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IMPROVEMENT OF NIGER DELTAIC PROBLEMATIC SOILS WITH COSTUS AFER BAGASSE FIBRE ASH AND CEMENT AS STABILIZERS

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ABSTRACT

This research work evaluated the engineering properties of Niger deltaic problematic clay and lateritic soils from Odioku Community road in Ahoada West Local Government, in Rivers State, stabilized with cement and costus afer bagasse ash (Bush Sugarcane fibre ash (BSBFA) to improve the CBR value of the subgrade and strength. The results of compaction test of soils obtained of maximum dry density (MDD) and Optimum moisture content (OMC) relationship of soil + cement + BSBFA treated soil of combined actions of percentage ratios, 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement and bagasse fibre ash (BSBFA) at corresponding ratios to clay and lateritic soils. OMC values of clay / laterite + cement + BSBFA increased from 12.39% to 12.79% (clay) and 11.79% to 14.02% (laterite). MDD increased from 1.640KN/m^3 and 1.78 KN/m^3 (clay) and 1.803KN/m^3 and 1.860KN/m^3 (laterite). Results of CBR test showed an increased to corresponding increased in additives, for clay soil, an increased from 7.6% to 13.9% (clay) and 9.8% to 35.3% (laterite). At optimum ratio of 85% + 7.5% + 7.5% of soils + cement + BSBFA. UCS of soils + cement + BSBFA with ratios ad above showed an increased values of 78.6kPa to 623kPa (clay) and 155kPa to 874kPa. Consistency limits results of index properties of soil + cement + BSBFA showed decreased values from 36.8% to 31.2 (clay) and 22.8% to 19.5%. The entire results showed the potential of using bagasse BSBFA as admixtures in cement treated soils of clay and laterite.

Key Words: Clay and lateritic soils, Costus Afer Fibre , CBR, UCS, Consistency, Compaction

1.0 INTRODUCTION

Soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals to achieve the desired effect. Generally, the addition of organic (bitumen) or inorganic (cement or lime) chemical compounds, to expansive soils increase the strength, bearing capacity and durability of the soil. These organic or inorganic chemical compounds perform cementations and bonding agents or water proofers/repellants (Slate and Johnson, [1]; Osinubi, [2] , [3]). Organic compounds including resinous and bituminous materials act as water proofers and sometimes behave similar to glue. These water-proofing agents reduce the capacity for water intake and help the soil to retain its dry strength, even under wet condition (Bowles, [4]; O'Flaherty, [5]) Inorganic agents employed for soil stabilization, include Portland cement, lime, slag, sodium silicate, etc. Their functions are to reduce plasticity and facilitate densification. The transformation of soil index properties by adding chemicals such as cement, cement kiln dust, fly ash, lime, or a combination of these, often alters the physical and chemical properties of the soil including the cementation of the soil particles. There are two primary mechanisms by which chemicals alter the soil into a stable subgrade (Production Division Office of Geotechnical Engineering, PDOGE [6]). Increase in particle size by cementation, internal friction among the agglomerates, greater shear strength, reduction in the plasticity index, and reduced shrink/swell potential. ii. Absorption and chemical binding of moisture that will facilitate compaction.

Kalantari *et al.,* [7] experimented the use of cement, polypropylene fibers and optimum moisture content values to strengthen peat. From their laboratory study it was observed that peat with cement and fibers can be used as the base course in the pavement construction. It appears that the fibers prevent the formation and the development of the cracks upon loading and thus increasing the strength of the samples.

Basha, *et al*., [8] 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.

Ganesan *et al*., [9] 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.

2 .0 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 Cement

The cement used was Eagle Portland Cement, purchased in the open market at Mile 3 market road, Port Harcourt, Rivers State.

2.1.3 Bush Sugarcane Bagasse Fibre Ash

The bush sugarcane bagasse fibre ash are the burnt crushed stalks of Bush Sugarcane fibre obtained 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) 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

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 Consistency Limits

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.

3.0 RESULTS AND DISCUSSIONS

3.1 Compaction Test Results

The results of compaction test of soils obtained of Maximum dry density (MDD) and Optimum moisture content (OMC) relationship of soil + cement + BSBFA treated soil of combined actions of percentage ratios, 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement and bagasse fibre ash (BSBFA) at corresponding ratios to clay and lateritic soils.

