Problematic Soils Stabilization with Costaceae Lacerus Bagasse Fibre and Cement in Combined Actions

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ABSTRACT

The research work investigated the engineering properties of problematic soils with unique attributes of swelling, shrinkage and crack potentials of highway subgrade pavement and stabilized with costaceae lacerus bagasse fibre + cement in combined actions of 0.25 +5.0%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% fibre + Cement inclusion to soils ratio. The soils were classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System. The soils percentage (%) passing BS sieves #200 are 28.35%, 40.55%, 36.85%, 33.45% and 39.25. There natural characteristics based on preliminary investigation showed that they fell short of the minimum requirements for such applications on specifications for road pavement structural materials (after FMW 1997). Compaction test results showed that an increase in fibre + cement percentage combinations increased maximum dry density(MDD) and Optimum moisture content (OMC) values of Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads. Results showed an increased in CBR of stabilized soils with peak rise at 0.75% + 7.5% combination, beyond this; lower values were obtained with cracks formation and failure status. Unconfined compressive strength (UCS) values increased with increase in combined ratio. Consistency limits result showed decreased in plastic index properties due to additives inclusion to lateritic soil. The entire results showed good combinations of laterite + costaceae lacerus bagasse fibre + cement as admixtures in soil stabilization. Swelling potential of treated soils decreased with the inclusion of bagasse fibre + Cement.

Key Words: *Lateritic soils, Costaceae Lacerus Bagasse Fibre , Cement, CBR, UCS, Consistency, Compaction*

1.0 Introduction

Natural soil underlying the Niger delta roads are mainly clay and silt of poor quality as subgrade and sub base material however fine grained sandy soil stockpiled at road side as waste maybe modified for strength gain to replace the excavated natural soil during road construction the optimum stabilization condition of the soil were determined in the study to evaluate the strength improvement for beneficial use as road construction materials in view of their large quantity and nearness to the point of use. Soil stabilization is aimed at the enhancement of the engineering properties of deficient soils to enable them perform and sustain their intended engineering use (Yoder and Witczak, [1]; Gillott, [2]; Osinubi, [3]; Nicholas and Lester, [4]; Sherwood, [5]).

Prabakar and Sridhar [6]) 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.

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.

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

Charles *et al*. [9] 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.

Mesbah *et al*. [10] 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.

Bouhicha *et al*. [11] used the shear box test method to evaluate the strength of compacted earth reinforced with barley straw. Their work was part of a wider study of the physical and mechanical properties of fibre-

Ramakrishna and Pradeep [12] 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.

Sharma *et al*., [13] investigated the behavior of expansive clay stabilized with lime, calcium chloride and RHA. The optimum percentage of lime and calcium chloride was found to be 4 % and 1% respectively in stabilization of expansive soil without addition of RHA. From UCS and CBR point of view when the soil was mixed with lime or calcium chloride, RHA content of 12 % was found to be the optimum. In expansive soil – RHA mixes, 4% lime and 1% calcium chloride were also found to be optimum.

2.0 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.

ISSN 2229-5518

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.

3.0 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 [14]; Allam and Sridharan [15]; Omotosho and Akinmusuru [16]; Omotosho [17]). 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 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% at 100%. At 0.25 +5.0%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% fibre and Cement inclusion at shown in table 3.4, MDD increased to 2.97 KN/m^3, 2.885 KN/m^3 , 3.005 KN/m^3, 3.115 KN/m^3 and 3.365 KN/m^3, and OMC increased to 13.86%, 16.35%, 15.87%,13.05% and 12.85% respectively for Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads. Results showed that an increase in fibre + cement percentage combinations increased MDD and OMC values.

