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Effect of Hybridized Composite Materials on Engineering Properties of an Expansive Soil

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Abstract: **This study investigated the susceptible to pavement degradation resulted in very many failures, potholes and cracks along the stretches of Odioku road, Ahoada West, Rivers State. Stabilizers were used in single and combined actions to determine the suitability of the composite material that will solve these problems. Results obtained of lime treated soil in single and double action of soil + lime + bagasse fibre treated soils of laterite and clay compaction results presented of OMC at preliminary engineering properties soil test are 12.39% (clay) and 11.79 (laterite) while MDD 1.640KN/m^3 and 1.803KN/m^3 respectively. Results of OMC lime treated soil of 2% to 10% increased from 12.39% to 14.93% (clay) and 11.79% to 13.22% (laterite). MDD increased from 1.640KN/m^3 to 1.758KN/m^3 (clay) and 1.803KN/m^3 to 1.860KN/m^3. soil + lime + bagasse fibre treated soils, OMC increased from 12.93% to 24.61% (clay) and 11.79% to 14.32% (laterite). MDD increased from 1.640KN/m^3 to 1.864KN/m^3 (clay) and 1.803KN/m^3 to 1.841KN/m^3 (laterite). CBR results obtained of lime + soil treated, increased from 7.6% to 16.4% (clay) and 9.8% to 40.8% at optimum of 0.75% line percentage inclusion of both soils. Beyond the optimum limit, crack formation was noticed which led to failure. Results of UCS of soil + lime treated increased from 78.6kPa to238.7kPa (clay) and 155kPa to 325kPa (laterite). Soil + lime +BSBF treated soil at mix ratio of lime + fibre 3.75% + 0.25%, 5.5% + 0.5%, 7.25% + 0.75% and 9.0% + 1.0% respectively, has strength increased from 78.6kPa to 308kPa (clay) and 155kPa to356kPa (laterite) .is sign of failure. Results of consistency limits of soil + lime treated soil, LL decreased from 56.1% to 43.4% (clay) and 39% to 36% (laterite), PL increased from 22.4% to 26.8% (clay) and 22% to 27% (laterite), IP decreased from 33.7% to 16.6% (clay) and 17% to 10.4% (laterite). For soil + lime + BSBF treated soil, LL decreased from 56.1% to 47.7% (clay) and 39% to 32%, LP increased from 22.4% to 24.7% (clay), 22% to 25% (laterite), IP decreased from 33.7% to 26.8% (clay) and 17% to 16.6% (laterite).**

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

1. INTRODUCTION

Lime is produced by burning limestone. Laboratory testing indicates that lime reacts with medium, moderately fine, and fine-grained soils to produce decreased plasticity, increased workability, and increased strength. Strength gain is primarily due to the chemical reactions that occur between the lime and soil particles. These chemical reactions occur in two phases, with both immediate and long-term benefits. The chemical reaction involves immediate changes in soil texture and soil properties caused by cation exchange. In addition, the mixture of soil and lime must be thoroughly compacted; otherwise the desirable cementation will not take place (Holt, 2010) .

Bell (1996) and Guney *et al*., (2005), indicated that, flocculation is primarily responsible for the modification of the engineering properties of clay soils when treated with even a small amount of lime. The studies also showed that the addition of lime increased the optimum water content, shrinkage limit and strength, and reduced the swelling potential, liquid limit, plasticity index and maximum dry density of the soil. Guney found that the optimum addition of lime needed for the stabilization of the soils is between 2% and 8% lime by dry weight of the soil.

Lime stabilization results in higher bearing capacity and lower compressibility of the treated soil mass (Deboucha *et al*. (2008), they found, increase in CBR value corresponded to increase of the additives content and curing period. Furthermore, the added lime reacts with the pore water, resulting in chemical bonding between soil particles, a reduction in water content and, in turn, an increase in undrained shear strength.

Wahab *et al*. (2011), lime stabilization creates a number of important engineering properties in soils to improved workability, providing a working platform for subsequent construction, reducing plasticity to meet specifications, conditioning the soil for further treatment.

Rao *et al*., (2011) studied the effects of RHA, lime and gypsum on engineering properties of expansive soil and found that UCS increased by 548 % at 28 days of curing and CBR increased by 1350 % at 14 days curing at RHA- 20%, lime -5 % and gypsum -3%.

