Groundnut Shell Ash Stabilization of Black Cotton Soil

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ABSTRACT

The growing cost of traditional stabilizing agents and the need for the economical utilization of industrial and agricultural waste for beneficial engineering purposes has prompted an investigation into the stabilizing potential of groundnut shell ash (GSA) in highly expansive clay soil **(**black cotton soil). Index properties of the natural soil showed that it belongs to A – 7 – 6 or CL in the AASHTO and Unified Soil Classification System (USCS), respectively. Soils under these groups are of poor engineering benefit. The unconfined compressive strength (UCS) of the natural soil are 319 kN/m^2 and 435 kN/m^2 at standard Proctor (SP) and West African Standard compactive effort respectively, while the California bearing ratio (CBR) under soaked condition for the natural soil were 2% and 4% at standard Proctor (SP) and West African Standard compactive effort (WA) respectively. Peak UCS values of 455 kN/m^2 at SP and 526 kN/m^2 at WA compactive effort, were attained at 4 % (GSA) and 6 % (GSA) content respectively. However, none of the specimens attained the 1710 kN/m^2 UCS value for 7 days cured specimens recommended by Road Note 31 for base material. The peak soaked CBR values of 4 % at SP and 4% at WA were attained at 6 % (GSA) and 0% (GSA) respectively. These values fell short of the specification requirement of the C.B.R. value for base or sub-bas material. The durability of specimen determined in terms of resistance to loss in strength failed to meet the 80 % resistance to loss in strength recommended for 7 days cured and 4 days soaked samples. The stabilization of black cotton soil with groundnut shell ash is thus unattainable. However, groundnut shell ash shows progressive strength development with longer curing periods from the observations of the 7, 14 and 28 days cured unconfined compressive strength of specimens.

KEYWORDS: California bearing ratio (CBR), compaction, unconfined compressive strength (UCS), durability.

INTRODUCTION

The need to bring down the cost of waste disposal and the growing cost of soil stabilizers has lead to intense global research towards economic utilization of wastes for engineering purposes.

The safe disposal of industrial and agricultural waste products demands urgent and cost effective solutions because of the debilitating effect of these materials on the environment and to the health hazards that these wastes constitute.

In order to make deficient soils useful and meet geotechnical engineering design requirements researchers (Osinubi, 1997; 2000a,b; Moses, 2008; Alhassan and Mustapha, 2007; Osinubi and Medubi, 1998; Medjo and Riskowiski, 2004; Osinubi and Eberemu, 2005; Osinubi and Stephen, 2006; Osinubi et al., 2007a,b; Osinubi et al., 2008a,b; Osinubi and Eberemu, 2009b; Osinubi et.al., 2009) have focused more on the use of potentially cost effective materials that are locally available from industrial and agricultural waste in order to improve the properties of deficient soils.

The over dependence on industrially manufactured soil improving additives (cement, lime etc) 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 to meet the need of their rural dwellers who constitute large percentage of their population which are mostly rural farmers. Furthermore, the World Bank has been expending substantial amount of money on research aimed at harnessing industrial waste products for further usage.

Thus, the possible use of agricultural waste (such as Groundnut Shell Ash - GSA) will considerably reduce the cost of construction and as well as reduce or eliminate the environmental hazards caused by such waste. Groundnut shell is an agricultural waste obtained from milling of groundnut. Nigeria contributes about 7 percent of world groundnut production which makes Nigeria the 3rd largest producer of groundnut in the world. In 2002, about 2,699,000 Mt of groundnut were produced in about 2,783,000 Hectares of Land. Meanwhile, the ash from groundnut shell has been categorized under pozzolana (Alabadan et.al, 2006), with about 8.66% Calcium Oxide (CaO), 1.93% Iron Oxide (Fe_2O_3), 6.12% Magnesium Oxide (MgO), 15.92% Silicon Oxide (SiO_2), and 6.73% Aluminum Oxide (Al_2O_3). The utilization of this pozzola as a replacement for traditional stabilizers will go a long way in actualizing the dreams of most developing countries of scouting for cheap and readily available construction materials. Groundnut shell ash has been used in concrete as a partial replacement material for cement with a measure of success achieved (Alabadan *et al.*, 2005).

