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Expansive Soil Stabilization using Composite Hybridized Materials of Plantain Rachis Fibre Ash and Cement

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Abstract The experimental research investigated the inclusion of blended materials of plantain fibre ash + cement at 2.5% + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% percentages ratio inclusions to lateritic soils of unstable and deceptive characteristics of seasonal volume changes. Preliminary investigation tests classified the soils as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System. Results shown in table 3.2 indicated that soils fell short of standard requirements as specified in Federal ministry of works (FMW 1997) and stabilization an only option. Results of stabilized soils in comparison of compaction test parameters of maximum dry density (MDD) and Optimum moisture content (OMC) increased with percentages ratio inclusion as against unstabilized soils. California bearing ratio of stabilized lateritic soils increased tremendously with respect to stabilizer percentages ratio inclusion as against un-stabilized soils with maximum ratio percentages of 7.5% + 7.5% optimum. Reversed values were obtained beyond optimum with cracks and failure modes. Results of unconfined compressive strength modified lateritic soils increased with respect to corresponding percentages ratio inclusion against un-stabilized soils. Comparatively, computed plastic index results of modified lateritic soils decreased with additives inclusion percentages ratio against un-stabilized soils. Entire results showed the use of plantain rachis fibre ash + cement as soil stabilizer.

Keywords Lateritic Soils, Plantain Rachis Fibre Ash, Cement, CBR, UCS, Consistency, Compaction

1. Introduction

The alteration of soil index properties by adding additives either in single and combined actions, such as cement, cement kiln dust, fly ash, lime often alters the physical and chemical properties of the soil including the cementation of the soil particles. There are two primary mechanisms by which chemicals alter the soil into a stable subgrade (Production Division Office of Geotechnical Engineering, PDOGE [1]. Increase in particle size by cementation, internal friction among the agglomerates, greater shear strength, reduction in the plasticity index, and reduced shrink/swell potential.

Gandhi [2] successfully worked on improving the existing poor and expansive sub grade soil using bagasse ash. Bagasse ash effectively dries wet soils and provides an initial rapid strength gain, which is useful during construction in wet, unstable ground conditions. He conducted tests like Liquid Limit, Plastic Limit, Plasticity Index, Shrinkage Limit, Free Swell Index and Swelling Pressure with the increasing percentage of Bagasse ash at 0 %, 3 %, 5 %, 7 % and 10 % respectively .He found out that as the percentage of bagasse ash increases in the soil sample, all the properties decrease.

Manikandan and Moganraj [3] had found that the combined effect of bagasse ash and lime were more effective than the effect of bagasse ash alone in controlling the consolidation characteristics of expansive soil along with the improvement in other properties.

Charles *et al*. [4] 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.

Prabakar*et et al*., [5] studied influence of fly ash on soils and reported that the addition of fly ash reduced the dry density of the soil due to the low specific gravity and unit weight of soil and improved the shear strength.

Ramakrishna and Pradeep [6] 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.

Sharma *et al*., [7] investigated the behavior of expansive clay stabilized with lime, calcium chloride and RHA. The optimum percentage of lime and calcium chloride was found to be 4 % and 1% respectively in stabilization of expansive soil without addition of RHA. From UCS and CBR point of view when the soil was mixed with lime or calcium chloride, RHA content of 12 % was found to be the optimum. In expansive soil – RHA mixes, 4% lime and 1% calcium chloride were also found to be optimum.

Charles *et al*. [8] investigated the effectiveness of natural fibre, costus afer bagasse (Bush sugarcane bagasse fibre (BSBF) as soil stabilizer / reinforcement in clay and lateritic soils with fibre inclusion of 0.25%, 0.50%, 0.75% and 1.0%. They concluded that both soils decreased in MDD and OMC with inclusion of fibre percentage, CRB values increased tremendously with optimum values percentage inclusion at 0.75%, beyond this value, crack was formed which resulted to potential failure state.

2. Materials and Methods

2.1. Materials

2.1.1. Soil

The soils used for the study were collected from Ogbogoro Town Road, in Obio/Akpor Local Government, Egbeda Town Road, in Emuoha Local Government Area, Igwuruta Town Road, in Ikwerre Local Government Area and Aleto Town Road, in Eleme 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 (Ash)

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. And the ash was obtained from burnt fibre.

