International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 1, pp: (148-156), Month: April - September 2018, Available at: www.researchpublish.com

Stabilization of Deltaic Soils using Costus Afer Bagasse Fiber

[1]Charles Kennedy, [2]Essien Udo, [3]Gbinu Samuel Kabari

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

Abstract: **Odioku, Ahoada-West roads are susceptible to pavement degradation resulting in very many failures, potholes and cracks along the stretches. The study investigated the effectiveness natural fibre of costus afer bagasse (Bush sugarcane bagasse fibre (BSBF) as soil stabilizer / reinforcement. Results of preliminary investigations conducted on the deltaic clay and laterite soils as seen in detailed test results showed that the physical and engineering properties fell below the minimum requirement for such application and needs stabilization to improve its properties. The soils classified as A-2-7 and A-7-6 on the AASHTO classification schemes and are less matured in the soils vertical profile and probably much more sensitive to all forms of manipulation that other deltaic lateritic soils are known. The soils are reddish brown and dark grey in color (from wet to dry states) with liquid limits of 56.1 % and 44.5 %, plastic limits of 22.4 % and 18.3 %, and plasticity index of 33.7 % and 26.1 %. The soil has unsoaked CBR values of 7.6%, and 9.8 % and soaked CBR values of 7.4%, and 9.2 %, unconfined compressive strength (UCS) values of 78.6kPa and 155kPa when compacted with British Standard light (BSL), respectively. Compaction results of lateritic and clay soils at 100% of maximum dry density (MDD) at preliminary test were 1.803kN/m^3 and 1.640kN/m^3 with fibre (BSBF) at 0.2%, 0.4%, 0.6%, 0.8% and 1.0% inclusion decreased from 1.803kN/m^3 and 1.652kN/m^3 for lateritic soil and 1.640kN/m^3 to 1.521kN/m^3. Optimum moisture content of lateritic and clay soils were 11.79% and 16.39% at 100% soils (ie no additives), increased from 17.33% (laterite) and 23.26% (clay). California Bearing Ratio (CBR) test results obtained for lateritic and clay soils at 100% and fibre inclusion of 0.25%, 0.50%, 0.75% and 1.0% increased from 9.8% to 17.7% (unsoaked), 7.2 to 14.8% (soaked) for lateritic soil and 7.6% to 15.2% (unsoaked), 6.9% to 12.6% (soaked) for clay soil, both had optimum values percentage inclusion at 0.75%, beyond this value, crack was formed which resulted potential failure state. Unconfined compressive strength test results obtained of lateritic and clay soils at preliminary engineering soil properties are 155KPa and 78.6kPa at 100% soils, increased to 264.8kPa and 143.4kPa respectively. Consistency limits test results at 100% soil of lateritic were LL 44.5%, PL 18.3% and IP 26.1%, at fibre inclusion, decreased to LL 37%, PL 24% and IP 13%, for clay soil at 100%, LL 56.1%, PL 24.4%, IP 33.7% decreased to %, LL 49.7%, PL 22.8%, IP 24.9%. The entire results showed good potential of using Bush sugarcane bagasse fibre as soil stabilizer.**

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

1. INTRODUCTION

Researches and findings stated that natural fibres such as hey, wood and bamboo were used for the improvement of construction materials (Khedari *et al.* [1]). Application of appropriate elements in soil improves its engineering properties such as strength, hardness and deformability. Materials used for reinforcement are usually made of metal, geosynthetics or natural materials such as plant roots and stems. Nowadays, natural fibres such as kenaf, coir, banana, jute, flax, sisal, palm, reed, bamboo and wood fibres are used for soil reinforcement and stabilization (Ramakrishna and Sundararajan [2]

Ghavami *et al.*, [3] observed that the addition of 4 % coconut and sisal fibres to soil causes its deformability to increase significantly. Besides, the creation of cracks in dry seasons was highly lessened.

Prabakar and Sridhar [4] studied on soil specimens reinforced with sisal fibres showed that both fibre content and aspect ratio have important influences in shear strength parameters (c, ∅). They observed that an optimum value for the fibre content exists such that the shear strength decreases with increasing fibre content above this optimum value.

Mesbah *et al*. [5] carried out tensile tests on soil specimens reinforced with sisal fibres and concluded that the fibres, length and their tensile strength are the most important factors affecting the tensile strength of the soil composite.

