International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 1, pp: (133-141), Month: April - September 2018, Available at: www.researchpublish.com

Stabilization of Deltaic Soils Using Costus Afer Bagasse Fibre Ash as Pozzolana

[1]Charles Kennedy, [2]Isaac Olufemi Agbede, [3]Terence Temilade Tam Wokoma

[1]Faculty of Engineering, Department of Civil Engineering, Rivers State University, Nkpolu, Port Harcourt, Nigeria.
[1]Civil Engineering Department, University of Uyo, Akwa Ibom State, Nigeria
[2]Department of Civil Engineering University of Agriculture, Makurdi
[3]School of Engineering, Department of Civil Engineering, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria.

Abstract: **The experimental study evaluated the engineering properties of soil with the inclusion of costus afer (Bush sugarcane bagasse fiber ash (BSBFA) at varying percentages. Results of compaction of soil between the relationship of optimum moisture content (OMC) and maximum dry density (MDD) of soil and bagasse ash inclusion. MDD and OMC results of lateritic and clay soils at 100% (0%) are 1.803KN/m^3 and 1.640 kN/m^3 and 11.79 Table 3.4 and 3.5 showed the results of compaction of soil between the relationship of optimum moisture content (OMC) and maximum dry density (MDD) of soil and bagasse ash inclusion. MDD and OMC results of lateritic and clay soils at 100% (0%) are 1.803kN/m^3 and 1.640kN/m^3 and 11.79% and 16.39%. At 2.5% to 10% bagasse ash inclusion, lateritic soil decreased from 1.803KN/m^3 to1.589KN/m^3 and of clay, 1.640KN/m^3 to 1.500KN/m^3. While OMC increased from 11.79% to 20.10% (latrite) and 16.39% to 24.61% (clay). Obtained results of CBR test for bagasse fibre ash inclusion of 2.5% to 10% increased from 9.8% to 15.2% (Unsoaked) and 7.% to 13.6% (Soaked) for laterite and 7.6% to 13.92% (Unsoaked) and 6.9% to 11.47% (Soaked) for clay, this showed good remarks to AASHTO classification and to FMW standard. Results of lateritic and clay soils at 100% (0%), 2.5% to 10% BSBFA inclusion increased from 155kPa to 215.2kPa and 78.6kPa to 116.8kPa respectively. Consistency limits test showed the results of lateritic soils at 100% of LL 44.5%, PL 18.3%, IP 26.1%, with BSBFA inclusion increased to LL 51.4%, PL 24.1%., IP 26.7% and clay soil at 100% LL 57.2%, PL 23%, IP 24.2% and clay treated soil increased to LL 58.4%, PL 24.7% and 25.7%. Stabilization was found to satisfy subgrade requirements. The entire results showed the potential of using BSBFA as admixture in soils of clay and laterite.**

Keywords: **Clay and lateritic soils, Costus Afer ash, CBR, UCS, Consistency, Compaction.**

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1. INTRODUCTION

Bagasse is a residue obtained from the burning of bagasse in sugar producing factories. Bagasse is the cellular fibrous waste product after the extraction of the sugar juice from cane mills. For each 10tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse which is a byproduct of the sugar cane industry. When this bagasse is burnt the resultant ash is bagasse ash. Western Maharashtra is having maximum number of sugar factories, these factories faces a disposal problem of large quantity bagasse.

Sabat (2012) , investigated the effects of bagasse ash and lime sludge on OMC, MDD, UCS, soaked CBR and Swelling pressure of an expansive soil in order to study its cost effectiveness in strengthening the sub-grade of a flexible pavement in expansive soil areas. The best stabilization effects were obtained when the optimum percentage of bagasse ash was 8% and lime sludge was

Manikandan and Moganraj (2014) , found that the combined effect of bagasse ash and lime were more effective than the effect of bagasse ash alone in controlling the consolidation characteristics of expansive soil along with the improvement in other properties

Gandhi (2012) successfully worked on improving the existing poor and expansive sub grade soil using bagasse ash. Bagasse ash effectively dries wet soils and provides an initial rapid strength gain, which is useful during construction in wet, unstable ground conditions. The swell potential of expansive soils decreases by replacing some of the volume previously held by order to evaluate the possibility of their use in the industry. He found out that as the percentage of bagasse ash increases in the soil sample, all the properties decrease.