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 Ogbogoro Town, (latitude 4.81° 33‘S and longitude 6.92° 18‘E), Egbeda a Town, (latitude 5.14° 15‘N and longitude 6.45° 23‘E), Igwuruta Town, latitude 4.97° 93‘N and longitude 6.99° 80‘E), and Aleto Town, latitude 4.81° 32‘S and longitude 7.09° 28‘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 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 [9]; Allam and Sridharan [10]; Omotosho and Akinmusuru [11]; Omotosho [12]. The soils are reddish brown in color (from wet to dry states) plasticity index of 17.11%, 22.5%, 14.10%, and 18.51% respectively for Ogbogoro, Egbeda, Igwuruta and Aleto Town Roads. The soil has unsoaked CBR values of 9.25%, 9.48%, 7.85% and 8.65 %, and soaked CBR values of 7.40%, 8.05%, 6.65% and 6.65 %, unconfined compressive strength (UCS) values of 168kPa, 178kPa, 163kPa and 175kPa when compacted with British Standard light (BSL), respectively.

3.1. Compaction Test Results

Investigative results of lateritic soils of sampled roads at preliminary of natural soils of maximum dry density (MDD), 1.755KN/m^3, 1.838KN/m^3, 1.924KN/m^3, 1.865KN/m^3, and Optimum moisture content (OMC), 14.85%, 14.40%, 15.03% and 16.05%. Stabilized lateritic soils with plantain fibre ash + cement at 2.5% + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% percentages ratio to soils peak values are maximum dry density (MDD)1.887KN/m^3, 2.035KN/m^3, 1.995KN/m^3, 2.245KN/m^3, and optimum moisture content (OMC) 16.73%, 17.63%, 15.93% and 16.69%. In comparison, stabilized lateritic soils compaction test parameters of maximum dry density (MDD) and Optimum moisture content (OMC) increased with percentages ratio inclusion as against unstabilized soils.

3.2. California Bearing Ratio (CBR) Test

The computed results of un-stabilized soils of California bearing ratio test values of unsoaked are 9.25%, 9.48%, 7.85% 8.65 % and soaked are 7.40%, 8.05%, 6.65% and 6.65 %. Modified lateritic test results with plantain rachis fibre ash + cement maximum CBR values are unsoaked 69.37%, 62.18%, 73.82%, 56.40% and soaked 62.40%, 57.33%, 68.72% and 51.15%. Results of California bearing ratio of stabilized lateritic soils increased tremendously with respect to stabilizer percentages ratio inclusion as against un-stabilized soils with maximum ratio percentages of 7.5% + 7.5% optimum. Reversed values were obtained beyond optimum with cracks and failure modes.

3.3. Unconfined Compressive Strength Test

Computed investigated results from preliminary test are 168kPa, 178kPa, 163kPa and 175kPa from sampled roads. Modified lateritic soils unconfined compressive strength test maximum recorded values are 465kPa, 483kPa, 493kPa and 461kPa. Results of unconfined compressive strength modified lateritic soils increased with respect to corresponding percentages ratio inclusion against un-stabilized soils.

3.4. Consistency Limits Test

Computed results from 100% lateritic soils consistency limits test (Plastic index) properties are 17.11 %, 22.50%, 14.1 0% and 18.51%. Modified lateritic soils unconfined compressive strength test maximum values are 15.92%, 17.08%, 20.96% and 12.84%. Comparatively, computed plastic index results of modified lateritic soils decreased with additives inclusion percentages ratio against un-stabilized soils.

