Effects of Coconut Husk Ash on Stabilization of Poor Lateritic Soils.

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ABSTRACT

The volume of wastes generated in the world over has increased over the years due to increase in population, socioeconomic activities and social development. The waste that comes from agricultural, industrial, commercial as well as construction activities are composed of a very wide variety of materials such as food wastes, construction waste, paper, plastic and other discarded residual items. One of the most attractive options of managing such wastes is to look into the possibility of waste minimization and re-use.

This research is aimed at assessing the effects of coconut husk ash on the stabilization of poor lateritic soil deposit found at Otu in Itesiwaju Local Government Area in Oyo State, Southwestern Nigeria, using 0, 2, 4, 6, 8, and 10% of coconut ash by mass of soil sample. In order to achieve our research goal, the following laboratory soil tests were carried out on the stabilized soil samples: particle size distribution analysis, Atterberg limit test, compaction test, and California Bearing Ratio in accordance with British Standard 1377 (1990) and Head (1992). Chemical composition analysis of the coconut husk ash was done as well.

Chemical analysis of the coconut husk ash is shown in Table 1. The liquid limit ranges between 58.9% and 67.2%, plastic limit ranges between 25% and 47.14%, and plasticity index is between 20% and 37%. The maximum dry density ranges between 1.512g/cm3 and 1.62 g/cm3 with their optimum water contents ranging between 13.5 and 24% while California bearing ratio (soaked) is between 14% and 36%. Result shows that maximum dry density of 1.62 g/cm^3 with corresponding optimum water content of 13.5% was obtained at 4% of ash addition.

The result indicates that coconut husk ash is suitable for improving the California bearing ratio because this parameter increases with addition of coconut husk ash. Addition of coconut husk ash also increases the plastic limit but reduces the plasticity index. Therefore, this study shows that coconut husk ash can be effectively used to improve lateritic soils with low CBR values but not suitable for improving soils with high liquid limit.

(Keywords: coconut husk ash; lateritic soil, soil graduation, Atterberg limit, compaction, California bearing ratio)

INTRODUCTION

Wastes either solid or liquid are inevitable products of the bulk of man's activities whether in urban or rural areas. Their type, amount and composition vary with the type of activity which may be domestic, agricultural or industrial in nature.

The waste that comes from agricultural, industrial, commercial as well as construction activities are composed of a very wide variety of materials such as food wastes, construction waste, paper, plastic and other discarded residual items. The volume of wastes generated in the world over has also increased over the years due to increase in population, socioeconomic activities and social development.

Based on the statistical data given in the 1980's, the quantity of municipal solid wastes in the urban center has doubled in size (Ghazali and Kassim, 1994). If it is improperly handled, these wastes will be a source of land, air, surface water and groundwater pollution. In other to minimize the effects of these wastes, one of the most attractive options of managing such wastes is to look into the possibility of waste minimization and recovery. Coconut husk can therefore be seen as an agricultural waste which will result in air and land pollution if not properly managed.

Over the years, cement and lime have been 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 dependence on the utilization of industrially manufactured soil improving additives (cement, lime, etc.), have kept the cost of construction of stabilized road financially high. This has continued to deter the underdeveloped and poor nations of the world from providing accessible roads and safe structures to their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. Thus the use of agricultural waste materials such (such as coconut husk ash or coir fiber ash) will considerably reduce the cost of construction and as well reducing the environmental hazards they cause.

It has been observed that many coal combustion by-products have properties that are beneficial in soil stabilization applications such as soil drying, a soil amendment to enhance subgrade support capacities for pavements and floor slabs, reduction of shrink–swell properties of soils, and a stabilizer in aggregate road base construction and asphalt recycling. It has also been shown by Sear (2005) that Portland cement, by the nature of its chemistry, produces large quantities of CO_2 for every ton of its final product which contributes to the melting of the ozone layer covering the Earth's surface.

Coconut husk ash has been categorized as pozzolana, with about 67-70% silica and, approximately 4.9 and 0.95% of aluminum and iron oxides, respectively (Oyetola and Abdullahi, 2006). Therefore, replacing proportions of the Portland cement in soil stabilization with a material like coconut husk ash will reduce the overall environmental impact of the stabilization process. Tejano (1985) stated that several coconut-producing regions have sufficient supply of husks to support the profitable extraction of coir, yet less than 0.6% of the total husk supply is utilized.

