Performance Characteristics of Cement, Lime - Pozzolanic Bagasse Fibre Ash Stabilized Expansive Lateritic Soils for Highway Pavement Materials

Terence Temilade Tam Wokoma[1], Charles Kennedy[2], Amakiri – Whyte Belema[3]

[1]**School of Engineering, Department of Civil Engineering, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria.**

[2]**Faculty of Engineering, Department of Civil Engineering, Rivers State University, Nkpolu, Port Harcourt, Nigeria**

[3]**Department of Architecture, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria.**

Authors E-mail: [1]terencett.wokoma@gmail.com, [2]ken_charl@yahoo.co.uk, [3]whytebh@gmail.com

ABSTRACT

Expansive soils within the Niger Delta territory has posed great concerns and challenges to civil engineering constructional works and has limited their design specifications, life spans and durability, thus, needs modifications to improve its properties and required strength. The study examined and evaluated the application of costaceae lacerus bagasse fibre ash in combination with cement and lime in varying mix ratio percentages of 95+2.5+2.5%, 90+5.0+5.0%, 85+7.5+7.5%, 80+10.0+10% and ascertained the variances in strengths. Preliminary results on lateritic soils as seen in detailed test results given in tables: 3.1 showed that the physical and engineering properties fall below the minimum requirement for such application of highway pavement materials. The soils classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System. Computed statistical descriptive percentile comparative compaction test results of maximum dry density (MDD) and optimum moisture content (OMC) from sampled roads are, Odioku, 1.015% and 1.021%, Oyigba 1.027% and 1.056%, Anakpo 1.024% and 1.043%, Upatabo 1.101% and 1.016%, Ihubuluko 1.038% and 11.037%, respectively of MDD and OMC. Results of California bearing ratio (CBR) test results of unsoaked are 2.626%, 3.724%, 3.635%, 3.048%, 3.014%, and soaked, 3.410%, 3.199%, 3.215%, 2.782%, 2.842%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively at 100% clay natural conditions. Unconfined compressive strength test of sampled roads are Odioku 1.275%, Oyigba 1.414%, Anakpo 1.303%, Upatabo 1.316% and Ihubuluko 1.483% respectively at 100% natural state. Compaction test results obtained of maximum dry density (MDD) and optimum moisture content (OMC) showed incremental percentile values with inclusion of composite stabilizers agents to soils with varying percentages ratio. Figures 3.2 and 3.3 graphically represented performance potential strengths of cement / lime and CLBFA, with cement hybridized composition at higher values to lime. California bearing ratio (CBR) of unsoaked and soaked stabilized soils with composite materials of cement, lime and CLBFA yielded incremental percentile vlues relatively to inclusion percentages ratio variations with optimum mix ratio of 85+7.5+7.5%. Crack formation noticed beyond optimum with values reductions. Results from figure 3.7 showed graphical representation of strength variance with cement at peak level of values. Results of unconfined compressive strength test from unstabilized and stabilized soils with cement / lime + CLBFA showed incremental percentile values as ratio of additives to soil increases. Obtained results showed decreased percentile values of consistency limits (Plastic index) with rate of decreased in stabilizer agents percentages to soils ratio. Results showed potential use of additives as soil stabilizers with cement in dominant strength values to lime.

Key Words: Clay soils, Costaceae Lacerus Bagasse Fibre Ash, Cement,CBR, UCS, Consistency, Compaction

1.0 Introduction

The rapid growth in development of Orashi's region of Niger Delta of Nigeria has resulted in demand for stronger and more durable roads that will meet the challenges. Subsequently, engineers are forced to be more careful in the utilization of construction materials. Variety of factors such as increase in construction volume, severe loading conditions, shortage of suitable materials as well as poor site conditions and high cost of additives (cement, lime etc) have greatly increased and the need for modification and stabilization of soils using agricultural waste.

Charles *et al.* [1] 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 were mixed in single and combines actions to improved their unique properties. Results of tests carried out show that the optimum moisture content increased with increasing cement ratios to both soils and. Treated soils with Cement decreased in liquid limits and increased in plastic limits. Soils with Cement and fibre products in combinations increased CBR appreciably both at soaked and unsoaked conditions.At 8% of lime, CBR reached optimum, beyond this range, cracks exist and 7.5% cement cement + 0. 75% BSBF, optimum value are reached.

Charles *et al.* [2] 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.

Charles *et al.* [3] 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.

Rao *et al*., [4] studied the effects of RHA, lime and gypsum on engineering properties of expansive soil and found that UCS increased by 548 % at 28 days of curing and CBR increased by 1350 % at 14 days curing at RHA- 20%, lime -5 % and gypsum -3%.

Goyal *et al*., [5] reported that SCBA with high specific surface area, high contents of amorphous silica and calcium oxide fulfilled the principal requirements of a pozzolanic material.

Ganesan *et al*., [6] studied on the use of bagasse ash (BA) as partial cement replacement material in respect of cement mortars. Up to 20 % of ordinary Portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete. Several studies have been carried out on the effectiveness of clay stabilization by RHA admixing.

Basha, *et al*., [7] studied the stabilization of residual soils by chemically using cement and RHA. In general, 6 %, 8 % of cement and 10 %, 15 % RHA show the optimum amount to reduce the plasticity of soil. CBR value determined maximum at 4% cement and 5 % RHA mixtures with soil. According to compressive strength and PI, 6 %, 8% of cement and 15 %,

20 % RHA showed the optimum amount to improve the properties of soils. Jha and Gill [8] evaluated the effectiveness of RHA to enhance the lime treatment of soil.

Sabat [9] studied the effect of lime sludge (from paper manufacturing industry) on compaction, CBR, shear strength parameters, coefficient of compression, Ps and durability of an expansive soil stabilized with optimum percentage of RHA after 7days of curing. The optimum proportion soil: RHA: lime sludge was found to be 75:10:15.

