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Improvement of Expansive Soils with Blended Composite Materials as Stabilizers

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Abstract: **The study observed the application of waste extracted bagasse fibre ash of costaceae lacerus blended with lime to improve the engineering geotechnical properties of an expansive soil subgrade for road pavement materials. Preliminary investigations proved the sampled soils poor and fell below the minimum requirement for such application. The soils are classified as A-7-6 of American Association of State and Transport Officials (AASHTO) soil classification system with plastic index properties of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively of sampled roads. Compaction test results obtained showed increased values in both maximum dry density and optimum moisture content relatively to ratio percentage additives. Comparatively, stabilized clay soils California bearing ratio increased with increase in additives inclusion with optimum mix proportion of 7.5% + 7.5%. Cracks occurred beyond optimum mixed level. Unconfined compressive strength test results increased with varying additive percentages. Costaceae lacerus bagasse fibre ash and lime proved to be good composite materials combination in soil stabilization.**

Keywords: **Clay soils, costaceae lacerus bagasse ash, Lime CBR, UCS, Consistency, Compaction.**

1. INTRODUCTION

The desirable requirement of widely used soils (lateritic and clay) for materials for road earthworks can be achieved with the use of soil stabilizers of fibre , lime, cement, fly- ash and others, either in single or in combined actions. Except in very rare and exceptional cases, soils (including deltaic lateritic soils) in their natural states hardly possess characteristics suitable for desired engineering applications, particularly for road works. The minimum requirements for soils or soil-based materials usable in road pavement structures have been indicated by the FMW Specifications [1]. Soil Stabilization has proved to be very economical as it provides cheap materials for the construction of low cost roads. Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. A number of stabilizers, such as lime, cement and fly ash, depend on their chemical reactions with the soil elements in the presence of water (Azadegan *et al*. [2]; Mallela *et al*. [3];).

Other additives, such as geofiber and geogrid, depend on their physical effects to improve soil properties (Alawaji, [4]; Viswanadham *et al*. [5]). In addition, it can be combined both of chemical and physical stabilization, for example, by using lime and geofiber or geotextile together (Yang *et al*. [6]; Chong and Kassim, [7]). Lime is the oldest traditional chemical stabilizer used for soil stabilization (Mallela *et al*. [3]).

Rao *et al*. [8] 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%.

Charles *et al*. [9] investigated and evaluated the engineering properties of an expansive lateritic soil with the inclusion of cement / lime and costus afer bagasse fibre ash (locally known as bush sugarcane fibre ash(BSBFA) with ratios of laterite to cement, lime and BSBFA of 2.5% 2.5%, 5.0% 5.0%, 7.5% 7.5% and 10% 10% to improve the values of CBR of less than 10% and termed poor on remarks required subgrade and strength fo constructional works. At 8% of both cement and lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% cement and lime 7.5% BSBFA, and 7.25% cement and lime 0. 7.5% BSBF, optimum value are reached. The entire results showed the potential of using bagasse, BSBFA as admixtures in cement and lime treated soils of laterite.

Sabat [10] 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.

Charles *et al.* [11] evaluated the effectiveness in the used of lime and costus afer fibre (Bush sugarcane bagasse fiber ash (BSBFA) in single and combined actions as soil stabilizer to improve its properties. Considering the fact that Niger Deltaic soils fall short of the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW [1). Entire results showed tremendous strength increased in soil properties with the inclusion of additives. The entire results showed the potential of using bagasse BSBFA as admixture in lime treated soils of clay and laterite with 8 % lime + 7.5% lime + BSBFA. Treated soils with Lime decreased in liquid limits and increased in plastic limits. Soils with Lime and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions respectively At 8% of both cement and lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% lime+ 7.5% BSBFA, optimum value are reached.

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 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.

2.1.3 Lime

The lime used for the study was purchased in the open market at Mile 3 market road, Port Harcourt.

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), Ula-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, 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)

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

The results of clay soils at 100% (no additives) of maximum dry density (MDD) at preliminary test 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% . Results of Stabilized clay soils with costaceae lacerus bagasse fibre ash (CLBFA) + lime with percentages ratio combination of 2.5% + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of MDD are 1.975KN/m^3, 1.990KN/m^3, 1.918KN/m^3, 1.925KN/m^3, 2.553KN/m^3 and OMC are 17.35%, 16.28%, 17.88%, 18.64%, 16.85%. Results showed increased in both MDD and OMC values as shown table 3.4 and represented in figures 3.1 – 3.5. Increase in MDD and OMC are proportional to increased in additives percentages.

