Differential Settlement Reduction of Black Cotton Soils using Bagasse Fibre and Lime as Stabilizers for Highway pavement

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ABSTRACT

The research work experimentally examined the geotechnical and physical properties of black cotton soils across failed sections of highway road pavement of Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Town Roads in the Niger Delta regions that are prone to degradation and differential settlement due to their unique attributes of swelling and shrinkage. The soils were stabilized with composite materials of costaceae lacerus bagasse fibre and lime with 0.25% +2.5%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% to soil corresponding ratio. The soil deposit belonged to the group A-7-6 of the American Association of State and Transport Officials (AASHTO) soil classification system with plastic index properties of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively. Unconfined compressive strength test results increased with varying additive percentage ratio. Compaction test results obtained showed increased values of both MDD and OMC as graphically represented in figures with increase values as a ratio to percentage additives. Stabilized clay soils California bearing ratio increased with an increase in additives inclusion with an optimum mix of 0.75% + 7.5%. Unconfined compressive strength test results increased with varying additive percentage ratio Consistency limits result showed decreased of the plastic index properties of soils as shown in figures. Costaceae lacerus bagasse fibre and lime demonstrated to be good composite materials in combined actions in soil stabilization.

Key Words: Clay soils, costaceae lacerus bagasse, Lime CBR, UCS, Consistency, Compaction

1.0 INTRODUCTION

Changes in the index properties of soil resulting from additives like fibers, chemicals such as cement, cement kiln dust, fly ash, lime or a combination of these, often alter the physical and chemical properties of the soil, including soil cementation. Cement (OPC) is one of the most commonly used soil stabilization. This will reduce soil plasticity with consequent effects on soreness/swelling and similar behavior [1]. They found that the improvement of soil characteristics depends on the chemical components of the cementing agent and the properties of the soil.

[2] Evaluated the geotechnical properties of an expansive soil found along the Odioku - Odiereke road in the Niger State of Ahoda-West, Rivers State. Application of two cement agents of hybridized cement and lime with costus afer bagasse fiber to strengthen the failing section of the road. Combined test results obtained for optimum moisture content (OMC) and compaction test results for maximum dry density (MDD) of clay soil cement and bush sugarcane bagasse fiber (BSBF) at combined actions to soil ratios of 3.75%, 0.25%, 5.5% 0.5%, 7.25% 0.75% and 9% 1.0% of cement and BSBF combined percentages.

[3] Studied the effects of RHA, lime, and gypsum on the engineering properties of expandable soils and found that UCS increased by 548% over 28 days of treatment and 1350% at CBR 1450 when treated with RHA-20%, Lime-5%, and gypsum-3%.

[4] Studied condensation, CBR, shear strength parameters, coefficient of compression, the effect of lime sludge, PS and durability of compression, the durability of soil stabilized with an optimal percentage of RHA within 7 days of curing. Soil with optimum ratio: RHA: Lime mud 75:10:15

[5] Investigated that the pavement is susceptible to erosion resulting in a number of failures, pits, and cracks along the Odioku Road, Ahoada West, parts of the Rivers State. Stabilizers were used in single and joint works to determine the suitability of composite materials that would solve these problems. Soil treated with lime decreased the liquid boundaries and the plastic limit increased. At 8% lime, the CBR value reached the optimum, beyond this range; cracks are present and 7.5% lime + 0. 75% BSBF, the optimal value is reached.

[6] Evaluated the characteristics of lateritic soil (LS) stabilized with sawdust ash (SDA), subjected to British standard light (BSL) compactive effort to determine their index, compaction, unconfined compressive strength (UCS), and California Bearing Ratio (CBR) results. The results of the laboratory tests show that the properties of LS improved when stabilized with SDA.

[7] Evaluated the application of plantain rachis fibers to agricultural wastes, which were hybridized with cement and lime and modified the engineering properties of swelling / expansive lateritic soils. The comparative strength of un-stabilized and stabilized soil with mixed material compaction test results showed that the maximum dry density (MDD) and static soil maximum moisture (OMC) of the sample roads increased incremental percentage to include mixed stabilizing agents in the soil

values displayed with varying percentage ratios. Unconfined compressive strength test results of soils stabilized with cementitious agents of cement/lime + PRF showed an incremental percentage value as the ratio of additives to soils in the test results. Computed results of the California bearing ratio (CBR) of stabilized and soaked soils with stabilizing agents of cement, lime and PRF showed a percentile value increase for the corresponding additives to the relatively optimal mix ratio.

[8] Evaluated the engineering behavioral characteristics of stable extensional lateritic soils with cement, lime, and irvinga gabonesis fibers for their combined strength characteristics. The result of unconfined compressive strength test from the sampled roads, being stabilized with cement/lime + IGF, increased the proportion of composite materials to the soil. Incremental percentage values with ratio variance appeared in the results of the stabilized California bearing ratio (CBR) of sampled roads with mixed materials of cement, lime and IGF. In comparison, the results of the un-stabilized and overall stabilized soil, the maximum dry density (MDD) and optimum moisture content (OMC) of the compaction test parameters reflect the percentage increase in the percentage ratio of composite stabilizers for the soil.

[9] Investigated improved contribution on expansive lateritic soils with less mature characteristics, sensitive to manipulation in many forms with hybridized composite materials of cement + costaceae lacaceous bagasse fibers and lime + costaceae lacaceous bagasse fibers, their varying strengths and the behavioral attributes for soil modifications. The incremental percentile values of the California bearing ratio (CBR) were stabilized with cement, lime, and CLBF, achieving an optimal percentage ratio at 91.75 + 0.75 + 7.5%. The stabilized soil maximum dry density (MDD) and optimal moisture content (OMC) ratio of soil exhibited incremental percentage values with an increase in the percentage of composite stabilizers inclusion. Unconfined compressive strength test of soils stabilized with cement/lime + CLBF showed relatively low the incremental percentage to static and soil percentage ratios. The result of summarized stabilized soil showed an incremental percentage value of cement and lime + costaceous lecherous fiber.

