Expansive Soils Volume Change Control Using Hybridized Composite Materials as Soil Stabilizer

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ABSTRACT

Black Cotton soils are predominantly the most that stretches Ebiriba, Ochigba, Eneka and Isiokpo roads in Rivers State of Nigeria. The soils are characterized with high plasticity that has caused differential settlements and degradations that has led the abandoned state of the roads. The study evaluated the geotechnical properties of these soils and modified the problematic them with composite materials of plantain rachis fibre ash + cement with percentages shown in table 3.2. Preliminary investigations shown in table 3.1 indicated that the clay soils fell short of standards and specifications. Stabilized soils result of compaction test parameters, maximum dry density (MDD) and optimum moisture content (OMC) of plantain rachis fibre ash + cement to soils increased with percentage additives inclusion increase. Summarized results of stabilized clay soils with composite materials yielded increased in California bearing ratio test of both unsoaked and soaked states with optimum mixed percentage ratio of 7.5% + 7.5%. Confirmation results indicated crack formation and values reduction beyond optimum. Final results of stabilized clay soils unconfined compressive strength test with additives to soils percentages inclusion increased with respect to additives percentile. Summed up results of stabilized clay soils consistency limits (Plastic index) decreased in values with increase percentile ratio of additives. The entire results showed good potential of using plantain rachis fibre ash + cement as soil stabilizer.

Key Words: *Clay, Plantain Rachis Fibre Ash , Cement, CBR, UCS, Consistency, Compaction*

1.0 Introduction

The modification of black cotton soils with special attributes of cracks, swelling and shrinkage into a stabilized mass, which increases its strength and durability, is due to the long-term reaction which includes pozzolanic reaction. Their functions are to reduce plasticity and facilitate densification. 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 (Azadegan *et al*. [1]; Mallela *et al*. [2]; Ramadas *et al*. [3]). Other additives, such as geofiber and geogrid, depend on their physical effects to improve soil properties (Alawaji, [4]; Viswanadham *et al*. [5]). In addition, it can be combined both of chemical

and physical stabilization, for example, by using lime and geofiber or geotextile together (Yang *et al*. [6]; Chong and Kassim, [7]).

Charles *et al.* [8] investigated and evaluated the engineering properties of an expansive lateritic soil with the inclusion of cement / lime and costus afer bagasse fibre ash (locally known as bush sugarcane fibre ash (BSBFA) with ratios of laterite to cement, lime and BSBFA of 2.5% 2.5%, 5.0% 5.0%, 7.5% 7.5% and 10% 10% to improve the values of CBR of less than 10%. At 8% of both cement and lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% cement and lime 7.5% BSBFA, and 7.25% cement and lime 0. 7.5% BSBF, optimum value are reached. The entire results showed the potential of using bagasse, BSBFA as admixtures in cement and lime treated soils of laterite.

Sabat [9] 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 [10] 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.

2.0 Materials and Methods

2.1 Materials

2.1.1 Soil

The soils used for the study were collected from Ebiriba Town Road, in Ahoada-West Local Government, Ochigba Town Road, in Ahoada-East Local Government Area, Eneka Town Road, in Obio/Akpor Local Government Area and IsiokpoTown Road, in Ikwerre Local Government area, all in Rivers State, Niger Delta region, Nigeria. It lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Plantain Rachis Fibre

The Plantain Rachis fibres are obtained from Iwofe markets, in Obio/Akpor Local Area of Rivers State, they are abundantly disposed as waste products both on land and in the river.

2.1.3 Cement

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

2.2 Method

2.2.1 Sampling Locality

The soil sample used in this study were collected along Ebiriba Town, (latitude 5.10° 31‘N and longitude 6.38° 8‘E), Ochigba a Town, (latitude 5.1° 30‘N and longitude 6.35° 55‘E), Eneka Town, latitude 4.90° 28‘N and longitude 7.03° 15‘E), and Isiokpo Town, latitude 5.05° 41‘N and longitude 6.92° 33‘E) all in Rivers State, Nigeria.

2.2.2 Test Conducted

Test conducted were (1) Moisture Content Determination (2) Consistency limits test (3) Particle size distribution (sieve analysis) and (4) Standard Proctor Compaction test, California Bearing Ratio test (CBR) and Unconfined compressive strength (UCS) tests;

2.2.3 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.

2.2.4 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.