Also, 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 presence 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; Osinubi and Bajeh, 1994).

It is discovered that no work has been carried out on the likely effects of the coconut husk ash on the engineering properties of soil in Nigeria. This scenario has therefore prompted the need for this research work because there is large quantity of coconut husk in Nigeria and many Africa countries. Hence, the main aim of this investigation is to examine the likely effects of the coconut husk ash as a stabilizing agent for poor lateritic soils and making necessary recommendations for engineers and contractors.

LOCATION OF COLLECTED SAMPLES

The soil samples used in this study were obtained as disturbed samples from an existing poor lateritic soil deposit located at Otu in Itesiwaju Local Government Area, Oyo State, which lies within the geographical coordinates of 8°N and 4°E. Geologically, the study area falls within the basement complex of south-western Nigeria which consists predominantly of magmatized and undifferentiated gneisses and quartzite (Akintola, 1982 and Areola, 1982; Bello and Adegoke, 2010).

The coconut husks were collected from Badagry, Lagos State, where coconut is harvested on a large scale.

MATERIAL AND METHODS

Preparation of Samples

The poor lateritic soil obtained from Otu was wet washed on sieve 425μm. The retained sample was weighed and kept in the oven for 24hours at a regulated temperature of $105^0{}_{C.}$ The samples were then broken into smaller fragments, care being taken not to reduce the sizes of the individual particles. The Samples were prepared in accordance with BS 1377 (1990) and Head (1992).The coconut husk collected from Badagry, Lagos State was dried and burnt in a controlled environment untill it completely turned to ashes. The product called coconut husk ash was mixed in 0%, 2%, 4%, 6%, 8%, and 10% by mass of the soil sample with the oven-dried samples of poor lateritic soil.

Test Procedures

The following tests viz; chemical composition test, particle size analysis test, Atterberg limit test, British Standard (BS) compaction test, and California bearing were carried out on each of the mixed samples. The procedures of these tests are as follows:

***Chemical Composition*:** The quantitative analysis of the percentage composition of silica oxide and other chemical compound such as P_2O_5, SO_3, K_2O, MnO, Fe_2O_3 and so on, were carried out on the coconut husk ash at Kappa Biotechnologies Laboratories, a research center in Ibadan, Nigeria. Each of these tests was done three times to justify the exact quantity of the oxides.

Sieve Analysis: Representative sample of approximately 500g of the poor lateritic soil was used for the test after washing and oven-dried. The sieving was done by mechanical method using an automatic shakers and a set of sieves. The objective of this, is to determine the particle size distribution of the soil sample to be stabilized.

Liquid Limit Determination: The mixture of the oven-dried soil sample passing through 425µm sieve and percentages of coconut husk ash, weighing 300g was mixed with water to form a think homogeneous paste. The paste was collected and placed into the Casangrade's apparatus cup with a grove created and the number of blows to close it was recorded. Also, moisture contents were determined.

Plastic Limit Determination: Soil sample-coconut husk ash mixture weighing 300g was taken from the material passing the 425µm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball. The ball of soil-ash mixture was rolled on a glass plate until the thread cracks at approximately 3mm diameter. Therefore, the moisture contents were determined.

Compaction: Compaction tests were carried out on the air dried soil samples which were mixed with the aforementioned percentages of coconut husk ash and 6% water addition according to British standard (BS). Maximum Dry Density and Optimum Moisture Contents were determined for each of the mixtures.

California Bearing Ratio (CBR): Air-dried soil-coconut husk ash mixture was mixed with about 6% of its weight of water. This was put in C.B.R mold in 3 layers with each layer compacted with 27 blows using 4.5kg hammer. The compacted soil-ash mixture and the mold was weighed and placed under C.B.R machine and a seating load of approximately 4.5kg was applied. Load was recorded at penetration of 0.5, 1.0, 2.0, 2.5, 3.5, 5.0, and 6.5mm. The moisture content of the compacted soil was determined. The same procedure was repeated for 2%, 4%, 6%, 8%, and 10% coconut husk ash additions.