[10] Evaluated the applications of composite materials of cement + plantain rachis fibers and lime + plantain rachis fibers and their performance characteristics for large clay soil amendments. The combined results of the comparative results of unconfined compressive strength tests of cemented materials showed incremental percentage values according to the percentage increase of composite material to clay ratio with cement performance in higher values of lime. Comparative results of clay soil on natural condition and compaction test results of mixed stable soil maximum dry density (MDD) and optimum moisture content.

[11] Explored the effective use of mixed soil stabilizers of irvinga gabonesis fiber + lime in combined action to improve the performance of problematic soils with swelling and shrinkage capacity and to meet the required standard of suburban road pavement materials to create trivial soils. In comparison, the static soil concentration results both MDD and OMC increase the respective values to increase the proportion of stable soils. The overall results showed the ability to use irvinga gabonesis fiber + lime in treated soil. CBR results in stabilized samples with an optimal percentage ratio of 0.75 + 7.5% soil. The swelling capacity of the treated soil decreased to 0.75% + 7.5% for subsequent soils with the inclusion of fiber + lime. The obtained results showed an increase in UCS values corresponding to the additive percentage. Results in the plastic index for percentage ratios of additives were less visible.

[12] Investigated the potential application of hybridized composite materials of plantain rachis fiber + cement in a mixed state for the manipulation/modification of problematic soft clay soils with failed dispersal of highway subgrade soil in the Niger Delta region of Nigeria. The final stability limit (plastic index) of the mixed material stabilized soil varied for the increase in values involving a decrease percentage ratio. Proportional, California bearing ratio of mixed hybridization material increased to both uncorrelated and soaked values with optimal percentage inclusions at 0.75% + 7.5%, beyond this value, cracks were formed, resulting in a possible failure state. The final calculation results of compaction tests of mixed stagnant soil soils increased both maximum dry density (MDD) and optimum moisture content (OMD). The values have been increased with varying percentage ratios in the compacted clay soils without enhanced corrosive strength testing. Test results of the test showed that an increase in fiber + cement percentage combinations increased the maximum dry density (MDD) and optimal moisture content (OMC) values of Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads

[13] Investigated the engineering properties of problematic soils with potential characteristics of swelling, shrinkage, and crack of highway subgrade pavement in joint operations and stabilized with costaceae lacerus bagasse fibre + cement in combination. The whole results showed a good combination of laterite + costaceous laceruscrus bagasse fiber + cement as an entry into soil stabilization. The result is an increase in the CBR of stable soils with an increase of over 0.75% + 7.5% combination, beyond this; Lower values were obtained with cracks formation and failure conditions. The inclusion of bagasse fiber + cement reduced the swelling capacity of treated soil.

[14] Assessed and investigated the application of costaceae lacerus bagasse fiber (CLBF) and cement as soil stabilizers in the combined state. The results obtained at UCS appeared to be increased in the soil in a similar proportion with an increase in fiber percentage. The inclusion of additives reduced

the prices of plastic index properties. The result is an increase in UCS for the corresponding proportion of soil with increased fiber and cement percentage increase. The result is an increase in CBR values for both, soaked by a combination of the same ratios of 0.75% + 7.5% without any ratios. The entire results showed the ability to use CLBF + cement in the treatment of clay soils.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil

The soils used for the study are Ogoda Town Road, Ubie, Districts of Ekpeye, Ahoada-East and Ahoada-West Local Government Area, Bodo Town Road, Gokana Local Government Area, Ogbogu Town Road, Egbema/Ndoni/Egbema Local Government Area, Ula-Ikata Town Road, Ahoada-East Local Government Area, and Kaani Town Road, Khana Local Government Area, all of Rivers State, Niger Delta, Nigeria.

2.1.2 Costaceae Lacerus Bagasse Fibre

Costaceae Lacerus Bagasse fibers are widespread plants, are used medicinally in local areas, are abundant in riverside farms/shrubs, they cover large areas of Oyigba Town Farmland / Bush, Ubie Clan, Ahoada-West, Rivers State, Nigeria.,

2.1.3 Lime

The lime was acquired from the market

2.2 METHOD

2.2.1 Sampling Locality

The soil sample used in this study was collected along Ogoda Town, (latitude 5.04 ° 59'S and longitude 6.38 ° 42'E), Bodo Town, (latitude 4.65 ° 05'S and longitude 7.27 ° 15'E, Ogbogu Town., Latitude 5.13 ° 08'S and longitude 6.33 ° 25'E), Ula-Ikata Town, (latitude 5.95 ° 45'S and longitude 6.66 ° 13'E) and Kanni Town, latitude 4.67 ° 13'S and longitude 6.81 ° 55'E) all river states. , In Nigeria.

2.2.2 Test Conducted

Tests were performed (1) moisture content determination (2) Consistency limit test (3) particle size distribution (sieve analysis) and (4) Compaction test, California Bearing Ratio test (CBR) and Unconfined Compressive Strength (UCS) test ;

2.2.3 Moisture Content Determination

The natural moisture content of the soil obtained from the site was determined according to BS 1377 (1990) Part 2. The freshly collected sample was dug up and placed loosely in the containers and the containers were weighed together with samples at 0.01g.