OMC values of clay / laterite + cement + BSBFA increased from 12.39% to 12.79% (clay) and 11.79% to 14.02% (laterite). MDD increased from 1.640KN/m^3 and 1.78 KN/m^3 (clay) and 1.803KN/m^3 and 1.860KN/m^3 (laterite).

3.2 California Bearing Ratio (CBR) Test

Results of CBR test showed an increased to corresponding increased in additives, for clay soil, an increased from 7.6% to 13.9% (clay) and 9.8% to 35.3% (laterite). At optimum ratio of 85% + 7.5% + 7.5% of soils + cement + BSBFA.

3.3 Unconfined Compressive Strength Test

Obtained results from table 3.5 and 3.6 of UCS of soils + cement + BSBFA with ratios ad above showed an increased values of 78.6kPa to 623kPa (clay) and 155kPa to 874kPa.

3.4 Atterberg Limits Test

Results of index properties of soil + cement + BSBFA showed decreased values from 36.8% to 31.2 (clay) and 22.8% to 19.5%.

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 4.4: 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 3.4: 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/m^3)	OMC (%)	CBR (%)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO Class	Remarks
LATERITE + CEMENT													
1	LATERITE 100%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.803	11.83	9.80	44.5	18.3	26.1	36.8	A-2-6	POOR
2	LATERITE 98% + CEMENT 2%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.853	8.82	18.90	40.8	22.6	18.2	36.8	A-2-6	GOOD
3	LATERITE 96%+ CEMENT 4%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.887	9.67	27.30	40.1	23	17.1	36.8	A-2-6	GOOD
4	LATERITE 94%+ CEMENT 6%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.925	10.19	52.60	38	23.5	14.5	36.8	A-2-6	GOOD
5	LATERITE 92%+ CEMENT 8%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.934	10.75	78.35	36	25	11	36.8	A-2-6	GOOD
6	LATERITE 90%+ CEMENT 10%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.938	12.09	37.35	35.4	26	10.4	36.8	A-2-6	GOOD
LATERITE + CEMENT + BSBFA													
7	LATERITE 95%+ CEMENT 2.5% +BSBFA 2.5%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.858	12.61	21.30	44.8	22	22.8	36.8	A-2-6	GOOD
8	LATERITE 90 %+ CEMENT 5% +BSBFA 5%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.860	14.03	28.14	45.9	24.2	21.7	36.8	A-2-6	GOOD
9	LATERITE 85%+ CEMENT 7.5% +BSBFA 7.5%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.850	16.45	35.30	46.9	25.6	21.3	36.8	A-2-6	GOOD
10	LATERITIE 80%+ CEMENT 10% +BSBFA 10%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.846	17.89	27.30	45.6	26.1	19.5	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/m^3)	OMC (%)	CBR (%)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO Class	Remarks
CLAY +CEMENT													
1	CLAY 100%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.640	12.39	7.6	56.1	22.4	33.7	74.4	A-7-6.	POOR
2	CLAY 98% + CEMENT 2%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.774	9.67	9.8	51.8	23	27.8	74.4	A-7-6.	POOR
3	CLAY 96%+ CEMENT 4%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.784	10.23	14.8	49.9	25.2	24.7	74.4	A-7-6.	GOOD
4	CLAY 94%+ CEMENT 6%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.794	11.14	16.9	47.5	24.9	22.5	74.4	A-7-6.	GOOD
5	CLAY 92%+ CEMENT 8%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.801	12.77	21.3	45.5	26	19.5	74.4	A-7-6.	GOOD
6	CLAY 90%+ CEMENT 10%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.808	13.99	15.7	43.8	26.8	17.6	74.4	A-7-6.	GOOD
CLAY +CEMENT + BUSH SUGARCANE BAGASSE FIBRE ASH (BSBFA)													
7	CLAY 95%+ CEMENT 2.5% +BSBFA 2.5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.778	10.96	12.2	57.8	26	31.8	74.4	A-7-6.	GOOD
8	CLAY 90 %+ CEMENT 5% +BSBFA 5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.780	12.79	13.8	59.2	27	32.2	74.4	A-7-6.	GOOD
9	CLAY 85%+ CEMENT 7.5% +BSBFA 7.5%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.770	13.81	14.8	60.2	29	31.2	74.4	A-7-6.	GOOD
10	CLAY 80%+ CEMENT 10% +BSBFA 10%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.768	15.29	12.8	62	31	31	74.4	A-7-6.	GOOD