2.0 Materials and Methods

2.1 Materials

2.1.1 Soil

The soils used for the study were collected from Ubie, Upata and Igbuduya Districts of Ekpeye, Ahoada- East and Ahoada-West Local Government of Rivers State, beside the at failed sections of the Unity linked roads at 1.5 m depth, at 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, all of Rivers State, Niger Delta, Nigeria. It lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Costaceae Lacerus Bagasse Fibre Ash

The Costaceae Lacerus bagasse fibre are wide plants, medicinally used in the local areas, abundant in Rivers State farmlands / bushes, they covers larger areas, collected from at Oyigba Town Farmland / Bush, 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

2.1.4 Cement

The cement used was Portland Cemenet, purchased in the open market at Mile 3 market road, Port Harcourt, Rivers State.

2.2 Method

2.2.1 Sampling Locality

The soil sample used in this study were collected along Odioku Town, (latitude 5.07° 14‘S and longitude 6.65° 80‘E), Oyigba Town, (latitude 7.33° 24‘S and longitude 3.95° 48‘E), Oshika Town, latitude 4.05° 03‘S and longitude 5.02° 50‘E), Upatabo Town, (latitude 5.35° 34‘S and longitude 6.59° 80‘E) and Ihubujuko Town, latitude 5.37° 18‘S and longitude 7.91° 20‘E) all in Rivers State, Nigeria.

2.2.2 Test Conducted

Test conducted were (1) Moisture Content Determination (2) Consistency limits test (3) Particle size distribution (sieve analysis) and (4) Standard Proctor Compaction test, California Bearing Ratio test (CBR) and Unconfined compressive strength (UCS) tests;

2.2.3 Moisture Content Determination

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

2.2.4 Grain Size Analysis (Sieve Analysis)

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles.

2.2.5 Consistency Limits

The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second.

2.2.6 Moisture – Density (Compaction) Test

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort.

2.2.7 Unconfined Compression (UC) Test

The unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test. The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions

2.2.8 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test was developed by the California Division of Highways as a method of relegating and evaluating soil- subgrade and base course materials for flexible pavements.

3.0 Results and Discussions

Preliminary results on lateritic soils as seen in detailed test results given in Tables: 5 showed that the physical and engineering properties fall below the minimum requirement for such application and needs stabilization to improve its properties. The soils classified as A-2-6 / SC and A-2-4 / SM on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1 and are less matured in the soils vertical profile and probably much more sensitive to all forms of manipulation that other deltaic lateritic soils are known for. The soil has unsoaked CBR values of 8.7%,8.5%, 7.8%, 9.4%, and 10.6% and soaked CBR values of 8.3%, 7.8%, 7.2%, 8.5% and 9.8 %, unconfined compressive strength values of 178kPa, 145kPa, 165kPa,158kPa and 149kPa when compacted with British Standard light.

.3.1 Compaction Test Results

Compaction test results of maximum dry density (MDD) and optimum moisture content (OMC) derived from tables 3.2 and 3.3 into 3.2A and 3.3A are Odioku, 1.015% and 1.021%, Oyigba 1.027% and 1.056%, Anakpo 1.024% and 1.043%,

Upatabo 1.101% and 1.016%, Ihubuluko 1.038% and 11.037%, respectively of MDD and OMC. Same as above from tables 3.2, 3.3 into 3.3A, 3.3A, results of stabilized clay soil results with composites materials are Odioku laterite + Cement + CLBFA MDD, 2.138%, 7.767%, 8.791%, 12.015%, laterite + lime + CLBFA, 0.511%, 0.921%, 1.995%, 5.578%, OMC are laterite + Cement + CLBFA, 1.448%, 3.465%, 5.483%, 7.662%, laterite + lime + CLBFA, 1.448%, 1.770% , 4.434%, 9.276%. Oyigba MDD are laterite + cement + CLBFA, 5.104%, 5.643%, 11.028%, 16.413%, laterite + lime + CLBFA 0.860%, 2.044%, 4.252%, 6.783%. OMC are laterite + cement + CLBFA, 1.804%, 3.058%, 3.407%, 5.288%, laterite + cement + CLBFA, 1.804%, 2.988%, 4.661%, 8.563%. Anakpo MDD are laterite + cement + CLBFA, 5.378%, 8.959%, 10.657%, 12.510%, laterite + lime + CLBFA 0.924%, 1.696%, 2.623%,1.593%, OMC are laterite + cement + CLBFA, 2.868%, 4.312%, 4.673%, 7.416%, laterite + cement + CLBFA, 3.294%, 4.377%, 7.410%, 9.576%. Upatabo are MDD laterite + cement + CLBFA, 10.314%, 11.111%, 13.386%, 16.799%, laterite + lime + CLBFA, 0.908%, ,2.103%, 4.833%, 10.806% , OMC are laterite + cement + CLBFA 2.696%, 3.544%, 5.495%, 6.767%, laterite + lime + CLBFA, 1.353%, 1.861%, 4.236%, 6.272%. Compaction test results obtained of maximum dry density (MDD) and optimum moisture content (OMC) showed incremental percentile values with inclusion of composite stabilizers agents to soils with varying percentages ratio. Figures 3.2 and 3.3 graphically represented performance potential strengths of cement / lime and CLBFA, with cement hybridized composition at higher values to lime.