Problematic soils such as expansive soils are normally encountered in foundation engineering designs for highways, embankments, retaining walls, backfills etc. Expansive soils are normally found in semi – arid regions of tropical and temperate climate zones and are abundant, where the annual evaporation exceeds the precipitation and can be found anywhere in the world (Chen, 1975; Warren and Kirby; 2004).

Expansive soils are also referred to as “black cotton soil” in some parts of the world. They are so named because of their suitability for growing cotton. Black cotton soils have varying colors’ 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 3m or more in case of high deposits (Adeniji, 1991).The three most commonly used stabilizer for expansive clays are; bitumen; lime, and cement.

Researchers (Ola,1983; Balogun,1991 and Osinubi,1995) attempted to stabilize this soil have reported that the stabilization of this soil with bitumen: lime or cement is effective. Unfortunately, the costs of these stabilizers are on the high side making them economically unattractive as stabilizing agents. Recent trend in research works in the field of geotechnical engineering and construction materials (Osinubi, 1997; Osinubi, 2000a,b; Cokca, 2001; Medjo and Riskowski, 2004; 2000a,b; Moses, 2008; Osinubi and Medubi, 1997; Medjo and Riskowiski, 2004; Osinubi and Eberemu, 2005; Osinubi and Stephen, 2006; Osinubi et al., 2007a,b; Osinubi et al., 2008a,b; Osinubi and Eberemu, 2009b; Osinubi et al., 2009) focuses more on the search for cheap and locally available materials such as bagasse ash, fly ash, blast furnace slag e.t.c. as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers. Agricultural waste is increasingly becoming a focus of researchers because of the enhanced pozzolanic capabilities of such waste when oxidized by burning.

Thus, this study is aimed at evaluating the possibility of utilizing groundnut shell ash (GSA) in the stabilization of black cotton soils.

LOCATION OF STUDY AREA

The soil used in this study is black cotton soil (light grey in colour) obtained along Gombe – Biu road in Yamatu Deba Local Government Area of Gombe State 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 clays are not restricted to the area of study but are wide spread through out the north – eastern Nigeria. While the groundnut shell were obtained and ashed in open air under normal temperature in Zaria, Kaduna State of Nigeria.

METHODS OF TESTING

Index tests on the natural and stabilized soils were carried out in accordance with the procedures outlined in BS 1377 (1990) and BS 1924 (1990) respectively, for the stabilized soil specimens, step percentages of groundnut shell ash by dry weight of soil (0, 2, 4, 6 and 8%) was introduced into the soil. The soaked California bearing ratio test method was adopted in accordance with the Nigerian General Specification (1997) which stipulates that specimens be cured in the dry for six days and soaked for 24 hours before testing.

The tests carried out on the natural and treated soils include compaction and strength tests (i.e., unconfined compression and California bearing ratio) Compaction was carried out at the energy level of the standard Proctor compaction only because this can easily be achieved in the field.

Compaction

All the compactions were carried out using the standard Proctor (SP) compactve effort. For the determination of moisture - density relationships it involved energy derived from a hammer of 2.5 kg mass falling through a height of 30 cm in a 1000 cm^3 mould. The soil was compacted in three layers, each layer receiving 27 blows. The California bearing ratio (CBR) compaction involved the same hammer weight and drop height with each layer receiving 62 blows in a 2360 cm^3 mould.

The West African Standard (WAS) compaction, moisture-density relationship were determined using energy derived from a rammer of 4.5kg mass falling through a height of 45cm in a 1000 cm^3 mould. The soil was compacted in five layers, each layer receiving 10 blows. For the CBR compaction, the same rammer weight and drop height with each layer receiving 30 blows into a CBR mould was used.