Sabat (2013) studied the effect of lime sludge (from paper manufacturing industry) on compaction, CBR, shear strength parameters, coefficient of compression, Ps and durability of an expansive soil stabilized with optimum percentage of RHA after 7days of curing. The optimum proportion soil: RHA: lime sludge was found to be 75:10:15.

Amu *et al*., (2005)[83] used (Class- F) fly ash and cement for stabilization of expansive soil. It was found that stabilizing effect of 9% cement and 3% fly ash was better than the stabilizing effect 12 % cement.

Cokca (2001), Nalbantoglu (2004), Pandian and Krishna (2003) and Misra *et al*., (2005) studied effect of class- C fly ash on different engineering properties of expansive soil and had found varied success.

Sharma and Gupta (2013) investigated the effect of fly ash(class-F) on sand stabilized black cotton soil based on compaction and CBR test the optimum proportion of soil: sand :fly ash was found to be 63:27:15.

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 Lime:

The lime used for the study was purchased in the open market at Mile 3 market road, Port Harcourt.

2.1.3 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:

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. RESULTS AND DISCUSSIONS

3.1 Compaction Test Results:

Results obtained of lime treated soil in single and double action of soil + lime + bagasse fibre treated soils of laterite and clay compaction results presented in tables 3.1, 3.4 and 3.5 of OMC at preliminary engineering properties soil test are 12.39% (clay) and 11.79 (laterite) while MDD 1.640KN/m^3 and 1.803KN/m^3 respectively. Results of OMC lime treated soil of 2% to 10% increased from 12.39% to 14.93% (clay) and 11.79% to 13.22% (laterite). MDD increased from 1.640KN/m^3 to 1.758KN/m^3 (clay) and 1.803KN/m^3 to 1.860KN/m^3. soil + lime + bagasse fibre treated soils, OMC increased from 12.93% to 24.61% (clay) and 11.79% to 14.32% (laterite). MDD increased from 1.640KN/m^3 to 1.864KN/m^3 (clay) and 1.803KN/m^3 to 1.841KN/m^3 (laterite).

3.2 California Bearing Ratio (CBR) Test:

Results obtained of lime + soil treated, increased from 7.6% to 16.4% (clay) and 9.8% to 40.8% at optimum of 0.75% line percentage inclusion of both soils. Beyond the optimum limit, crack formation was noticed which led to failure.

3.3 Unconfined Compressive Strength Test:

Results of UCS of soil + lime treated increased from 78.6kPa to238.7kPa (clay) and 155kPa to 325kPa (laterite). Soil + lime +BSBF treated soil at mix ratio of lime + fibre 3.75% + 0.25%, 5.5% + 0.5%, 7.25% + 0.75% and 9.0% + 1.0% respectively, has strength increased from 78.6kPa to 308kPa (clay) and 155kPa to356kPa (laterite) .is sign of failure.

3.4 Consistency Limits Test:

Results of soil + lime treated soil, LL decreased from 56.1% to 43.4% (clay) and 39% to 36% (laterite), PL increased from 22.4% to 26.8% (clay) and 22% to 27% (laterite), IP decreased from 33.7% to 16.6% (clay) and 17% to 10.4% (laterite). For soil + lime + BSBF treated soil, LL decreased from 56.1% to 47.7% (clay) and 39% to 32%, LP increased from 22.4% to 24.7% (clay), 22% to 25% (laterite), IP decreased from 33.7% to 26.8% (clay) and 17% to 16.6% (laterite).