3.2 California Bearing Ratio (CBR) Test

Computed results from table 3.4 into 3.4A presented derived percentile values of California bearing ratio (CBR) test results of unsoaked are 2.626%, 3.724%, 3.635%, 3.048%, 3.014%, and soaked, 3.410%, 3.199%, 3.215%, 2.782%, 2.842%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively at 100% clay natural conditions. Stabilized unsoaked laterite + cement + CLBFA are 269.856%, 365.259% , 619.282%, 539.971%, laterite + lime + CLBFA; 169.117%, 290.956%, 486.933%, 444.979%, soaked laterite + cement + CLBFAA 211.397%, 306.577%, 547.541%, 415.011%, laterite + lime + CLBFA, 127.745%, 262.443%, 467.504%, 407.504%. Oyigba stabilized unsoaked laterite + cement + CLBFA are 250.903%, 325.021%, 522.079%, 440.903%, laterite + lime + CLBFA, 172.413%, 258.296%, 483.001%, 426.531% ,soaked laterite + cement + CLBFA, 201.788%, 297.942%, 468.454%, 404.352%, laterite + lime + CLBFA, 139.982%, 231.777%, 471.649%, 433.187%. Anakpo unsoaked laterite + cement + CLBFA are 244.430%, 332.892%, 455.328%, 382.892%, laterite + lime + CLBFA, 161.909%, 265.114%, 449.088%, 368.319%, soaked laterite + cement + CLBFA, 215.624%, 315.624%, 425.346%, 359.374%, laterite + lime + CLBFA, 179.224%, 264.363%, 463.668%, 383.807%. Upatabo unsoaked laterite + cement + CLBFA are 244.046%, 266.918%, 539.259%, 467.982%, laterite + lime + CLBFA are 214.310%, 313.247%, 474.949%, 423.885%, soaked laterite + cement + CLBFA, 237.637%, 359.402%, 531.166%, 465.284%, laterite + lime + CLBFA 209.727%, 304.668%, 481.139%, 427.845%. Ihubuluko unsoaked laterite + cement + CLBFA are 233.285%, 337.530%, 571.021%, 513.473%, laterite + lime + CLBFA, 211.640%, 289.942%, 429.565%, 390.414%, soaked laterite + cement + CLBFA, 197.495%, 302.597%, 553.617%, 491.882%, laterite + lime + CLBFA, 2183.605%, 265.748%, 408.605%, 372.380%. Figure 3.4 represented strength characteristics of sampled soils with varying percentages of composite materials with cement compositions in higher values dominance over lime. California bearing ratio (CBR) of unsoaked and soaked stabilized soils with composite materials of cement, lime and CLBFA yielded incremental percentile relatively to inclusion percentages ratio variations with optimum mix ratio of 85+7.5+7.5%. Crack formation noticed beyond optimum with values reductions.

3.3 Unconfined Compressive Strength Test

Percentile derived values from table 3.5 into 3.5A of unconfined compressive strength test from sampled roads are Odioku 1.275%, Oyigba 1.414%, Anakpo 1.303%, Upatabo 1.316% and Ihubuluko 1.483% respectively at 100% natural state. Stabilized composite materials unconfined compressive strength of Odioku laterite + cement + CLBFA are 28.339%, 62.047%, 80.586%, 123.283%, laterite + lime + CLBFA 32.248%, 41.237%, 69.327%, 93.484% , Oyigba laterite + cement + CLBFA are 37.833%, 86.108%, 127.488%, 167.488%, laterite + lime + CLBFA, 25.914%, 48.673%, 75.569%, 101.776%. Anakpo laterite + cement + CLBFA are 33.566%, 74.779%, 106.900%, 142.051%, laterite + lime + CLBFA 22.932%, 42.932%, 71.417%, 90.205% .Upatabo laterite + cement + CLBFA are 30.586%, 63.498%, 94.510%, 119.827%, laterite + lime + CLBFA 25.023%, 35.150%, 54.770%, 93.377%, Ihubuluko laterite + cement + CLBFA, 67.528%, 90.287%, 112.356%, 147.528%, laterite + lime + CLBFA 22.218%, 43.597%, 75.321%, 103.597%. Results from figure 3.7 showed graphical representation of strength variance with cement at peak level of values. Results of unconfined compressive strength test from unstabilized and stabilized soils with cement / lime + CLBFA showed incremental percentile values as ratio of additives to soil increases.

3.4 Consistency Limits Test

Results from tables 3.4, 3.5 and 3.6 developed summarized percentile values of tables 3.4A, 3.5A into 3.6A of consistency limits (Plastic index) test results at 100% natural condition from sampled roads are Odioku 0.936%, Oyigba 1.019%, Anakpo 1.069%, Upatabo 0.947% and Ihubuluko 1.038%. Stabilized Odioku laterite + cement + CLBFA are-2.326%, -3.886%,-4.060% , -5.736%, laterite + lime + CLBFA -1.392%, -2.317%, -3.473%, -5.381%, Oyigba laterite + cement + CLBFA -3.259%, -5.367%, -7.124%, -10.146%, laterite + lime + CLBFA -2.831%, -4.026%, -7.610%, -9.858%. Anakpo laterite + cement + CLBFA laterite + cement + CLBFA -3.029%, -3.814%, -6.232%,-7.539%, laterite + lime + CLBFA -3.295%, -4.537%, -6.694%, -8.981%, Upatabo laterite + cement + CLBFA --6.742%, -10.399%, -11.142%, -12.856%, laterite + lime + CLBFA --5.211%, -6.354%, -9.211%, -10.925%, Ihubuluko laterite + cement + CLBFA -1.246%, -1.867%, -5.283%, -9.631%, laterite + lime + CLBFA -2.752% , -4.926%, -6.230%, -7.907%. Figures 3.4, 3.5 and 3.6 exemplified graphs presentation of consistency limits with cement composition in dominance reduction over lime. Obtained results showed decreased percentile values of consistency limits (Plastic index) with rate of decreased in stabilizer agents percentages to soils ratio.

Table 3.1: Engineering Properties of Soil Samples of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

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	
(%) 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/ UCS classification	A-2-6/SC	A-2-4/SM	A-2-4/SM	A-2-6/SC	A-2-4/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 Maximum Dry Density (MDD) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
MDD (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	1.95	1.98	2.09	2.11	2.17
MDD (kN/m3) (Laterite + Lime + CLBFA)ODIOKWU TOWN ROAD	1.95	1.96	1.97	1.99	2.06
MDD (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	1.86	1.91	1.92	2.02	2.12
MDD (kN/m3) (Laterite + Lime + CLBFA)OYIGBA TOWN ROAD	1.86	1.87	1.89	1.93	1.98
MDD (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	1.94	1.99	2.08	2.11	2.14
MDD (kN/m3) (Laterite + Lime + CLBFA)ANAKPO TOWN ROAD	1.94	1.95	1.97	1.99	1.97
MDD (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	1.76	1.85	1.87	1.91	1.97
MDD (kN/m3) (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	1.76	1.77	1.79	1.84	1.94
MDD (Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	2.11	2.23	2.31	2.41	2.44
MDD (kN/m3) (Laterite + Lime + CLBFA)IHUBULUKO TOWN ROAD	2.11	2.11	2.13	2.24	2.18