Table 3.1: Engineering Properties of Soil Samples

Location Description	**Ogobogoro Road Obio/Akpor L.G.A**	**Egbeda Road Emuoha L.G.A**	**Igwuruta Road Ikwere L.G.A**	**Aleto Road Eleme L.G.A**
Depth of sampling (m)	1.5	1.5	1.5	1.5
Percentage(%) passing BS sieve #200	38.35	42.15	36.35	39.40
Colour	Reddish	Reddish	Reddish	Reddish
Specific gravity	2.59	2.78	2.77	15.35
Natural moisture content (%)	22.6	19.48	10.95	15.35
Consistency				
Liquid limit (%)	38.46	42.35	35.15	38.65
Plastic limit (%)	21.35	19.85	21.05	20.14
Plasticity Index	17.11	22.50	14.1 0	18.51
AASHTO soil classification Unified Soil Classification System	A-2-4/SM	A-2-4/SM	A-2-4/SC	A-2-4/SC
Optimum moisture content (%)	14.85	14.40	15.08	16.05
Maximum dry density ($kN/m^{3)}$	1.755	1.883	1.924	1.865
Gravel (%)	3.25	2.85	3.83	2.35
Sand (%)	38.65	36.50	32.58	39.45
Silt (%)	23.85	38.75	33.45	37.85
Clay (%)	34.25	22.90	30.14	20.35
Unconfined compressive strength (kPa)	168	178	163	175
California Bearing Capacity (CBR)				
Unsoaked (%) CBR	9.25	9.48	7.85	8.65
Soaked (%) CBR	7.40	8.05	6.65	6.93

Table 3.2: Results of Subgrade Soil (Latrite) 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**
		LATERITE + PLANTAIN RACHIS FIBRE ASH (PRFA) + CEMENT										
OGOBOGORO ROAD OBIO/AKPOR L.G.A	100%	1.755	14.85	9.25	7.40	168	38.46	21.35	17.11	38.46	A–2–4/SM	POOR
	95+2.5+2.5%	1.787	15.38	36.38	31.45	238	40.23	23.31	16.92	38.46	A–2–4/SM	GOOD
	90+5.0+5.0 %	1.805	15.65	49.75	43.30	318	40.68	24.03	16.65	38.46	A–2– 4/SM	GOOD
	85+7.5+7.5 %	1.845	16.05	69.37	62.40	375	40.93	24.69	16.24	38.64	A –2–4/SM	GOOD
	80+10+10 %	1.887	16.73	58.35	54.85	465	41.15	25.23	15.92	38.64	A –2–4/SM	GOOD
ALETO ROAD ELEME L.G.A	100%	1.865	16.05	8.65	6.93	175	38.65	20.14	18.51	39.40	A –2– 4/SC	POOR
	95+2.5+2.5%	1.897	16.48	31.45	27.60	247	38.93	20.68	18.25	39.40	A –2– 4/SC	GOOD
	90+5.0+5.0 %	1.927	16.93	48.64	42.15	296	39.24	21.26	17.98	39.40	A–2– /SC	GOOD
	85+7.5+7.5 %	1.964	17.28	62.18	57.33	388	40.15	23.07	17.08	39.40	A–2– 4/SC	GOOD
	80+10+10 %	2.035	17.63	54.80	49.45	483	40.15	23.07	17.08	39.40	A–2– 4/SC	GOOD
EGBEDA ROAD EMUOHA L.G.A	100%	1.883	14.40	9.48	8.05	178	42.35	19.85	22.50	42.15	A–2– 4/SM	POOR
	95+2.5+2.5%	1.874	14.78	38.30	33.60	241	42.73	20.45	22.28	42.15	A–2– 4/SM	GOOD
	90+5.0+5.0 %	1.915	15.04	56.30	49.96	318	42.96	21.02	21.94	42.15	A–2– 4/SM	GOOD
	85+7.5+7.5 %	1.967	15.63	73.82	68.72	410	43.28	21.65	21.63	42.15	A–2– 4/SM	GOOD
	80+10+10 %	1.995	15.93	64.85	59.73	493	43.70	22.74	20.96	42.15	A–2– 4/SM	GOOD
IGWURUTA ROAD IKWERE L.G.A	100%	1.924	15.08	7.85	6.65	168	35.15	21.05	14.10	36.35	A –2– 4/SC	POOR
	95+2.5+2.5%	1.965	15.38	25.65	22.30	197	35.54	21.81	13.73	36.35	A –2– 4/SC	GOOD
	90+5.0+5.0 %	1.993	15.95	37.05	32.45	228	35.80	24.42	13.38	36.35	A –2– 4/SC	GOOD
	85+7.5+7.5 %	2.185	16.35	56.40	51.15	353	36.17	23.09	13.08	36.35	A–2– 4/SC	GOOD
	80+10+10 %	2.245	16.69	49.80	43.35	461	36.68	23.84	12.84	36.35	A–2– 4/SC	GOOD

