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Modification of Expansive Clay Soils using Plantain Rachis Fibre Ash

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Abstract The study examined the application of waste fibre ash of plantain rachis in single action to strengthen the unstable subgrade road formation of Ebiriba, Ochigba, Eneka and Isiokpo roads characterized with failure attributes of high plasticity, swelling, shrinkage and cracks. Preliminary geotechnical investigations classified the clay soils as A-7-6/CH on the AASHTO classification schemes / Unified Soil Classification System and soils unfit for standard road constructional materials as specified by Federal Ministry of Works (FMW 1997) except modified. Results of modified clay soils compaction test from table 3.2 and figures 3.1 – 3.4 showed decreased values of maximum dry density and increased values of optimum moisture content (OMC) in relation to fibre ash percentages inclusion. Final results of plantain rachis fibre ash stabilized clay soils California bearing ratio (CBR) of both unsoaked and soaked increased tremendously with fibre ash percentages ratio increase. Results of unconfined compressive strength test values increased with respect to percentages inclusion increase. Results as shown in table 3.3 and figures 3.1 – 3.4 showed decreased values of plastic index with fibre ash inclusion relative to percentage increase. The entire results showed good potential of using plantain rachis fibre ash as soil stabilizer.

Keywords Clay, Plantain Rachis Fibre Ash, CBR, UCS, Consistency, Compaction

1. Introduction

The changed in natural state of soils is an important system of improving the performance of expansive soils and makes marginal soils perform higher as civil engineering materials. Many researchers has contributed to the new trend of soil modifications with the likes of (Mohammedbhai and Baguant, [1]; Osinubi, [3]; [4], [5]; [6]; Cokca, [7]; Medjo and Riskowski, [8]; Moses, [9]; Akinmade, [10]; Ochepo, [11]) to gain inexpensive components which may be used to alternative these luxurious industrially manufactured soil enhancing components (cement, lime, bitumen, etc.) brought about the attention of agricultural waste resources inclusive of rice husk ash (RHA), bagasse ash (BA) and locust bean waste ash (LBWA) accordingly, the use of cheap admixtures to replace or supplement cement or lime stabilized soils mainly wastes from agricultural or commercial merchandise will in the end lessen the cost of creation works wherein expansive soils are determined.

Charles *et al*. [12] evaluated the engineering properties of soil with the inclusion of costus afer (Bush sugarcane bagasse fiber ash (BSBFA) at varying percentages. Results of compaction of soil between the relationship of optimum moisture content (OMC) and maximum dry density (MDD) of soil and bagasse ash inclusion increased with increase in BSBFA percentages of 7.5% and decreased at 2.5% to 10% bagasse ash inclusion. Stabilization was found to satisfy subgrade requirements. Their results showed the potential of using BSBFA as admixture in soils of clay and laterite. Swelling of treated soil decreased with the inclusion of bagasse fibre ash up to 7.5% for both soils.

Agunwamba *et al.* [13] stated that soil stabilization with bagasse ash has come forth as a comely option to foresee low-cost roads construction and to achieve sufficient strength.

2. 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.

2.2 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. Results and Discussions

Preliminary results on clay soils as seen in detailed test results given in Tables: 3.1 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-7-6/CH 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 [14]; Allam and Sridharan [15]; Omotosho and Akinmusuru [16]; Omotosho [17]). The soils are re dark grey in colour (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

Table 3.1 presented the compaction test results of preliminary investigations of the engineering properties of clay soils of Ebiriba, Ochigba, Eneka and Isiokpo roads at natural state. The compaction test parameters computed are maximum dry density (MDD) 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%. Stabilized clay soils results of compaction test maximum dry density (MDD) are 1.565KN/m^3, 1.563KN/m^3, 1.543KN/m^3, 1.518KN/m^3 and optimum moisture content (OMC) 17.96%, 18.17%, 17.93% and 17.96%, at 2.5%, 5.0%, 7.5% and 10% of plantain rachis fibre ash to clay soils ratio . Results from table 3.2 and figures 3.1 – 3.4 showed decreased values of maximum dry density and increased values of optimum moisture content (OMC) in relation to fibre ash percentages inclusion.