Table 3.6: Results of Unconfined Compressive strength Soils (Clay and Laterite) Test Stabilization with Binding Cementitious additives + fibre Products at different Percentages and Combinations

			CLAY SOILS UNCONFINED COMPRESSIVE STRENGTH (UCS) TEST SUMMARY RESULTS AT (CH6+300)					LATERITIC SOILS UNCONFINED COMPRESSIVE STRENGTH (UCS) TEST SUMMARY RESULTS AT (CH0+750)				
S/NO	DESCRIPTION OF MATERIALS BUSH SUGARCANE BAGASSES FIBRE PRODUCTS	LOCATION OF ROAD/SITE	2 DAYS CURING PERIODS	7 DAYS CURING PERIODS	14 DAYS CURING PERIODS	21 DAYS CURING PERIODS	28 DAYS CURING PERIODS	2 DAYS CURING PERIODS	7 DAYS CURING PERIODS	14 DAYS CURING PERIODS	21 DAYS CURING PERIODS	28 DAYS CURING PERIODS
Soil +Cement												
1	SOIL 100%	Odioku Rd(CH0+750) and (CH6+300)	78.6	-	-	-	-	155	-	-	-	-
2	SOIL 98% + CEMENT 2%	Odioku Rd(CH0+750) and (CH6+300)	156	178	195	228	245	335	360	385	408	438
3	SOIL 96%+ CEMENT 4%	Odioku Rd(CH0+750) and (CH6+300)	278	304	334	356	375	485	508	537	555	570
4	SOIL 94%+ CEMENT 6%	Odioku Rd(CH0+750) and (CH6+300)	456	470	495	515	538	743	760	785	815	542
5	SOIL 92%+ CEMENT 8%	Odioku Rd(CH0+750) and (CH6+300)	631	648	663	695	720	912	938	954	977	995
6	SOIL 90%+ CEMENT 10%	Odioku Rd(CH0+750) and (CH6+300)	864	885	905	925	928	945	1345	1365	1390	1415
Soil +Cement +Bush sugarcane Bagasse Fibre Ash (BSBFA)												
12	SOIL 95%+ CEMENT 2.5% +BSBFA 2.5%	Odioku Rd(CH0+750) and (CH6+300)	262	281	301	318	328	478	493	515	533	553

13	SOIL 90 %+ CEMENT 5% +BSBFA 5%	Odioku Rd(CH0+750) and (CH6+300)	448	460	481	495	518	735	752	770	794	805
14	SOIL 85%+ CEMENT 7.5% +BSBFA 7.5%	Odioku Rd(CH0+750) and (CH6+300)	438	453	470	419	506	914	930	948	963	984
15	SOIL 80%+ CEMENT 10% +BSBFA 10%	Odioku Rd(CH0+750) and (CH6+300)	563	580	597	609	623	785	816	835	856	874

