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POTENTIAL APPLICATION OF HYBRIDIZED COMPOSITE MATERIALS IN THE STABILIZATION OF BLACK COTTON SOILS

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ABSTRACT
The study investigated the potential application of hybridized composite materials of plantain rachis fibre + cement in blended state for the manipulation/modification of problematic soft clay soils along failed stretches of highway subgrade soils in the Niger Delta region of Nigeria. The soils classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System with percentage(%) passing BS sieve #200; 75.55%, 75.05%, 82.85% and 69.55% for the sampled roads in table 3.1. Their natural characteristics based on preliminary investigation show that they fell short of the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW 1997). Final computed results of compaction test of composite stabilized clay soils increased in both maximum dry density (MDD) and optimum moisture content (OMC). Recorded results increases along varying composite percentage ratio. Proportionally, California bearing ratio of composite hybridized materials increased in both unsoaked and soaked values with optimum percentage inclusion at 0.75% +7.5%, beyond this value, crack was formed which resulted to potential failure state. Summarized stabilized clay soils unconfined compressive strength test results increased in values with varying percentage ratio increase. Final consistency limits (Plastic index) of composite materials stabilized clay soils recorded decreased values to varying percentages ratio inclusion increase. Entire results showed potential of the researched composites as good soil stabilizer

Keywords:
Clay, Plantain Rachis Fibre, Cement, CBR, UCS, Consistency, Compaction

INTRODUCTION
Expansive soils found in Niger Delta are complicated with unique and unstable attributes, generally encountered in foundation engineering designs for highways, embankment and backfills. They are seen in tropical / temperate zones marked with dry and wet season variations. The climatic condition is such that the once a year evaporation exceeds precipitation (Chen, [1]; Nelson and Miller, [2]; Warren and Kirby, [3]). They do not conform to the widely reported parent-rock-related gradation trend common to other lateritic soils and did not meet the (Ola [4]; Lohnes, Fish, and Daniel [5]; Tuncer and Lohnes [6]; Akpokodje [7]; Omotosho [8]; Leton and Omotosho [9]). To achieve the required standards, soils have to be improved before use by stabilization with additives in single or combined state.

Charles *et al*. [10] evaluated the geotechnical properties of an expansive clay soil found along Odioku – Odiereke road in Ahoada-West, Rivers State, in the Niger Deltaic region. The application of two cementitious agents of cement and lime, hybridized with costus afer bagasse fiber to strength the failed section of the road. Results obtained of compaction test of Optimum moisture content (OMC) and maximum dry density (MDD) of clay soils cement bush sugarcane bagasse fibre (BSBF) reinforced soils at combined actions to soil ratios of 3.75% 0.25%, 5.5% 0.5%, 7.25% 0.75% and 9% 1.0% of cement and BSBF combined percentages.

Edeh *et al.*[11] studied the evaluation of the characteristics of lateritic soil (LS) stabilized with sawdust ash (SDA), subjected to British standard light (BSL) compactive effort to determine their index, compaction, unconfined compressive strength (UCS), and California Bearing Ratio (CBR) results. The results of the laboratory tests show that the properties of LS improved when stabilized with SDA.

Charles *et al.*[12] 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. Treated soils with Lime decreased in liquid limits and increased in plastic limits. At 8% of lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% lime + 0. 75% BSBF, optimum value are reached.

MATERIALS AND METHODS

Materials

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.

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.

Cement

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

METHODS

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.

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;

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.

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.

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.

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.

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

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.

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 [13]; Allam and Sridharan [14]; Omotosho and Akinmusuru [15]; Omotosho [8]).

The soils are reddish brown and 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.

Compaction Test Results

Recorded results of compaction tests of sampled roads of Ebiriba, Ochigba, Eneka and Isiokpo soils at natural state 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%. Composite materials stabilized clay soils with plantain rachis fibre + cement at 0.25% + 2.5%, 0.5% +5.0%, 0.75% + 7.5% and 1.0% + 10% peak values of maximum dry density (MDD) are 1.793KN/m^3, 1.825KN/m^3, 1.785KN/m^3, 1.715KN/m^3 and optimum moisture content (OMC) 18.24%, 19.27%, 18.25% and 17.04%. Compaction test results of composite stabilized clay soils increased in both maximum dry density (MDD) and optimum moisture content (OMC). Recorded results increases along varying composite percentages ratio.

