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COCONUT SHELL AND FIBRE ASHES FOR LATERITIC STABILIZATION: INDEX AND BEARING CAPACITY PROPERTIES

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Abstract: This paper presented results of stabilizing lateritic soil with Coconut husk ash and Coconut shell ash calcined at 450ºC of Coconut husk and Coconut shell respectively to index and bearing capacity in road construction. Lateritic soil was treated with 2, 4, 6, 8, 10, 12, and 14% of Coconut husk ash and Coconut shell ash separately. Both Coconut husk ash and Coconut shell ash were subjected to elemental analysis using Energy Dispersive Spectroscopy and Scanning Electron Microscope. Laboratory tests were conducted to determine the index properties and bearing capacity effects on the untreated and treated soil samples. Elemental analysis showed that both Coconut husk ash and Coconut shell ash are pozzolans. The Maximum Dry Density of the soil sample increases with an increase in Coconut husk ash and Coconut shell ash percentage replacement but a decrease in Optimum Moisture Content and plastic index. A decrease in the plastic index indicates a reduction in the swelling potential of the soil sample. The California Bearing Ratio value increases with an increase in percentage replacement with Coconut husk ash and decreases with Coconut shell ash. Coconut husk ash improved the engineering properties of lateritic soil and, Coconut shell ash alone may not be appropriate
Keywords: coconut husk ash, coconut shell ash, lateritic, road construction, pozzolanic materials

INTRODUCTION

The rate at which waste are been generated over the years worldwide is skyrocketing as a result of an increase in population and socio-economic activities. Mostly, these wastes come from agricultural and industrial establishments. The resultant effects of accumulating these wastes include unsightly surroundings and obstruction to traffic flow due to their improper disposal. However, to minimize these effects, researchers have made several efforts to examine their suitability in construction industries to stabilize construction materials that are deficient in morphological properties and incapable of meeting construction. They serve as substitute materials for traditional soil stabilizers like cement, lime, and bitumen which had been in use since ancient times [5,25]. The act address challenges that have been thrown up by continuous economic decline and over-dependence on these most common and widely used soil stabilizers. Besides, the excessive cost of production like cement and the adverse environmental consequences associated with its products coupled with its corrosive action when working with it in the field has made sourcing for alternatives important. This has however made researchers focus on the use of industrial and agricultural byproducts whose ashes could produce good pozzolans and are available in exploitable quantity [9,10,15,17,18,20,21,22,24].

Lateritic soils can be described as products of tropical weathering with red, reddish brown, or dark brown colour, with or without nodules or concretions, and generally, they are found below hardened ferruginous crusts or hard pan [28]. They are one of the most naturally predominant civil engineering materials in tropical regions used in construction industries. At times they are deficient in morphological properties thereby limiting their suitability as construction materials and such soils are termed problematic soils because they have low strength, high compressibility, susceptibility to excessive deflection, and differential settlement [29] characterized by alternate dry and wet seasons [8,14,33]. Hence, there is a need for improvement through stabilization either partially or wholly to improve its morphological properties. One of these agricultural residues is coconut.

Coconut produce is readily available in very large quantities throughout the tropical countries in the world. According to [7], coconut production was estimated at 61.52 million metric tons across the globe. Coconut has a wide range of applications, and its tree is commonly referred to as the "tree of life" due to its wide applications. The coir, a natural elastic fibre taken from coconut husks, can be used to make floor mats and brushes; coconut oil and coconut milk are among the products extracted from coconut meat. Coconut is considered a potent cure for illnesses such as nausea, rash, fever, and the like by Asian cultures.

