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Pozzolanic Effects Of Groundnut Husk Ash On Expansive Clay Soil

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ABSTRACT

Pozzolanic materials quest from Economical Agricultural waste for beneficial engineering purposes has in recent times has been used by researchers. This research attempts to explore the potentials of Groundnut Husk Ask (GHA) for the improvement of expansive clay soil. The GHA was added at various percentages. The natural soil showed that it belongs to A-7-6 group and Unified Soil Classification System (USCS). Soils under these groups are poor in terms of engineering requirements for construction of barrier systems. The laboratory results the Unconfirmed Compressive Strength (UCS) of the natural soil was 163 kN/m^2, while the UCS at optimum GHA content of 9%, gave values of 315 kN/m^2, for British Standard Light (BSL), West African Standard (WAS) 355 kN/m^2 and British Standard Heavy (BSH) 641 kN/m^2 compaction efforts. BSH compaction effort resulted in the highest UCS Values. The hydraulic conductivity of the natural soil was 7.78 x 10^{-9}m/s while minimum values for the treated condition at 9% GHA were 5.61 x10^{-9} m/s, 4.90 x 10^{-9} m/s and 3.90 x 10^{-9} m/s corresponding to BSL, WAS and BHS compaction efforts respectively. These values fell short of the requirement of 1.0 x 10^{-9} m/s for clay liners therefore, it can use as a lining material for erosion channel embankment.

Keywords: Groundnut Husk Ash (GHA), Atterberg's limits**,** Compaction, Unconfined Compressive Strength (UCS) and Hydraulic Conductivity.

INTRODUCTION

The need to bring down the cost of waste disposal and the growing cost of soil stabilizers has led to intensive global research towards economic utilization of industrial and agricultural wastes for engineering purposes. Safe disposal of these wastes requires urgent attention because of the environmental problems associated with the various types of wastes generated all over the world. Groundnut husk ash (GHA) is an agricultural waste obtained from groundnut shell. Agricultural waste is increasingly becoming a focus by researchers because of the enhanced pozzolanic potentials. Nigeria contributes about 7 percent of world groundnut production which makes Nigeria the 3rd largest producer of groundnut in the world. In 2002, 2,699,000 metric tons of groundnuts were produced on 783,000 hectares of land. GHA has successfully been used in concrete as a partial replacement for cement [1].

Problematic soils are usually encountered in foundation engineering designs for highways, embankments, retaining walls, backfills, expansive soils are normally found in semi – arid regions of tropical and temperate climate zones, where the annual evaporation exceeds the precipitation, and can be found anywhere in the world [2,3]. These soils are also referred to as "black cotton soils" in some parts of the world. They are so named because of their suitability for growing cotton. Black cotton soils have varying colours ranging from light grey to dark grey and black. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. Deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. Cracks measuring 70 mm wide and over 1 m deep have been observed and may extend up to 3 m or more in case of high deposits [4].

One of the parameters for the design of soil liners and covers for municipal solid waste (MSW) containment is hydraulic conductivity. For a soil to perform effectively as a waste containment barrier, it must achieve a hydraulic conductivity ≤ 1 x 10^{-9} m/s when compacted with percentages of fines of 20 - 30%. Therefore, the design of earthen barrier has often been based on the assumption that hydraulic conductivity controls the rate of leachate migration [5].

Several investigators studied the efficacy of waste resources as materials for the design of waste containment barrier, for example, [6] in their study of the compatibility and attenuative properties of Blast Furnace Slag (BFS) found that compacted lateritic soil treated with up to 15% of BFS yielded hydraulic conductivity values required for good hydraulic barrier materials for prolong contact with the permeated fluid. Researchers, [7, 8, 9, 10, 11, 12, 13, 14, 15] have focused attention on the use of wastes resources that are locally available from industrial and agricultural waste to improve the engineering and allied properties of deficient soils. The conventional stabilizing agents (i.e. cement, lime and bitumen) have kept the cost of construction very exorbitant. Therefore, the use of agricultural and industrial wastes in construction works will improve the properties of problematic soils and reduce construction costs.

MATERIALS AND METHODS

Materials

The Soil used in this study is naturally occurring black cotton soil (light grey in colour) obtained along Km 24 Gombe – Biu road in Yamaltu Deba Local Government Area of Gombe State. The soil was collected using the method of disturbed sampling. The location lies within latitude 10° 19'N and longitude 11° 30'E. In terms of extent of deposit, black cotton soils are not restricted to the study area but are wide spread throughout the North – Eastern Nigeria. The Groundnut husks were obtained in Bauchi, Bauchi Local Government Area of Bauchi State, Nigeria. The husk was burnt at the Department of Industrial Design, Abubakar Tafawa Balewa University, Bauchi, under a controlled temperature of 600ºC Kiln. The temperature of burning was carefully monitored using a thermocouple.