2.2.4 Grain Size Analysis (Sieve Analysis)

Mechanical or sieve analysis is performed to determine the distribution of coarser, large-sized particles. Test performance was aimed at obtaining the different grain size percentages in a sample soil

2.2.5 Consistency Limits

The liquid limit (LL) is defined as the arbitrary water content, in percentage, at which a portion of the soil in the standard cup and a groove of standard dimensions is cut, for a distance of 13 mm will flow simultaneously at the base of the drain (1 / 2in.) When subjected to 25 shocks being dropped 25 mm from the cup in a standard fluid limit mechanism 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 moisture content and soil dry density for a specified compact effort

2.2.7 Unconfined Compression (UC) Test

Unconfined compressive strength is taken as the maximum load achieved per unit area, or loaded at 15% axial stress per unit area, whichever occurs during the performance of a test. The primary objective of this test is to determine the unconfined compressive strength, which is then used to calculate the undeclared unabsorbed shear strength of the soil under unconventional conditions.

2.2.8 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test by the California Division of Ratio was developed and evaluated and evaluated the soil-sub-base and base course material for flexible pavements.

3.0 RESULTS AND DISCUSSIONS

The soils classified as A – 7 – 6 on the AASHTO 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 [15]; [16] 1981; [17]; [18]. Preliminary results on clay 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 are reddish brown and dark grey in color (from wet to dry states) plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Town Roads. The soil has unsoaked CBR values of 8.58%, 8.83%, 8.05%, 7.38%, and 9.05% and soaked CBR values of 6.33%, 7.15%, 7.35%, 5.9% and 8.23 %, unconfined compressive strength (UCS) values of 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

Obtained results at preliminary investigation of clay soils at 100% of maximum dry density (MDD) at natural state 100% clay as 1.875KN/m3, 1.923KN/m3, 1.823KN/m3, 1.795KN/m3, 1.985KN/m3 having percentile representations of 99.58%, 98.26%, 98.75%, 98.84%, 99.35% and Optimum moisture content (OMC) as 15.68%, 14.93%, 16.30%, 17.45% and 15.35% with percentile value representations of 97.51%, 98.16%, 98.25%, 97.92%, 97.77%. Results of stabilized clay soils with costaceae lacerus bagasse fibre (CLBF) + lime with percentage ratio combination of 0.25% + 2.5%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% + 10% yielded MDD values of 1.985 KN/m3, 2.105 KN/m3, 1.935 KN/m3, 1.910 KN/m3 and 2.555 KN/m3 having percentile peak ratios values of 105.87%, 109.46%, 106.14%,106.47%, 128.72% and OMC values of 17.20%, 16.15%, 17.38%, 18.83%, and 16.47% percentile peak values of 109.69%, 108.17%, 106.63%, 107.91%, 107.30%. Detail results obtained showed increased values of both MDD and OMC, graphical representation of figures 3.1 and 3.2 showed increased values as ratio to percentage additives.

3.2 California Bearing Ratio (CBR) Test

Results obtained of clay soils at 100% natural state are 8.58%, 8.83%, 8.05%, 7.38%, and 9.05% unsoaked and soaked values 6.33%, 7.15%, 7.35%, 5.9% and 8.23 % with percentile representations of 36.89%, 29.83%, 30.17%, 31.54%, 32.04%, and 29.93%, 26.63%, 30.12%, 30.97%, 31.00% . Costaceae lacerus bagasse fibre (CLBF) + lime to soil ratio stabilized / modified samples values are 51.85%, 56.30%, 49.75%, 45.80% and 57.30% unsoaked values and soaked values are 48.35%, 52.65%, 47.25%, 40.60% and 56.35% with percentile peak values rise of unsoaked 599.422%,637%, .599%, 603.03%, 620.596%, 633.149% and 763.823%%, 736.364%, 642.857%, 688.136%, 684.69%. Comparatively, stabilized clay soils CBR of both unsoaked and soaked increased with increased in additives inclusion with optimum mix of 0.75% + 7.5%. Cracks noticed occurred beyond optimum level mix.

3.3 Unconfined Compressive Strength Test

Preliminary investigation results obtained of sampled road at 100% clay soils are 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa. Composite stabilized soils yielded peak values are

ISSN 2229-5518

374kPa, 308kPa, 368kPa, 335kPa and 388kPa. Results of percentile values at zero percent additives are 56.05%, 56.56%, 42.78%, 46.74%, 47.65% and a peak percentile rise of 635.51%, 486.19%, 637.23%, 623.26%, and 607.67%. Unconfined compressive strength test results increased with varying additive percentages ratio as seen in figure 3.5

3.4 Consistency Limits Test

Results of consistency limits (Plastic index) at 100% soils are 20.33%, 20.35%, 21.85%, 26.30% and 21.35%. For stabilized soils, index properties are 19.25%, 18.88%, 19.82%, 17.05% and 18.97%. Plastic Index at 100% percentile values representations are 101.04%, 102.62%, 105.30%, 101.39%, 101.50% and stabilized soils percentile values are 94.69%, 92.78%, 90.71%, 93.17%, 93.22%. Results showed additives decreases the plastic index properties of soils with respect to ratio percentages increase.

Table 3.1: Engineering Properties of Soil Samples

LOCATION DESCRIPTION	OGODA TOWN ROAD, AHOADA-WEST L.G.A RIVERS STATE	BODO TOWN ROAD ,GOKANA L.G.A RIVERS STATE	OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A RIVERS STATE	ULA-IKATA TOWN ROAD, AHOADA-BEMA EAST L.G.A RIVERS STATE	KAANI TOWN ROAD, KHANNA L.G.A RIVERS STATE
Depth of sampling (m)	1.5	1.5	1.5	1.5	1.5
(%) passing BS sieve #200	73.85	67.38	76.35	82.35	71.55
Colour	Grey	Grey	Grey	Grey	Grey
Specific gravity	2.71	2.68	2.63	2.63	2.71
Natural moisture content (%)	46.25	45.38	45.86	49.30	46.85
Consistency Limits					
Liquid limit (%)	58.85	59.45	58.35	56.67	48.25
Plastic limit (%)	38.52	39.10	37.50	30.37	24.90
Plasticity Index	20.33	20.35	21.85	26.30	21.35
AASHTO soil classification Unified Soil Classification System	A – 7 – 6	A – 7 – 6	A – 7 – 6	A – 7 – 6	A – 7 – 6
Optimum moisture content (%)	15.68	14.93	16.30	17.45	15.35
Maximum dry density ($kN/m^{3)}$	1.875	1.923	1.823	1.795	1.9.85
Gravel (%)	1.85	0.85	2.45	0.53	1.95
Sand (%)	12.35	11.08	9.75	7.34	13.25
Silt (%)	52.35	47.35	47.85	53.68	48.25

