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Modification of Problematic Soil with Costaceae Lacerus Bagasse Fibre Ash as Pozzolana Material

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Abstract The study investigated the application of costaceae lacerus bagasse fibre ash (CLBFA) as Pozzolana material for stabilization of problematic soils found in Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Town roads in the Niger Delta region of Nigeria. Preliminary results showed that the soils fell low of approved standard and specifications of FMW and the need to improved the soil required. Swelling potential of treated soil decreased with the inclusion of 2.5%, 5.0%, 7.5% and 10% bagasse fibre ash. Results showed a decreased in plastic index due CLBFA inclusion to lateritic soil. Unconfined compressive strength results showed tremendous increased with increased in additive percentages to soil ratios. California bearing ratio of unsoaked and soaked reached optimum values percentage inclusion at 7.5% to soil ratio, beyond this value, crack was formed which resulted potential failure state.

Keywords Lateritic soils, costaceae lacerus, CBR, UCS, Consistency, Compaction

1. Introduction

Niger Delta soils are problematic always encountered when pavement is being design including other engineering jobs. They are known to be notorious soil because of their poor performance as a road construction material. These soils are found in the whole regions of the Niger delta and with high rainfall. (Chen,[1]). Although poor and undesirable for engineering purposes, the properties of lateritic soil could be improved to meet standard specification by modification and stabilization processes. Stabilization of the soil with chemical additives is a common method of reducing the swelling and shrinkage tendencies of the soil and also makes the soil less plastic (Ola, [2]; Balogun, [3]; Osinubi, [4]; [5]). Cement is one of the most effective in reducing the swelling properties of these soils (Osinubi *et al.,* [6]).

Charles *et al*. [7] 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.* [8] 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.

Sabat [9] investigated the effects of bagasse ash and lime sludge on OMC, MDD, UCS, soaked CBR and Swelling pressure of an expansive soil in order to study its cost effectiveness in strengthening the sub-grade of a flexible pavement in expansive soil areas. The best stabilization effects were obtained when the optimum percentage of bagasse ash was 8% and lime sludge was

Manikandan and Moganraj [10] 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

2. Materials and Methods

2.1 Materials

2.1.1 Soil

The soils used for the study were collected from Ubie, Upata and Igbuduya Districts of Ekpeye, Ahoada- East and Ahoada-West Local Government of Rivers State, beside the at failed sections of the Unity linked roads at 1.5 m depth, at Odiokwu Town Road(CH 0+950), Oyigba Town Road(CH 4+225), Anakpo Town Road(CH6+950) , Upatabo Town Road (CH8+650), Ihubuluko Town Road, all of Rivers State, Niger Delta, Nigeria. It lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Costaceae Lacerus Bagasse Fibre Ash

The Costaceae Lacerus bagasse fibre are wide plants, medicinally used in the local areas, abundant in Rivers State farmlands / bushes, they covers larger areas, collected from at Oyigba 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 Town, (latitude 5.07° 14‘S and longitude 6.65° 80‘E), Oyigba Town, (latitude 7.33° 24‘S and longitude 3.95° 48‘E), Oshika Town, latitude 4.05° 03‘S and longitude 5.02° 50‘E), Upatabo Town, (latitude 5.35° 34‘S and longitude 6.59° 80‘E) and Ihubujuko Town, latitude 5.37° 18‘S and longitude 7.91° 20‘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 laterite 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 [2]; Allam and Sridharan [10]; Omotosho and Akinmusuru [11]; Omotosho [12]).

The soils are reddish brown and dark grey in colour (from wet to dry states) plasticity index of 17.30%, 14.23%, 15.20%, 15.50%, and 16.10% respectively for Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads. The soil has unsoaked CBR values of 8.7%,8.5%, 7.8%, 9.4%, and 10.6% and soaked CBR values of 8.3%, 7.8%, 7.2%, 8.5% and 9.8 %, unconfined compressive strength (UCS) values of 178kPa, 145kPa, 165kPa, 158kPa and 149kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

The results of lateritic soils of Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads at 100% of maximum dry density (MDD) at preliminary test were 1.954KN/m^3, 1.857KN/m^3, 1.943KN/m^3, 1.758KN/m^3 and 2.105KN/m^3 with costaceae lacerus bagasse fibre ash (CLBFA) at 2.5%, 5.0%, 7.5%, and 10% inclusion decreased to 1.904KN/m^3, 1.665KN/m^3, 1.705KN/m^3, 1.578KN/m^3 and 1.826KN/m^3 respectively. Optimum moisture content (OMC) of lateritic soils were 12.39%, 14.35%, 13.85%, 11.79 and 10.95% at 100% soils (ie no additives), increased to 14.35%, 15.75%, 15.75%, 13.65% and 12.65% correspondingly.

