Swelling and Shrinkage Potentials of Black Cotton Reduction Using Costaceae Lacerus Bagasse Fibre Ash as Pozzolona material

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ABSTRACT

Black Cotton soils in the Niger Delta has exceptional traits phenomenon of swell-shrinkage potential that is proned to severe, crack and differential settlement. An investigative study in the use of bagasse fibre ash of Costaceae Lacerus to improve the engineering properties to meet required standard specifications for the use as road subgrade pavement material. The soils classified as A – 7 – 6 on the AASHTO classification System, with plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for the sampled roads . Compaction test results demonstrated decreased in MDD while OMC increased in CLBFA inclusion to clay soils. Relative results showed an increased in CBR values with increase in in bagasse fibre percentages to a peak ration of 7.5% to soil ratio. Results demonstrated an increased in CBR values for both unsoaked and soaked with optimum ratio inclusion of 7.5% to soil corresponding ratio. Results demonstrated an increased in UCS with increase in fibre percentages to soil corresponding ratio with the maximum values at 10%. Results demonstrated decreased in values of plastic index properties due to additives inclusion. The entire results showed the potential of using CLBFA as admixtures in treatment of clay soils with pozzolana character.

Key Words: *Clay soils, costaceae lacerus bagasse fibre ash, CBR, UCS, Consistency, Compaction*

1.0 Introduction

Black cotton soils consist of silt, sand and, or gravel and are primarily the result of physical and mild chemical weathering processes and retain much of the chemical structure of their parent rocks. The engineering properties and behavior of clays also are quite different from other soils (Coduto, [1]). Clays generally have particle sizes less than about 2µm. According to the British Soil Classification System (BSCS), clay soil comprising 35% to 100% fines where the clay particles predominate to produce cohesion, plasticity and low permeability. Studies have shown that swelling potential of black cotton soil decreases by placing some volume of fibre bagasse as stabilizers / reinforcements.

Manikandan and Moganraj [2] 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*. [3] 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.

Gandhi [4] 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.

Agunwamba *et al* [5] 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.

Kalkan [6] stabilized expansive clay with red mud (a waste material generated during the production of alumina) and cement-red mud and found increase in strength and decrease in swelling percentage and hydraulic conductivity

2.0 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 Gvernment area, and Kaani Town Road, Khana Local Government Area, all of Rivers State, Niger Delta, Nigeria.

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 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.

3.0 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

Table 3.1 illustrated 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%. Modified clay soils with costaceae lacerus bagasse fibre ash (CLBFA) at 2.5%, 5.0%, 7.5%, and 10%

percentage inclusion decreased to, 1.782KN/m^3, 1.835KN/m^3, 1.753KN/m^3, 1.709KN/m^3, 1.912KN/m^3 and Optimum moisture content (OMC) increased to 16.33%, 15.85%, 16.96%, 18.23% and 16.21%. Results demonstrated decreased in MDD and while OMC increased in CLBFA inclusion to clay soils.

3.2 California Bearing Ratio (CBR) Test

Table 3.1 summarized the CBR results at 100% clay soils of the sampled sites 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. Obtained maximum values of reinforced clay soils as shown table 3.4 and figures 3.1 – 3.4 are 13.85%, 14.30%, 13.65%, 13.60%, and 15.75% unsoaked values and 12.78%, 12.85%, 13.05%, 12.85%, 14.98% soaked values. Results demonstrated an increased in CBR values for both unsoaked and soaked with optimum ration inclusion of 7.5% to soil corresponding ratio.

3.3 Unconfined Compressive Strength Test

Preliminary results obtained at sampled roads at 100% natural clay soils for unconfined compressive strength (UCS) test are 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa. CLBFA stabilized clay soils shown in table 3.4 and represented in figures 3.6 are 121.35kPa, 143.57kPa, 143.58kPa, 123.85kPa and 151.30kPa. Results demonstrated an increased in UCS with increase in fibre percentages to soil corresponding ratio with the maximum values at 10%.