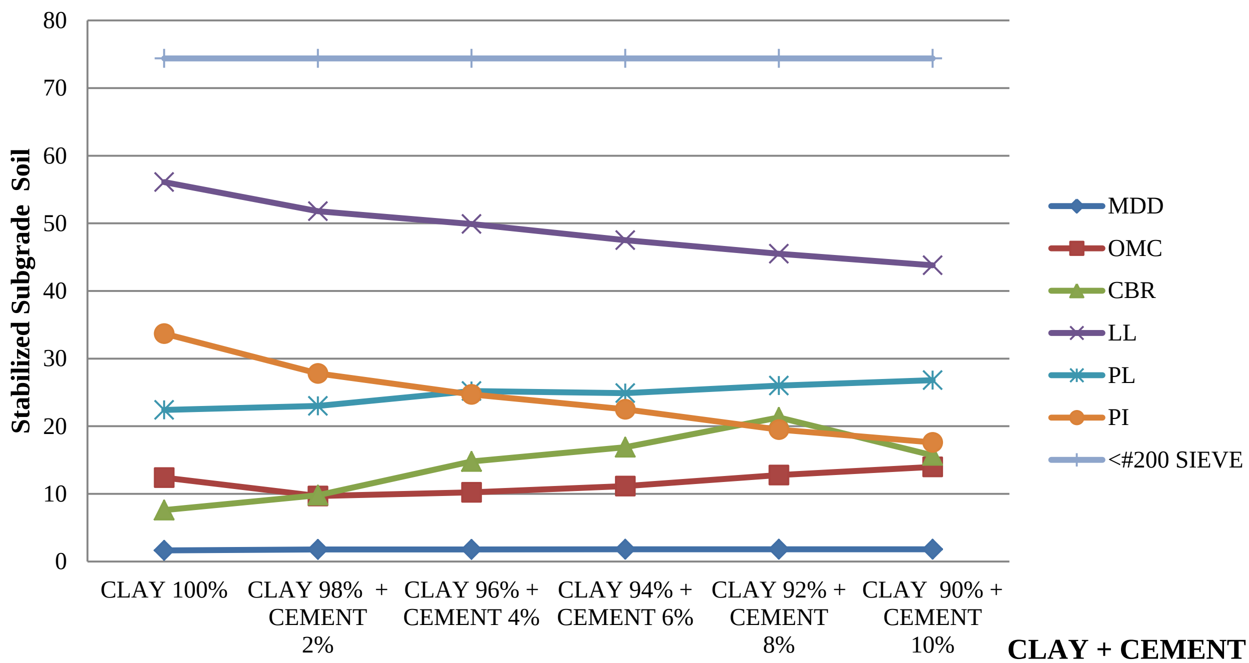

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combination

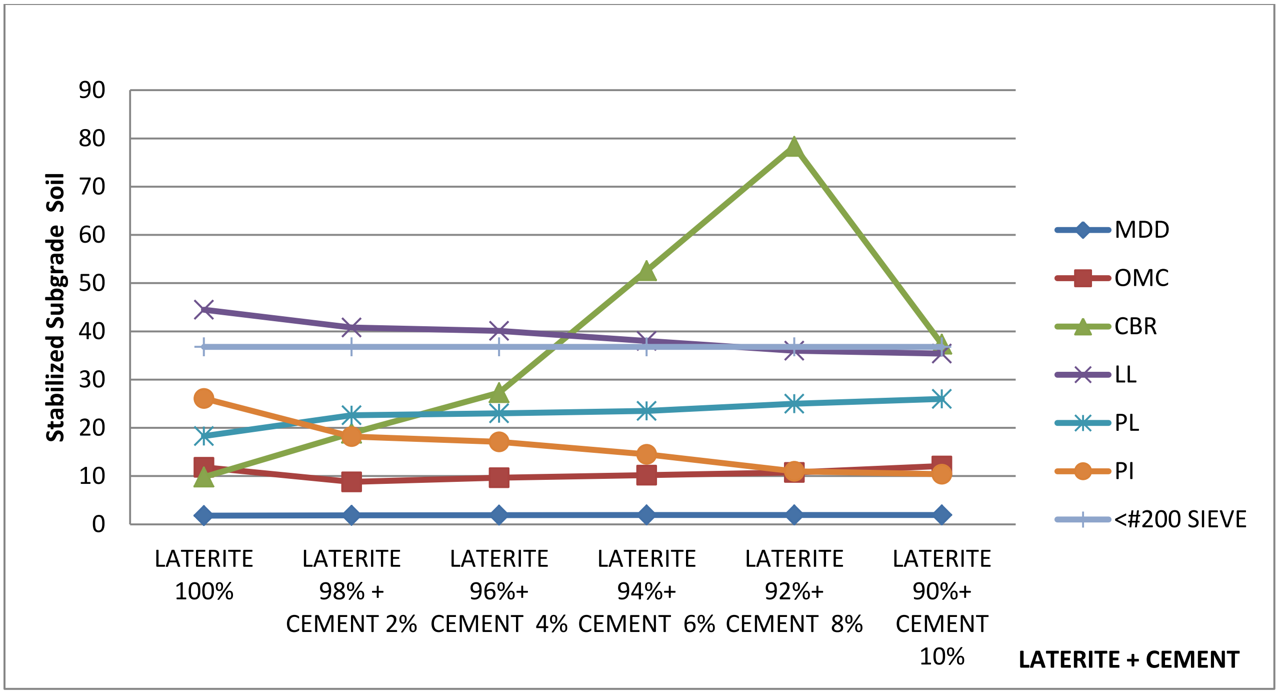

Figure 3.2: Subgrade Stabilization Test of Laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combination