California Bearing Ratio (CBR) Test

Results obtained from sampled roads, clay soils at 100% preliminary investigation has 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%. Composite hybridized stabilized clay soils with percentages specified in table 3.1 has maximum 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%. Proportionally, California bearing ratio of composite hybridized materials increased in both unsoaked and soaked values with optimum percentage inclusion at 0.75% +7.5%, beyond this value, crack was formed which resulted potential failure state.

Unconfined Compressive Strength Test

Results from Sampled roads preliminary investigation of clay soils at zero percentage inclusion, the unconfined compressive strength are 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa. Final recorded results of composite stabilized clay soil with varying inclusions shown in table 3.2 are 455kPa, 473kPa, 515kPa, and 435kPa. Final summarized stabilized clay soils unconfined compressive strength test results increased in values with varying percentage ratio increase.

Consistency Limits Test

Computed consistency limits (Plastic index) test results at elemental investigation of zero percentage additives of clay soils are 28.55%, 25.97%, 33.50%, and 28.40% respectively for Ebiriba, Ochigba, Eneka and Isiokpo roads. Composite stabilized clay soils yielded maximum values of 27.45%, 28.53%, 32.59% and 27.43%. Final consistency limits (Plastic index) of composite materials stabilized clay soils recorded decreased values to varying percentages ratio inclusion increase.

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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

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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 + CEMENT	MDD (kN/m³)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
CLAY SOIL + PLATAIN RACHIS FIBRE ASH (PRF) + 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
	97.25+0.25+2.5%	1.693	16.93	33.45	29.30	108	57.58	29.35	28.23	79.55	A – 7 –6/CH	GOOD
	94.5+0.5+5.0%	1.725	17.38	42.68	38.60	243	57.74	29.71	28.03	79.55	A – 7 –6/CH	GOOD
	91.75+0.75+7.5%	1.765	17.83	56.25	52.85	365	58.05	30.22	27.83	79.55	A – 7 –6/CH	GOOD
	89+1.0+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
	97.25+0.25+2.5%	1.731	17.98	36.20	31.35	125	56.73	27.35	29.38	75.05	A – 7 –6/CH	GOOD
	94.5+0.5+5.0%	1.754	18.34	47.85	42.45	236	57.92	22.84	29.08	75.05	A – 7 –6/CH	GOOD
	91.75+0.75+7.5%	1.788	18.86	60.35	55.75	356	58.15	23.27	28.88	75.05	A – 7 –6/CH	GOOD
	89+1.0+10%	1.825	19.27	52.63	48.15	473	58.46	23.96	28.53	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
	97.25+0.25+2.5%	1.682	17.08	39.65	36.30	136	63.58	30.23	33.35	82.85	A – 7 –6/CH	GOOD
	94.5+0.5+5.0%	1.708	17.58	48.60	44.65	297	63.85	30.76	33.09	82.85	A – 7 –6/CH	GOOD
	91.75+0.75+7.5%	1.735	17.93	64.35	61.25	423	64.08	31.22	32.86	82.85	A – 7 –6/CH	GOOD
	89+1.0+10%	1.785	18.25	56.23	54.05	515	64.39	31.80	32.59	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
	97.25+0.25+2.5%	1.628	16.15	33.80	28.60	112	57.92	29.80	28.12	69.55	A – 7 –6/CH	GOOD
	94.5+0.5+5.0%	1.672	16.52	44.55	39.33	245	58.23	30.30	27.93	69.55	A – 7 –6/CH	GOOD
	91.75+0.75+7.5%	1.683	16.86	60.98	57.85	326	58.57	30.91	27.66	69.55	A – 7 –6/CH	GOOD
	89+1.0+10%	1.715	17.04	53.82	51.33	435	58.83	31.40	27.43	69.55	A – 7 –6/CH	GOOD