Methods

The GHA was prepared by burning groundnut shell in a kiln to a temperature of 600 degrees Celsius (ºC). The oxide composition of GHA is presented in Table 2. Batches of the soil with GHA at step concentrations of 0 %, 3 %, 6 %, 9 %, 12% and 15% GHA by dry weight of soil were prepared by using the water content derived from moisture-density relationship plots for the treated soil. Index property tests on the natural and stabilized soils were carried out in accordance with the procedures outlined in [16, 17], respectively. Compaction tests were conducted using the BSL, WAS and BSH compaction energies. The BSL compaction involved compaction using the energy derived from a 2.5 kg rammer, falling through a height of 30 cm in a 1000 cm^3 mould. The soil was compacted in three equal layers, each receiving 27 blows. The WAS compaction, entails the energy derived from a 4.5 kg rammer falling through a height of 45 cm in a 1000 cm^3 mould. The soil was compacted in five layers, each layer subjected to 10 blows. The BSH compaction, entails compacting the soil using a rammer of 4.5kg mass falling through a height of 45cm in a 1000 cm^3 mould. The soil was compacted in three layers, each layer receiving 27 blows.

Specimens of soil + GHA were compacted at molding water contents using the three compactive efforts, the BSH and BSL compactions are the British Standard (BS) equivalents of the modified and standard Proctor compaction (ASTM D 1557 and ASTM D 698), respectively. The WAS or "intermediate" compaction consists of the energy derived from a 4.5kg rammer falling through 45.72cm onto five layers in a BS 1000 cm^3 capacity mould each receiving ten blows (Osinubi,1998), the RBSL compaction is equivalent to the reduced proctor compaction suggested by Daniel and Benson (1990). The Unconfined compressive strength (UCS) test specimens were compacted at the three energy levels presented in the Table 1: The crushed specimen of sizes smaller than US Number 4 sieve (4.76mm aperture) were mixed with various proportions of GHA (5, 7.5, 10, 12.5, and 15%)

moistened to various water contents mixed thoroughly by hand compacted thereafter using the energy levels investigated in the study.

Table 1. Comparison of compaction test procedures

Test procedure	Weight of rammer (kg)	Height of fall (m)	Number of blows	Number of layers	Compaction energy (kNm/m²)
BS light compaction (BSL)	2.5	0.3048	27	3	336.6
West African Standard (WAS)	4.5	0.4570	10	5	1,008.7
British Standard Heavy (BSH)	4.8	0.4570	27	5	2,723.5

RESULTS AND DISCUSSION

The results obtained for the natural soil (control) are summarized in Table 2. The soil was classified as A – 7 – 6 in accordance with the American Association of State Highway and Transportation Officials (AASHTO) [18] classification system, and CL in accordance with the Unified Soil Classification System (USCS) [19]. The oxides compositions of the GHA used in the study is presented in Table 3. Chemical analysis test result of GHA revealed that it contains 15.63 % Calcium Oxide (CaO), 2.04% Iron Oxide (Fe_2O_3), 1.2 % Magnesium Oxide (MgO), 51.54 % Silicon Oxide (S_iO_2), and 22.45 % Aluminum Oxide (Al_2O_3). Others are, 0.98% Sulphur Oxide (SO_3), 0.6% Phosphorous Pentaoxide (P_2O_5), 0.38 % Sulphur (S), Titanium Oxide (TiO_2), Manganese Oxide (MnO), 3.98 % Loss on Ignition (LOI), and 0.38 % Others (trace elements). Therefore, the material satisfies the ASTM (1992) requirements for pozzolanic materials., which stipulates that the sum of silicon oxide (S_iO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) should be ≥ 70 %. The utilization of this pozzolana for the treatment of problematic soils will go a long way in actualizing the aspirations of most developing countries in search of affordable construction materials.