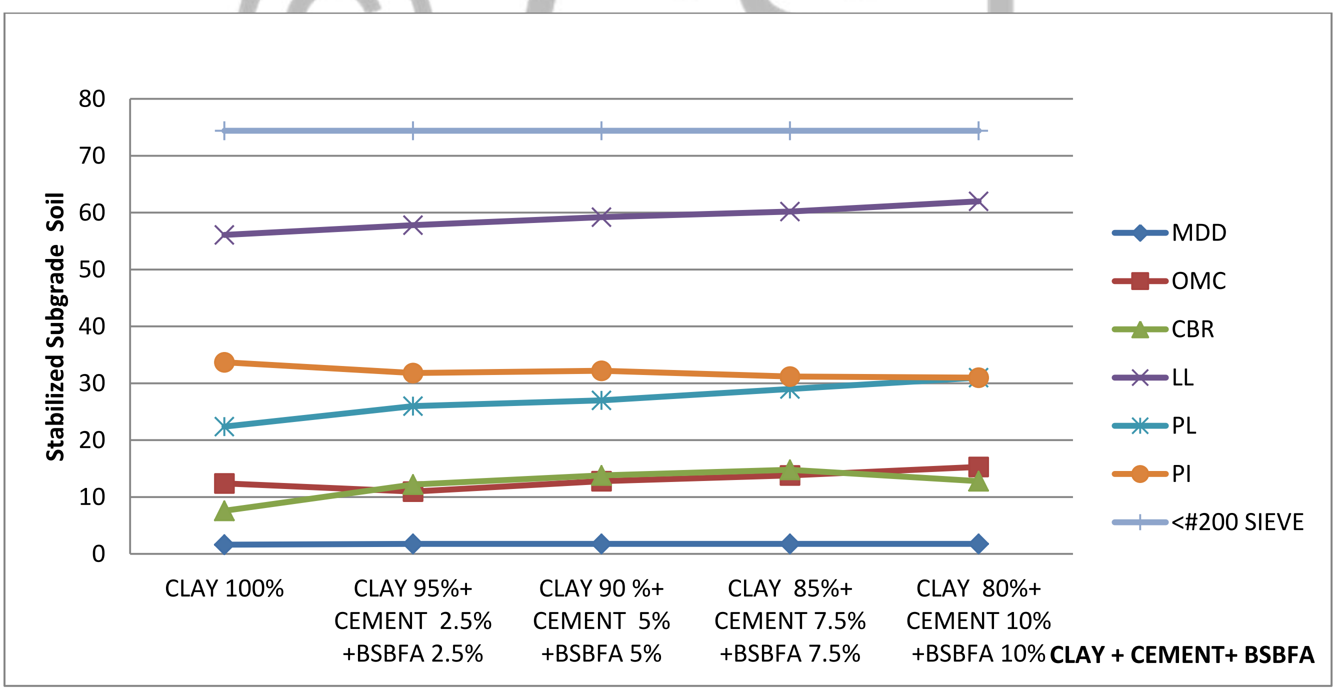

Figure 3.3: Subgrade Stabilization Test of Clay soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBFA at Different Percentages and Combination

