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THE ENGINEERING CHARACTERISTICS OF BLACK COTTON SOIL TREATED WITH CORN STRAW ASH.

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ABSTRACT: *Black cotton soils (BCS) are found in extensive quantities in the North – East region of Nigeria specifically in the northern parts of Adamawa State and southern parts of Borno State. This soil expands while it gets wet and shrinks as the water dries out. On account of this high volumetric changes they are not directly suitable for construction. The excessive swelling and shrinkage are sequel to the presence of fine particles of clay. Swelling and shrinkage of soil often results in differential settlement of the structure. Black cotton soils must therefore be treated by using suitable admixtures to stabilize it for use in civil engineering works. In this research work, stabilization of black cotton soil is done by using Corn Straw Ash* ***(CSA)*** *as an admixture. The CSA reacts with clay particles from the black cotton soil to form a material of higher strength. The physical and chemical properties of the soil were obtained. Other tests such Atterberg's limits, California Bearing Ratio(CBR), Unconfined Compressive Strength(UCS) were carried out at different percentage contents of CSA: at 0%, 4%, 6%, 8% and 10%. From the test results, it is observed that optimum value of CBR and UCS are at 8% of the ash. At this percentage of the additive the following improvement occurred in the black cotton soil; CBR improved from 4.5% to 11.3%, UCS 107.5KN/m^2 to 140.5KN/m^2 and plasticity index decreased from 24% to 11.2%. It is concluded that CSA has a great potential in the improvement of the mechanical properties of black cotton soil.*

Keywords: *Black cotton soil, corn straw ash, California bearing ratio, plasticity index, unconfined compressive strength.*

1.0 INTRODUCTION

The black cotton soil used in this study is a highly plastic clay that depicts high volumetric charges. It is known to be very problematic for the construction of various infrastructures like dams, highway embankments, foundation backfill material in building substructure, etc. Black cotton soils contain the Montmorillonite clay mineral: one alumina sheet is sandwiched between two silica sheets. There exists a very weak bond between the sheets which causes the swelling in soil due to ease of permeation of water through the weak bond. [1]

Expansive soils are those which swell in contact with moisture and shrinks on drying. This leads to cracking of structures supported by them and therefore an increase in the cost of construction and maintenance. They create numerous problems in the field of civil engineering while during design, construction and during the maintenance of various Civil Engineering projects like Building foundations, Roads, Railways and Airport Runways. These swelling soils are commonly known by the name of Black Cotton Soils. They are called black cotton soils because they are black in colour and are more suitable for growing cotton. They give higher yield of cotton when compared to other types and colours of soils. The presence of clay in these soils imparts them with high swell–shrink potentials. [2]

Black cotton soils are found in extensive quantities in the of north – east region of Nigeria specifically in the northern parts of Adamawa state and southern parts of Borno state. On account of their high volumetric changes they are not suitable for engineering construction. Swelling and shrinking of soil often results in differential settlement of a structure. Therefore, there is the need that black cotton soils should be treated by using suitable admixtures to stabilize them for use in civil engineering works. In this research work, stabilization is done by using **corn straw ash** as an admixture.

Barani [4] presented a study in engineering behavior of black cotton soil treated with Waste Paper Sludge Ash and concluded that Stabilization of expansive soil using admixtures gives a good solution for the swelling and shrinkage issues. Elias [5], presented the effect of waste paper sludge on plasticity, free swell index, compaction, unconfined compressive strength and CBR in soft clayey soil. In his works compressive strength was increased by adding 5% WPS. The compressive increased by 65% (496KN/m2) at 7days and by 107.9% (590 KN/m2) at 28 days

Norazlan et.al [6], presented the effect of WPSA on unconfined compressive strength and California bearing ratio of sandy clay soil. It is concluded that increase in WPSA content improves unconfined compressive strength content about 2 times by the addition of 10% WPSA. The addition of 10% WPSA increased the CBR value by about 1.5 times in unsoaked condition and 3.6 times in soaked condition, compared with untreated soil sample.

