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Research Article

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Effect of Composite Materials on Geotechnical Characteristics of Expansive Soil Stabilization Using Costus Afer and Cement

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Abstract This experimental study investigated the problematic engineering properties of soils with high plasticity level, high swelling and shrinkage potentials used in pavement design in the Nigerian Niger Delta region. The application of stabilizing agents of cement and costus afer bagasse fibre (Bush Sugarcane Bagaase Fibre) were mixed in single and combines actions to improved their unique promerties since the soils in this zone fall short of the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW 1997). Results of compaction test of optimum moisture content of soil + cement treated soil increased from 12.93% to 13.99% (clay), 11.83% to 12.0% (laterite). Soil + cement + BSBF treated soils increased from 12.93% to 13.10% (clay) and 11.79% to 12.992% (laterite). Maximum dry density results for cement + soil of 2% to 10 %, increased from 1.640KN/m^3 and 1.808 KN/m^3 (clay) and 1.803KN/m^3 and 1.939KN/m^3 (laterite), clay / laterite + cement + BSBF of ratio above increased from 1.640KN/m^3 and 1.79KN/m^3 (clay) and 1.803KN/m^3 and 1.868KN/m^3 (laterite). California bearing ratio test results of soil + cement and soil + cement + bagasse fibre (BSBF) shown in tables 3.4 and 3.5 increased from 7.6% to 21.3% (clay) and 9.8% to 78.35% (laterite) at optimum percentage inclusion of soils (clay and laterite) 92% + cement 8%). For soil + cement + BSBF, an increased from 7.6% to 24.7% (clay) and 9.8% to 90.84%, with optimum inclusion percentage ratio of soils 92% + cement 7.25 + BSBF 0.75%. Unconfined compressive strength test results of soil + cement treated soils of clay and laterite increased from 78.6kPa to 928kPa (clay) and 155kPa to 1415kPa (laterite), soil + cement + BSBF increased from 78.6kPa to 678kPa (clay) and 155kPa to 885kPa (laterite). Results of consistency showed decreased values of LL from 56.1% to 43.8% (clay) and 44.5% to 35.4% (laterite), of soil + cement treated soil and decreased increased from 56.1% to 47.9% (clay) and 44.5 % to 41.5% (laterite), of soil + cement + BSBF treated soils. Entire results showed that inclusion stabilizing material improved strength properties of the soils.

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

1. Introduction

Soil Stabilization has proved to be very economical as it provides cheap materials for the construction of low cost roads. Local materials can be used effectively. There are many techniques of soil stabilization. Cement stabilization is an important method of stabilization. it has proved very much effective in case of sandy soil due to the ease of pulverization and mixing and the smaller quantity of cement required. Cement stabilization refers to stabilizing soils with Portland cement. The primary reaction is with the water in the soil that leads to the formation of a cementitious material. Soil stabilization is the process of the alteration of the geotechnical properties to satisfy the engineering requirements [1]. Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. A number of stabilizers, such as lime, cement and fly ash, depend on their chemical reactions with the soil elements in the presence of water [2-3]. Other additives, such as geofiber and geogrid, depend on their physical effects to improve soil properties [4-5]. In addition, it can be combined both of chemical and physical stabilization, for example, by using lime and geofiber or geotextile together [6-7]. Lime is the oldest traditional chemical stabilizer used for soil stabilization [3]. However, soil stabilization using lime involves advantages and disadvantages. This study provides details of advantages and disadvantages of using lime as soil stabilizer. In addition, to control the disadvantages inherent to lime treated soil, proposing an alternative material was discussed.

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 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

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 [8-9].

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 Consisteny 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. Results and Discussions

Table 3.1 showed the experimented results of groundwork results of lateritic and clay soils obtained fron Odiokwu – Odiereke road at CH0+750 and CH6+300. Soils are classified to as A-2 -7 and A – 7 – 6 on the AASHTO classification scheme.

3.1 Compaction Test Results

Results of compaction test of the relationship linking Optimum moisture content (OMC) and maximum dry density (MDD) of clay and lateritic soils + cement reinforced soil and soil + cement +bush sugarcane bagasse fibre (BSBF) reinforced soils at combined actions of 0% soils, 2%, 4%, 6%, 8% 10% cement to soil ratios and 3.75% + 0.25%, 5.5% + 0.5%, 7.25% + 0.75% and 9% + 1.0% of cement and BSBF combined percentages.

