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Research article

STABILIZATION OF NIGERIAN DELTAIC CLAY (CHIKOKO) WITH GROUNDNUT SHELL ASH.

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ABSTRACT.

This paper presents a study on the physical properties and engineering characteristics of Nigerian Deltaic clay, which is extremely soft requiring expensive deep foundation and which is locally called "Chikoko"; and further examines the feasibility of using groundnut shell ash, an agricultural waste, as a stabilizing agent to improve the clay.

It is concluded that the marine clays are characterized by low undrained shear strength, high Atterberg limits and natural water contents. On stabilizing the soil with groundnut shell ash (GSA), the unconfined compressive strength (UCS) improved from 315kN/m^2 to 450kN/m^2 (for standard Proctor compaction) and from 430kN/m^2 to 525kN/m^2 (for West Africa standard compaction) at 3% and 5% groundnut shell ash content respectively, which represents peak values of UCS. However, these improvements are not satisfactory as they are not up to the 1710kN/m^2 UCS value for 7days cured specimens recommended by road note 31 for base material. Similar trend was observed for the California bearing Ratio (CBR); although GSA shows progressive strength development with longer curing periods.

Keywords: Chikoko, Groundnut shell ash, Stabilizing agents, UCS, CBR, Compaction.

INTRODUCTION.

Large scale construction activities are currently going on in the Niger Delta due to the rapid industrialization of the area. Most of the area consist of extremely soft marine clays (locally known as 'Chikoko') posing numerous problems for foundation engineers. Adesunloye (1987) perhaps was one of the earliest to report on the deltaic marine clays as part of his studies on problem soils of Nigeria. According to him, the deltaic marine clays present as dark grey dark brown to black material with characteristic, foul odour of decaying organic matters. Depending on the thickness and uniformity of deposits, large scale settlement, differential settlement and shear strength failures are the fears of founding structures on these soils. Also, the collection of undisturbed samples in very soft 'Chikoko' clay sometimes is problematic. As such, engineers have to resort to insitu strength tests, more so, as the soils tend to be sensitive and easily disturbed.

The three most commonly used stabilizer for these clays are bitumen, lime and cement (Otoko 2014). Unfortunately these stabilizers are expensive, making them unattractive economically. Therefore researchers are now searching for cheap locally available materials such as bagasse ash, fly ash, blast furnace slag (Osinubi 1997, Osinubi 2000a, 2000b; Alhassan and Mustapha 2007, Osinubi and Medubi 1997; Medjo and Riskowiski 2004, Osinubi and Eberemu 2005).

This paper therefore, examines the feasibility of using groundnut shell ash (GSA) as a cost effective and locally available stabilizer; as the safe disposal of this agricultural waste product would solve the environmental and health hazards that they constitute.

Groundnut shell ash (fig.1) is produced by burning groundnut shell to ash; and groundnut shell (fig. 2) is produced by milling of groundnut. Nigeria is the 3rd largest producer of groundnut in the world. Up to about 2,699,000Mt of groundnut was produced in 2002 from about 2,783,000 Hectares of Land. Alabadan et al (2006) has used GSA as a pozzolanic replacement material for cement with success. It is in this light, that the feasibility of using GSA as stabilizer for the marine clay is examined.

Figure 1: Groundnut Shell Ash

Figure 2: Groundnut Shell

GEOMOPHOLOGY.

The project area of about 36,270 km^2 in Southern Nigeria lies between latitudes $4^0 15'$ and $5^0 47'$N and between longitudes $5^0 22'$ and $7^0 37'$E in the Rivers/Bayelsa State. It is low lying, flat and riddled with an intricate system of natural water channels through which the River Niger reaches the sea. The area rises from 2m along the coast to over 60m above sea level farther inland.