Strength

Batches of soil with stabilizer and admixture were prepared by mixing with the desired proportion of portable water obtained from the moisture-density relationship. The mixes consisted 0, 2, 4, 6, 8, groundnut shell ash by dry weight of soil. The CBR and Unconfined compressive strength (UCS) test specimen were compacted at the energy levels of Standard Proctor and West African Standard. Specimens were cured for 7, 14 and 28 days in case of the unconfined compression, while the CBR specimens were tested in accordance with the Nigerian General Specification (Nigerian 1997) for the soaked condition.

Durability

The durability assessment of the soil stabilized specimens was carried out by immersion in water test for the measurement of resistance to loss in strength rather than the wet-dry and freeze-thaw tests highlighted in ASTM (Annual 1992), that are not very effective under tropical conditions. The resistance to loss in strength were determined as a ratio of the 7 days cellophane-cured specimens, unsealed, and later immersed in water for another 7 days to that of the 14 days UCS value of cellophane –cured specimen.

RESULTS AND DISCUSSION

Index Properties

Preliminary tests results were conducted for the identification of the natural soil and the determination of its properties that are summarized in Table 1. The soil is classified under the A – 7 – 6 subgroup of the American Association of State Highway and Transportation Officials (AASHTO) classification system, low plasticity clay (CL) according to the Unified Soil Classification system (USCS) (ASTM, 1992) and high swell potential soil according to the Nigerian Building and Road Research Institute (NBRRI, 1983) classification. The tests results revealed that the soil is not suitable for use as sub-grade, sub-base or base course material for pavement construction. The oxide composition obtained from the Chemical Analysis of Groundnut Shell Ash (GSA) is summarized in Table 2. While Table 3 and Table 4 show the oxide composition and classification of black cotton soil.

Table 1: Index Properties Results of Unstabilized Black Cotton Soil

Property	Quantity
Percentage passing BS No 200 sieve	87
Natural moisture content,%	15
Liquid limit,%	93
Plastic limit, %	21
Plasticity index, %	72
Linear shrinkage, %	21

Free swell, %	90
Specific gravity	2.5
AASHTO classification	A-7-6
USCS	CL
NBRRI classification	High swell potential
Maximum Dry Density, Mg/m3	
Standard Proctor	1.41
West African Standard	1.52
Optimum moisture content, %	
Standard Proctor	24.3
West African Standard	20.7
Unconfined compressive Strength, kN/m2	
Standard Proctor	319
West African Standard	435
California bearing ratio, %	
Standard Proctor	2
West African Standard	4
pH	7.2
Colour	Dark grey

Table 2: Oxide compositions of groundnut shell ash used in this study as compared with bagasse ash and ordinary Portland cement

Oxide	Groundnut shell ash (%)	Bagasse ash (%)	Cement (OPC) (%)
CaO	10.91	3.23	63
SiO2	33.36	57.12	20
Al2O3	6.73	29.73	6
Fe2O3	2.16	2.75	3
MgO	4.72%	-	-
K2O +Na2O	25.38%	-	1
TiO2	-	1.13	-
SO3	6.40%	0.02	2
CO3	6.02%	-	-

* After Czernin,
** Alabadan et.al, 2005

Table 3: Oxide composition of the Black Cotton Soil

Oxide	CaO	SiO_2	Fe_2O_3	Al_2O_3	MnO	TiO_2
(%)	-	31.01	4.74	16.19	0.13	1.34

(Source Umar, 2003)

Table 4: Categorization of Black Cotton Soil of North Eastern Nigeria

S/No	Plasticity Index (%)	Free Swell (%)	%Smaller than 1μm	Swelling Potential
1	< 20	<50	<20	Low
2	15 – 30	50 – 80	15 – 30	Medium
3	> 30	> 80	> 30	

(Source NBRRI, 1983)

COMPACTION CHARACTERISTICS

Maximum dry density

The SP compaction showed an increase maximum dry density (Fig.1) with increasing dosage of GSA up to about 4% of GSA. The increase in the MDD is due to the flocculation and agglomeration leading to volumetric decrease in density (Medubi 1998).The decrease in MDD initially for SP compaction was due to the presence of large, low density aggregate of particles (Osula, 1984).