According Rahul et.al [7], the compressive strength and stability of the soil can be considerably improved by soil stabilization through controlled compaction and addition of suitable admixture in some proportion. Lime and Sugarcane

Straw Ash were used as soil stabilization additives in their study. Lime is calcium oxide (CaO) or Hydroxide of Calcium and Magnesium and is made by calcining Limestone into either calcite lime (High in Calcium) or Dolomite lime (High in magnesium). According to them use of Lime in stabilization improves strength, resistance to fracture, fatigue and permanent deformation. Sugarcane Straw Ash is a pozzolanic material which is very rich in oxides of silica, aluminum and sometimes calcium.

Gupta et.al [1] presented black cotton soil modification by application of domestic waste material as per ASTM D1883-05 [8], California Bearing Ratio test for all optimum composites were conducted. The result showed that soaked and unsoaked CBR values of virgin black cotton soil were 2.78% and 7.38%. When the soil was mixed with waste material at optimum mixture it gave soaked and unsoaked CBR values of 8.04% and 14.75% respectively. Thus this application caused an increase of CBR by 189.20% and 99.86% respectively.

Brajesh [3], presents a study on engineering behavior of black cotton soil and its stabilization by use of lime. On the basis of this study and experimental investigations it was observed that the property of black cotton soil effectively improved by use of different percentage of lime contents. In this research varying percentages of 3% and 5% of lime were used to stabilize the black cotton soil. The following Points were drawn from this study: addition of 3% of lime decreases the liquid limit by 2.70% while addition of 5% lime reflects a decrease of 15.27%. The Maximum Dry Density (MDD) was increased slightly by 6.29% and 5.59% at 3% and 5% lime content respectively. Decrease in Optimum Moisture Contents (OMC) of 3.4% and 10.7% were observed at 3% and at 5% lime content respectively. The C.B.R. value of black cotton soil improved considerably by 325% and 476% with 3% and 5% lime respectively.

Nagaraju et.al [10] in their Experimental Investigation on Black Cotton Soil using Lime and Rice Husk Ash(RHA) observed that the property of black cotton soil effectively improved by use of different percentages of lime with rice husk ash content. In this study 5%,10% and 15% of RHA with 5% lime to stabilize the black cotton soil. Their findings were used were: liquid limit values decreased from 59% to 28% by the addition of lime and RHA. This means that the properties change from highly compressible to low compressibility, plasticity index values decreased from 30% to 5% on addition of lime and RHA. This means that the plasticity of the material changed from very high to low. Free swell index values decreased. This implies that swelling of the soil also decrease. Hence, it can be concluded from this investigation that the properties of black cotton soil can be optimally improved by the addition of 5 percent lime and 10 per cent Rice husk ash.

2.0 MATERIALS AND METHOD.

2.1 Material

2.1.1 Corn straw Ash (CSA)

Corn straw ash was obtained from the burnt straw of maize after harvesting. The straw was gathered from a farm in Biu in Borno state.

Figure 1.0 corn straw ash (CSA)

2.1.2 Expansive Clay Soil

The soil for the research was collected from Biu Town at 10.61º N and 12.19ºE. The sample was picked along the soil profile at the depth of 1.2m to avoid the inclusion of organic matter. Preliminary checks indicated that the soil was greyish black in colour and highly plastic in nature.

Figure 2.0 Black cotton soil

2.2 PREPARATIONN OF CORN STRAW ASH

Corn straw were transferred from Biu farm to the geotechnical laboratory belonging Federal Polytechnic Mubi. The straw was burnt to ashes in an incinerator at 400^{oc} for the period of two hours and allowed to cool for three hours before being packed for the experiment.

2.3 LABORATORY TEST CONDUCTED ON NATURAL SOIL AND STABILIZED SOIL

The black cotton soil used in this study was mixed with corn straw ash(CSA) in varying percentages 0%, 4%, 6%, 8%, 10%.

2.3.1 COMPACTION TEST. [14] Compaction tests were conducted in the laboratory on the corn straw ash mixed with black cotton soil. The test was in accordance with AASHTO T99-97 to determine maximum dry density (MDD) and optimum water content (OMC) of all composite were found out and was concluded in the Table 4.

