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Characterization Performance of Composite Stabilizer Materials on Soft Clay Soils Modification for Highway Pavement

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ABSTRACT: *The study examined the expansive clay soils of Niger Delta with deceptive characteristics in physical appearance, swelling and shrinkage apparent and their improvement / modifications with composite materials of irvinga gabonesis ash and lime in blended condition. Basis tests classified the soils as A–7–6/CH on the AASHTO Classification Schemes/Unified Soil Classification System and other parameters as shown in table 3.1. Preliminary test results revealed the soils are unstable for road constructional purposes except modified. Final modified soil test results obtained showed the inclusion of additives increased the maximum dry density and optimum moisture content compaction parameters of expansive clay soils with increase in values to corresponding percentages ratio. Comparative results showed increased values in stabilized soils to un-stabilized. Optimum inclusion values were gotten at 7.5% + 7.5% percentage ratio, beyond this ratio, reduction in values were noticed with visual cracks. This point signified failure potential. Unconfined compressive strength results showed increased values with percentage inclusion ratio. Comparatively from both results, modified clay soils plastic index properties decreased with additive percentages inclusion ratio against un-stabilized. Entire performed test results showed the potential of used of irvinga gabonesis ash and lime as expansive stabilizers.*

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

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I. INTRODUCTION

The physical and engineering properties of soil lime and other additives in combined state depend on the nature of soil treated, the type and amount of additives utilized, the placement and cure conditions adopted. Soil-lime content varying from 5% to 20 % for satisfactory stabilization. For clays, lime content may range from 3 % to 16 % by dry weight of soil, depending on the type of soil and properties required. Generally as the clay content of soil increases, so does the quantity of cement and other additives required [1].

[2]Wahab et al. (2011), 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.

[3]Ramakrishna and Pradeep (2006) 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.

[4]Charles et al. (2018) investigated the problematic engineering properties of soils with high plasticity levels, high swelling and shrinkage potentials used in pavement design in the Nigerian, Niger Delta region. The application of stabilizing agents of cement and costus afe bagasse fiber (bush sugarcane bagasse fiber) was mixed into a single and combines functions to improve their unique properties. The results showed that the material stabilizing the inclusions had improved soil strength. The results of the tests conducted showed that the optimum moisture content increased with increasing cement ratio in both soil (clay) and (laterite). The soil treated with cement decreased in the liquid limit and the plastic limit increased. Soil with cement and fiber products in combination increased CBR values and appreciated both in hanging condition. At 8% lime, the CBR

value reached the optimum, beyond this limit; cracks are present and 7.5% cement + 0. 75% BSBF, the optimum value reached

[5]Sharma et al. (2008) investigated stable soil behavior with lime, calcium chloride, and RHA. The optimal percentage of lime and calcium chloride addition to RHA was found to be 4% and 1%, respectively, in stabilization of the soil without expansion. From the viewpoint of UCS and CBR, when the soil was mixed with lime or calcium chloride, an RHA content of 12% was found to be optimal. In expanded soils - RHA mix, 4% lime and 1% calcium chloride were also found to be optimal.

[6]Charles et al. (2018) Cement / Lime and costus afer bagasse fibre ash (locally known as Bush Sugarcane Fiber Ash (BSBFA)) of engineering properties of expansive lateritic clay with a ratio of cement, lime and BSBFA of 2.5 Investigated and evaluated. % 2.5%, 5.0% 5.0%, 7.5% 7.5% and 10% 10% to improve CBR values below 10%. At 8% of both cement and lime, the CBR value reached the 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, have reached the optimum value. The entire results have demonstrated the ability of bagasse, BSBFA to be used as cement in cement, and letter in soil-treated soil.

[7]Sabat (2012) studied the effects of polypropylene fibers on the engineering properties of RHA-Lime. Polypropylene fibers were added 0.5% to 2% at a 0.5% increase. The determined properties were condensation, the effect of UCS, soaked CBR, hydraulic conductivity and P soaking of 0-day, 7-day and 28-day curing vessels were also studied by UCS. CBR, hydraulic conductivity and swelling pressure. The optimum soil ratio: RHA: lime: fiber was found to be 84.5: 10: 4: 1.5.

[8]Charles et al. (2018) evaluated the geotechnical properties of a massive soil found along the Odioku - Odiereke road in the Niger State of Ahoada-West, Rivers State. Application of two cement agents of hybridized cement and lime with costus af bagas fiber to strengthen the failing section of the road. Preliminary investigation values indicate that the soil is highly plastic. The results showed the ability to use bagasse, BSBF as lime in cement and used lime clay soil and laterite with optimum values of 8% cement and lime and 7.5% + 7.5% cement / lime + BSBF.