Above 4 % GSA content there is a decrease in the MDD, this decrease could be as a result of the void within the coarse aggregate being filled with groundnut shell ash particles (Steven and Osinubi, 2006). This result is in conformity to the general trend and earlier findings by Osinubi (1998), Marks and Harlibutton (1970).

However, above 6% GSA content there is a possibility that the formation of new compounds have occured which consequently lead to an increase in the MDD at 8% of GSA content with the general trend. The MDD for the WAS compactive effort is in conformity with the trend of decreasing OMC with increasing MDD. At specific ash contents, the results indicate a decrease in MDD with increasing GSA contents. The initial decrease in the MDD can be attributed to the replacement of the soil by the GSA which has lower specific gravity compared to that of the soil (Osinubi, 1996; Moses, 2008; Steven and Osinubi, 2007,). 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 (Osula, 1984; and, Ola, 1983).

The increase in density from the minimum attained value at 6% GSA contents to 8% GSA contents could be due to molecular rearrangement in the formation of “transitional compounds” which have high density at 8% GSA content (Osinubi, 1998a).

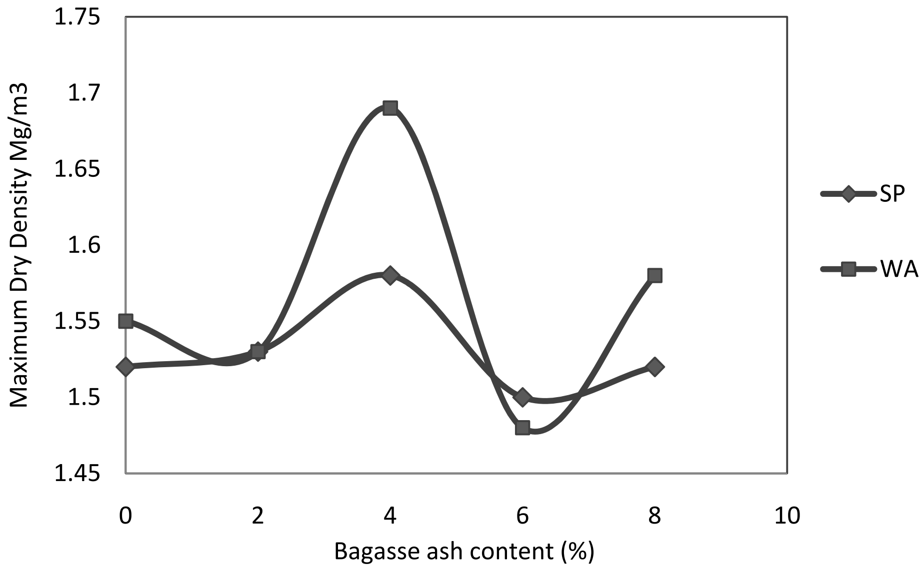

Figure 2: Varition of maximum dry density with black cotton soil treated groundnut shell ash

Optimum moisture content

The variation of OMC with GSA of the SP, and WA energy levels are shown in Figs. 2. There was an initial increase in OMC with increase in GSA for the Standard Proctor and West African Standard compactive efforts. 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 (Moses, 2008; Osinubi, 1997; Steven and Osinubi, 2006,). The subsequent decrease might have been due to cation exchange reaction that caused the flocculation of clay particles.

For specimens compacted at the energy level of West African standard, the final decrease in OMC recorded was probably due to self – desiccation in which all the water was used, resulting in low hydration. When no water movement to or from cement – paste permitted, the water is used up in the hydration reaction, until too little is left to saturate the solid surfaces and hence the relative humidity within the paste decreases. The process described above might have affected the reaction mechanism of stabilized soil (Osinubi, 2000).

