

Stabilization of Niger Deltaic Expansive Clay Soils Using Composite Materials

Charles Kennedy¹, Terence Temilade Tam Wokoma¹ and Gbinu Samuel Kabari³

¹⁻³School of Engineering, Department of Civil Engineering,

Kenule Beeson Saro-Wiwa Polytechnic,

Bori, Rivers State,

Nigeria.

ABSTRACT

The study examined the hybridization effect of irvinga gabonesis fibre (Bush Mango) ash and cement as composite materials in the modification of weak expansive clay soils found in Iwofe, Chokocho, Ndoni, and Ogbele town roads in the Niger Delta region of South-South part of Nigeria. Preliminary test carried out classified as A – 7 – 6 /CH on the AASHTO classification schemes / Unified Soil Classification System. The soils are dark grey in color with the plastic index of 31.10%, 24.55%, 31.05%, and 32.17% respectively. Experimental results analyzed showed increased in compaction test parameters of MDD and OMC with the increase in additives corresponding percentage ratio to clay soils. Results of unstabilized and stabilized results showed increased values with respect to corresponding percentages with the optimum inclusion of 7.5% + 7.5% to soils ratio. Results showed decreased in plastic index parameters with additives inclusion to soils. Comparative results showed increased in the unconfined compressive strength of stabilized clay soils with respect to the percentage. Entire results showed the use of irvinga gabonesis fibre (Bush Mango) ash and cement as soil stabilizer products.

Key Words: Clay soils, Irvinga Gabonesis Fibre Ash, Cement, CBR, UCS, Consistency, Compaction

1. INTRODUCTION

Niger Deltaic soils are however, the most available, suitable and most widely used soil materials for road earthworks in the entire Niger Delta (Arumala and Akpokodje, [1]). Except in very rare and exceptional cases, soils (including deltaic clay and 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 [2]. To gain the specified standards, soils ought to be stepped forward earlier than use. Stabilization is an obvious option required to bridge the gap to enable these soils with inique characteristics of swelling and shrinkage status meet specified standard indicated. Ramakrishna and Pradeep [3] 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.

Charles *et al.* [4] 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.

Sharma *et al* [5] 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.

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.

Wahab *et al.* [7] lime stabilization creates a number of important engineering properties in soils to improved workability, providing a working platform for subsequent construction, reducing plasticity to meet specifications, conditioning the soil for further treatment. Lime stabilization results in higher bearing capacity and lower compressibility of the treated soil mass.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil

The soils used for the study were collected within failed sections of the at 1.5 m depth from Iwofe Town Road, in Obio/Akpor Local Government Area, Chokocho Town Road, in Etche Local Government Area, Ndoni Town Road, in Ogba/Egbema/Ndoni Local Government Area and Ogbele Town Road in ahoada – East Local Government Area, all in Rivers State, Nigeria.

2.1.2 Irvinga Gabonensis Fibre

The Irvinga Gabonensis, popularly called Bush mango , with Nigerian native name (Egbono) are widely spread plants across Nigerian bushes and farm land with edible fruits that bears the fibre , they are collected from at Olokuma village, a river side area in 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 Iwofe Town, (latitude 4.49° 41'S and longitude 6.57° 24'E), Chokocho Town, (latitude 4.9882° N ° 34'S and longitude 7.0525° ° 13'E), Ndoni Town, latitude 5.5487 ° 21'S and longitude 6.5917° ° 39'E), Ogbele Town, (latitude 4.9198 ° 23'S and longitude 6.6751 ° 34'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 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 than other deltaic lateritic soils are known for (Ola [8]; Allam and Sridharan [9]; Omotosho and Akinmusuru [10]; Omotosho [11]). The soils are reddish brown and dark grey in colour (from wet to dry states) plasticity index of 31.10%, 24.55%, 31.05%, and 32.17% respectively for Iwofe, Chokocho, Ndoni, and Ogebele Town Roads. The soil has unsoaked CBR values of 7.35%, 7.75%, 8.15%, and 7.85% and soaked CBR values of 6.35%, 6.23%, 7.05% and 5.55%, unconfined compressive strength (UCS) values of 87.85kPa, 78.75kPa, 105.75kPa, and 85.35kPa when compacted with British Standard light (BSL), respectively

3.1 Compaction Test Results

Compaction test results from preliminary soils engineering properties at natural state are maximum dry density (MDD) 1.685KN/m³, 1.635KN/m³, 1.657KN/m³, 1.697KN/m³ and optimum moisture content (OMC) are 15.28%, 16.28%, 16.05% and 15.73%. Fibre ash + cement reinforced clay soils of 2.5% +2.5%, 5.0% +5.0%, 7.5% +7.5% and 10% + 10% to clay soils ratio peak MDD values are 1.995 KN/m³, 1.778 KN/m³, 1.740 KN/m³, 1.820 KN/m³ and OMC are 17.05%, 17.45%, 17.68%, 17.25%. Experimental results analyzed showed increased in compaction test parameters of MDD and OMC with increase in additives corresponding percentage ratio to clay soils.

