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Performance of Expansive Soils Stabilized with Costaceae Lacerus Bagasse Fibre Ash and Cement Composition

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Abstract The study evaluated the application of environmentally friendly agricultural waste product of costaceae lacerus bagasse fibre ash combined with cement for the purposed of soil modification of expansive lateritic soils of failed highway road pavement. First stage investigation showed that the soils are low, weak an never met minimum requirements for soils or soil-based materials usable in road pavement structures as i indicated by the FMW Specifications (1997). The soils at natural state has 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.Results showed a decreased in plastic index due CLBFA + Cement inclusion to lateritic soil. Swelling potential of treated soil decreased with inclusion of bagasse fibre ash and cement ratio of 7.5% + 7.5%. soils + additives. Unconfined compressive strength results showed tremendous increased with increased in additive percentages to soil ratio. California bearing ratio of unsoaked and soaked reached optimum values percentage inclusion at 7.5% + 7.5%. beyond this value, crack was formed which resulted to potential failure state. . Results showed an increased in MDD and OMC values with increase in inclusions percentages. Results showed that increased in additives inclusion percentages increases CBR values up to combined ratio of 7.5% + 7.5%. Beyond this combination, CBR values plunged. Results showed increased values of UCS with increase in additives inclusion percentages. Results showed decreased in plastic index due to CLBFA + cement additives inclusion to lateritic soil.

Keywords Lateritic soils, Costaceae Lacerus, Cement, CBR, UCS, Consistency, Compaction

1. Introduction

Stabilization is one of the effective methods to improve the engineering properties of soils with low strength for which the required standard are not met. Researchers have been carried out on lateritic soil using stabilizers such as lime, cement and bitumen to improve the strength properties in the past (Ola, [1]; Bairwa *et al.*, [2]). Researchers have shown that fibres are used to improve the ductility of stabilized soil. Fibre reinforcement increases the peak and residual shear strength of cement treated soil. Natural fibres such as kenaf, coir, banana, jute, flax, sisal, palm, reed, bamboo and wood fibres are used for soil reinforcement and stabilization (Ramakrishna and Sundararajan ([3]).

Charles *et al.* [4] 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 [5]). 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.

Charles *et al*. [6] investigated the problematic engineering properties of soils with high plasticity level, high swelling and shrinkage potentials used in pavement design in the Nigerian Niger Delta region. The application of stabilizing agents of cement and costus afer bagasse fibre (Bush Sugarcane Bagaase Fibre) were mixed in single and combines actions to improved their unique properties. Results showed that inclusion stabilizing material improved strength properties of the soils. Results of tests carried out show that the optimum moisture content increased with increasing cement ratios to both soils (clay) and (laterite). Treated soils with Cement decreased in liquid limits and increased in plastic limits. Soils with Cement and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions. At 8% of lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% cement + 0. 75% BSBF, optimum value are reached.

Charles *et al.* [7] 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 strengthen the failed section of the road. The preliminary investigation values indicated that the soils are highly plastic. The results showed the potential of using bagasse, BSBF as admixtures in cement and lime treated soils of clay and laterite with optimum values of 8 % cement and lime and 7.5% +7.5 % of cement / lime + BSBF.

Sabat [8] studied the effects of polypropylene fiber on engineering properties of RHA-lime stabilized expansive soil. Polypropylene fiber added were 0.5 % to 2 % at an increment of 0.5 %.The properties determined were compaction, UCS, soaked CBR, hydraulic conductivity and P effect of 0 day, 7 days and 28 days of curing ware also studied on UCS, soaked CBR, hydraulic conductivity and swelling pressure. The optimum proportion of Soil: RHA: lime: fiber was found to be 84.5:10:4:1.5.

Ramakrishna and Pradeep [9] 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.

Prabakar and Sridhar [10] studied on soil specimens reinforced with sisal fibres showed that both fibre content and aspect ratio have important influences in shear strength parameters (c, ∅). They observed that an optimum value for the fibre content exists such that the shear strength decreases with increasing fibre content above this optimum value.

