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Stabilization of Black Cotton Soil with Groundnut Shell Ash and Ferric Chloride

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ABSTRACT:
The study is a potential stabilization of black cotton soils using Groundnut Shell ash and $Feclo_3$. Index properties of the natural soil showed that, the soil belongs to A-7-6 in AASHTO classification system and CH in USCS classification system. This indicates a poor soil for engineering use. Liquid limit and Plasticity index values of 83.36 % and 38.96% respectively for the natural soil suggest that the soil is highly plastic. There was gradual decrease in the free swell to a minimum value of 4.76% at 8% GSA and further decreased to 3.50% at 1.5% of $Feclo_3$ as compared to the natural value of 15.25%. The soaked CBR for the natural soil is 1.67% which increased to 1.98% at 8% GSA and further increased to 2.85% at 1.5% $Feclo_3$. This value fell short of specification requirement of the CBR value to be used as sub-base or base material; there was increase in strength for UCS of 28 days curing period from a value of 134kN/m^2 as compared to 312.89 KN/m^2 for the unstabilized soil

INTRODUCTION:
Black cotton soils are expansive clays with potential for shrinking or swelling under changing moisture condition. The soils are formed under conditions of poor drainage from basic rocks or limestones 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. (Osinubi,1997)

Groundnut Shell is an agricultural waste obtained from milling of groundnut. In the world, the total hectare planted to groundnut is over 20 million hectares per year.. Groundnuts are mostly intercropped. Groundnut contains about 25% Protein and 45 to 50 % oil. The skins are high in Vitamin B. Groundnut can be decorticated by hand-operated decorticating machine. (NAERLS, 2009) In this work, an exercise is done to utilize groundnut shell ash (GSA) and ferric chloride to improve the engineering performance of Black Cotton soil which may be an economical solution of soil stabilization.

MATERIALS, METHODS AND RESULTS
BLACK COTTON SOIL
The **black cotton soil** was collected by method of disturbed sampling after removing the top soil at 500mm depth and transported in sacks to the laboratory. Little amount of the sample was sealed in polythene bag for determining its natural moisture content. The soil was air dried, pulverized and sieved with Standard Sieve N0. 4 (4.75mm aperture) as required for laboratory test. (Head 1970).

GROUNDNUT SHELL ASH:
The groundnut shell ash was decorticated, ashed in open air under normal temperature at the same place where it was procured. The oxide composition of both ash and soil was carried out to fully understand the pozzolanic behaviour of the ash on the soil.

FERRIC CHLORIDE:
Laboratory grade Ferric chloride consisting of 96% FeCl3 was used in this work. The amount of Ferric chloride used was between 0 to 2% by dry weight of soil.

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Oxide Composition of Black Cotton Soil

Oxide	Concentration (%)
Al_2O_3	20
SiO_2	5.2.61
CaO	2.53
Fe_2O_3	18.53
MnO	0.376
TiO_2	2.05
K_2O	2.29

Oxide Composition of Groundnut Shell Used

Oxide	Concentration (%)
SiO_2	26.2
CaO	14.9
Fe_2O_3	7.3
TiO_2	1.23
K_2O	41.74

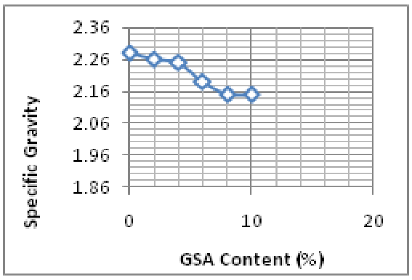
METHODS:

Index tests on the natural and stabilized BC soils were carried out in accordance with theprocedures outlined in BS 1377 (1990) and BS 1924 (1990) respectively, for the stabilized soilspecimens, step percentages of groundnut shell ash by dry weight of soil (0, 2, 4, 6 8 and 10%) wasintroduced into the soil for optimum percentage of soil and GSA,FECL3 is introduced to soil (0%,0.5%,1%,1.5%,2%)

