Stabilization of Black Cotton Soil using Groundnut Shell Ash

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***Abstract*: Laboratory studies to investigate the possibility of utilizing Groundnut Shell Ash (GSA) as a stabilizing agent to improve the engineering properties of black cotton soil was carried out. Black cotton soil is classified as A-7-6 in accordance with AASHTO soil classification system. Groundnut shell is an agricultural waste product obtained from the milling of groundnut. The groundnut shell are found extensively in the northern part of Nigeria where they are cultivated. The results obtained show that the moisture- density relationship follows a trend of increasing optimum moisture content (OMC)/decreasing maximum dry density (MDD) at the standard Proctor compaction energy. California bearing ratio (CBR) values obtained are lower than the 80% CBR criterion recommended for untreated base course materials. The peak CBR value obtained was 6% at 8 % GSA. This value did not meet the recommended criterion for subgrade materials. The unconfined compressive strength (UCS) at 7 days is lower than the 1034.25kN/m^2 evaluation criterion recommended by TRRL (1977) for adequate stabilization. It is therefore recommended that groundnut shell ash could be used as an admixture with a more potent stabilizer compacted at standard Proctor compaction in order to reduce the cost of stabilization.**

***Keywords*: Groundnut shell ash, optimum moisture content, maximum dry density, unconfined compressive strength, California bearing ratio.**

1.1 INTRODUCTION

The black cotton soil is a type of expansive soil with high plasticity and can retain moisture throughout the dry season which is why they are valuable for growing crops. It exhibits low bearing capacity, low permeability and high volume change due to presence of montmorillonite in its mineralogical content and these properties makes it unfit for construction of embankment and other engineering structures (Bowles; 1979, Das; 1998).

Black cotton soils are expansive clay with potential for shrinkage or swelling under moisture change (Fredlund and Rahardjo, 1993). The soils are formed under conditions of poor drainage from basic rocks or limestone under alternating wet or dry climatic conditions. They usually exhibit high shrink-swell characteristics with surface cracks, opening during the dry seasons which are more than 50mm or more wide and several mm deep. These cracks close during the wet season and an uneven soil surface is produced by irregular swelling and heaving. Such soils are especially troublesome as pavement sub-grades. The soil cause more damage to structure, particularly light building and pavement, than any other natural hazard, including earthquakes and floods (Jones and Holtz, 1973). The name black cotton soil (BCS) is derived from the fact that cotton plant thrives well on it. The black cotton soils of veppanthattai at perambalur. derive their origin from basalts of the upper Benue trough which covers a wide area extending north and east of and from quaternary sediments of lacustrine origin from the Chad basin consisting mainly of shales, clay and shaly sediments (NBRRI, 1983). Specifically, Veppanthattai black cotton soils are formed from the weathering of shaly and clayey sediments and basaltic rocks. According to Ola (1983a), the Nigerian black cotton soil contains more of the montmorillonite clay mineral with subsequent manifestation of swell properties and expansive tendencies. The soil is found 2km from veppanthattai at perambalur., Cameroon, Lake Chad Basin, Sudan, Ethiopia, Kenya, South Zimbabwe and other Eastern African countries, India, Australia, South Western U.S.A., South Africa and Israel (Ola, 1978). Its colour is dark-grey to black probably due to iron and titanium compounds present. It is classified as an A-7-6 soil according to the AASHTO (1986) classification system and has index properties that indicate an inadequacy for most practical engineering use. Expansive soils cause more damage to structures than any other natural hazard including earthquakes and floods (Jones and Holtz, 1973). The amount of damage caused by expansive soils is alarming. In Nigeria, the damages caused by expansive soils are not documented; however, in the United States, it has been estimated that losses from expansive soils exceed two billion dollars annually (Chen, 1988).

Groundnut Shell Ash (GSA) is an agricultural waste product obtained from the milling of groundnut. Groundnuts are found extensively in the northern part of Nigeria where they are cultivated. During and after the harvest of groundnut, the shells are regarded as waste which when accumulated in large quantities in a particular area will constitute an environmental hazard. Therefore, the utilization of GSA as a possible stabilizer will go a long way in reducing the cost of stabilization of the deficient soil and also alleviate the environmental problem associated with the accumulation of the GSA in a large quantity in a particular area.