Table 3.2A: Results of Maximum Dry Density (MDD) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
MDD (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	1.01%	2.14%	7.77%	8.79%	12.02%
MDD (kN/m3) (Laterite + Lime + CLBFA)ODIOKWU TOWN ROAD	1.00%	0.51%	0.92%	2.00%	5.58%
MDD (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	1.03%	5.10%	5.64%	11.03%	16.41%
MDD (kN/m3) (Laterite + Lime + CLBFA)OYIGBA TOWN ROAD	1.00%	0.86%	2.04%	4.25%	6.78%
MDD (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	1.02%	4.38%	8.96%	10.66%	12.51%
MDD (kN/m3) (Laterite + Lime + CLBFA)ANAKPO TOWN ROAD	1.00%	0.92%	1.70%	2.62%	1.59%
MDD (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	1.05%	10.31%	11.11%	13.39%	16.80%
MDD (kN/m3) (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	1.00%	0.91%	2.10%	4.83%	10.81%
MDD (Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	1.06%	11.09%	14.89%	19.65%	21.07%
MDD (kN/m3) (Laterite + Lime + CLBFA)IHUBULUKO TOWN ROAD	1.00%	0.85%	1.52%	6.60%	4.18%

Table 3.3: Results of Optimum Moisture Content (OMC) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
OMC%(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	12.39	12.48	12.73	12.98	13.25
OMC%(Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	12.39	12.48	12.52	12.85	13.45
OMC%(Laterite + Cement+ CLBFA) OYIGBA TOWN ROAD	14.35	14.48	14.66	14.71	14.98
OMC%(Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	14.35	14.48	14.65	14.89	15.45

OMC% (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	13.85	14.05	14.25	14.30	14.68
OMC%(Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	13.85	14.08	14.23	14.65	14.95
OMC% (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	11.79	11.95	12.05	12.28	12.43
OMC%(Laterite + Lime + CLBFA) UPATABO TOWN ROAD	11.79	11.87	11.93	12.21	12.45
OMC%(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	10.95	11.05	11.28	11.33	12.62
OMC%(Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	10.95	11.08	11.25	11.65	11.95

Table 3.3A: Results of Optimum Moisture Content (OMC) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
OMC%(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	1.01%	1.45%	3.47%	5.48%	7.66%
OMC%(Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	1.01%	1.45%	1.77%	4.43%	9.28%
OMC%(Laterite + Cement+ CLBFA) OYIGBA TOWN ROAD	1.01%	1.80%	3.06%	3.41%	5.29%
OMC%(Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	1.01%	1.80%	2.99%	4.66%	8.56%
OMC% (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	1.01%	2.87%	4.31%	4.67%	7.42%
OMC%(Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	1.02%	3.29%	4.38%	7.41%	9.58%
OMC% (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	1.01%	2.70%	3.54%	5.49%	6.77%
OMC%(Laterite + Lime + CLBFA) UPATABO TOWN ROAD	1.01%	1.35%	1.86%	4.24%	6.27%
OMC%(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	1.01%	1.82%	3.92%	4.38%	16.16%
OMC%(Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	1.01%	2.36%	3.91%	7.57%	10.31%

Table 3.4: Results of California Bearing Ratio (CBR) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
UNSOAKED (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	8.70	26.35	34.65	56.75	49.85
UNSOAKED (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	8.70	18.75	29.35	46.40	42.75
SOAKED(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	8.30	20.85	28.75	48.75	37.75
SOAKED (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	8.30	15.15	26.33	43.35	38.37
UNSOAKED (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	8.50	24.30	30.60	47.35	40.45
UNSOAKED (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	8.50	18.55	25.85	44.95	40.15
SOAKED(Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	7.80	18.95	26.45	39.75	34.75
SOAKED (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	7.80	14.98	22.14	40.85	37.85
UNSOAKED (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	7.80	21.85	28.75	38.30	32.65
UNSOAKED (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	7.80	16.35	24.40	38.75	32.45
SOAKED(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	7.20	18.35	25.55	33.45	28.70
SOAKED (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	7.20	16.12	22.25	36.60	30.85
UNSOAKED (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	9.40	26.30	28.45	54.05	47.35
UNSOAKED (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	9.40	23.85	33.15	48.35	43.55
SOAKED(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	8.50	23.30	33.65	48.25	42.65
SOAKED (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	8.50	21.23	29.30	44.30	39.77
UNSOAKED(Laterite + Cement + CLBFA) IHUBULUKO TOWN	10.60	28.65	39.70	64.45	58.35

ROAD					
UNSOAKED (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	10.60	26.65	34.95	49.75	45.60
SOAKED(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	9.80	23.45	33.75	58.35	52.30
SOAKED (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	9.80	22.30	30.35	44.35	40.80

Table 3.4A: Results of California Bearing Ratio (CBR) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
UNSOAKED (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	3.03%	269.86%	365.26%	619.28%	539.97%
UNSOAKED (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	2.16%	169.12%	290.96%	486.93%	444.98%
SOAKED(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	2.51%	211.40%	306.58%	547.54%	415.01%
SOAKED (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	1.83%	127.74%	262.44%	467.50%	407.50%
UNSOAKED (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	2.86%	250.90%	325.02%	522.08%	440.90%
UNSOAKED (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	2.18%	172.41%	258.30%	483.00%	426.53%
SOAKED(Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	2.43%	201.79%	297.94%	468.45%	404.35%
SOAKED (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	1.92%	139.98%	231.78%	471.65%	433.19%
UNSOAKED (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	2.80%	244.43%	332.89%	455.33%	382.89%
UNSOAKED (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	2.10%	161.91%	265.11%	449.09%	368.32%
SOAKED(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	2.55%	215.62%	315.62%	425.35%	359.37%
SOAKED (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	2.24%	179.22%	264.36%	463.67%	383.81%
UNSOAKED (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	2.80%	244.05%	266.92%	539.26%	467.98%
UNSOAKED (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	2.54%	214.31%	313.25%	474.95%	423.88%
SOAKED(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	2.74%	237.64%	359.40%	531.17%	465.28%
SOAKED (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	2.50%	209.73%	304.67%	481.14%	427.84%
UNSOAKED(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	2.70%	233.28%	337.53%	571.02%	513.47%
UNSOAKED (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	2.51%	211.64%	289.94%	429.56%	390.41%
SOAKED(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	2.39%	197.49%	302.60%	553.62%	491.88%
SOAKED (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	2.28%	183.60%	265.75%	408.60%	372.38%