3.2 California Bearing Ratio (CBR) Test

Analyzed results from preliminary investigations from sampled roads at 100% clay soils are CBR values soils has unsoaked 7.35%, 7.75%, 8.15%, 7.85% and soaked 6.35%, 6.23%, 7.05% and 5.55%. Fibre ash + cement stabilized clay soils maximum values obtained are (CBR) unsoaked 70.85%, 73.35%, 78.60% and soaked are 63.65%, 67.80%, 69.25%, 69.95%. Results from unstabilized and stabilized results showed increased values with respect to corresponding percentages with optimum inclusion of 7.5% + 7.5% to soils ratio.

3.3 Unconfined Compressive Strength Test

Preliminary soil test results at 100% clay soils are 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa respectively as indicated in table 3.1 sampled roads. Results of stabilized soils at peak of samples are 574kPa, 586kPa, 606kPa and 589kPa. Comparative results showed increased in unconfined compressive strength of stabilized clay soils with respect to percentage increase.

3.4 Consistency Limits Test

Results of consistency limits (Plastic index) at 100% clay soils are 31.10%, 24.55%, 31.05%, and 32.17%. Fibre ash + cement stabilized soils plastic index peak values are 28.87%, 23.15%, 29.86% and 30.92%. Comparative results showed decreased in plastic index parameters with additives inclusion to soils.

Table 3.1: Engineering Properties of Soil Samples

Location Description	Iwofe Road Obio/Akpor	Chokocho Road Etche	Ndoni Road Ogba/Egbema/N	Ogebele Road Ahoda East L.G.A
----------------------	--------------------------	------------------------	-----------------------------	----------------------------------

	L.G.A	L.G.A	doni L.G.A	
Depth of sampling (m)	1.2	1.2	1.2	1.2
Percentage(%) passing BS sieve #200	76.35	80.25	83.65	78.25
Colour	Greyish	Greyish	Greyish	Greyish
Specific gravity	2.52	2.58	2.45	2.44
Natural moisture content (%)	42.58	48.35	44.65	44.30
Consistency Limits				
Liquid limit (%)	68.35	53.85	62.40	58.75
Plastic limit (%)	37.25	29.30	31.35	26.58
Plasticity Index	31.10	24.55	31.05	32.17
AASHTO soil classification	A-7-6	A-7-6	A-7-6	A-7-6
Unified Soil Classification System	CH	CH	CH	CH
Optimum moisture content (%)	15.28	16.28	16.05	15.73
Maximum dry density (kN/m³)	1.685	1.635	1.657	1.697
COMPACTION CHARACTERISTICS				
Gravel (%)	0.0	0	0	0
Sand (%)	13.18	12.3	12.8	16.5
Silt (%)	42.3	48.5	42.3	48.2
Clay (%)	44.6	38.2	44.9	35.3
Unconfined compressive strength (kPa)	87.85	78.75	105.75	85.35
California Bearing Capacity (CBR)				
Unsoaked (%) CBR	7.35	7.75	8.15	7.85
Soaked (%) CBR	6.35	6.23	7.05	5.55

Table 3.2: Results of Subgrade Soil (Clay) Test Stabilization with Binding Cementitious Products at Different Percentages And Combination

SAMPLE LOCATION	SOIL + FIBRE	MDD (kN/m ³)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(Kpa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
CLAY SOIL+IRVINGA GARBONESIS FIBRE ASH + CEMENT												
IWOFE ROAD	100(%)	1.68	15.28	7.35	6.35	87.85	68.3	37.2	31.1	76.3	A – 7 – 6	POOR
		5					5	5	0	5	/CH	
OBIO/AKPO L.G.A	95+2.5+2.5(%)	1.73	15.74	28.5	23.4	128	68.7	38.9	29.7	76.3	A – 7 – 6	GOOD
		8		0	5		3	5	8	5	/CH	
	90+5.0+5.0(%)	1.77	16.05	57.5	48.3	221	69.1	39.8	29.3	76.3	A – 7 – 6	GOOD
		9		0	5		5	0	5	5	/CH	
	85+7.5+7.5(%)	1.97	16.75	70.8	63.6	387	69.6	40.6	29.4	76.3	A – 7 – 6	GOOD
		8		5	5		5	1	0	5	/CH	