2.3.2 UNCONFINED COMPRESSIVE STRENGTH TEST. As per ASTM D2166-13[15], unconfined compressive test for all composite were conducted in the laboratory using a strain rate 1.2mm/minute and the result was concluded in Table 4.

2.3.3 CALIFORNIA BEARING RATIO (CBR). As per AASHTO T193-93[11], California bearing ratio test for all optimum composite were conducted in the laboratory and the result was in Table 4.

2.3.4 ATTEBERG LIMITS. The test included the determination of the liquid limit, plastic limit and the plasticity index for the natural soil and the soil- ash mixtures. The tests are conducted for uncured stabilized soil samples in accordance with AASHTO T89-90 and T90-96 [17] testing procedures.

Table 1:0 Experiment set up

S/NO	THE MIXTURE WITH CSA PIT 1 DARK BSC
SA1	Clay soil + 0% of Ashes(CSA) + water
SA2	Clay soil + 4% of Ashes(CSA) + water
SA3	Clay soil + 6% of Ashes(CSA) + water
SA4	Clay soil + 8% of Ashes(CSA) + water

3.0 RESULT

Table 2: physical characteristics of virgin black cotton.

S/N	PROPERTY	Test value BCS
1	Percentage passing No.200 sieve (%).	95.8
2	Liquid limit (%).	44.0
3	Plastic limit (%).	20.0
4	Plasticity index (%).	24.0
5	Linear shrinkage (%).	10.9
6	Specific gravity kg/cm3.	2.40
7	Maximum dry density, kg/cm3	1.58
8	Optimum moisture content, %	16.3
9	UCS KN/m2	107.3
10	CBR value %	4.2

3.1 Table 3: chemical composition of corn straw ashes (CSA) and black cotton soil.

CHEMICAL		Silica Si	Iron Fe	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Loss of Ignition	Alumina Al	Titanium Ti	Manganese Mn
CORN STRAW ASHES (CSA)	1	66.32	6.48	5.48	2.20	1.08	6.45	9.57	1.90	0.07	0.45
	2	66.30	6.45	5.46	2.20	1.06	6.46	9.75	1.80	0.06	0.46
	3	66.20	6.46	5.47	2.21	1.07	6.44	9.62	1.90	0.08	0.47
AVERAGE		**66.20**	**6.46**	**5.47**	**2.20**	**1.07**	**6.45**	**9.65**	**1.90**	**0.07**	**0.46**
BLAC COTTON SOIL	1	60.10	21.80	ND	1.95	0.98	13.10	0.98	0.01	ND	0.45
	2	60.00	21.70	ND	1.96	0.97	13.10	0.98	0.02	ND	0.46
	3	60.00	21.60	ND	1.97	0.97	13.10	0.98	0.02	ND	0.45
AVERAGE		**60.00**	**21.7**	**ND**	**1.96**	**0.97**	**13.10**	**0.98**	**0.02**	**ND**	**0.45**