The study area comprises of five broad geomorphological zones (Fig. 3) viz:

1. Dry flat country
2. The Sombreiro - Warri deltaic plane

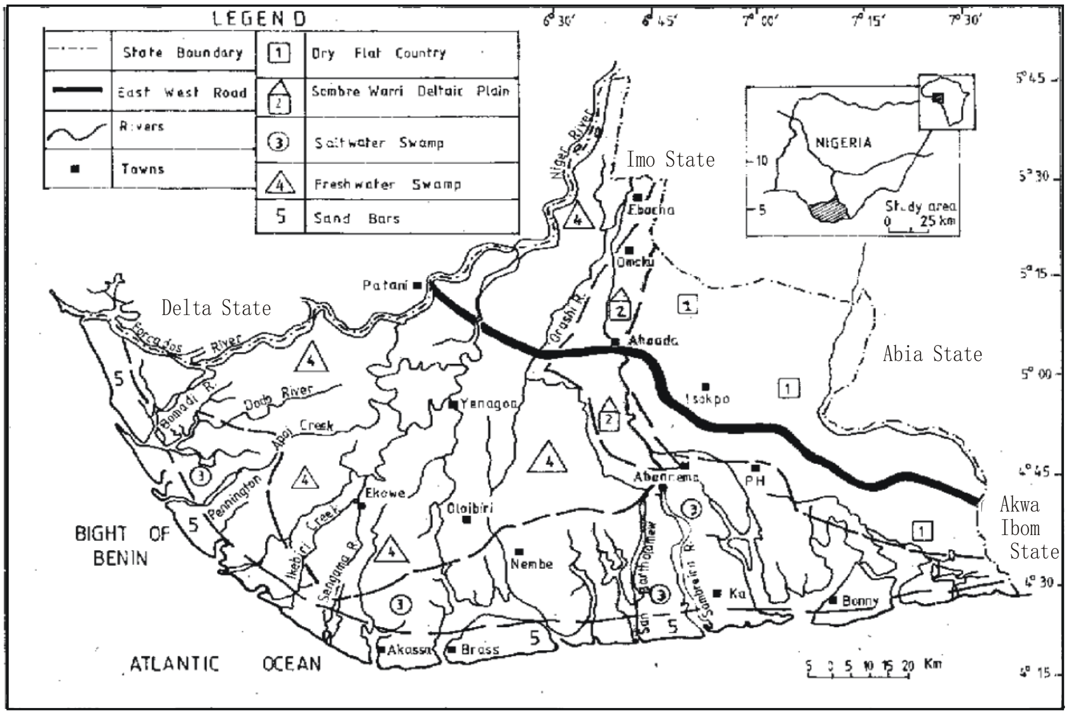

Figure 3: Geomorphological Zones of the Niger Delta, Nigeria.

3. The saltwater mangrove swamp area with estuaries and creeks; and are bordered on the landward side by firm sedimentary deposits of the coastal plain formation (Ofomata, 1975).
4. The fresh- water swamps and alluvial plains, with high concentrations of silt and alluvium and high susceptibility to annual inundation by river floods (Alabo and Pandey, 1987).
5. Sand bars.

ENGINEERING GEOLOGY OF THE STUDY AREA.

The geology of the study area has been given in detail by Simpson, 1954, Onyeagocha 1980, and Short and Stauble 1967. Generally, the study area is part of the Niger Delta. The deposits are therefore geologically young ranging from the Eocene to the recent Pliocene (Asseez 1974). As is typical of a Delta region, the soil deposits consists of unconsolidated clays, silts, fine clayey sand, muds and mangrove swamps (Madedor et al 1987).

It is the marine clays of the fresh and salt water swamps of fig.1 that is the subject of this study.

EXPERIMENTAL METHODS.

Marine clay (chikoko) samples were collected from Eagle Island. The groundwater table was quite high, and the sampling was carried out below the water table using a hand auger. Representative samples were collected in polythene bags and sealed immediately to avoid any loss of pore fluid.

Index tests on the natural and stabilized soils were carried out in accordance with BS 1377 (1990) and BS 1924 (1990) respectively. The marine clay was stabilized with 0%, 1%, 3%, 5% and 7% groundnut shell ash (GSA) content by dry weight of soil. The California bearing ratio tests were carried out in accordance with the Nigerian General specification (1997) which stipulates 6days curing of specimen in the dry and soaking for 24hours before testing.