Mesbah *et al*. [11] carried out tensile tests on soil specimens reinforced with sisal fibres and concluded that the fibres, length and their tensile strength are the most important factors affecting the tensile strength of the soil composite.

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

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

The soils are reddish brown and dark grey in color (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

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 and Optimum moisture content, 12.39%, 14.35%, 13.85%, 11.79 and 10.95%. With 2.5 +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% inclusion of costaceae lacerus bagasse fibre ash (CLBFA) +

cement, MDD values increased to 2.608 KN/m^3, 2.465 KN/m^3, 2.544 KN/m^3, KN/m^3, 1.965 KN/m^3 and 2.535 KN/m^3, and OMC increased to 13.25%, 14.98%, 14.68%, 12.43 and 12.62% respectively as shown in table 3.4. Results showed an increased in MDD and OMC values with increase in inclusions percentages.

3.2 California Bearing Ratio (CBR) Test

Results obtained from table 3.1 for lateritic soils at 100% CBR values of unsoaked are 8.7%,8.5%, 7.8%, 9.4%, 10.6% and 8.3%, 7.8%, 7.2%, 8.5% and 9.8 %, soaked. With 2.5 +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% inclusion of costaceae lacerus bagasse fibre ash (CLBFA) + cement, CBR values increased to 56.75%, 47.35%, 38.30%, 54.05& and 64.45% (Unsoaked) and 48.75%, 39.75%, 33.45%, 48.25%, and 58.35% (soaked) respectively to corresponding values of table 3.4. Results showed that increased in additives inclusion percentages increases CBR values up to combined ratio of 7.5% + 7.5%. Beyond this combination, CBR values plunged.

3.3 Unconfined Compressive Strength Test

Unconfined compressive strength (UCS) test results are 178kPa, 145kPa, 165kPa,158kPa and 149kPa when compacted with British Standard light (BSL), Results of stabilized soils with 2.5 + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% inclusion of costaceae lacerus bagasse fibre ash (CLBFA) + cement yielded 374kPa, 363kPa, 374kPa, 325kPa, and 318kPa. Results showed increased values of UCS with increase in additives inclusion percentages.

3.4 Consistency Limits Test

Preliminary results of consistency limits (Plastic Index) at 100% lateritic soils as shown in table 3.1 are 17.30%, 14.23%, 15.20%, 15.50%, and 16.10%.The inclusion of additives as shown in table 3.4 decreased (PI) values to 16.51%, 13.02% and 12.85%, 15.85%, and 14.65% were recorded. Results showed decreased in plastic index due to CLBFA + cement additives 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 (Clay) Test Stabilization with Binding Cementitious Products at Different percentages and Combination