3.4 Consistency Limits Test

Preliminary results presented in table 3.1 of 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%. Stabilized clay soils plastic index properties at peak are 15.78%, 16.85%, 18.93%, 16.27% and 17.88%. 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
Unified Soil Classification System					
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	1.985
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 RATIO	MDD (kN/m^3)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
		SOFT CLAY + COSTACEAE LACERUS BAGASSES FIBRE ASH (CLBFA)										
OGODA	100%	1.875	15.68	8.58	6.33	58.85	58.85	38.52	20.33	73.85	A – 7 – 6	POOR
TOWN	97.5+2.5%	1.849	15.72	9.89	8.75	69.30	58.68	38.83	19.85	73.85	A – 7 – 6	POOR
ROAD,	95 + 5.0%	1.830	15.89	11.95	10.65	84.35	58.37	40.02	18.35	73.85	A – 7 – 6	GOOD
AHOADA-	92.5 + 7.5%	1.809	16.05	13.85	12.78	108.05	58.05	41.18	16.87	73.85	A – 7 – 6	GOOD
WEST L.G.A	90 + 10%	1.782	16.33	12.35	11.65	121.35	57.38	41.60	15.78	73.85	A – 7 – 6	GOOD
BODO TOWN	100%	1.923	14.93	8.83	7.15	63.35	59.45	39.10	20.35	67.38	A – 7 – 6	POOR
ROAD	97.5+2.5%	1.904	15.18	10.85	10.13	87.85	59.31	39.57	19.74	67.38	A – 7 – 6	GOOD
GOKANA	95 + 5.0%	1.885	15.29	12.25	10.85	105.60	59.05	40.19	18.86	67.38	A – 7 – 6	GOOD
L.G.A	92.5 + 7.5%	1.862	15.53	14.30	12.85	123.65	58.88	41.65	17.23	67.38	A – 7 – 6	GOOD
	90 + 10%	1.835	15.85	13.58	11.35	143.57	58.54	41.69	16.85	67.38	A – 7 – 6	GOOD
OGBOGU	100%	1.828	16.30	8.25	7.35	57.75	58.35	37.50	21.85	76.35	A – 7 – 6	POOR
TOWN ROAD	97.5+2.5%	1.808	16.48	9.38	8.95	73.83	58.08	33.63	20.45	76.35	A – 7 – 6	GOOD
OGBA EGE/	95 + 5.0%	1.783	16.73	10.95	10.28	92.80	57.85	37.80	20.05	76.35	A – 7 – 6	GOOD
ELEANA	92.5 + 7.5%	1.779	16.79	13.65	13.05	118.33	57.51	38.06	19.45	76.35	A – 7 – 6	GOOD
NDONI L.G.A	90 + 10%	1.753	16.96	12.60	12.08	143.58	57.28	38.35	18.93	76.35	A – 7 – 6	GOOD
ULA-IKATA	100%	1.794	17.45	7.38	5.90	53.75	56.67	38.37	18.30	82.35	A – 7 – 6	POOR
TOWN	97.5+2.5%	1.782	17.58	8.85	7.35	62.90	56.34	38.48	17.86	82.35	A – 7 – 6	POOR
ROAD,	95 + 5.0%	1.766	17.73	10.65	10.15	87.35	56.18	38.32	17.23	82.35	A – 7 – 6	GOOD
AHOADA-	92.5 + 7.5%	1.735	18.98	13.60	12.85	106.25	55.91	39.06	16.85	82.35	A – 7 – 6	GOOD
EAST L.G.A	90 + 10%	1.709	18.23	12.38	11.65	123.85	55.78	39.57	16.27	82.35	A – 7 – 6	GOOD
KAANI	100%	1.985	15.35	9.05	8.23	63.85	48.25	27.90	20.35	71.55	A – 7 – 6	POOR
TOWN	97.5+2.5%	1.968	15.57	11.35	10.68	92.30	48.09	28.24	19.85	71.55	A – 7 – 6	GOOD
ROAD,	95 + 5.0%	1.951	15.70	13.85	13.23	114.85	47.87	28.35	19.53	71.55	A – 7 – 6	GOOD