Table 3.5: Results of Liquid Limit (LL) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
LL(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	39.75	41.05	42.68	43.78	44.36
LL (Laterite + Lime + CLBFA)ODIOKWU TOWN ROAD	39.75	39.58	39.15	38.75	38.21
LL(Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	36.90	37.85	38.15	39.55	40.15
LL (Laterite + Lime + CLBFA)OYIGBA TOWN ROAD	36.90	35.93	35.65	35.26	34.88
LL(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	36.75	37.15	37.65	38.23	38.85
LL (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	36.75	36.45	36.15	35.98	35.23

LL(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	36.85	37.90	38.25	38.68	39.35
LL (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	36.85	36.65	36.65	36.03	35.70
LL(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	37.65	38.15	38.65	38.75	39.12
LL (Laterite + Lime + CLBFA)IHUBULUKO TOWN ROAD	37.65	37.35	37.08	36.77	36.25

Table 3.5A: Results of Liquid Limit (LL) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
LL(Laterite + Cement+ CLBFA) ODIOKWU TOWN ROAD	1.03%	6.44%	10.54%	13.31%	14.76%
LL (Laterite + Lime + CLBFA)ODIOKWU TOWN ROAD	1.00%	-0.86%	-1.94%	-2.95%	-4.30%
LL(Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	1.03%	5.08%	5.90%	9.69%	11.32%
LL (Laterite + Lime + CLBFA)OYIGBA TOWN ROAD	0.97%	-5.33%	-6.09%	-7.14%	-8.17%
LL(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	1.01%	2.17%	3.53%	5.10%	6.79%
LL (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	0.99%	-1.64%	-2.46%	-2.92%	-4.96%
LL(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	1.03%	5.62%	6.57%	7.74%	9.55%
LL (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	0.99%	-1.09%	-1.09%	-2.77%	-3.67%
LL(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	1.01%	2.64%	3.97%	4.23%	5.21%
LL (Laterite + Lime + CLBFA)IHUBULUKO TOWN ROAD	0.99%	-1.60%	-2.32%	-3.14%	-4.52%

Table 3.6: Results of Plastic Limit (PL) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
PL(Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	22.45	24.65	25.85	26.98	27.85
PL (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	22.45	22.40	22.13	21.93	21.72
PL(Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	22.67	23.85	24.45	26.10	27.13
PL (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	22.67	21.90	21.79	21.91	20.82
PL(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	21.45	22.08	22.70	23.18	26.00
PL (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	21.45	21.40	20.29	21.45	21.55
PL(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	19.35	20.48	21.37	22.55	23.50
PL (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	19.35	19.50	19.50	19.68	19.65
PL(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	21.55	22.15	22.75	23.10	23.77
PL (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	21.55	21.47	21.55	21.45	21.20

Table 3.6A: Results of Plastic Limit (PL) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
PL(Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	1.10%	18.72%	24.07%	29.10%	32.98%
PL (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	1.00%	-0.45%	-1.65%	-2.54%	-3.47%
PL(Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	1.05%	10.15%	12.80%	20.08%	24.62%

PL (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	0.97%	-6.91%	-7.40%	-6.87%	-11.68%
PL(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	1.03%	5.79%	8.68%	10.92%	24.07%
PL (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	1.00%	-0.47%	-5.64%	-0.23%	0.23%
PL(Laterite + Cement + CLBFA) UPATABO TOWN ROAD	1.06%	11.36%	15.96%	22.06%	26.96%
PL (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	1.01%	1.54%	1.54%	2.47%	2.32%
PL(Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	1.03%	5.49%	8.28%	9.90%	13.01%
PL (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	1.00%	-0.74%	-0.37%	-0.84%	-2.00%

Table 3.7: Results of Plastic Index (PI) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
PI (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	17.30	17.10	16.83	16.80	16.51
PI (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	17.30	17.18	17.02	16.82	16.49
PI (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	14.23	14.00	13.70	13.45	13.02
PI (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	14.23	14.03	13.86	13.35	13.03
PI (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	15.30	15.07	14.95	13.05	12.85
PI (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	15.30	15.05	14.86	14.53	14.18
PI (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	17.50	16.92	16.28	16.15	15.85
PI (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	17.50	17.05	16.85	16.35	16.05
PI (Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	16.10	16.00	15.90	15.35	14.65
PI (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	16.10	15.88	15.53	15.32	15.05

Table 3.7A: Results of Plastic Limit (PL) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
PI (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	0.99%	-2.33%	-3.89%	-4.06%	-5.74%
PI (Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	0.99%	-1.39%	-2.32%	-3.47%	-5.38%
PI (Laterite + Cement + CLBFA) OYIGBA TOWN ROAD	0.98%	-3.26%	-5.37%	-7.12%	-10.15%
PI (Laterite + Lime + CLBFA) OYIGBA TOWN ROAD	0.99%	-2.83%	-4.03%	-7.61%	-9.86%
PI (Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	0.98%	-3.03%	-3.81%	-16.23%	-17.54%
PI (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	0.98%	-3.30%	-4.54%	-6.69%	-8.98%
PI (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	0.97%	-6.74%	-10.40%	-11.14%	-12.86%
PI (Laterite + Lime + CLBFA) UPATABO TOWN ROAD	0.97%	-5.21%	-6.35%	-9.21%	-10.93%
PI (Laterite + Cement + CLBFA) IHUBULUKO TOWN ROAD	0.99%	-1.25%	-1.87%	-5.28%	-9.63%
PI (Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD	0.99%	-2.75%	-4.93%	-6.23%	-7.91%

Table 3.8: Results of Unconfined Compressive Strength (UCS) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5 +2.5%	90+5.0 +5.0%	85+7.5 +7.5%	80+10.0 +10%
UCS (Laterite + Cement + CLBFA) ODIOKWU TOWN ROAD	178.00	205.00	265.00	298.00	374.00
UCS(Laterite + Lime + CLBFA) ODIOKWU TOWN ROAD	178.00	209.00	225.00	275.00	318.00