RESULTS AND DISCUSSION

Chemical Composition

Three tests carried out for each compound show the same result as shown in Table 1 below. This reveals that the coconut husk ash contains large percentage of K_2O (62.43%) follows by SiO_2 (17.9%), which corroborate the fact that coconut husk ash is a pozzolanic material.

Geotechnical Analysis Results

The summary of the geotechnical tests carried out on the samples are as shown in Table 2.

Uniformity Coefficient $C_u = \frac{D60}{D10} = \frac{2.5}{0.35} = 7.14$

Coefficient of Gradation $C_g = \frac{D30^2}{D60 \times D10} = \frac{0.45^2}{2.5 \times 0.35}$
$= 0.23$

Particle Size Distribution: The grain size analysis as shown in Figure 1 shows that the percentages passing No. 200 BS sieve are 0.16% for the poor lateritic soil sample. This result satisfies the specification limits of 35% or less for road according to Road and Bridges Specification Revised Edition of Federal Ministry of Works, Nigeria (1997). Result also reveals that the sample is well graded since the uniformity coefficient of the soil sample is greater than 5.

Table 1: Analysis of Coconut Husk Ash.

Compound	P_2O_5	SiO_2	SO_3	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3
% Composition	2.6	17.9	1.4	62.43	8.76	0.73	0.007	0.11
Compound	MnO	Fe_2O_3	NiO	CuO	BaO	ZnO	MoO_3	Re_2O_7
% Composition	0.11	4.65	0.087	0.089	0.48	0.12	0.3	0.1

Table 2: Summary of Atterberg Limit, Compaction and CBR Results.

Ash Composition	0%	2%	4%	6%	8%	10%
OMC(%)	23	21	13.5	17.5	24	22
MDD(g/cm^3)	1.538	1.58	1.62	1.59	1.555	1.512
LL(%)	62	59.8	58.9	62.9	62.85	67.2
PL(%)	25	39.8	33.54	35.09	47.14	46.94
PI(%)	37	20	25.36	27.81	16.71	20.6
CBR(%)	14	14	27	31	32	36

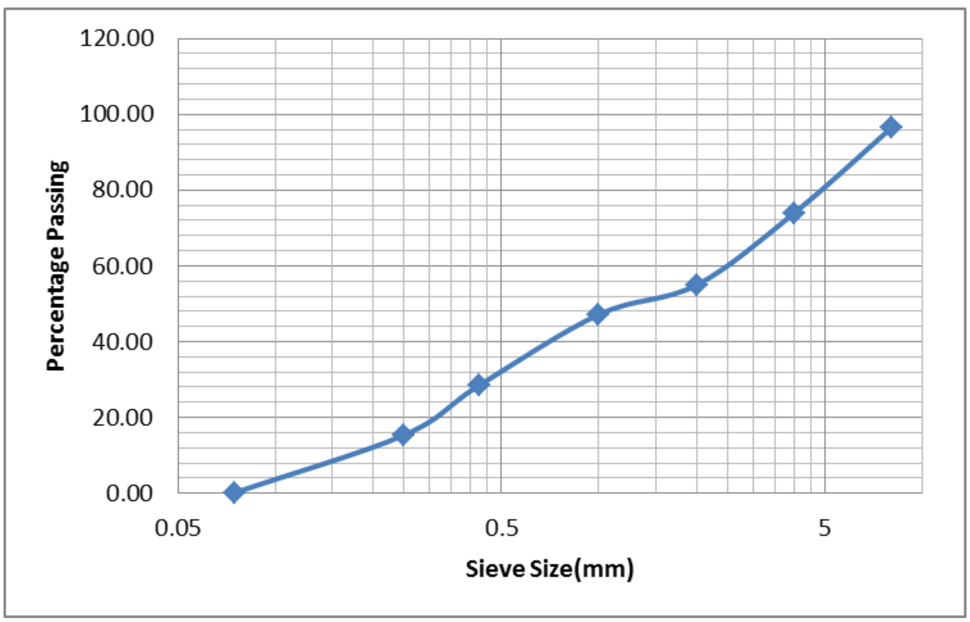

Figure 1: Grading Curve of Soil Sample.

The soil can be further classified as A-2-7 under the AASHTO classification based on the percentage passing sieve No. 200 of 0.16% and the liquid limit of 62%.