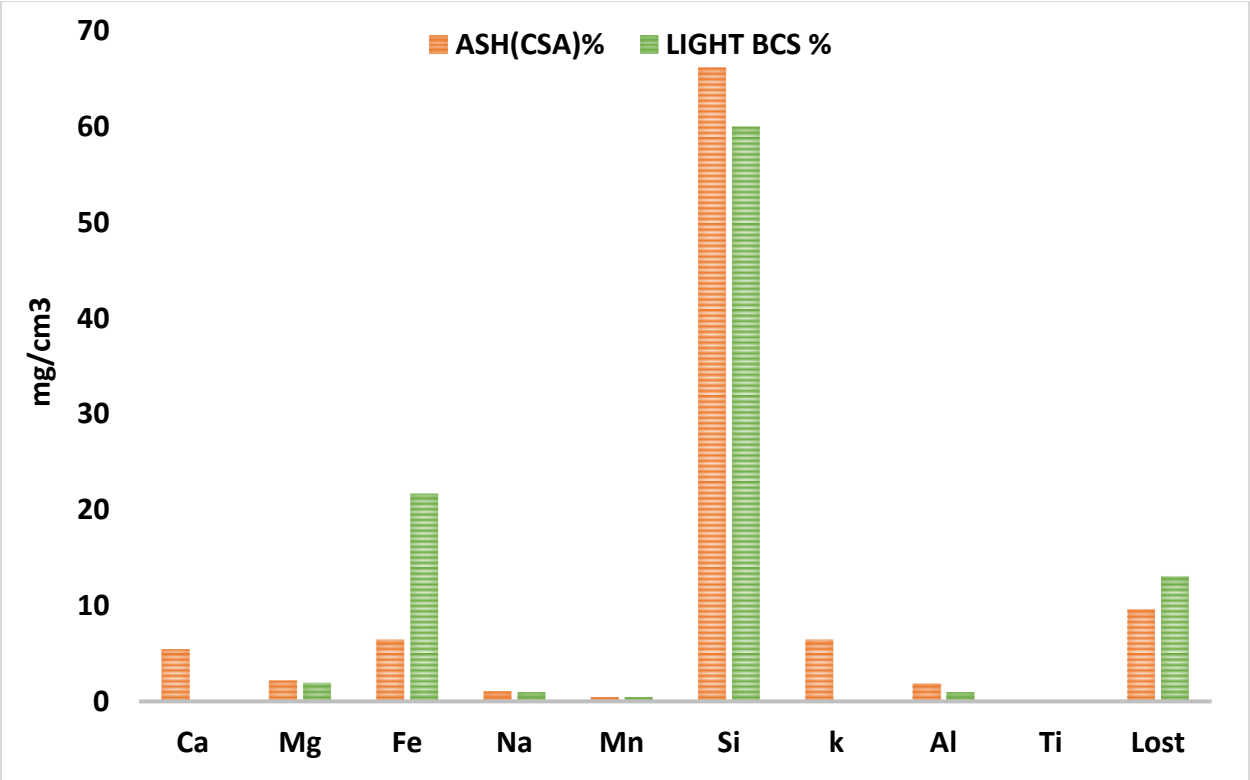

Figure:3 chemical composition of corn straw ash and black cotton soil

3.2 Determining the mechanical Properties

The research investigated the physical properties of clay which include the following; moisture content, dry density, Atteberg limits.

Table 4: plasticity index, CBR and UCS.

ASH %	PLASTICITY INDEX(%)	CBR (%)	UCS KN/M^2
0%	24.0	4.5	107.3
4%	12.8	8.0	125.0
6%	12.6	10.0	133.6
8%	12.4	11.3	140.5
10%	11.3	10.2	86.7

4.1 California bearing ratio (CBR),

The addition of corn straw ash led to an increase of the CBR value. This shows that the load bearing capacity of the sample increased considerably with corn straw ash treatment. Curing however has a significant effect on the CBR values. CBR value increased from 4.2% to 11.3% with CSA at 4% to 8% respectively. And the CBR declined from 11.3% to 10.2% with CSA at 8% to 10% respectively. The improvements in the CBR values satisfy the minimum requirements at 8% ash that qualify them for backfill, embankments and subgrade materials. This increases were as a result of the formation of cementitious compounds, calcium-silicate-hydrates (CSH) and Calcium- aluminate-hydrates (CAH), by calcium from CSA and the readily available silica and alumina from both the soil and corn straw ash. CSH and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to the strength of stabilized soil layers. This is attributed to the pozzolanic reaction between the soil and corn straw ash resulting in the formation of more cementitious compounds.