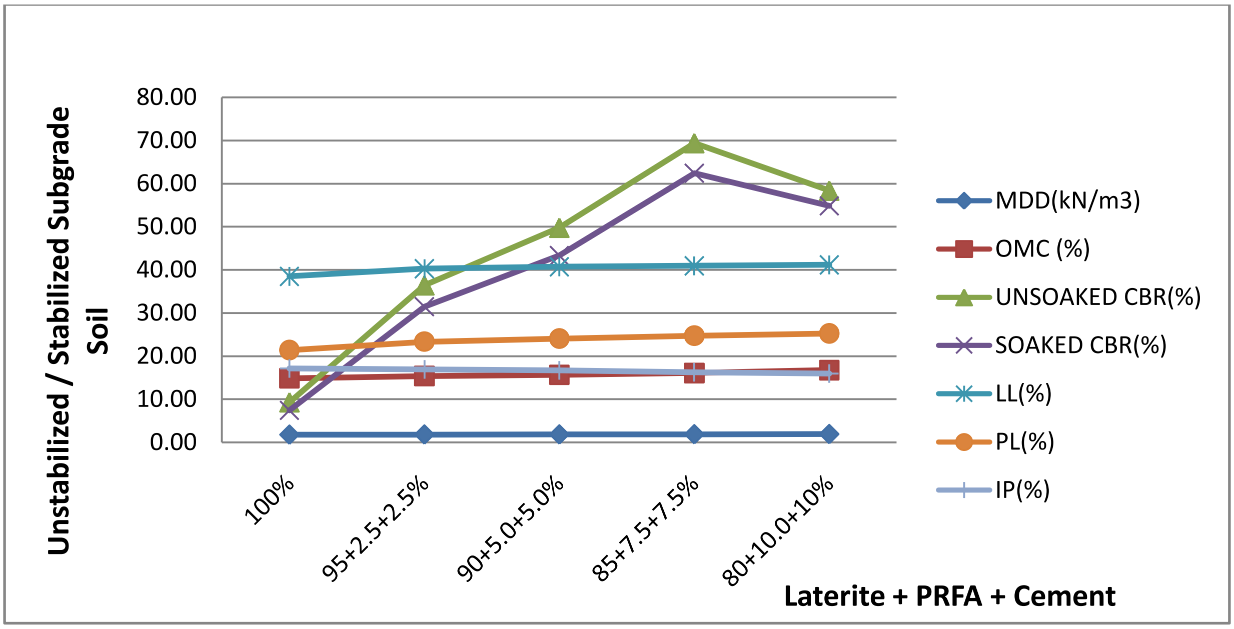

Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Ogbogoro in Obio/Akpor L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