Clay (%)	33.45	40.72	39.95	38.45	36.55
Unconfined compressive strength (kPa)	58.85	63.35	57.75	53.75	63.85
California Bearing Capacity (CBR)					
Unsoaked (%) CBR	8.58	8.83	8.05	7.38	9.05
Soaked (%) CBR	6.33	7.15	7.35	5.9	8.23

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 (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
	SOFT CLAY +COSTACEAE LACERUS BAGASSE FIBRE (CLBF) + LIME											
	100%	1.875	15.68	8.65	6.33	58.85	58.85	38.52	20.33	73.85	A-7-6	POOR
	97.25+0.25+2.5%	1.883	16.08	23.45	21.15	105	58.93	38.91	20.12	73.85	A-7-6	GOOD
	94.5+0.5+0.5%	1.936	16.35	37.55	32.80	215	59.83	40.21	19.62	73.85	A-7-6	GOOD
	92.25+0.75+7.5%	1.934	16.85	51.85	48.35	296	59.83	40.21	19.62	73.85	A-7-6	GOOD
	89+1.0 + 10%	1.985	17.20	46.33	41.60	374	60.15	40.90	19.25	73.85	A-7-6	GOOD
BODO TOWN ROAD GOKANA. L.G.A	100%	1.923	14.93	8.83	7.15	63.35	59.45	39.10	20.35	67.35	A-7-6	POOR
	97.25+0.25+2.5%	1.957	15.21	29.60	26.85	112	59.78	39.95	19.83	67.35	A-7-6	GOOD
	94.5+0.5+0.5%	1.987	15.31	41.30	38.15	187	60.15	40.53	19.62	67.38	A-7-6	GOOD
	92.25+0.75+7.5%	2.15	15.78	56.30	52.65	264	61.48	43.87	19.30	67.38	A-7-6	GOOD
	89+1.0 + 10%	2.105	16.15	48.36	39.30	308	62.65	43.77	18.88	67.38	A-7-6	GOOD
OGBOGU TOWN ROAD OGBA/EGBEMA/ NDONI L.G.A	100%	1.823	16.30	8.25	7.35	57.75	58.35	37.50	21.85	76.35	A-7-6	POOR
	97.25+0.25+2.5%	1.846	16.59	27.35	24.40	135	59.85	39.10	20.75	76.35	A-7-6	GOOD
	94.5+0.5+0.5%	1.875	16.83	34.30	29.88	224	60.18	39.82	20.36	76.35	A-7-6	GOOD
	92.25+0.75+7.5%	1.897	17.05	49.75	47.25	298	60.66	40.63	20.03	76.35	A-7-6	GOOD
	89+1.0 + 10%	1.935	17.38	37.37	32.35	368	60.97	41.15	19.82	76.35	A-7-6	GOOD
ULA-IKATA TOWN ROAD AHODA EAST L.G.A	100%	1.794	17.45	7.38	5.90	53.75	56.67	38.37	18.30	82.35	A-7-6	POOR
	97.25+0.25+2.5%	1.815	17.82	23.40	19.05	115	57.15	34.10	18.05	82.35	A-7-6	GOOD
	94.5+0.5+0.5%	1.865	18.15	31.45	27.35	234	57.65	39.83	17.82	82.35	A-7-6	GOOD
	92.25+0.75+7.5%	1.885	18.52	45.80	40.60	268	58.15	40.72	17.43	82.35	A-7-6	GOOD
	89+1.0 + 10%	1.910	18.83	36.35	31.78	335	58.65	41.60	17.05	82.35	A-7-6	GOOD
KAANI TOWN ROAD KHANA	100%	1.985	15.35	9.05	8.23	63.85	48.25	27.90	20.35	71.55	A-7-6	POOR
	97.25+0.25+2.5%	1.998	15.70	28.25	26.55	134	48.53	28.48	20.05	71.55	A-7-6	GOOD
	94.5+0.5+0.5%	2.120	15.96	48.35	46.85	225	48.96	29.14	19.82	71.55	A-7-6	GOOD

L.G.A	92.25+0.75+7.5%	2.408	16.12	57.30	56.35	285	49.23	29.88	19.35	71.55	A-7-6	GOOD
	89+1.0 + 10%	2.555	16.47	53.45	49.75	388	49.75	30.98	18.97	71.55	A-7-6	GOOD