Bouhicha *et al*. [6] used the shear box test method to evaluate the strength of compacted earth reinforced with barley straw. Their work was part of a wider study of the physical and mechanical properties of fibre-reinforced compressed earth blocks. Their test results are showed that a 1.5 and 3.5 % (by weight of soil) addition of straw increased the apparent cohesion by up to 50 % (from 330 to 493 kPa), but decreased the angle of internal friction.

Sabat [7] studied the effects of polypropylene fiber on engineering properties of RHA-lime stabilized expansive soil. Polypropylene fiber added were 0.5 % to 2 % at an increment of 0.5 %.The properties determined were compaction, UCS, soaked CBR, hydraulic conductivity and P effect of 0 day, 7 days and 28 days of curing ware also studied on UCS, soaked CBR, hydraulic conductivity and swelling pressure. The optimum proportion of Soil: RHA: lime: fiber was found to be 84.5:10:4:1.5.

Ramakrishna and Pradeep [8] studied combined effects of RHA and cement on engineering properties of black cotton soil. From strength characteristics point of view they had recommended 8 % cement and 10 % RHA as optimum dose for stabilization.

Sharma *et al*., [9] investigated the behavior of expansive clay stabilized with lime, calcium chloride and RHA. The optimum percentage of lime and calcium chloride was found to be 4 % and 1% respectively in stabilization of expansive soil without addition of RHA. From UCS and CBR point of view when the soil was mixed with lime or calcium chloride, RHA content of 12 % was found to be the optimum. In expansive soil – RHA mixes, 4% lime and 1% calcium chloride were also found to be optimum.

2. MATERIALS AND METHODS

2.1 Materials:

2.1.1 Soil:

The clay and lateritic soils are abundant in Rivers State within the dry flat country. The soils used for the study were 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 Costus Afer (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 [10]; Omotosho and Akinmusuru [11]) .

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) Consistency 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:

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):

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:

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. 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. 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.

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 relegating and evaluating soil- subgrade and base course materials for flexible pavements. CBR is a quantification of resistance of a material to perforation. The CBR tests were performed in order to determine effect of fibre inclusion on CBR values of reinforced soils.

3. RESULTS AND DISCUSSIONS

Results of preliminary investigations conducted on the deltaic clay and laterite soils as seen in detailed test results given in Tables: 5 showed that the physical and engineering properties fall below the minimum requirement for such application and needs stabilization to improve its properties. The soils classified as A-2-7 and A-7-6 on the AASHTO classification schemes and are less matured in the soils vertical profile and probably much more sensitive to all forms of manipulation that other deltaic lateritic soils are known for (Ola 1974; Allam and Sridharan 1981; Omotosho and Akinmusuru 1992; Omotosho 1993).

The soils are reddish brown and dark grey in colour (from wet to dry states) with liquid limits of 56.1 % and 44.5 %, plastic limits of 22.4 % and 18.3 %, and plasticity index of 33.7 % and 26.1 %. The soil has unsoaked CBR values of 7.6%, and 9.8 % and soaked CBR values of 7.4%, and 9.2 %, unconfined compressive strength (UCS) values of 78.6kPa and 155 kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results:

The results of lateritic and clay soils at 100% of maximum dry density (MDD) at preliminary test were 1.803KN/m^3 and 1.640KN/m^3 with costus afer (bush sugarcane bagasse fibre (BSBF) at 0.2%, 0.4%, 0.6%, 0.8% and 1.0% inclusion decreased from 1.803KN/m^3 and 1.652KN/m^3 for lateritic soil and 1.640KN/m^3 to 1.521KN/m^3. Optimum moisture content of lateritic and clay soils were 11.79% and 16.39% at 100% soils (ie no additives), increased from 17.33% (laterite) and 23.26% (clay).

3.2 California Bearing Ratio (CBR) Test:

Results obtained for lateritic and clay soils at 100% and fibre inclusion of 0.25%, 0.50%, 0.75% and 1.0% increased from 9.8% to 17.7% (unsoaked), 7.2% to 14.8% (soaked) for lateritic soil and 7.6% to 15.2% (unsoaked), 6.9% to 12.6% (soaked) for clay soil, both had optimum values percentage inclusion at 0.75%, beyond this value, crack was formed which resulted potential failure state..

3.3 Unconfined Compressive Strength Test:

Results obtained of lateritic and clay soils at preliminary engineering soil properties are 155KPa and 78.6kPa at 100% soils, increased to 264.8kPa and 143.4kPa respectively.