3.2 California Bearing Ratio (CBR) Test

Results obtained for lateritic soils at 100% are 8.7%,8.5%, 7.8%, 9.4% and 10.6% and bagasse fibre ash inclusion of 2.5%, 5.0%, 7.5% and 10% increased from 11.35%, 12.25%, 13.25%, 13.85% and 15.35% (unsoaked), 12.45% , 10.35%, 12.35%, 12.38% and 14.15% (soaked), both had optimum values percentage inclusion at 0.75%, beyond this value, crack was formed which resulted potential failure state.

3.3 Unconfined Compressive Strength Test

Results obtained of lateritic soils at preliminary investigation of unconfined compressive strength are 178kPa, 145kPa, 165kPa, 158kPa and 149kPa at 100%. For bagasse fibre ash inclusion of 2.5%, 5.0%, 7.5%, and 10%, UCS values are 215kPa, 198kPa, 215kPa, 208kPa and 202kPa respectively. Results showed tremendous increased with increased in additive percentages to soil ratios.

3.4 Consistency Limits Test

Results of consistency limits (Plastic Index) at 100% lateritic soil are 17.30%, 14.23%, 15.20%, 15.50%, and 16.10%. With bagasse fibre ash inclusion, decreased of 12.30%, 11.11% and 11.90%, 14.10%, and 12.81% were recorded. Results showed decreased in plastic index due to CLBFA inclusion to lateritic soil.

Table 3.1: Engineering Properties of Soil Samples

Location Description	Odiokwu Town Road (CH 0+950)	Oyigba Town Road (CH 4+225)	Anakpo Town Road (CH6+950)	Upatabo Town Road (CH8+650)	Ihubuluko Town Road (CH10+150)
	(Laterite)	(Laterite)	(Laterite)	(Laterite)	(Laterite)
Depth of sampling (m)	1.5	1.5	1.5	1.5	
Percentage(%) passing BS sieve #200	28.35	40.55	36.85	33.45	39.25
Colour	Reddish	Reddish	Reddish	Reddish	Reddish
Specific gravity	2.65	2.50	2.59	2.40	2.45
Natural moisture content (%)	9.85	11.25	10.35	11.85	8.95
Consistency Limits					
Liquid limit (%)	39.75	36.90	36.75	36.85	37.65
Plastic limit (%)	22.45	22.67	21.45	19.35	21.55
Plasticity Index	17.30	14.23	15.20	15.50	16.10
AASHTO soil classification	A-2-6	A-2-4	A-2-4	A-2-6	A-2-4
Unified Soil Classification System	SC	SM	SM	SC	SM

Compaction Characteristics					
Optimum moisture content (%)	12.39	14.35	13.85	11.79	10.95
Maximum dry density (kN/m$^{3)}$	1.953	1.857	1.943	1.953	2.105
Grain Size Distribution					
Gravel (%)	6.75	5.35	5.05	8.25	7.58
Sand (%)	35.56	37.35	28.45	29.56	34.25
Silt (%)	33.45	35.65	39.45	38.85	33.56
Clay (%)	24.24	21.65	27.05	23.34	24.61
Unconfined compressive strength (kPa)	178	145	165	158	149
California Bearing capacity (CBR)					
Unsoaked (%) CBR	8.7	8.5	7.8	9.4	10.6
Soaked (%) CBR	8.3	7.8	7.2	8.5	9.8

Table 3.2: Properties of Coataceae Lacerus bagasse fibre. (University of Uyo, Chemical Engineering Department, Material Lab.1)

Property	Value
Fibre form	Single
Average length (mm)	400
Average diameter (mm)	0.86
Tensile strength (MPa)	68 - 33
Modulus of elasticity (GPa)	1.5 – 0.54
Specific weight (g/cm^3)	0.69
Natural moisture content (%)	6.3
Water absorption (%)	178 - 256

Source, 2018

Table 3.3: Composition of Bagasse. (University of Uyo, 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 (laterite) Test Stabilization with Fibre Bagasse Products at Different Percentages

