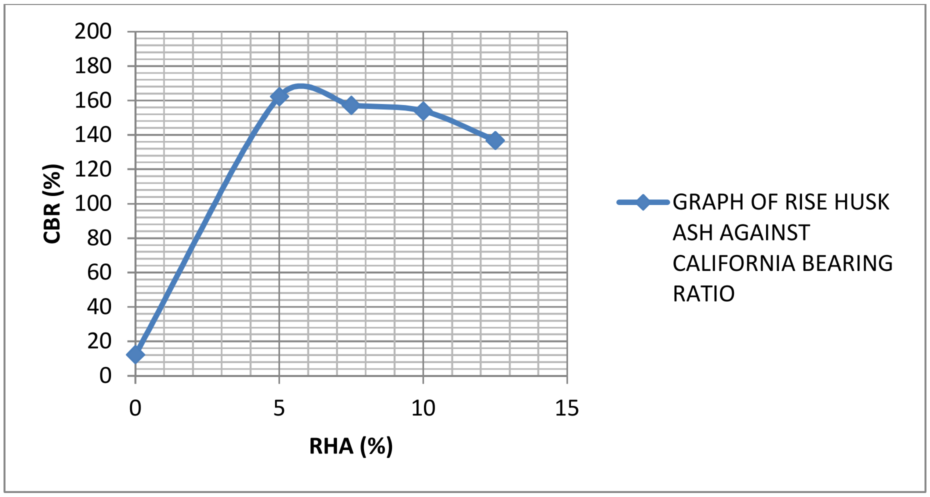

Fig. 1. Influence of RHA on soaked CBR

RHA may be due to the excess RHA added to the soil and therefore forming weak bonds between the soil and the cementitious layers of soil formed.

4. STATISTICAL CONCLUSION

The laboratory experimental results analysis for this research work was carried out using Correlation analysis as the primary statistical tool and statistical package for social science (SPSS) as statistical software packages for statistical analysis.

Correlation analysis is a statistical technique to quantify the dependence of two or more variables. The purpose of a CORRELATION ANALYSIS is to determine whether there is a relationship between sets of variables- CBR, RHA, and OMC or UCS, RHA, and OMC.

Inference shall be based on the strength tests (CBR-soaked and UCS) results gotten from Rice Husk Ash (RHA) stabilized soil other than those obtained from RH.

4.1 California Bearing Ratio

In the test statistics for CBR (see Table 6), the result of the r-cal was obtained at 0.998 at 0.002 probability level. There is a positive correlation between the CBR, RHA and the OMC (n = 15, r = 0.998, critical value = 0.002).

Based on the results above, P-value < 0.05, and this shows that there is a significant relationship between the variables. This implies that the OMC and Rice Husk Ash (RHA) -Stabilizer have a significant contribution towards the CBR of the soil. Based on the inference, it can be reliably adjudged that there is significant relationship between the CBR, RHA and OMC.

Table 5. Experimental results for unconfined compressive strength test

% stabilizer	Rice husk ash (RHA)
	UCS (N/mm²)
0%	107.32
5%	68.82
7.50%	44.42
10%	28.95
12.50%	23.83

4.2 Unconfined Compressive Strength Test

In the test statistics for UCS (see Table 7), the result of the r-cal was obtained at -0.982 at 0.003 probability level. This indicate a significant negative correlation between the UCS and RHA (n = 10, r = -0.982, critical value = 0.003).

Based on the results above, P-value < 0.05, we conclude that there is significant relationship between the variables. This implies that contribution of RHA (Stabilizer) is significant towards UCS. Based on the inference, it can be reliably be adjudged that there is significant relationship between the UCS and RHA.

From the Table 4 (Experimental Result for CBR) and also relating to the graph of RHA against CBR from Figs. 1.0-3.0, the CBR value increased by 90.92% at 5% stabilization using RHA, and the CBR value began to drop steadily with increase in stabilization percentages i.e. from 7.5%- 12.5% respectively. It can therefore be inferred that the optimum RHA stabilization can best be achieved at 5% stabilization.

Table 6. Relationship between CBR (Soaked), RHA and OMC (H_O: there is no significant relationship between, CBR (SOAKED), OMC AND RHA (Stabilizer)

Variable	N	Mean	Std Dev	r-cal	P-value	Remark
STABILIZER	5	7.0000	4.80885	0.998	0.002	Reject H_o
OMC	5	23.8200	1.62542			
SOAKED	5	124.5000	63.44805			

Table 7. Relationship between UCS and RHA (H_O: there is no significant relationship between UCS (RHA) AND (Stabilizer)

Variable	N	Mean	Std Dev	r-cal	P-value	Remark
STABILIZER	5	7.0000	4.80885			
UCS (RHA)	5	53.6240	33.77863	-0.982	0.003	Reject H_o