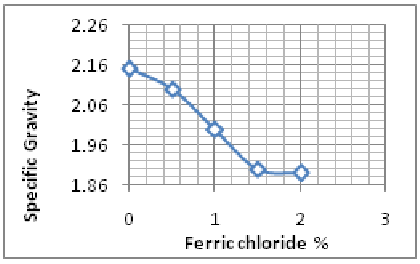
NATURAL MOISTURE CONTENT

The natural moisture content was determined to be **26.95 %**

SPECIFIC GRAVITY

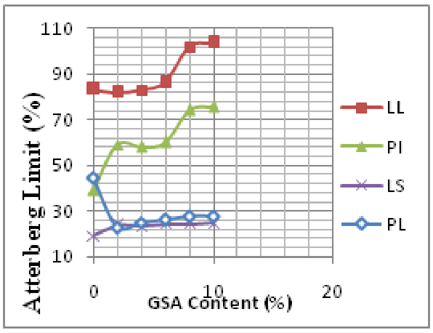


Variation of Specific Gravity with GSA content

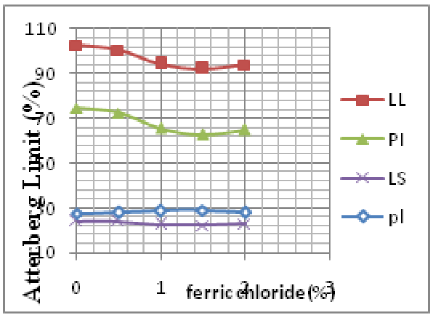


Variation of Specific Gravity with 8% GSA and Ferric chloride content

Atterberg limits

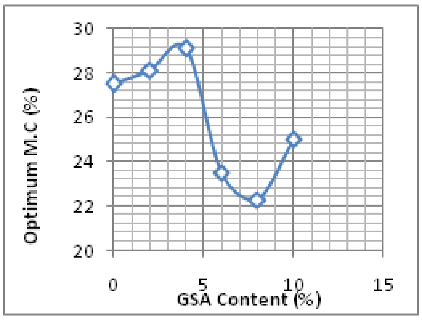


Variation of Atterberg limits with GSA content



Variation of Atterberg limit with 8% GSA and Ferric chloride content

Compaction tests



Variation of OMC with GSA content

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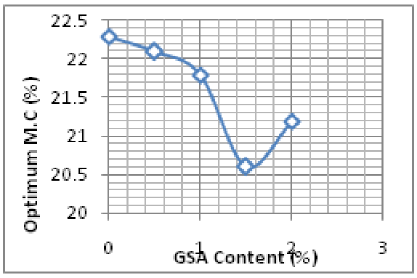
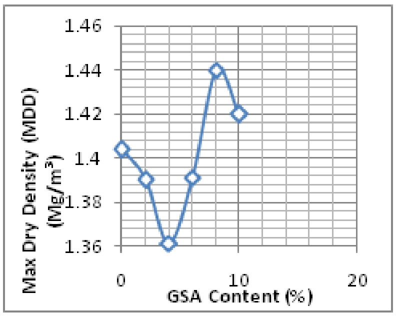
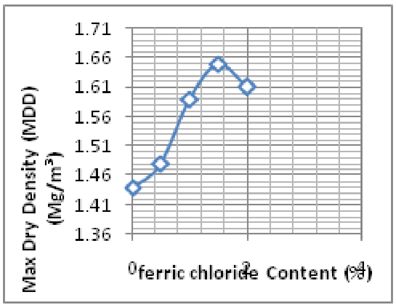


Variation of OMC with 8%GSA and Ferric chloride content

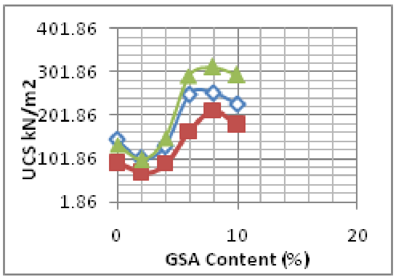


Variation of MDD with GSA content

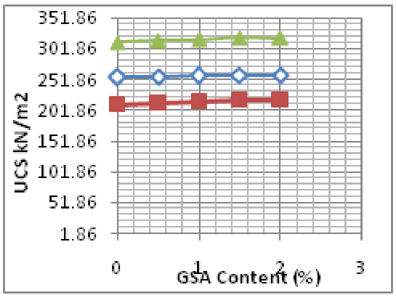


Variation of MDD with 8% GSA Ferric chloride content

Unconfined compressive strength (UCS) tests

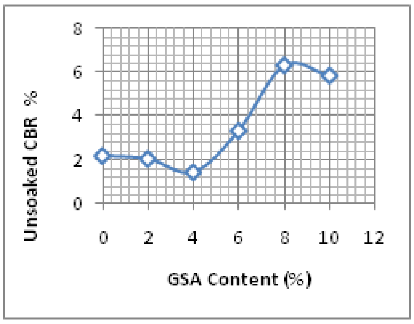


Variation of UCS with GSA content

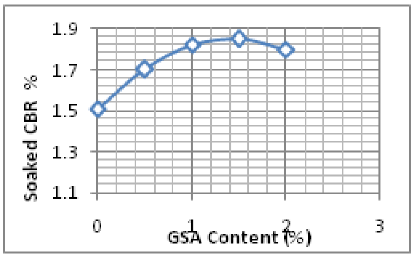


Variation of UCS with 8% GSA and Fecl3 content

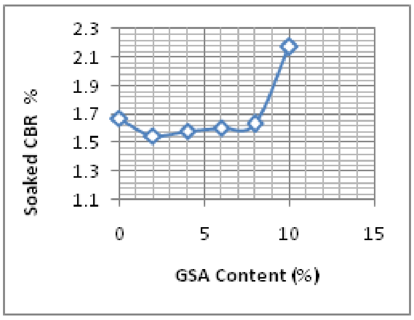
California bearing ratio (CBR)