SAMPLE LOCATION	SOIL+ BAGASSE FIBRE ASH + CEMENT	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 + CEMENT												
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
	95 + 2.5+2.5%	1.975	12.48	26.35	20.85	205	41.05	24.65	17.10	28.35	A-2-6/SC	GOOD
	90 +5.0+5.0%	2.085	12.73	34.65	28.75	265	42.68	25.85	16.83	28.35	A-2-6/SC	GOOD
	85+7.5+7.5%	2.345	12.98	56.75	48.75	298	43.78	26.98	16.80	28.35	A-2-6/SC	GOOD
	80+10+10%	2.608	13.25	49.85	37.75	374	44.36	27.85	16.51	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	40.55	A-2-4/SM	GOOD
	95 + 2.5+2.5%	1.905	14.48	24.30	18.95	175	37.85	23.85	14.0	40.55	A-2-4/SM	POOR
	90 +5.0+5.0%	1.975	14.66	30.60	26.45	245	38.15	24.45	13.70	40.55	A-2-4/SM	GOOD
	85+7.5+7.5%	2.215	14.71	47.35	39.75	305	39.55	26.10	13.45	30.55	A-2-6/SM	GOOD
	80+10+10%	2.465	14.98	40.45	34.75	363	40.15	27.13	13.02	40.55	A-2-4/SM	GOOD
Anakpo Town Road (CH6+950)	100%	1.943	13.85	7.80	7.20	165	36.75	21.45	15.30	36.85	A-2-4/SM	POOR
	95 + 2.5+2.5%	1.986	14.05	21.85	18.35	195	37.15	27.08	15.07	36.85	A-2-4/SM	GOOD
	90 +5.0+5.0%	2.175	14.25	28.75	25.55	263	37.65	22.70	14.95	36.85	A-2-4/SM	GOOD
	85+7.5+7.5%	2.328	14.30	38.30	33.45	316	38.23	25.18	13.05	36.85	A-2-4/SM	GOOD
	80+10+10%	2.544	14.68	32.65	28.70	374	38.85	36.00	12.85	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
	95 + 2.5+2.5%	1.185	11.95	26.30	23.30	184	37.90	20.48	16.92	33.45	A-2-6/SC	GOOD
	90 +5.0+5.0%	1.865	12.05	28.45	33.65	236	38.25	21.37	16.28	33.45	A-2-6/SC	GOOD
	85+7.5+7.5%	1.905	12.28	54.05	48.25	285	38.68	22.55	16.15	33.45	A-2-6/SC	GOOD
	80+10+10%	1.965	12.43	47.35	42.65	325	39.35	23.50	15.85	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
	95 + 2.5+2.5%	2.225	11.05	28.65	23.45	202	38.15	22.15	16.00	39.25	A-2-6/SC	GOOD
	90 +5.0+5.0%	2.405	11.28	39.70	33.75	235	38.65	22.90	15.75	39.25	A-2-6/SC	GOOD
	85+7.5+7.5%	2.485	11.33	64.45	58.35	267	39.10	23.75	15.35	39.25	A-2-6/SC	GOOD
	80+10+10%	2.535	12.62	58.35	52.30	318	39.77	25.12	14.65	39.25	A-2-6/SC	GOOD

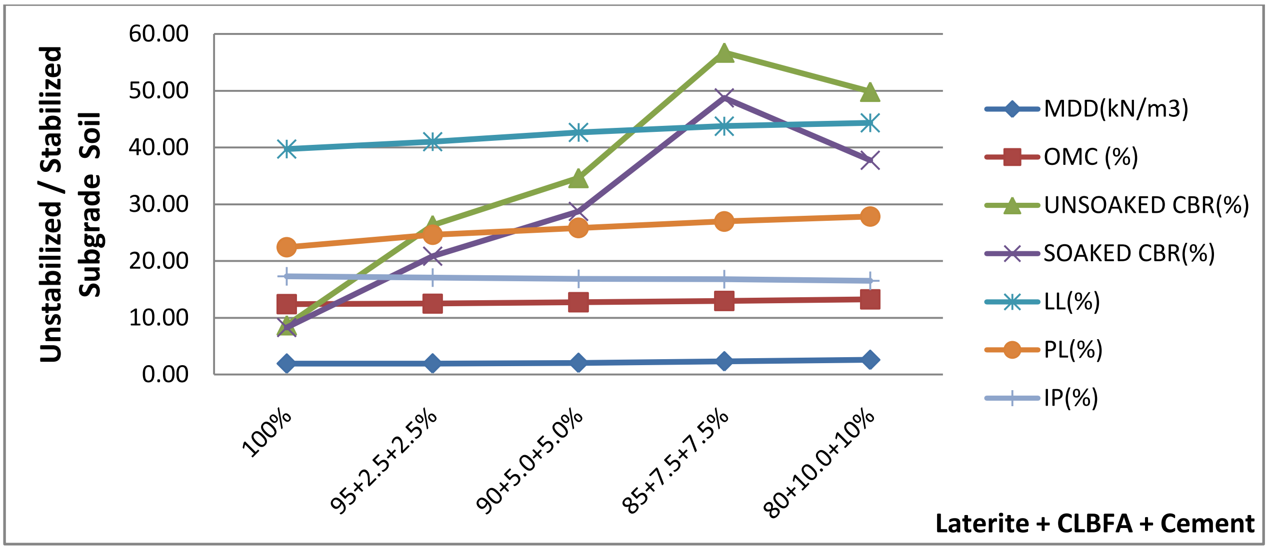

Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with CLBFA + Cement at Different Percentages and Combination