[9]Barisua et al. (2018) evaluated the strength gained distinction of expansive clay soils with swelling – shrinkage attributes on the application of two cementitious stabilizing agents of cement and lime in combination with bagasse fibre ash of pozzolanic characteristics from waste agricultural products of costaceae lacerus. Results demonstrated an incremental percentile CBR values for both unsoaked and soaked with optimum composite combined mix ratio of 0.75% + 7.5% to soil corresponding clay soil. Unconfined compressive strength test results obtained showed incremental percentile values with composite ratio increase for cement / lime + CLBFA combination with cement in higher values to lime composition respectively of sampled roads of Ogoda, Bodo, Ogbogu, Ula-Ikata and Kaani, all in Rivers state, Nigeria. Comparative results showed cement and lime + CLBFA good strength increased to optimum with dominance in cement to lime.

[10]Terence et al. (2018) investigated and evaluated the application of Costaceae lacrus bagasse fiber ash in combination with cement and lime. The results show the potential use of additives as soil stabilizers with cement in key strength values of lime. California bearing ratios of unsoaked and soaked stable soils with a mixed content of cement, lime and CLBFA produced relatively incremental percentage values to include a percentage ratio with an optimal mixing ratio of 85 + 7.5 + 7.5%. Incremental percentage values appeared as a proportion of the increase in soil with an increase in the results of unconfined compressive strength test from unsoaked and soakedsoils with cement / lime + CLBFA.

[11]Charles et al. (2018) evaluated the application of cement / lime and plantain rachis fiber ashes in the combined evaluation of cementitious stabilizing agents and compared their strength variance to clay soil modification in comparison. Consistency limit test results reflect a percentage in soil incorporating relatively stability with a percentage reduction in plastic index properties. Stabilized soils have increased the results of soil unconfined compressive strength tests, which combine relatively incremental values in percentage of the average material, including the composite material in soils with cement composition at high levels of lime. The result thus obtained, the incorporation of composite materials for clay soils increases the compaction properties of clay soils. The California bearing ratio (CBR) showed incremental percentile values for the corresponding cementation agents with PRFA inclusions, with an optimum mixing ratio of 85 + 7.5 + 7.5% for cement, soaked in mixed and mixed stabilized soils.

[12]Charles et al. (2018) investigated the hybridization effect of irvinga gabonesis fiber ash and cement in weak expansive clay soil modification found on the roads of Iwofe, Chokocho, Ndoni, and Ogbele Town roads in the Niger Delta region of the south-south part of Nigeria. Increased experimental results were analyzed in the compaction test parameters of MDD and OMC with an increase in additives to clay to clay percent percentage ratio. The results of un-soaked and soaked CBR results showed increased values with the corresponding percentages, with an optimum inclusion of soil ratio from 7.5 percent + 7.5%. The relative result is an increase in the undefined compressive strength of the stabilized soil with respect to the percentage. The overall results led to the use of irvinga gabonesis fiber (bush mango) ash and cement as soil stabilizer products.

[13]Letam et al. (2018) evaluated the failures associated with the sample roads of Ebiriba, Ochigba, Eneka and Isiokpo in the Niger Delta, Nigeria. To strengthen the poor condition and sections with soil stabilizer with application of mixed material of plantain rachis fiber ash + lime. Comparative results on compaction test parameters indicate an increase in the values of maximum dry density and optimum moisture content relative to the percentage inclusion increase. In contrast to the results, soils with stabilizer increased with respect to the mixed content of the Plantain Rachis Fiber + Lime percentage ratio with an optimum percentage of 0.75% + 7.5% in California bearing ratios of soaked values. Cracks outside the optimal percentage decreased in values were confirmed. Unconfined compressive strength tests increase the percentage increase involved. Comparative results with respect to relative percentages indicate decreased values of the plastic index. The whole results showed good ability of the plant to use Rachis fiber ash + lime as the soil is stable

II. MATERIALS AND METHODS

Materials

Soil

Studied soils are gotten from road failed sections 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.

Irvinga Gabonesis Fibre

The Irvinga Gabonesis, are collected from Olokuma village, in Ubie Clan, Ahoada-West, Rivers State, Nigeria.

Lime

The lime used for the study was purchased in the open market at Mile 3 market road, Port Harcourt

Method

2.2.1 Sampling Locality

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.

Test Conducted

Test conducted includes (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;

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.

Grain Size Analysis (Sieve Analysis)

This test is done to determine the percentage of different grain sizes.

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.

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.

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

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.

III. 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 [14](Ola 1974; [15], [16]Allam and Sridharan 1981;[17] Omotosho and Akinmusuru 1992; Omotosho 1993).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, 105.75 kPa , and 85.35kPa when compacted with British Standard light (BSL), respectively.