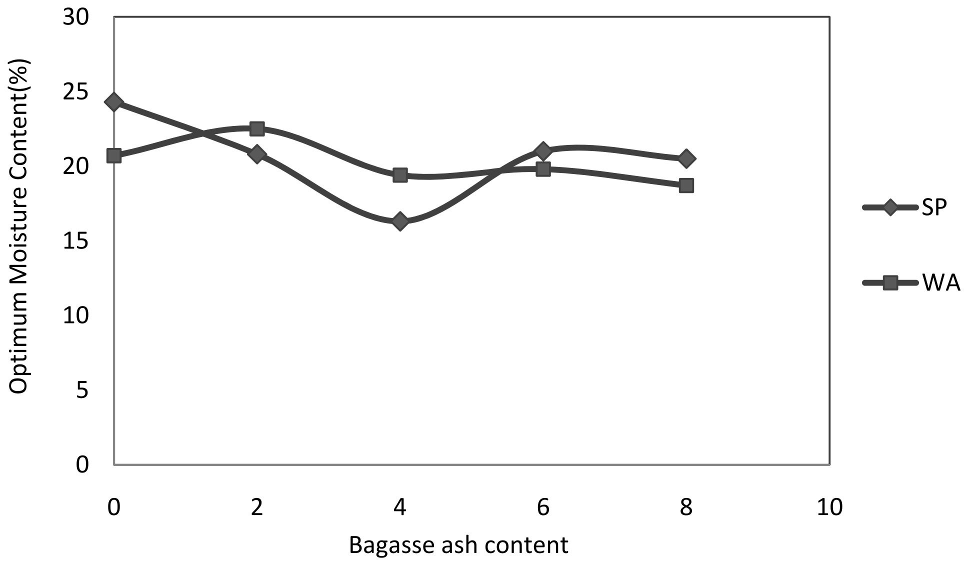

Figure 2: Varition of optimum moisture content with black cotton soil treated groundnut shell ash

STRENGTH CHARACTERISTICS

Unconfined compressive strength

The main test recommended for use for determining required amount of additive to be used in the stabilization of soils is the unconfined compressive strength (UCS) test (Singh, 1991). The 7day UCS test results (Fig.4.) showed slight improvement with increasing compactive effort. The peak 7 days UCS value for the SP energy level is 455kN/m^2 at 4% GSA content. This value fell short of 1710 kN/m^2 specified by TRRL (1977) as criterion for adequate stabilization using OPC. The decrease in strength at higher groundnut shell ash content was as a result of insufficient water to bring the pozzolanic reaction to completion.

The UCS at WA energy levels for the 7 days curing period had peak values of 526 kN/m^2 at 6% GSA content. The trend of the UCS for the WAS compactive energy level shows a similarity. The values of UCS obtained failed to meet the recommendation by Iges and Metcalf (1972) for sub-base material.

The UCS at 14 days (Fig.4.) showed marked differences in values from one another and from that of the 7 days curing period for both SP and WA compactive effort . This indicates that GSA admixture has long time strength improving capability, which implies that the progressive increase in strength will enhance the stability of the pavement. The peak 14 day UCS values for SP and WAS are 935kN/m^2, and 542kN/m^2 at 4 % and 6% GSA contents respectively. The peak values at 28 days curing (Fig.5.) period are 867 kN/m^2 and 2253 kN/m^2 at the energy levels of SP and WA with their GSA content being 4% for both.

The trend of increased compressive strength with curing period can be attributed to time dependent strength gain action of the pozzolanas. The increase in compressive strength at SP and WA compaction is due to the sufficient water which enhanced hydration reaction that is attributed to the reaction between black cotton soil and the groundnut shell ash to form secondary cementatious compounds (Osinubi and Medubi, 1997).