UCS (Laterite + Cement + CLBFA)OYIGBA TOWN ROAD	145.00	175.00	245.00	305.00	363.00
UCS(Laterite + Lime + CLBFA)BODO TOWN ROAD	145.00	165.00	198.00	237.00	275.00
UCS(Laterite + Cement + CLBFA) ANAKPO TOWN ROAD	165.00	195.00	263.00	316.00	374.00
UCS (Laterite + Lime + CLBFA) ANAKPO TOWN ROAD	165.00	185.00	218.00	265.00	296.00
UCS (Laterite + Cement + CLBFA) UPATABO TOWN ROAD	158.00	184.00	236.00	285.00	325.00
UCS(Laterite + Lime + CLBFA) UPATABO TOWN ROAD	158.00	179.00	195.00	226.00	287.00
UCS (Laterite + Cement + CLBFA) IHUBULUKOTOWN ROAD,	145.00	202.00	235.00	267.00	318.00
UCS(Laterite + Lime + CLBFA) IHUBULUKO TOWN ROAD,	145.00	162.00	193.00	239.00	280.00

Table 3.8A: Results of Unconfined Compressive Strength (UCS) Percentile Increase / Decrease of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

RATIO %	100%	95+2.5+2.5%	90+5.0+5.0%	85+7.5+7.5%	80+10.0+10%
UCS (Laterite + Cement + CLBFA) Odiokwu Town Rd	1.151685	28.33927	62.04714	80.58646	123.2831
UCS(Laterite + Lime + CLBFA) Odiokwu Town Rd	1.174157	32.24827	41.23703	69.32692	93.48422
UCS (Laterite + Cement + CLBFA) Oyigba Town Rd	1.206897	37.83251	86.10837	127.4877	167.4877
UCS(Laterite + Lime + CLBFA) Oyigba Town Rd	1.137931	25.91432	48.67294	75.56949	101.7764
UCS(Laterite + Cement + CLBFA) Anakpo Town Rd	1.181818	33.56643	74.77855	106.8998	142.0513
UCS (Laterite + Lime + CLBFA) Anakpo Town Rd	1.121212	22.93202	42.93202	71.41687	90.20475
UCS (Laterite + Cement + CLBFA) Upatabo Town Rd	1.164557	30.58613	63.49752	94.51018	119.8266
UCS(Laterite + Lime + CLBFA) Upatabo Town Rd	1.132911	25.02298	35.14957	54.76982	93.37741
UCS (Laterite + Cement + CLBFA) Ihubulukotown Rd,	1.393103	67.52817	90.28679	112.3558	147.5282
UCS(Laterite + Lime + CLBFA) Ihubuluko Town Rd,	1.117241	22.21797	43.59728	75.32141	103.5973

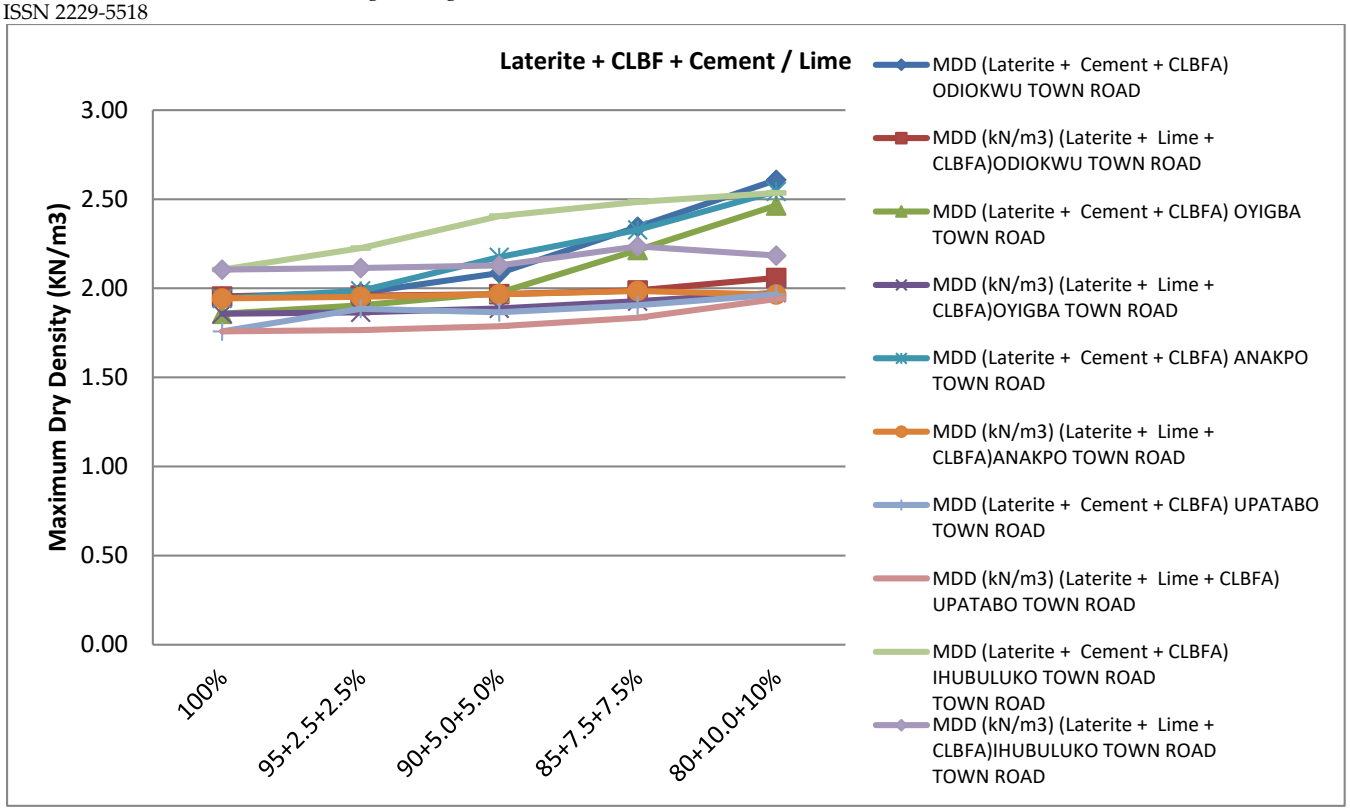

Figure 3.1: Maximum Dry Density (MDD) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