Compaction Test Results

Investigated compaction test results from sampled roads of Iwofe, Chokocho, Ndoni, and Ogbele at 100% controlled clay soils 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%. Modified clay soils with Irvinga gabonesis fibre ash + lime of 2.5% + 2.5%, 5.5% +5.5%, 7.5 + 7.5% and 10% + 10% to clay soils maximum MDD values are 1.824 KN/m^3, 1.745 KN/m^3, 1.753 KN/m^3, 1.925 KN/m^3 and OMC 16.65%, 17.38%, 17.29%, 17.09%. comparably, conducted tests of un-stabilized and peak rise stabilized soils are MDD percentile values 99.53%, 99.57%, 99.52%, 99.65% and 108.25%, 106.73%, 105.79%, 113.44%. OMC values are 98.39%, 98.97%, 98.47%, 98.01% and 108.97%, 106.76%, 107.73%, 108.65%. Results obtained showed the inclusion of additives increased the MDD and OMC compaction parameters of expansive clay soils with increase in values to corresponding percentages ratio.

3.2 California Bearing Ratio (CBR) Test

Investigated preliminary test at 100% clay soils CBR values soils are unsoaked 7.35%, 7.75%, 8.15%, and 7.85% and soaked 6.35%, 6.23%, 7.05% and 5.55%. Modified clay soils are unsoaked 63.89%, 68.30%, 78.30%, 68.80% and soaked are 57.38%, 59.75%, 68.45%, and 59.78%. Comparably, percentile values of un-stabilized and stabilized soil peaked values of unsoaked are 28.43%, 27.34%, 22.24%, 27.45% and 766.67%, 700.65%, 780.98%, 750.96%. For soaked soils percentile values are 29.22%, 27.73%, 22.88%, 19.27% and 841.73%, 760.51%, 812.77%, 881.98%. Comparative results showed increased values in stabilized soils to un-stabilized. Optimum inclusion values were gotten at 7.5% + 7.5% percentage ratio, beyond this ratio, reduction in values were noticed with visual cracks. This point signified failure potential.

3.3 Unconfined Compressive Strength Test

Preliminary investigation test results at 100% clay soils of sampled roads values recorded were 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa respectively as indicated in table 3.1. Fibre ash + lime stabilized clay soils yielded maximum of 465kPa, 515kPa, 623kPa and 525kPa with corresponding percentages ratio. The percentile computed results are56.31%, 55.07%, 51.35%, 42.53% at 100% soil and a peak percentile rise of 670.46%, 765.71%, 609.76%, and 737.85%. Entire unconfined compressive results showed increased values with percentage inclusion ratio.

3.4 Consistency Limits Test

Preliminary test rests of plastic index of 100% clay soils are 31.10%, 24.55%, 31.05%, and 32.17% with indicative percentile values of104.08%, 100.57%, 103.67%, 100.69%. Modified clay soils with composite additive values are 28.85%, 23.84%., 29.01 and 31.66% with percentile peak values of 94.37%, 97.11%, 94.43%, 97.39%.Comparatively from both results, modified clay soils decreased with additive percentages inclusion ratio against un-stabilized.

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: Results of Subgrade Soil (Clay) Test Stabilization with Binding Cementitiou Products at Different percentages and Combination

SAMPLE LOCATION	SOIL + FIBRE ASH + LIME	MDD (KN/m^3)	OMC (%)	CBR UNSOAKED (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
CLAY SOIL + IRVINGA GABONESIS FIBRE ASH + LIME												
IWOFE ROAD.	100%	1.685	15.28	7.35	6.35	87.85	68.35	37.25	31.10	76.35	A-7-6/CH	POOR
OBIO/AKPOR L.G.A	95+2.5+2.5%	1.693	15.53	25.85	21.73	120	68.57	38.69	29.88	76.35	A-7-6/CH	GOOD
	90+5.0+5.0%	1.715	15.95	45.30	40.53	234	68.90	39.25	29.65	76.35	A-7-6/CH	GOOD
	85+7.5+7.5%	1.765	16.15	63.89	57.38	309	69.23	39.88	29.35	76.35	A-7-6/CH	GOOD
	80+10+10%	1.824	16.65	56.35	53.45	465	69.46	40.61	28.85	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
	95+2.5+2.5%	1.642	16.45	28.35	22.47	129	54.12	29.71	24.41	80.25	A-7-6/CH	GOOD
	90+5.0+5.0%	1.682	16.93	43.86	38.57	257	54.58	30.53	24.05	80.25	A-7-6/CH	GOOD
	85+7.5+7.5%	1.705	17.22	68.30	59.75	385	54.89	31.05	23.84	80.25	A-7-6/CH	GOOD
	80+10+10%	1.745	17.38	54.30	47.38	515	55.41	31.79	23.62	80.25	A-7-6/CH	GOOD
NDONI ROAD. OGBA/EGBEMA/NDONI	100%	1.657	16.05	8.15	7.05	105.7	62.40	31.35	31.05	83.65	A-7-6/CH	POOR
	95+2.5+2.5%	1.665	16.30	36.65	30.81	158	62.58	32.63	29.95	83.65	A-7-6/CH	GOOD
	90+5.0+5.0%	1.693	16.73	52.75	50.15	267	62.94	33.21	29.73	83.65	A-7-6/CH	GOOD
	85+7.5+7.5%	1.715	16.08	78.30	68.45	490	63.21	33.89	29.32	83.65	A-7-6/CH	GOOD
	80+10+10%	1.753	17.29	63.65	57.30	623	63.48	34.47	29.01	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
	95+2.5+2.5%	1.703	16.05	28.60	28.80	173	58.65	26.70	31.95	78.45	A-7-6/CH	GOOD
	90+5.0+5.0%	1.718	16.35	43.83	39.67	265	58.93	27.28	31.65	78.45	A-7-6/CH	GOOD
	85+7.5+7.5%	1.763	16.86	68.80	59.78	393	59.18	27.53	31.33	78.45	A-7-6/CH	GOOD
	80+10+10%	1.925	17.09	58.95	48.95	525	59.37	27.71	31.66	78.45	A-7-6/CH	GOOD

