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Stabilization of Deltaic Soft Clay Soils using Irvinga Gabonesis Fiber Ash as Stabilizer

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A*bstract:* **The study examined the functional use of fiber ash of irvinga gabonesis to improve the geotechnical characteristics of weak and unstable subgrade pavement of Iwofe, Chokocho, Ndoni, and Ogbele roads characterized with differential settlement, degradation and cracks that resulted from swelling and shrinkage due to seasonal variation of wet and dry. Preliminary investigation revealed the soils are dark grey in color (from wet to dry states), plasticity index of 31.10%, 24.55%, 31.05%, and 32.17%. The soils 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 and has classified the soils as poor and unfit for its applications for road constructional materials except modified. Results of stabilized state obtained signified decreased values of MDD and increased values of OMC, this implies the increased in fibre ash content decreases MDD and increases OMC compaction parameters of stabilized clay. Comparably, results indicated increased in CBR of altered soils with optimum mixed percentage ratios of 7.5% to soils. Results also indicated that at percentage ratio of 10% to soils and above, decreased in values were noticed as well as cracked presence. Comparative results of unconfined compressive strength showed increased values corresponding to percentage ratio of stabilizer inclusion. Results, when compared to unstabilized soils decreased in plastic index with fibre inclusion. Entire results showed potential use of fiber ash of irvinga gabones is as stabilizer.**

Keywords: **Clay soils, Irvinga Gabonesis Fibre, CBR, UCS, Consistency, Compaction.**

1. INTRODUCTION

The desired properties of improved soil are to increased strength, reduced compressibility, appropriate permeability to solve stability and settlement problems. Soft clay formations, especially those with high in situ water contents, are susceptible to large settlements and possess low shear strength unless they are naturally cemented. For soil to meet the desirable standard recommended by Federal Ministry of Works (FMW [1]) for subgrade pavement, stabilization is needed to improve the soil to minimum requirements for soils or soil-based materials usable in road pavement structures. Studies have shown the effect of reinforcement on swelling behavior of clays (Puppala and Musenda, [2]); reduction of soil swell potential with fibre reinforcement (Loher *et al*. [3], and effect of fibres on swelling characteristics of bentonite (Banu *et al.*, [4]).

Charles *et al*. [5] 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.

Sabat [6] 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 [7] 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*. [8] 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.

Agunwamba *et al* [9] 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.

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 Gabonesis Fibre

The Irvinga Gabonesis, 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.

2.2 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.

2.6 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 [10]; Allam and Sridharan [11]; Omotosho and Akinmusuru [12]; Omotosho [13]).

The soils are 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 Ogbele 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, 78.75 kPa, 105.75 kPa, and 85.35kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

Results of compaction determination from preliminary investigation conducted on 100% natural soils are maximum dry density (MDD) as) 1.685KN/m^3, 1.635KN/m^3, 1.657KN/m^3, 1.697KN/m^{3}and 2.105KN/m^3 at 100% soils and optimum moisture content (OMC), 15.28%, 16.28%, 16.05% and 15.73%. Results of irvinga gabonesis fibre ash (IGFA) stabilized clay soils at mix percentages of 2.5% , 5.0%, 7.5% and 10% to soils corresponding ratios maximum values are (MDD) 1.545KN/m^3, 1.518KN/m^3, 1.530KN/m^3, 1.553KN/m^3, and OMC 16.84%, 17.65%, 17.65%, 17.08%. Results obtained signified decreased values of MDD and increased values of OMC, this implies the increased in fibre ash content decreases MDD and increases OMC compaction parameters of stabilized clay soils

3.2 California Bearing Ratio (CBR) Test

Obtained CBR values results of clay soils at 100% natural state from sampled roads as shown in table 3.1 are unsoaked, 7.35%, 7.75%, 8.15%, 7.85% and soaked, 6.35%, 6.23%, 7.05% and 5.55%.