1.2 LOCATION OF STUDY AREA

The soil samples were obtained 2 km from veppanthattai bus stand at perambalur district which lies on latitude 11·32'N and longitude 78 83'E. The GSA ash was collected at perambalur. Tamil Nadu State. All tests carried out on the natural and treated soil was in accordance with specifications outlined in BS 1924 (1990) and BS 1377 (1990). The oxide composition of the soil used is shown in Table 1.

Table 1: Oxide composition of Black Cotton Soil

Oxide	(%)
CaO	2.53
SiO_2	52.61
Fe_2O_3	18.53
Al_2O_3	20
MnO	0.376
TiO_2	2.05

1.3MATERIALS AND METHODS

1.3.1Groundnut Shell Ash (GSA)

The GSA used for the study was sourced locally and ashed by open air burning. The resultant ash was carefully sieved through 0.075mm aperture sieve to remove unwanted materials.A sample of the ash was analyzed for its oxide composition; the results are summarized in Table 2.

Table 2: Oxide Composition (%) of Groundnut shell Relative to Ordinary Portland cement (OPC).

Oxide	♦Groundnut shell Ash (%)	*OPC (%)
CaO	14.9	63
SiO_2	26.2	20
Al_2O_3	-	6
Fe_2O_3	7.3	3
Mn_2O_3	-	-
Na_2O +	-	-
K_2O	41.74	-
K_2O	1.23	1
TiO_2	-	2

1.4 DISCUSSION OF RESULTS

1.4.1ATTERBERG LIMITS

Fig. 1 shows the variation of liquid limit of BCS treated with GSA content. The results indicate an increase in liquid limit from 83 % for the natural soil to a value of 103 % for soil treated with 10 % GSA. The overall decrease in liquid limit could be attributed to the flocculation and aggregation of the clay particles and the accompanying reduction in surface area and increase in strength. Fig. 2 shows the variation of plastic limits of GSA treated black cotton soil. There was a decrease in plastic limit from 44 % for the natural soil to a value of 23 % at 2 GSA. This alteration of soil character probably occurred due to bi-valent calcium ions supplied by the GSA replacing less firmly attached monovalent ions in the double layer surrounding the clay particles. This according to O'Flaherty (1974) tends to decrease the thickness of the double layer and to depress the zeta potential (i.e., a measure of the effectiveness of the particle negative charges in repelling a second particle) thereby causing flocculation and agglomeration. With higher doses of GSA, there was a corresponding increase in the plastic limit and this could probably be due to the increase in the amount of fines content.

