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Expansive Soil Stabilization using Costaceae Lacerus Bagasse Fibre and Cement Stabilized as Highway Pavement Materials

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Abstract Ogoda, Bodo, Ogbogu, Ula-Ikata and Kaani roads in Rivers State, Niger Delta region are vulnerable to pavement degradation due to it expansive and problematic nature and unique characteristics of swelling, shrinkage and crack potentials. The research work assessed and investigated the application of costaceae lacerus bagasse fibre (CLBF) and Cement as soil stabilizers in combine state. The soils are classified as A – 7 – 6 on the AASHTO classification System and are dark grey in color from wet to dry states with plastic index properties of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively and did no meet minimum requirements for soils or soil-based materials usable in road pavement structures as stated by the FMW Specifications (1997). Results obtained showed increased in UCS with increase in fibre percentages to soil corresponding ratio. Compaction results demonstrated decreased in values of plastic index properties due to additives inclusion. Results demonstrated an increased in UCS with increase in fibre and cement percentages to soil corresponding ratio. Results demonstrated an increased in CBR values for both unsoaked and soaked with optimum ratio combination of 0.75% + 7.5% to soil corresponding ratio. The entire results showed the potential of using CLBF + cement as admixtures in treatment of clay soils.

Keywords Clay soils, Costaceae Lacerus Bagasse Fibre, Cement,CBR, UCS, Consistency, Compaction

1. Introduction

Researchers showed that fibers are used to improve the ductility of cement- stabilized soils in combined actions making them meet the required standard for specific subgrade pavement. Consoli et al, [1] reported that fiber reinforcement increases the peak and residual shear strength of cement treated soil, and it also changes its brittle behavior to ductile behavior. With development of using polymeric fiber since late 1980's, triaxial compression tests, unconfined compression tests have been conducted to study the effect of synthetic fiber on shear strength. Additional, fiber reinforcement is used to improve road structure.

Charles *et al*. [2] 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.

Charles *et al*. [3] 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.

Rao *et al*., [4] studied the effects of RHA, lime and gypsum on engineering properties of expansive soil and found that UCS increased by 548 % at 28 days of curing and CBR increased by 1350 % at 14 days curing at RHA- 20%, lime -5 % and gypsum -3%.

Sabat [5] studied the effect of lime sludge (from paper manufacturing industry) on compaction, CBR, shear strength parameters, coefficient of compression, Ps and durability of an expansive soil stabilized with optimum percentage of RHA after 7days of curing. The optimum proportion soil: RHA: lime sludge was found to be 75:10:15.

Edeh *et al.* [6] 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.

2. Materials and Methods

2.1 Materials

2.1.1 Soil

The soils used for the study were collected from Ogoda Town Road, Ubie, Districts of Ekpeye, Ahoada-East and Ahoada-West Local Government Area, Bodo Town Road, Gokana Local Government Area, Ogbogu Town Road, Egbema/Ndoni/Egbema local Government Area, Ula-Ikata Town Road, Ahoada-East Local Government area, and Kaani Town Road, Khana Local Government Area, all of Rivers State, Niger Delta, Nigeria.

2.1.2 Costaceae Lacerus Bagasse Fibre

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 Ogoda Town, (latitude 5.04° 59‘S and longitude 6.38° 42‘E), Bodo Town, (latitude 4.65° 05‘S and longitude 7.27° 15‘E), Ogbogu Town, latitude 5.13° 08‘S and longitude 6.33° 25‘E), U[a-Ikata Town, (latitude 5.95° 45‘S and longitude 6.66° 13‘E) and kaani Town, latitude 4.67° 13‘S and longitude 6.81° 55‘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, Califonia 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)

The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles. This test is performed to determine the percentage of different grain sizes contained within a soil.