KHANA	92.5 + 7.5%	1.935	15.98	15.75	14.98	136.35	47.56	29.21	18.35	71.55	A – 7 – 6	GOOD
L.G.A	90 + 10%	1.912	16.21	14.25	13.35	151.30	47.27	29.39	17.88	71.55	A – 7 – 6	GOOD

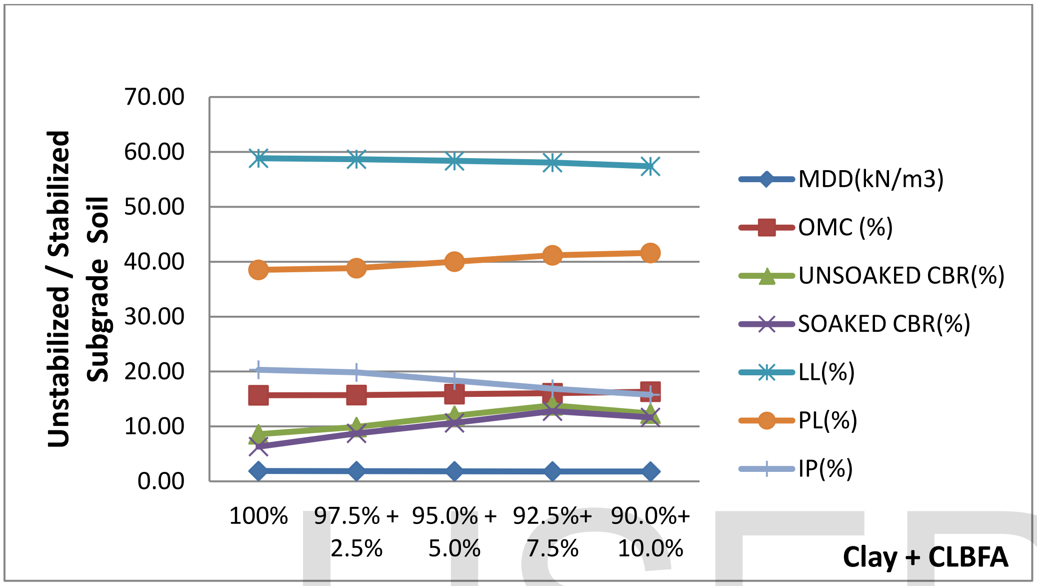

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ogoda in Ahoada-West L.G.A of Rivers State with CLBFA at Different Percentages and Combination