Fibre ash treated clay soils with fibre inclusion of 2.5%, 5.0%, 7.5% and 10% to soil percentages maximum values are unsoaked, 15.75%, 14.85%, 15.60%, 14.96% and soaked, 13.43%, 12.85%, 14.25%, 12.80%. Results obtained from table 3.2 and graphical illustrations of figures 3.1-3.4 showed increased CBR values of both unsoaked and soaked samples with optimum combined ratio of 0.75% to soils. Results also indicated that at percentage ratio of 10% to soils, decreased in values were noticed as well as cracked presence.

3.3 Unconfined Compressive Strength Test

Preliminary test on clay soils from sampled roads at 100% natural state of unconfined compressive strength are 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa. Fibre ash treated clay soils maximum values are 253kPa, 238kPa, 265kPa and 259kPa. Comparative results showed increased values corresponding to percentage ratio of stabilizer inclusion.

3.4 Consistency Limits Test

Obtained test of consistency limits (plastic index) at 100% clay soils are 31.10%, 24.55%, 31.05%, and 32.17%. Stabilized clay soils with fibre ash results are 29.25%, 23.43%, 28.86% and 30.90%. Results, when compared to unstabilized soils decreased in plastic index with fibre inclusion.

Table 3.1: Engineering Properties of Soil Samples

Location Description	Iwofe Road Obio/Akpor L.G.A	Chokocho Road Etche L.G.A	Ndoni Road Ogba/Egbema/ Ndoni L.G.A	Ogbele Road Ahoda East 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 Unified Soil Classification System	A-7-6 CH	A-7-6 CH	A-7-6 CH	A-7-6 CH
Optimum moisture content (%)	15.28	16.28	16.05	15.73
Maximum dry density (kN/m^{3})	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 BAGASSE ASH	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 (IGFA)											
IWOFE ROAD OBIA/AKPO L.G.A	100%	1.685	15.28	7.35	6.35	87.85	68.35	37.25	31.10	76.35	A – 7 – 6 /CH	POOR
	97.5+2.5%	1.658	15.65	10.05	7.98	115	68.18	38.26	29.92	76.35	A – 7 – 6 /CH	GOOD
	95+5.0%	1.614	15.95	12.65	10.85	150	67.69	37.95	29.74	76.35	A – 7 – 6 /CH	GOOD
	92.5+7.5%	1.597	16.28	15.75	13.43	196	67.93	38.30	29.63	76.35	A – 7 – 6 /CH	GOOD
	90+10 %	1.545	16.84	14.60	12.82	253	66.78	37.53	29.25	76.35	A – 7 – 6 /CH	GOOD
CHOKOCHO ROAD ETCHE L.G.A	100%	1.635	16.28	7.75	6.23	78.75	53.85	29.30	24.55	80.25	A – 7 – 6 /CH	POOR
	97.5+2.5%	1.615	16.75	11.28	8.25	87	53.68	29.48	24.20	80.25	A – 7 – 6 /CH	GOOD
	95+5.0%	1.586	16.91	13.30	11.08	148	53.94	29.91	24.03	80.25	A – 7 – 6 /CH	GOOD
	92.5+7.5%	1.553	17.28	14.85	12.85	189	52.55	28.69	23.86	80.25	A – 7 – 6 /CH	GOOD
	90+10 %	1.518	17.65	13.50	12.05	238	52.06	28.63	23.43	80.25	A – 7 – 6 /CH	GOOD
NDONI ROAD OGBA/EGBE MA/NDONI L.G.A	100%	1.657	16.05	18.15	7.05	105.75	62.40	31.35	31.05	83.65	A – 7 – 6 /CH	POOR
	97.5+2.5%	1.635	16.42	11.28	10.35	133	62.18	32.33	29.85	83.65	A – 7 – 6 /CH	GOOD
	95+5.0%	1.608	16.85	13.95	12.25	197	61.94	32.53	29.41	83.65	A – 7 – 6 /CH	GOOD
	92.5+7.5%	1.585	17.22	15.60	14.25	226	61.65	32.63	29.02	83.65	A – 7 – 6 /CH	GOOD
	90+10 %	1.530	17.65	14.08	13.65	265	61.28	32.42	28.86	83.65	A – 7 – 6 /CH	GOOD
OGBELE ROAD AHODA EAST L.G.A	100%	1.697	15.73	7.85	5.55	85.35	58.75	26.58	32.17	78.45	A – 7 – 6 /CH	POOR
	97.5+2.5%	1.665	16.08	10.08	8.10	118	57.85	26.00	31.85	78.45	A – 7 – 6 /CH	GOOD
	95+5.0%	1.625	16.38	12.45	10.55	157	57.58	26.05	31.53	78.45	A – 7 – 6 /CH	GOOD
	92.5+7.5%	1.586	16.85	14.96	12.80	205	57.15	26.00	31.15	78.45	A – 7 – 6 /CH	GOOD
	90+10 %	1.553	17.08	13.12	11.48	259	56.87	25.97	30.90	78.45	A – 7 – 6 /CH	GOOD