Proctor compaction, CBR and unconfined compression tests (UCS) were carried out on the natural and treated soils.

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COMPACTION TESTS.

The Proctor compaction tests involved using a rammer of 2.5kg mass falling through a height of 30cm in a 1000cm^3 mould. The soil was compacted in three layers, each layer receiving 25 blows whereas, in the CBR test, for the same weight of rammer, each of the three layers receiving 62 blows in a 2360cm^3 mould.

The West African standard compaction involved a rammer of 4.5kg mass falling through a height of 45cm in a 1000cm^3 moulds, and compacted in five layers, each layer receiving 10blows. The CBR is the same with each layer receiving 30blows in CBR mould.

STRENGTH TESTS.

Soil was mixed at optimum water content with 0, 1, 3, 5, 7% groundnut shell ash content by weight of dry soil, and compacted at the same energy level for standard Proctor and West African standard compaction. They were then cured for 7, 14 and 28days for unconfined compressive strength tests, while for soaked CBR tests they were tested in accordance with the Nigerian General Specification (1977).

DURABILITY.

The durability assessment was by immersion of the stabilized soil in water and resistance to loss in strength measured as a ratio of the 7days cellophane cured specimens, unsealed and later immersed in water for another 7days to that of the 14days UCS value of cellophane - cured specimen.

TEST RESULTS.

Representative physical properties of the sample are presented in Table 1. The natural moisture content is close to the liquid limit.

Table 1: Typical Physical Properties.

S/No	Location	Eagle Island
	Depth of sampling (m)	2.50
1	Specific gravity	2.55
2	Bulk unit weight (kN/m^3)	14.3
3	Natural moisture content (%)	97.0
4	Liquid limit (%)	128.5
5	Plastic limit (%)	45.3
6	Plasticity index (%)	83.2
7	Liquidity index	0.62
8	Shrinkage limit (%)	19.5
9	Grain size distribution i Clay size (%) (<0.002mm) ii Silt size (%) (>0.002<0.075mm) iii Sand size (%) (>0.075mm)	 37 42 21
10	Activity	2.25
11	Free swell index (cc/g)	4.55
12	Salinity (g/l)	5.93
13	Organic matter (%)	7.60
14	pH value	7.50
15	UCS	CH
16	Maximum dry unit weight (kN/m^3)	
17	Standard Proctor Compaction	14.2
18	WA Standard Compaction	15.1

19	Optimum Moisture content %	
20	Standard Proctor Compaction	24.0
20	WA Standard Compaction	20.5
21	UCS (kN/m^2)	
22	Standard Proctor Compaction	315
23	WA Standard Compaction	430
24	CBR	
25	Standard Proctor Compaction	3
26	WA Standard Compaction	5
27	Colour	Dark grey

Figure 4 presents the relationship between clay size fraction and the plasticity index. It shows Skemptions (1953) classification of clays as "active", "normal" and "inactive" clays. The results indicate that the marine clay falls into the active zone. It also indicates that the soil is not suitable for use as sub-grade, sub-base or base course material for pavement construction. Chemical analysis of groundnut shell ash (GSA) shows the oxide composition summarised in table 2; while table 3 shows that of the Chikoko clay.

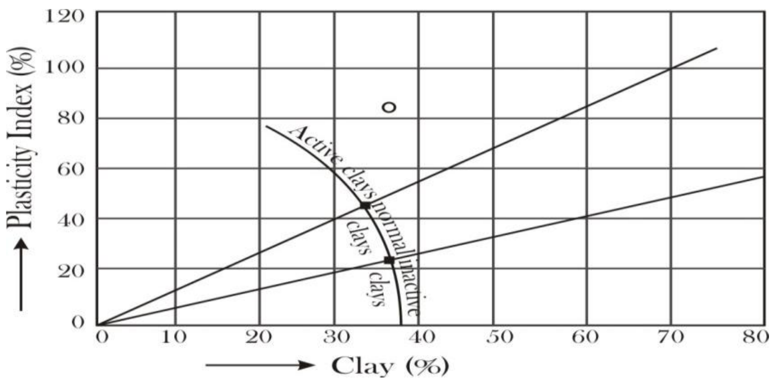

Figure 4: Variation of Plasticity index with clay content (after Skempton 1953)