Cordeiro (2009) obtained the important parameter for the production of Sugar Cane Bagasse Ash (SCBA) with pozzolanic activity. The SCBA produced with air calcination at 600°C for 3 hr. with a rate of heating of 10°C/min presents amorphous silica, low carbon content and high specific surface area. The sample produced with these characteristics presents considerable pozzolanic activity according to both mechanical and chemical methods of evaluation.

Goyal *et al*., (2007) reported that SCBA with high specific surface area, high contents of amorphous silica and calcium oxide fulfilled the principal requirements of a pozzolanic material. Ganesan *et al*., (2007) studied on the use of bagasse ash (BA) as partial cement replacement material in respect of cement mortars. Up to 20 % of ordinary Portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete. Several studies have been carried out on the effectiveness of clay stabilization by RHA admixing.

Basha, *et al*., (2005) studied the stabilization of residual soils by chemically using cement and RHA. In general, 6 %, 8 % of cement and 10 %, 15 % RHA show the optimum amount to reduce the plasticity of soil. CBR value determined maximum at 4% cement and 5 % RHA mixtures with soil. According to compressive strength and PI, 6 %, 8% of cement and 15 %, 20 % RHA showed the optimum amount to improve the properties of soils.

2. MATERIALS AND METHODS

2.1 Materials:

2.1.1 Soil:

The deltaic soils (laterite) are abundant in Rivers State within the dry flat country. The soils used for the study was collected from a borrow pit at 1.5 m depth, at Odioku – Odiereke Town Road, Ubie Clan, Ahoada-West, Rivers State, Nigeria, lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Costus Afer (Bush Sugarcane) Bagasse Fibre:

The bush sugarcane bagasse fibre are abundant in Rivers State farmlands / bushes, they are wide plants and covers larger areas, collected from at Odioku Town Farmland / Bush, Ubie Clan, Ahoada-West, Rivers State, Nigeria.

2.2 METHOD:

2.2.1 Sampling Locality:

The soil sample used in this study were collected along Odioku Community road in Ahoada West Local Government, in Rivers state, of Nigeria, (latitude 5.07° 14‘S and longitude 6.65° 80‘E), from trial borrow-pits the various earthworks within the entire roads. The top soil was removed to a depth of 0.5 m before the soil samples were taken, sealed in plastic bags and put in sacks to avoid loss of moisture during transportation. All samples were air dried for about two weeks to take advantage of the aggregating potentials of lateritic soils upon exposure (Allam and Sridharan 1981; Omotosho and Akinmusuru 1992) .

These tests were conducted to prove that fibre product at varying proportions to give positive effect on the stabilization of soil and with binding cementitious inclusions. A number of tests were conducted as these tests include (1) Moisture Content Determination (2) Atterberg limits test (3) Particle size distribution (sieve analysis) and (4) Standard Proctor Compaction test, Califonia Bearing Ratio test (CBR) and Unconfined compressive strength (UCS) tests;

2.2.2 Moisture Content Determination Test:

The natural moisture content of the soil as obtained from the site was determined in accordance with BS 1377 (1990) Part 2. The sample as freshly collected was crumbled and placed loosely in the containers and the containers with the samples were weighed together to the nearest 0.01g.

2.2.3 Grain Size Analysis (Sieve Analysis) Test:

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles.

2.2.4 ConsistencyLimits Test:

This test is performed to determine the plastic and liquid limits of a fine grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

2.2.5 Moisture – Density (Compaction) Test:

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933, therefore, the test is also known as the Proctor test.

2.2.6 Unconfined Compression (UC) Test:

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

2.2.7 California Bearing Ratio (CBR) Test:

The California Bearing Ratio (CBR) test was developed by the California Division of Highways as a method of classifying and evaluating soil- subgrade and base course materials for flexible pavements. CBR is a measure of resistance of a material to penetration. The CBR tests were performed in order to determine effect of fibre inclusion on CBR values of reinforced soils.