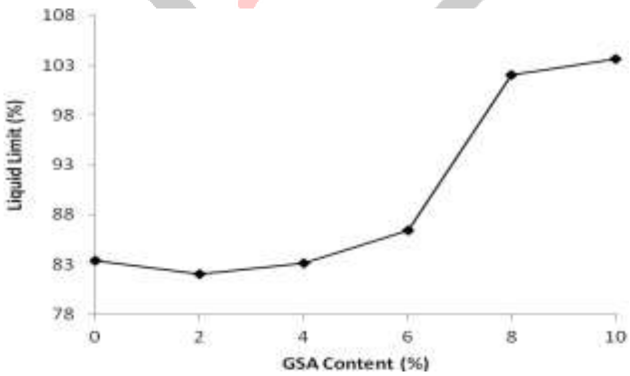

Figure 1: Variation of Liquid limit with GSA content

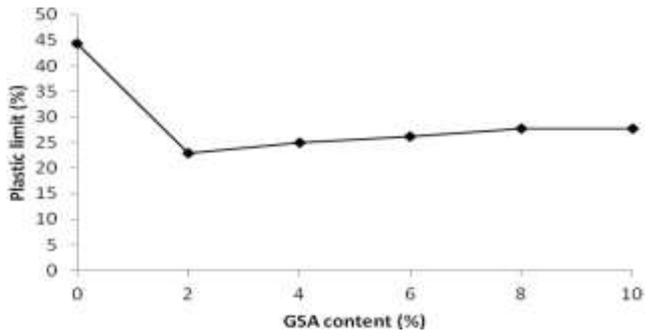

Figure 2: Variation of Plastic limit with GSA content

1.5 COMPACTION CHARACTERISTICS

Fig. 3 shows the variation of maximum dry density (MDD) of GSA treated black cotton soil. The MDD of the natural soil was 1.40 Mg/m^3. The MDD decreased on addition of GSA to a value of 1.39 Mg/m^3 at 4% GSA content. It was observed that as the GSA content increased, the MDD increased.

The decrease in MDD with addition of GSA was probably due to the lower specific gravity of GSA occupying spaces within the soil lattice thereby decreasing the MDD (Ola, 1983a; Less, et al., 1982; Osinubi and Stephen, 2007). However, as the amount of GSA increased, the MDD equally increased which may be due to the increased amounts of more pozzolanic material in the soil matrix.

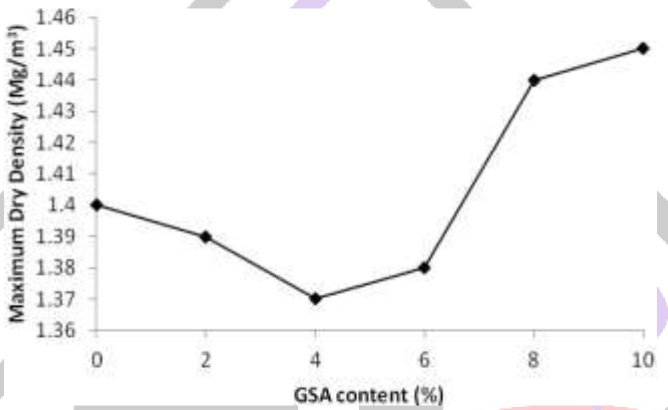

Figure 3: Variation of Maxiumum dry density with GSA content

Fig. 4 shows the variation of OMC of the GSA treated black cotton soil. The OMC of the natural soil was 27%. At 4 % GSA content the OMC was 29 % and with further additions of GSA, the OMC decreased. The increase in OMC agrees with previous research work by Osinubi and Katte (1997) that attributed the increase to the amount of water required for pozzolanic reactions to take place.

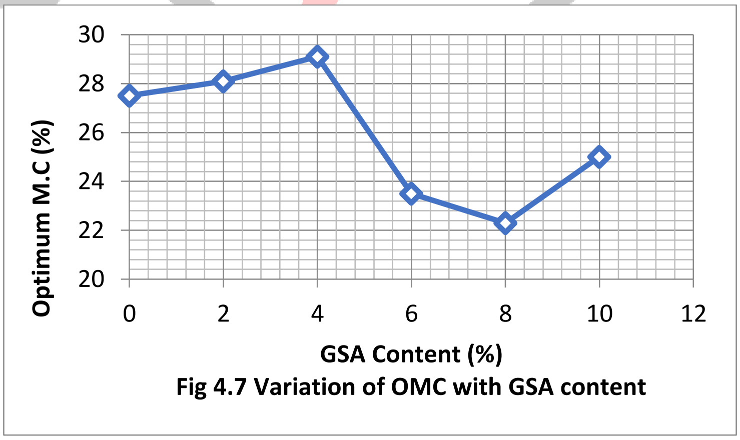

Figure 4: Variation of Optimum Moisture Content with GSA content

1.6STRENGTH CHARACTERISTICS

1.6.1California bearing ratio

Fig. 5 shows the variations of un soaked C.B.R of GSA treated black cotton. The CBR value of the natural soil was 2 %. At 8 % GSA content, a CBR value of 6.3 % was obtained. This showed a marginal improvement. The reason for the slight improvement in the strength could be due to inadequate amounts of calcium required for the formation of calcium silicate hydrate (CSH), which is the major element for strength gain. It has been recommended that the CBR value of 180 % should be attained in the laboratory for cement-stabilized material to be constructed by the mix-in-place method (Nigerian General Specification, 1997). Although, the GSA treated black cotton soil do not meet the minimum criteria as specified (Nigerian General Specification, 1997) for materials suitable for use as base course material of not less than 30% C.B.R determined at MDD and OMC, the GSA could be used in admixture stabilization with a more potent stabilizer in order to reduce the cost of stabilization.