3.2 California Bearing Ratio (CBR) Test

CBR results obtained of clay soils at 100% natural state are 8.58%, 8.83%, 8.05%, 7.38%, and 9.05% unsoaked and soaked values 6.33%, 7.15%, 7.35%, 5.9% and 8.23 % . Costaceae lacerus bagasse fibre (CLBFA) + lime stabilized soils unsoked values are 48.35%, 53.80%, 47.75%, 40.85% and 56.40% and soaked values are 42.30%, 48.53%, 42.85%, 36.30% and 51.67. Relatively, stabilized clay soils CBR increased with increase in additives inclusion with optimum mix of 7.5% + 7.5%. Reduction in values was noticed beyond optimum percentages inclusion.

3.3 Unconfined Compressive Strength Test

Sampled road results at 100% clay soils are 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa. Stabilized soils values are 314kPa, 266kPa, 322kPa, 312kPa and 346kPa. Unconfined compressive strength test results increased with increase in additive inclusion as seen in table 3.4 and figure 3.6.

3.4 Consistency Limits Test

Sampled preliminary results of consistency limits (Plastic index) at 100% soils are 20.33%, 20.35%, 21.85% , 26.30% and 21.35%. Stabilized soils index properties are 19.78%, 18.85%, 20.05%, 16.93% and 18.83%. Results showed additives decreased the plastic index properties of soils as shown in figures 3.1 – 3.5.

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	**2.1 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 Unified Soil Classification System	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 BAGASSE ASH + LIME	MDD (kN/m3)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
	SOFT CLAY +COSTACEAE LACERUS BAGASSE FIBRE ASH(CLBFA) + LIME											
OGODA	100%	1.875	15.68	8.65	6.33	58.85	58.85	38.52	20.33	73.85	A-7-6	POOR
TOWN	97.25+2.5+2.5%	1.903	15.89	21.38	18.85	97	59.18	39.00	20.18	73.85	A-7-6	GOOD
ROAD,	94.5+5.0+0.5%	1.935	16.24	33.45	28.45	204	59.45	39.52	19.93	73.85	A-7-6	GOOD
AHODA	92.25+7.5+7.5%	1.950	16.78	48.35	42.30	236	59.93	40.15	19.78	73.85	A-7-6	GOOD
WEST. L.G.A	80+10 + 10%	1.975	17.35	42.50	37.75	314	60.35	41.11	19.24	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	67.35	A-7-6	POOR
ROAD	97.25+2.5+2.5%	1.948	15.33	24.85	20.43	106	59.73	39.85	19.88	67.35	A-7-6	GOOD
GOKANA.	94.5+5.0+0.5%	1.966	15.68	44.75	38.60	167	61.23	41.70	19.53	67.38	A-7-6	GOOD
L.G.A	92.25+7.5+7.5%	1.985	15.98	53.80	48.53	232	61.65	42.45	19.20	67.38	A-7-6	GOOD
	80+10 + 10%	1.990	16.28	48.75	42.35	266	61.87	43.02	18.85	67.38	A-7-6	GOOD
OGBOGU	100%	1.823	16.30	8.25	7.35	57.75	58.35	37.50	21.85	76.35	A-7-6	POOR
TOWN ROAD	97.25+2.5+2.5%	1.845	16.74	18.50	18.05	78	59.05	37.70	21.35	76.35	A-7-6	GOOD
OGBA/EGBE	94.5+5.0+0.5%	1.869	17.08	29.75	23.50	168	59.33	38.88	20.95	76.35	A-7-6	GOOD
MA/NDONI	92.25+7.5+7.5%	1.894	17.59	47.75	42.85	215	59.77	39.21	20.48	76.35	A-7-6	GOOD
L.G.A	80+10 + 10%	1.918	17.88	38.80	33.85	322	60.18	40.13	20.05	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 ROAD	97.25+2.5+2.5%	1.818	17.75	21.83	18.35	93	57.21	39.26	17.35	82.35	A-7-6	GOOD
AHODA	94.5+5.0+0.5%	1.836	17.92	31.25	27.83	176	57.68	40.05	17.63	82.35	A-7-6	GOOD
EAST L.G.A	92.25+7.5+7.5%	1.878	18.23	40.85	36.30	238	58.15	40.90	17.25	82.35	A-7-6	GOOD
	80+10 + 10%	1.925	18.64	34.80	29.45	312	58.75	41.83	16.93	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 ROAD	97.25+2.5+2.5%	1.992	15.65	28.81	23.33	102	48.58	28.73	19.85	71.55	A-7-6	GOOD
KHANA	94.5+5.0+0.5%	2.185	15.98	37.35	31.85	173	49.35	29.95	19.40	71.55	A-7-6	GOOD
L.G.A	92.25+7.5+7.5%	2.310	16.28	56.40	51.67	236	50.18	31.10	19.08	71.55	A-7-6	GOOD
	80+10 + 10%	2.553	16.85	43.65	40.75	346	50.35	31.52	18.83	71.55	A-7-6	GOOD