However, the produce from coconut which was regarded as wastes like coconut shell and coconut husk among others have been used severally in construction industries either as additives or to replace certain construction materials partially along with other materials that were necessary to serve as reinforcing elements. They are natural fibers from the plants. In accordance with [27], the husk of the coconut is composed of 70 percent pith and 30 percent fibre on a dry weight basis. Normally, they are 50–350 mm long, and consist mainly of lignin, tannin, cellulose, pectin, and other water-soluble substances. The water absorption is about 130–180% and, with diameters ranging between 0.1 and 0.6 mm with a service life of 4–10 years which poses a problem to stabilization. This fibre deteriorates slowly and affects the performance of the pavement [13,30].

In the modern history of soil stabilization, 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 [16]. Hence, this study looked into the effectiveness of the ashes of coconut husk and coconut shell as additives to improve the engineering properties of lateritic soil in road construction.

MATERIALS AND METHODS

Samples collection and preparation Coconut husk and shell (Plates 1-2) used for this research were collected from Badagry, Lagos State, and, the lateritic soil sample was from a borrow pit site at 0.3 m depth in Abeokuta. The lateritic soil samples were sealed in airtight plastic bags to prevent loss of moisture content and transported to the Department of Civil Engineering laboratory for testing.

Plate 1: Coconut Husk

Plate 2: Coconut Shells

Before putting coconut husk and shell into use, they were processed and reduced to fine particles as follows.

Coconut husk and shell were dried in sun, crushed into pieces and, oven dried at 105°C to remove moisture. These were later calcined at 450°C under a controlled temperature and, prepared samples of coconut husk ash (CHA) (Plate 3) and coconut shell ash (CSA) (Plate 4) were taken to the University of Ibadan, Ibadan, for elemental analysis using Electron Diffraction Spectrum (EDS) and Scanning Electron Microscope (SEM) while lateritic soil was subjected to moisture content, particle size distribution, soil classification, Atterberg Limit, Compaction and California Bearing Ratio (CBR) tests in accordance with [6].

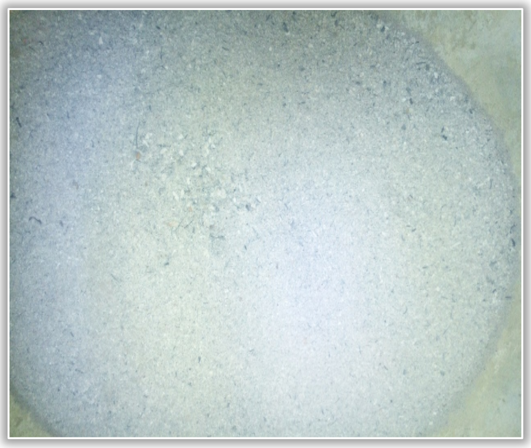

Plate 3: Coconut Husk Ash

Plate 4: Coconut Shell Ash.

The percentage replacement of 2, 4, 6, 8, 10, 12, and 14% by coconut husk ash and coconut shell ash was added to lateritic soil separately.

RESULTS AND DISCUSSIONS

— Chemical Analysis Results

The oxides of Al, Si, and Fe were significantly present in CHA and CSA as revealed by EDS (Figures 1-2), and these chemical compounds are usually present in materials that are classified as pozzolans [5], indicating that CHA and CSA are pozzolanic materials.

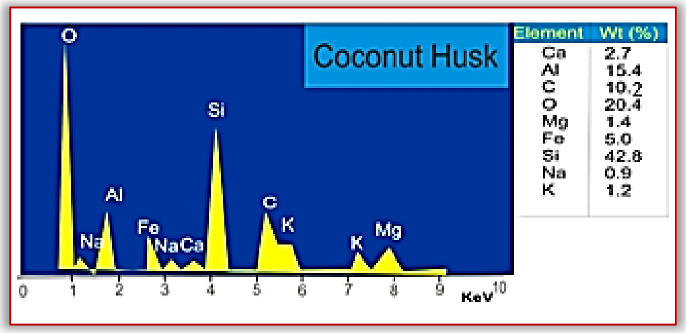

Figure 1: EDS for Coconut Husk Ash

These materials, pozzolans react with calcium hydroxide when water is present to form cementitious properties to stabilize materials. Also, the Calcium content in these materials indicates that they have self-cementing properties though calcium content is small in CHA (2.7%) compared with CSA (15.4%).