Atterberg Limits: The Liquid limit ranges between 58.9% and 65%, plastic limit ranges between 25% and 47.14%, and plasticity index is between 16.71% and 37%. Federal Ministry of Works and Housing (1972) for road works recommend liquid limits of 50% (35%) and plasticity index of 10% maximum for sub-base and base materials. All the studies soil samples are more than the maximum values recommended by Federal Ministry of Works and Housing therefore renders the soil unsuitable for use as sub-base and base materials. Results show that coconut husk ash increases the plastic limit, reduces the plasticity index and shows little or no effect on the liquid limit of soil. This indicates that coconut husk ash is unfit for improving soils with high liquid limit. Figures 2 and 3 show that the minimum values of both liquid and plastic limits occurred at 4% addition of coconut husk ash.

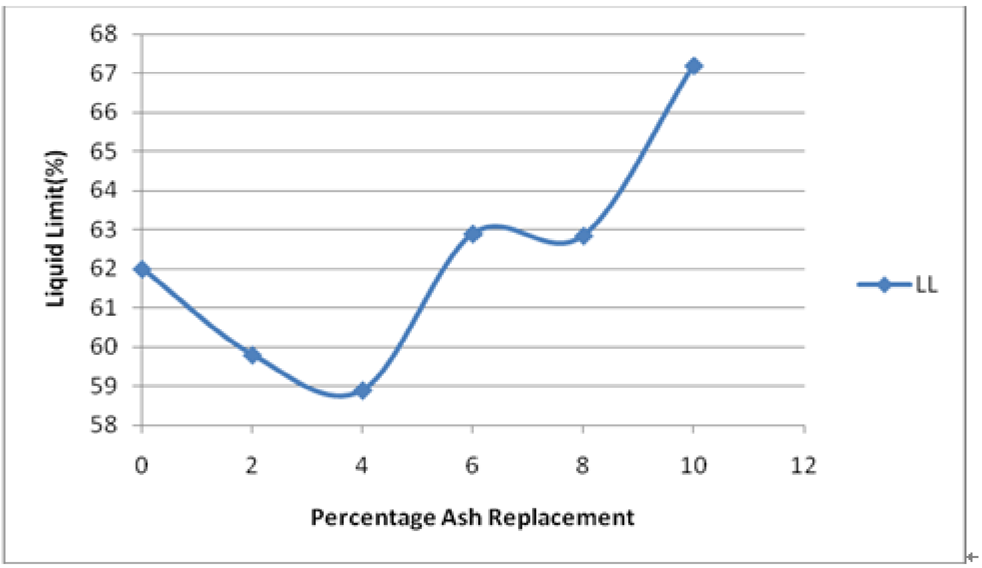

Figure 2: Relationship between Liquid Limit and Percentages of Ash Replacement.

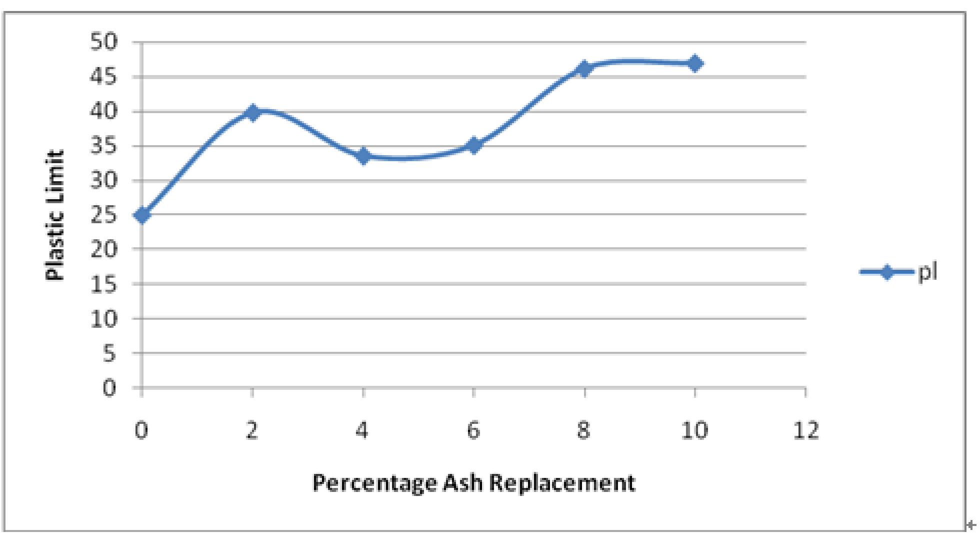

Figure 3: Relationship between Plastic Limit and Percentages of Ash Replacement.