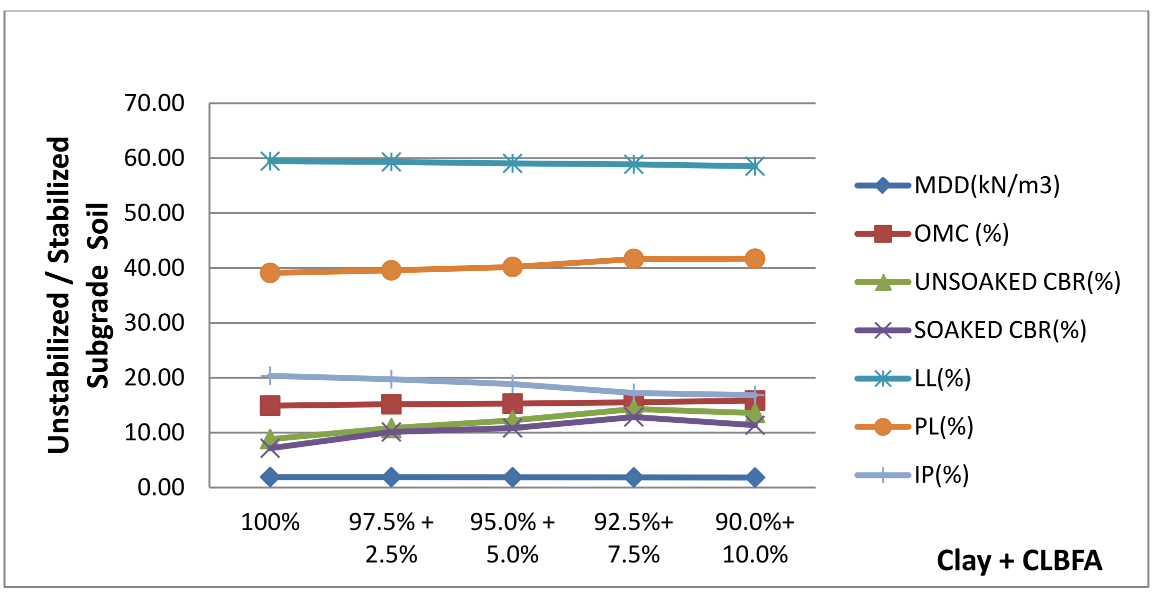

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Figure 3.2: Subgrade Stabilization Test of Clay Soil from Bodo in Gokana L.G.A of Rivers State with CLBFA at Different Percentages and Combination

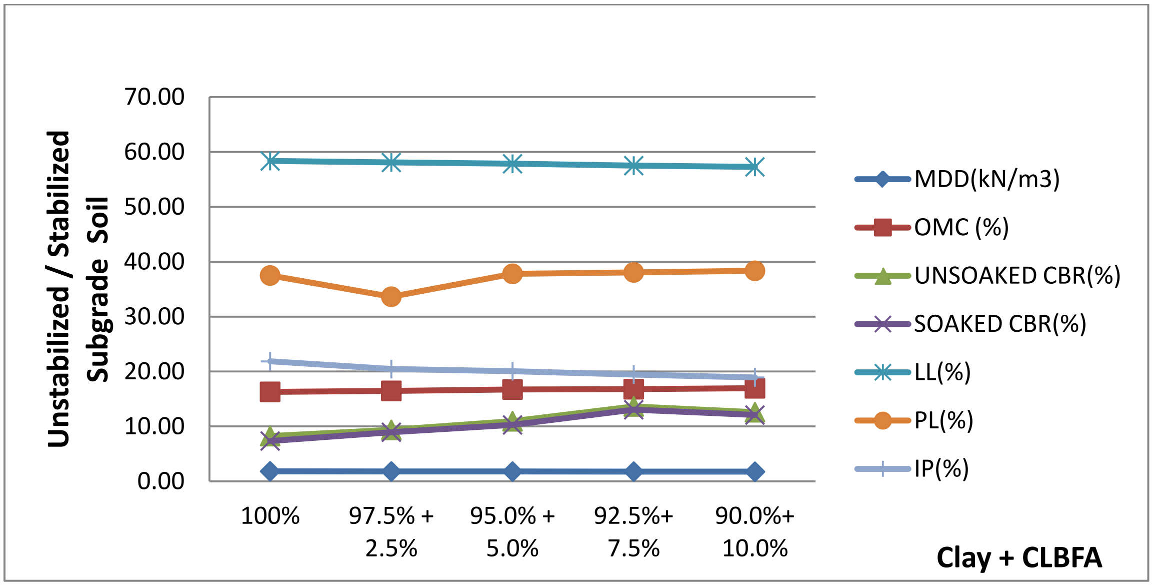

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Ogbogu in Ogba/Egbema/Ndoni L.G.A of Rivers State with CLBFA at Different Percentages and Combination