OMC soil + cement treated soil increased from 12.93% to 13.99% (clay), 11.83% to 12.0% (laterite). Soil + cement + BSBF treated soils increased from 12.93% to 13.10% (clay) and 11.79% to 12.992% (laterite).

MDD results for cement + soil of 2% to 10 %, increased from 1.640KN/m^3 and 1.808 KN/m^3 (clay) and 1.803KN/m^3 and 1.939KN/m^3 (laterite), clay / laterite + cement + BSBF of ratio above increased from 1.640KN/m^3 and 1.79KN/m^3 (clay) and 1.803KN/m^3 and 1.868KN/m^3 (laterite).

3.2 California Bearing Ratio (CBR) Test

CBR test results of soil + cement and soil + cement + bagasse fibre (BSBF) shown in tables 3.4 and 3.5 increased from 7.6% to 21.3% (clay) and 9.8% to 78.35% (laterite) at optimum percentage inclusion of soils (clay and laterite) 92% + cement 8%).

For soil + cement + BSBF, an increased from 7.6% to 24.7% (clay) and 9.8% to 90.84%, with optimum inclusion percentage ratio of soils 92% + cement 7.25 + BSBF 0.75%.

3.3 Unconfined Compressive Strength Test

Table 3.4 and 3.5 showed the results of soil + cement treated soils of clay and laterite increased from 78.6kPa to 928kPa (clay) and 155kPa to 1415kPa (laterite), soil + cement + BSBF increased from 78.6kPa to 678kPa (clay) and 155kPa to 885kPa (laterite).

3.4 Consistency Limits Test

Results from tables 3.4 and 3.5, results showed decreased values of LL from 56.1% to 43.8% (clay) and 44.5% to 35.4% (laterite), of soil + cement treated soil and decreased increased from 56.1% to 47.9% (clay) and 44.5 % to 41.5% (laterite), of soil + cement + BSBF treated soils.

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/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

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/m^3)	OMC (%)	CBR (%)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO Class	Remarks
		LATERITE +CEMENT +BUSH SUGARCANE BAGASSE FIBRE (BSBF)											
1	LATERITE 100%	Odioku Rd(CH0+ 750)	1.5 m	Borrow pit	1.80 3	11.83	9.80	44. 5	18. 3	26. 1	36.8	A-2-6	POOR
2	LATERITE 96%+ CEMENT 3.75% +BSBF 0.25%	Odioku Rd(CH0+ 750)	1.5 m	Borrow pit	1.86 1	10.97	28.0 8	43. 9	23	20. 9	36.8	A-2-6	GOOD
3	LATERITE 94%+ CEMENT	Odioku Rd(CH0+ 750)	1.5 m	Borrow pit	1.86 6	11.85	53.1 5	42. 4	23. 6	18. 8	36.8	A-2-6	GOOD

	5.5% +BSBF 0.50%												
4	LATERITE 92%+ CEMENT 7.25% +BSBF 0.75%	Odioku Rd(CH0+ 750)	1.5 m	Borrow pit	1.869	12.92	90.84	41.6	24.8	16.8	36.8	A-2-6	GOOD
5	LATERITE 90%+ CEMENT 9% +BSBF1.0%	Odioku Rd(CH0+ 750)	1.5 m	Borrow pit	1.863	13.75	56.30	40.7	26	14.7	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/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 (BSBF)													
7	CLAY 96%+ CEMENT 3.75% +BSBF 0.25%	Odioku Rd(CH6 +300)	1.5m	Borrow pit	1.783	10.34	13.8	54	25	29	74.4	A-7-6.	GOOD
8	CLAY 94%+ CEMENT 5.5% +BSBF	Odioku Rd(CH6 +300)	1.5m	Borrow pit	1.789	12.02	16.8	52.7	26.6	22.1	74.4	A-7-6.	GOOD

9	0.50% CLAY 92%+ CEMENT 7.25% +BSBF 0.75%	Odioku Rd(CH6 +300)	1.5m	Borrow pit	1.791	13.10	24.7	48.5	28	20.5	74.4	A-7-6.	GOOD
10	CLAY 90%+ CEMENT 9% +BSBF1.0%	Odioku Rd(CH6 +300)	1.5m	Borrow pit	1.785	14.04	17.6	47.9	24.5	23.4	74.4	A-7-6.	GOOD