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	10.85	3.23	63
SiO_2	33.35	57.12	20
Al_2O_3	6.69	23.73	6
Fe_2O_3	2.17	2.75	3
MgO	4.75%	-	-
$K_2O + Na_2O$	25.40%	-	1
TiO_2	-	1.13	-
SO_3	6.38%	0.02	2
CO_3	6.05%	-	-

* After Czernin,

** Alabadan et al, 2005

Table 3: Oxide Composition of Chikoko Soil.

Oxide	CaO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO
(%)	-	30.7	16.15	4.75	1.35	0.12

COMPACTION PROPERTIES.

Maximum Dry Unit Weight

For the standard Proctor compaction, there was an increase in the maximum dry unit weight up to about 3% GSA, probably due to the flocculation and agglomeration leading to volumetric decrease in unit weight (Medubi 1998), while the initial decrease may be due to the presence of large, low density aggregate of particles (Osula 1984). The further decrease above 3% GSA could be as a result of the coarse aggregate voids being filled with groundnut shell ash particles (Osinubi 1998; Marks and Halliburton 1970).

Possible formation of new compounds above 5% GSA may account for the increase in the maximum dry unit weight at 7% GSA. For the WA standard compaction, the initial decrease in the maximum dry unit weight can be attributed to the partial replacement of the soil by GSA which has lower specific gravity than the soil (Osula 1984, Ola 1983, Moses 2008).

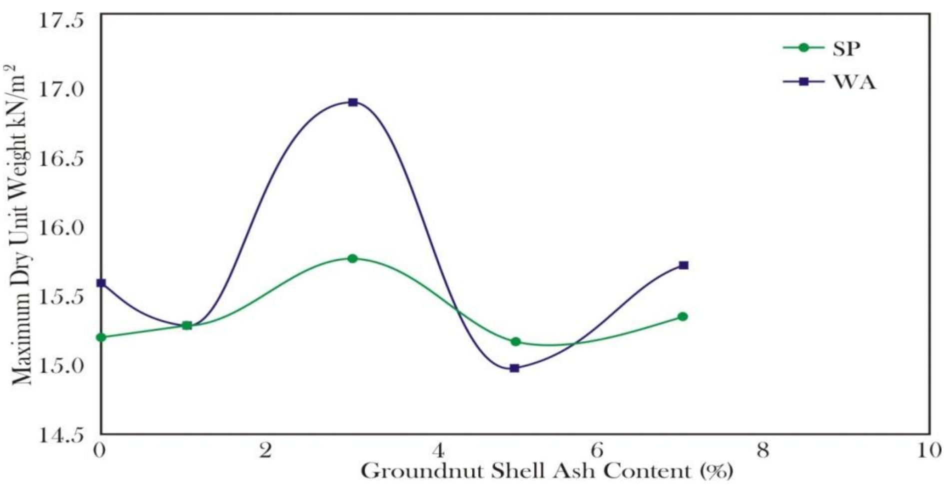

Figure 5: Variation of maximum dry unit weight with groundnut shell ash content

OPTIMUM MOISTURE CONTENT.

The initial increase in OMC (fig 6) may have resulted from increasing demand for water by various cations and the clay mineral particles to undergo hydration reaction (Osinubi and Stephen 2006; Moses 2008, Osinubi 1997). For the WA standard compaction, the final decrease in OMC was probably because all the water was used, resulting in low hydration.