Compaction: As shown in Figures 4 – 6, the maximum dry density ranges between 1.512g/cm3 and 1.62 g/cm^3, and the optimum water contents ranging between 13.5% and 24%. Result shows that maximum dry density increases from 0% to 4% and reduces at a reducing rate after 4% addition of coconut ash. It can also be established that the minimum value of optimum water content occurs at 4% coconut husk ash addition. The increase and decrease in maximum dry density might be as a result of binding action and complete reaction of calcium hydroxide on clay soil and coconut husk ash respectively. This reveals that the optimum value of the coconut husk ash on lateritic soil is 4%.

California Bearing Ratio: CBR (soaked) values range from 14% to 36%. Result from Figure 7 reveals that coconut husk ash gradually increases the CBR value of the poor lateritic soil, which shows that the higher the coconut ash addition the higher the CBR value with the maximum value of CBR obtained at 10% addition of the coconut husk ash. This gives indication that coconut husk ash can be effectively used to improve the CBR value of soil.

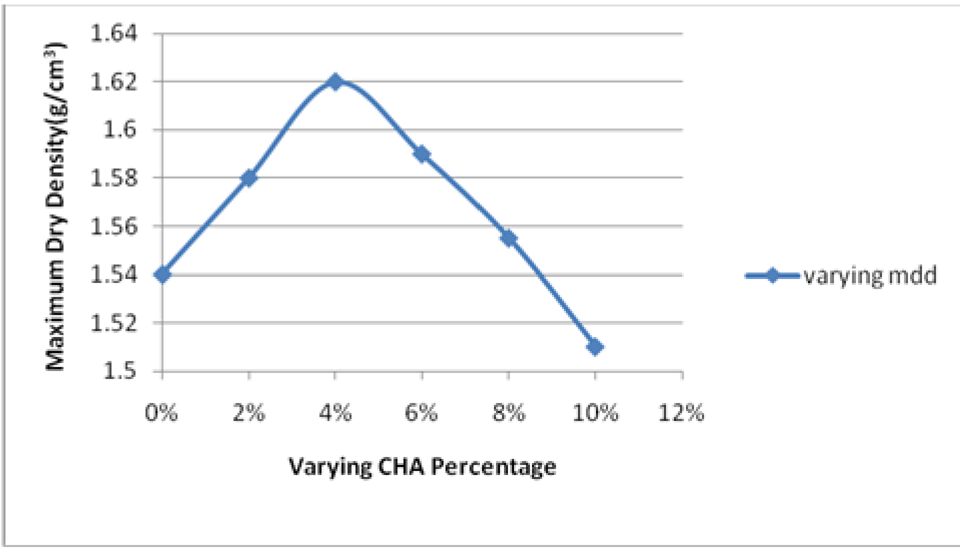

Figure 4: Relationship between Maximum Dry Density and Percentages of CHA Addition.