SAMPLE LOCATION	SOIL + FIBRE BAGASSE ASH RATIO	MDD (KN/m$^{3)}$	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
LATERITE + COSTACEAE LACERUS BAGASSE FIBRE ASH (CLBFA)												
Odiokwu Town Road (CH (0+950)	100%	1.954	12.39	8.70	8.30	178	39.75	22.45	17.30	28.35	A-2-6/SC	POOR
	97.5% + 2.5%	1.949	12.64	9.50	8.55	181	38.65	22.68	15.97	28.35	A-2-6/SC	POOR
	95.0% + 5.0%	1.938	13.24	10.65	10.35	190	37.85	23.08	14.77	28.35	A-2-6/SC	GOOD
	92.5%+ 7.5%	1.927	13.87	12.45	11.57	197	36.95	23.73	13.17	28.35	A-2-6/SC	GOOD
	90.0%+ 10.0%	1.904	14.35	11.35	10.68	215	36.35	24.05	12.30	28.35	A-2-6/SC	GOOD
Oyigba Town Road (CH 4+225)	100%	1.857	14.35	8.50	7.80	145	36.90	22.67	14.23	22.67	A-2-4/SM	POOR
	97.5% + 2.5%	1.805	14.86	9.35	8.95	146	36.35	22.96	13.99	40.55	A-2-4/SM	POOR
	95.0%+ 5%	1.764	14.97	10.45	10.25	156	36.08	23.35	12.73	40.55	A-2-4/SM	GOOD
	92.5%+ 7.5%	1.706	15.25	12.25	11.65	175	35.79	23.95	11.84	40.55	A-2-6/SM	GOOD
	90%+ 10%	1.665	15.75	11.25	10.35	198	35.26	24.15	11.11	40.55	A-2-4/SM	GOOD
Anakpo	100%	1.943	13.85	7.80	7.20	165	36.75	21.45	15.30	36.85	A-2-4/SM	POOR

Town Road (CH6+950)	97.5% + 2.5%	1.906	14.06	9.05	8.75	176	36.28	21.85	14.43	36.85	A-2-4/SM	GOOD
	95.% + 5.0%	1.875	14.67	10.28	9.65	183	35.94	22.36	13.58	36.85	A-2-4/SM	GOOD
	92.5%+ 7.5%	1.825	15.05	13.25	12.35	194	35.35	22.85	12.50	36.85	A-2-4/SM	GOOD
	90%+ 10%	1.705	15.75	11.65	11.35	215	35.05	23.15	11.90	36.85	A-2-4/SM	GOOD
Upatabo Town Road (CH8+650)	100%	1.758	11.79	9.40	8.50	158	36.85	19.35	17.50	33.45	A-2-6/SC	POOR
	97.5% + 2.5%	1.715	12.25	11.06	10.36	167	36.35	19.83	16.52	33.45	A-2-6/SC	GOOD
	95.0%+ 5%	1.685	12.76	12.35	11.85	181	36.04	20.18	15.56	33.45	A-2-6/SC	GOOD
	92.5% + 7.5%	1.625	13.05	13.85	12.38	193	35.75	20.65	15.10	33.45	A-2-6/SC	GOOD
	90% + 10%	1.578	13.65	12.04	11.65	208	35.18	21.08	14.10	33.45	A-2-6/SC	GOOD
Ihubuluko Town Road (CH10+150)	100%	2.105	10.95	10.60	9.80	145	37.65	21.55	16.10	39.25	A-2-6/SC	GOOD
	97.5% + 2.5%	1.965	11.25	12.15	10.45	152	37.08	21.98	15.10	39.25	A-2-6/SC	POOR
	95.0%+ 5%	1.925	11.65	13.85	12.65	168	36.28	22.35	14.43	39.25	A-2-6/SC	GOOD
	92.5%+ 7.5%	1.886	12.05	15.35	14.15	187	36.45	22.85	13.60	39.25	A-2-6/SC	GOOD
	90%+ 10%	1.826	12.65	14.40	13.35	202	36.06	23.25	12.81	39.25	A-2-6/SC	GOOD