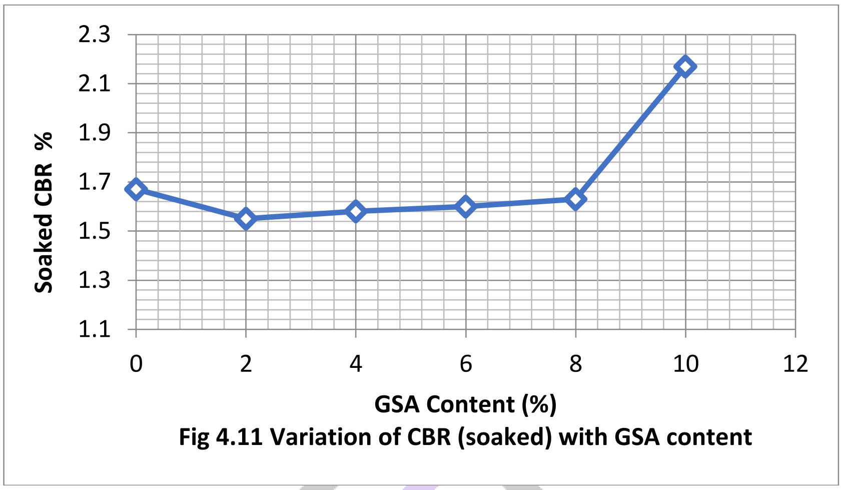

Figure 5: Variation of CBR with GSA content

1.6.2 UNCONFINED COMPRESSIVE STRENGTH

The variation of unconfined compressive strength (UCS) with GSA content at at 7 days curing period is shown in Fig. 6. It is observed that the UCS of the GSA treated black cotton soil initially decreased from 91 kN/m^2 at 0 % GSA content to a peak value of 211 kN/m^2 at 8% GSA content. Increased UCS values observed between 2 and 4 % GSA contents could be attributed to ion exchange at the surface of clay particles as the Ca^{2+} in the stabilizer reacted with the lower valence metallic ions in the clay microstructure which resulted in agglomeration and flocculation of the clay particles.

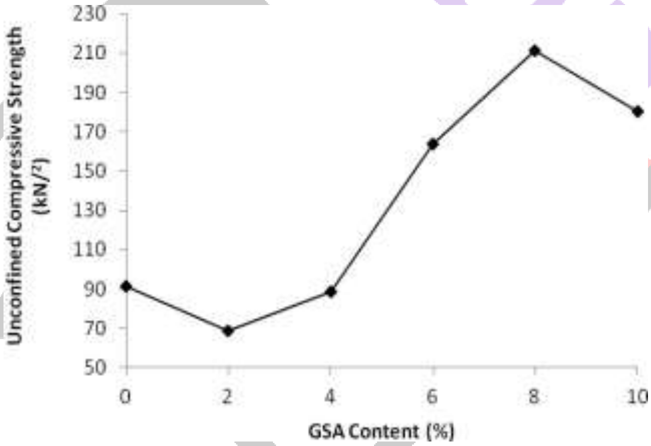

Figure 6: Variation of UCS with GSA content

1.7 CONCLUSION

- The natural black cotton soil obtained at, 2km from veppanthattai at perambalur district. falls under the A–7–6 [5] classification.
- The GSA increased the liquid limit from 83 % to 103 % at 10 % GSA, the plastic limit increased from 44 % to 23 % at 2 % GSA content. The plasticity index increased from 38.9 to 75.8 % at 10% GSA content.
- The UCS of the GSA treated black cotton soil did not improve considerably. The increase recorded was marginal at 7 days curing period. The UCS obtained is less than the criterion of 1034.25KN/m^2 for lime-stabilized soils recommended by Road Note 31 (TRRL, 1977).

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