3.2 California Bearing Ratio (CBR) Test

Results obtained for lateritic soils at 100% CBR were 8.7%,8.5%, 7.8%, 9.4%, and 10.6% (unsoaked) and 8.3%, 7.8%, 7.2%, 8.5% and 9.8 % (unsoaked). With fibre + Cement inclusion of 0.25 +5.0%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% percentages to lateritic soils, an increase of 62.85%, 66.75%, 59.35%, 67.87%, 73.85% (unsoaked) and 57.65%, 52.37%, 49.65%, 59.64%, and 68.73% (soaked) were recorded. Results showed an increased in CBR of stabilized soils with peak rise at 0.75% + 7.5% combination, beyond this, lower values were obtained.

3.3 Unconfined Compressive Strength Test

Unconfined compressive strength (UCS) values of 178kPa, 145kPa, 165kPa, 158kPa and 149kPa were recorded at preliminary soil investigation of 100% lateritic soil. With fibre + Cement inclusion of 0.25 +5.0%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% percentages to lateritic soils, an increased of 414kPa, 378kPa, 395kPa, 381kPa, and 345kPa were recorded. Results showed tremendous increased in values of stabilized soil with inclusions.

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 fibre + Cement inclusion of 0.25 +5.0%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% percentages to lateritic soils 15.40%, 12.80% and 17.77%, 15.50%, and 15.20% were recorded. Results showed decreased in plastic index additives inclusion to lateritic soil.

Table 3.1: Engineering Properties of Soil Samples

Location Description	Odiokwu Town Road (CH 0+950) (Laterite)	Oyigba Town Road (CH 4+225) (Laterite)	Anakpo Town Road (CH6+950) (Laterite)	Upatabo Town Road (CH8+650) (Laterite)	Ihubuluko Town Road (CH10+150) (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 Binding Cementitious Products at Different Percentages and Combination

SAMPLE LOCATION	SOIL + FIBRE BAGASBE + 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 (CLBF)+ CEMENT											
	100%	1.954	12.39	8.70	8.30	178	39.75	22.45	17.30	28.35	A-2-6/SC	POOR