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: 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+ LIME								
7	LATERITE 100%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.803	11.78	9.8	39	22	17	36.8	A-2-6	POOR
8	LATERITE 98% + LIME 2%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.806	9.31	16.6	39	22.8	16.2	36.8	A-2-6	GOOD
9	LATERITE 96%+ LIME 4%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.838	10.06	20.5	37	23	14	36.8	A-2-6	GOOD
10	LATERITE 94%+ LIME 6%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.850	10.89	26.85	36	25	11	36.8	A-2-6	GOOD
11	LATERITE 92%+ LIME 8%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.860	12.05	40.80	36	26	10	36.8	A-2-6	GOOD
12	LATERITE 90%+ LIME 10%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.860	13.25	33.14	37.4	27	10.4	36.8	A-2-6	GOOD
				LATERITE+ LIME +BUSH SUGARCANE BAGASSE FIBRE (BSBF)									
13	LATERITE 96%+ LIME 3.75% +BSBF 0.25%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.834	10.99	22.50	42.7	23	18.3	36.8	A-2-6	GOOD
14	LATERITE 94%+ LIME 5.5% +BSBF 0.50%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.847	11.36	25.40	42	23	19	36.8	A-2-6	GOOD
15	LATERITE 92%+ LIME 7.25% +BSBF 0.75%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.854	12.08	46.81	40	24	16	36.8	A-2-6	GOOD
16	LATERITE 90%+ LIME 9% +BSBF 1.0%	Odioku Rd(CH0+750)	1.5m	Borrow pit	1.841	14.32	34.60	41.6	25	16.6	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
					CLAY+ LIME								
1	CLAY 100%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.64	10.37	7.6	56.1	22.4	33.7	74.4	A-7-6.	POOR
2	CLAY 98% + LIME 2%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.716	10.94	8.4	50.3	22	27.7	74.4	A-7-6.	POOR
3	CLAY 96%+ LIME 4%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.725	11.61	11.6	48.4	24.2	24.2	74.4	A-7-6.	GOOD
4	CLAY 94%+ LIME 6%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.737	12.02	13.8	46.7	24.9	21.6	74.4	A-7-6.	GOOD
5	CLAY 92%+ LIME 8%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.755	13.32	16.4	44.3	26	18.3	74.4	A-7-6.	GOOD
6	CLAY 90%+ LIME 10%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.758	14.93	12.3	43.4	26.8	16.6	74.4	A-7-6.	GOOD
				CLAY+ LIME +BUSH SUGARCANE BAGASSE FIBRE (BSBF)									
7	CLAY 96%+ LIME 3.75% +BSBF 0.25%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.727	12.70	12.6	52	22	30	74.4	A-7-6.	GOOD
8	CLAY 94%+ LIME 5.5% +BSBF 0.50%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.734	12.79	15.2	50.3	24.8	25.5	74.4	A-7-6.	GOOD
9	CLAY 92%+ LIME 7.25% +BSBF 0.75%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.742	14.35	18.4	48.3	26	22.3	74.4	A-7-6.	GOOD
11	CLAY 90%+ LIME 9% +BSBF1.0%	Odioku Rd(CH6+300)	1.5m	Borrow pit	1.735	15.07	12.8	47.7	24.7	23	74.4	A-7-6.	GOOD

Figure 3.6: Subgrade stabilization test of laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with lime at different percentages and combination

			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 ROADSITE	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 + Lime												
1	SOILS 100% + LIME 0%	Odioku Rd(CH0+750) and (CH6+300)	78.6	-	-	-	-	155	-	-	-	-
2	SOILS 98% + LIME 2%	Odioku Rd(CH0+750) and (CH6+300)	116.1	123.6	131.1	143.1	150.6	193.6	20.5	218.2	231.6	244.3
3	SOIL 96%+ LIME 4%	Odioku Rd(CH0+750) and (CH6+300)	158.6	176.4	191.4	208.7	223	231.6	253.6	264.6	284.1	295.6
4	SOIL 94%+ LIME 6%	Odioku Rd(CH0+750) and (CH6+300)	203.6	218	235	258.6	272	271.1	284.1	299.4	308.4	321.4
5	SOIL 92%+ LIME 8%	Odioku Rd(CH0+750) and (CH6+300)	238.7	256.3	271.4	288	306	303.4	324.4	339.6	353.6	374.8
6	SOIL 90%+ LIME 10%	Odioku Rd(CH0+750) and (CH6+300)	280.3	299.4	307.1	319.4	325	331.7	346.4	361.4	378.4	381.1
Soil + Lime + Bush Sugarcane Bagasse Fibre (BSBF)												
7	SOIL 96%+ LIME 3.75% +BSBF 0.25%	Odioku Rd(CH0+750) and (CH6+300)	165.6	171.3	184.2	191.1	203.1	256.1	264.3	281.2	298	318
8	SOIL 94%+ LIME 5.5% +BSBF 0.50%	Odioku Rd(CH0+750) and (CH6+300)	198.1	207.4	215.6	223.1	223.6	274.3	286.1	295.1	306.2	313
9	SOIL 92%+ LIME 7.25% +BSBF 0.75%	Odioku Rd(CH0+750) and (CH6+300)	258.5	264.1	277.4	291	308.1	296.6	308	322	336	356
10	SOIL 90%+ LIME 9% +BSBF1.0%	Odioku Rd(CH0+750) and (CH6+300)	183.4	192.1	212.1	221.1	236.1	234.1	256.1	273.1	293.7	301.5