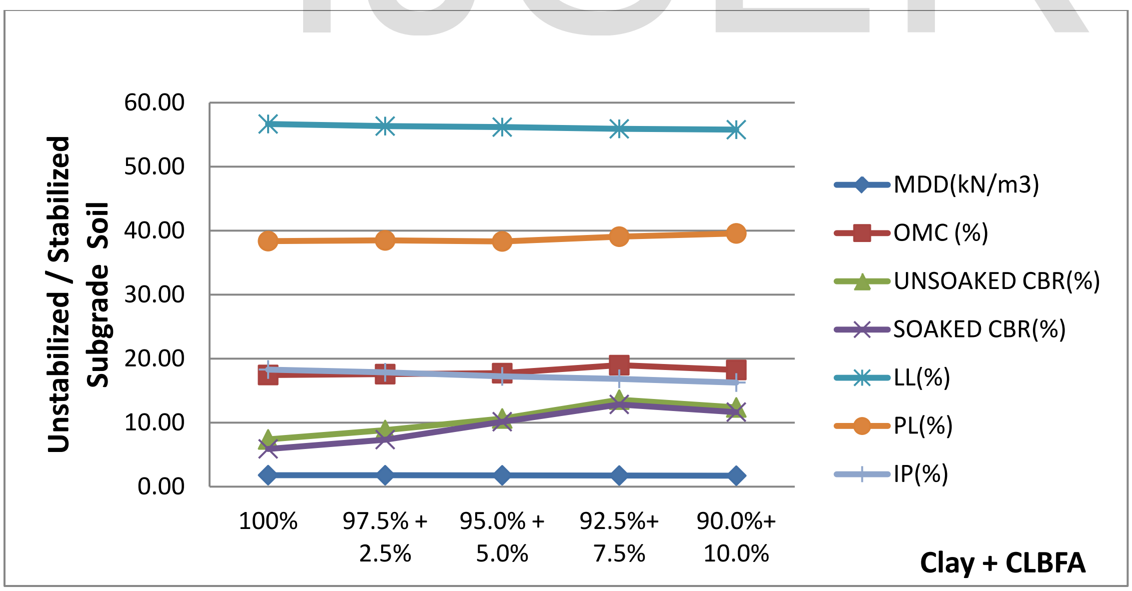

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Ula-Ikata in Ahoada-East L.G.A of Rivers State with CLBFA at Different Percentages and Combination

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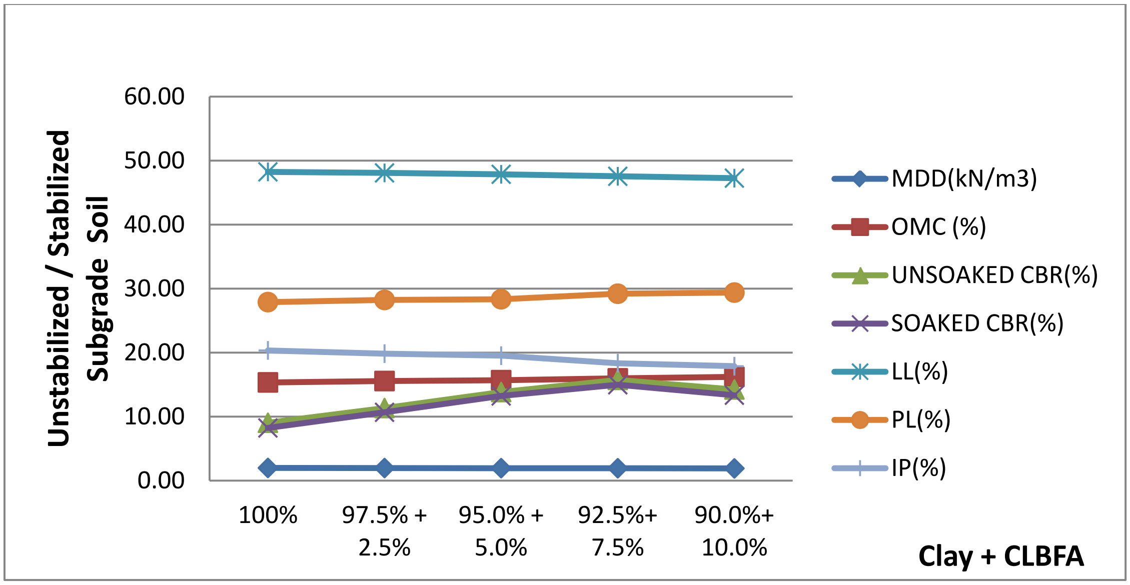