Odiokwu	97.25+0.25+2.5%	1.984	12.65	22.85	28.30	227	40.35	24.15	16.20	28.35	A-2-6/SC	GGOOD
Town Road	94.5+ 0.5+ 5.0%	2.235	12.90	48.50	42.65	284	42.45	26.55	15.90	28.35	A-2-6/SC	GOOD
(CH (0+950)	91.75+0.75+7.5%	2.685	13.32	62.85	57.65	343	43.67	27.95	15.70	28.35	A-2-6/SC	GOOD
	89+1.0+10%	2.975	13.86	55.25	47.36	414	45.15	29.75	15.40	28.35	A-2-6/SC	GOOD
Oyigba Town	100%	1.857	14.35	8.50	7.80	145	36.90	22.67	14.23	40.55	A-2-4/SM	POOR
Road	97.25+0.25+2.5%	1.938	15.15	31.65	24.95	205	38.75	23.65	14.50	40.55	A-2-4/SM	GGOOD
(CH 4+225)	94.5+ 0.5+ 5.0%	2.115	15.75	50.95	38.65	265	38.95	26.15	12.80	40.55	A-2-4/SM	GOOD
	91.75+0.75+7.5%	2.486	15.98	66.75	52.37	315	40.15	28.35	11.80	40.55	A-2-4/SM	GOOD
	89+1.0+10%	2.885	16.35	44.65	41.30	378	42.10	29.30	12.80	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	97.25+0.25+2.5%	2.350	14.45	28.35	23.15	215	38.25	21.90	16.35	36.85	A-2-4/SM	GGOOD
(CH6+950)	94.5+ 0.5+ 5.0%	2.745	14.86	42.85	38.65	278	40.15	23.08	17.07	36.85	A-2-4/SM	GOOD
	91.75+0.75+7.5%	2.99	15.36	59.35	49.65	335	42.25	24.75	17.75	36.85	A-2-4/SM	GOOD
	89+1.0+10%	3.005	15.87	51.45	43.45	395	44.85	25.08	17.77	36.85	A-2-4/SM	GOOD
Upatabo	100%	1.758	11.79	9.40	8.50	158	36.85	19.35	17.50	33.45	A-2-6/SC	POOR
Town Road	97.25+0.25+2.5%	1.935	11.98	28.65	23.65	208	37.93	21.35	16.58	33.45	A-2-6/SC	GGOOD
(CH8+650)	94.5+ 0.5+ 5.0%	2.457	12.25	47.35	42.85	258	39.15	22.95	16.20	33.45	A-2-6/SC	GOOD
	91.75+0.75+7.5%	2.861	12.65	67.87	59.64	328	41.35	24.35	16.00	33.45	A-2-6/SC	GOOD
	89+1.0+10%	3.115	13.05	53.83	51.35	381	42.35	26.85	15.50	33.45	A-2-6/SC	GOOD
Ihubuluko	100%	2.105	10.95	10.60	9.80	145	37.65	21.55	16.10	39.25	A-2-6/SC	GOOD
Town Road	97.25+0.25+2.5%	2.205	11.35	31.95	27.85	215	39.86	23.15	16.71	39.25	A-2-6/SC	GOOD
(CH10+150)	94.5+ 0.5+ 5.0%	2.735	11.85	48.30	43.65	245	40.85	25.38	15.47	39.25	A-2-6/SC	GOOD
	91.75+0.75+7.5%	2.981	12.25	73.85	68.73	298	42.30	27.05	15.25	39.25	A-2-6/SC	GOOD
	89+1.0+10%	3.365	12.85	57.85	53.65	345	44.35	28.15	16.20	39.25	A-2-6/SC	GOOD