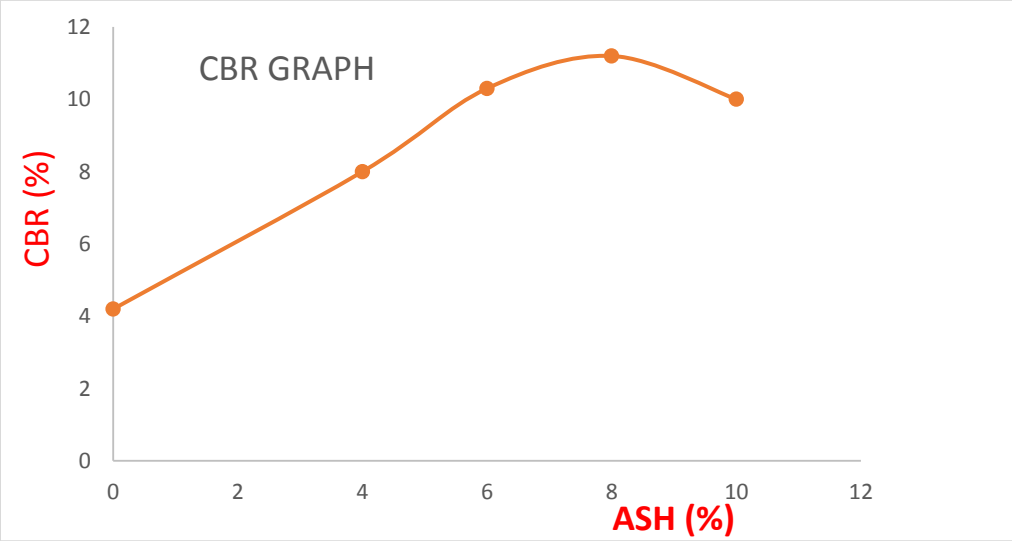

Figure:4 California bearing ratio (CBR)

4.2 UNCORNFINED COMPRESSIVE STRENGTH.

The UCS value of black cotton soil increases from 104 to 140.5kN/m^2 with an increase of corn straw ash from 0% to 8%. The optimum UCS is 140.5%KN/m^2 obtain with 8% ash. The UCS start to decline after this, be coming 86KN/m^2 at 10% ash.

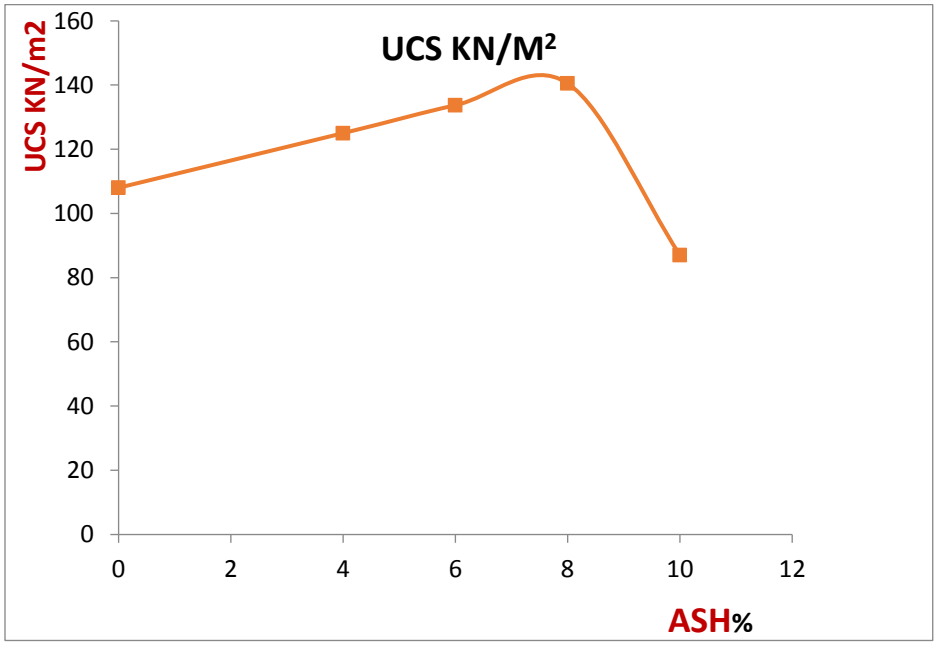

Figure: 5 UCS Graph

4.3 VARIATION OF PLASTICITY INDEX WITH ADDITION OF DIFFERENT CORN STRAW ASH.

In general, the plasticity of the soil is decreases with the addition of CSA. This is clearly shown figure 6. These effects are due to the partial replacement of plastic soil particles with corn straw ash which is non plastic material. Also, flocculation and agglomeration of clay particles caused by cation exchange, occurs, hereby reducing the plasticity of the soil.