	80+10+10(%)	1.99	17.05	62.8	54.5	574	70.0	41.1	28.8	76.3	A-7-6	GOOD
		5		5	5		5	8	7	5	/CH	
CHOKOCH	100(%)	1.63	16.28	7.75	6.23	78.25	53.8	29.3	24.5	80.2	A-7-6	POOR
O ROAD		5					5	0	5	5	/CH	
ETCHE	95+2.5+2.5(%)	1.66	16.55	30.1	28.1	138	54.1	30.1	24.0	80.2	A-7-6	GOOD
L.G.A		5		5	5		5	0	5	5	/CH	
	90+5.0+5.0(%)	1.69	16.80	49.5	36.0	246	54.6	30.8	23.8	80.2	A-7-6	GOOD
		8		0	5		5	1	4	5	/CH	
	85+7.5+7.5(%)	1.72	17.03	73.3	67.8	375	54.9	31.3	23.5	80.2	A-7-6	GOOD
		5		5	0		2	6	6	5	/CH	
	80+10+10(%)	1.77	17.45	61.7	54.5	586	55.1	32.0	23.1	80.2	A-7-6	GOOD
		8		5	3		8	3	5	5	/CH	
NDONI	100(%)	1.65	16.05	8.15	7.05	105.7	62.4	31.3	31.0	83.6	A-7-6	POOR
ROAD		7				5	0	5	5	5	/CH	
OGBA/EGB	95+2.5+2.5(%)	1688	16.52	34.1	28.3	181	62.6	31.8	30.8	83.6	A-7-6	GOOD
EMA/NDON				5	5		8	8	0	5	/CH	
I L.G.A	90+5.0+5.0(%)	1.69	16.94	56.3	49.2	238	62.8	32.4	30.4	83.6	A-7-6	GOOD
		4		0	0		8	2	6	5	/CH	
	85+7.5+7.5(%)	1.71	17.13	78.6	69.2	485	63.0	33.0	30.0	83.6	A-7-6	GOOD
		5		0	5		5	0	5	5	/CH	
	80+10+10(%)	1.74	17.68	61.2	57.8	606	63.5	33.6	29.8	83.6	A-7-6	GOOD
		0		3	5		5	9	6	5	/CH	
OGBELE	100(%)	1.69	15.73	7.85	5.55	85.35	58.2	26.5	32.1	78.4	A-7-6	POOR
ROAD		7					5	8	7	5	/CH	
AHODA	95+2.5+2.5(%)	1.72	16.05	27.3	22.4	156	58.5	26.7	31.8	78.4	A-7-6	GOOD
EAST L.G.A		3		0	5		8	3	5	5	/CH	
	90+5.0+5.0(%)	1.77	16.63	45.1	38.6	286	58.9	27.4	31.5	78.4	A-7-6	GOOD
		8		5	0		3	0	3	5	/CH	
	85+7.5+7.5(%)	1.79	16.98	69.9	62.3	495	59.1	27.9	31.1	78.4	A-7-6	GOOD
		5		5	5		7	9	8	5	/CH	
	80+10+10(%)	1.82	17.25	57.5	52.1	589	59.6	28.7	30.9	78.4	A-7-6	GOOD
		0		5	8		2	0	2	5	/CH	