3. RESULTS AND DISCUSSIONS

3.1 Compaction Test Results:

Table 3.4 and 3.5 showed the results of compaction of soil between the relationship of optimum moisture content (OMC) and maximum dry density (MDD) of soil and bagasse ash inclusion. MDD and OMC results of lateritic and clay soils at 100% (0%) are 1.803KN/m^3 and 1.640KN/m^3 and 11.79% and 16.39%. At 2.5% to 10% bagasse ash inclusion for lateritic soil decreased from 1.803KN/m^3 to1.589KN/m^3 and of clay, 1.640KN/m^3 to 1.500KN/m^3 . While OMC increased from 11.79% to 20.10% (latrite) and 16.39% to 24.61% (clay).

3.2 California Bearing Ratio:

Obtained results of CBR test for bagasse fibre ash inclusion of 2.5% to 10% increased from 9.8% to 15.2% (Unsoaked) and 7.% to 13.6% (Soaked) for laterite and 7.6% to 13.92% (Unsoaked) and 6.9% to 11.47% (Soaked) for clay, this showed good remarks to AASHTO classification and to FMW standard,.

3.3 Unconfined Compressive Strength Test:

Results of lateritic and clay soils at 100% (0%), 2.5% to 10% BSBFA inclusion increased from 155kPa to 215.2kPa and 78.6kPa to 116.8kPa respectively.

3.4 Consistency Limits Test:

Tables 3.4 and 3.5 and figure 3.1 showed the results of lateritic soils at 100% of LL 44.5%, PL 18.3%, IP 26.1%, with BSBFA inclusion increased to LL 51.4%, PL 24.1%., IP 26.7% and clay soil at 100% LL 57.2%, PL 23%, IP 24.2% and clay treated soil increased to LL 58.4%, PL 24.7% and 25.7%.

Table 3.1: Engineering Properties Of Soil Samples

	(CLAY)	(LATERITE)
Percentage(%) passing BS sieve #200	80.5	36.8
Colour	Grey	Reddish
Specific gravity	2.65	2.40
Natural moisture content (%)	45.5	31.2
Atterberg limits		
Liquid limit (%)	56.1	44.5
Plastic limit (%)	22.4	18.3
Plasticity Index	33.7	26.1
AASHTO soil classification	A-7-6	A-2-6
Compaction characteristics		
Optimum moisture content (%)	12.39	11.79
Maximum dry density ($kN/m^{3)}$	1.64	1.803
Grain size distribution		
Gravel (%)	0	5
Sand (%)	10	20
Silt (%)	48	38
Clay (%)	42	37
Unconfined compressive strength (kPa)	78.6	155
California Bearing capacity (CBR)		
Unsoaked (%) CBR	7.6	9.8
Soaked (%) CBR	7.4	9.2

Table 3.2: Properties of Bush sugarcane bagasse fibre. (Rivers State University of Science and Technology, Chemical Engineering Department, Material Lab.1)

Property	Value
Fibre form	Single
Average length (mm)	150
Average diameter (mm)	0.5
Tensile strength (MPa)	60 - 23
Modulus of elasticity (GPa)	1.1 – 0.35
Specific weight (g/cm^3)	0.52
Natural moisture content (%)	8.8
Water absorption (%)	150 - 223

Source, 2018

Table 3.3: Composition of Bagasse. (Rivers State University of Science and Technology, Chemical Engineering Department, Material Lab.1)

Item	%
Moisture	49.0
Soluble Solids	2.3
Fiber	48.7
Cellulose	41.8
Hemicelluloses	28
Lignin	21.8

Source, 2018

Table 3.4: Oxides Composition of Bagasse Ash (Rivers State University of Science and Technology, Chemical Engineering Department, Material Lab.1)

Oxide	Composition (%)
SiO2	57.95
Al2O3	8.23
FeO3	3.96
CaO	4.52
MgO	4.47
K2O	2.41
LOI*	5.0