Table 3.7: 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 (BSBF)												
7	SOIL 96%+ CEMENT 3.75%	Odioku Rd(CH0+750) and (CH6+300)	290	311	328	342	365	503	531	550	573	598

	+BSBF 0.25%											
8	SOIL 94%+ CEMENT 5.5% +BSBF 0.50%	Odioku Rd(CH0+750) and (CH6+300)	473	495	518	532	550	765	790	825	848	863
9	SOIL 92%+ CEMENT 7.25% +BSBF 0.75%	Odioku Rd(CH0+750) and (CH6+300)	650	672	689	712	738	938	954	977	991	101 5
11	SOIL 90%+ CEMENT 9% +BSBF1.0%	Odioku Rd(CH0+750) and (CH6+300)	583	605	636	660	678	809	826	841	866	885

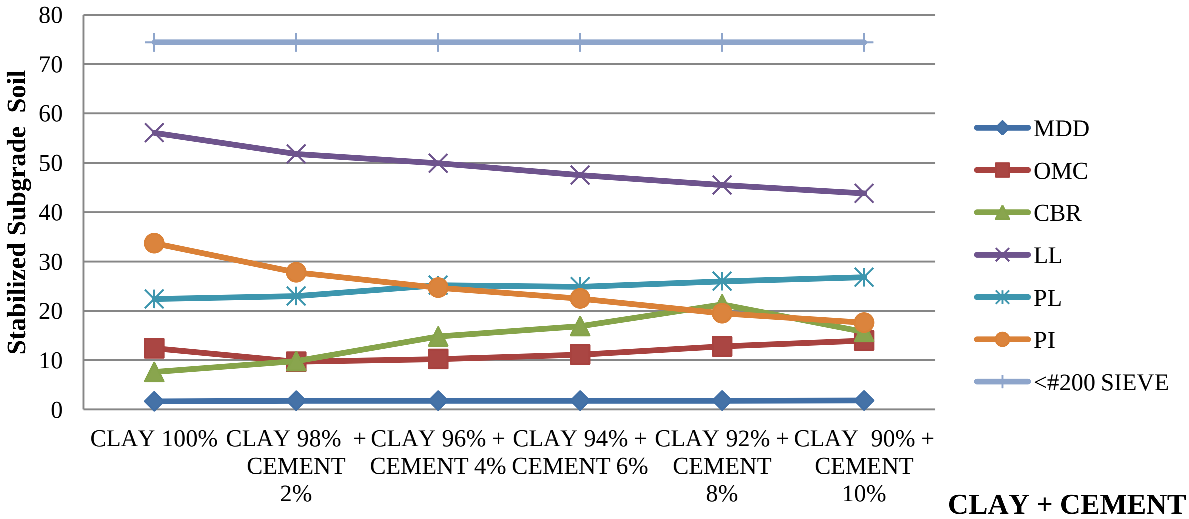

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combination

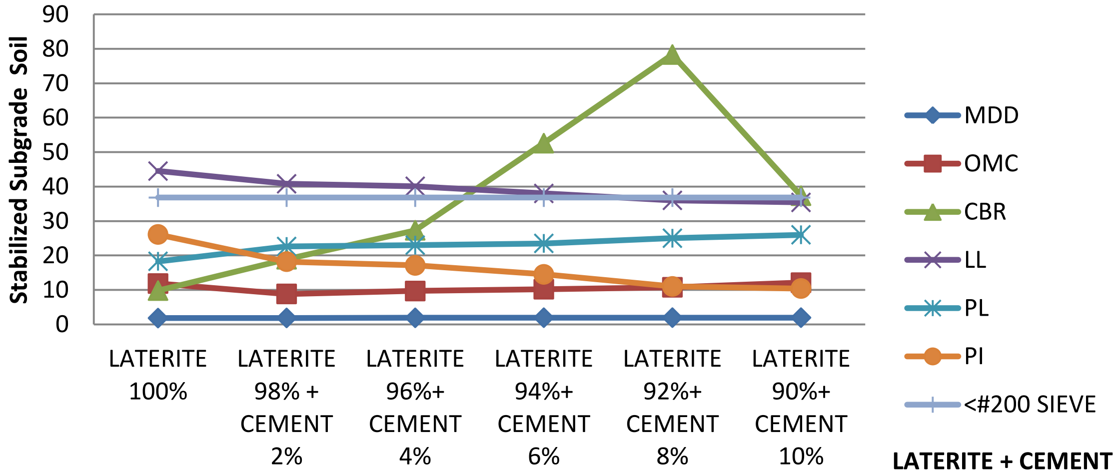

Figure 3.2: Subgrade Stabilization Test of Laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combination