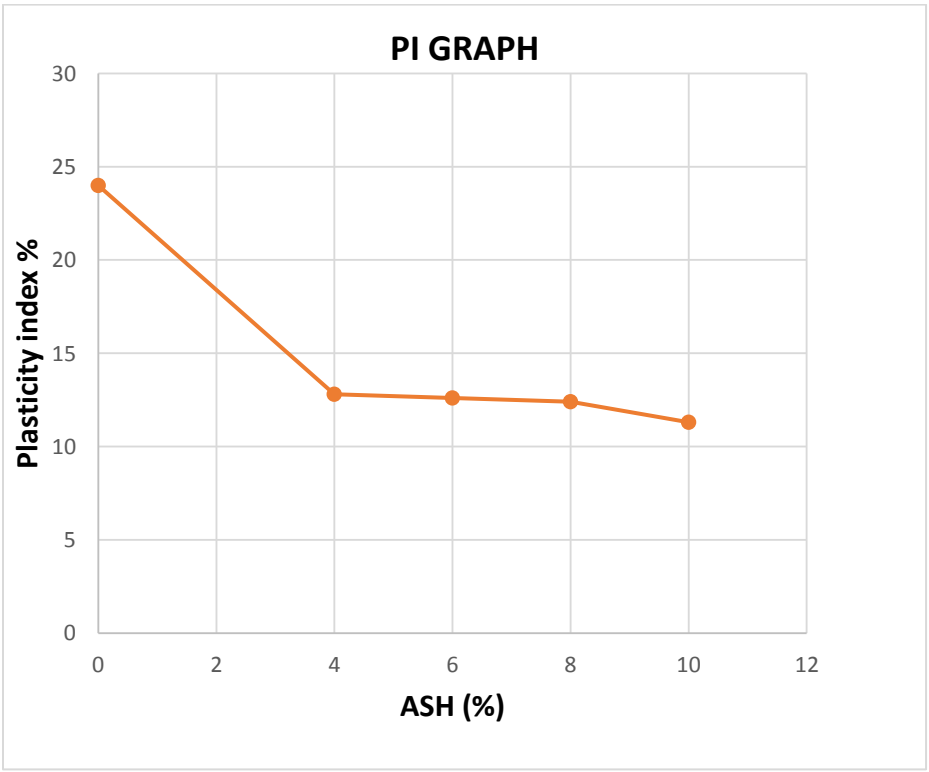

Figure :6 Plasticity index graph

5.0 CONCLUSION

The following conclusions can be drawn from the results of the investigation carried out within the scope of this study.

1. The chemical analysis of corn straw ash indicated that the main elements are silica (66.23%), potassium (6.44%) iron (3.09%), their combined percent composition is 75.76 %. The addition of these percentages is above 70 %, which therefore satisfies ASTM C618 – 12 (ASTM 2012) specification for pozzolanic reaction [13].
2. The plasticity index reduced from 24.2% to 11.3% with increased in content of corn straw ash was satisfies compare with the set standard by Road design manual part III CSA can be used for expansive clay soil stabilization.
3. California bearing ratio increased with increase of corn straw ash CSA. he CBR increase from 4% to 8%and decline from 8% to 10% of an ash.
4. The CBR value of black cotton soil was from 4.2% to 11.2%, the optimum content of ash being 8%. This values of CBR satisfies the requirements for subgrade materials as specified by both American Association of State Highway and transportation(AASTHO) and the Nigeria Highway Design Manual part III, Federal Ministry of Works and Housing.
5. An increase in CBR value will significantly reduce the total thickness of the designed pavement and reduce the cost of the road project.

5.1 RECOMMENDATIONS

Based on the findings of this research, the following recommendations are made:
1. corn straw ash can be used as a soil stabilizing agent for black cotton soil at 8% ash ratio.
2. Further study should be done on corn straw ash as a soil stabilizing material on different types of soils.
3. Further study should be done using finely ground as stabilizer and the result compared with existing ones.
4. A composite additive consisting of CSA and another admixture is recommended for further study.

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