3.4 Consistency Limits Test:

Results of consistency limits at 100% soil of lateritic were LL 44.5%, PL 18.3% and IP 26.1%, at fibre inclusion, decreased to LL 37%, PL 24% and IP 13%, for clay soil at 100%, LL 56.1%, PL 24.4%, IP 33.7% decreased to %, LL 49.7%, PL 22.8%, IP 24.9%.

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
Consistency 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: 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 Class	Remarks
LATERITE + BUSH SUGARCANE BAGASSE FIBRE (BSBF)													
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 99.75% + BSBF 0.25%	Odioku Rd (CH0+750)	1.5m	Borrow pit	1.767	12.53	13.8	42	20	22	36.8	A-2-6	GOOD
3	LATERITE 99.50%+ BSBF 0.5%	Odioku Rd (CH0+750)	1.5m	Borrow pit	1.700	15.12	15.9	41	21	20	36.8	A-2-6	GOOD
4	LATERITE 99.25%+ BSBF 0.75%	Odioku Rd (CH0+750)	1.5m	Borrow pit	1.671	16.46	17.7	39	23	16	36.8	A-2-6	GOOD
5	LATERITE 99%+ BSBF 1.0%	Odioku Rd (CH0+750)	1.5m	Borrow pit	1.652	17.33	13.3	37	24	13	36.8	A-2-6	GOOD

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

CLAY+ BUSH SUGARCANE BAGASSE FIBRE (BSBF)													
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 99.75% + BSBF 0.25%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.614	17.82	9.6	54.3	22.8	31.5	74.4	A-7-6.	POOR
3	CLAY 99.50%+ BSBF 0.5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.585	19.27	13.4	52	23.5	28.5	74.4	A-7-6.	GOOD
4	CLAY 99.25%+ BSBF 0.75%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.556	21.20	15.2	50.8	23.9	26.9	74.4	A-7-6.	GOOD
5	CLAY 99%+ BSBF 1.0%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.521	23.26	11.3	49.7	24.8	24.9	74.4	A-7-6.	GOOD

International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 1, pp: (148-156), Month: April - September 2018, Available at: www.researchpublish.com

Table 3.6: 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

S/No	Names of fibre products added to the lateritic/clay soil	Fibre Products %	Laterite and Clay soil %	Lateritic soil		Swelling test results of lateritic after 72hours period and volume changes measured			Uconfined Compressive strength (KPa)	Clay soil		Swelling test results after 72hours period and volume changes measured			Uconfined Compressive strength (KPa)
				Unsoaked CBR %	Soaked CBR %	Initial height of samples (mm)	Final height of sample after swelling (mm)	Volume change (mm)		Unsoaked CBR %	Soaked CBR %	Initial height of samples (mm)	Final height of sample after swelling (mm)	Volume change (mm)	
1	Nil	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	0.25	99.75	13.8	10.9	50.5	53.4	2.9	183.3	11.2	8.5	50.2	55.7	5.5	93.6
		0.5	99.50	15.9	12.7	50.7	53.8	3.1	204.9	13.4	10.8	50.5	56.8	6.3	108.6
		0.75	99.25	17.7	14.8	50.4	54.5	4.1	229.9	15.2	12.6	50.4	58.7	8.3	128.
		1.0	99.00	13.3	11.5	50.5	53.7	3.2	264.8	11.3	10.5	50.7	59.6	8.9	143.4