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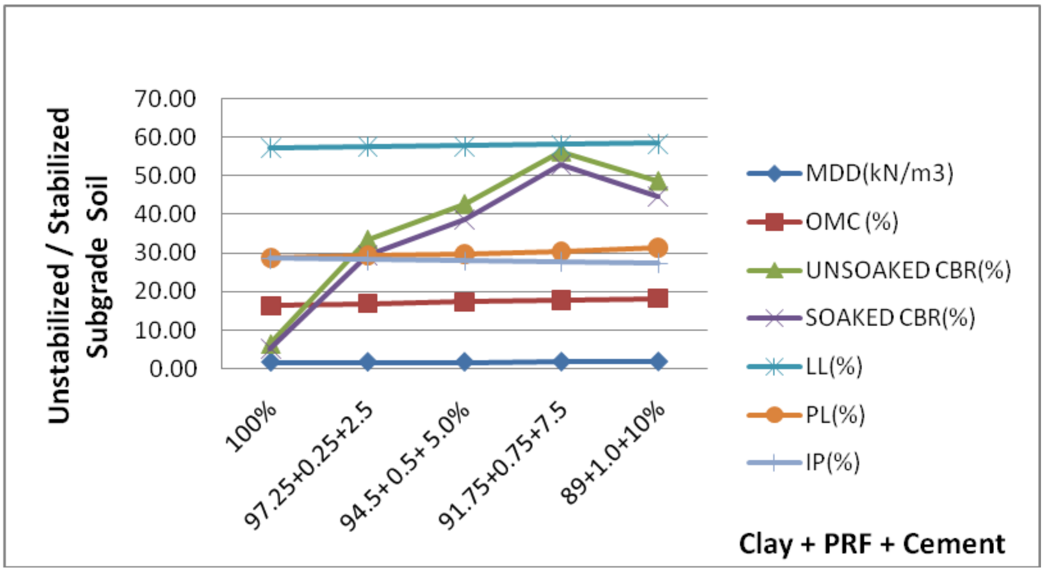

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ebiriba in Ahoada - West L.G.A of Rivers State with PRF + Cement at Different Percentages and Combination

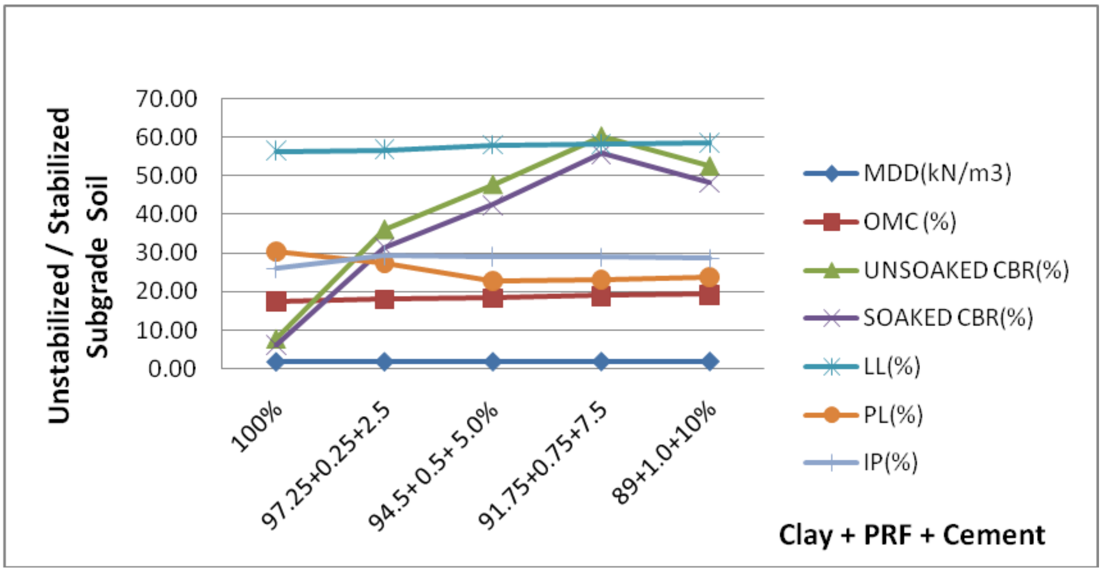

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Ochigba in Ahoada - East L.G.A of Rivers State with PRF + Cement at Different Percentages and Combination