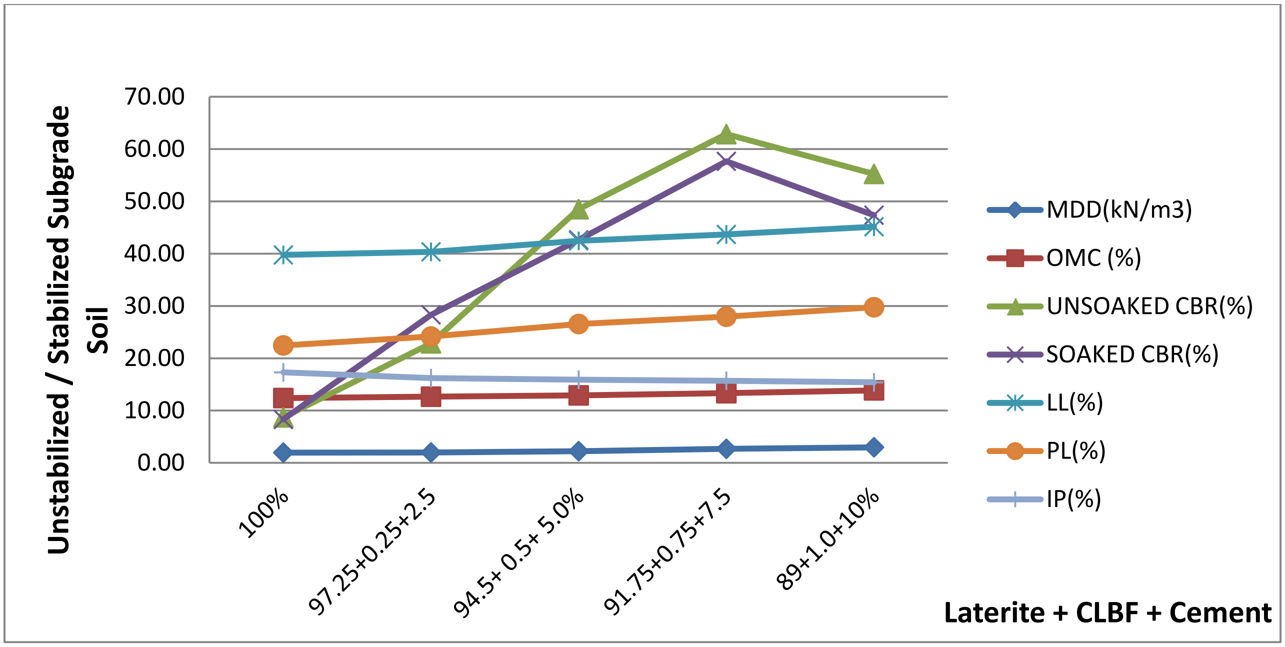

Figure 3.1: **Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination**

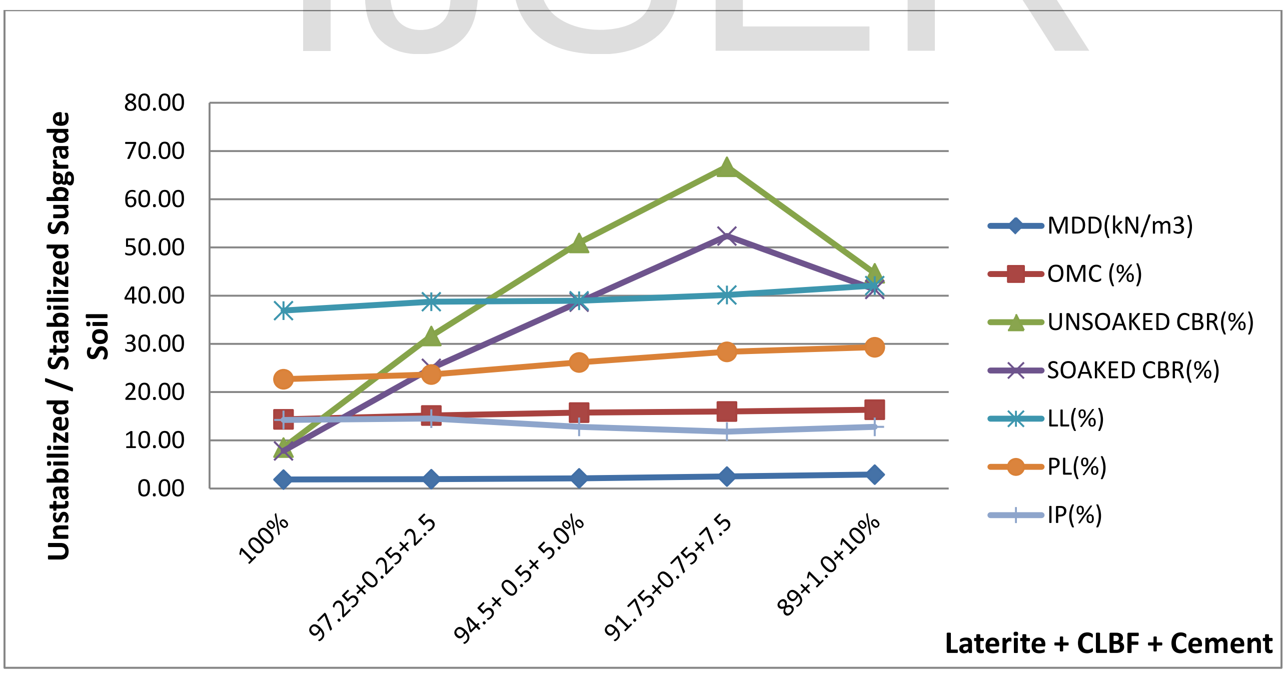

Figure 3.2: **Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoada-West L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination**