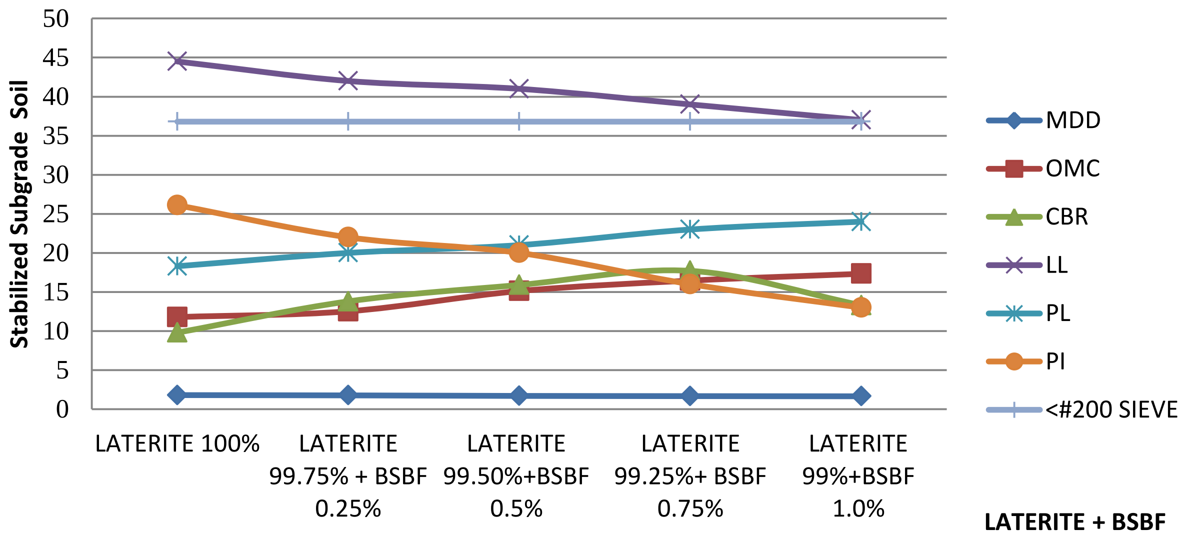

Figure 3.1: Subgrade Stabilization Test of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with BSBF at Different Percentages and Combinations

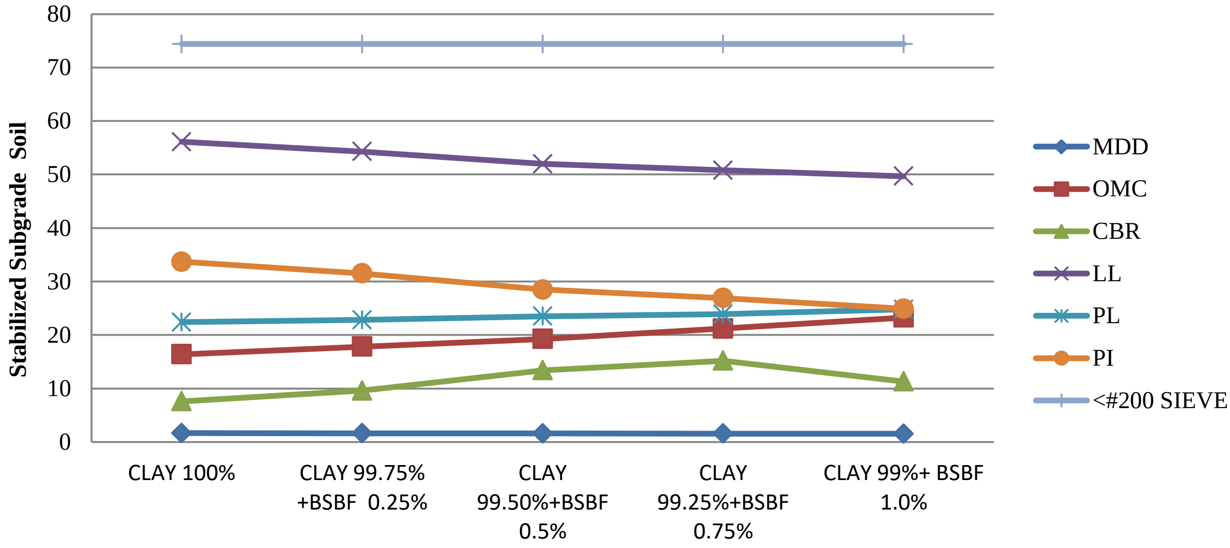

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with BSBF at Different Percentages and Combination