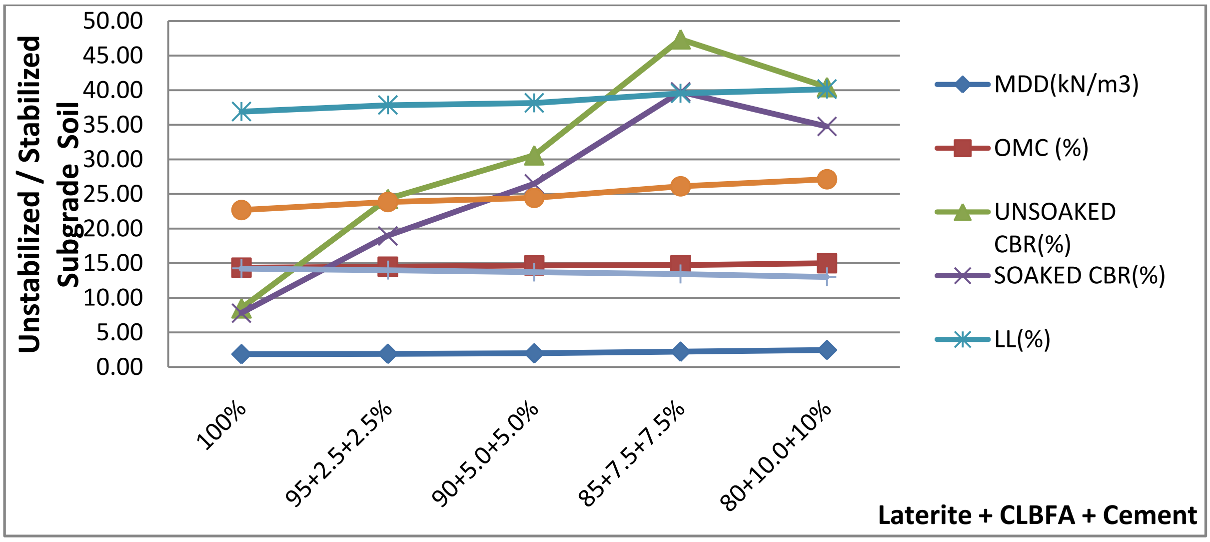

Figure 3.2: Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoada-West L.G.A of Rivers State with CLBFA + Cement at Different Percentages and Combination