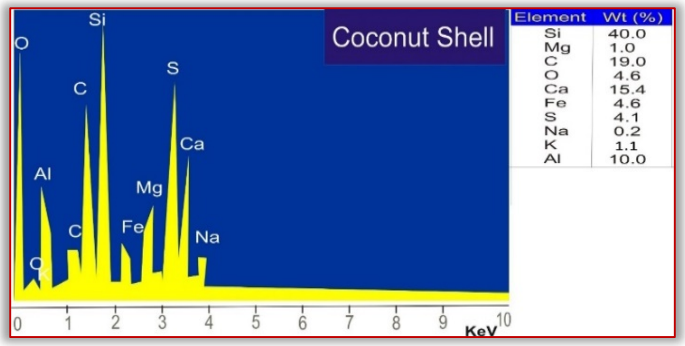

Figure 2: EDS for Coconut Shell Ash

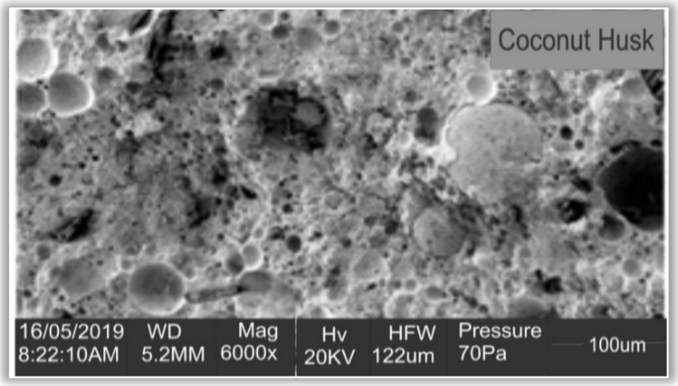

Figure 3: SEM for Coconut Husk Ash

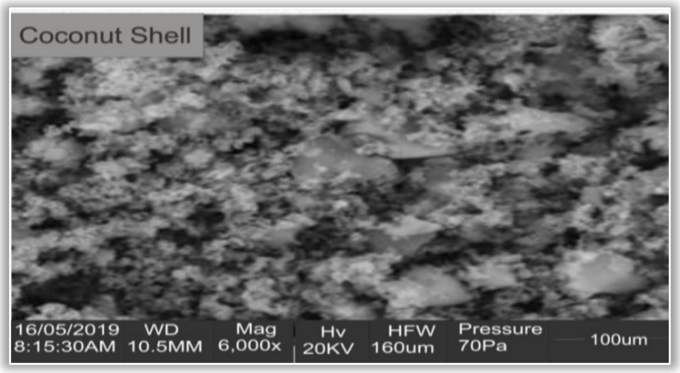

Figure 4: SEM for Coconut Shell Ash

The SEM analysis revealed that CHA has voids that are spherical (Figure 3) while voids in CSA are platy in shape (Figure 4). The arrangement of the particles showed that their voids can accommodate other compatible materials for proper mixing.

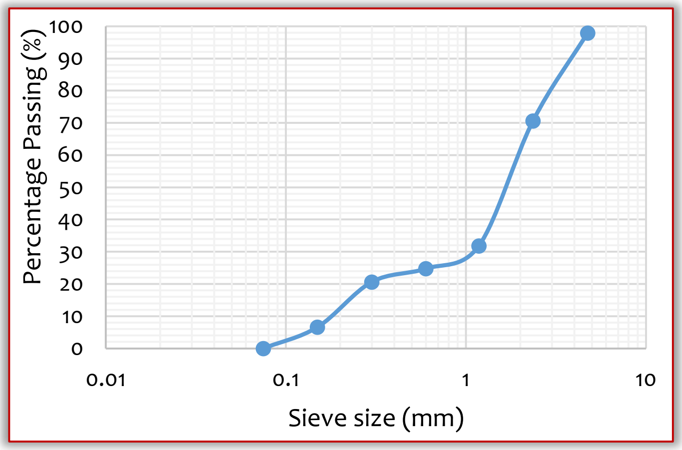

Figure 5: Particle size distribution (Soil Sample)