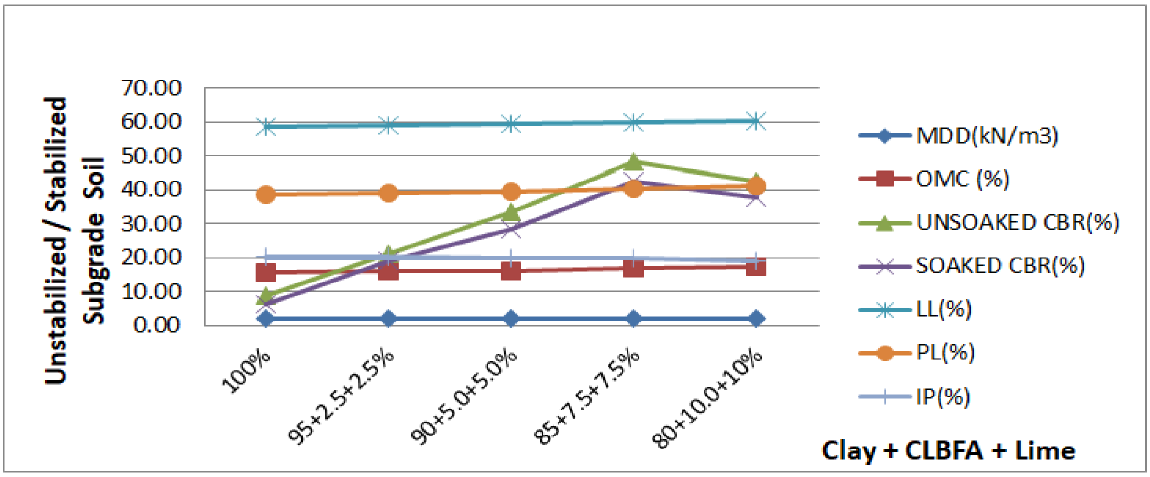

Figure 3.1:Subgrade Stabilization Test of Clay Soil from Ogoda in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination

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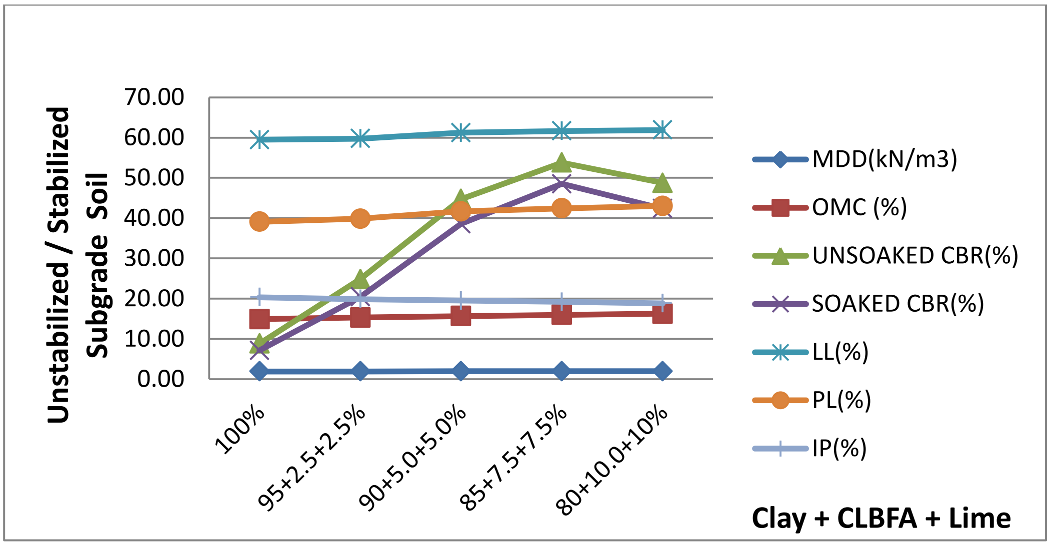

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Bodo in Gokana L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination

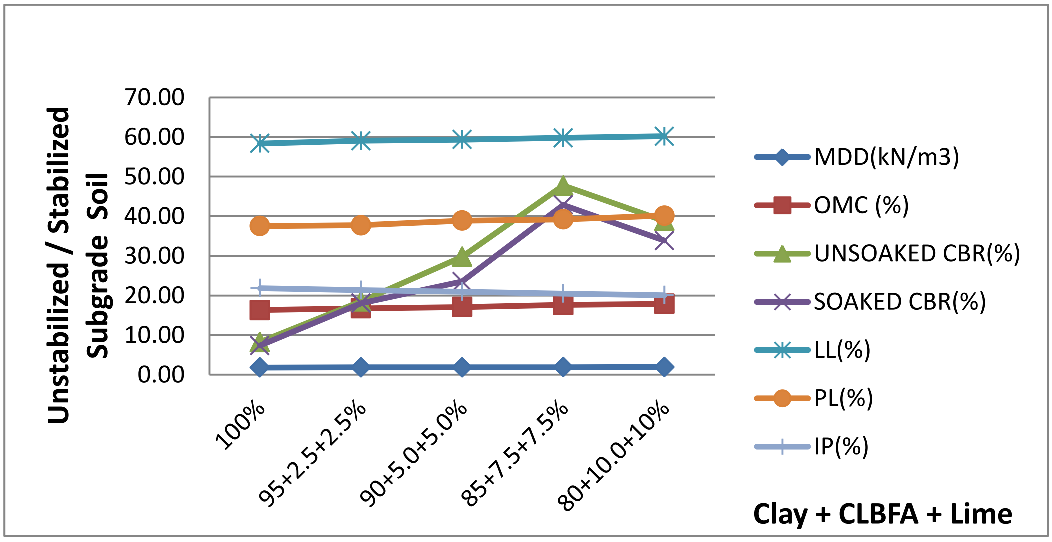

Figure 3.3:Subgrade Stabilization Test of Clay Soil from Ogbogu in Ogba/Egbema/Ndoni L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination

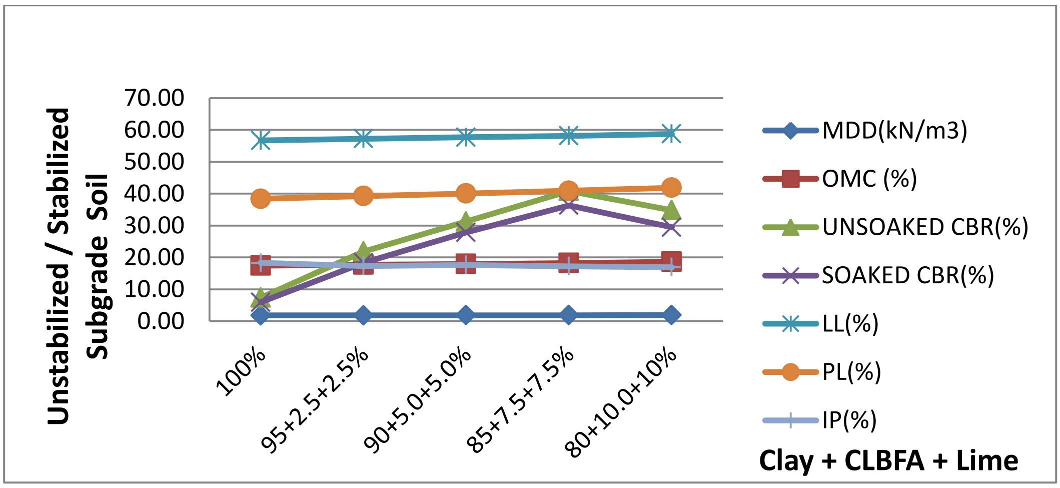

Figure 3.4:Subgrade Stabilization Test of Clay Soil from Ula-Ikata in Ahoada-East L.G.A of Rivers State with CLBFA + Limet at Different Percentages and Combination