3.2 California Bearing Ratio (CBR) Test

Results obtained at preliminary stages of test at 100% clay soils are California bearing ratio (CBR) values of unsoaked are 6.38%, 7.75%, 8.24% and 7.85%, and soaked 5.25%, 6.03%, 6.35% and 6.30%. Stabilized clay soils maximum results shown in table 3.2 are California bearing ratio (CBR) unsoaked values of 14.87%, 15.22%, 15.45%, 15.18%, and soaked 14.28%, 13.85%, 14.43% and 14.30%. Final results of plantain rachis fibre ash stabilized clay soils California bearing ratio of both unsoaked and soaked increased tremendously with fibre ash percentage ratio increase.

3.3 Unconfined Compressive Strength Test

Results computed from zero percentage clay soils from sampled road of unconfined compressive strength test are 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa. Plantain rachis fibre ash stabilized clay soils has peak values of 152kPa, 180kPa, 193kPa and 138kPa. Results of unconfined compressive strength test values increased with respect to percentage inclusion increase variations.

3.4 Consistency Limits Test

Computed results of preliminary investigation of clay soils at 100% natural state of consistency limits (Plastic index) are 28.55%, 25.97%, 33.50%, and 28.40%. Stabilized clays yielded maximum values of 27.42%, 28.27%, 32.41%, and 27.27%. Results as shown in table 3.3 and figures 3.1 – 3.4 showed decreased values of plastic index with fibre ash inclusion relative to percentage increase.

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	Grey	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	A-7-6/CH	A-7-6/CH	A-7-6/CH	A-7-6/CH

Unified Soil Classification System				
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	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)												
EBIRIBA	100%	1.685	16.38	6.38	5.25	68.85	57.30	28.75	28.55	79.55	A – 7 – 6/CH	POOR
ROAD	97.5+2.5%	1.650	16.85	9.28	7.85	83	57.18	28.86	28.32	79.55	A – 7 – 6/CH	POOR
AHOADA	95.0+5.0%	1.618	17.28	12.15	11.86	118	56.85	28.80	28.05	79.55	A – 7 – 6/CH	GOOD
WEST L.G.A	92.5+7.5%	1.583	17.64	14.87	14.28	123	56.45	28.59	27.86	79.55	A – 7 – 6/CH	GOOD
	90.0+10%	1.565	17.96	13.63	12.93	152	56.32	28.90	27.42	79.55	A – 7 – 6/CH	GOOD
OCHIGBA	100%	1.705	17.45	7.75	6.03	77.35	56.35	30.38	25.97	75.05	A – 7 – 6/CH	POOR
ROAD	97.5+2.5%	1.675	17.86	9.85	8.56	103	56.15	26.24	29.41	75.05	A – 7 – 6/CH	POOR
AHOADA	95.0+5.0%	1.645	18.25	12.85	11.05	126	55.85	26.77	29.08	75.05	A – 7 – 6/CH	GOOD
EAST L.G.A	92.5+7.5%	1.598	18.56	15.22	13.85	153	55.62	27.86	28.76	75.05	A – 7 – 6/CH	GOOD
	90.0+10%	1.563	18.17	13.95	12.36	180	55.37	27.10	28.27	75.05	A – 7 – 6/CH	GOOD
ENEKA	100%	1.663	16.75	8.24	6.35	79.85	63.30	29.80	33.50	82.85	A – 7 – 6/CH	POOR
ROAD	97.5+2.5%	1.645	16.96	10.38	9.51	108	63.05	29.69	33.36	82.85	A – 7 – 6/CH	GOOD
OBIO/AKPOR	95.0+5.0%	1.682	17.28	13.40	12.65	123	62.83	28.87	32.96	82.85	A – 7 – 6/CH	GOOD
L.G.A	92.5+7.5%	1.596	17.78	15.45	14.43	168	62.52	29.92	32.41	82.85	A – 7 – 6/CH	GOOD
	90.0+10%	1.543	17.93	14.28	13.28	193	62.33	29.92	32.41	82.85	A – 7 – 6/CH	GOOD
ISIOKPO	100%	1.605	15.87	7.85	6.30	65.75	57.75	29.35	28.40	69.55	A – 7 – 6/CH	POOR
ROAD	97.5+2.5%	1.591	16.18	10.30	8.95	79	57.43	29.39	28.09	69.55	A – 7 – 6/CH	GOOD
IKWERRE	95.0+5.0%	1.563	16.35	13.65	11.48	108	57.05	29.19	27.86	69.55	A – 7 – 6/CH	GOOD
L.G.A	92.5+7.5%	1.543	16.72	15.18	14.30	112	56.95	29.32	27.63	69.55	A – 7 – 6/CH	GOOD
	90.0+10%	1.518	17.96	14.35	13.86	138	56.81	29.54	27.27	69.55	A – 7 – 6/CH	GOOD