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

The soils classified as A – 7 – 6 on the AASHTO 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 [7]; Allam and Sridharan [8]; Omotosho and Akinmusuru [9]; Omotosho [10]). Preliminary results on clay 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 are reddish brown and dark grey in colour (from wet to dry states) plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Town Roads. The soil has unsoaked CBR values of 8.58%,8.83%, 8.05%, 7.38%, and 9.05% and soaked CBR values of 6.33%, 7.15%, 7.35%, 5.9% and 8.23%, unconfined compressive strength (UCS) values of 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

Compaction test results of clay soils at 100% natural state of maximum dry density (MDD) are 1.875KN/m^3, 1.923KN/m^3, 1.823KN/m^3, 1.795KN/m^3, 1.985KN/m^3 and Optimum moisture content (OMC) as 15.68%, 14.93%, 16.30%, 17.45% and 15.35%. Stabilized soil with costaceae lacerus bagasse fibre (CLBF) + Cement inclusion at 0.25+2.5%, 0.50% +5.0%, 0.75% + 7.5%, and 1.0% + 10% percentage inclusion increase to,2.923KN/m^3, 2.265KN/m^3, 1.945KN/m^3, 1.905KN/m^3, 2.318KN/m^3 and Optimum moisture content (OMC) increased to 16.75%,16.08%, 17.33%, 18.15% and 16.15%. Results demonstrated increased in both MDD and OMC values with increase in CLBF + Cement inclusion.

3.2 California Bearing Ratio (CBR) Test

CBR results obtained at 100% natural state are 8.58%, 8.83%, 8.05%, 7.38% and 9.05% unsoaked and 6.33%, 7.15%, 7.35%, 5.9% and 8.23 % soaked. Stabilized clay soils with percentage ratio in table 3.4 are 54.85%, 59.35%, 56.75%, 49.30%, and 62.35% unsoaked values and 49.38 %, 53.60%, 52.85%, 46.35%, 59.85% soaked values. Results demonstrated an increased in CBR values for both unsoaked and soaked with optimum ration combination of 0.75% + 7.5% to soil corresponding ratio.

3.3 Unconfined Compressive Strength Test

Table 3.1 outlined the preliminary investigation of engineering soil properties of sampled roads at 100% (no additives) unconfined compressive strength (UCS) values of 58.85kPa , 63.35 kPa, 57.75 kPa, 53.75kPa and 63.85kPa. (CLBF) + Cement reinforced clay soils shown in table 3.4 and represented in figures 3.6 increased to 385kPa, 328kPa, 375kPa, 361kPa and 395kPa. Results demonstrated an increased in UCS with increase in fibre percentages to soil corresponding ratio.

3.4 Consistency Limits Test

Table 3.1 confirmed the consistency limits (plastic index) properties of clay soils of sampled roads at 100% are 20.33%, 20.35%, 21.85%, 26.30% and 21.35%. Modified clay soils plastic index with percentages outlined in table 3.5 and represented in figures 3.1 – 3.5 are 16.80%, 18.28%, 19.62%, 17.23% and 18.85%. Results demonstrated decreased in values of plastic index properties due to additives inclusion.

Table 3.1: Engineering Properties of Soil Samples

Location Description	**Ogoda Town Road, Ahoada-West L.G.A Rivers State**	**Bodo Town Road ,Gokana L.G.A Rivers State**	**Ogbogu Town-Road, Ogba/Egbema Ndoni L.G.A Rivers State**	**Ula-Ikata Town Road, Ahoada-Bema East L.G.A Rivers State**	**Kaani Town Road, Khanna L.G.A Rivers State**
Depth of sampling (m)	1.5	1.5	1.5	1.5	1.5
Percentage(%) passing BS sieve #200	73.85	67.38	76.35	82.35	71.55
Colour	Grey	Grey	Grey	Grey	Grey
Specific gravity	2.71	2.68	**2.63**	2.63	2.71
Natural moisture content (%)	46.25	45.38	45.86	49.30	46.85
Consistency Limits					
Liquid limit (%)	58.85	59.45	58.35	56.67	48.25
Plastic limit (%)	38.52	39.10	37.50	30.37	24.90
Plasticity Index	20.33	20.35	21.85	26.30	21.35
AASHTO soil classification	A – 7 – 6	A – 7 – 6	A – 7 – 6	A – 7 – 6	A – 7 – 6
Optimum moisture content (%)	15.68	14.93	16.30	17.45	15.35
Maximum dry density ($kN/m^{3)}$	1.875	1.923	1.823	1.795	1.9.85
Gravel (%)	1.85	0.85	2.45	0.53	1.95
Sand (%)	12.35	11.08	9.75	7.34	13.25
Silt (%)	52.35	47.35	47.85	53.68	48.25
Clay (%)	33.45	40.72	39.95	38.45	36.55
Unconfined compressive strength (kPa)	58.85	63.35	57.75	53.75	63.85
California Bearing Capacity (CBR)					
Unsoaked (%) CBR	8.58	8.83	8.05	7.38	9.05
Soaked (%) CBR	6.33	7.15	7.35	5.9	8.23