— Soil Sample

The average natural moisture content of the lateritic soil was 19.41%. Particle Size Distribution The particle size distribution analysis revealed that the laterite sample satisfied the Specification limits for Roads and Bridges [11] with not greater than 35% passing through sieve No 200 (Figure 5). The coefficient curvature, C_C (2.84) and coefficient of uniformity, C_U (11.01) not greater than 5, showed that the sample is well graded. The lateritic soil can be classified further as A-2-7 under the AASHTO classification based on the analysis.

— Consistency of the soil sample

The liquid limit (50.8%) and plasticity index (14.8%) results did not satisfy [11] liquid limits of 50% and plasticity index of 10% maximum for sub-base and base materials, therefore, rendering the soil unsuitable for use as sub-base and base materials.

— Compaction

The soil sample has a maximum dry density (MDD) of 1600 kg/m^3 and the optimum moisture content (OMC) of 23.81%

— California bearing ratio (CBR)

The CBR of 17.42% and 16.01% were obtained for the unsoaked and soaked soil samples accordingly. The lateritic soil is classified further as S5 in the subgrade class designation by [12] (Table 1).

Table 1: Subgrade Classification by [12]

	Subgrade Class Designation					
	S1	S2	S3	S4	S5	S6
Subgrade CBR ranges %	2	3-4	5-7	8-14	15-29	30+

— Effect of CHA and CSA on Compaction of soil with CHA, CSA

The result of MDD is presented in Figure 6, it was observed that MDD increases with different percentages of CSA and, CHA only increased to 8% which is the optimum value while the reverse case was observed for OMC (Figure 7).

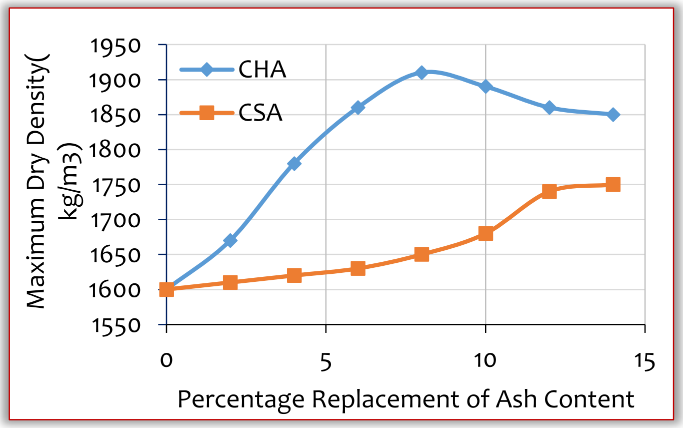

Figure 6: Relationship between MDD and Ash content of CHA and CSA

The increase in MDD could be attributed to the rearrangement of the soil molecular structure to form "transitional compounds" [21] by the finer particles of the ashes filling the voids in the soil particles when compaction takes place [32] and, the increase in MDD is a good indication of improvement in soil property. The decreased value in MDD for CHA immediately after 8% could be a result of the pores created within the soil sample by the continuous addition of CHA to the soil sample [23]. The decrease in OMC recorded was probably due to self–desiccation in which all the water was used when the reaction took place.