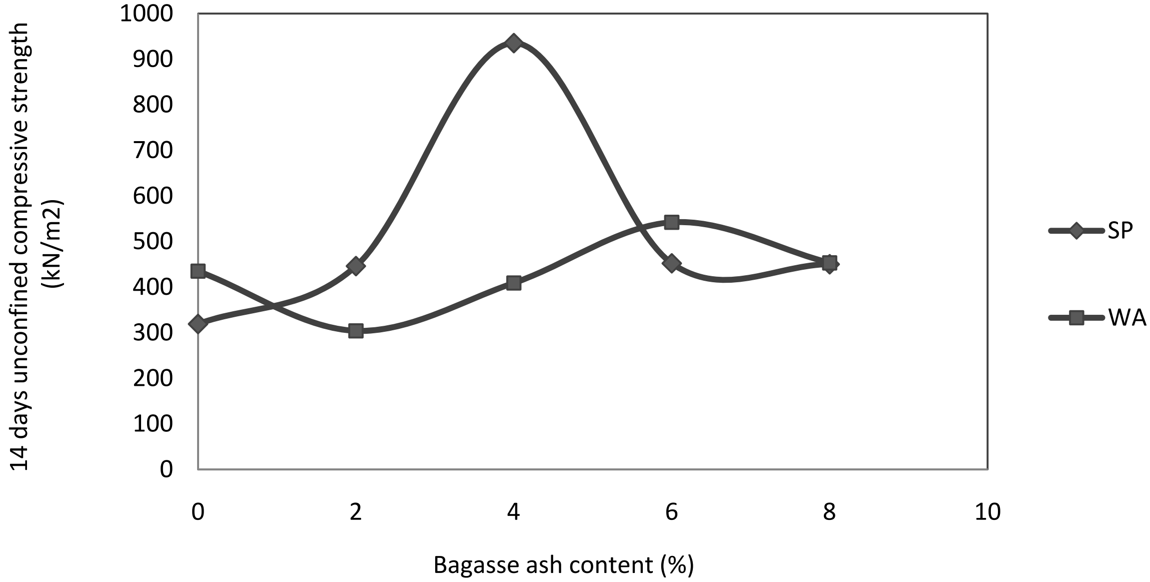

Figure 4: Varition of 14 days unconfined compressive strength with black cotton soil treated groundnut shell ash