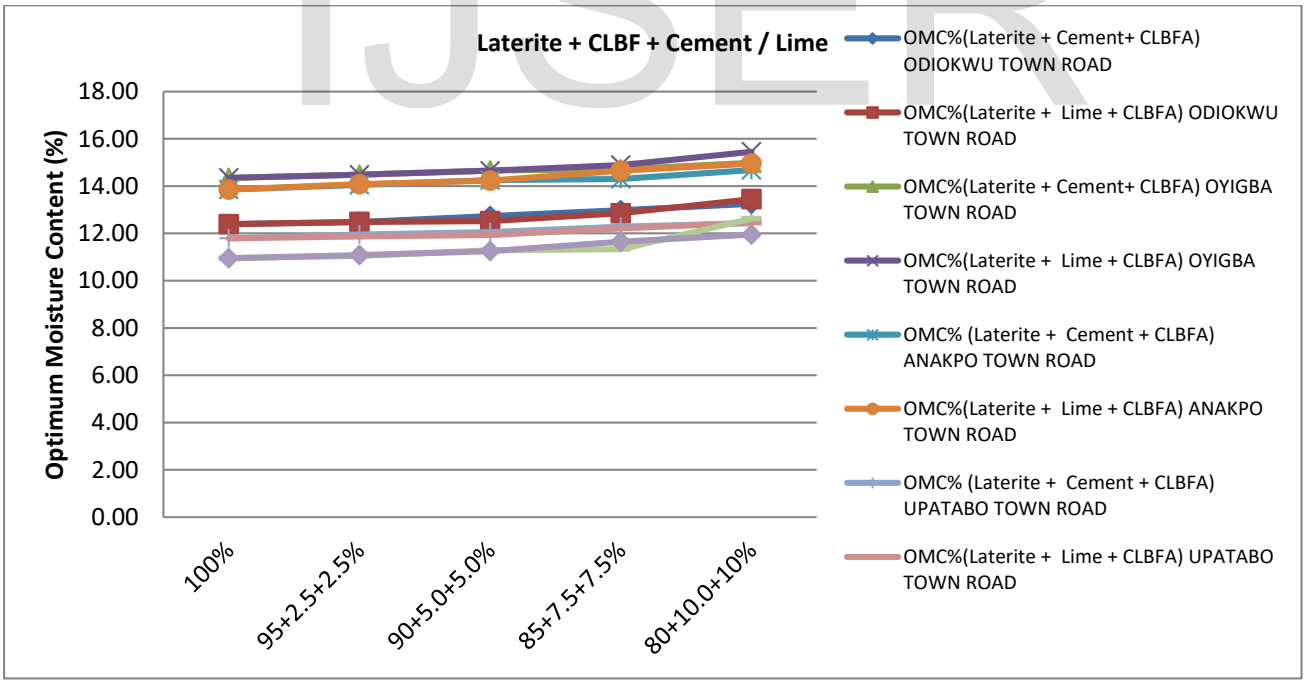

Figure 3.2: Optimum Moisture Content (OMC) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

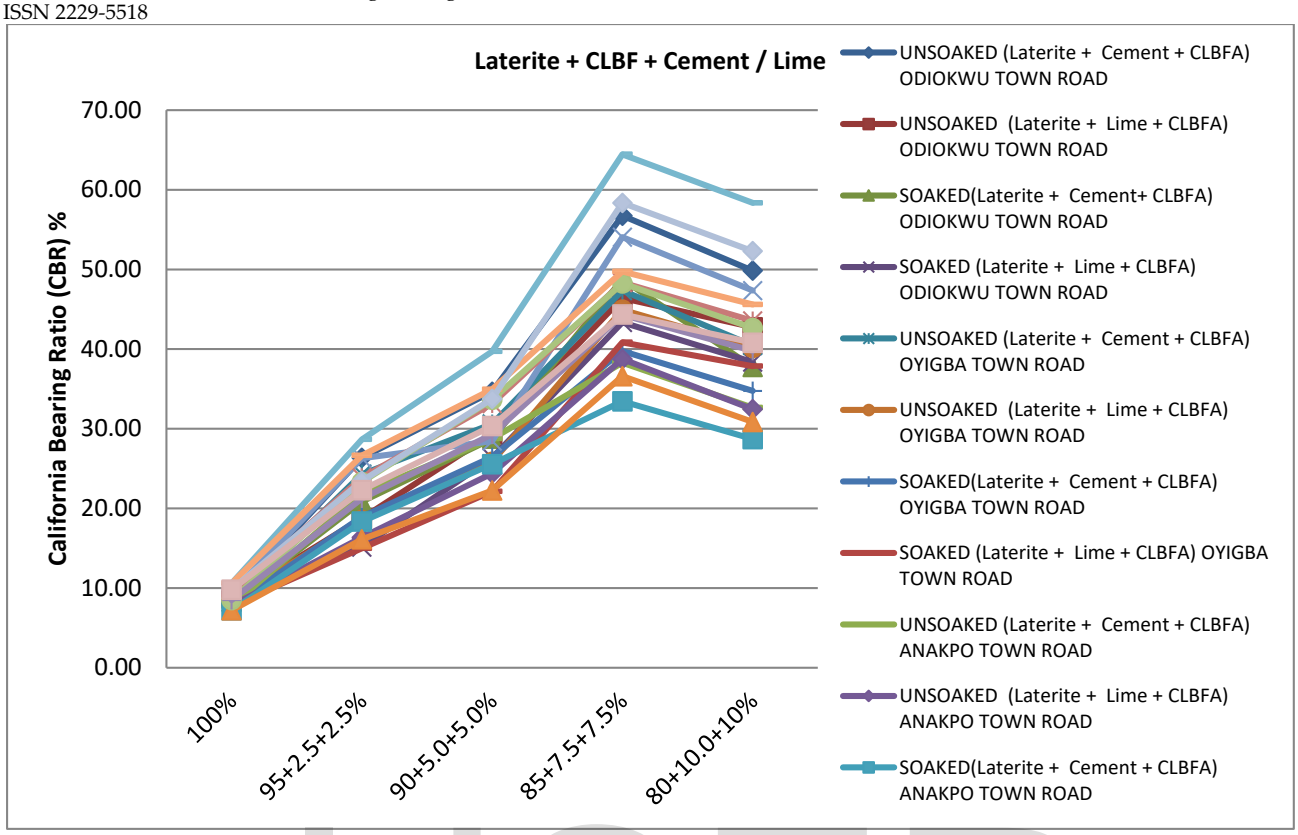

Figure 3.3: California Bearing Ratio (CBR) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