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 (Clay) Test Stabilization with Binding Cementitious Products at Different Percentages and Combination

SAMPLE LOCATION	SOIL + FIBRE BAGASE + CEMENT	MDD (kN/m3)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
SOFT CLAY + COSTACEAE LACERUS BAGASSES FIBRE (CLBF) + CEMENT												
OGODA TOWN ROAD, AHOADA-WEST L.G.A	100%	1.875	15.68	8.58	6.33	58.85	58.85	38.52	20.33	73.85	A – 7 – 6	POOR
	97.25+0.25+2.5%	1.995	15.85	28.35	25.75	115	60.35	41.85	18.50	73.85	A – 7 – 6	GOOD
	94.5+0.5+5.0%	2.055	16.05	41.35	37.30	235	61.78	44.53	17.25	73.85	A – 7 – 6	GOOD
	92.25+0.75+7.5%	2.150	16.38	54.85	49.38	293	62.35	45.56	16.80	73.85	A – 7 – 6	GOOD
	89+1.0+10%	2.235	16.75	47.35	42.35	385	62.95	46.75	16.20	73.85	A – 7 – 6	GOOD
BODO TOWN ROAD GOKANA L.G.A	100%	1.923	14.93	8.88	7.15	63.35	59.45	39.10	20.35	67.38	A – 7 – 6	POOR
	97.25+0.25+2.5%	1.965	15.18	28.35	25.75	115	60.35	41.85	18.50	67.38	A – 7 – 6	GOOD
	94.5+0.5+5.0%	1.998	15.39	46.25	41.50	207	61.75	42.80	18.95	67.38	A – 7 – 6	GOOD
	92.25+0.75+7.5%	2.125	15.75	59.35	53.60	276	62.15	43.42	18.73	67.38	A – 7 – 6	GOOD
	89+1.0+10%	2.265	16.08	49.85	42.85	328	62.45	44.17	18.28	67.38	A – 7 – 6	GOOD
OGBOGU TOWN ROAD OGBA EGE/ ELEANA NDONI L.G.A	100%	1.823	16.30	8.25	7.35	57.75	58.35	37.50	21.85	76.35	A – 7 – 6	POOR
	97.25+0.25+2.5%	1.853	16.58	29.45	24.85	108	59.83	39.58	20.25	76.35	A – 7 – 6	GOOD
	94.5+0.5+5.0%	1.887	16.83	41.53	38.35	217	60.25	40.40	19.85	76.35	A – 7 – 6	GOOD
	92.25+0.75+7.5%	1.907	17.08	56.75	52.85	263	60.78	41.16	19.62	76.35	A – 7 – 6	GOOD
	89+1.0+10%	1.945	17.33	49.70	43.60	375	61.35	42.05	19.30	76.35	A – 7 – 6	GOOD
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A	100%	1.794	17.45	7.38	5.90	53.75	56.67	38.37	18.30	82.35	A – 7 – 6	POOR
	97.25+0.25+2.5%	1.815	17.52	24.85	18.85	118	57.21	39.16	18.05	82.35	A – 7 – 6	GOOD
	94.5+0.5+5.0%	1.836	17.83	36.65	31.85	235	57.68	39.33	17.85	82.35	A – 7 – 6	GOOD
	92.25+0.75+7.5%	1.873	17.99	49.30	46.35	289	58.23	40.61	17.62	82.35	A – 7 – 6	GOOD
	89+1.0+10%	1.905	18.15	47.45	38.35	361	58.79	40.97	17.23	82.35	A – 7 – 6	GOOD
KAANI TOWN ROAD, KHANA L.G.A	100%	1.985	15.35	9.05	8.23	63.85	48.25	27.90	20.35	71.55	A – 7 – 6	POOR
	97.25+0.25+2.5%	2.015	15.58	39.40	33.60	124	49.65	29.79	19.86	71.55	A – 7 – 6	GOOD
	94.5+0.5+5.0%	2.235	15.75	48.66	45.35	208	49.93	30.41	19.52	71.55	A – 7 – 6	GOOD
	92.25+0.75+7.5%	2.263	15.93	62.35	59.85	265	50.23	31.02	19.21	71.55	A – 7 – 6	GOOD
	89+1.0+10%	2.318	16.15	57.30	52.23	395	50.86	32.01	18.85	71.55	A – 7 – 6	GOOD