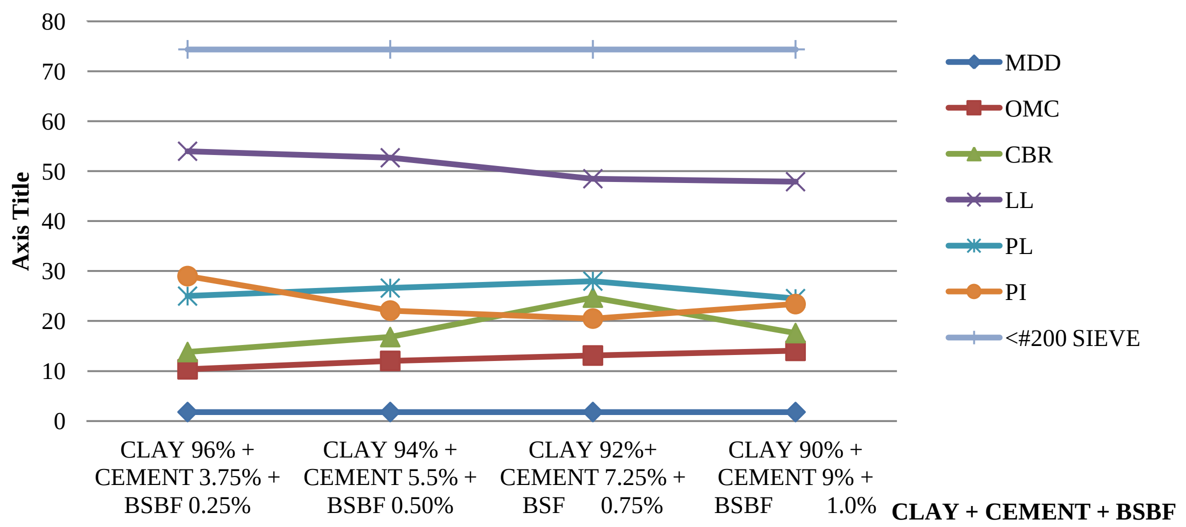

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBF at Different Percentages and Combination

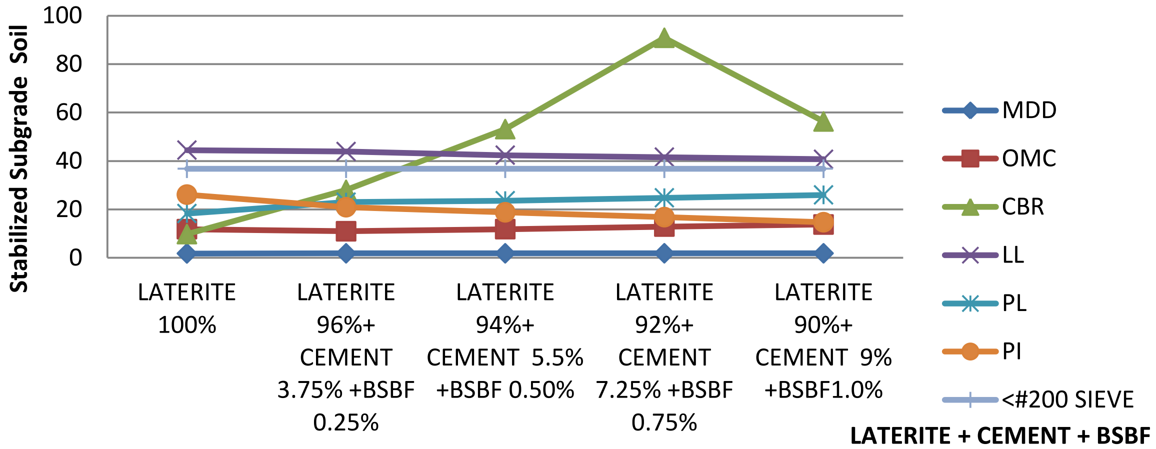

Figure 3.4: Subgrade stabilization test of Laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with cement and BSBF at different percentages and combination