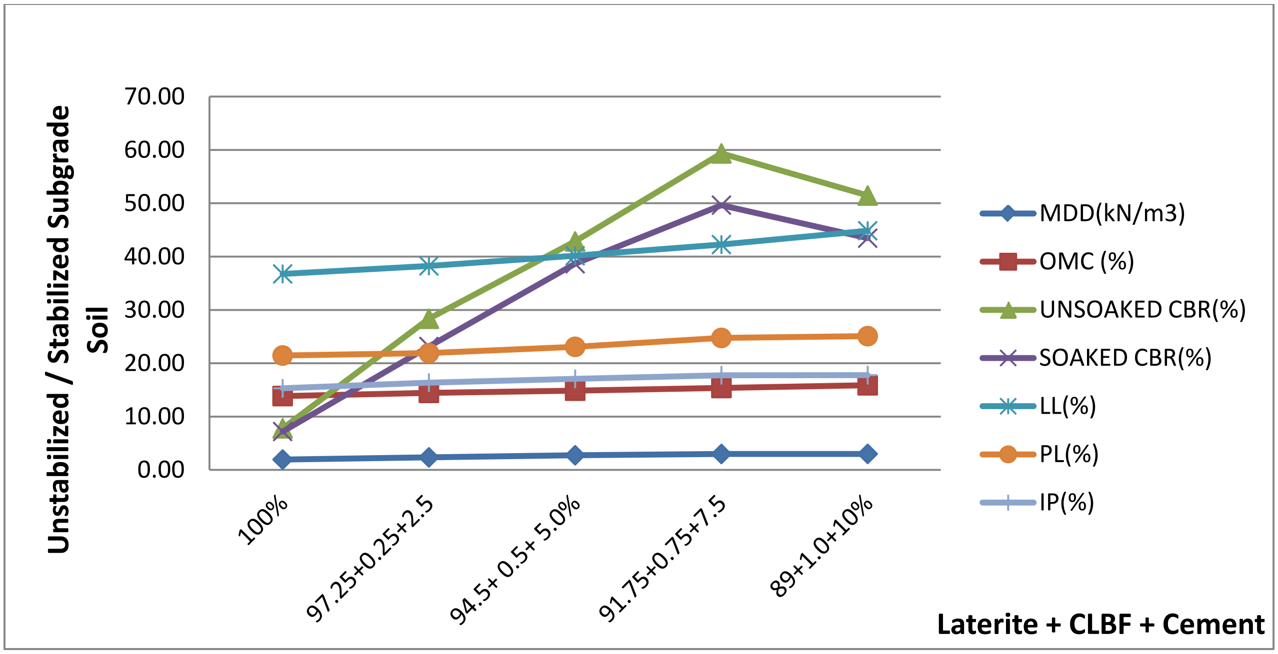

Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoada-West L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