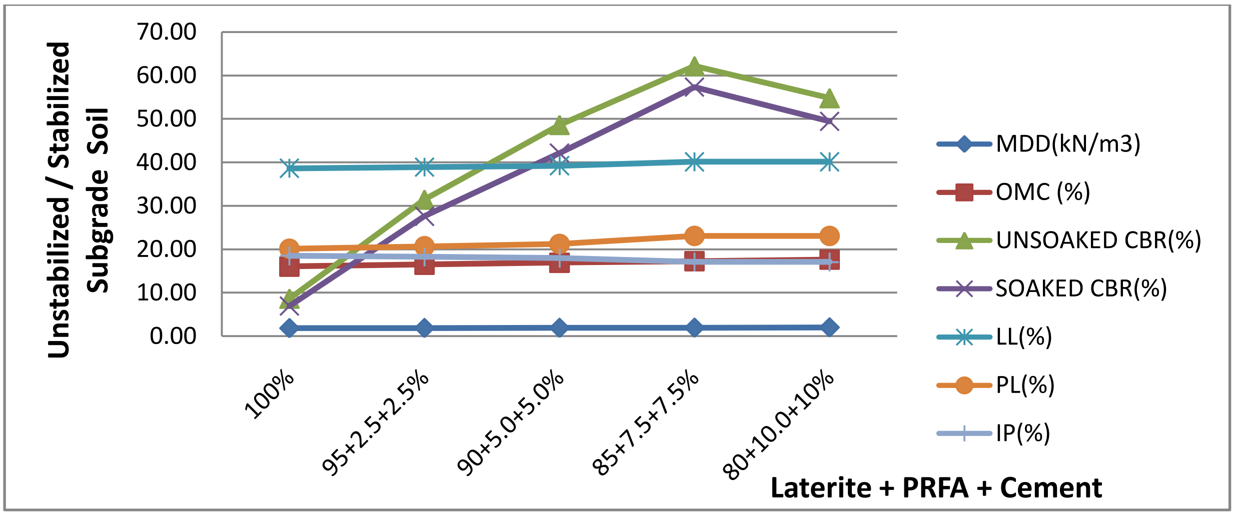

Figure 3.2: Subgrade Stabilization Test of Lateritic Soil from Aleto in Eleme L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

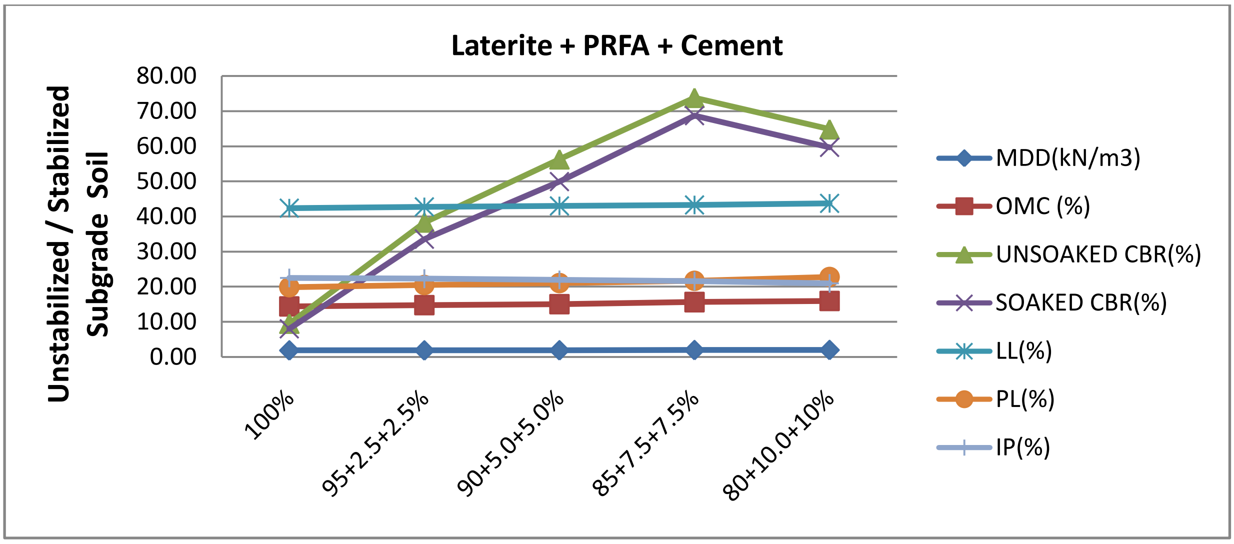

Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Egbeda in Emuoha L.G.A of Rivers State with PRF A+ Cement at Different Percentages and Combination