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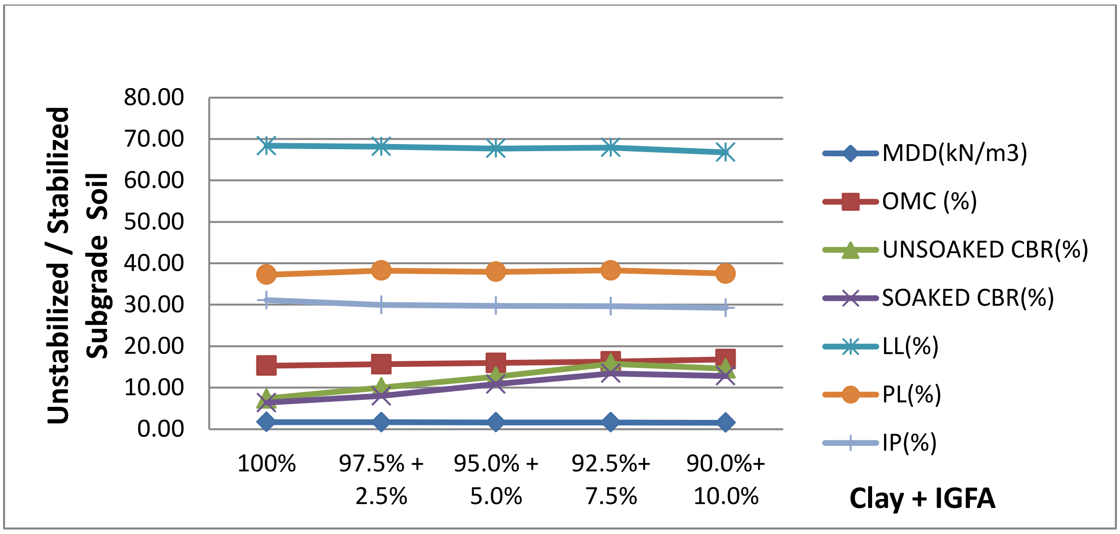

Figure 3.1:Subgrade Stabilization Test of Clay Soil from Iwofe, in Obio/Akpor L.G.A of Rivers State with IGFA at Different Percentages and Combination