Figure 3.5: Subgrade Stabilization Test of Clay Soil from Kaani in Khana L.G.A of Rivers State with CLBFA at Different Percentages and Combination

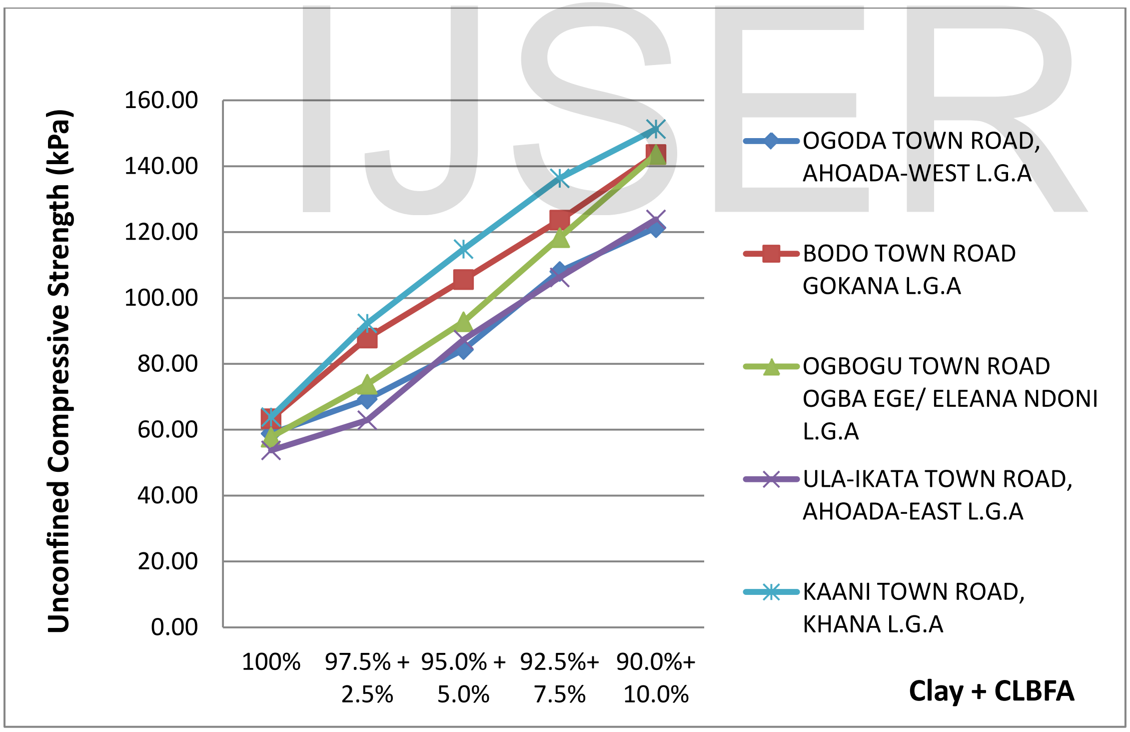

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with CLBFA of (Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State

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Plate i. Costaceae Lacerus plant

Plate ii. Costaceae Lacerus stem

Plate iii. Costaceae Lacerus dry bagasses/fibre

Plate iv. Costaceae Lacerus Bagasses Fibre ash

4.0 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 CLBFA as admixtures in treatment of clay soils
iv. Costaceae Lacerus Bagasse Fibre Ash(CLBFA) acts as pozzolana
v. Results obtained showed increased in UCS with increase in fibre percentages to soil corresponding ratio
vi. Relative results showed an increased in CBR values with increase in in bagasse fibre percentages to a peak ration of 7.5% to soil ratio

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