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Research Article

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Hybridized Composite Materials Effect on Stabilization of Soft Clay Soils in Niger Delta

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Abstract The research work evaluated the improvement of soft clay soils within Iwofe, Chokocho, Ndoni, and Ogbele roads in the Niger Delta of Nigeria with hybridized composite materials of irvinga gabonesis fibre + lime with 0.25% + 2.5%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% combined ratio to soils. Preliminary test classified the soils as A – 7 – 6 / CH on the AASHTO classification schemes / Unified Soil Classification System. The soils are dark grey in color (from wet to dry states) with plastic index of 31.10%, 24.55%, 31.05%, and 32.17% and California bearing ratio unsoaked values of 7.35%, 7.75%, 8.15%, and 7.85% and soaked 6.35%, 6.23%, 7.05%, 5.55%. They are less matured and sensitive to all forms of manipulation and do not conform to the standard materials usable in road pavement structures as indicated by the FMW Specifications (1997). Stabilized soils result of compaction test confirmed increased values in both maximum dry density and optimum moisture content with inclusion percentages ratio increase. Unconfined compressive strength test results showed increased values with additives percentages ratio increase. Consistency final results illustrated decreased values of plastic index with increase in percentage ratio additives. California bearing ratio results illustrated increased values with ratio variation as shown in figures with optimum ratio inclusion of 0.75% + 7.5% to soils. Entire results showed the potential of using irvinga gabonesis fibre + lime as stabilizers.

Keywords Clay soils, Irvinga Gabonesis Fibre, Lime, CBR, UCS, Consistency, Compaction

1. Introduction

The principle mechanism of ground improvement is done by forming chemical bonds between the soil particles. When the soil particles are bonded, it will be strengthened and become more stable physically and mechanically. Soft clay, when mixed with cement, will be stabilized because cement and water react to form cementitious calcium silicate and aluminate hydrates, which bind the soil particles together.

Charles *et al.* [1] 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.

Sabat [2] 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 [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] 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.

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.

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.

2.1.3 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 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. 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 [7]; Allam and Sridharan [8]; Omotosho and Akinmusuru [9]; Omotosho [10]). 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 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 , 78.75kPa, 105.75kPa , and 85.35kPa when compacted with British Standard light (BSL), respectively

3.1 Compaction Test Results

Results obtained from table 3.1 compaction test of clay soils at 100% preliminary test are maximum dry density (MDD) 1.685KN/m^3, 1.635KN/m^3, 1.657KN/m^3, 1.697KN/m^3 and optimum moisture content (OMC) are 15.28%, 16.28%, 16.05% and 15.73%. Irvinga gabonesis fibre + lime stabilized clay soils at 0.25% + 2.5%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% combined ratio to soils maximum value results are MDD 1.923KN/m^3, 1.787KN/m^3, 1.773KN/m^3, 1.814KN/m^3 and OMC 16.57%, 17.09%, 17.15%, 16.73%. Results proved increased values in both MDD and OMC with inclusion percentages ratio ascend.

3.2 California Bearing Ratio (CBR) Test

Results of California bearing ratio of sampled roads at preliminary test of 100% clay soils are unsoaked 7.35%, 7.75%, 8.15%, 7.85% and soaked 6.35%, 6.23%, 7.05% and 5.55%. For Irvinga gabonesis fibre + lime stabilized clay soils, maximum obtained values for Unsoaked and soaked are 69.78%, 71.35%, 78.30%, 68.80% and 63.45%, 64.85%, 73.55%, 59.85%. Results illustrated, increased with ratio variation as shown in table 3.2 with optimum ratio inclusion of 0.75% + 7.5%.

3.3 Unconfined Compressive Strength Test

Results obtained from unconfined compressive strength results at 100% clay soils are 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa. Stabilized soils maximum values are 550kPa, 578kPa, 638kPa and 565kPa. Results showed increased values with additives percentages ratio increase.

3.4 Consistency Limits Test

Obtained results of plastic index at 100% clay soils are 31.10%, 24.55%, 31.05%, and 32.17%. Soil stabilized results with irvinga gabonesis fibre + lime are 28.90%, 23.57%, 28.85% and 30.93%. Final results illustrated decreased values of plastic index with increase in percentage ratio additives.