2.2.5 Consistency Limits

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.

2.2.6 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.

2.2.7 Unconfined Compression (UC) Test

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. 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

2.2.8 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.

3.0 Results and Discussions

Preliminary results on lateritic 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-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1 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 [11]; Allam and Sridharan [12]; Omotosho and Akinmusuru [13]; Omotosho [14]. The soils are dark grey in color (from wet to dry states) plasticity index of 28.55%, 25.97%, 33.50%, and 28.40% respectively for Ebiriba, Ochigba, Eneka and Isiokpo Town Roads. The soil has unsoaked CBR values of 6.38%, 7.75%, 8.24% and 7.85%, and soaked CBR values of 5.25%, 6.03%, 6.35% and 6.30%, unconfined compressive strength (UCS) values of 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

Results from table 3.1, presented the compaction test parameters of clay soils at preliminary natural state, the maximum dry density (MDD) values are 1.685 KN/m^3, 1.705 KN/m^3, 1.663 KN/m^3, 1.605 KN/m^3 and optimum moisture content (OMC) 16.38%, 17.45%, 16.75% and 15.87%. Plantain rachis fibre ash + cement stabilized clay soils with 2.5% + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% yielded peak values of maximum dry density (MDD) values are 1.793KN/m^3, 1.815KN/m^3, 1.763KN/m^3, 1.702KN/m^3 and optimum moisture content (OMC) 18.24%, 19.34%, 18.34% and 17.34%. Stabilized soils result of compaction test parameters, maximum dry density (MDD) and optimum moisture content (OMC) of plantain rachis fibre ash + cement to soils increased with percentage additives inclusion increase.

3.2 California Bearing Ratio (CBR) Test

Results obtained from table 3.1 at preliminary investigation of 100% clay soils are California bearing ratio (CBR) values of unsoaked 6.38%, 7.75%, 8.24% and 7.85%, and soaked 5.25%, 6.03%, 6.35% and 6.30%. Modified clay soils with mixed ratios specified in table 3.1 yielded peak California bearing ratio (CBR) unsoaked values of 56.25%, 60.35%, 64.35%, 60.98%, and soaked 52.85%, 55.75%, 61.25% and 57.85%. California bearing ratio (CBR) unsoaked values of 56.25%, 57.35%, 58.53%, 57.85%, and soaked 52.85%, 55.28%, 56.33% and 55.35%. Summarized results of stabilized clay soils with composite materials of plantain rachis fibre ash + cement yielded increased in California bearing ratio test of both unsoaked and soaked states with optimum mixed percentage ratio of 7.55 + 7.5%. Confirmation results indicated crack formation and values reduction beyond optimum.

3.3 Unconfined Compressive Strength Test

Recorded unconfined compressive strength test results at preliminary stage of clay soils with zero percentage additives inclusion are 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa. Results of stabilized clay soils unconfined compressive strength with inclusion percentages showed in table 3.2 yielded maximum values of 455kPa, 426kPa, 448kPa and 367kPa. Final results of stabilized clay soils unconfined

compressive strength test with plantain rachis fibre ash + cement to soils percentages inclusion increased with respect to additives percentile.

3.4 Consistency Limits Test

Results of consistency limits (Plastic index) of clay soils at zero percentage of natural state are 28.55%, 25.97%, 33.50%, and 28.40%. Modified clay soils yielded maximum values of 27.45%, 28.30%, 32.24% and 27.48%. Summed up results of stabilized clay soils consistency limits (Plastic index) decreased in values with increase percentile ratio of additives.

Table 3.1: Engineering Properties of Soil Samples

LOCATION DESCRIPTION	EBIRIBA ROAD AHOADA WEST L.G.A	OCHIGBA ROAD AHOADA EAST L.G.A	ENEKA ROAD OBIO/AKPOR L.G.A	ISIOKPO ROAD IKWERRE L.G.A
Depth of sampling (m)	1.0	1.0	1.0	1.0
Percentage(%) passing BS sieve #200	75.55	75.05	82.85	69.55
Colour	Greyish/black	Greyish	Greyish	Greyish
Specific gravity	2.45	2.68	2.62	2.48
Natural moisture content (%)	47.36	43.85	47.80	48.15
Consistency limits				
Liquid limit (%)	57.30	56.35	63.30	57.75
Plastic limit (%)	28.75	30.38	29.80	29.35
Plasticity Index	28.55	25.97	33.50	28.40
AASHTO soil classification Unified Soil Classification System	A-7-6/CH	A-7-6/CH	A-7-6/CH	A-7-6/CH
Compaction characteristics				
Optimum moisture content (%)	16.38	17.45	16.75	15.87
Maximum dry density ($kN/m^{3)}$	1.685	1.705	1.663	1.665
Grain size distribution				
Gravel (%)	0	0	0	0
Sand (%)	16.25	12.35	12.80	14.35
Silt (%)	43.83	39.85	41.85	42.35
Clay (%)	39.92	46.80	45.35	56.70