Table 3.3: Percentile Combination of Clay Soil + Irvinga Gabonesis Fibre Ash + Lime

RATIO %	100%	97.25 +0.25+2.5	94.5+ 0.5+ 5.0	91.75+ 0.75 +7.5	89+1.0 +10
MAXIMUM DRY DENSITY (MDD(kN/m3)					
IWOFE ROAD OBIO/AKPO L.G.A , MDD(kN/m3)	1.69	1.69	1.72	1.77	1.82
CHOKOCHO ROAD ETCHE L.G.A , MDD(kN/m3)	1.64	1.64	1.68	1.71	1.75
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , MDD(kN/m3)	1.66	1.67	1.69	1.72	1.75
OGBELE ROAD AHODA EAST L.G.A , MDD(kN/m3)	1.70	1.70	1.72	1.76	1.93
OPTIMUM MOISTURE CONTENT (%)					
IWOFE ROAD OBIO/AKPO L.G.A, OMC (%)	15.28	15.53	15.95	16.15	16.65
CHOKOCHO ROAD ETCHE L.G.A , OMC (%)	16.28	16.45	16.93	17.22	17.38
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , OMC (%)	16.05	16.30	16.73	16.88	17.29
OGBELE ROAD AHODA EAST L.G.A, OMC (%)	15.73	16.05	16.35	16.86	17.09
CONSISTENCY LIMITS (%)					

IWOFE ROAD OBIO/AKPO L.G.A, LL(%)	68.35	68.57	68.90	69.23	69.46
IWOFE ROAD OBIO/AKPO L.G.A, PL(%)	37.25	38.69	39.25	39.88	40.61
IWOFE ROAD OBIO/AKPO L.G.A, IP(%)	31.10	29.88	29.65	29.35	28.85
CHOKOCHO ROAD ETCHE L.G.A , LL(%)	53.85	54.12	54.58	54.89	55.41
CHOKOCHO ROAD ETCHE L.G.A , PL(%)	29.30	29.71	30.53	31.05	31.79
CHOKOCHO ROAD ETCHE L.G.A , IP(%)	24.55	24.41	24.05	23.84	23.62
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , LL(%)	62.40	62.58	62.94	63.21	63.48
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , PL(%)	31.35	32.63	33.21	33.89	34.47
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , IP(%)	31.05	29.95	29.73	29.32	29.01
OGBELE ROAD AHODA EAST L.G.A, LL(%)	58.25	58.65	58.93	59.18	59.37
OGBELE ROAD AHODA EAST L.G.A, PL(%)	26.58	26.70	27.28	27.53	27.71
OGBELE ROAD AHODA EAST L.G.A, IP(%)	32.17	31.95	31.65	31.33	31.66
CALIFORNIA BEARING RATIO (%)					
IWOFE ROAD OBIO/AKPO L.G.A, UNSOAKED CBR(%)	7.35	25.85	45.30	63.89	56.35
IWOFE ROAD OBIO/AKPO L.G.A, SOAKED CBR(%)	6.35	21.73	40.53	57.38	53.45
CHOKOCHO ROAD ETCHE L.G.A , UNSOAKED CBR(%)	7.75	28.35	43.86	68.30	54.30
CHOKOCHO ROAD ETCHE L.G.A , SOAKED CBR(%)	6.23	22.47	38.57	59.75	47.38
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , UNSOAKED CBR(%)	8.15	36.65	52.75	78.30	63.65
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , SOAKED CBR(%)	7.05	30.81	50.15	68.45	57.30
OGBELE ROAD AHODA EAST L.G.A, UNSOAKED CBR(%)	7.85	28.60	43.83	68.80	58.95
OGBELE ROAD AHODA EAST L.G.A, SOAKED CBR(%)	5.55	28.80	39.67	59.78	48.95
UNCONFINED COMPRESSIVE STRENGTH (KPa)					
IWOFE ROAD OBIO/AKPO L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	87.85	156.00	287.00	338.00	589.00
CHOKOCHO ROAD ETCHE L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	78.75	143.00	304.00	438.00	603.00
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	105.78	206.00	315.00	465.00	645.00
OGBELE ROAD AHODA EAST L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	83.35	196.00	289.00	466.00	615.00