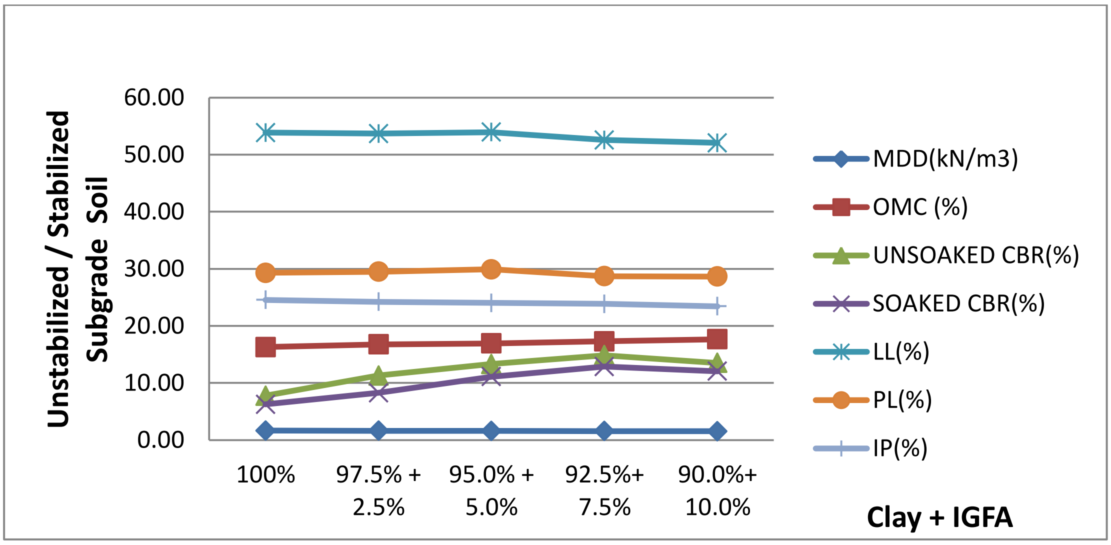

Figure 3.2:Subgrade Stabilization Test of Clay Soil from Chokocho in Etche L.G.A of Rivers State with IGFA at Different Percentages and Combination

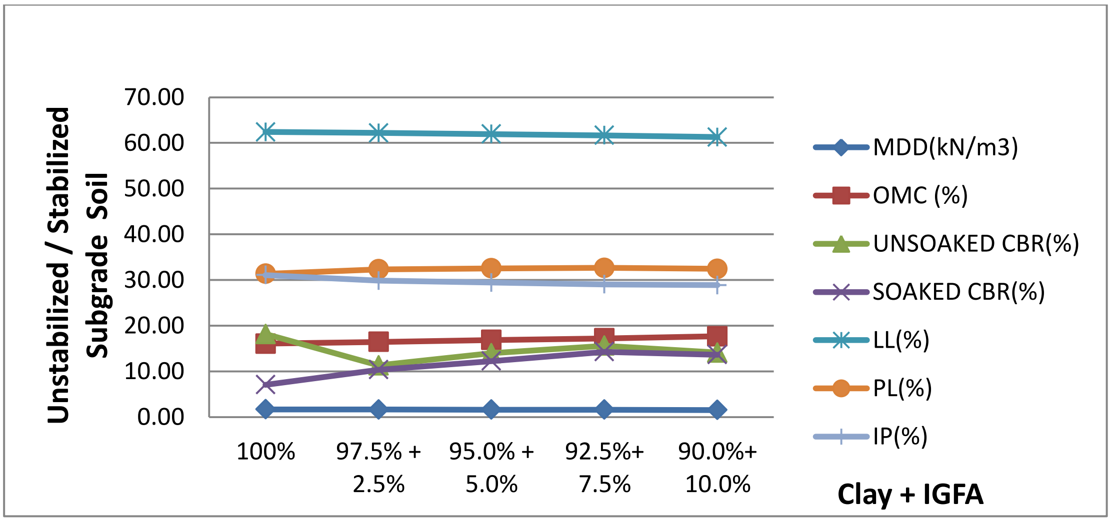

Figure 3.3:Subgrade Stabilization Test of Clay Soil from Ndoni in Ogna/Egbema/Ndoni L.G.A of Rivers State with IGFA at Different Percentages and Combination