Unconfined compressive strength (kPa)	68.85	77.35	79.85	65.57
California Bearing Capacity (CBR)				
Unsoaked (%) CBR	6.38	7.75	8.24	7.85
Soaked (%) CBR	5.25	6.03	6.35	6.30

Table 3.2: Results of Subgrade Soil (Clay) Test Stabilization with Binding Cementitious Products at Different Percentages and Combination

SAMPLE LOCATION	SOIL + FIBRE PLANTAIN RACHIS ASH + CEMENT	MDD (kN/m^3)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
	CLAY SOIL + PLATAIN RACHIS FIBRE ASH (PRFA)+ CEMENT											
EBIRIBA ROAD AHOADA WEST L.G.A	100%	1.685	16.38	6.38	5.25	68.85	57.30	28.75	28.55	79.55	A – 7 – 6/CH	POOR
	95+2.5+2.5%	1.693	16.93	33.45	29.30	108	57.58	29.35	28.23	79.55	A – 7 – 6/CH	GOOD
	90+5.0+5.0%	1.725	17.38	42.68	38.60	243	57.74	29.71	28.03	79.55	A – 7 – 6/CH	GOOD
	85+7.5+7.5%	1.765	17.83	56.25	52.85	365	58.05	30.22	27.83	79.55	A – 7 – 6/CH	GOOD
	80+10+10%	1.793	18.24	48.65	44.52	455	58.38	31.35	27.45	79.55	A – 7 – 6/CH	GOOD
OCHIGBA ROAD AHOADA EAST L.G.A	100%	1.705	17.45	7.75	6.03	77.35	56.35	30.38	25.97	75.05	A – 7 – 6/CH	POOR
	95+2.5+2.5%	1.724	17.88	31.40	26.60	109	56.83	27.55	29.28	75.05	A – 7 – 6/CH	GOOD
	90+5.0+5.0%	1.748	18.38	43.53	39.62	225	57.18	28.22	28.96	75.05	A – 7 – 6/CH	GOOD
	85+7.5+7.5%	1.794	18.93	57.35	55.28	318	57.45	28.82	28.63	75.05	A – 7 – 6/CH	GOOD
	80+10+10%	1.815	19.34	51.83	47.65	426	57.98	29.68	28.30	75.05	A – 7 – 6/CH	GOOD
ENEKA ROAD OBIO/AKPOR L.G.A	100%	1.663	16.75	8.24	6.35	79.85	63.30	29.80	33.50	82.85	A – 7 – 6/CH	POOR
	95+2.5+2.5%	1.680	17.18	36.41	33.62	115	63.68	30.50	33.18	82.85	A – 7 – 6/CH	GOOD
	90+5.0+5.0%	1.698	17.65	43.45	39.18	268	64.15	31.22	32.93	82.85	A – 7 – 6/CH	GOOD
	85+7.5+7.5%	1.727	18.08	58.53	56.33	363	64.48	31.81	32.6	82.85	A – 7 – 6/CH	GOOD
	80+10+10%	1.763	18.34	49.28	43.38	448	64.73	32.49	32.24	82.85	A – 7 – 6/CH	GOOD
ISIOKPO ROAD IKWERRE L.G.A	100%	1.605	15.87	7.85	6.30	65.75	57.75	29.35	28.40	69.55	A – 7 – 6/CH	POOR
	95+2.5+2.5%	1.615	16.31	33.28	28.61	97	58.15	30.07	28.08	69.55	A – 7 – 6/CH	GOOD
	90+5.0+5.0%	1.653	16.86	44.96	42.85	165	58.34	30.41	27.93	69.55	A – 7 – 6/CH	GOOD
	85+7.5+7.5%	1.678	17.08	57.85	55.35	239	58.70	31.04	27.66	69.55	A – 7 – 6/CH	GOOD
	80+10+10%	1.702	17.34	51.35	48.63	367	58.93	31.45	27.48	69.55	A – 7 – 6/CH	GOOD