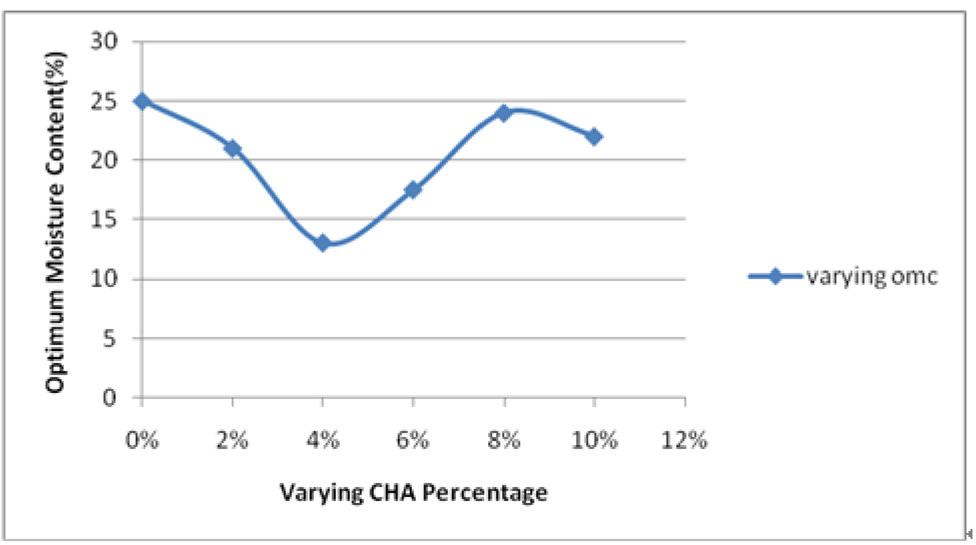

Figure 5: Relationship between Optimum Moisture Content against Varying Percentages of CHA Addition.

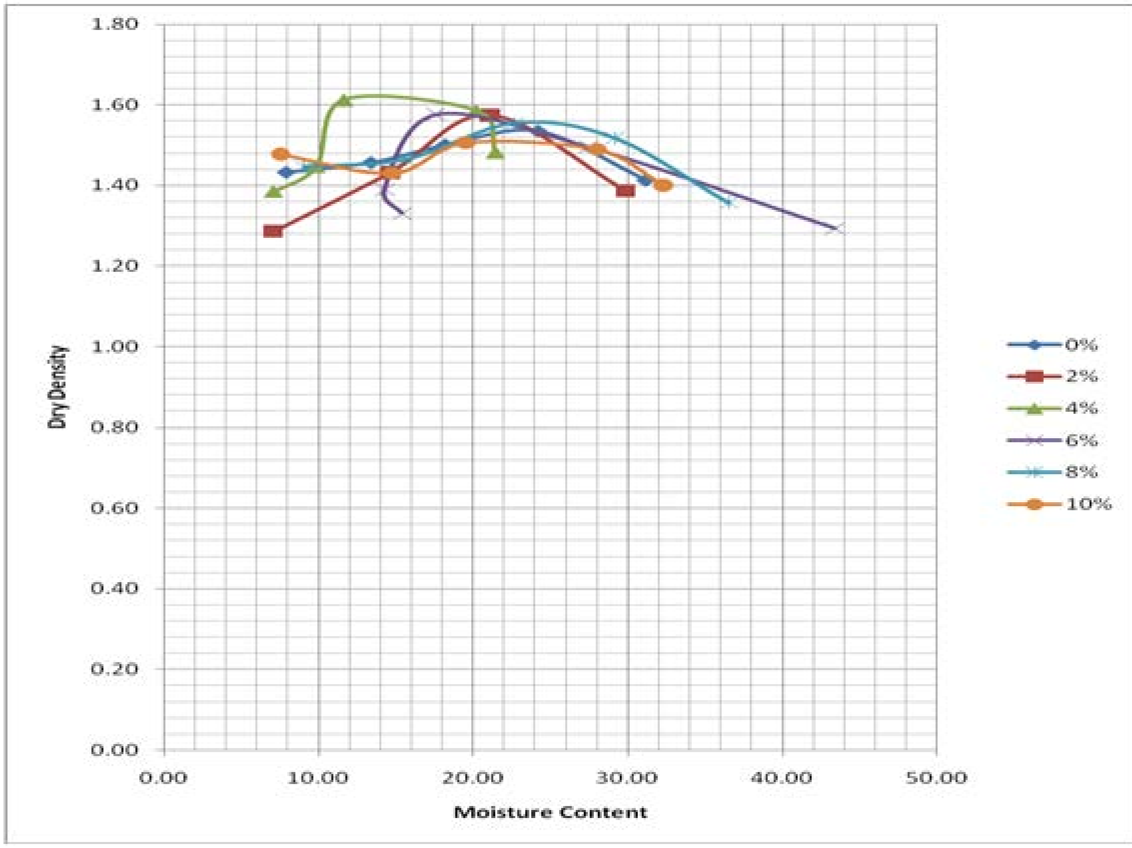

Figure 6: Relationship between Dry Density and Moisture Content for percentages of CHA addition.