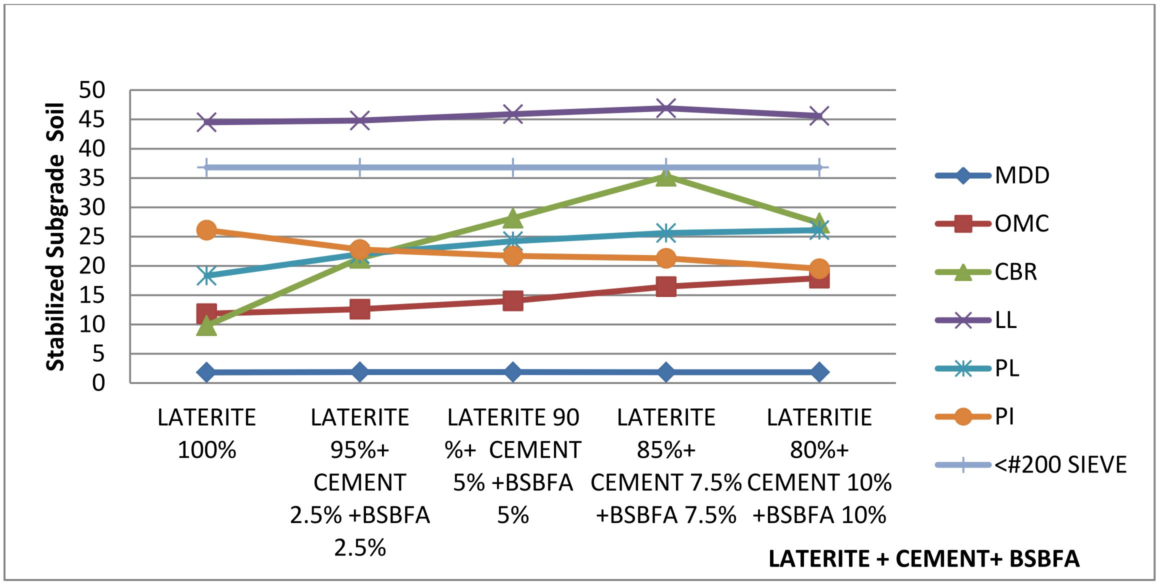

Figure 3.4: **Subgrade Stabilization Test of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBFA at Different Percentages and Combination**

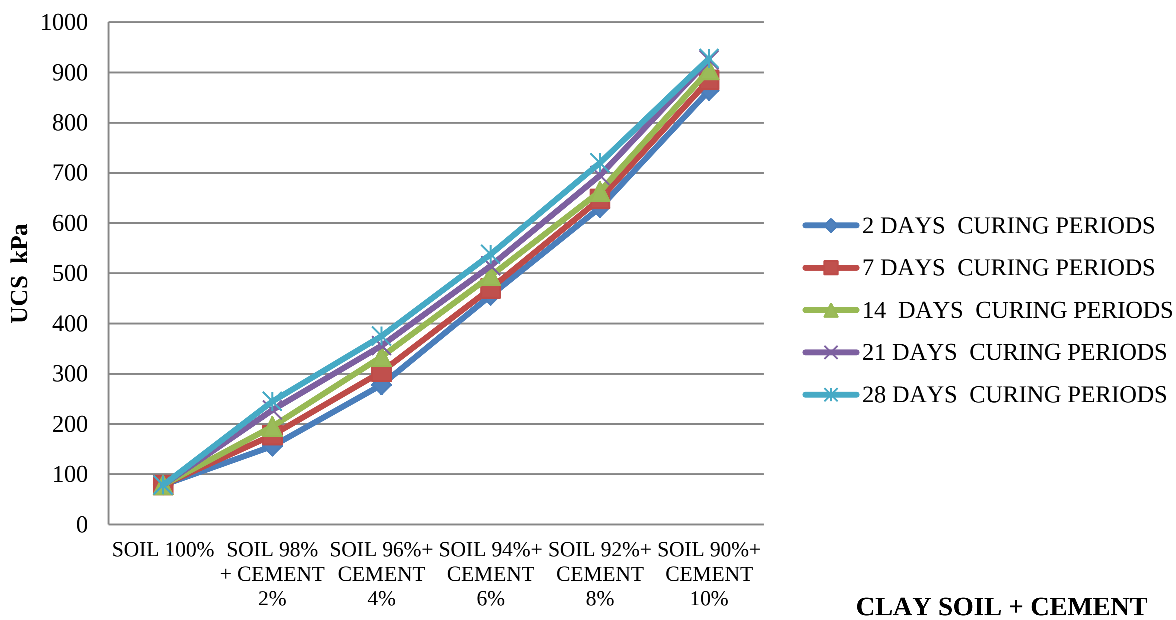

Figure 3.5: **Unconfined compressive strength (UCS) of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combinations**