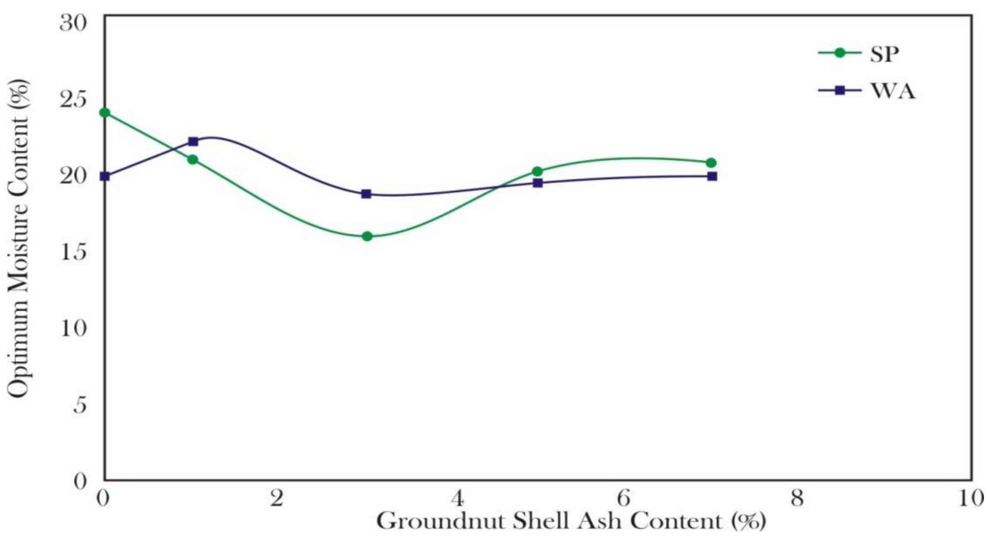

Figure 6: Variation of Optimum moisture content with groundnut shell ash content

STRENGTH PROPERTIES.

UCS is the main test for determining required amount of additive (Singh 1991). Peak UCS value for the standard Proctor compaction is 430kN/m^2 at 3% GSA, (fig 7) which is not up to 1710kN/m^2 specified by TRRL (1977) as criterion for adequate stabilization using OPC. The subsequent decrease in strength at higher GSA may have resulted from insufficient water to complete the pozzolanic reaction.

WA standard compaction for 7days curing period gave UCS peak value of 525kN/m^2 at 5% GSA, which failed to meet the recommendation by Ingles and Metcalf (1972) for sub-base; while the peak 14days UCS values are 930kN/m^2 and 540kN/m^2 at 3% and 5% GSA respectively. For 28days, the peak values are 850kN/m^2 and 2250kN/m^2 for SP and WAS respectively at 3% GSA.