Table 2: Test result of black cotton soil

Property	Quantity
Percentage Passing BS No. 200 Sieve	83
Clay Content (%)	43
Silt Content (%)	23
Sand Content (%)	34
Liquid Limit, LL (%)	68
Plastic Limit, PL (%)	46
Plasticity Index PI (%)	22
Linear Shrinkage	10
AASHTO Classification	A-7-6
USCS Classification	CL
Maximum Dry Density, Mg/m^3	1.45
Optimum Moisture Content (OMC), %	22.9
Unconfined Compressive Strength, kN/m^2	163
Free Swell, FS (%)	80
Specific Gravity	2.68
Colour	Light Grey

Table 3: Oxide Composition of GHA

Compound	Percentage
CaO	15.63
SiO_2	51.54
Al_2O_3	22.45
Fe_2O_3	2.04
MgO	1.20
SO_3	0.93
TiO_3	0.13
MnO	0.05
P_2O_5	0.60
S	0.38
LOI	3.98
Others	1.67
Total	100

Atterberg's Limits

Fig. 1 shows the liquid limit as it decreases with GHA content and the plasticity index also in a similar manner. Consequently, there is the possibility of improvement in the workability of the soil by reducing the plasticity, as the GHA content also increase for the linear shrinkage test the value also reduce to a considerable limit (fig 1).

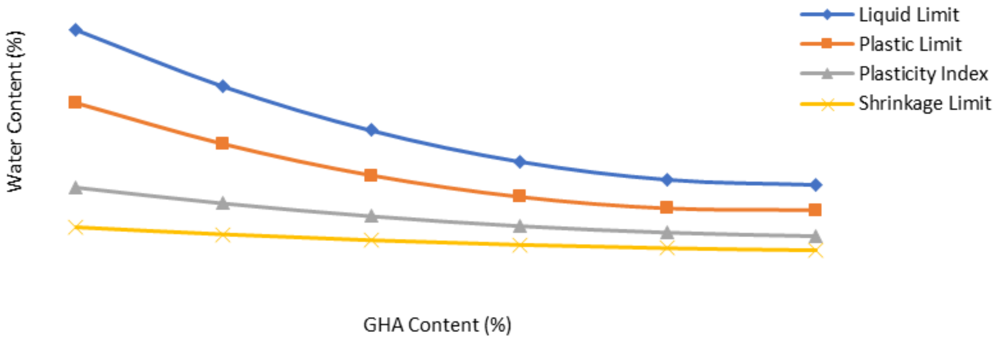

Fig. 1: Variation of Atterberg's Limits with GHA Content

Compaction characteristics

All the compaction methods showed increase in maximum dry density with increasing GHA content from 3% to 12% (Fig.2), this may be attributed to agglomeration and flocculation of the GHA-Soil fraction. However, at 15% GHA content the MDD were almost the same as for the natural soil. The curves exhibited same trend throughout for all the compaction methods. The variation of OMC with GHA for the BS light WAS and BS heavy is shown in Fig. 2. There were increase in OMC with GHA content for the BSL and WAS compactive efforts. However, for BS heavy compaction a decrease at 10% and increase in OMC was observed at GHA content of 15%. The initial increase for BS light and WAS could have been as a result of increasing demand for water by various cat ions and the clay mineral particle for hydration reaction. Subsequent decrease might have been due to cat ion exchange reactions that cause the flocculation of clay particles.