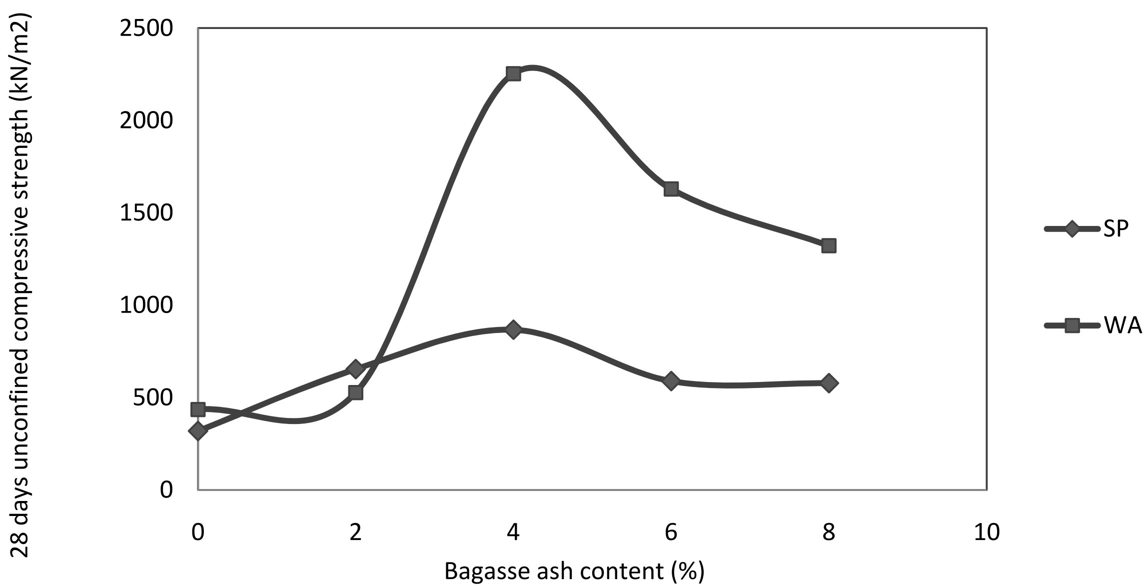

Figure 5: Varition of 28 days unconfined compressive strength with black cotton soil treated groundnut shell ash

CALIFORNIA BEARING RATIO

The California bearing ratio (CBR) value, of the stabilized soils is an important parameter in gauging the suitability of the stabilized soils. Thus, it gives an indication of the strength and bearing ability of the soil; which will assist the designer in recommending or rejecting the suitability of the soil for base or sub-base material.

For the soaked condition the peak CBR values obtained was at 6 % and 2% GSA content with a CBR value of 4.2 % and 2.3% for SP and WAS compactive effort respectively. This value falls short of that required for a base course material, as recommended by the Nigerian General Specification, 1997. Judging from the results obtained, the higher energy levels did not impact any significant improvement on the CBR values of black cotton soil which is consistent with other research work (Moses,2007).

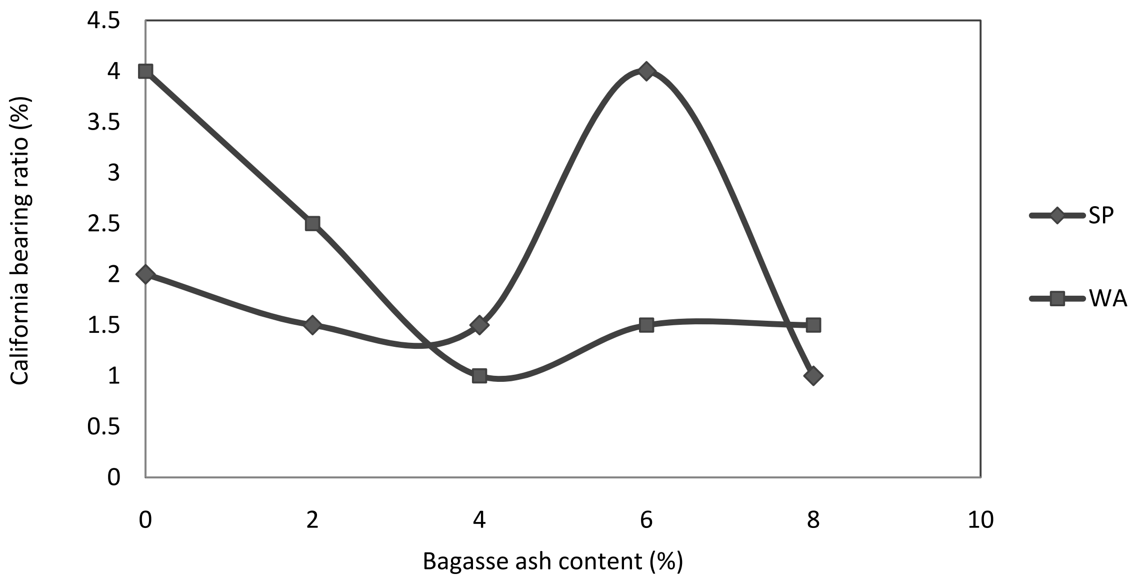

Figure 6: Varition of soaked Carlifornia bearing ratio with black cotton soil treated groundnut shell ash

DURABILITY

The durability assessment of specimen is normally in such a manner as to simulate some of the worst conditions that can be attained in the field for any soil to be used for engineering purposes, immersion of the cured specimen in water before testing its compressive strength is employed to ensure that the stabilized material do not fail under adverse field conditions. The values obtained under these conditions are analyzed in conjunction with the 14 days curing period UCS test results. Cured specimens are normally soaked for 7 days before testing to obtain the percentage resistance to loss in strength of the stabilized material as recommended for tropical countries by Ola (1974).