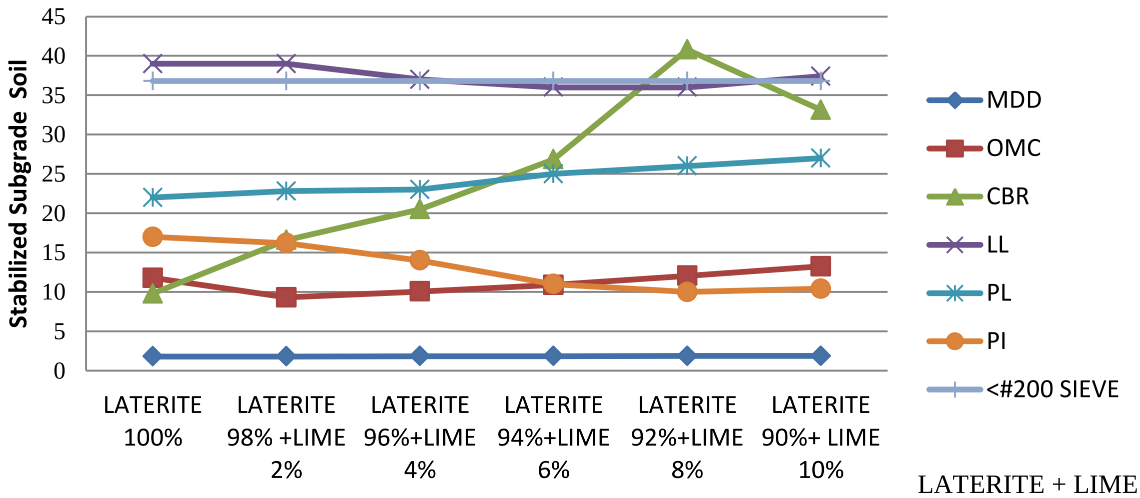

Figure 3.1: Subgrade Stabilization Test of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Lime at Different Percentages and Combination

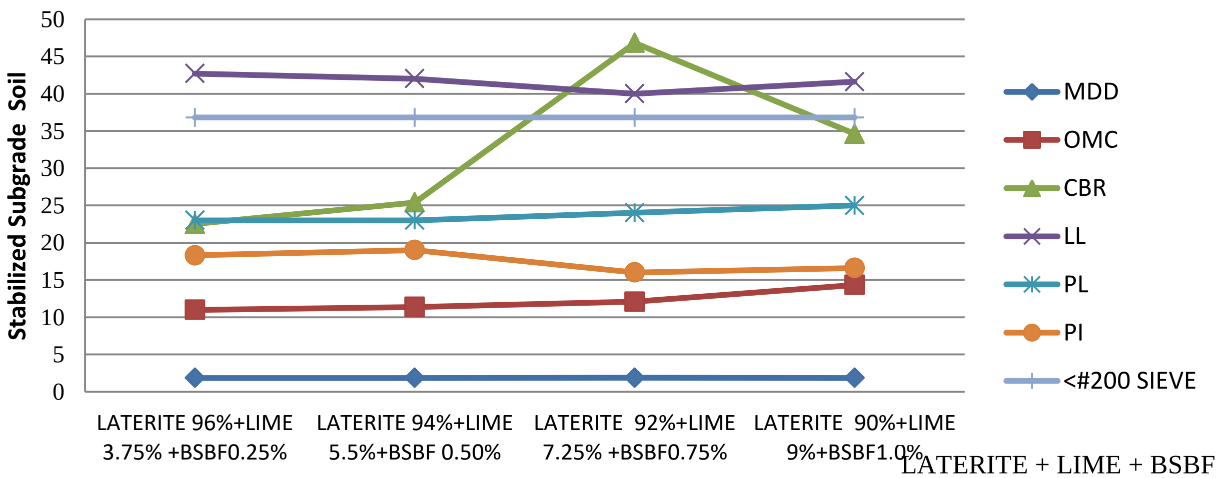

Figure 3.2: Subgrade Stabilization Test of Laterite Soil from Odioku in Ahoada-West L.G.A of Rivers State with Lime and BSBF at Different Percentages and Combination