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	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/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 + LIME**	**MDD (KN/m^3)**	**OMC (%)**	**UNSOAKED CBR (%)**	**SOAKED CBR (%)**	**UCS(KPa)**	**LL(%)**	**PL(%)**	**PI(%)**	**SIEVE #200**	**AASHTO / USCS (Classification)**	**NOTES**
CLAY SOIL + IRVINGA GABONESIS FIBRE + LIME												
IWOFE ROAD. OBIO/AKPOR 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+0.25+2.5%	1.695	15.43	28.32	23.45	138	68.45	38.55	29.90	76.35	A-7-6/CH	GOOD
	94.5+0.5+5.0%	1.735	15.82	43.45	38.33	267	68.65	39.00	29.65	76.35	A-7-6/CH	GOOD
	91.25+0.75+7.5%	1.845	16.05	69.78	63.45	325	68.95	39.80	29.15	76.35	A-7-6/CH	GOOD
	89+1.0+10%	1.923	16.57	58.75	53.45	550	69.12	40.22	28.90	76.35	A-7-6/CH	GOOD
CHOKOCHO	100%	1.635	16.28	7.75	6.23	78.75	53.85	29.30	24.55	80.25	A-7-6/CH	POOR

ROAD. ETCHE L.G.A	97.5+0.25+2.5%	1.657	16.33	31.45	26.45	131	53.90	29.55	24.35	80.25	A-7-6/CH	GOOD
	94.5+0.5+5.0%	1.696	16.86	50.85	48.25	265	54.25	30.19	24.06	80.25	A-7-6/CH	GOOD
	91.25+0.75+7.5%	1.735	16.95	71.35	64.85	397	54.75	30.89	23.86	80.25	A-7-6/CH	GOOD
	89+1.0+10%	1.787	17.09	64.32	55.60	578	54.85	31.28	23.57	80.25	A-7-6/CH	GOOD
NDONI ROAD. OGBA/EGBE MA/NDONI	100%	1.657	16.05	8.15	7.05	105.78	62.40	31.35	31.05	83.65	A-7-6/CH	POOR
	97.5+0.25+2.5%	1.675	16.25	36.65	30.85	183	62.65	32.80	29.85	83.65	A-7-6/CH	GOOD
	94.5+0.5+5.0%	1.692	16.63	52.75	48.75	297	62.85	33.24	29.61	83.65	A-7-6/CH	GOOD
	91.25+0.75+7.5%	1.725	16.94	78.30	73.55	495	63.08	33.87	29.21	83.65	A-7-6/CH	GOOD
	89+1.0+10%	1.773	17.15	63.65	57.30	638	63.38	34.53	28.85	83.65	A-7-6/CH	GOOD
OGBELE ROAD. AHOADA-EAST L.G.A	100%	1.697	15.73	7.85	5.55	83.35	58.25	26.58	32.17	78.45	A-7-6/CH	POOR
	97.5+0.25+2.5%	1.708	15.93	28.60	23.35	180	58.48	26.63	31.85	78.45	A-7-6/CH	GOOD
	94.5+0.5+5.0%	1.724	16.15	43.83	37.32	295	58.81	27.31	31.51	78.45	A-7-6/CH	GOOD
	91.25+0.75+7.5%	1.783	16.38	68.80	59.85	426	59.05	27.82	31.23	78.45	A-7-6/CH	GOOD
	89+1.0+10%	1.814	16.73	58.95	53.40	565	59.14	28.21	30.93	78.45	A-7-6/CH	GOOD

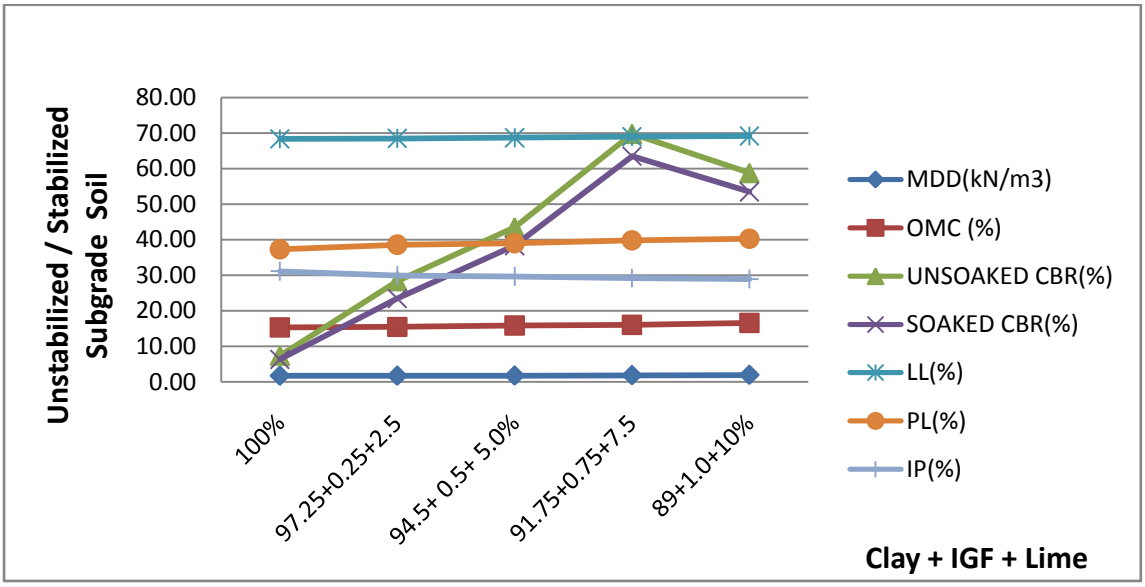

Figure 3.1: Subgrade Stabilization Test of Clay Soil from Iwofe,in Obio/Akpor L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