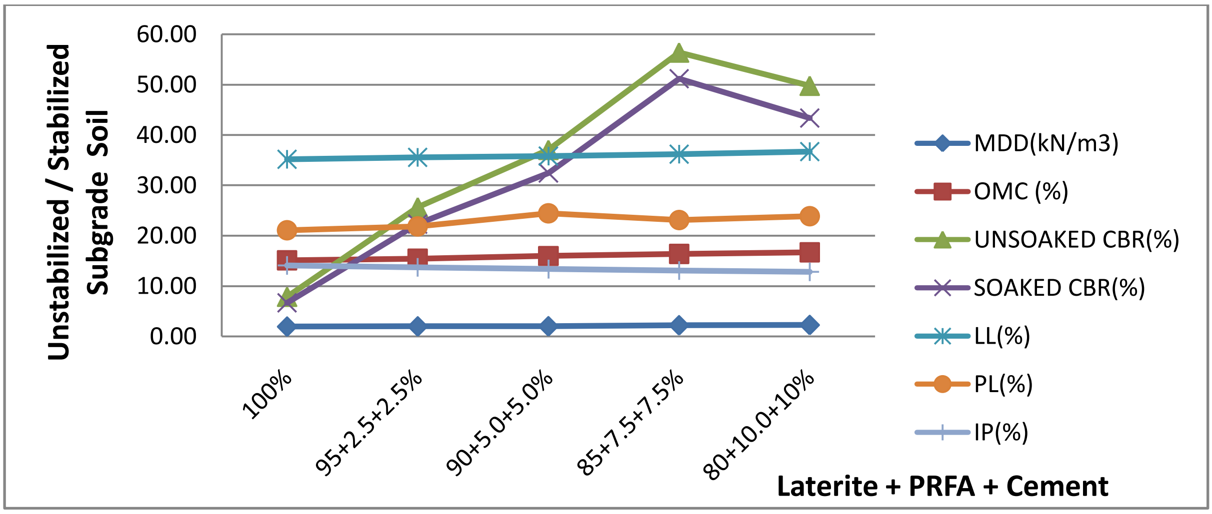

Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Igwuruta in Ikwerre L.G.A of Rivers State with PRFA + Cement at Different Percentages and Combination

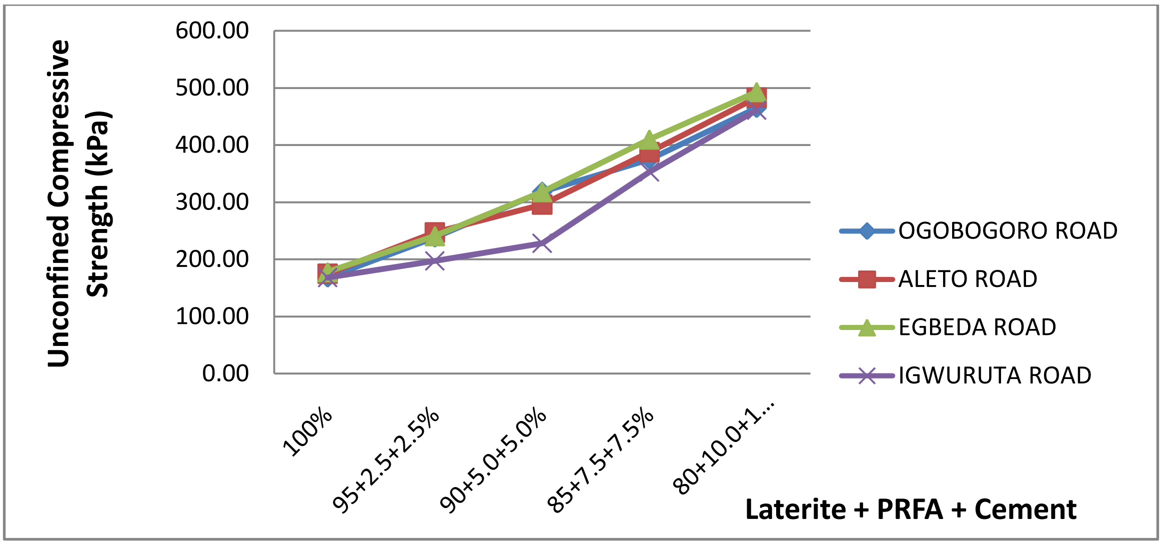

Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with PRFA + Cement of (Ogbogoro, Aleto, Egbeda andIgwuruta Towns) all in Rivers State

4. Conclusions

The following conclusions were made from the experimental research results.

i. Soils are classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System.

ii. In comparison, stabilized lateritic soils compaction test parameters of maximum dry density (MDD) and Optimum moisture content (OMC) increased with percentages ratio inclusion as against unstabilized soils.

iii. Results of California bearing ratio of stabilized lateritic soils increased tremendously with respect to stabilizer percentages ratio inclusion as against un-stabilized soils with maximum ratio percentages of 7.5% + 7.5% optimum. Reversed values were obtained beyond optimum with cracks and failure modes.

iv. Results of unconfined compressive strength modified lateritic soils increased with respect to corresponding percentages ratio inclusion against un-stabilized soils.

v. Comparatively, computed plastic index p results of modified lateritic soils decreased with additives inclusion percentages ratio against un-stabilized soils.

vi. Entire results showed the use of plantain rachis fibre ash + cement as soil stabilizer.

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