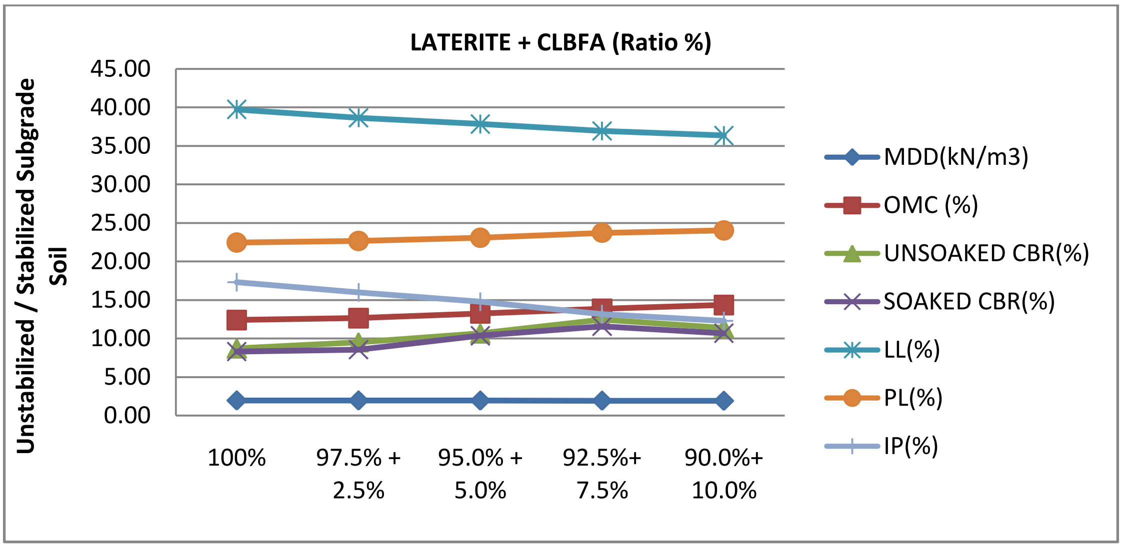

Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

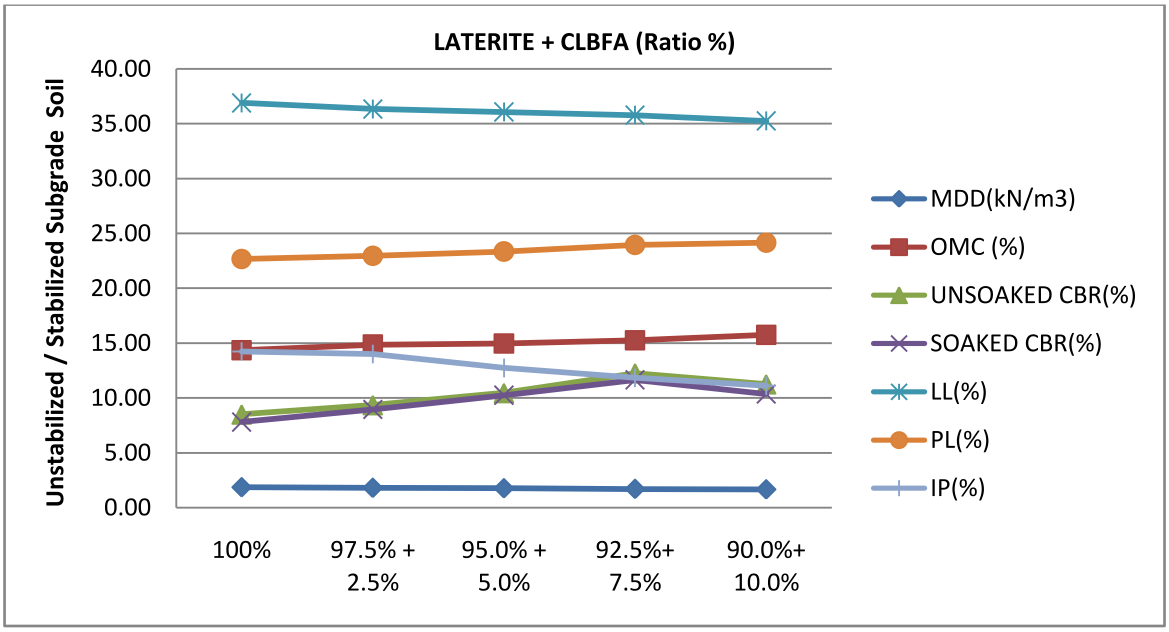

Figure 3.2: Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

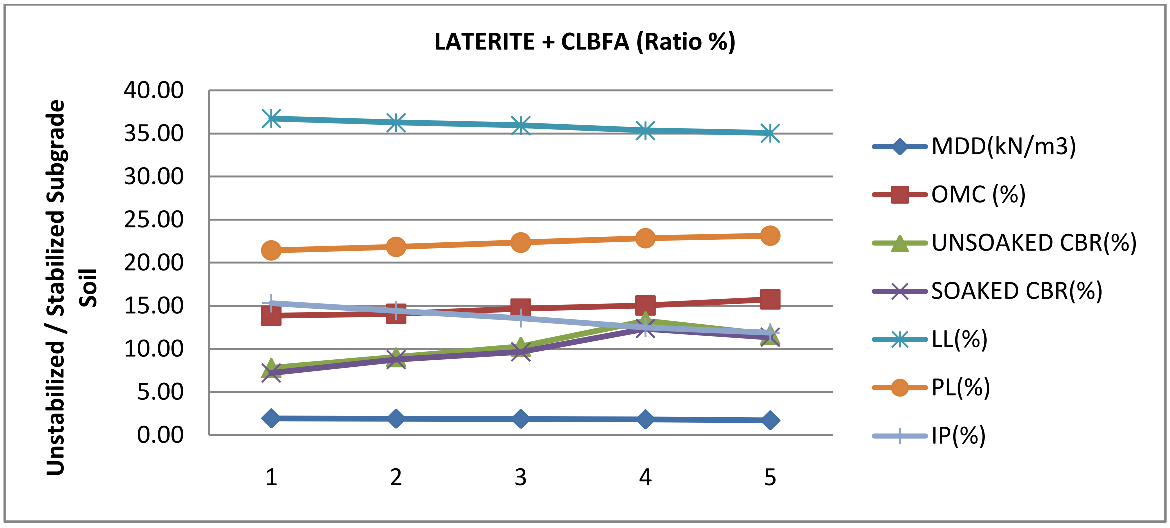

Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

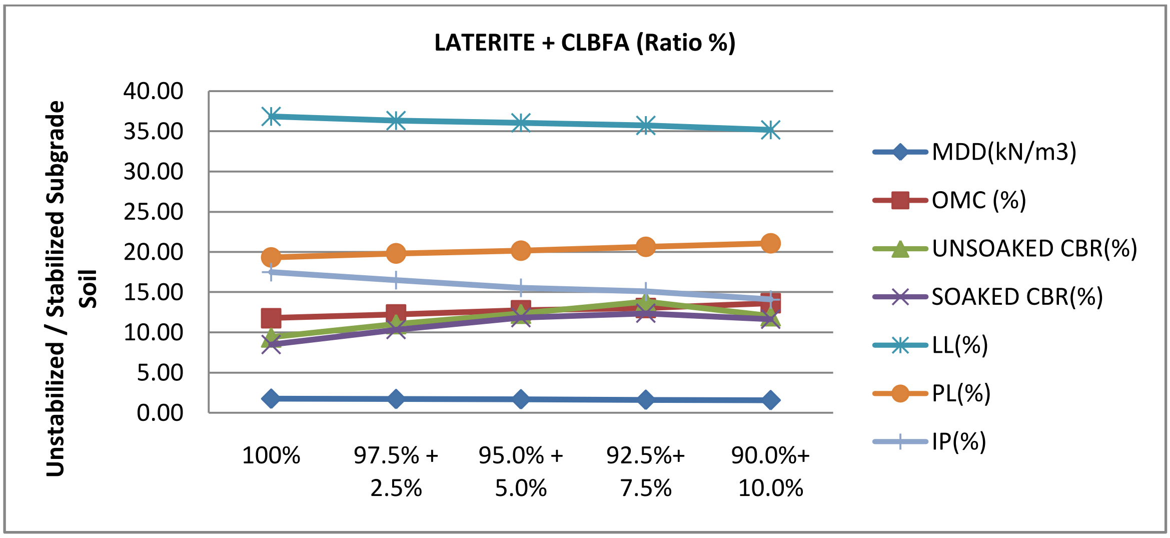

Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

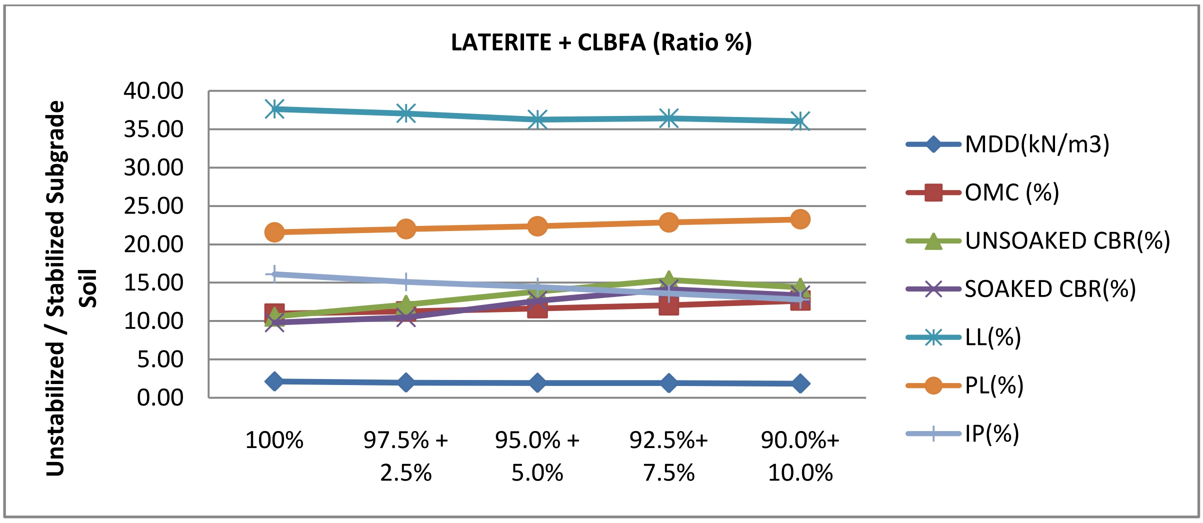

Figure 3.5: Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

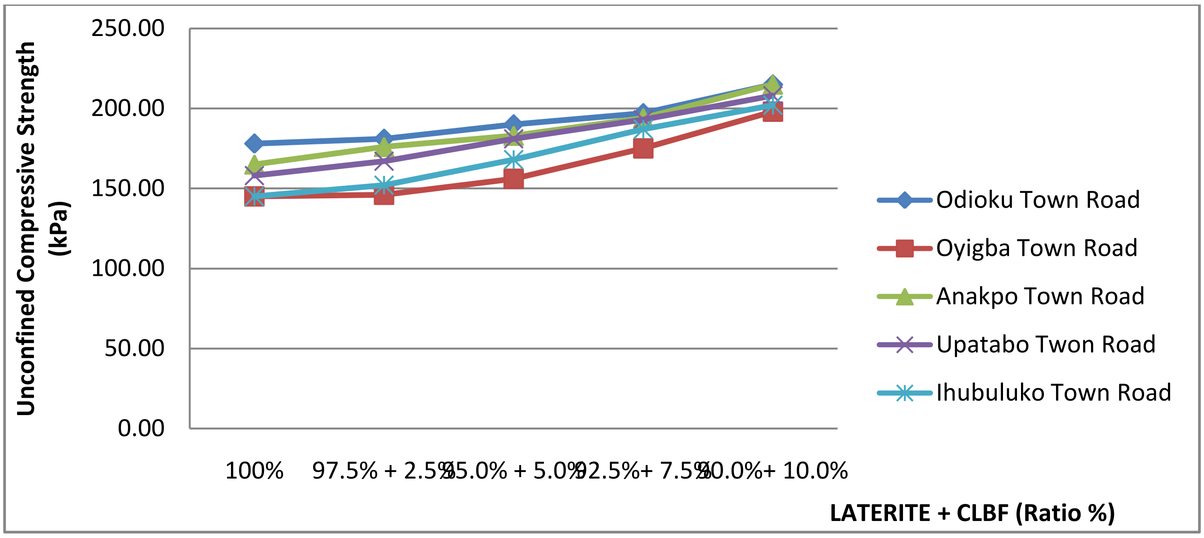

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with CLBF of (Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoad-West L.G.A, Rivers State

Plate i. Costaceae Lacerus plant

Plate ii. Costaceae Lacerus stem

Plate iii. Costaceae Lacerus dry bagasses/fibre

Plate iv. Costaceae Lacerus Bagasses Fibre ash

4. Conclusions

The following conclusions were made from the experimental research results.

i. Preliminary investigations of the engineering Properties of soils at natural state are percentage (%) passing BS sieves #200 are 28.35%, 40.55%, 36.85%, 33.45% and 39.25% (laterite), and 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.
ii. Swelling potential of treated soil decreased with the inclusion of bagasse fibre ash of up to 7.5 soils
iii. Results showed a decreased in plastic index due CLBFA inclusion to lateritic soil.
iv. Unconfined compressive strength results showed tremendous increased with increased in additive percentages to soil ratios.
v. California bearing ratio of unsoaked and soaked reached optimum values percentage inclusion at 7.5%, beyond this value, crack was formed which resulted potential failure state.

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