Table 3.5: Results of Parameter Combination of Soft Clay + Costaceae Lacerus Bagasse Fibre (CLBF) + 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)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A MDD(kN/m3)	1.88	1.88	1.94	1.93	1.99
BODO TOWN ROAD GOKANA L.G.A MDD(kN/m3)	1.92	1.96	1.99	2.15	2.11
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A MDD(kN/m3)	1.82	1.85	1.88	1.90	1.94
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A MDD(kN/m3)	1.79	1.82	1.87	1.89	1.91
KAANI TOWN ROAD, KHANA L.G.A MDD(kN/m3)	1.99	2.00	2.12	2.41	2.56
OPTIMUM MOISTURE CONTENT (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A OMC (%)	15.68	16.08	16.35	16.85	17.20
BODO TOWN ROAD GOKANA L.G.A OMC (%)	14.93	15.21	15.31	15.78	16.15
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A OMC (%)	16.30	16.59	16.83	17.05	17.38
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A OMC (%)	17.45	17.82	18.15	18.52	18.83
KAANI TOWN ROAD, KHANA L.G.A OMC (%)	15.35	15.70	15.96	16.12	16.47
CONSISTENCY LIMITS (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A LL(%)	58.85	58.93	59.83	59.83	60.15
OGODA TOWN ROAD, AHOADA-WEST L.G.A PL(%)	38.52	38.91	40.21	40.21	40.90
OGODA TOWN ROAD, AHOADA-WEST L.G.A IP(%)	20.33	20.12	19.62	19.62	19.25
BODO TOWN ROAD GOKANA L.G.A LL(%)	59.45	59.78	60.15	61.48	62.65
BODO TOWN ROAD GOKANA L.G.A PL(%)	39.10	39.95	40.53	43.87	43.77
BODO TOWN ROAD GOKANA L.G.A IP(%)	20.35	19.83	19.62	19.30	18.88
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A LL(%)	58.35	59.85	60.18	60.66	60.97
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A PL(%)	37.50	39.10	39.82	40.63	41.15
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A RIVERS STATE P(%)	21.85	20.75	20.36	20.03	19.82
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A LL (%)	56.67	57.15	57.65	58.15	58.65
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A PL (%)	38.37	34.10	39.83	40.72	41.60
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A IP(%)	18.30	18.05	17.82	17.43	17.05
KAANI TOWN ROAD, KHANA L.G.A LL (%)	48.25	48.53	48.96	49.23	49.75
KAANI TOWN ROAD, KHANA L.G.A PL (%)	27.90	28.48	29.14	29.88	30.98
KAANI TOWN ROAD, KHANA L.G.A IP(%)	20.35	20.05	19.82	19.35	18.97
CALIFORNIA BEARING RATIO (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A UNSOAKED CBR (%)	8.65	23.45	37.55	51.85	46.33
OGODA TOWN ROAD, AHOADA-WEST L.G.A SOAKED CBR (%)	6.33	21.15	32.80	48.35	41.60

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BODO TOWN ROAD GOKANA L.G.A UNSOAKED CBR (%)	8.83	29.60	41.30	56.30	48.36
BODO TOWN ROAD GOKANA L.G.A SOAKED CBR (%)	7.15	26.85	38.15	52.65	39.30
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A UNSOAKED CBR (%)	8.25	27.35	34.30	49.75	37.37
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A SOAKED CBR(%)	7.35	24.40	29.88	47.25	32.35
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UNSOAKED CBR(%)	7.38	23.40	31.45	45.80	36.35
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A SOAKED CBR (%)	5.90	19.05	27.35	40.60	31.78
KAANI TOWN ROAD, KHANA L.G.A UNSOAKED CBR (%)	9.05	28.25	48.35	57.30	53.45
KAANI TOWN ROAD, KHANA L.G.A SOAKED CBR (%)	8.23	26.55	46.85	56.35	49.75
UNCONFINED COMPRESSIVE STRENGTH (KPa)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A UCS (Kpa)	58.85	105.00	215.00	296.00	374.00
BODO TOWN ROAD GOKANA L.G.A UCS (Kpa)	63.35	112.00	187.00	264.73	308.00
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A UCS (Kpa)	57.75	135.00	224.00	298.00	368.00
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UCS (Kpa)	53.75	115.00	234.00	268.00	335.00
KAANI TOWN ROAD, KHANA L.G.A UCS (Kpa)	63.85	134.00	225.00	285.00	388.00

Table 3.6: Percentile Decrease / Increase of Soft Clay +Costaceae Lacerus Bagasse Fibre (CLBF) + 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)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A MDD(kN/m3)	99.575	100.427	103.253	103.147	105.867
BODO TOWN ROAD GOKANA L.G.A MDD(kN/m3)	98.263	101.768	103.328	111.804	109.464
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A MDD(kN/m3)	98.754	101.262	102.852	104.059	106.144
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A MDD(kN/m3)	98.843	101.171	103.958	105.072	106.466
KAANI TOWN ROAD, KHANA L.G.A MDD(kN/m3)	99.349	100.655	106.801	121.310	128.715
OPTIMUM MOISTURE CONTENT (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A OMC (%)	97.512	102.551	104.273	107.462	109.694
BODO TOWN ROAD GOKANA L.G.A OMC (%)	98.159	101.875	102.545	105.693	108.171
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A OMC (%)	98.252	101.779	103.252	104.601	106.626
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A OMC (%)	97.924	102.120	104.011	106.132	107.908
KAANI TOWN ROAD, KHANA L.G.A OMC (%)	97.771	102.280	103.974	105.016	107.296
CONSISTENCY LIMITS (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A LL(%)	99.864	100.136	101.665	101.665	102.209
OGODA TOWN ROAD, AHOADA-WEST L.G.A PL(%)	98.998	101.012	104.387	104.387	106.179
OGODA TOWN ROAD, AHOADA-WEST L.G.A IP(%)	101.044	98.967	96.508	96.508	94.688
BODO TOWN ROAD GOKANA L.G.A LL(%)	99.448	100.555	101.177	103.415	105.383
BODO TOWN ROAD GOKANA L.G.A PL(%)	97.872	102.174	103.657	112.199	111.944
BODO TOWN ROAD GOKANA L.G.A IP(%)	102.622	97.445	96.413	94.840	92.776
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A LL(%)	97.494	102.571	103.136	103.959	104.490
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A PL(%)	95.908	104.267	106.187	108.347	109.733
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A IP(%)	105.301	94.966	93.181	91.670	90.709
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A LL(%)	99.160	100.847	101.729	102.612	103.494
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A PL(%)	112.522	88.872	103.805	106.125	108.418
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A IP(%)	101.385	98.634	97.377	95.246	93.169
KAANI TOWN ROAD, KHANA L.G.A LL(%)	99.423	100.580	101.472	102.031	103.109
KAANI TOWN ROAD, KHANA L.G.A PL(%)	97.963	102.079	104.444	107.097	111.039
KAANI TOWN ROAD, KHANA L.G.A IP(%)	101.496	98.526	97.396	95.086	93.219
CALIFORNIA BEARING RATIO (%)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A UNSOAKED CBR(%)	36.887	271.098	434.104	599.422	535.607