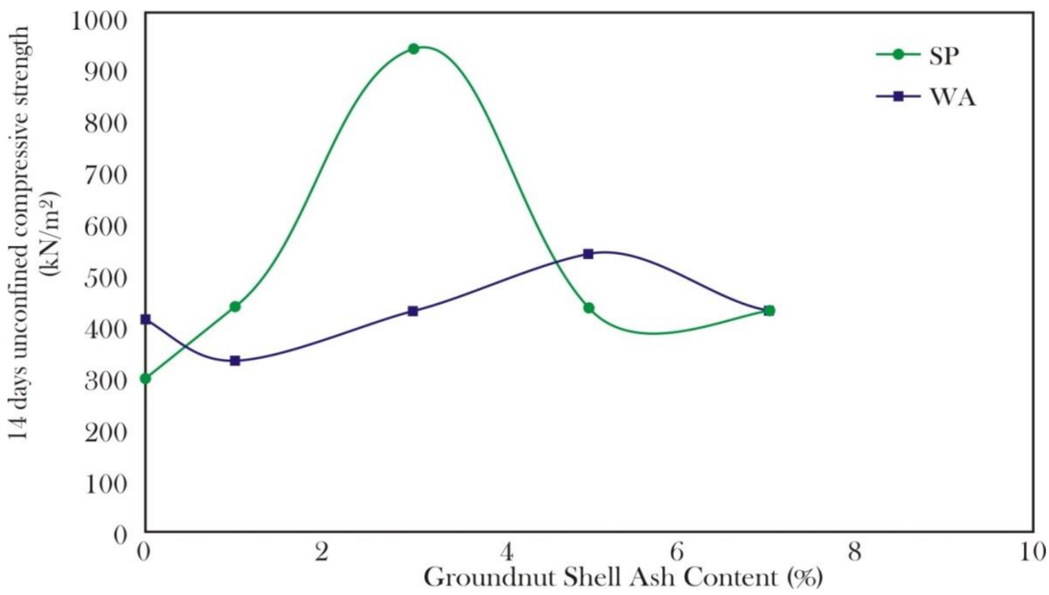

Figure 7: Variation of 14days UCS with groundnut shell ash content

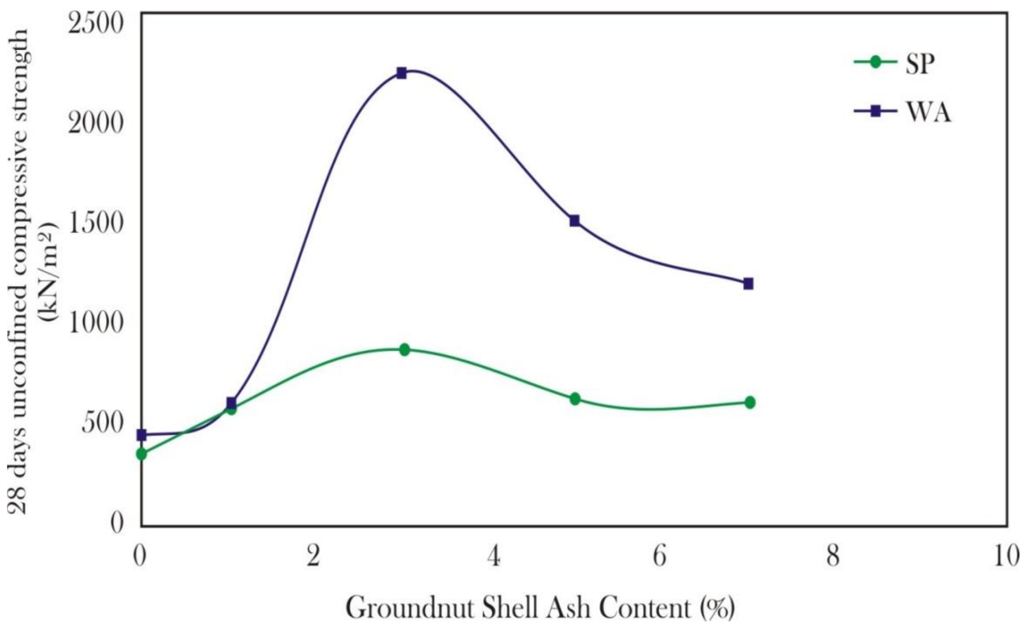

Figure 8: Variation of 28days UCS with groundnut shell ash content

CALIFORNIA BEARING RATIO (CBR).

CBR gives an indication of the strength and bearing capacity of the base or sub-bases material. Peak CBR values at 1.5% and 5% GSA were 2.4% and 4.0% for standard proctor and WA standard compaction respectively.