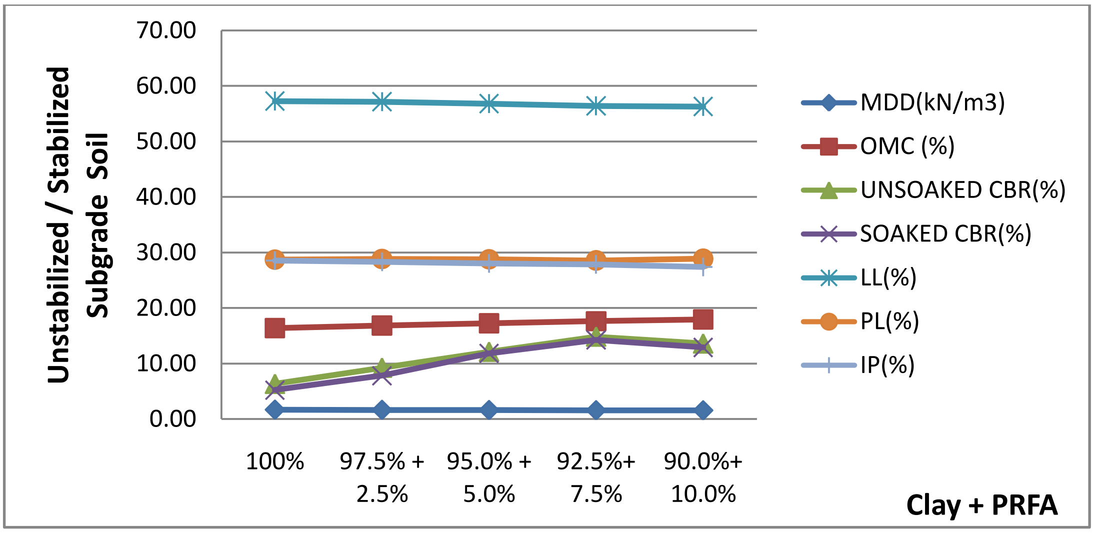

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ebiriba in Ahoada - West L.G.A of Rivers State with PRFA at Different Percentages and Combination