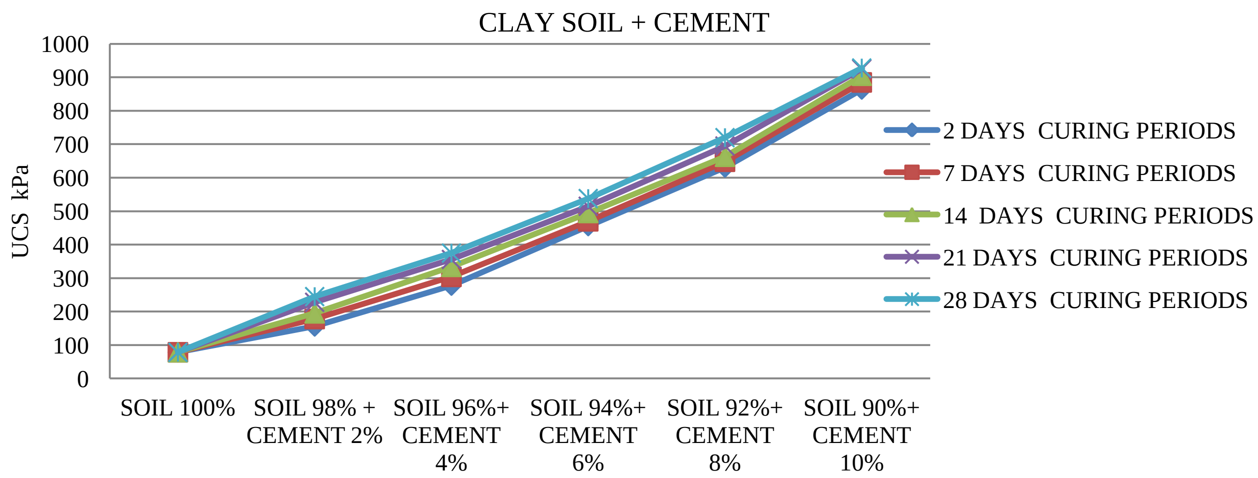

Figure 3.5: Unconfined compressive strength (UCS) of claysoil from Odioku in Ahoada-West L.G.A of Rivers State with cement at different percentages and combinations

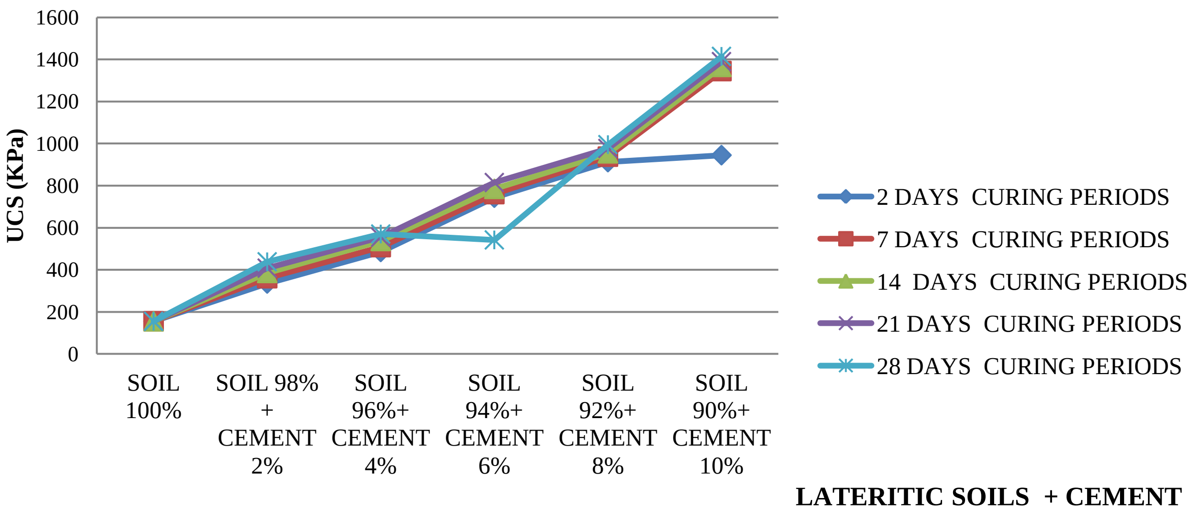

Figure 3.6: Unconfined Compressive Strength (UCS) of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement at Different Percentages and Combinations