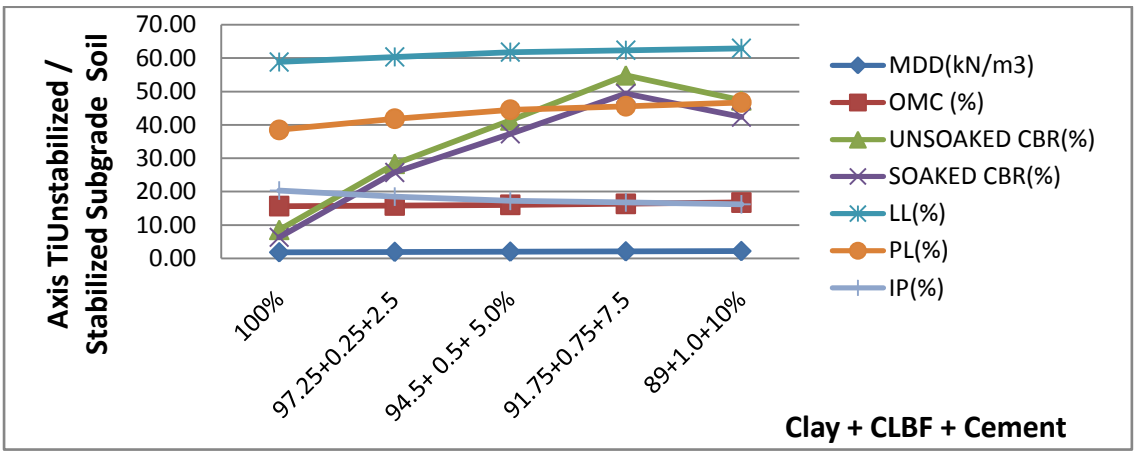

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ogoda in Ahoada-West L.G.A of Rivers State with CLBF+ Cement at Different Percentages and Combination

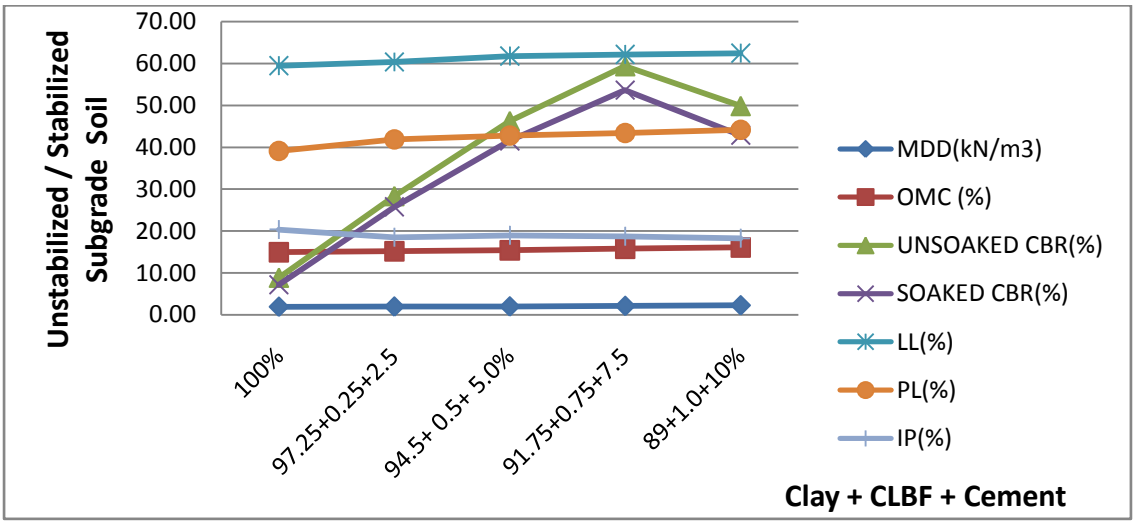

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Bodo in Gokana L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