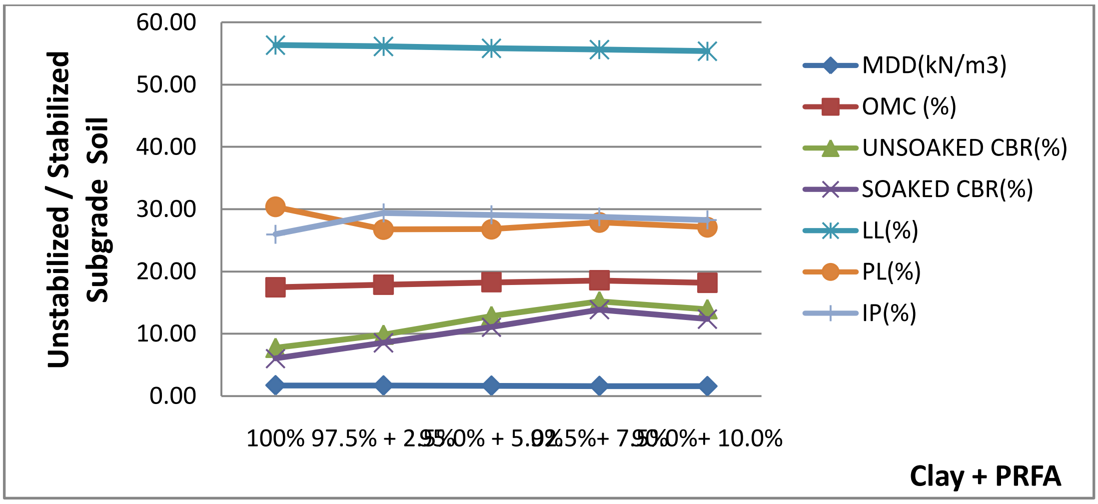

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Ochigba in Ahoada - East L.G.A of Rivers State with PRFA at Different Percentages and Combination

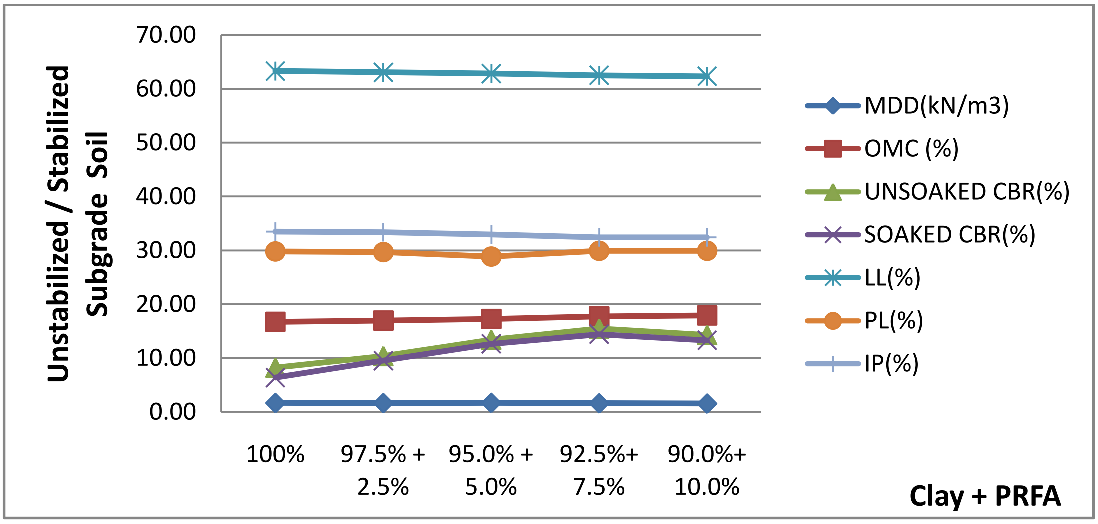

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Eneka in Obio/Akpor L.G.A of Rivers State with PRFA at Different Percentages and Combination