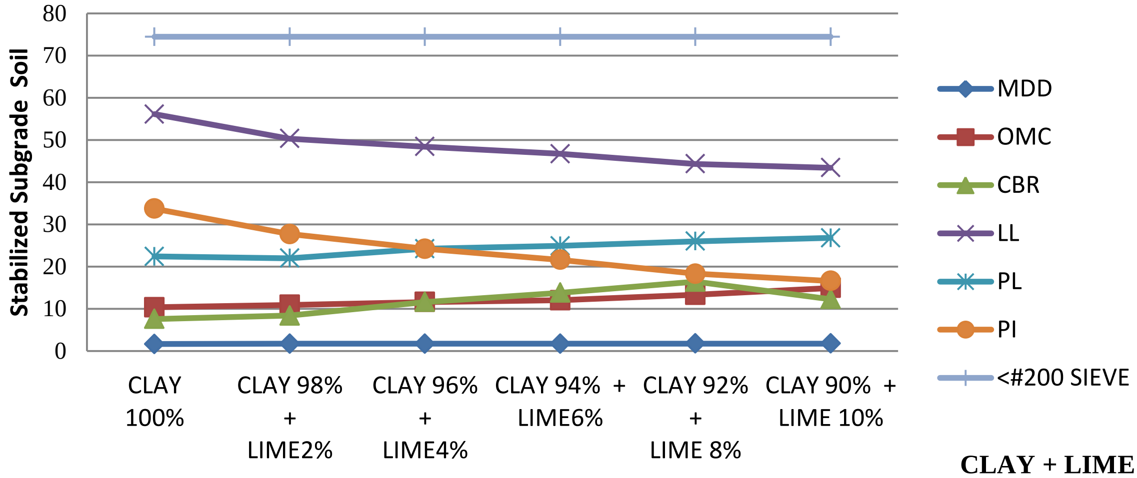

Figure 3.3: Subgrade stabilization test of clay soil from Odioku in Ahoada-West L.G.A of Rivers State with lime at different percentages and combinations

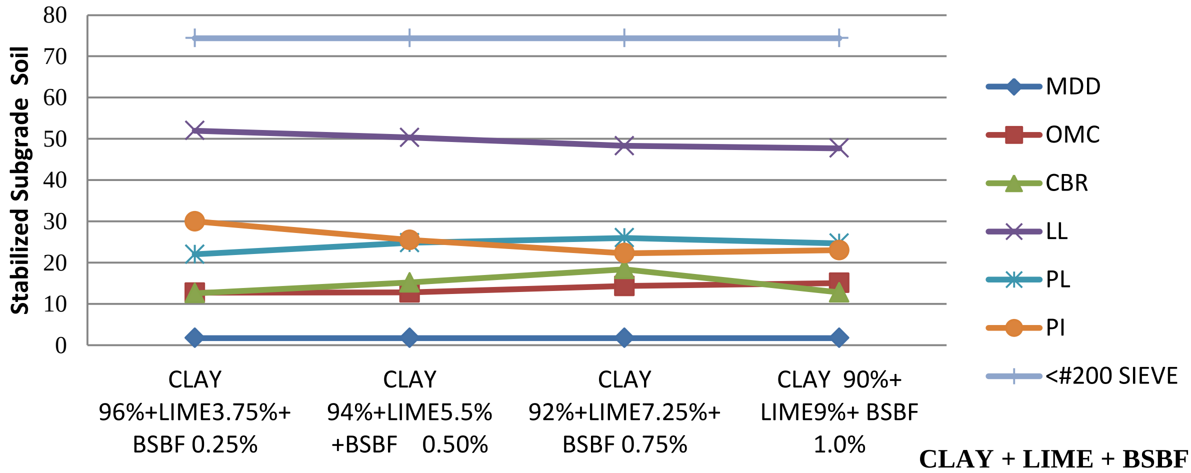

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Lime and BSBF at Different Percentages and combination