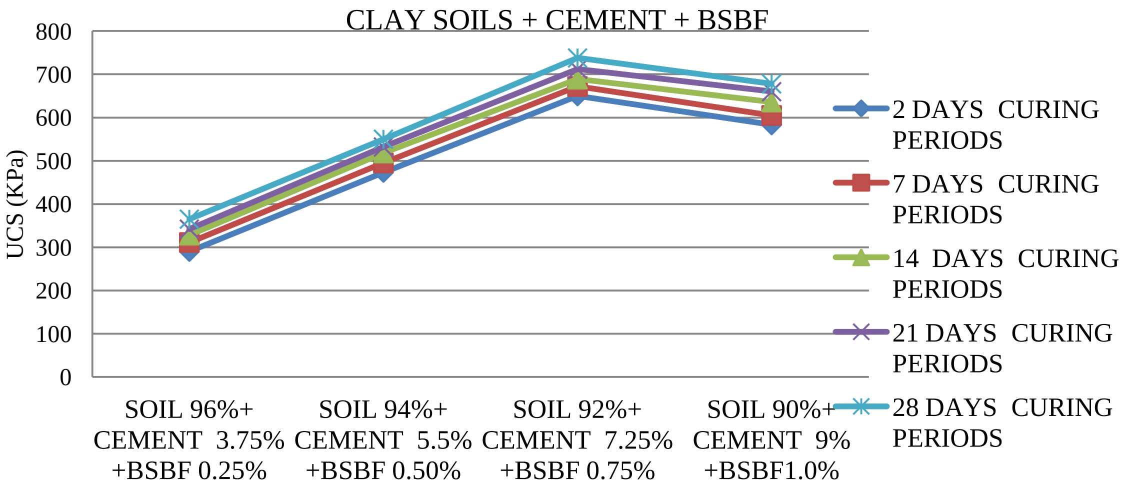

Figure 3.7: Unconfined Compressive Strength (UCS) of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBF at Different Percentages and Combinations

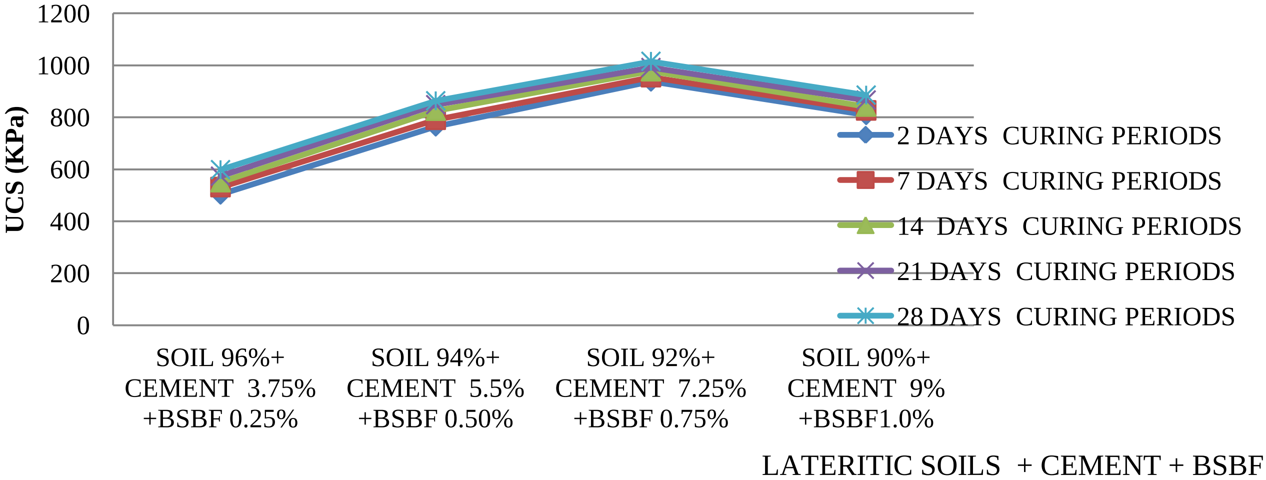

Figure 3.8: Unconfined Compressive Strength (UCS) of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement and BSBF at Different Percentages and Combinations

4. Conclusions

The following conclusions were made from the experimental research results.

i. Results of tests carried out show that the optimum moisture content increased with increasing cement ratios to both soils (clay) and (laterite).
ii. Treated soils with Cement decreased in liquid limits and increased in plastic limits. Soils with Cement and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions.
iii. At 8% of lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% cement + 0. 75% BSBF, optimum value are reached
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 %
vi. 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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