Table 3.4: Percentile Decrease / Increase of Clay Soil + Irvinga Gabonesis Fibre Ash + Lime

RATIO %	100%	97.25+ 0.25+2.5	94.5+ 0.5+ 5.0	91.75+0.75 +7.5	89+1.0 +10
MAXIMUM DRY DENSITY (MDD(kN/m3)					
IWOFE ROAD OBIO/AKPO L.G.A , MDD(kN/m3)	99.527	100.475	101.780	104.748	108.249
CHOKOCHO ROAD ETCHE L.G.A , MDD(kN/m3)	99.574	100.428	102.875	104.281	106.728
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , MDD(kN/m3)	99.520	100.483	102.173	103.500	105.794
OGBELE ROAD AHODA EAST L.G.A , MDD(kN/m3)	99.648	100.354	101.237	103.889	113.435
OPTIMUM MOISTURE CONTENT (%)					
IWOFE ROAD OBIO/AKPO L.G.A , MDD(kN/m3)	98.390	101.636	104.385	105.694	108.966
CHOKOCHO ROAD ETCHE L.G.A , MDD(kN/m3)	98.967	101.044	103.993	105.774	106.757
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , MDD(kN/m3)	98.466	101.558	104.237	105.171	107.726
OGBELE ROAD AHODA EAST L.G.A , MDD(kN/m3)	98.006	102.034	103.942	107.184	108.646
CONSISTENCY LIMITS (%)					
IWOFE ROAD OBIO/AKPO L.G.A, LL(%)	99.679	100.322	100.805	101.287	101.624
IWOFE ROAD OBIO/AKPO L.G.A, PL(%)	96.278	103.866	105.369	107.060	109.020

IWOFE ROAD OBIO/AKPO L.G.A, IP(%)	104.083	96.077	95.338	94.373	92.765
CHOKOCHO ROAD ETCHE L.G.A , LL(%)	99.501	100.501	101.356	101.931	102.897
CHOKOCHO ROAD ETCHE L.G.A , PL(%)	98.620	101.399	104.198	105.973	108.498
CHOKOCHO ROAD ETCHE L.G.A , IP(%)	100.574	99.430	97.963	97.108	96.212
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , LL(%)	99.712	100.288	100.865	101.298	101.731
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , PL(%)	96.077	104.083	105.933	108.102	109.952
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , IP(%)	103.673	96.457	95.749	94.428	93.430
OGBELE ROAD AHODA EAST L.G.A, LL(%)	99.318	100.687	101.167	101.597	101.923
OGBELE ROAD AHODA EAST L.G.A, PL(%)	99.551	100.451	102.634	103.574	104.251
OGBELE ROAD AHODA EAST L.G.A, IP(%)	100.689	99.316	98.384	97.389	98.415
CALIFORNIA BEARING RATIO (%)					
IWOFE ROAD OBIO/AKPO L.G.A, UNSOAKED CBR(%)	28.433	351.701	616.327	869.252	766.667
IWOFE ROAD OBIO/AKPO L.G.A, SOAKED CBR(%)	29.222	342.205	638.268	903.622	841.732
CHOKOCHO ROAD ETCHE L.G.A , UNSOAKED CBR(%)	27.337	365.806	565.935	881.290	700.645
CHOKOCHO ROAD ETCHE L.G.A , SOAKED CBR(%)	27.726	360.674	619.101	959.069	760.514
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , UNSOAKED CBR(%)	22.237	449.693	647.239	960.736	780.982
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A , SOAKED CBR(%)	22.882	437.021	711.348	970.922	812.766
OGBELE ROAD AHODA EAST L.G.A, UNSOAKED CBR(%)	27.448	364.331	558.344	876.433	750.955
OGBELE ROAD AHODA EAST L.G.A, SOAKED CBR(%)	19.271	518.919	714.775	1077.117	881.982
UNCONFINED COMPRESSIVE STRENGTH (KPa)					
IWOFE ROAD OBIO/AKPO L.G.A Soil UNCONFINED COMPRESSIVE STRENGTH (kPa)	56.314	177.575	326.693	384.747	670.461
CHOKOCHO ROAD ETCHE L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	55.070	181.587	386.032	556.190	765.714
NDONI ROAD OGBA/EGBEMA/NDONI L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	51.350	194.744	297.788	439.592	609.756
OGBELE ROAD AHODA EAST L.G.A SOIL UNCONFINED COMPRESSIVE STRENGTH (kPa)	42.526	235.153	346.731	559.088	737.852