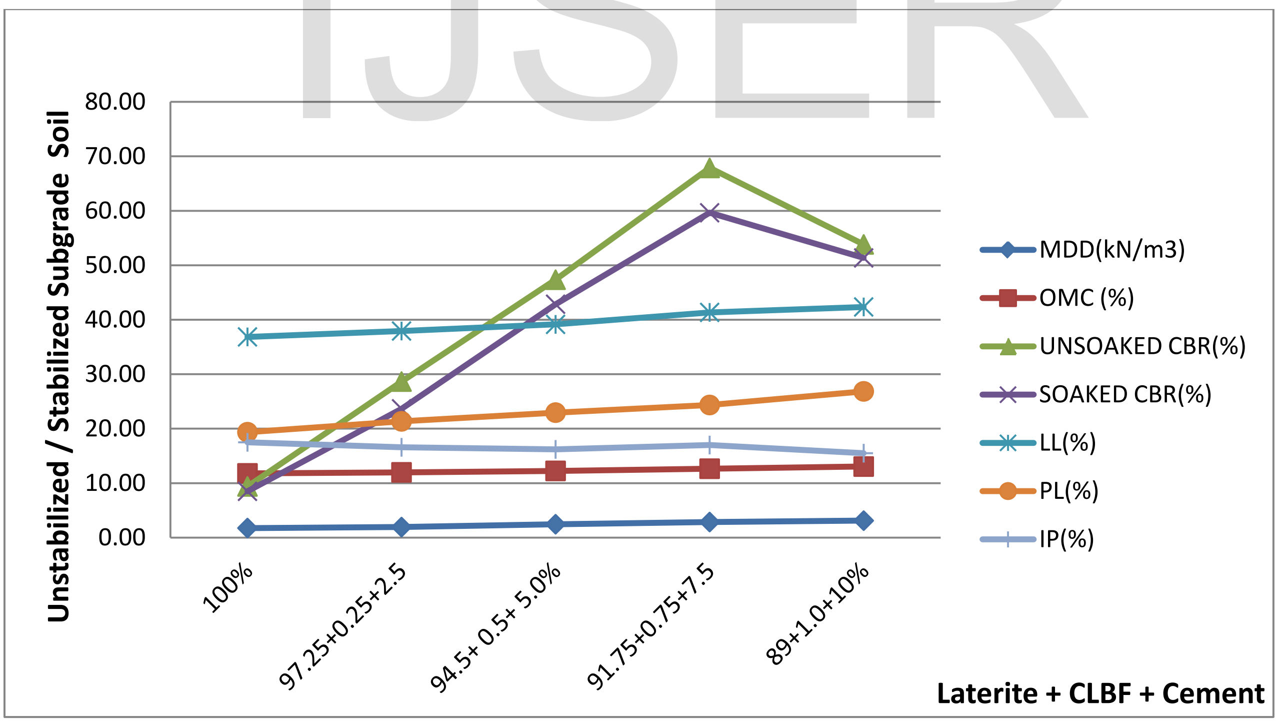

Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoada-West L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

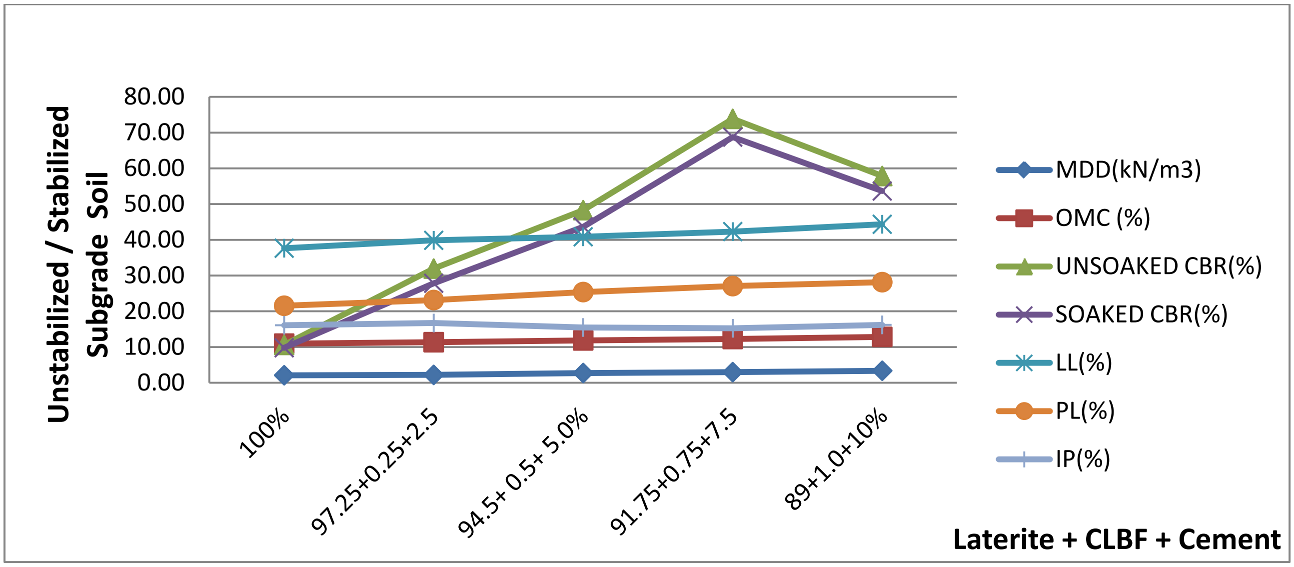

Figure 3.5: Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with CLBF + Cement at Different Percentages and Combination