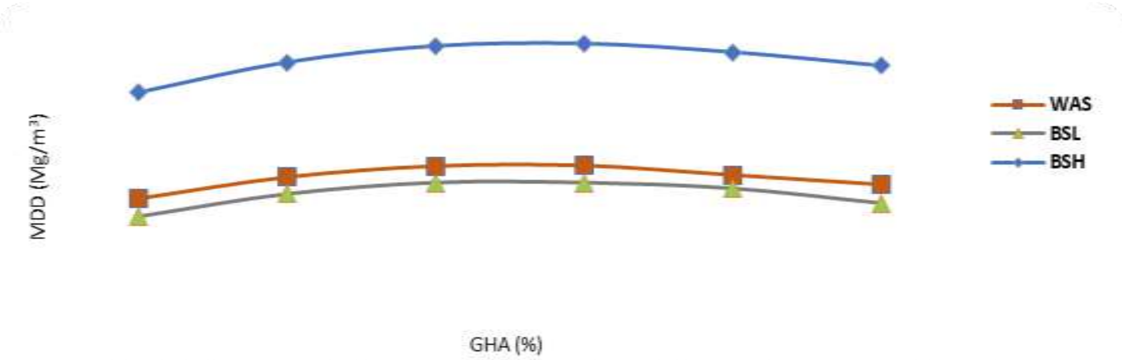

Fig. 2: Variation of MDD with Percent GHA for the various Compactive effort

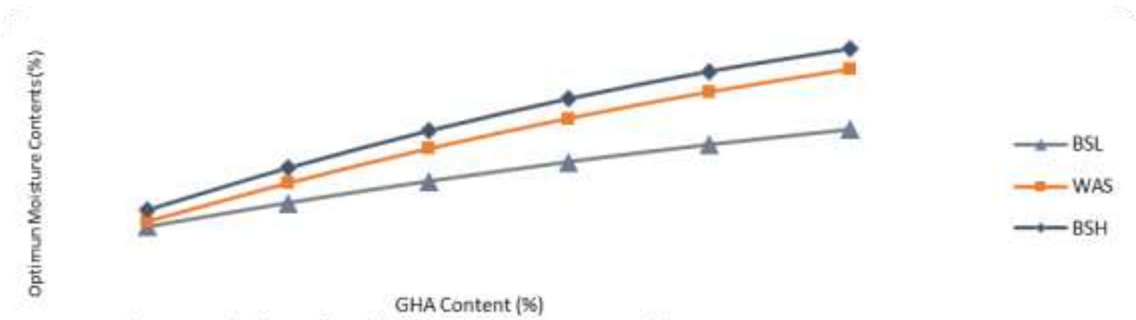

Fig. 3: Variation of Optimum Moisture Content with GHA Content

Unconfined compressive strength (UCS)

The UCS test result showed peak values of 315kN/m^2, 355kN/m^2, and 641kN/m^2 at 9% GHA content for all the compactive efforts this may due to the presence of just enough water for the pozzolana to react. The decrease in strength at higher GHA content for all the compactive efforts may be associated with insufficient water required for the pozzolanic reaction to complete because these samples have been prepared using water content obtained from compaction tests.

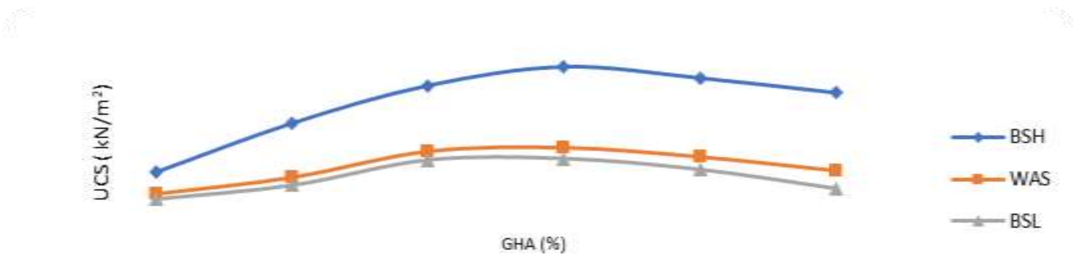

Fig. 4: Showing the Variation of UCS with GHA for the Various compactive efforts

Hydraulic conductivity

Hydraulic conductivity generally decreases with increase liquid limit and plasticity index. An increase in GHA content corresponds to a decrease in the size of pore spaces in the soil, which tend to inhibit the flow of water through the compacted soil, hence lower values of hydraulic conductivity were obtain when the soil was treated with GHA than that of the natural soil. However, result obtained showed lowest value of hydraulic conductivity was obtained at 6% for BSL and BSH compactive efforts; and at 9% for WAS compactive effort. This may be due to molecular rearrangement during the formation of "Transitional Compounds" [20].

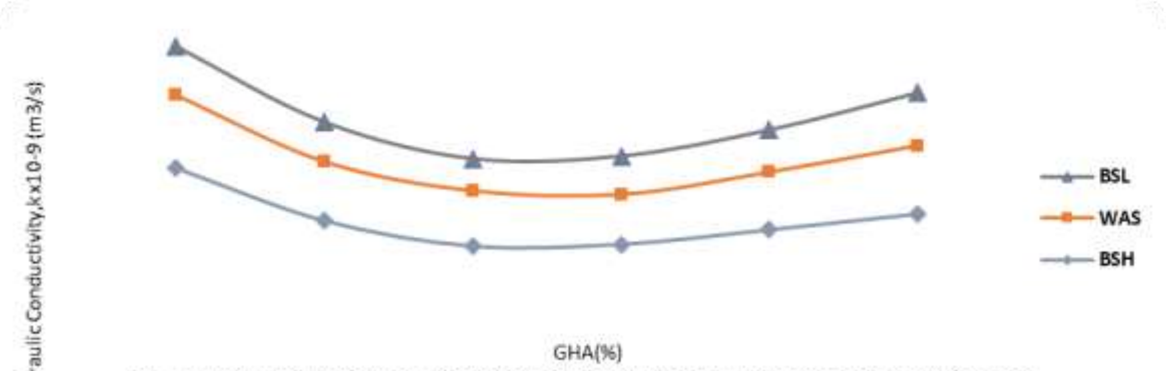

Fig. 5: Showing variation of Hydraulic Conductivity with percent GHA for the various compactive efforts