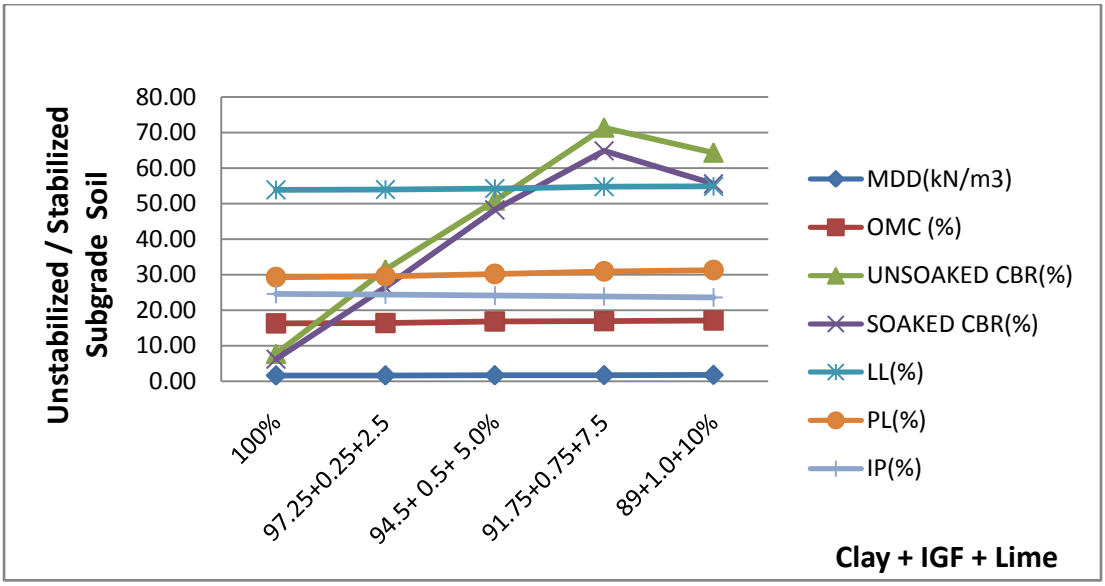

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Chokocho in Etche L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

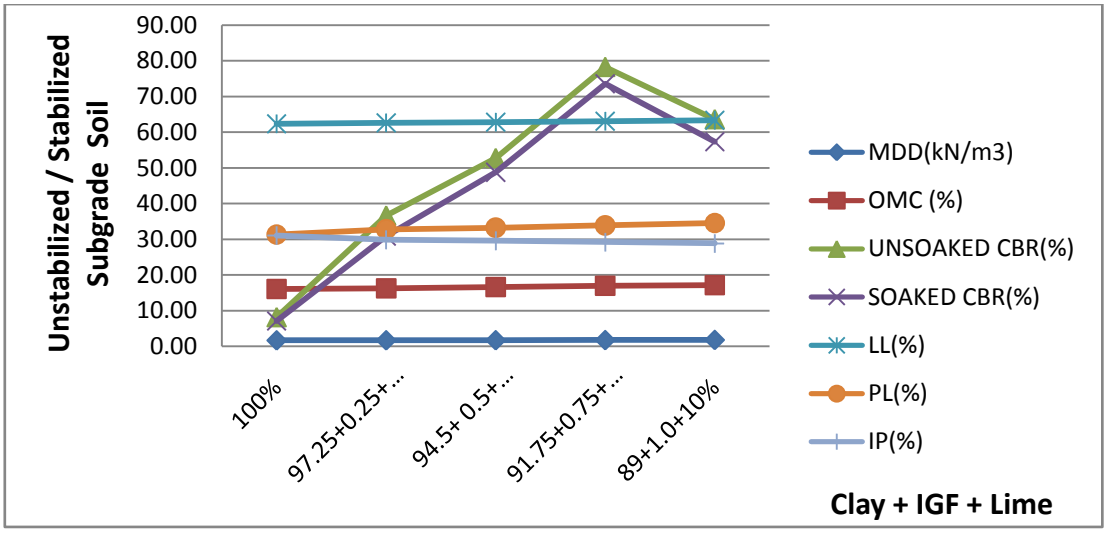

Figure 3.3: Subgrade Stabilization Test of Clay Soil from Ndoni in Ogna/Egbema/Ndoni L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