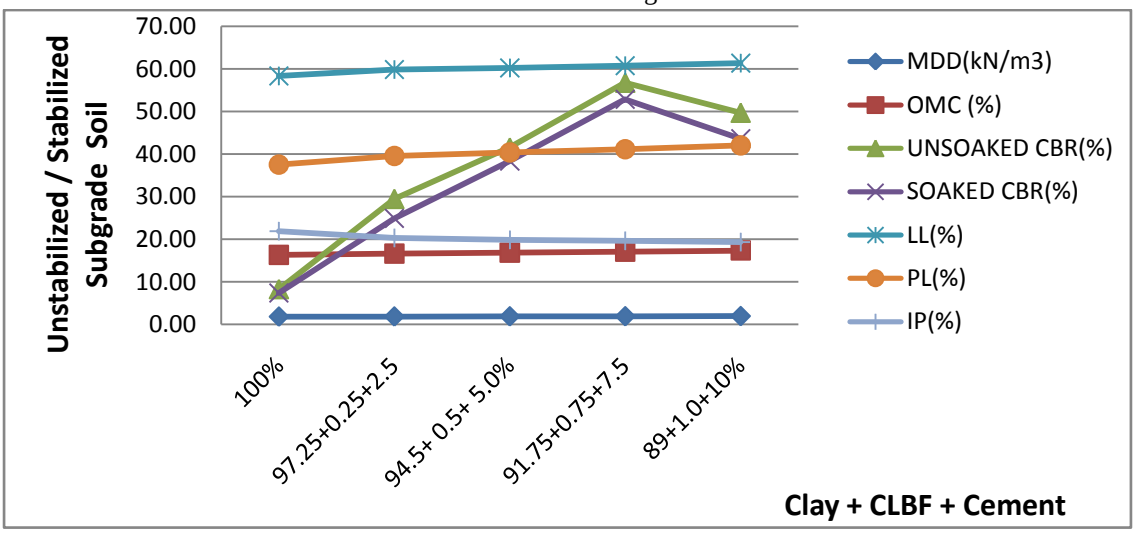

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Ogbogu in Ogba/Egbema/Ndoni L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

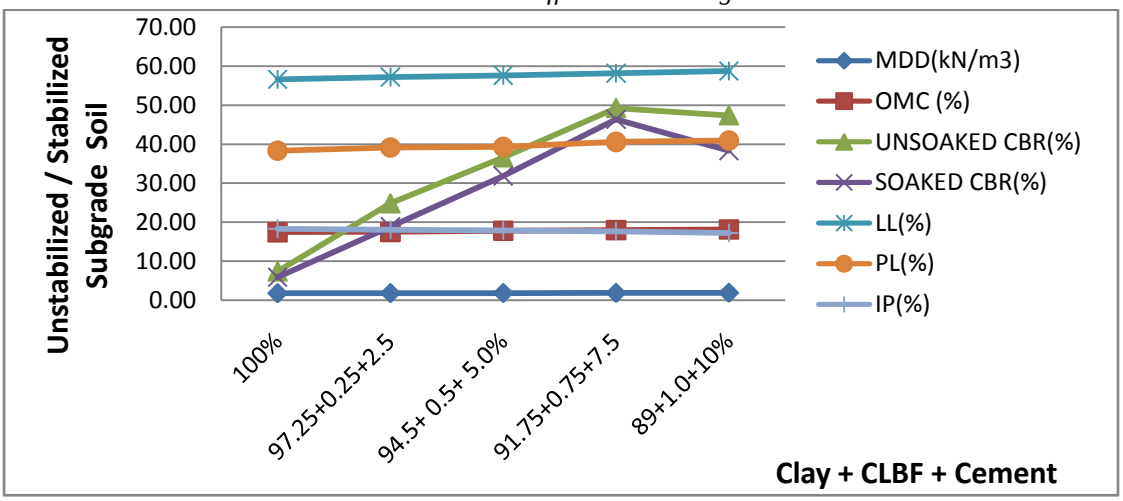

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Ula-Ikata in Ahoada-East L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