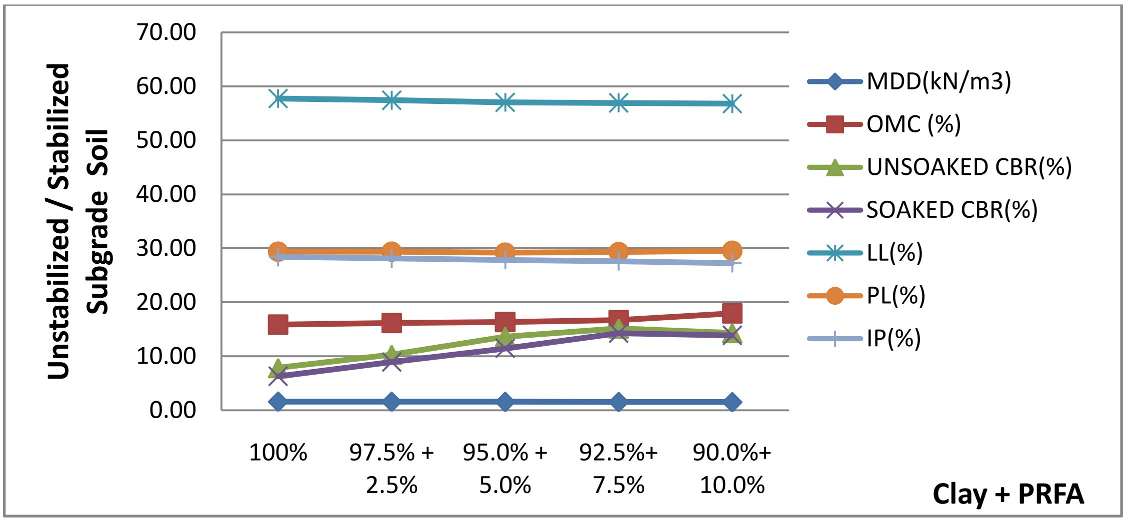

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Isiokpo in Ikwerre L.G.A of Rivers State with PRFA at Different Percentages and Combination

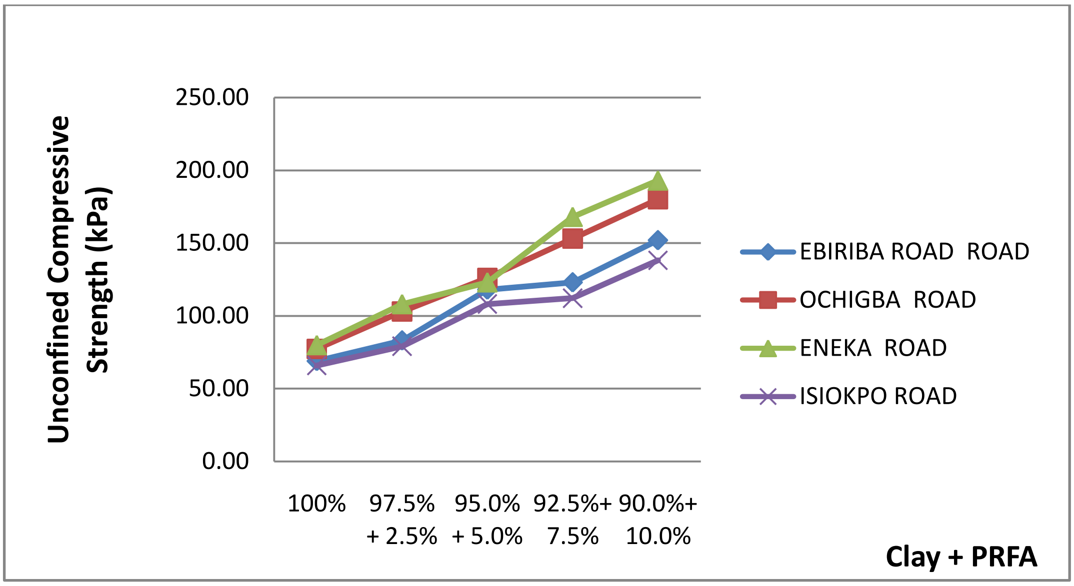

Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with PRFA of (Ebiriba, Ochigba, Eneka and Isiokpo Towns) all in Rivers State

4. 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. Results from table 3.2 and figures 3.1 – 3.4 showed decreased values of maximum dry density and increased values of optimum moisture content (OMC) in relation to fibre ash percentages inclusion.
iii. Final results of plantain rachis fibre ash stabilized clay soils California bearing ratio of both unsoaked and soaked increased tremendously with fibre ash percentage ratio increase.
iv. Results of unconfined compressive strength test values increased with respect to percentage inclusion increase variations
v. Results as shown in table 3.3 and figures 3.1 – 3.4 showed decreased values of plastic index with fibre ash inclusion relative to percentage increase.

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