The peak durability value for resistance to loss in strength for both SP and WAS. compactive energy levels were 34.9 % and 13.9 % at 8 % GSA contents for both energy levels respectively. The durability values of all tested specimens fell short of the acceptable conventional 80% accepted as minimum resistance to the loss of strength by Ola (1974) even though specimen in this test were subject to 7 days soaking period as against 4 day soaking period by Ola, 1974.

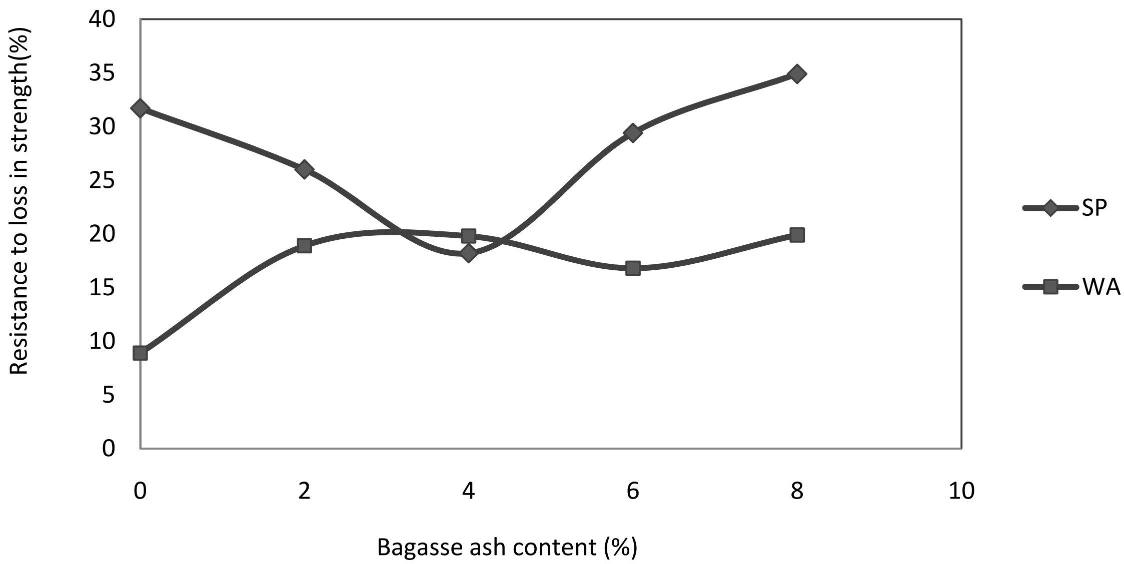

Figure 7: Variation of resistance to loss in strength with black cotton soil treated groundnut shell ash

CONCLUSIONS

The natural black cotton soil was classified as A – 7 – 6 or CL in the AASHTO and Unified Soil Classification System (USCS), respectively. Soils under these groups are of poor engineering benefit.

Treatment of natural the soil with Groundnut shell ash gave a peak 7 day UCS value at SP of 455kN/m^2 at 4% GSA content and 526kN/m^2 at 6% GSA content for WA compactive effort. This value fell short of 1710 kN/m^2 specified by TRRL (1977) for base materials stabilization using OPC. And they fell to meet the requirement of 687–1373 kN/m^2 for sub-base as specified by Ingles and Metcalf (1972).

The peak soaked CBR values of 4 % at SP and 4% at WA were attained at 6 % (GSA) and 0% (GSA) respectively. These values fell to satisfy the specification for base and sub-base materials as recommended by the Nigerian General Specifications (1997). Finally, the durability assessments of sample failed to meet the acceptable requirement.

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