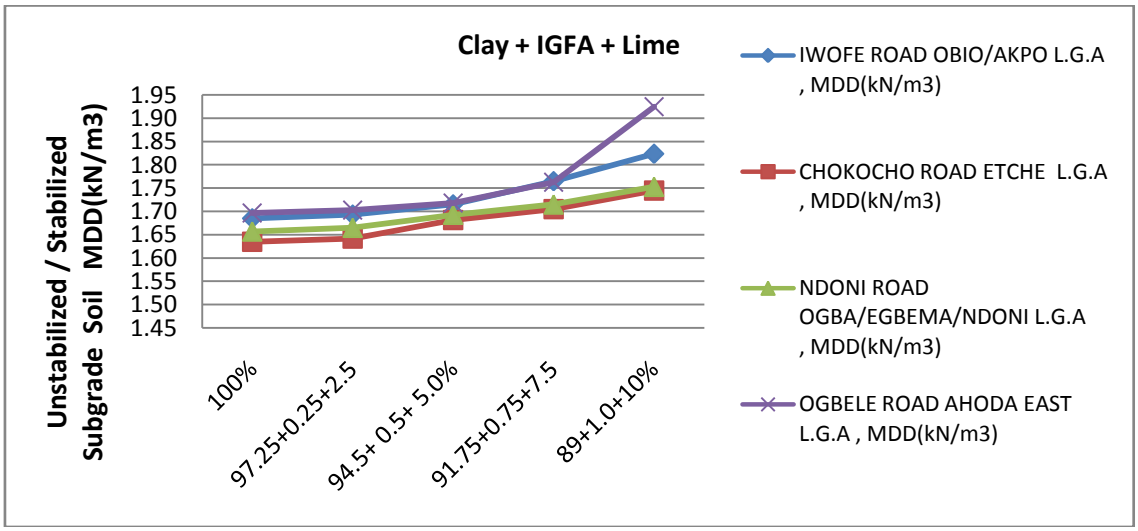

Figure 3.1: Maximum Dry Density of Subgrade Stabilization Test of Clay Soil from Iwofe, Chokocho, Ndoni and Ogbele Roads Ndoni Local Government Areas of Rivers State with IGFA + Lime at Different Percentages and Combinations

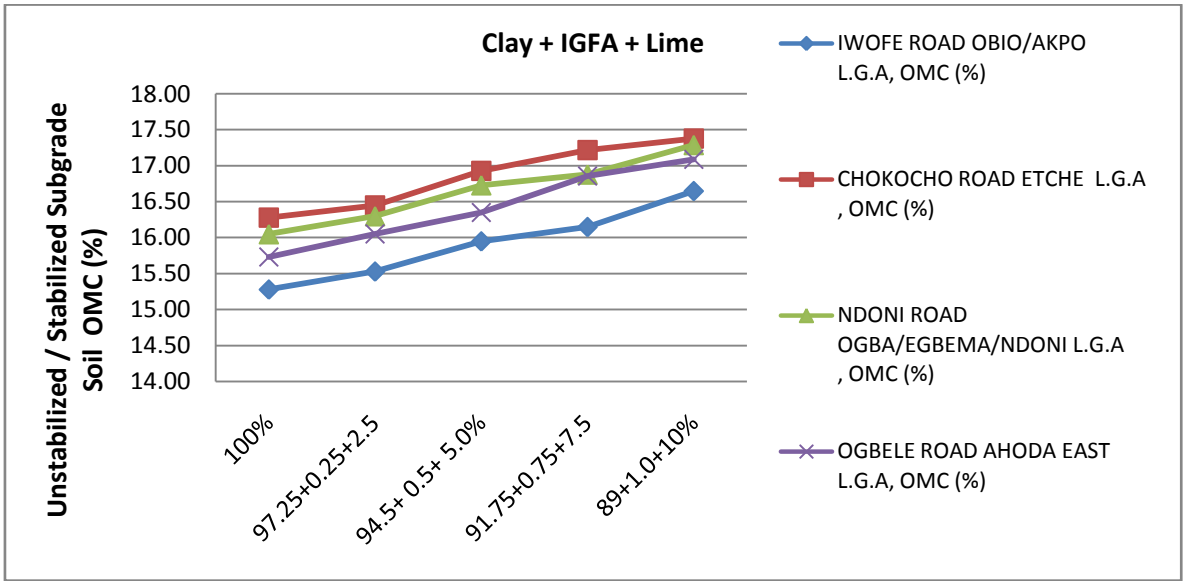

Figure 3.2: Optimum Moisture Content of Subgrade Stabilization Test of Clay Soil from Iwofe, Chokocho, Ndoniand Ogbele Roads Ndoni Local Government Areas of Rivers State with IGFA + Lime at Different Percentages and Combinations