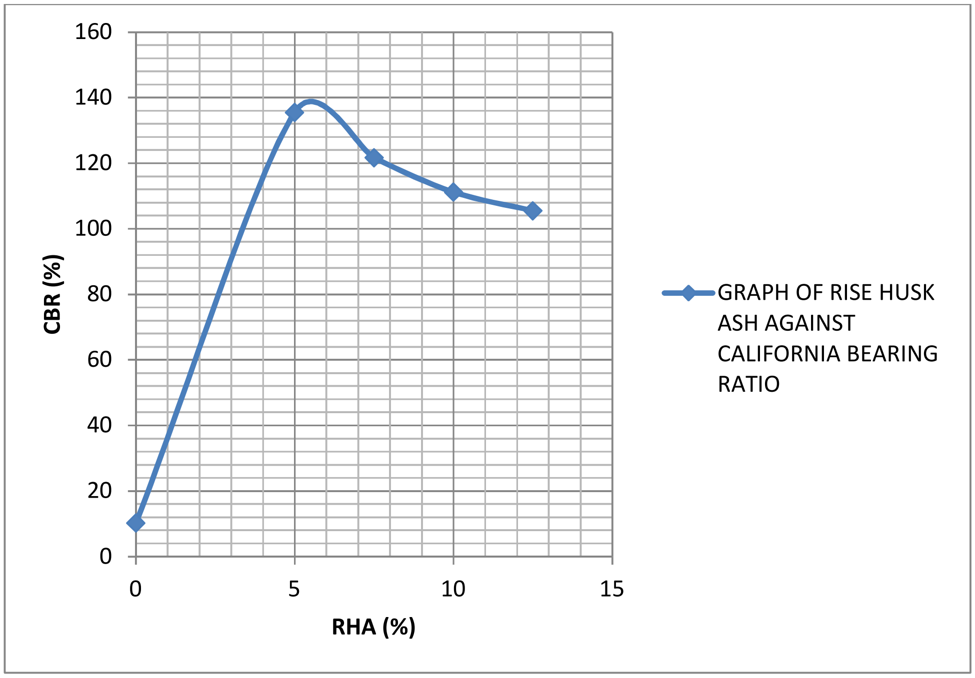

Fig. 2. Influence of RHA on unsoaked CBR

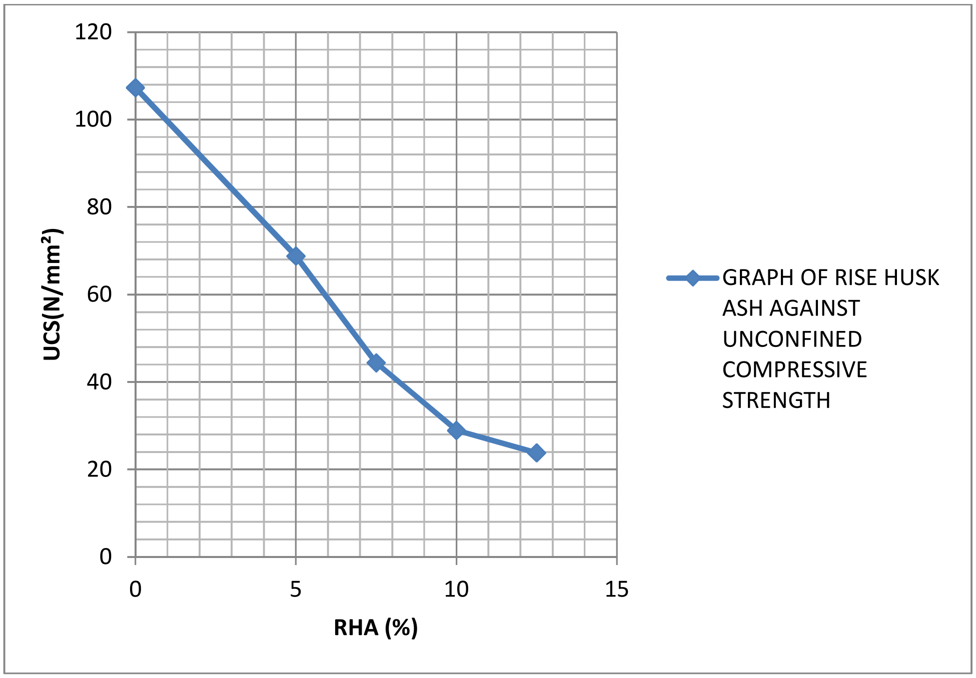

Fig. 3. Influence of RHA on UCS

5. SUMMARY

The laterite was identified to be an A-7 soil according to AASHTO [22] classification system. It is also a silty-clay according to the same classification system.

The properties of natural lateritic soil indicate Liquid limit (L.L) of 48.1%, Plastic limit (P.L) of 3.1, Shrinkage limit (S.L) of 9.4% and Plastic limit (P.L) of 16.9.