OGODA TOWN ROAD, AHOADA-WEST L.G.A SOAKED CBR(%)	29.929	334.123	518.167	763.823	657.188
BODO TOWN ROAD GOKANA L.G.A UNSOAKED CBR(%)	29.831	335.221	467.724	637.599	547.678
BODO TOWN ROAD GOKANA L.G.A SOAKED CBR(%)	26.629	375.524	533.566	736.364	549.650
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A UNSOAKED CBR(%)	30.165	331.515	415.758	603.030	452.970
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A SOAKED CBR(%)	30.123	331.973	406.531	642.857	440.136
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UNSOAKED CBR(%)	31.538	317.073	426.152	620.596	492.547
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A SOAKED CBR(%)	30.971	322.881	463.559	688.136	538.644
KAANI TOWN ROAD, KHANA L.G.A UNSOAKED CBR(%)	32.035	312.155	534.254	633.149	590.608
KAANI TOWN ROAD, KHANA L.G.A SOAKED CBR(%)	30.998	322.600	569.259	684.690	604.496
UNCONFINED COMPRESSIVE STRENGTH (KPa)					
OGODA TOWN ROAD, AHOADA-WEST L.G.A UCS (Kpa)	56.048	178.420	365.336	502.974	635.514
BODO TOWN ROAD GOKANA L.G.A UCS (Kpa)	56.563	176.796	295.185	417.885	486.188
OGBOGU TOWN-ROAD, OGBA/EGBEMA NDONI L.G.A UCS (Kpa)	42.778	233.766	387.879	516.017	637.229
ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UCS (Kpa)	46.739	213.953	435.349	498.605	623.256
KAANI TOWN ROAD, KHANA L.G.A UCS (Kpa)	47.649	209.867	352.388	446.359	607.674

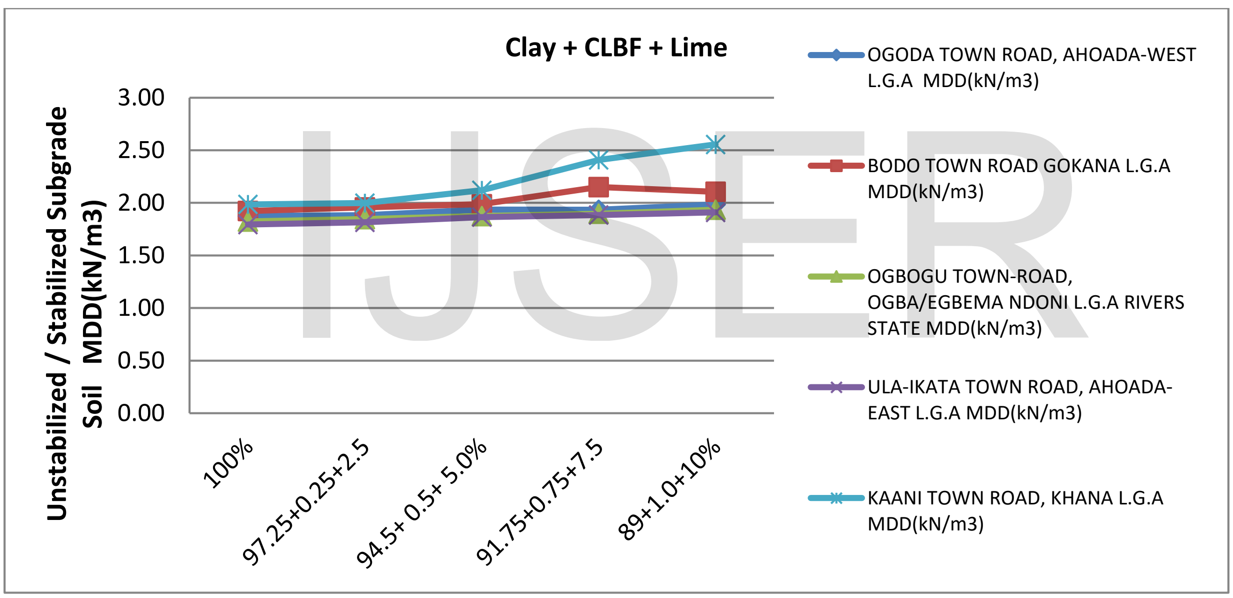

Figure 3.1: Maximum Dry Density of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns, Local Government Areas of Rivers State with CLBF+ Lime at Different Percentages and Combinations