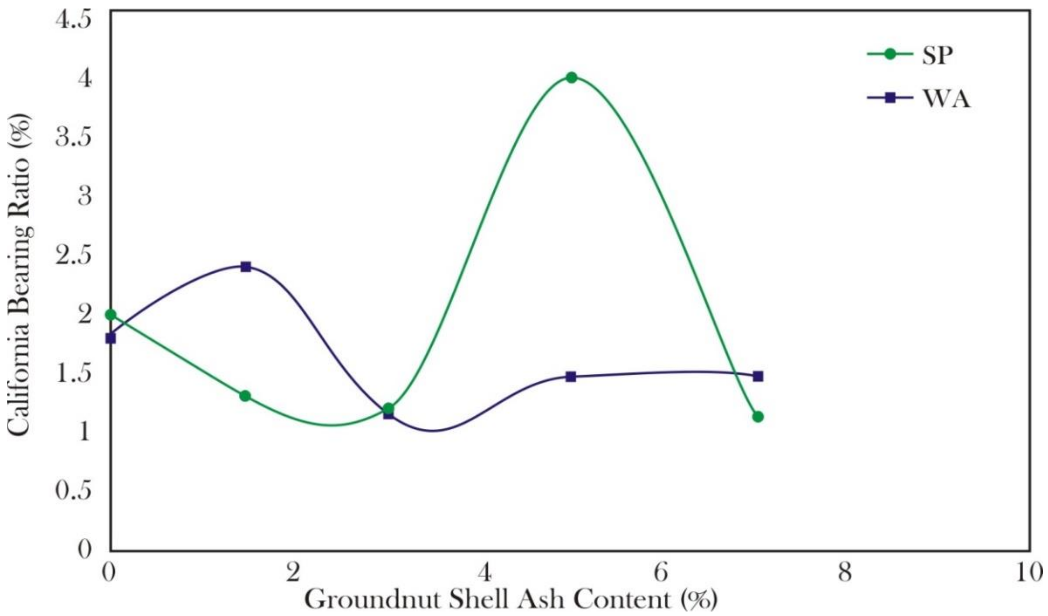

Figure 9: Variation of soaked CBR with groundnut shell ash content

DURABILITY.

Durability simulates worst field conditions, so the cured specimens are immersed in water before testing for compressive strength. Values so obtained are analysed with the 14days curing UCS test results. As recommended by Ola (1974) for tropical countries, cured specimens are soaked for 7days before testing to obtain the percentage resistance to loss in strength of the stabilized material. Peak values (fig 10) were 33.5% and 15.2% at 7 GSA for both SP and WAS respectively, which is not up to the conventionally acceptable value of 80% recommended by Ola (1974).

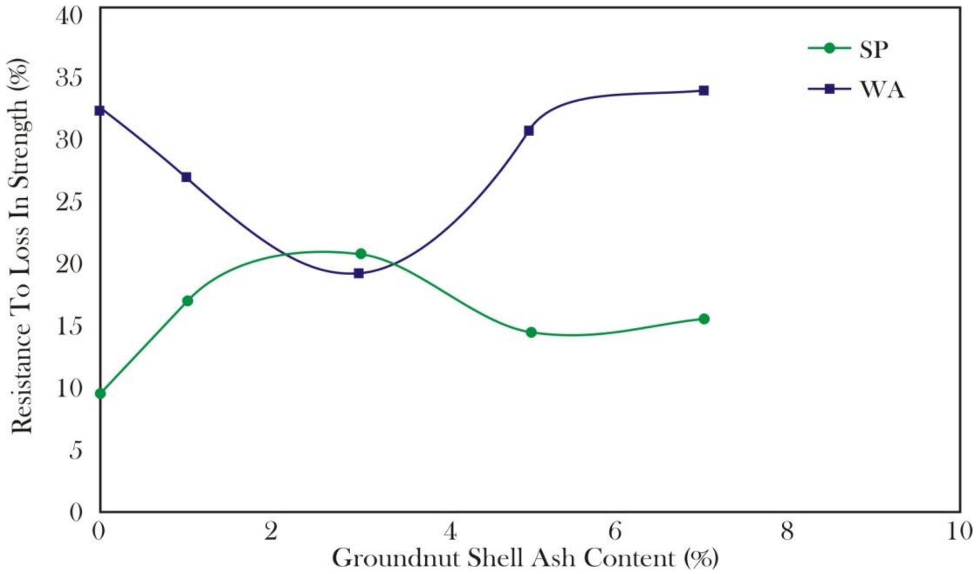

Figure 10: Variation of resistance to loss in strength with groundnut shell ash content

CONCLUSION.

It is concluded that the marine clays are characterized by low undrained shear strength, high Atterberg limits and natural water contents. On stabilizing the soil with groundnut shell ash (GSA), the unconfined compressive strength (UCS) improved from 315kN/m^2 to 450kN/m^2 (for standard Proctor compaction) and from 430kN/m^2 to 525kN/m^2 (for West Africa standard compaction) at 3% and 5% groundnut shell ash content respectively, which represents peak values of UCS. However, these improvements are not satisfactory as they are not up to the 1710kN/m^2 UCS value for 7days cured specimens recommended by road note 31 for base material. Similar trend was observed for the California bearing Ratio (CBR); although GSA shows progressive strength development with longer curing periods.

Finally, the durability of the samples failed to meet the acceptable requirement.

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