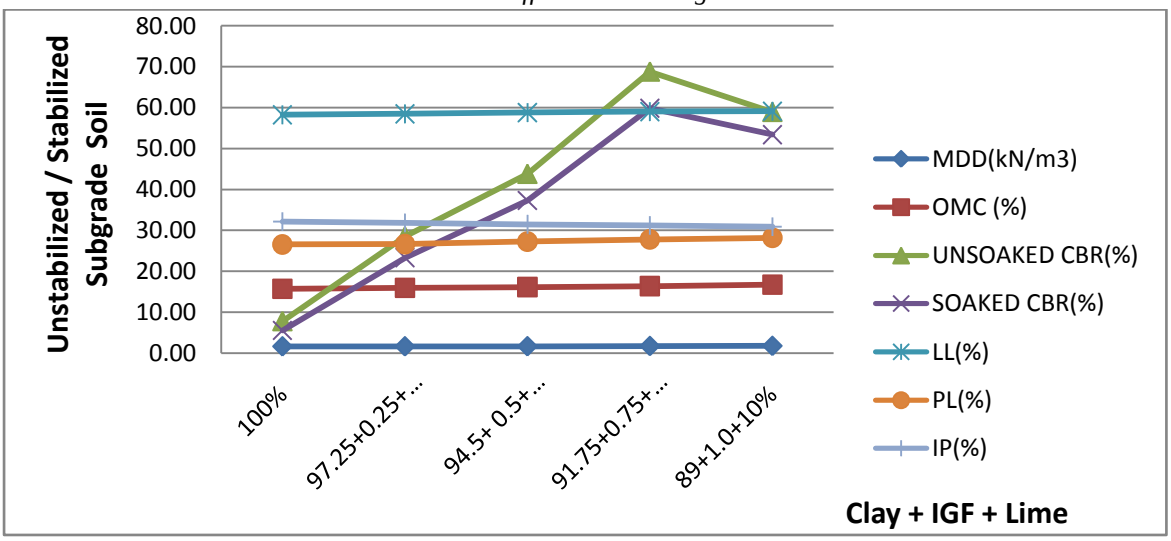

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Ogbele in Ahoada-East L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

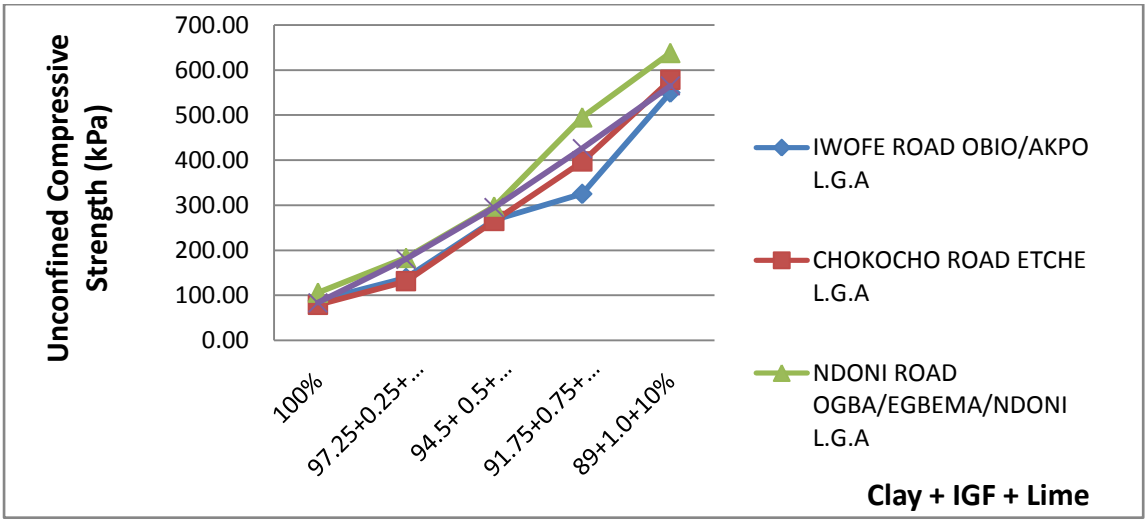

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with IGF + Lime of (Iwofe, Chokocho, Ndoni, and Ogbele Towns), Rivers State

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. Compaction test results proved increased values in both MDD and OMC with inclusion percentages ratio ascend.

iv. Unconfined compressive strength test results showed increased values with additives percentages ratio increase.

v. Consistency final results illustrated decreased values of plastic index with increase in percentage ratio additives.

vi. California bearing ratio results illustrated, increased with ratio variation as shown in table 3.2 with optimum ratio inclusion of 0.75% + 7.5%.

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