The compaction characteristics of the natural lateritic soils were altered with the addition of RHA. Treatment with RHA showed a general decrease in the MDD and increase in OMC with increase in the RHA content.

The Optimum RHA content was found at 5% for CBR tests for both soaked and unsoaked (157.2% and 121.7 at 7.5% RHA content) which indicate an improvement in the treated soil compared with the CBR of the natural soil (12.3 and 10.25% respectively).

The UCS values were at their peak at 5% RHA (see Table 5 above). The statistical analysis for CBR shows a positive correlation between the CBR, RHA and the OMC which indicate a direct relationship between the variables.

Statistical analysis for UCS shows a significant negative correlation between the UCS and RHA which indicate a direct relationship among the variables.

6. RECOMMENDATIONS

Based on the study, up to 5% Rice Husk Ash (RHA) content can be recommended as suitable material for treatment of lateritic soil to improve its geotechnical properties (in places where they are abundant) before using it as sub-base materials in road construction.

It is also recommended that Rice Husk Ash (RHA) intended for use for field stabilization be burnt between the temperature of 600ºC and 700ºC.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nick ZEW. Rice Husk Ash; 2009.
2. Oriola F and Moses G. Groundnut shell ash stabilization of black cotton soil. Available:http://www.scihub.org/AJSIR/PDF/2011/4/AJSIR-2-2-674-677.pdf
   AASHTO, Standard specifications for transportation materials and method of testing and sampling. American Association of State Highway and Transportation Officials, Washington D.C, USA; 1986.
3. Osinubi KJ, Bajeh I. Bituminous stabilization of laterite. Spectrum J. 1994; 1(2):104-12
4. Mustapha MA. Effect of Bagasse Ash on Cement Stabilized Laterite. AU J.T. 2008; 11(4):246-250
5. Oyetola EB, Abdullahi M. The use of rice husk ash in low-cost Sandcrete block production. Leonardo Electronic Journal of Practice and Technologies. 2006;8:58-70
6. Wen-Hwei H. Rice husks production and utilization. AVI Publishing Company Incoporated, West Port Connecticut; 1986.
7. Mustapha A, Muhammed M. Effect of rice husk ash on cement stabilized laterite. Leonardo Electronic journal of Practice and Technologies. 2007;11:47-58.
8. Kuwin M. A study of rice husk ash on cement stabilized laterite; 2011.
9. Singh G, Singh J. Highway engineering. Standard Publishers Distributors, Nai Sarak, Delhi, India. 1991;608-10.
10. Whitlow R. Basic soil mechanics. 3rd ed. Addison Wesley Longman Limited, Edinburgh Gate; 1995.
11. Rahman ZA, Yaacob WZW, Rahim, SA, Lihan T, Idris WMR, Mohd Sani WNF. Geotechnical characterisation of marine clay as potential liner material. Sains Malaysiana. 2013;42(8): 1081-1089. ISSN 0126-6039.
12. Osinubi KJ, Stephen TA. Effect of curing period on bagasse ash stabilized black cotton soil. Book of Proceedings Bi-monthly Meetings/Workshop, Materials Society of Nigeria, Zaria. 2006a;1-8.
13. Osinubi KJ, Stephen TA. Effect of bagasse ash content on particle size distribution and plasticity characteristics of black cotton soil. Proceedings of the 5 Nigerian Materials Congress; 2006b.
14. Osinubi KJ, Medubi AB. Evaluation of cement and phosphatic waste admixture on tropical black clay for road foundation. Structural Engineering Analysis and Modeling. SEAM4. 1997;2:297-307.
15. Moses G. Stabilization of black cotton soil with ordinary Portland cement using bagasse ash as admixture. IRJI Journal of Research in Engrg. 2008;5(3):107-115.
16. Osinubi KJ, Stephen TA. Effect of curing period on bagasse ash stabilized black cotton soil. Book of Proc. Bi-monthly Meetings/Workshop. Material Society of Nigeria. Zaria. 2006;1-8.

17. Gidigasu MD. Laterite soil engineer-ing: Pedogenesis and Engineering Principles. Elsevier, Amsterdam, the Netherlands; 1976.
18. Osula DOA. Lime modification of problem laterite. Engin Geol. 1991. 30: 141-9.
19. Ola SA. Stabilization of Nigeria lateritic soils with cement, bitumen and lime. Proc. 6th Reg. Conf. Africa on Soil Mechanics and Foundation Engineering. Durban, South Africa; 1975.
20. Emesiobi FC. Testing and quality control of materials in civil and highway engineering. ISBN 078-2009-36-16. 2000;5-7.
21. Singh G, Singh J. Highway engineering. Standard Publishers Distributors, Nai Sarak, Delhi, India. 1991;608-10.
22. AASHTO. Standard Specifications for Transportation Materials and Method of Sampling and Testing. Amer. Assoc. State Highway and Transportation Officials, Washington, DC, USA; 1986.

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