Variation of CBR (soaked) with GSA content



Variation of CBR (soaked) with GSA content



Variation of CBR (unsoaked) with 8% GSA and Ferric chloride content

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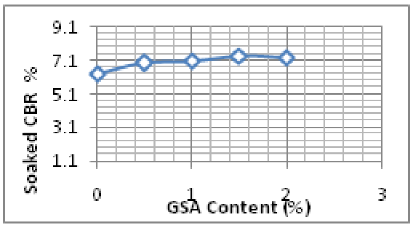
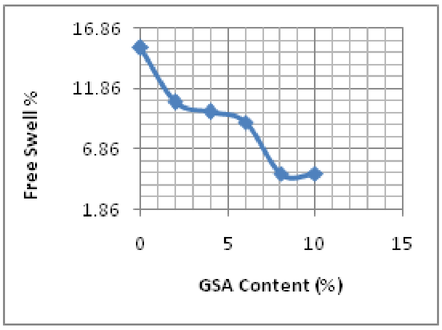
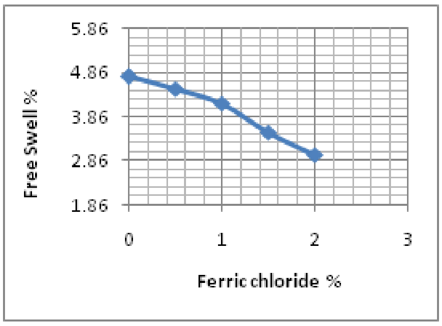


Variation of CBR (soaked) with 8% GSA and Ferric chloride content

Free Swell



Variation of Free Swell with GSA content



Variation of Free Swell with 8% GSA and Ferric chloride content

DISCUSSION OF RESULTS

Evaluating the effect of groundnut shell ash (GSA) and Ferric chloride on the black cotton soil

Specific Gravity

Gradual decrease in specific gravity to 2.15 was observed with increasing percentage of GSA up to 8%. Further addition of GSA led to increase in specific gravity. and for this optimum value with increase of FECL3 further decrease up to 1.90 with 1.5% and further increase of FECL3 increases the specific gravity.

Sieve Analysis:

This could be due to similar flocculation and aggregation into masses of similar sizes.

Atterberg Limits

Liquid Limit:

There was an increase in liquid limit with increase in groundnut shell ash content after an initial decrease at 2% GSA content. The result is in agreement with the definition of liquid limit, which is the moisture content at which the soil exhibits dynamic shear strength. When an alteration occur s in the system of a soil existing in its liquid limit such that there is relative decrease in the repulsive forces , its strength increase to a specific value that more moisture will be needed to bring the soil to its dynamic shear strength. This tended to increase the value of the liquid limit of the soil- GSA ash mixture from the value of 83.36% at no GSA content to a maximum value of 102.05% at 8 % GSA content. The initial decrease in the liquid limit could be due to the effect of reduction in the diffused double layer as well as due to the effect of dilution of clay content to the mix.

Plastic Limit:

As can be seen from the graph, the addition of GSA resulted in a decrease in the plastic limit of the treated soils., the free lime content is not sufficient enough as to increase the plastic limit and hence no such change was observed. reduction in the plastic limit (27.78%) was observed at 8% GSA. This is because of the fact that as the quantity of GSA in the mix increased, The amount of soil to be flocculated decreased and also the finer particles of GSA may be incorporated in the voids of flocculated soil. This lead to the decrease in the water held in the pores leading to the decrease of the plastic limit.

Plasticity index:

As seen from the graph, the addition of GSA increases the plasticity index of the soil samples. The plasticity index at no GSA content was 38.92 % and as stabilizer content was increased to 8% GSA, a peak value of

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74.27% and 62.8% in corresponding $FECLO_3$ is recorded. The increase in PI could probably be due to deficiency of Ca^{2+} which is required to replace the weakly bonded ions in the clay structure and hence, flocculation did not occur. Instead, there was an increase in the fine fraction which absorbed more water and became more plastic.