Source, 2018

Table 3.5: Results of Subgrade Soil (Lateritic) Test Stabilization with Binding Cementitious Products at Different percentages and Combination

S/no	Description of materials Bush sugarcane bagasses fibre products	Location of road/site	Depth	Chainage	MDD (kN/m³)	OMC (%)	CBR (%)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO Classification	Remarks
	LATERITE + BUSH SUGARCANE BAGASSE FIBRE ASH (BSBFA)												
1	LATERITE 100%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.803	11.79	9.8	44.5	18.3	26.1	36.8	A-2-6	POOR
2	LATERITE 97.5%+BSBFA 2.5%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.722	13.01	10.9	45	21	24	36.8	A-2-6	GOOD
3	LATERITE 95.0%+BSBFA 5.0%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.672	16.03	13.6	46.8	23	23.8	36.8	A-2-6	GOOD
4	LATERITE 92.5%+BSBFA 7.5%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.621	18.22	15.2	48.3	23.5	24.8	36.8	A-2-6	GOOD
5	LATERITE 90%+BSBFA 10%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.589	20.10	11.3	51.4	24.7	26.7	36.8	A-2-6	GOOD

Table 3.6: Results of Subgrade Soil Clay) Test Stabilization with Binding Cementitious Products at Different percentages and Combination

S/no	Description of materials Bush sugarcane bagasses fibre products	Location of road/site	Depth	Chainage	MDD (kN/m³)	OMC (%)	CBR (%)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO Class	Remarks
	CLAY+ BUSH SUGARCANE BAGASSE FIBRE ASH(BSBFA)												
1	CLAY 100%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.640	16.39	7.6	56.1	22.4	33.7	74.4	A-7-6.	POOR
2	CLAY 97.5%+BSBFA 2.5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.625	16.70	9.9	57.2	23	24.2	74.4	A-7-6.	POOR
3	CLAY 95.0%+BSBFA 5.0%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.588	18.40	11.4	58.8	23.9	24.8	74.4	A-7-6.	GOOD
4	CLAY 92.5%+BSBFA 7.5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.561	20.15	13.9	59.7	24.5	25.2	74.4	A-7-6.	GOOD
5	CLAY 90%+BSBFA 10%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.500	24.61	10.3	58.4	24.7	25.7	74.4	A-7-6.	GOOD

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Table 3.7: Summary Results of Soaked and Unsoaked California Bearing Ratio Values of Niger Deltaic Clay and Lateritic Soils Subgrade and Unconfined Compressive Strength Stabilized with Bush sugarcane Products

				Lateritic soil		Swelling test results of lateritic after 72hours period and volume changes measured				Clay soil		Swelling test results after 72hours period and volume changes measured			
S/No	Names of fibre products added to the lateritic/clay soil	Fibre Products %	Laterite and Clay soil %	Unsoaked CBR %	Soaked CBR %	Initial height of samples(mm)	Final height of sample after swelling (mm)	Volume change (mm)	Uconfined Compressive strength (KPa)	Unsoaked CBR %	Soaked CBR %	Initial height of samples(mm)	Final height of sample after swelling (mm)	Volume change (mm)	Uconfined Compressive strength (KPa)
1	Control	0	100	9.8	7.2	50.1	53.6	3.5	155	7.6	6.9	50.0	55.6	4.4	78.6
2	Bush sugarcane fibre ash	2.5	97.50	10.9	9.0	50.8	54.2	4.2	169.1	9.9	8.5	50.1	55.2	5.1	84.8
		5.0	95.00	13.6	12.8	50.9	53.3	2.4	179.7	11.4	10.7	50.0	56.3	6.3	97.7
		7.5	92.50	15.2	13.6	50.4	54.8	4.8	203.8	13.9	11.4	50.8	57.8	7.0	109.3
		10.0	90.00	11.3	10.5	50.6	55.9	5.3	215.2	10.3	8.5	50.5	59.3	8.5	116.8