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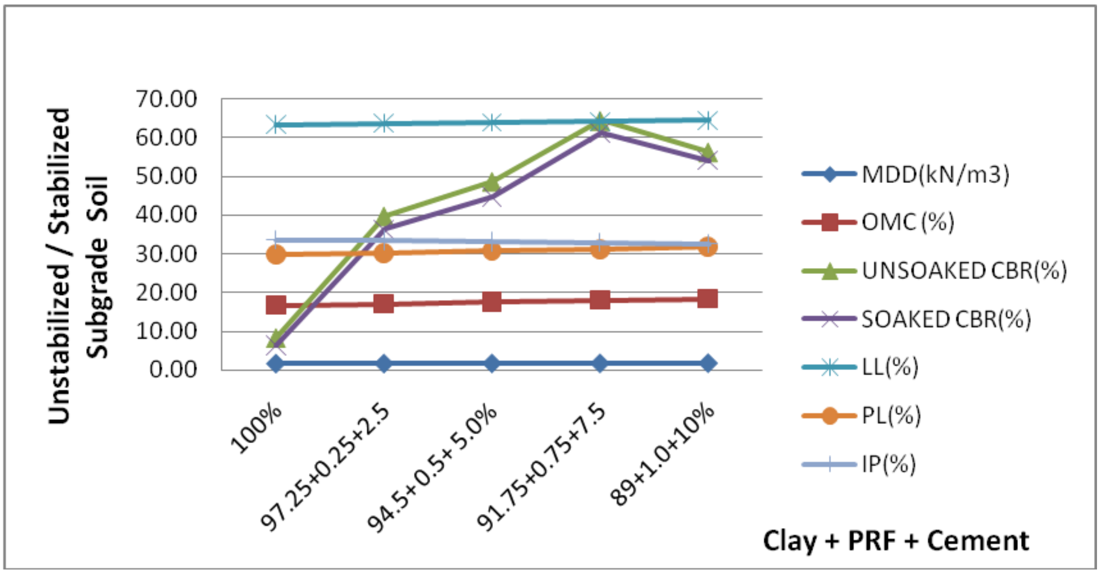

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Eneka in Obio/Akpor L.G.A of Rivers State with PRF + Cement at Different Percentages and Combination