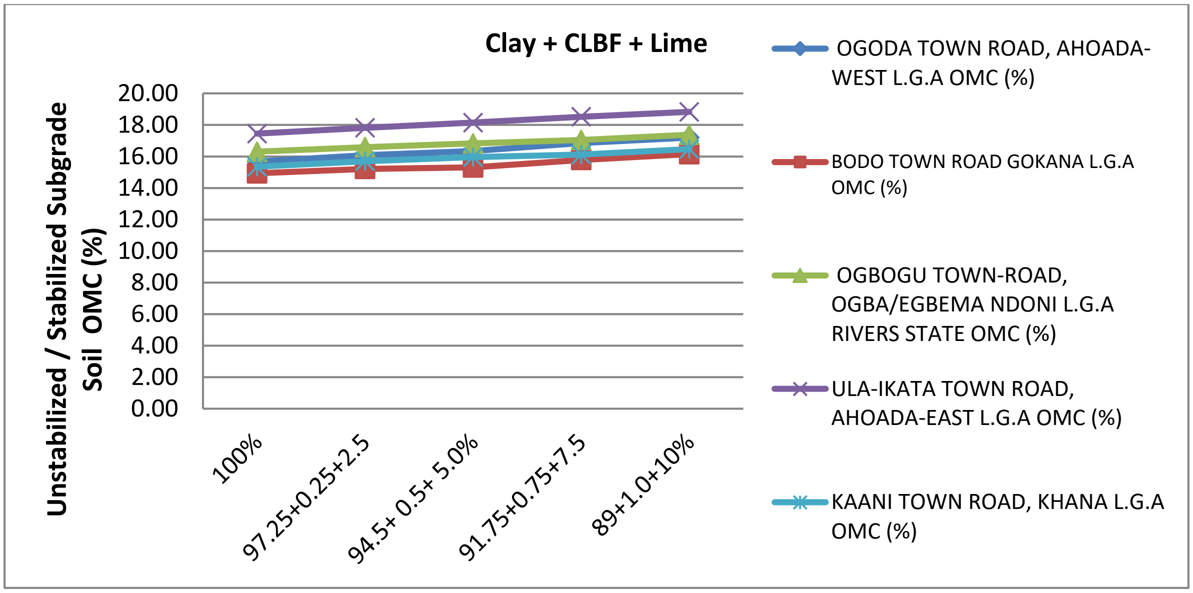

Figure 3.2: Optimum Moisture Content of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns, Local Government Areas of Rivers State with CLBF+ Lime at Different Percentages and Combinations

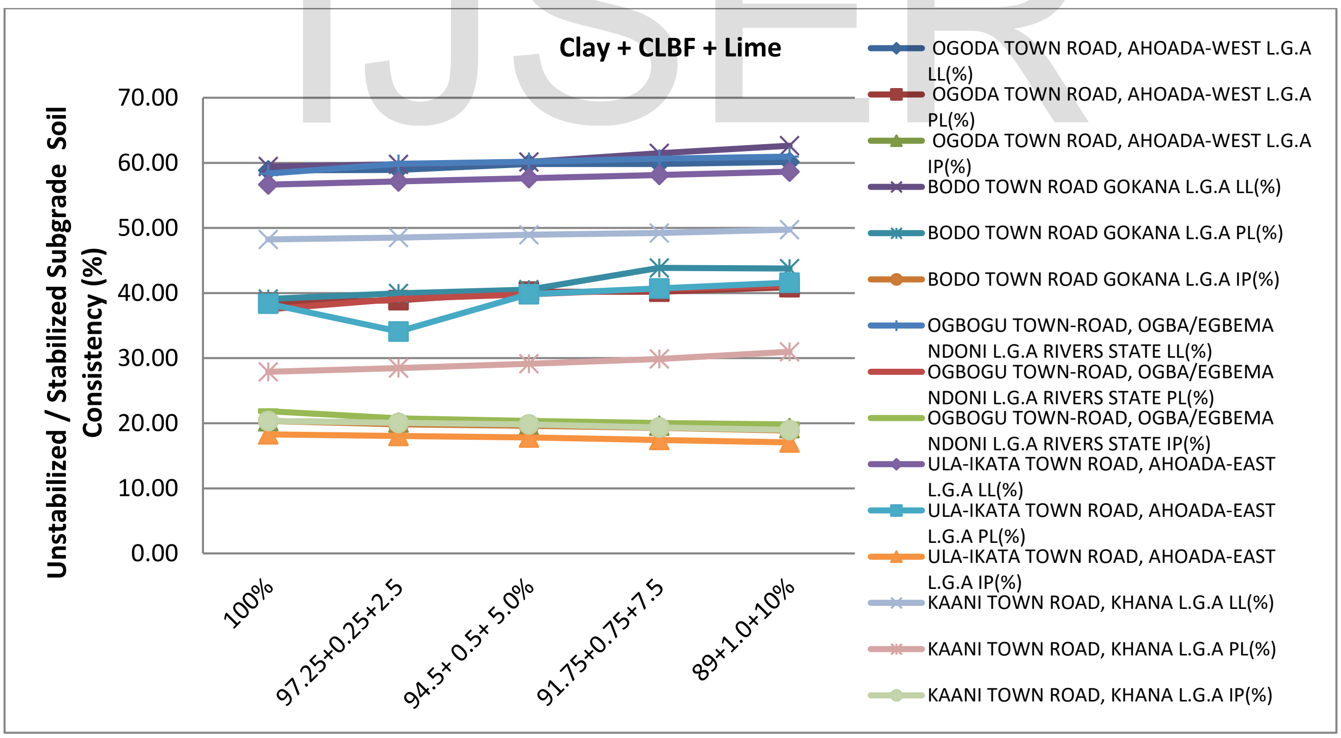

Figure 3.3: Consistency Limits of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns, Local Government Areas of Rivers State with CLBF+ Lime at Different Percentages and Combinations