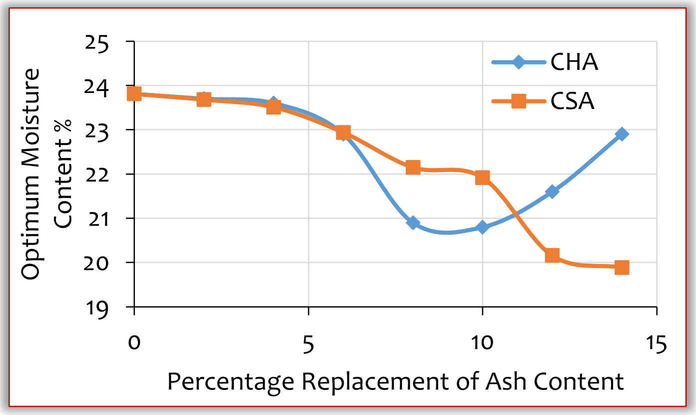

Figure 7: Relationship between OMC of CHA and CSA and its ash content

— Effect of CHA and CSA on Atterberg Limit of the soil sample

Figures 8 and 9 indicate the effect of CHA and CSA on the Atterberg's limit of the stabilized lateritic soil. Liquid limits of the stabilized lateritic soil increase as CHA increases and the treated soil sample was classified as s high plasticity (liquid limit between 50% and 70%) while it decreases as CSA was added to the soil sample reducing the LL from high plasticity to intermediate plasticity (liquid limit between 35% and 50%) [23].

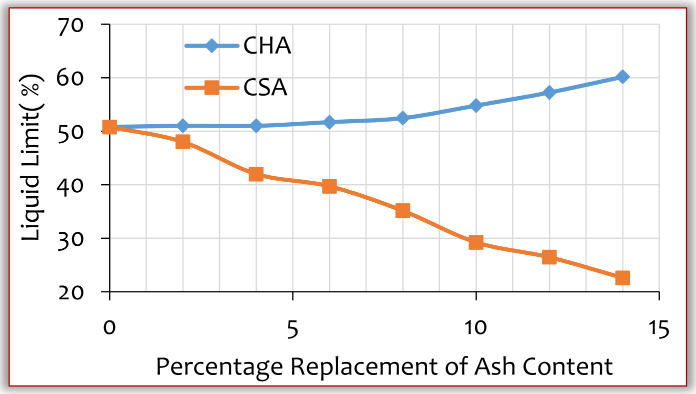

Figure 8: Relationship between Liquid Limit and Ash content of CHA and CSA.

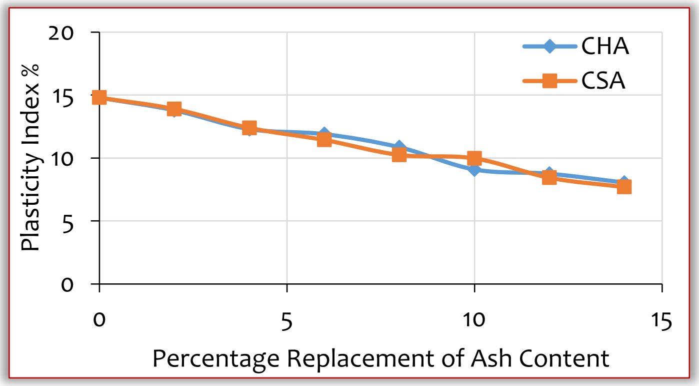

Figure 9: Relationship between Plasticity Index and Ash content of CHA and CSA

Stabilizing the lateritic soil with either CHA or CSA shows a decrease in plasticity index. This may be as a result of the decrease in the amount of soil-sized fraction owing to the flocculation and agglomeration or coagulation of clay particles that is, absorption of Ca2+ ions in soil particles and, resulting in the formation of cementitious compounds of greater effective grain size due to their pozzolanic action [31]. And it showed a reduction in the swelling potential of the soil sample which agreed with [3,4]. This shows a relative decrease in the repulsive forces present in the soil mixed with either CHA or CSA, hence, an increase in the strength of the soil to a specific value.