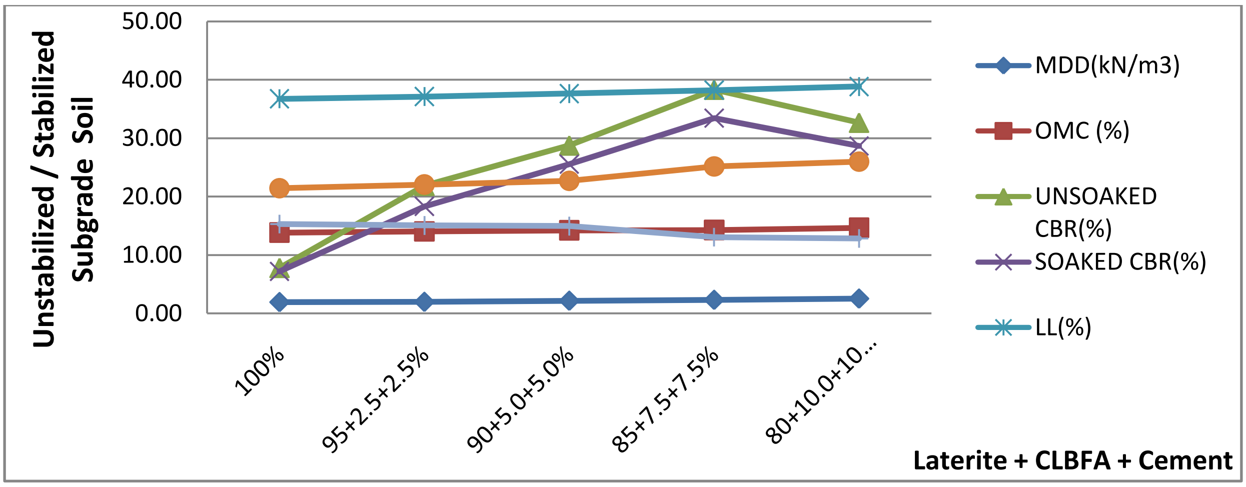

Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoada-West L.G.A of Rivers State with CLBFA + Cement at Different Percentages and Combination

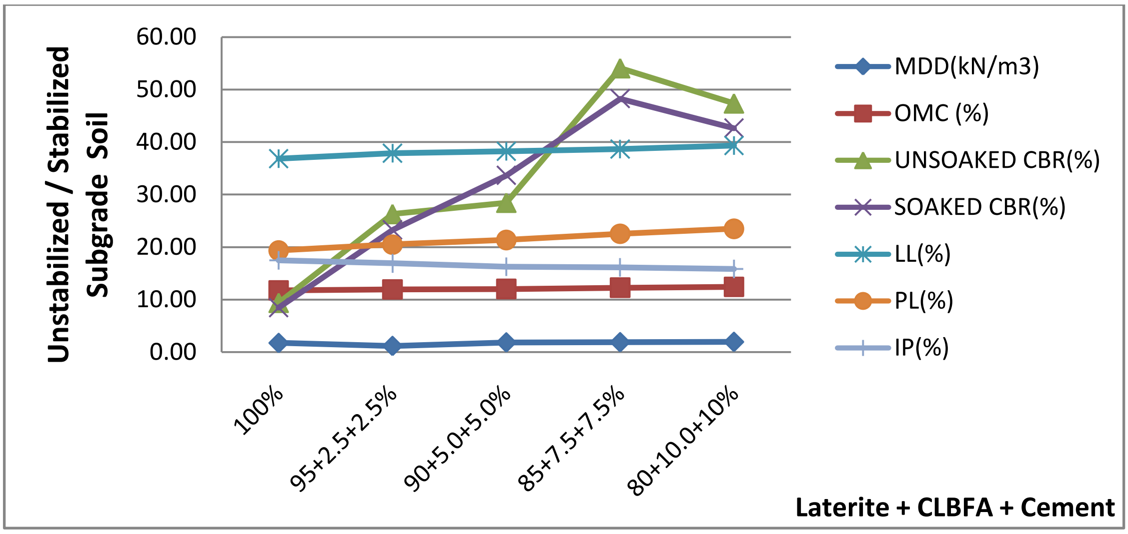

Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoada-West L.G.A of Rivers State with CLBFA + Cement at Different Percentages and Combination