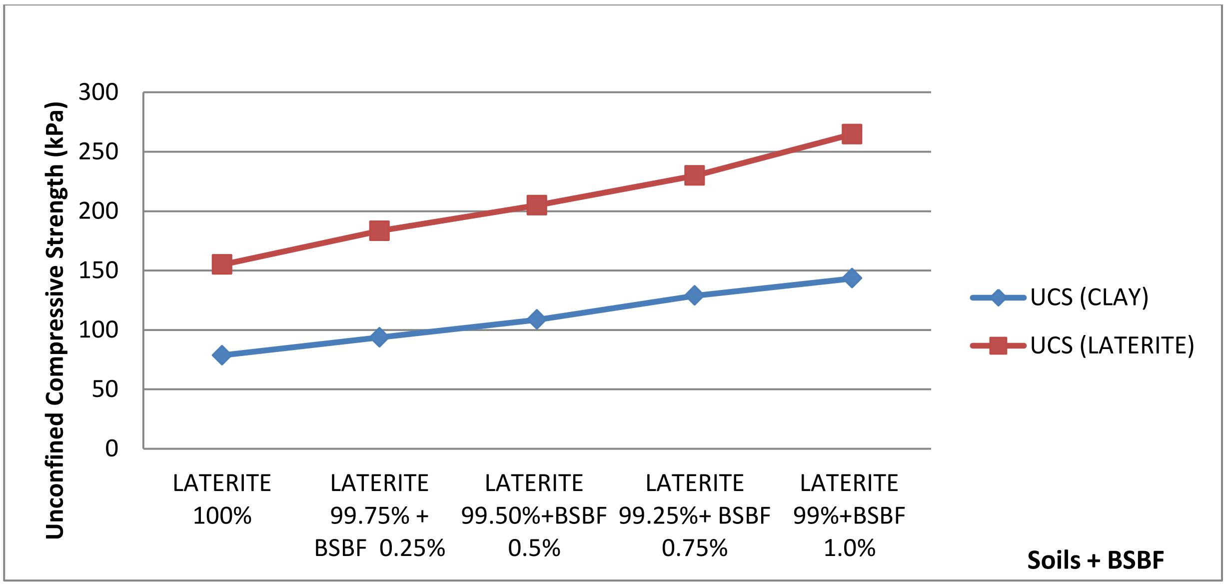

Figure 3.3: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay and Laterite Soils Subgrade with BSBF

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

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. 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

ii. The entire results showed the potential of using bagasse, BSBF as admixtures in treated soils of clay and laterite.

iii. Swelling potential of treated soil decreased with the inclusion of bagasse fibre up to 0.75% for both soils

iv. .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).

v. 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 % and 18.3 %, plasticity index of 33.7% and 26.1 % respectively of clay and laterite. The specific gravity properties are 2.65 % and 2.40 % and natural moisture content 45.5 % and 31.2 %.

vi. The compaction characteristic properties were optimum moisture content 12.39 % and 11.79 %, Maximum dry density 1.64kN/m^3 and 1.803kN/m^3. The preliminary investigation values indicated that the soils are highly plastic.

REFERENCES

[1] Khedari, J., Suttidonk, B., Pratinhong, N., Hirunlabh, J. (2001). New light weight composite construction materials with low thermal conductivity. Cement and Concrete Composites, 23, 65–70.

[2] Ramakrishna, G. and Sundararajan, T. (2005). Studies on the durability of natural fibres and the effect of corroded fibres on the strength of mortar. Cement and Concrete Composites, 27(5): 575-582.

[3] Ghavami, K. h., Toledo Filho, R.D., and Barbosa, N.P., (1999).Behavior of composite soil reinforced with nnatural fibres.Cement and Concrete Composites, 21, 39–48

[4] Prabakar, J. and Sridhar, R.S. (2002). Effect of random inclusion of sisal fibre on strength behavior of soil. Construction and Building Materials, 16, 123–131.

[5] Mesbah, A., Morel, J. C., Walker, P., Ghavami, K. H. (2004). Development of a direct tensile test for compacted earth blocks reinforced with natural fibers. *Journal of materials in Civil Engineering*, 16(1): 95–98.

[6] Bouhicha, M,. Aouissi, F. and Kenai, S. (2005). Performance of composite soil reinforced with barley straw. Cement and Concrete Composites 27(5): 617–621

[7] Sabat, A. K. (2012). Effect of polypropylene fiber on engineering properties of rice husk ash – lime stabilized expansive soil, *Electronic Journal of Geotechnical Engineering, 17(E), 651-660*

[8] Ramakrishna, A.N. and Pradeepkumar, A.V. (2006). Stabilization of Black Cotton Soil using Rice Husk Ash and Cement, Proc. of National conference, Civil Engineering meeting the challenges of Tomorrow, 215-220

[9] Sharma, R.S., Phanikumar, B. R. and Rao, B.V. (2008). Engineering Behaviour of a Remolded Expansive Clay Blended with Lime, Calcium Chloride and Rice-Husk Ash, *Journal of Materials in Civil Engineering*, *20(8): 509-515*

[10] Allam, M. M. and Sridharan, A. (1981). Effect of repeated wetting and drying on shear strength.*Journalof Geotechnical Engineering, ASCE*, 107(4):421–438.

[11] Omotosho, P .O. and Akinmusuru, J .O. (1992). Behaviour of soils (lateritic) subjected to multi-cyclic compaction. *Engineering Geology*, 32, 53–58.