Linear Shrinkage:

A value of 19.22 % was recorded for the natural soil; an increase in the linear shrinkage to a peak value of 24.16 % can be observed as it is been depicted in Fig.. The increase in the linear shrinkage with the addition of GSA could be attributed to lack of flocculation and agglomeration as explained earlier and hence the mixture contained more finer materials which exhibited more shrinkage characteristics. And optimum value of 24.16% further decreased to 22.20% at 1.5% $FECL_3$ and increased further i.e 2%.

Free Swell:

The free swell at 0% stabilizer content is 15.25%. Further increase in the GSA contents led to a reduction in the free swell to a minimum value of 4.71% . The sharp reduction in the free swell could be due to the increased presence of finer particles which are not clayey and hence lesser free swell. In fig .optimum value of 4.71% still reduced to 3.5% at 1.5% $FECL_3$

Compaction Parameters:

Optimum Moisture Content (OMC):

The OMC at no GSA is 27.5% and addition of groundnut shell ash led to a sharp reduction in the OMC to 22.3% at 8% GSA, and finally, increase of OMC to 23.5% was observed at 10% GSA content. At optimum value of 8% GSA when $FECL_3$ Is added, it decreases the value up to 20.6KN/M^2 and further increase the value. The initial increases in OMC recorded could be due to the increasing demand for water by the various cations and the clay mineral particles to undergo hydration reaction.

Maximum Dry Density (MDD):

For 0% GSA, the maximum dry density was 1.36Mg/m^3 and on addition of GSA, increase in GSA content led to increase in MDD to a peak value of 1.44 Mg/m^3 at 8% GSA and subsequently increase in GSA led to reduction in MDD value. and $FECL_3$. Added to this optimum value and at 1.5% it gives 1.65% The initial reduction in MDD could be partly attributable to the flocculation and agglomeration of clay particles occupying larger spaces leading to corresponding decrease in the MDD (O' Flaherty, 1988). Later increase in MDD observed is due to flocculation and agglomeration of the clay particles due primarily to ion exchange.

Unconfined compressive strength (UCS):

It is observed that on addition of 2% GSA, there was a decrease in the UCS of the mixture. The reasons for the decrease could be due to the lack of adequate calcium oxide in the GSA which is required for the stabilization of the BCS. However, at 4, 6 and 8% GSA, there were increased values of UCS recorded. The increased UCS could be due to the presence of adequate calcium oxide required for stabilization. The UCS values at 8% GSA increased with curing periods of 7, 14 and 28 days to 211, 255 and 313 KN/m^2 respectively. in fig.4.9.1 UCS values at optimum soil and GSA content are increased due adding of 0.5,1,1.5% $FECL_3$ respectively.

California Bearing Ratio:

On addition of 2% GSA, there was a slight decrease in the CBR. This could be due to the inadequacy of calcium required for the formation of GSA, which is the major element of strength gain. However, as the amount of GSA increased to 4, 6, and 8% respectively. And further decreased with Ferric chloride as 0.5,1,1.5% respectively, There was an increased CBR. Although the increase is still very much required which could also be attributed to the insufficient amount of calcium oxide present in the GSA.

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It is clear that the GSA stabilized BCS cement be used as a potent stand alone stabilization in agreement with the findings of Stephen (2006) For the unsoaked condition which is shown in Fig 4.12, the peak CBR value obtained was at 8% GSA content with a CBR value of 3.65%. Further increase in GSA percentage causes a reduction in the CBR value to 3.42%. The slight increase in CBR could be attributable to inadequate amount of calcium required.

Conclusion:

Based on the results of this investigation, the following conclusions and recommendations are drawn.

- ❖ The soil is classified under the A-7-6 subgroup of the AASHTO classification system. Liquid limit and Plasticity index values of 83.36 % and 38.96 % respectively suggest that the soil is highly plastic. Thus, from the results obtained, the soil falls below the standard recommended for most geotechnical work
- ❖ Groundnut Shell Ash (GSA) is used as a stabilizer for improving the geotechnical characteristics of black cotton soils. Addition of Groundnut Shell Ash significantly improves the index properties, compaction and strength characteristics of black cotton soil under study and the effect of GSA vary depending upon the quantity of GSA, that is mixed with the black cotton soil samples
- ❖ The plastic limit of the soils decrease with the addition of GSA which indicates a desirable change as the BCS with GSA mix can gain shear strength at an early stage than the virgin soil. The relative increase in the liquid limit and Plasticity index of the soils is an unfavourable change since decrease in LL and PI increase the workability of these soils. The linear shrinkage of the soils increases with the addition of groundnut shell ash, which facilitates in checking the volume change behaviour of the soils over a large variation in the moisture content as the season changes.

Recommendation:

The result obtained from this work show that groundnut shell ash with combination of Ferric chloride can be used more profitably as an admixture with a conventional stabilizer such as lime and cement.

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