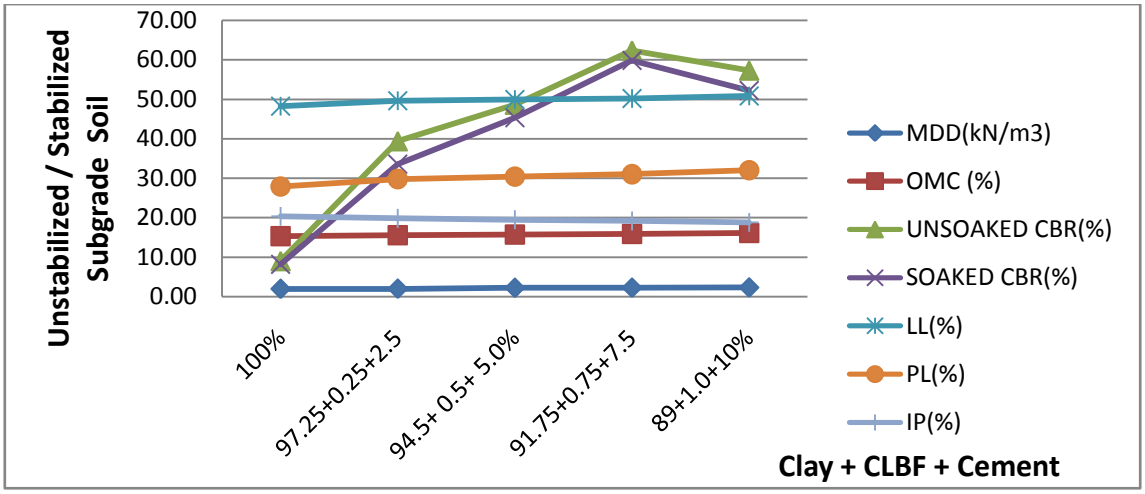

Figure 3.5: Subgrade Stabilization Test of Clay Soil from Kaani in Khana L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

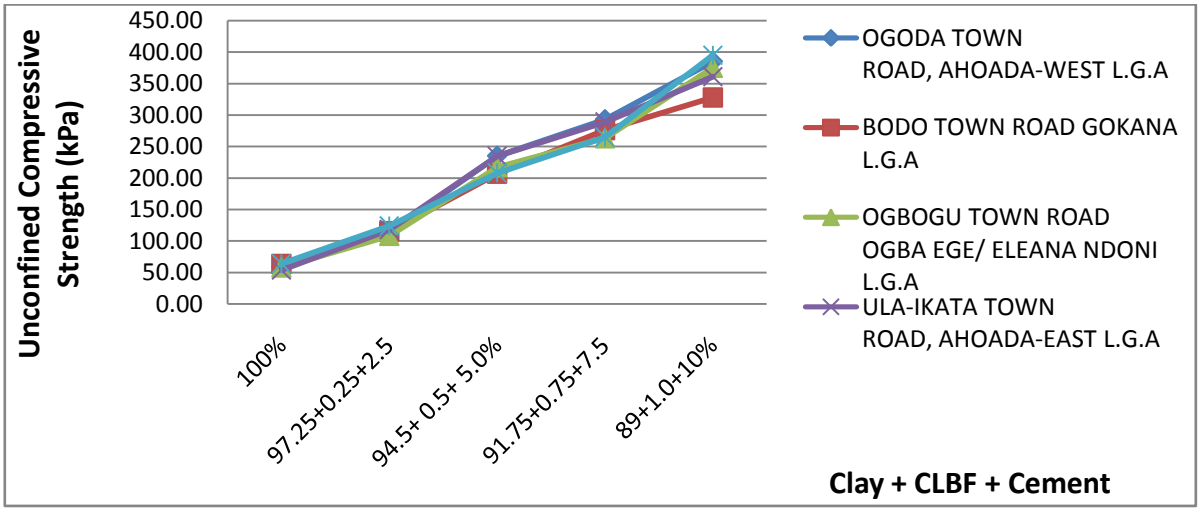

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with CLBF + Cement of (Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State

Plate i. Costaceae Lacerus plant *Plate ii. Costaceae Lacerus stem*

Plate iii. Costaceae Lacerus piled stem

Plate iv. Costaceae Lacerus pulverized stage

Plate vi. Costaceae Lacerus fibre bagasses

Plate vii. Costaceae Lacerus wet bagasses/fibre at day 3

4. Conclusions

The following conclusions were made from the experimental research results.

i. The soils classified as A – 7 – 6 on the AASHTO classification System

ii. Clay Soils are dark grey in color (from wet to dry states) plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for Ogoda, Bodo, Ogbogu, Ula-Ikata and Kaani.

iii. The entire results showed the potential of using CLBF + cement as admixtures in treatment of clay soils

iv. Results obtained showed increased in UCS with increase in fibre percentages to soil corresponding ratio

v. Comparative results showed an increased in CBR values with increase in bagasse fibre percentages to a peak ratio of 0.75% + 7.5% to soil ratio

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