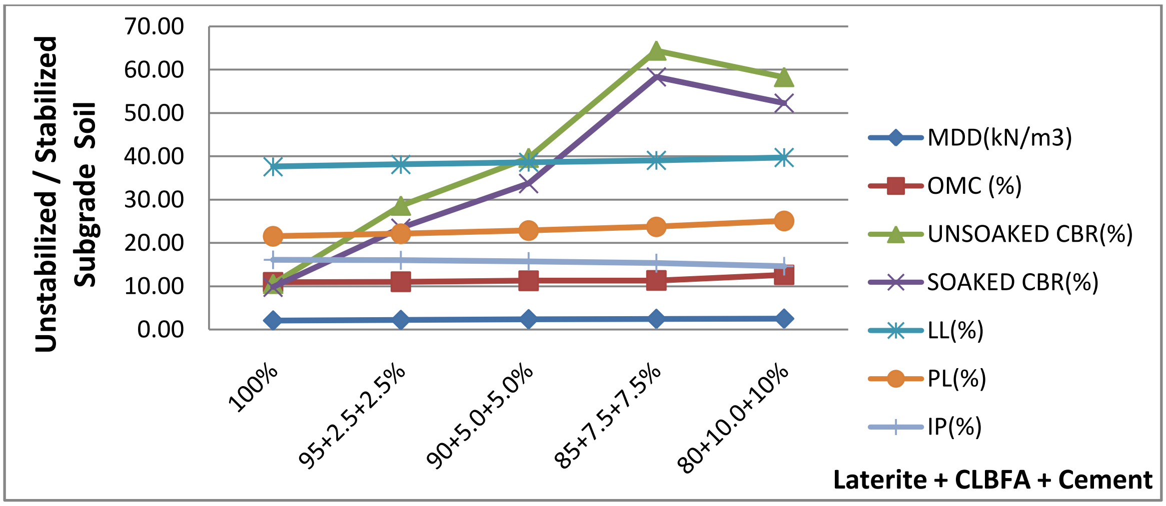

Figure 3.5: Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with CLBFA + Cement at Different Percentages and Combination

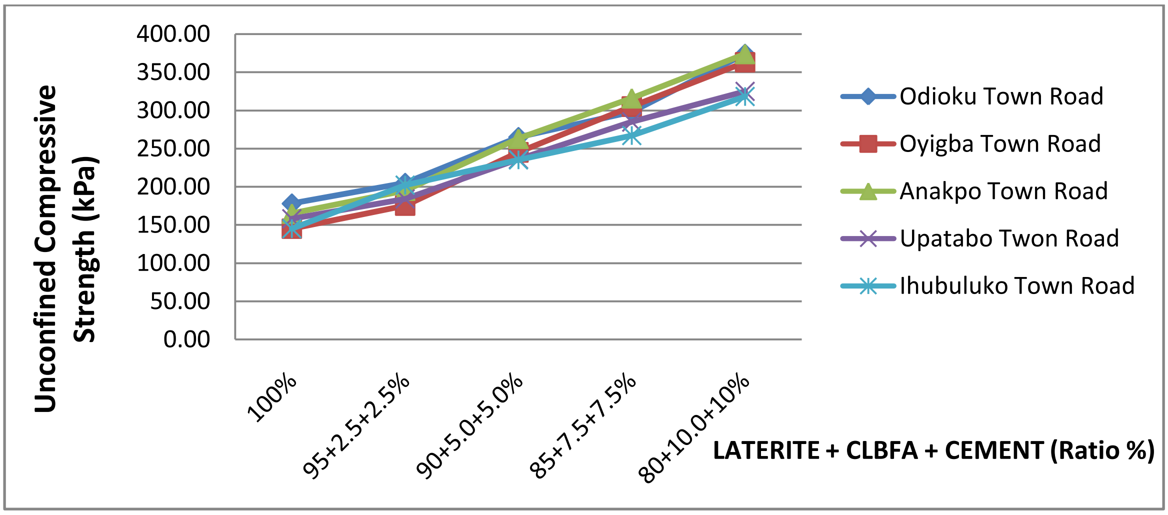

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with CLBFA + Cement of (Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoad-West L.G.A, Rivers State

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),
ii. Soils are 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.
iii. Results showed a decreased in plastic index due CLBFA + Cement inclusion to lateritic soil
iv. Swelling potential of treated soil decreased with the inclusion of bagasse fibre ash of up to 7.5 soils
v. Unconfined compressive strength results showed tremendous increased with increase in additive percentages to soil ratios.
vi. California bearing ratio of unsoaked and soaked reached optimum values percentage inclusion at 7.5%, beyond this value, crack was formed which resulted to potential failure state.

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