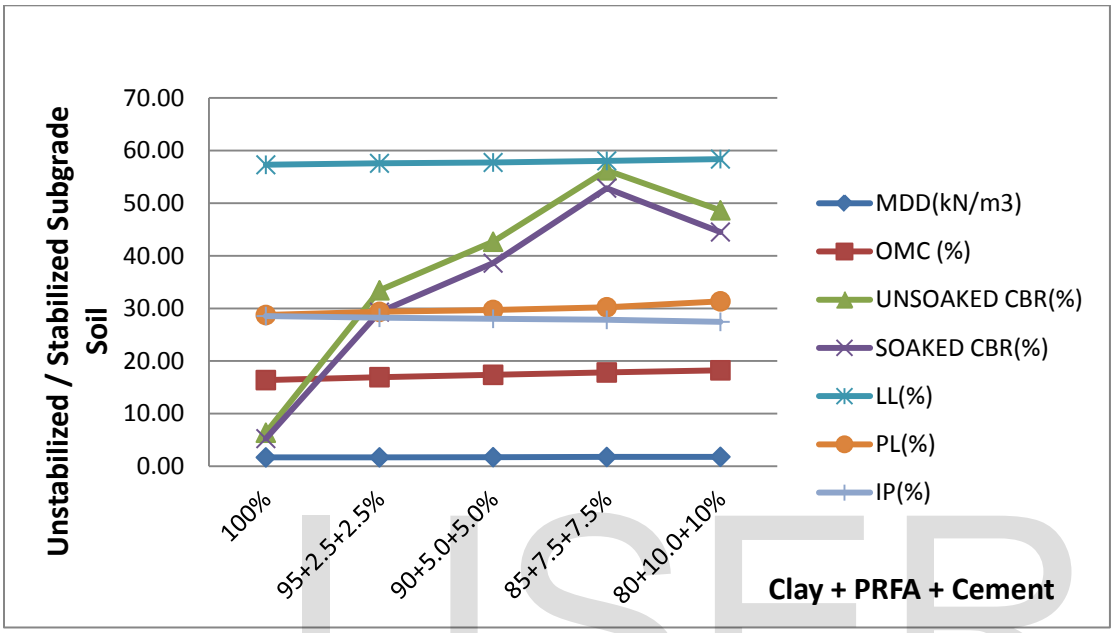

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ebiriba in Ahoada - West L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

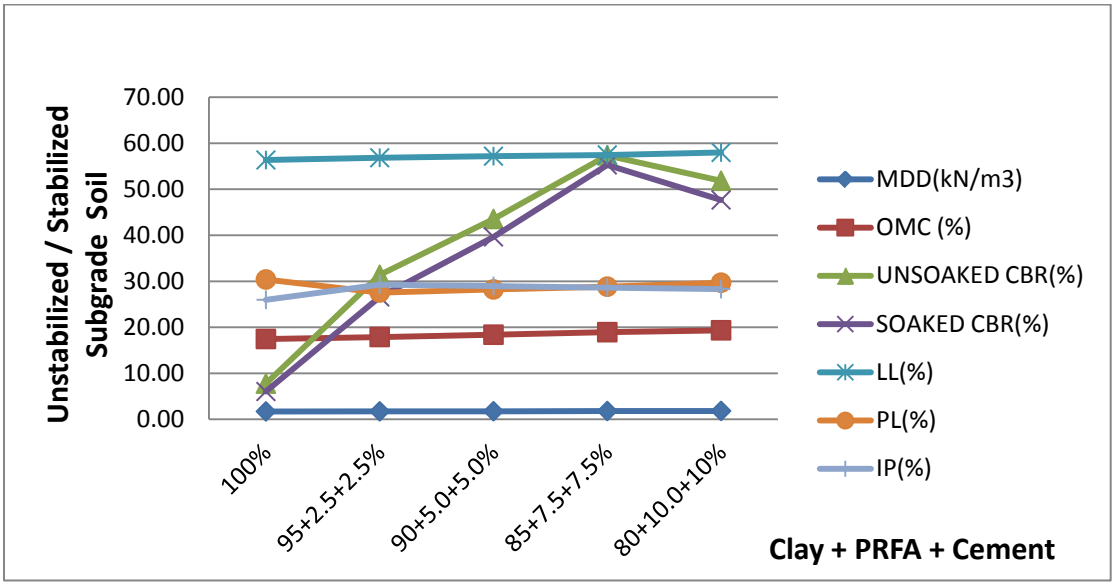

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Ochigba in Ahoada - East L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