Moulding water content also affected the hydraulic conductivity of the soil. For the different compactive efforts, the moulding water content is seen to affect the hydraulic conductivity in a manner similar to it's effect on the Maximum Dry Density (MDD), with minimum value of hydraulic conductivity at near Optimum Moisture Content (OMC).

Table 3. Effects of GHA on the Hydraulic Conductivity of the Compacted Soil

Method of Compaction	Property	GHA(%) 0	3	6	9	12	15
BSL	MDD (Mg/m^3)	1.40	1.45	1.48	1.48	1.47	1.43
	OMC (%)	13.26	14.24	15.12	15.92	16.62	17.24
	Hydr. Conduct. (10^{-9}m^3/s)	7.70	6.20	5.60	5.60	6.10	6.80
WAS	MDD (Mg/m^3)	1.44	1.50	1.53	1.53	1.51	1.48
	OMC (%)	13.47	15.04	16.45	17.69	18.77	19.70
	Hydr. Conduct. (10^{-9}m^3/s)	6.80	5.50	4.90	4.90	5.30	5.80
BSH	MDD (Mg/m^3)	1.71	1.79	1.83	1.84	1.82	1.78
	OMC (%)	13.96	15.67	17.18	18.49	19.60	20.52
	Hydr. Conduct. (10^{-9}m^3/s)	5.40	4.40	3.90	3.90	4.20	4.50

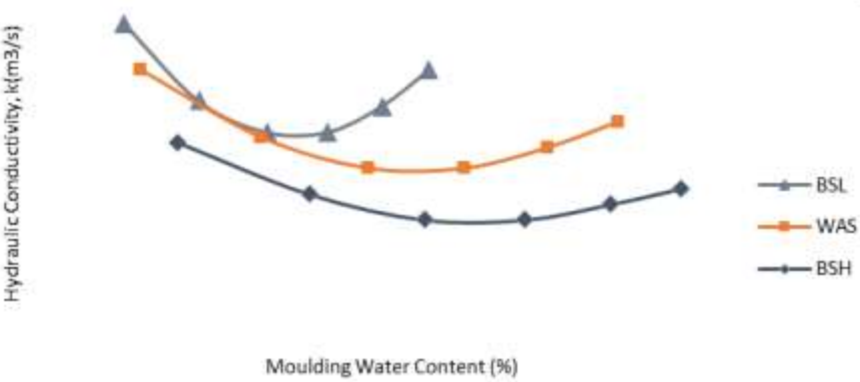

Fig. 6: Showing Variation of Hydraulic Conductivity with Moulding Water Content (%)

CONCLUSIONS

Generally, pozzolana are usually cheaper to obtain, have good resistance to sulphate attack and have the advantage of slowing hydration. Results obtained from previous studies [21] show that Groundnut Husk Ash (GHA) satisfies the test of pozzolanicity prescribed in BS 3892 part 1: 1982. The natural black cotton soil was classified as A-7-6 or CL in the AASHTO and USCS. Soils under this group are of poor engineering benefit. Examination of the hydraulic conductivity of the black cotton soil at its natural state gives a value of 7.79 x 10^{-9} m/s but when treated with various percentages of Groundnut Husk Ash (GHA) all showed decrease in the hydraulic conductivity of the material, with lowest value of 3.30m/s at 9% GHA content and BSH compactive effort. Highest values of compressive strengths were achieved at GHA content of 9 % for all the compaction methods used (BSL, WAS and BSH) with values of 315 kN/m^2, 355 kN/m^2, 641 kN/m^2, as shown in the values of UCS. Decreases recorded at 12% and 15% GHA contents for all the compactive efforts may be attributed to lack of sufficient water for the hydration of the GHA to complete it's reactions and attain sufficient strength. Also, there were variations in the MDD and OMC of the various compaction methods; this is ok even in the case natural soils without any form of additives. The result from this work indicated that GHA satisfies the test of pozzolanicity and improve the strength for the stabilization Black Cotton Soils.

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