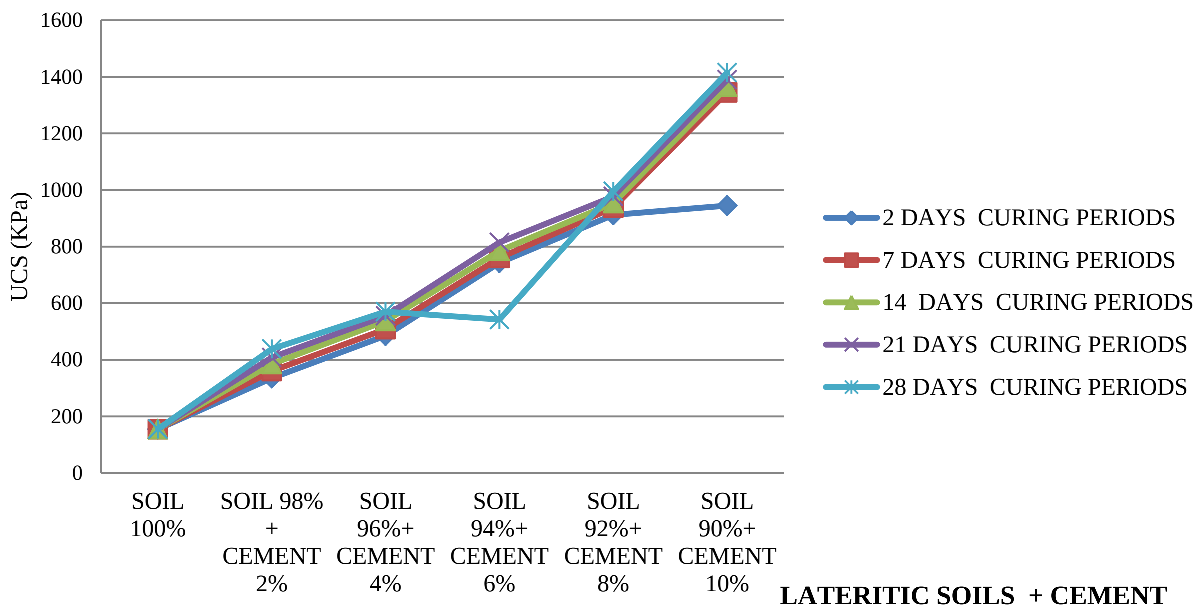

Figure 3.6: Unconfined compressive strength (UCS) of laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with cement at different percentages and combinations