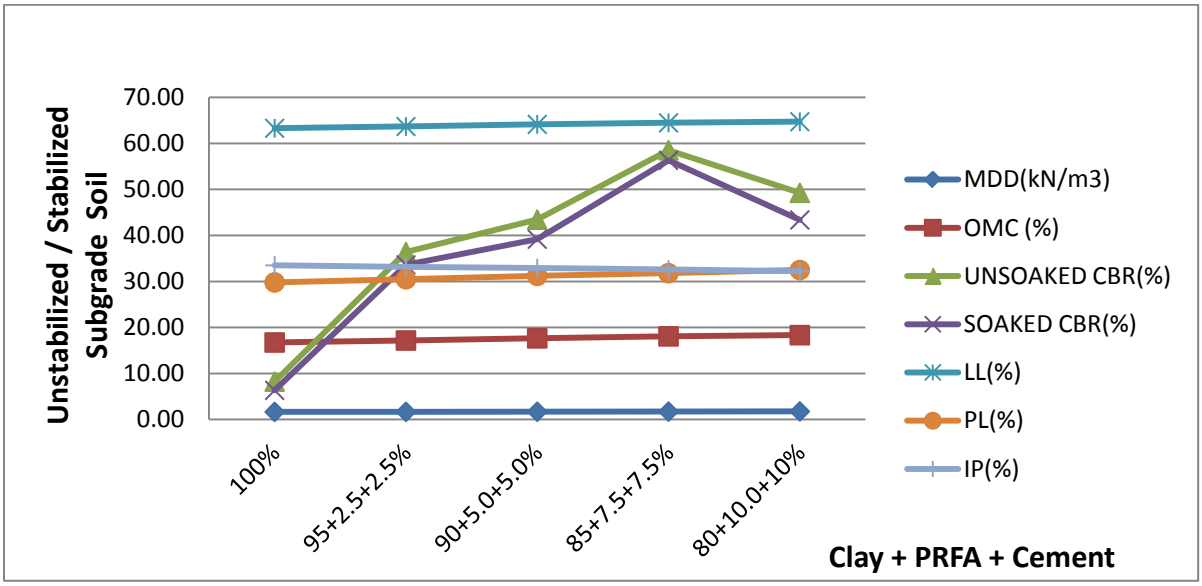

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Eneka in Obio/Akpor L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