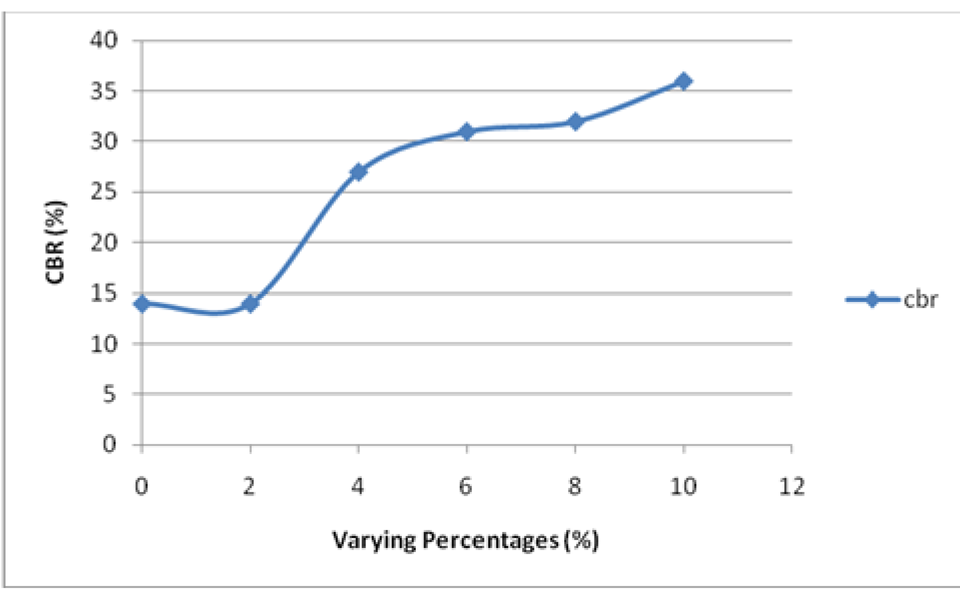

Figure 7: Relationship between CBR values and Percentages of CHA Addition.

CONCLUSION

The analysis of the geotechnical properties of poor lateritic soil mixed with varying percentages of coconut husk ash have been carried out in compliance with BS 1377 (1997) and head of (1990) methods of soil testing for Civil Engineers.

The results showed that coconut husk ash has effect on Atterberg limit, compaction and California bearing ratio of soil. The addition of coconut husk ash increases the plastic limit but reduces the plasticity index of the lateritic soil. California bearing ratio of the poor lateritic soil also increases continuously with the addition of coconut husk ash.

Result also shows that maximum dry density of soil increases from 0% to 4% addition of coconut husk ash but reduces after 4%, giving an indication that 4% addition of coconut husk ash is the effective optimum value because minimum optimum water content was also recorded at this value. Based on these results, it is very clear that coconut husk ash increases the California bearing ratio and can therefore be used to improve soils with low CBR values but unsuitable for stabilizing soils with extremely high liquid limits.

Based on this study, it is therefore necessary to recommend coconut husk ash as a stabilizing agent for improving soils with low California bearing ratio and to increase and decrease the plastic limit and plasticity index of soils, respectively.

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REFERENCES

1. AASHTO. 1986. *Standard Specification for Transportation Materials and Methods of Sampling and Testing, 14th Edition*. American Association of State Highway and Transportation Officials: Washington, D.C.

2. Akintola, F A. 1982. "Geology and Geomophology". *Nigeria in Maps*. R.M. Barbours, (ed.).. Hodder and Stoughton: London, UK.

3. Areola, O. 1982. "Soil". In: Barbours, K.M. (ed.). *Nigeria in Maps*. Hodder and Stoughton: London, UK.

4. Axelsson, K., S.E. Johansson, and R. Andersson. 2002. *Stabilization of Organic Soils by Cement and Puzzolanic Reactions*. Swedish Deep Stabilization Research Centre. Report 3:10.

5. Banzon and Velasco. 1982. *Coconut Production and Utilization*. p. 277.

6. Bello, A.A. and C.W. Adegoke. 2010. "Evaluation of Geotechnical Properties of Ilesha East Southwest Nigeria's Lateritic Soil". *Pacific Journal of Science and Technology*. 11(2):617-624.

7. British Standard Institution. 1990. "Methods of Test for Soils for Civil Engineering Properties (BS 1377)". British Standard Institution: London, UK. 143.