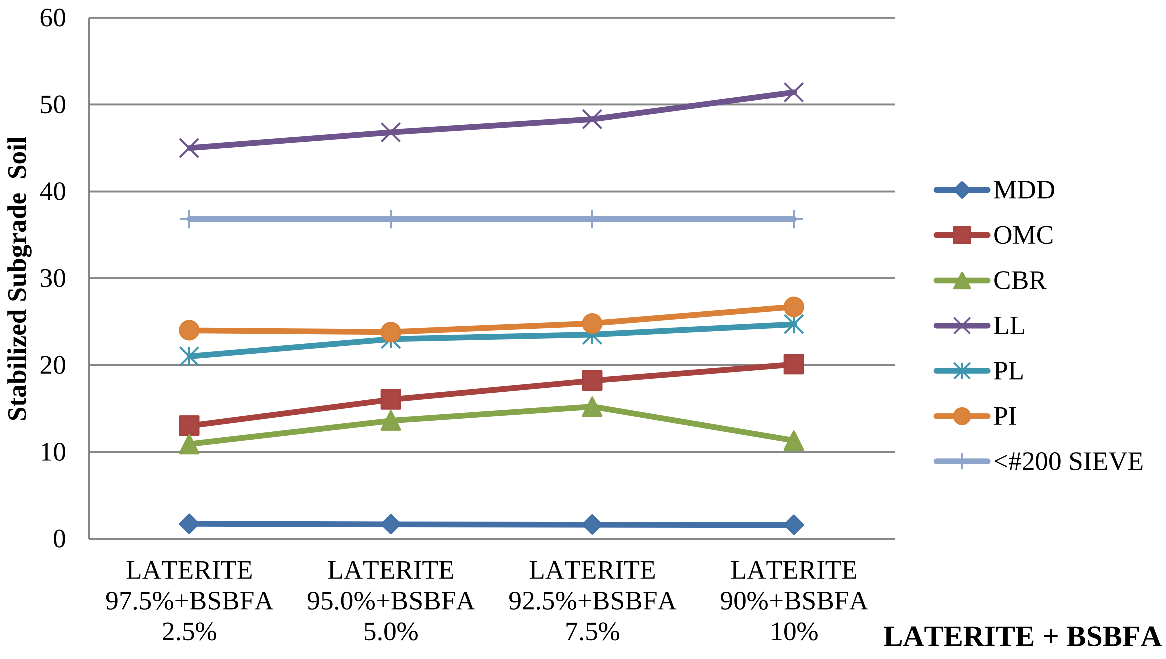

Figure 3.1: Subgrade Stabilization Test of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with BSBFA at Different Percentages and Combinations

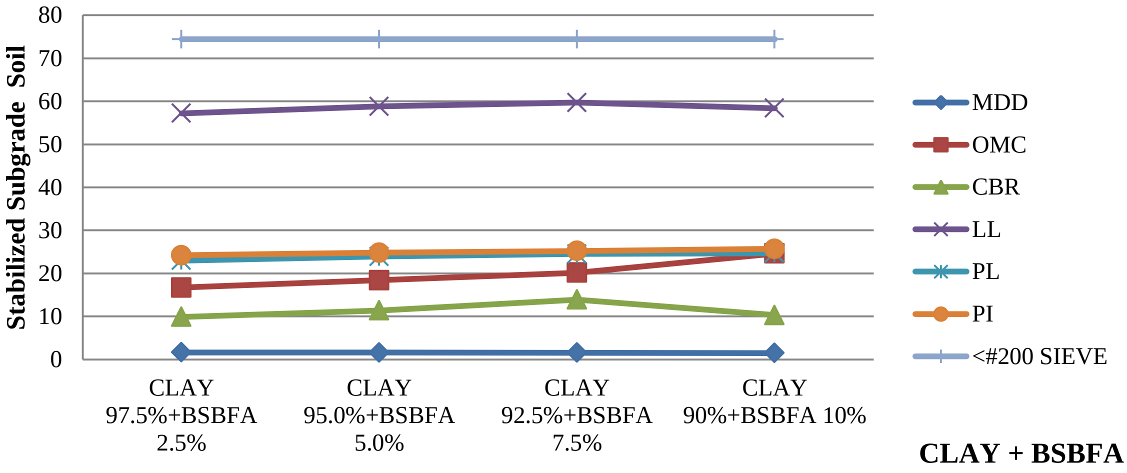

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with BSBFA at Different Percentages and Combination