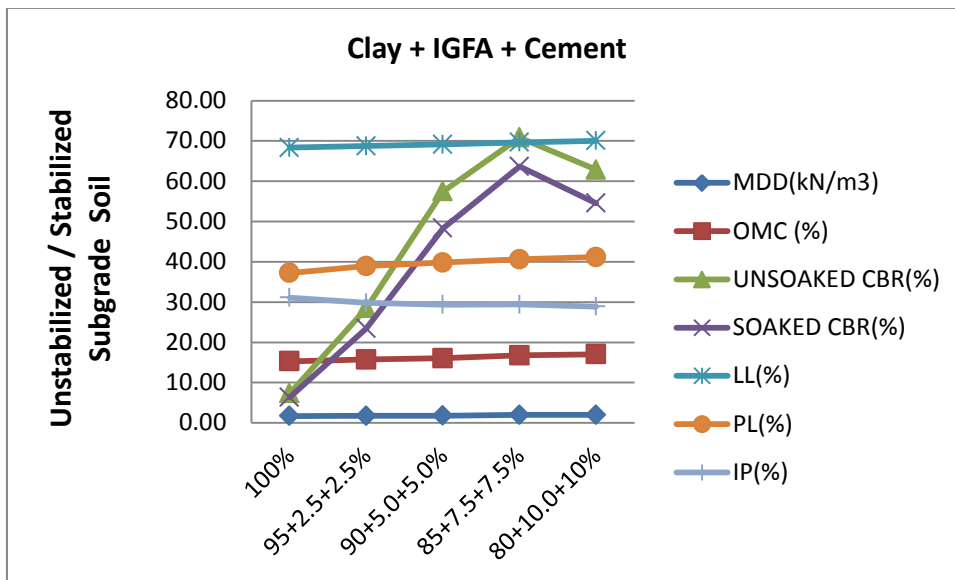


Figure 3.1: Subgrade Stabilization Test of Clay Soil from Iwofe, in Obio/Akpor L.G.A of Rivers State with IGFA + Cement at Different Percentages and Combination

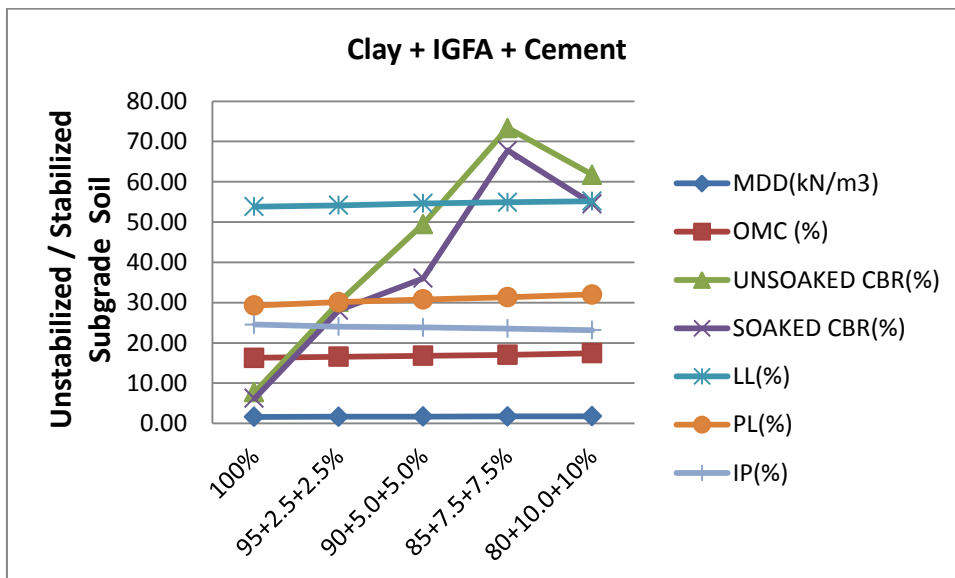


Figure 3.2: Subgrade Stabilization Test of Clay c Soil from Chokocho in Etche L.G.A of Rivers State with IGFA + Cement at Different Percentages and Combination