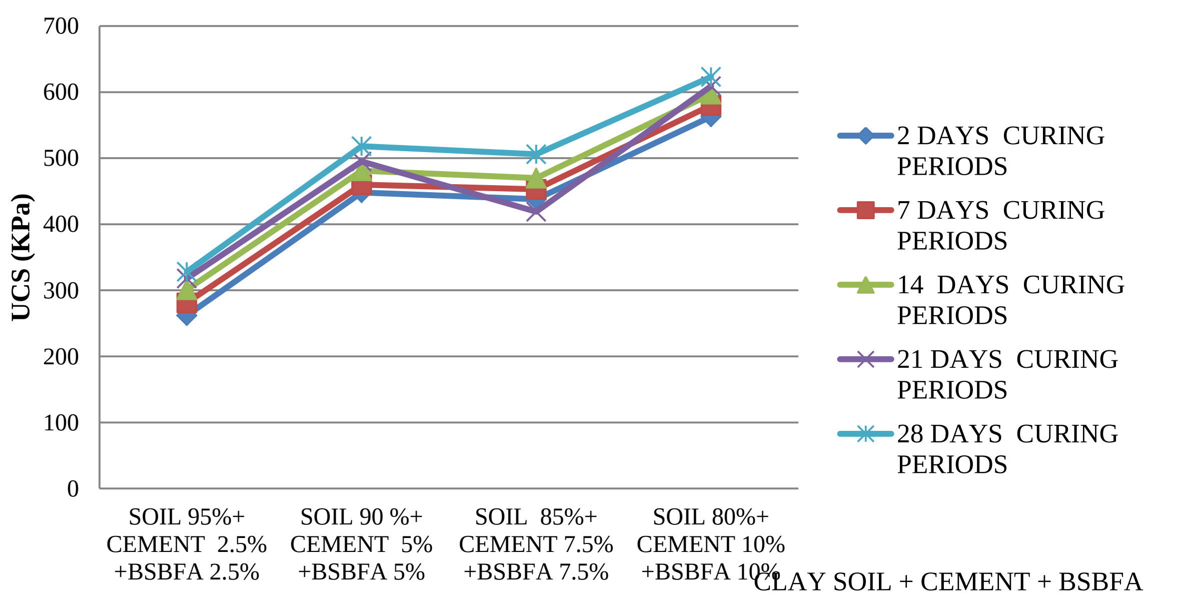

Figure 3.7: Unconfined compressive strength (UCS) of clay soil from Odioku in Ahoada-West L.G.A of Rivers State with cement and BSBFA at different percentages and combinations

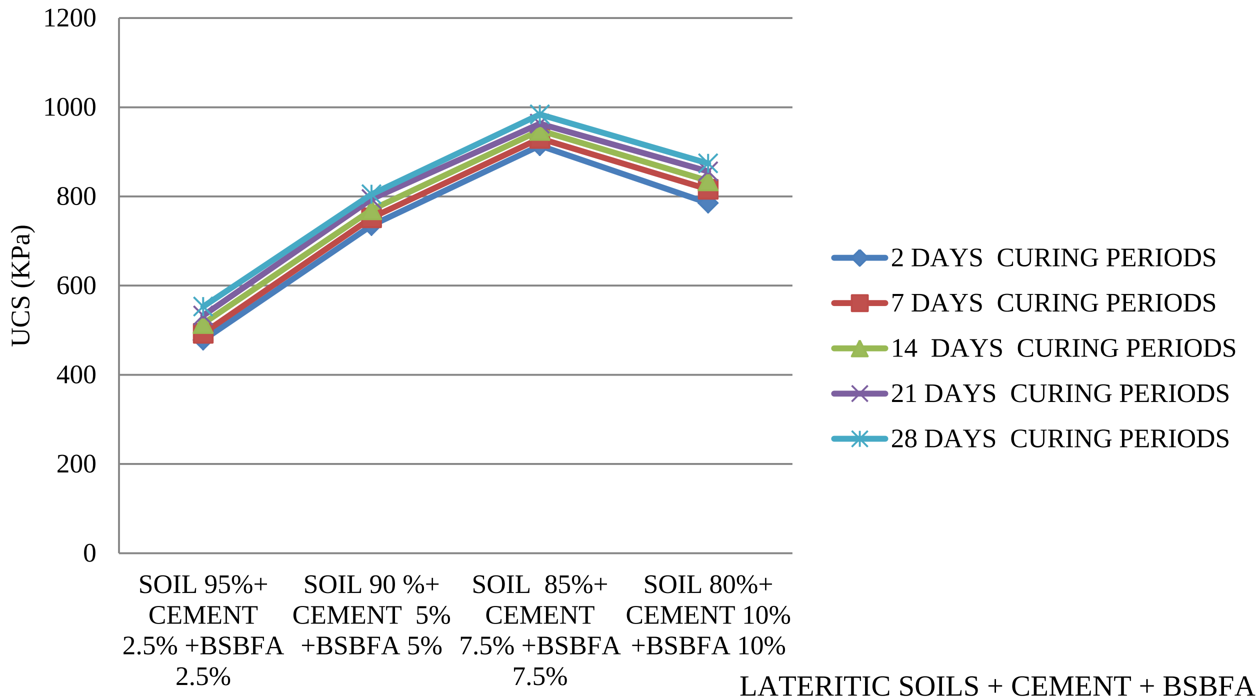

Figure 3.7: Unconfined Compressive Strength (UCS) of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBFA at Different Percentages and Combinations

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. Bagasse ash proved to be a good pozzolana in soil stabilization and modification

ii. At 8% of cement CBR values reached optimum, beyond this range, cracks exist and 7.5% cement + 7.5% BSBFA, optimum value are reached.

iii. The entire results showed the potential of using bagasse BSBFA as admixture in cement treated soils of clay and laterite with 8 % cement optimum

iv. The entire results showed the potential of using bagasse, BSBFA as admixtures in cement and lime treated soils of clay and laterite

v. 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.

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