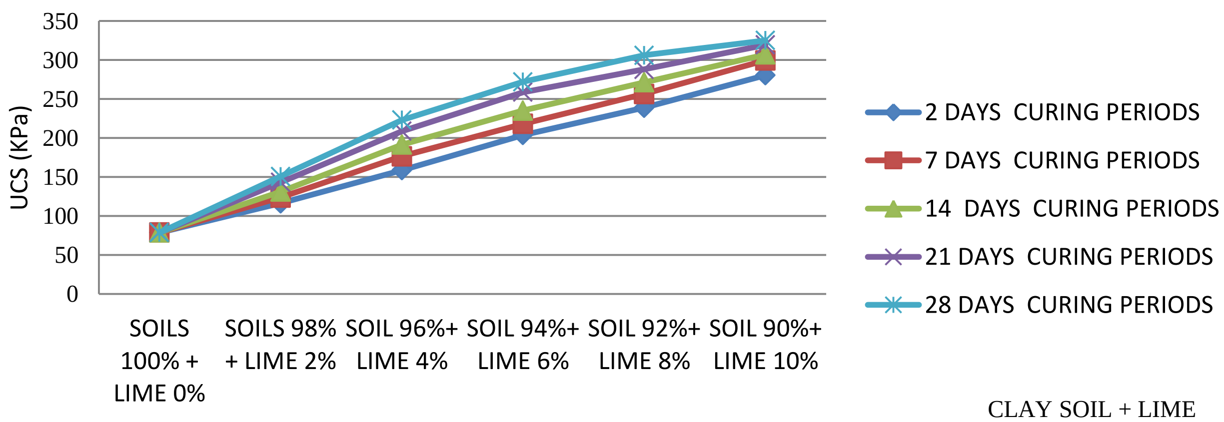

Figure 3.5: Unconfined Compressive Strength (UCS) of Clay soil from Odioku in Ahoada-WestL.G.A of Rivers State with Lime at Different Percentages and Combinations

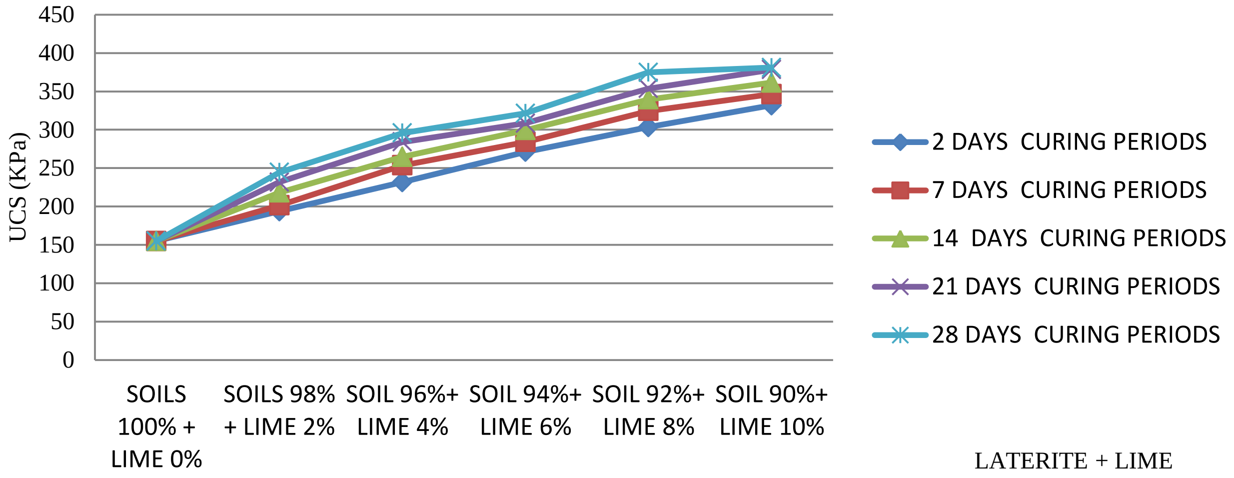

Figure 3.6: Unconfined Compressive Strength (UCS) of Laterite Soil from Odioku in Ahoada-WestL.G.A of Rivers State with Lime at Different Percentages and Combinations