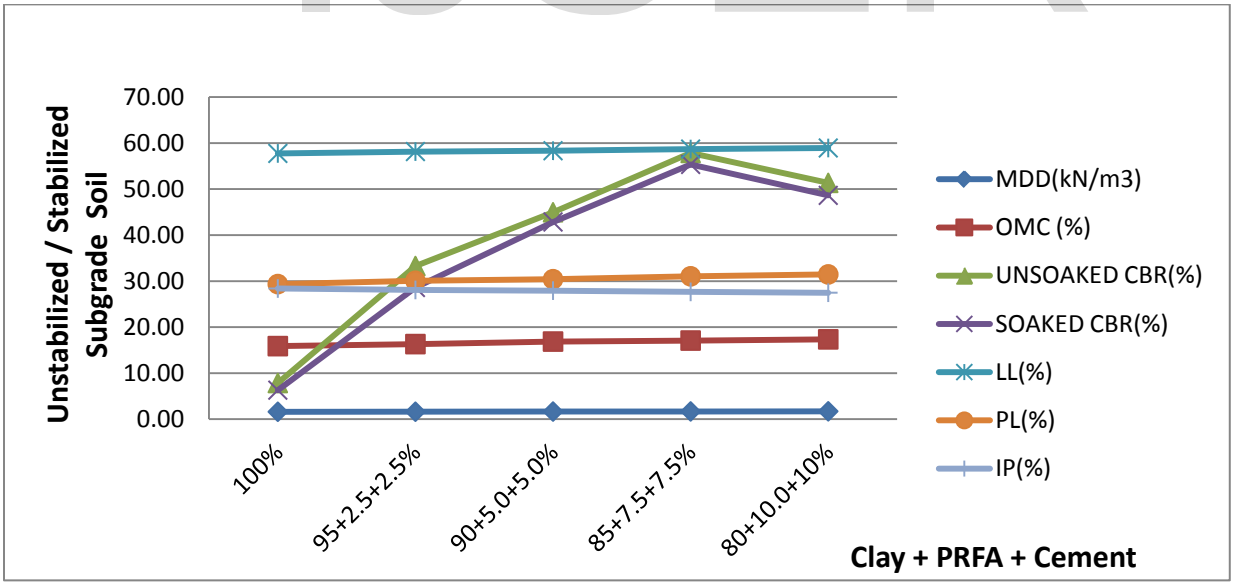

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Isiokpo in Ikwerre L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

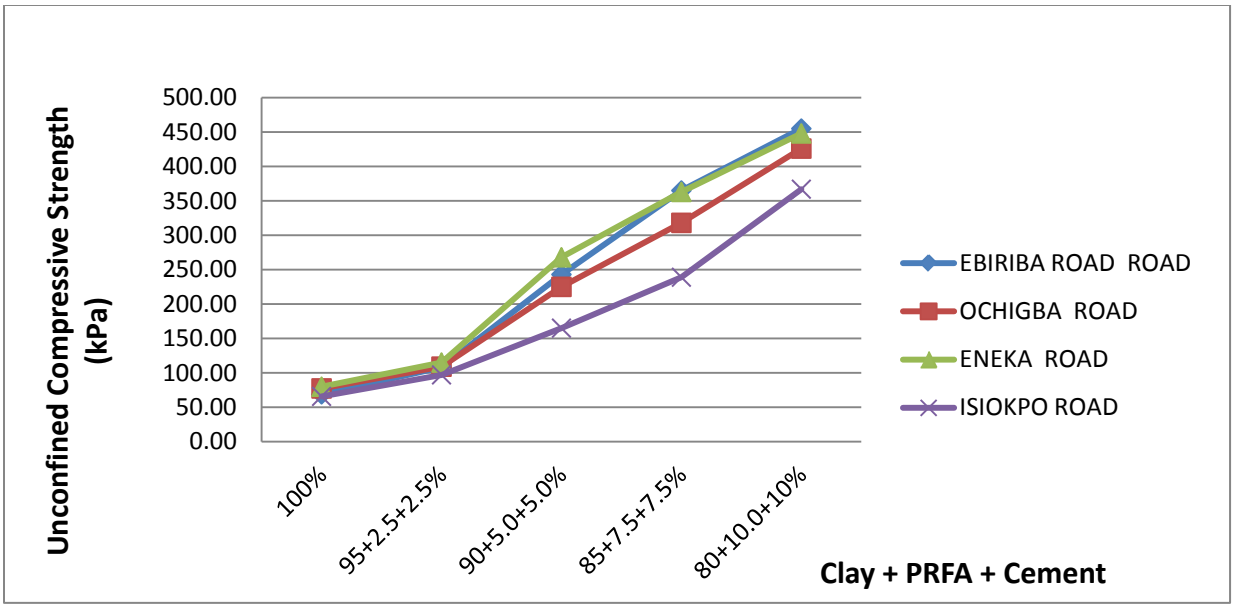

Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with PRFA + Cement of (Ebiriba, Ochigba, Eneka and Isiokpo Towns) all in Rivers State

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. Soils are classified as A-7-6/CH on the AASHTO classification schemes / Unified Soil Classification System.

ii. Stabilized soils result of compaction test parameters, maximum dry density (MDD) and optimum moisture content (OMC) of plantain rachis fibre ash + cement to soils increased with percentage additives inclusion increase.

iii. Summarized results of stabilized clay soils with composite materials of plantain rachis fibre ash + cement yielded increased in California bearing ratio test of both unsoaked and soaked states with optimum mixed percentage ratio of 7.5% + 7.5%. Confirmation results indicated crack formation and values reduction beyond optimum.

iv. Final results of stabilized clay soils unconfined compressive strength test with plantain rachis fibre ash + cement to soils percentages inclusion increased with respect to additives percentile.

v. Summed up results of stabilized clay soils consistency limits (Plastic index) decreased in values with increase percentile ratio of additives.

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