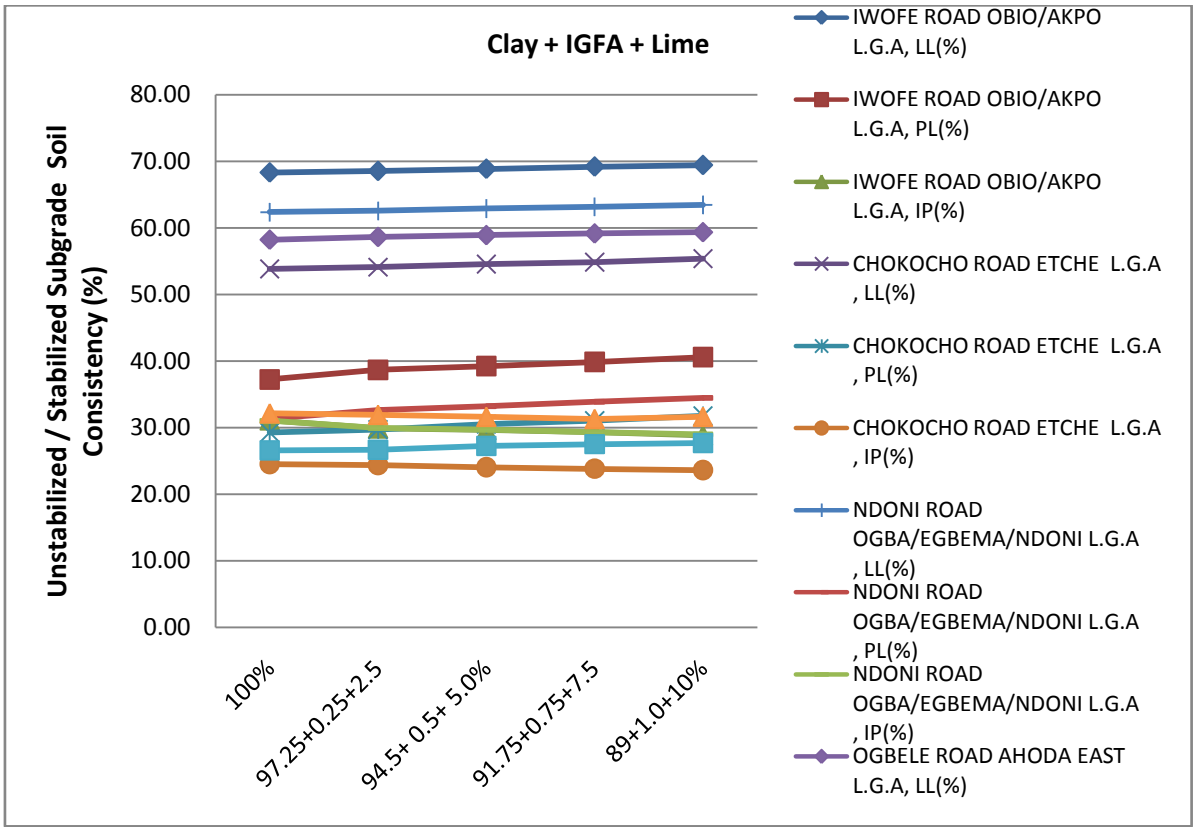

Figure 3.3: Consistency Limits of Subgrade Stabilization Test of Clay Soil from from Iwofe, Chokocho, Ndoniand Ogbele Roads Ndoni Local Government Areas of Rivers State with IGFA + Lime at Different Percentages and Combination