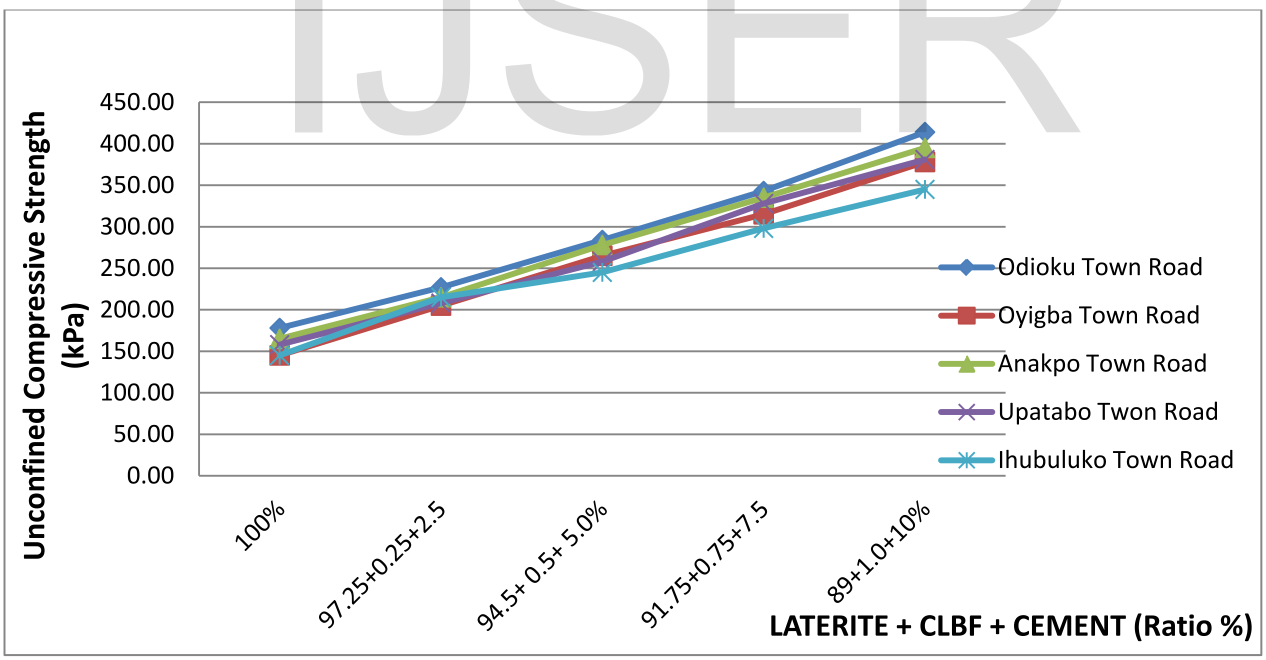

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with CLBF + Cement of (Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoad-West L.G.A, Rivers State

ISSN 2229-5518


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

Plate iii. Costaceae Lacerus dry bagasses/fibre

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. The soils were 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. The soils percentage (%) passing BS sieves #200 are 28.35%, 40.55%, 36.85%, 33.45% and 39.25%.
iii. California bearing ratio of unsoaked and soaked reached optimum values percentage inclusion at 0.75% + 7.5% combination, beyond this value, crack was formed which resulted potential failure state.
iv. The entire results showed good combination of laterite + Costaceae Lacerus Bagasse Fibre + Cement as admixtures in soil stabilization
v. Swelling potential of treated soils decreased with the inclusion of bagasse fibre + Cement .

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