8. Croucher and Martinez. 1935. "Cocohusk Ash as Fertilizer". *Chemical Abstracts*. 29:1976.

9. Drumm, E.C., J.S. Reeves. M.R. Madgett, and W.D. Trolinger. 1997. "Subgrade Resilient Modulus Correction for Saturated Effects". *Journal of Geotechnical Geo-Environmental Engineering*. 123(7):663-670.

10. Eskioglou, P. 1992. "The Effect of Water Impregnation on the Resistance of Lime-Stabilized Test-Pieces". *Scientific Annals of the Department of Forestry and Natural Environment*. LE/2:701–717.

11. Eskioglou, P. and P. 1996. "Alternative Stabilization Methods of Forest Roads for an Efficient and Gentle Mechanization of Wood Harvesting Systems". 2nd FAO World Congress 1996, July 21-26, 1996. Sinaia, Romania.

12. Federal Ministry of Works and Housing. 1997. "General Specifications for Roads and Bridges". Volume II.145-284. Federal Highway Department: Lagos, Nigeria

13. Gidigasu, M.D. 1976. *Laterite Soil Engineering: Pedogenesis and Engineering Principles*. Elsevier Scientific Publication Company: Amsterdam, Netherlands.

14. Groney, D. 1978. "The Design and Performance of Road Pavements Transport and Road Research". Laboratory HMSO: London, UK.

15. Head, K.H. 1992. "Manual of Soil Laboratory Testing". *Soil Specification and Compaction Tests. 2nd edition. Vol. 1*. Pentech Press: London, UK.

16. Joint Departments of the Army and Air Force. 1994. “Soil Stabilization for Pavements”. TM 5-822-14/AFMAN 32-8010, USA.

17. Marsellos, N., S. Christoulas, and S. Kollias. 1988. “Use of Flyash in Roadworks”. *Technical Chronicle*. 3:113-129. Greece.

18. Mitchell, J.K. 1986. “Practical Problems from Surprising Soil Behavior”. *J. Geotech. Eng.* 112(3):255-289.

19. Mustapha, M.A. 2005. “Effect of Bagasse Ash on Cement Stabilized Laterite”. Seminar Paper Presented at the Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria.

20. National Lime Association. 1972. “Lime Stabilization Construction Manual”. *Bulletin 326*.

21. National Lime Association. 2004. “Lime Stabilization Construction Manual”. *Bulletin 326*.

22. Neville, A.M. 2000. *Properties of Concrete. 4th ed.* Pearson Education Asia Publ.: London, UK. Produced by Longman: Malaysia.

23. Ola, S.A. 1975. “Stabilization of Nigeria Lateritic Soils with Cement, Bitumen and Lime”. *Proceeding of 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering*. Durban, South Africa.

24. Osinubi, K.J. 1999. “Evaluation of Admixture Stabilization of Nigeria Black Cotton Soil”. Nigeria Society of Engineers Technical Transaction. 34(3): 88-96.

25. Osinubi, K.J. and V.Y. Katte. 1997. “Effect of Elapsed Time After Mixing on Grain Size and Plasticity Characteristics; Soil Lime Mixes”. *Nigeria Society of Engineers Technical Transactions.* 32(4): 65-76.

26. Osula, D.O.A. 1991. “Lime Modification of Problem Laterite”. *Engineering Geology*. 30:141-9.

27. Oyetola, E.B. and M. Abdullahi. 2006. “The Use of Rice Husk Ash in Low-Cost Sandcrete Block Production”. *Leonardo Electronic Journal of Practice and Technologies*. 8:58-70.

28. Sear, L.K.A. 2005. “Should you be using more PFA?”. *Proc. Int. Conf.Cement Combination for Durable Concrete*. University of Dundee: Scotland, UK.

29. Singh, G. and J. Singh. 1991. *Highway Engineering*. Standard Publishers Distributors: Nai Sarak, Delhi, India. 608-10.

30. Thomson, D. 1970. “Autogenous Heading of Lime-Soil Mixtures”. Highway Research Board No. 263: London, UK.

31. Yoder, E.J. 1957. “Principles of Soil Stabilization”. *Proceedings 43rd Annual Purdue Road School*. Series No. 92

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