— Effect of CHA and CSA on California Bearing Ratio (CBR)

Figure 10 shows the unsoaked and soaked CBR of the stabilized lateritic soil with CHA and CSA. CBR increases gradually as CHA increases. The highest value was observed at 14% percentage replacement with CHA for both soaked and unsoaked CBR with an increase in CBR values of 103.25% and 97.70% respectively (Figure 10). An increase in CBR value may be attributed to higher cementitious material present in CHA which resulted in a pozzolanic reaction between the clay particles present in the soil and CHA which agreed with [25]. This enhances the strength of the stabilized soil. The class designation of the CBR values increased from S5 to S6 [11]. The CBR values of the soil sample decreased with an increase in

CSA percentage replacement for both soaked and unsoaked which agreed with [19] conditions and, the least value was observed at 14% percentage replacement with a reduction in values by 43.72% and 32.72% accordingly. A decrease in CBR value of the soil with CSA could be attributed to the elements identified by the EDX result, a low content of silica and alumina coupled with the shape resulted in low strength formation. The class designation of the CBR values decreased from S5 to S4 when CSA was added to the soil sample. It implied that CSA alone cannot be used effectively to stabilize laterite soil.

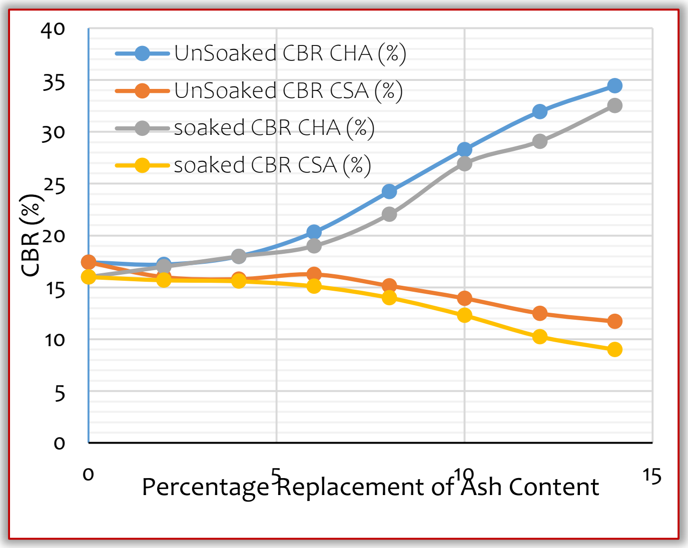

Figure 10: Relationship between Soaked and Unsoaked CBR and Ash content of CHA and CSA

CONCLUSIONS

The geotechnical analysis carried out on soil samples with CHA and CSA showed that both influenced the engineering properties of the lateritic soil sample. The MDD of the soil sample increased as percentage replacement with both CHA and CSA increased while a decrease in OMC occurred. Soil sample with CHA had the highest value at 8% replacement (1910 kg/m^3) with an increase in MDD by 19.38%, and a decrease in OMC by 12.22% while at 8% replacement, soil sample with CSA had MDD value (1650 kg/m^3) and increased by 3.13% and, a reduction in OMC value by 6.91%. But the highest value was at 14% replacement with an increase in MDD value (1750kg/m^3) by 9.38%, and a reduction in OMC value by 16.46%. Also, as percentage replacement with CHA increases, the liquid limit of the soil sample increases but decreases the liquid limit of the soil with CSA decreases its liquid limit. But the plastic index of the soil sample decreases with the addition of various percentages of both CHA and CSA to the soil sample. These revealed a reduction in the swelling potential of the soil sample, hence an increase in strength properties. Besides, there was an increase in CBR of the soil sample with CHA percentage replacement but a decrease in the value of CBR was observed when CSA was used. However, with these results, CHA can be added to improve the engineering properties of soils especially soil with low CBR values, but CSA alone may not be appropriate as a stabilizing agent for improving lateritic soils.

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