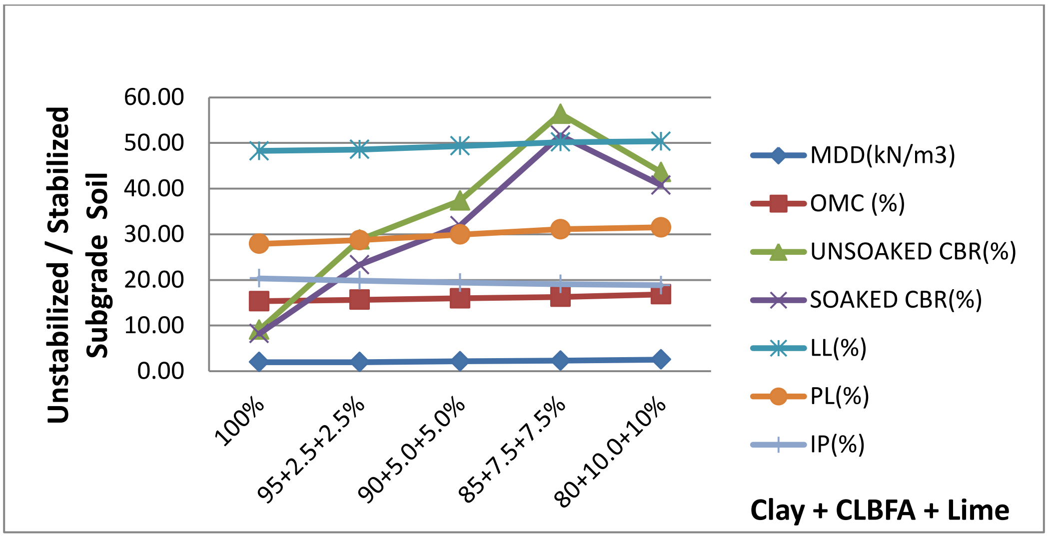

Figure 3.5:Subgrade Stabilization Test of Clay Soil from Kaani in Khana L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination

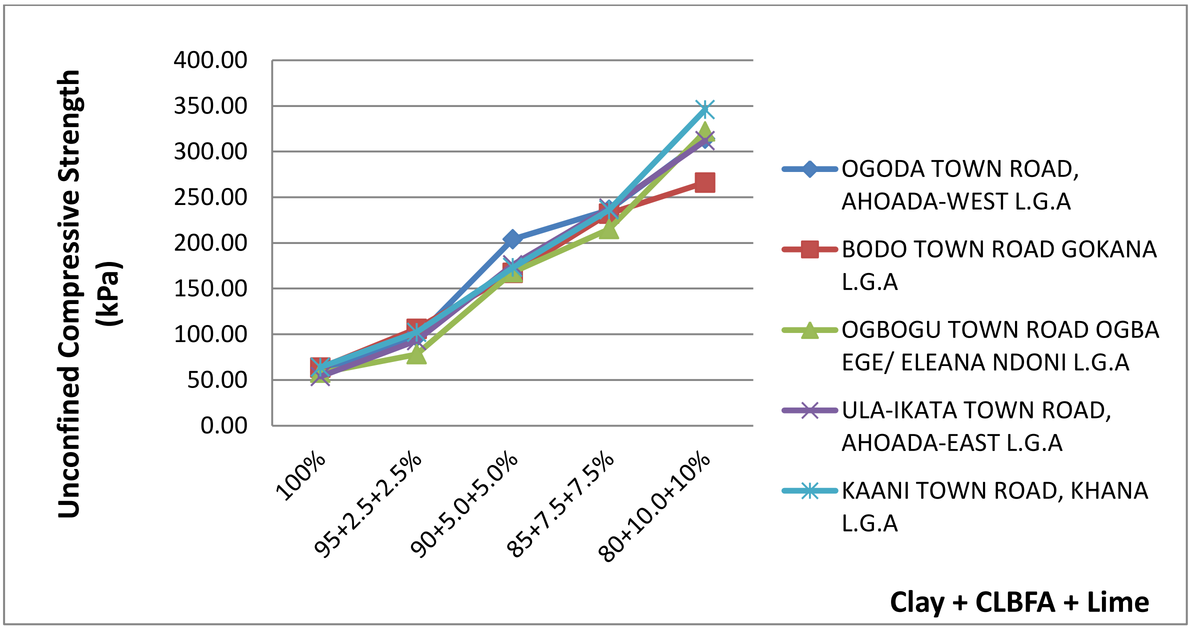

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with CLBFA + Lime of (Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State

4. CONCLUSIONS

The following conclusions were made from the experimental research results.

i. The soils deposit belonged to the group A-7-6 of American Association of State and Transport Officials (AASHTO) soil classification system with plastic index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively.

ii. Detail results obtained showed increased values in both MDD and OMC, graphical representation of figures 3.1 – 3.5 showed increased values as ratio to percentage additives.

iii. Comparatively, stabilized clay soils CBR increased with increase in additives inclusion with optimum mix of 0.75% + 7.5%. Cracks noticed occurred beyond optimum mixed level.

iv. Unconfined compressive strength test results increased with varying additive percentage ratio as seen in table 3.4 and figure 3.6.

v. Costaceae lacerus bagasse fibre (CLBFA) + lime proved to be good composite combination in soil stabilization.

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