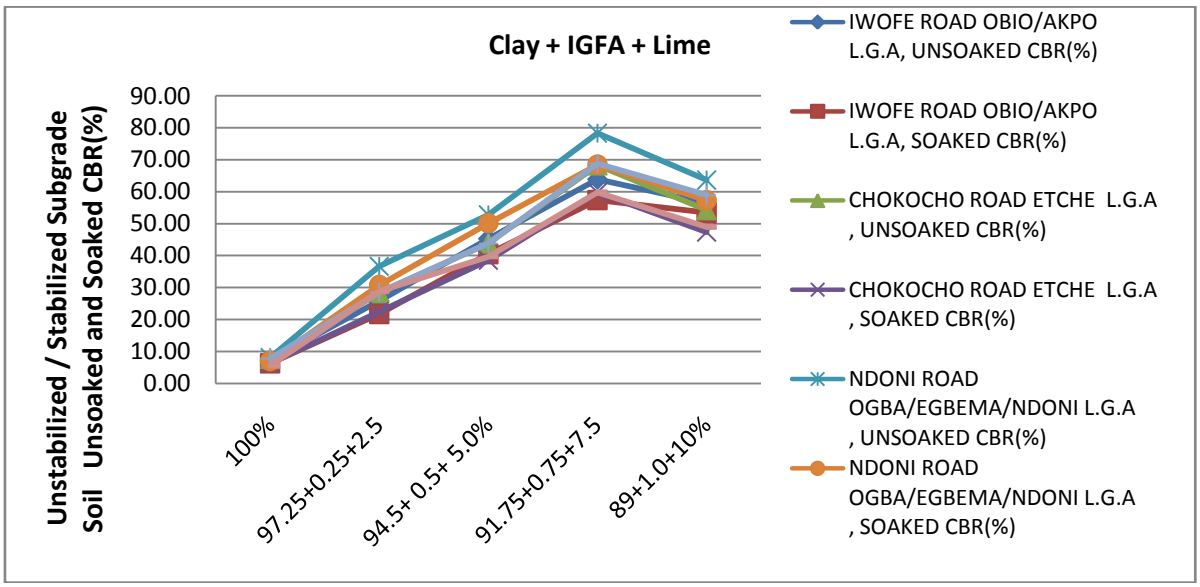

Figure 3.4: California Bearing Ratio of Subgrade Stabilization Test of Clay Soil from from Iwofe, Chokocho, Ndoni and Ogbele Roads Ndoni Local Government Areas of Rivers State with IGFA + Lime at Different Percentages and Combination

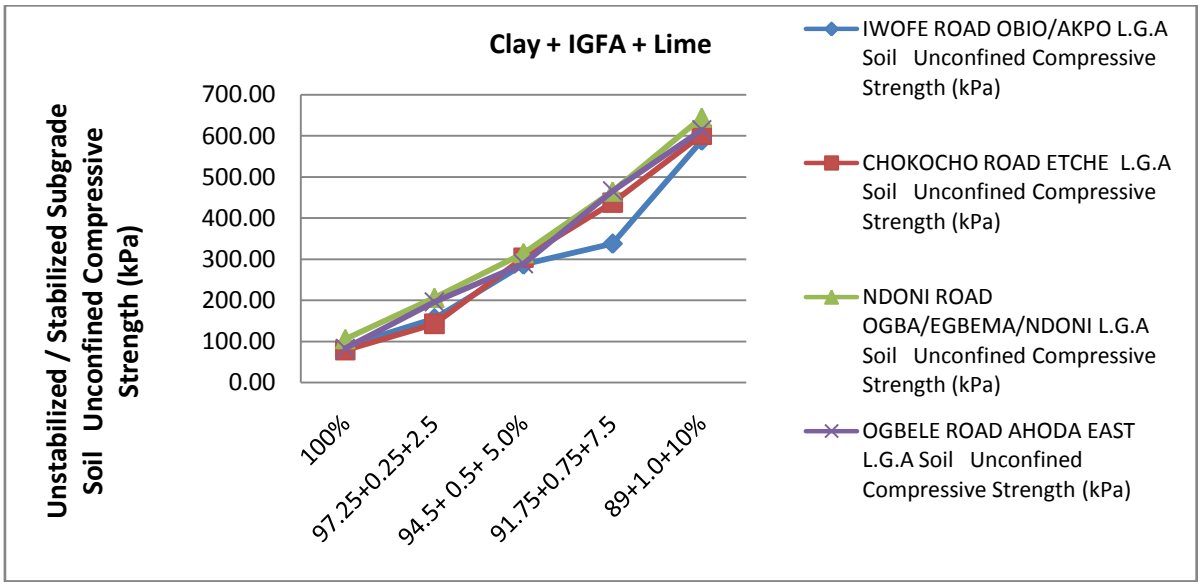

Figure 3.5: Unconfined Compressive Strength (UCS) of Subgrade Stabilization Test of Clay Soil from from Iwofe, Chokocho, Ndoni and Ogbele Roads Ndoni Local Government Areas of Rivers State with IGFA +Lime of (Iwofe, Chokocho, Ndoni, and Ogbele Towns), Rivers State

IV. 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 color (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 showed the inclusion of additives increased the MDD and OMC compaction parameters of expansive clay soils with increase in values to corresponding percentages ratio.
iv. Comparative results showed increased values in stabilized soils to un-stabilized. Optimum inclusion values were gotten at 7.5% + 7.5% percentage ratio, beyond this ratio, reduction in values were noticed with visual cracks. This point signified failure potential.
v. Entire unconfined compressive results showed increased values with percentage inclusion ratio.

vi. Comparatively from both results, modified clay soils plastic index properties decreased with additive percentages inclusion ratio against un-stabilized

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