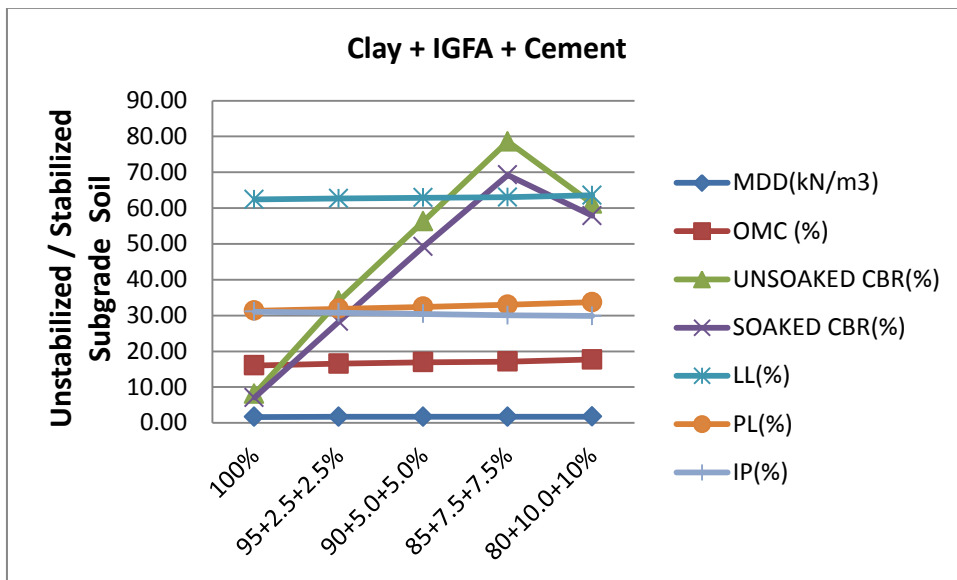


Figure 3.3: Subgrade Stabilization Test of Clay Soil from Ndoni in Onga/Egbema/Ndoni L.G.A of Rivers State with IGFA + Cement at Different Percentages and Combination

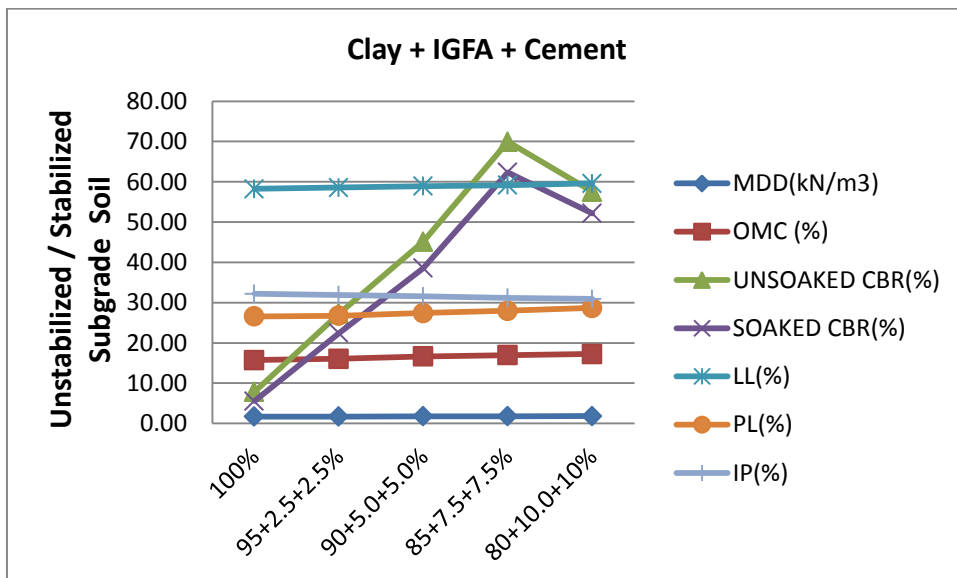


Figure 3.4: Subgrade Stabilization Test of Clay Soil from Ogbele in Ahoada-East L.G.A of Rivers State with IGFA + Cement at Different Percentages and Combination