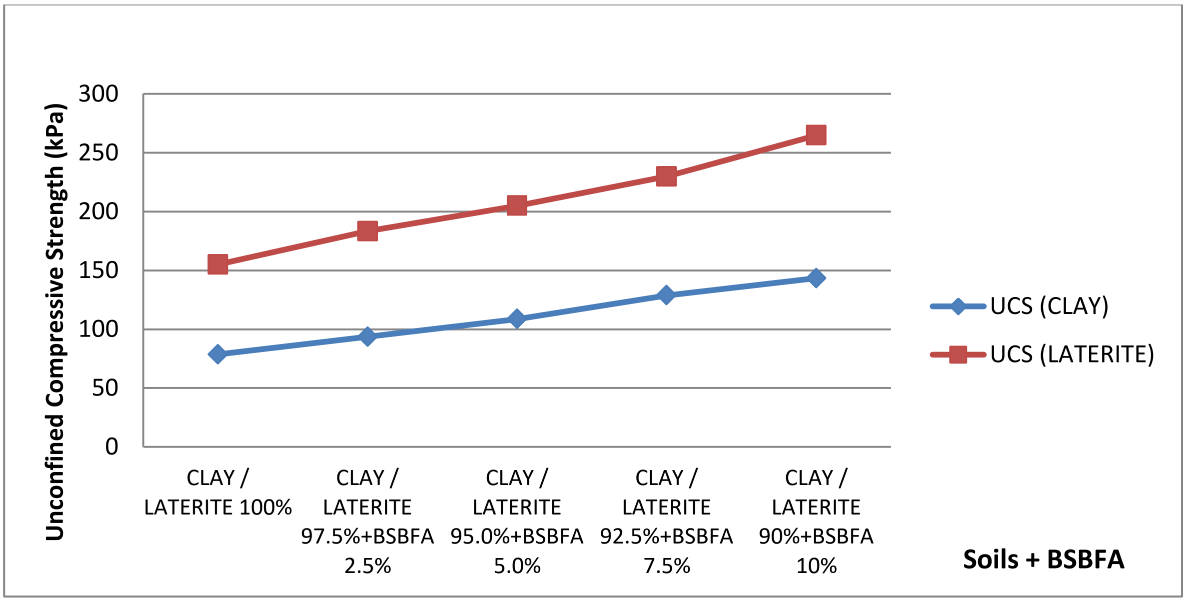

Figure 3.3: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay and Laterite Soils Subgrade with BSBFA

Plate i. Bush sugarcane plant

Plate ii. Bush sugarcane stem

Plate iii. Bush sugarcane wet bagasses/fibre

Plate iv. Bush sugarcane wet bagasses/fibre at day 3

Plate i. Bush Sugarcane Bagasses Fibre ash

4. CONCLUSIONS

From the 3.1, 3.4, 3.5 3.6 and figures 3.1, 3.2 and 3.3, the following conclusions were made from the experimental research results.

i. Preliminary investigations of the engineering Properties of soils at natural state are percentage (%) passing BS sieves #200 are 80.5% (clay) and 36.8 % (laterite).

ii. The soils from wet to dry states are dark grey and reddish brown in color with consistency limit properties of liquid limit of 56.1 % and 44.5 %, plastic limit of 22.4 %

iii. The soils deposit belonged to the group A-2-7 and A-7-6 of American Association of State and Transport Officials (AASHTO) soil classification system

iv. The entire results showed the potential of using bagasse BSBFA as admixture to treat soils of clay and laterite

v. Swelling potential of treated soil decreased with the inclusion of bagasse fibre ash up to 7.5% for both soils

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