Stabilization of Poor Lateritic Soils with Coconut Husk Ash

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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. These wastes come from agricultural, industrial, commercial as well as construction activities. 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 impact of coconut husk ash (CHA) on the stabilization of poor lateritic soil deposit found at Otu in Itesiwaju Local Government Area in Oyo State, Southwestern Nigeria.

In achieving this aim, Lateritic soil was collected from Otu in Oyo State. The soil was air dried and divided into six samples and each sample was stabilized using 0, 2, 4, 6, 8 and 10% of coconut ash by mass of soil sample. The samples were subjected to the following laboratory soil tests: 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 shows that it contains 62.43%, 17.9% and 8.79% of K_2O , SiO_2 and CaO respectively. 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 1.512 g/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/cm³ 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 gradation; 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 centre has doubled in size. If this is improperly handled, these wastes will be a source of land, air, surfacewater and groundwater pollution. In other to minimise the effects of this 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 & 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 and high demand for them (Neville 2000). The over dependence on the utilization of industrially manufactured soil improving additives such as cement, lime and others 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 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 as Coconut Husk Ash or Coir Fibre 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 shrinkswell 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 CO₂ for every ton of its final product which contributes to the melting of the ozone layer covering the earth surface. Since coconut husk ash has been categorized as pozzolana, with about 67-70% silica and, approximately 4.9 and 0.95% of aluminium 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. It was reported 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 soil 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 and Osinubi, 1999).

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 Out 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 425μ m. 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; particle size analysis test, Atterberg limit test, British Standard (BS) compaction test, and California bearing were carried out on each of the natural and stabilized samples in accordance with BS 1377 (1990) and Head (1992). In addition, chemical composition of the Coconut husk ash were analysed.

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 425μ m 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 samplecoconut 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 soilcoconut husk ash mixture was mixed with about 6% of its weight of water. This was put in C.B.R mould in 3 layers with each layer compacted with 27 blows using 4.5kg hammer. The compacted soilash mixture and the mould 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 SiO₂ (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 the Tables 2.

Uniformity Coefficient
$$C_u = \frac{D_{60}}{D_{10}} = \frac{2.5}{0.35} = 7.14$$

Coefficient of Gradation
$$C_g = \frac{D_{20}^2}{D_{60} \times D_{10}} = \frac{0.45^2}{2.5 \times 0.35} = 0.23$$

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. 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%. From the classification, the sample is a good subgrade material but it needs to be improved before it can be used as subbase and base material for highway pavement.

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 Table 2 show that the minimum values of both liquid and plastic limits occurred at 4% addition of coconut husk ash (CHA), however the minimum plasticity index was obtained at 8%CHA as show in Figure 3.

Compaction

As shown in Figures 4 - 6, the maximum dry densitv ranges between 1.512Mg/m³ and 1.62Mg/m³, and the optimum moisture 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.

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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Compound	P_2O_5	SiO ₂	SO ₃	K ₂ O	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 ₂ O 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 1: Analysis of Coconut Husk Ash

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



Figure 2: Relationship between Liquid Limit and CHA Content



Figure 3: Relationship between Plasticity Limit (PI) and CHA Content



Figure 4: Relationship between Maximum Dry Density and CHA Content (%)



Figure 5: Relationship between OMC(%) and CHA Content (%)



Figure 6: Relationship between Dry Density and Moisture Content



Figure 7: Relationship between CBR values and CHA Content (%)