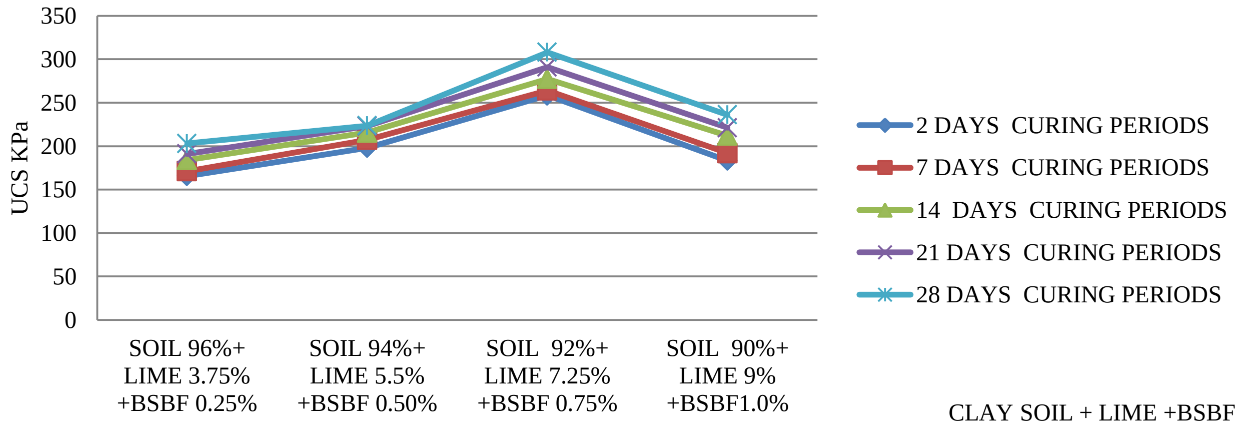

Figure 3.7: Unconfined Compressive Strength (UCS) of Clay soil from Odioku in Ahoada-West L.G.A of Rivers State with Lime and BSBF at Different Percentages and Combinations

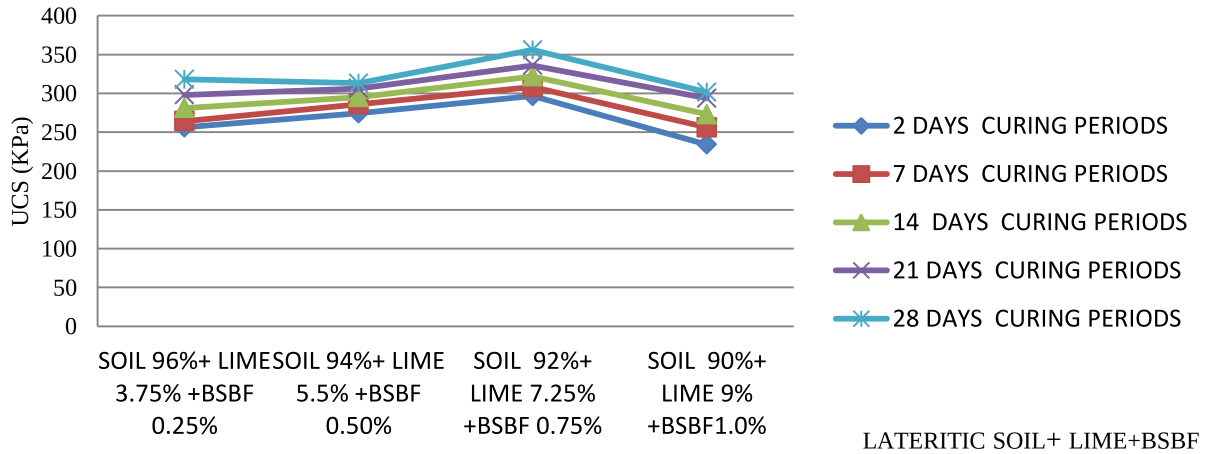

Figure 3.8: Unconfined Compressive Strength (UCS) of Laterite soil from Odioku in Ahoada-West L.G.A of Rivers State with Lime and BSBF at Different Percentages and Combinations

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. Treated soils with Lime decreased in liquid limits and increased in plastic limits.

ii. Soils with Lime and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions from 7.6 % to 9.8 %, and 8.5 % to 10.9 % (clay) and (laterite) respectively

iii. At 8% of lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% lime + 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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