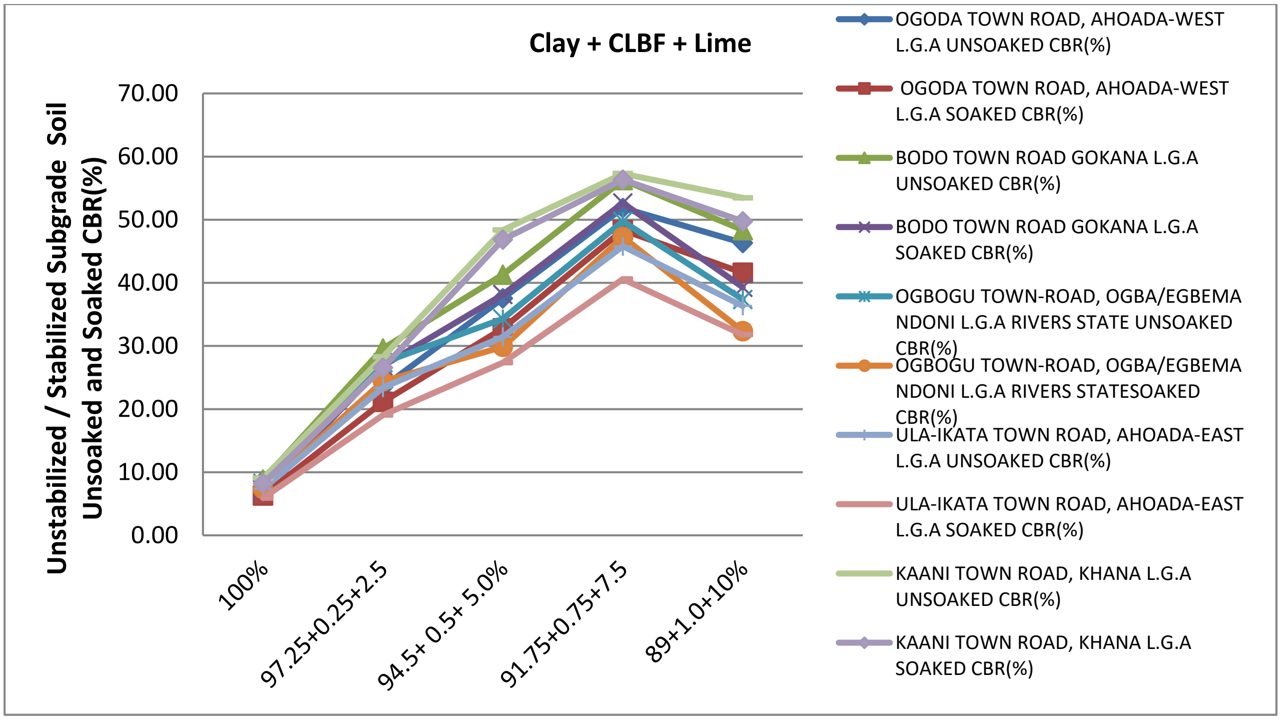

Figure 3.4: California Bearing Ratio of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns, Local Government Areas of Rivers State with CLBF+ Lime at Different Percentages and Combinations

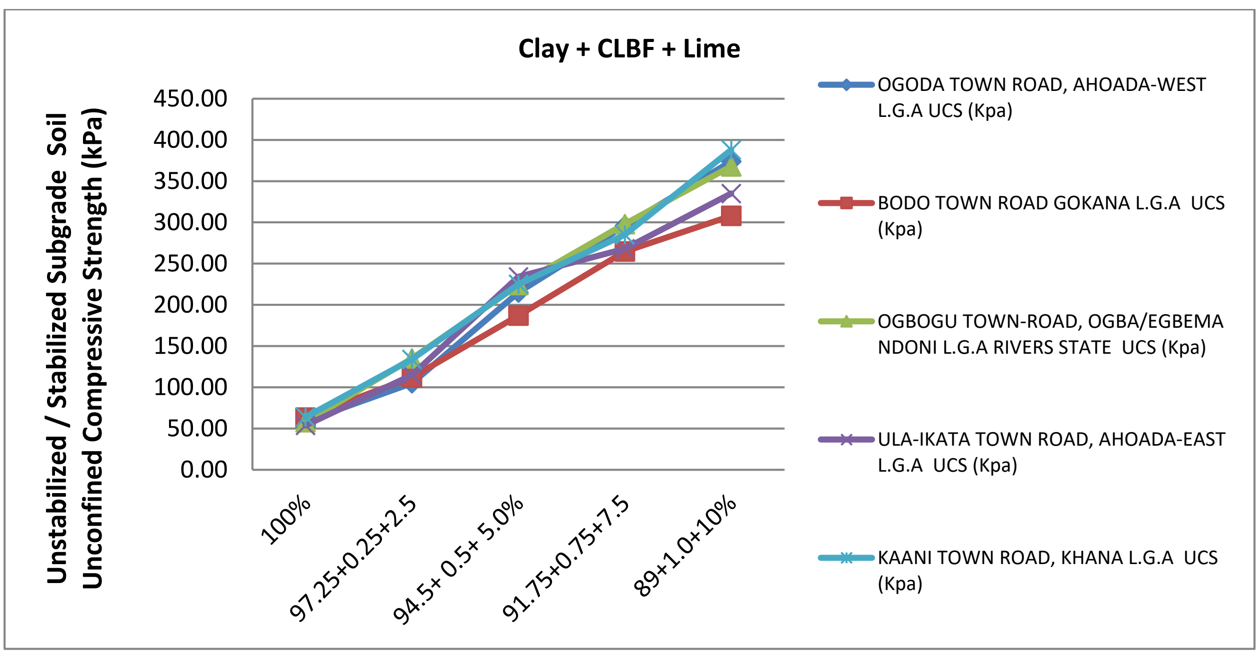

Figure 3.5: Unconfined Compressive Strength (UCS) of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns, Local Government Areas of Rivers State with CLBF+ Lime at Different Percentages and Combinations

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. The soils deposit belonged to the group A-7-6 of American Association of State and Transport Officials (AASHTO) soil classification system with plastic index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively

ii. Unconfined compressive strength test results increased with varying additive percentage ratio as seen in and figure 3.5.

Costaceae lacerus bagasse fibre (CLBF) + lime proved to be good composite combination in soil stabilization

iii. Detail results obtained showed increased values in both MDD and OMC, graphical representation of figures 3.1 and 3.2 showed increased values as ratio to percentage additives.

iv. Comparatively, stabilized clay soils CBR increased with increase in additives inclusion with optimum mix of 0.75% + 7.5%. Cracks noticed occurred beyond optimum level mix

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