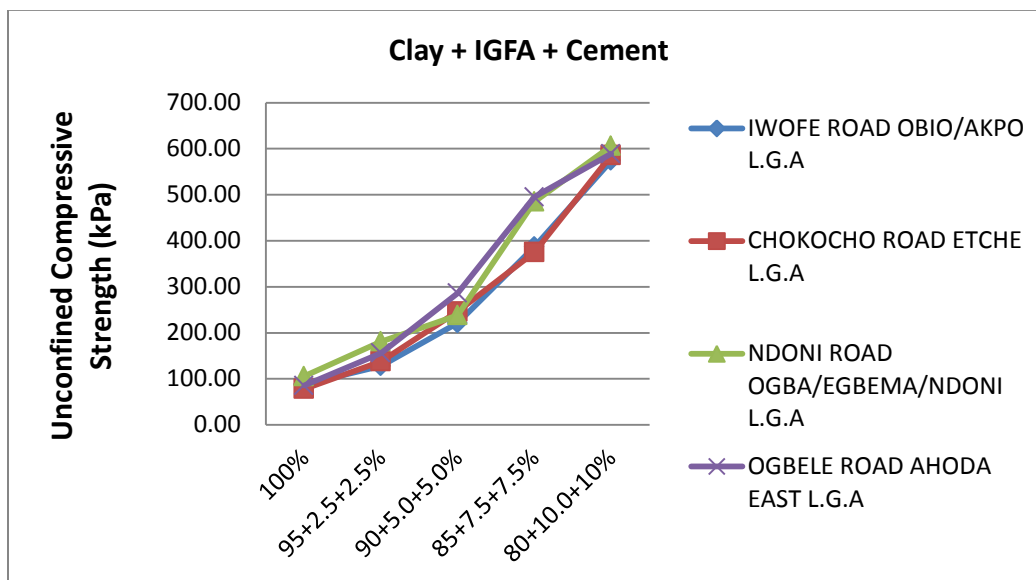


Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with IGFA + Cement of (Iwofe, Chokocho, Ndoni, and Ogebe Towns), Rivers State

4.0 CONCLUSIONS

The following conclusions were made from the experimental research results.

- i. The soils are classified as A – 7 – 6 /CH on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1
- ii. The soils are dark grey in colour (from wet to dry states) with plastic index of 31.10%, 24.55%, 31.05%, and 32.17% respectively for Iwofe, Chokocho, Ndoni, and Ogebe Town Roads.
- iii. Experimental results analyzed showed increased in compaction test parameters of MDD and OMC with increase in additives corresponding percentage ratio to clay soils.
- iv. Results from unstabilized and stabilized results showed increased values with respect to corresponding percentages with optimum inclusion of 7.5% + 7.5% to soils ratio.
- v. Comparative results showed decreased in plastic index parameters with additives inclusion to soils.
- vi. Comparative results showed increased in unconfined compressive strength of stabilized clay soils with respect to percentage increase.

REFERENCES

- [1] J. O. Arumala, and A E. Akpokodje, "Soil properties and Pavement Performance in the Niger Delta", *Quarterly Journal of Engineering Geology and Hydrogeology*, no. 20, pp. 287–296. 1987.
- [2] FMW (Federal Ministry of Works) *General Specifications (Roads and Bridges)*, Vol II, Federal Ministry of Works and Housing, Lagos, Nigeria, 1997.
- [3] A.N. Ramakrishna, and A.V. Pradeepkumar, "Stabilization of Black Cotton Soil using Rice Husk Ash and Cement, Proc. of National Conference", Civil Engineering Meeting the Challenges of Tomorrow, pp. 215-220, 2006.
- [4] K. Charles, T.T.W. Terence, S. K. Gbinu, "Effect of Composite Materials on Geotechnical Characteristics of Expansive Soil Stabilization Using Costus Afer and Lime", *Journal of Scientific and Engineering Research*, vol.5, no.5. pp. 603-613, 2018.
- [5] R.S. Sharma, B. R. Phanikumar, and B.V. Rao, "Engineering Behaviour of a Remolded Expansive Clay Blended with Lime, Calcium Chloride and Rice-Husk Ash", *Journal of Materials in Civil Engineering*, vol. 20, no. 8, pp. 509-515, 2008.

- [6] K. Charles, L. P. Letam, O. Kelechi, "Comparative on Strength Variance of Cement / Lime with Costus Afer Bagasse Fibre Ash Stabilized Lateritic Soil", *Global Scientific Journal*, vol.6, no.5, pp. 267-278, 2018.
- [7] S. F. Wahab, W. M. Nazmi and W. A. Rahman, " Stabilization Assessment of Kuantan Clay Using Lime, Portland Cement, Fly Ash, And Bottom Ash", National Conference on Road Engineering of Indonesian Road Development Association (IRDA), (Unpublished), 2011.
- [8] S. A. Ola, "Need for Sstimated Cement Requirements for Stabilizing Lateritic soils. *Journal of Transportation Engineering, ASCE*, vol. 100, no. 2, pp. 379–388,1974.
- [9] M. M. Allam, and A Sridharan, "Effect of Repeated Wetting and Drying on Shear strength", *Journal of Geotechnical Engineering, ASCE*, vol. 107, no, 4, pp. 421–438, 1981.
- [10] P .O. Omotosho, and J.O. Akinmusuru, "Behaviour of soils (lateritic) subjected to multi-cyclic compaction", *Engineering Geology*, no.32, pp. 53–58, 1992.
- [11] P. O. Omotosho, "Multi-Cyclic Influence on Standard Laboratory Compaction of Residual Soils", *Engineering Geology*, no .36, pp.109–115, 1993