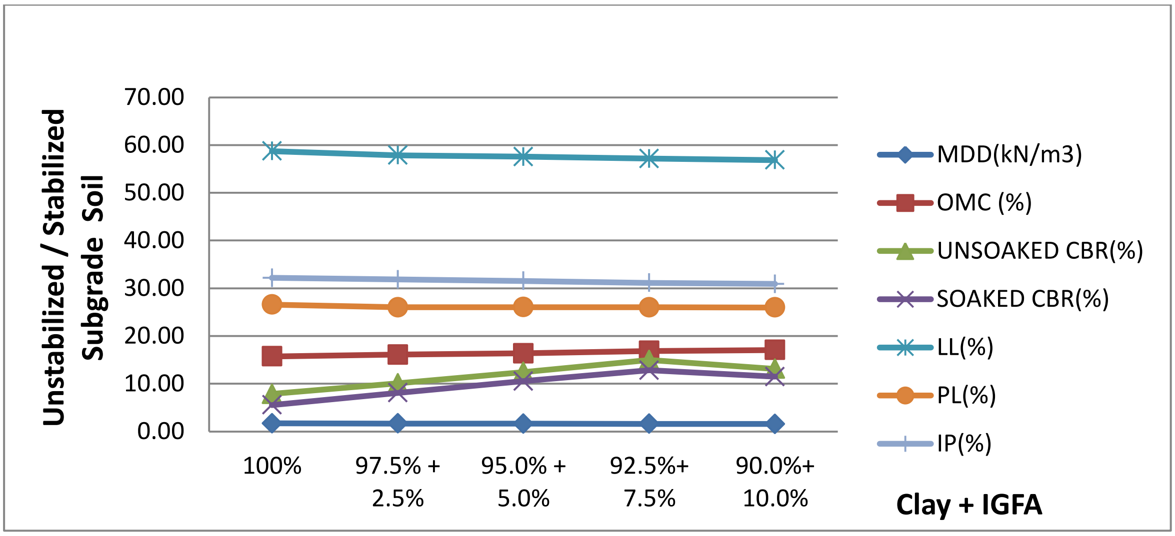

Figure 3.4:Subgrade Stabilization Test of Clay Soil from Ogbele in Ahoada-East L.G.A of Rivers State with IGFA at Different Percentages and Combination

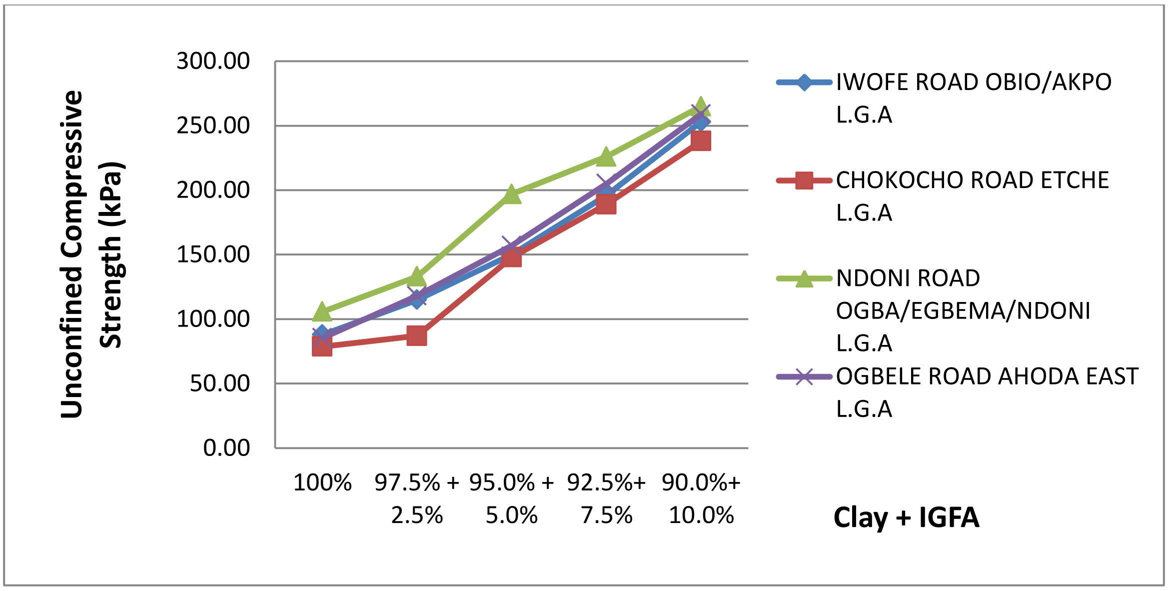

Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with IGFA of (Iwofe, Chokocho, Ndoni, and Ogbele Towns), Rivers State

4. 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 Ogbele Town Roads.

iii. Results obtained signified decreased values of MDD and increased values of OMC, this implies the increased in fibre ash content decreases MDD and increases OMC compaction parameters of stabilized clay soils

iv. Comparably, results indicated increased in CBR altered soils with optimum mixed percentage ratios of 7.5% to soils. Results also indicated that at percentage ratio of 10% to soils, decreased in values were noticed as well as cracked presence.

v. Results, when compared to unstabilized soils decreased in plastic index with fibre inclusion

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