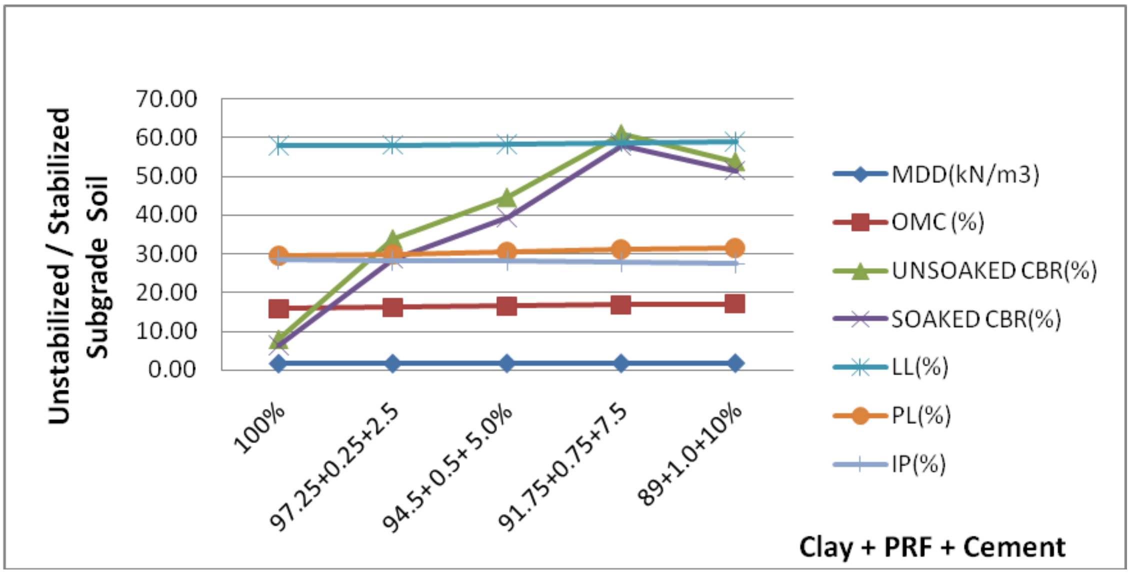

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Isiokpo in Ikwerre L.G.A of Rivers State with PRF + Cement at Different Percentages and Combination

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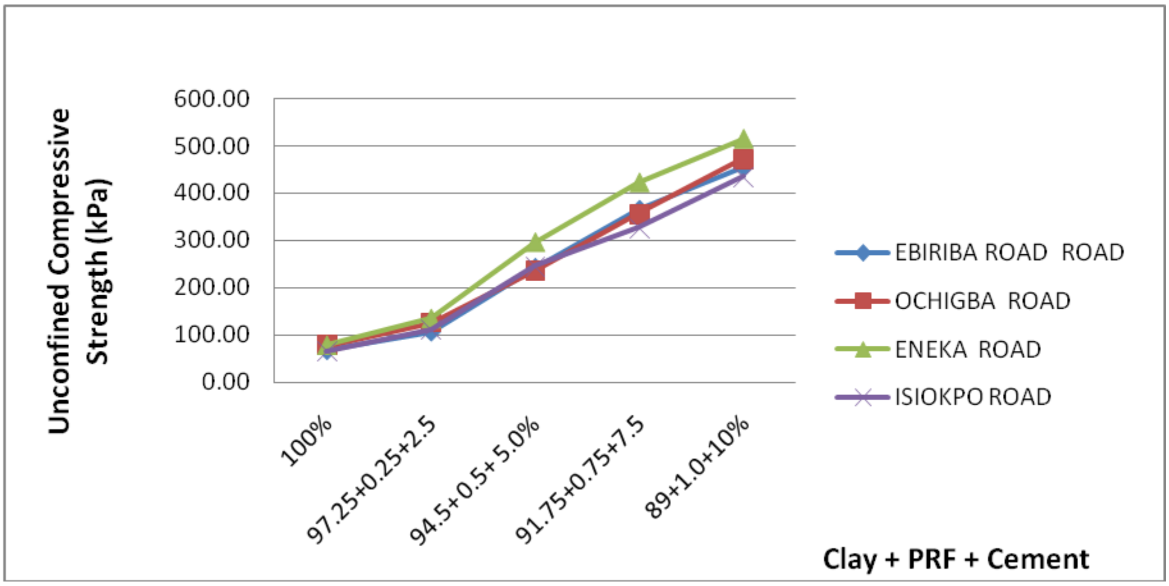

Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with PRF + Cement of (Ebiriba, Ochigba, Eneka and Isiokpo Towns) all in Rivers State

CONCLUSIONS

The following conclusions were made from the experimental research results.

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

[2] Compaction test results of composite stabilized clay soils increased in both maximum dry density (MDD) and optimum moisture content (OMC). Recorded results increases along varying composite percentages ratio.

[3] Proportionally, California bearing ratio of composite hybridized materials increased in both unsoaked and soaked values with optimum percentage inclusion at 0.75% +7.5%, beyond this value, crack was formed which resulted potential failure state.

[4] Final summarized stabilized clay soils unconfined compressive strength test results increased in values with varying percentage ratio increase.

[5] Final consistency limits (Plastic index) of composite materials stabilized clay soils recorded decreased values to varying percentages ratio inclusion increase.

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iJETRM
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