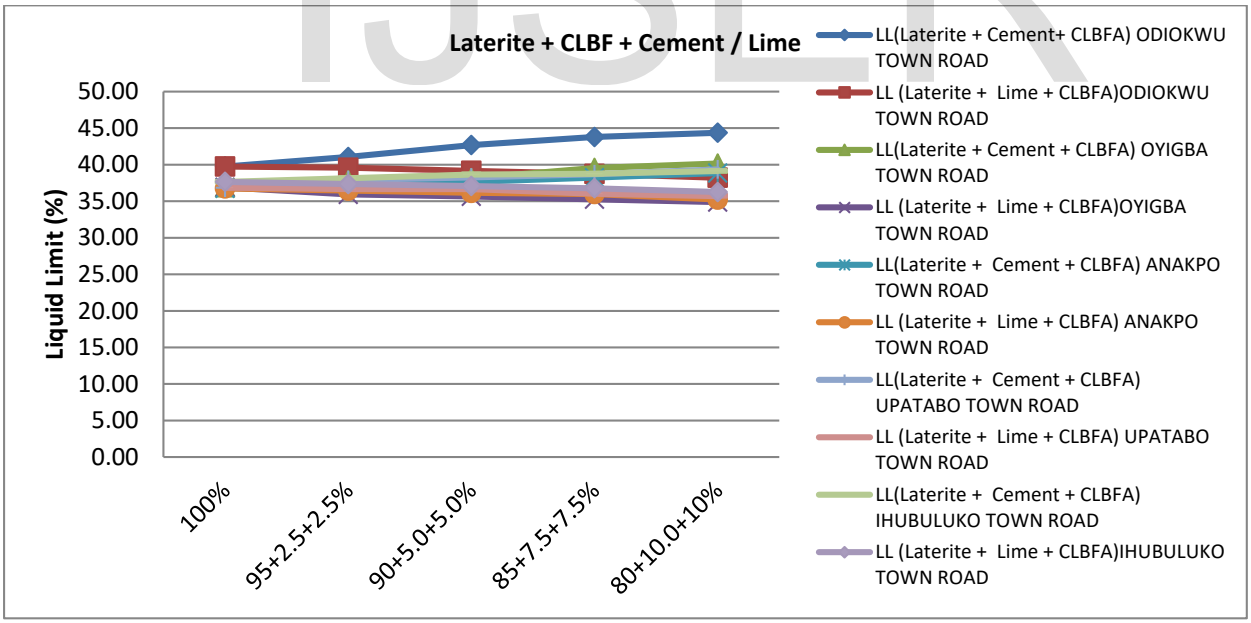

Figure 3.4: Liquid Limit (LL) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

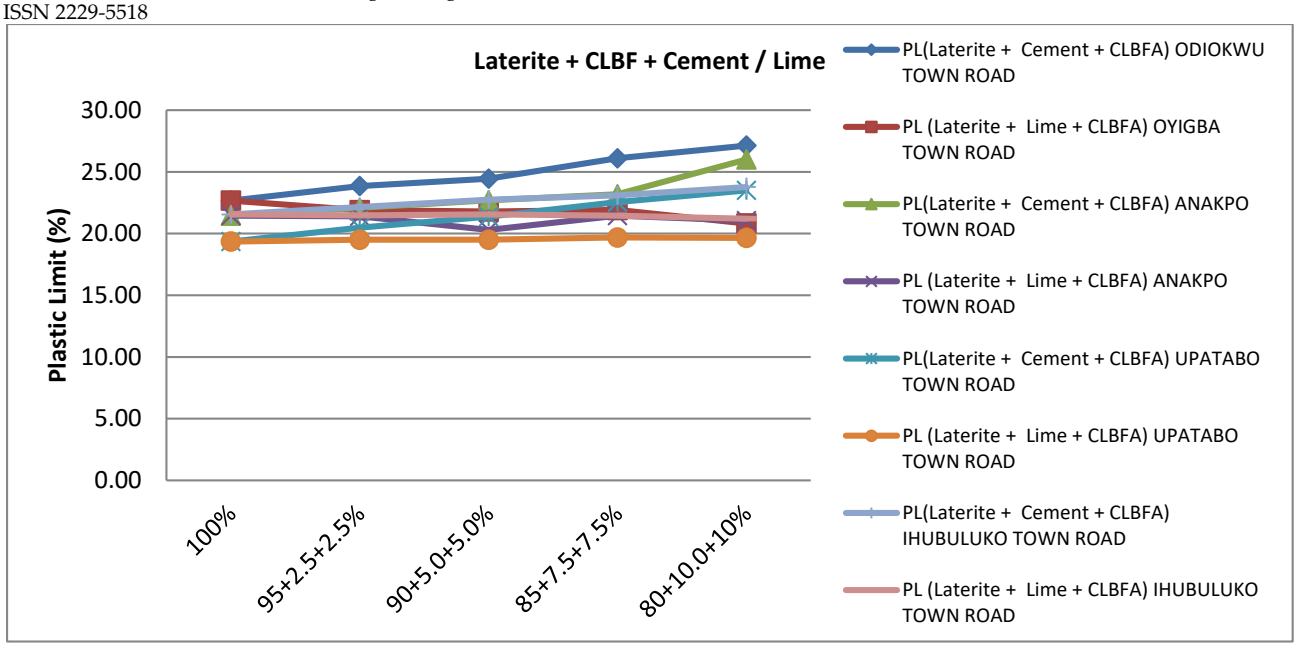

Figure 3.5: Plastic Limit (PL) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

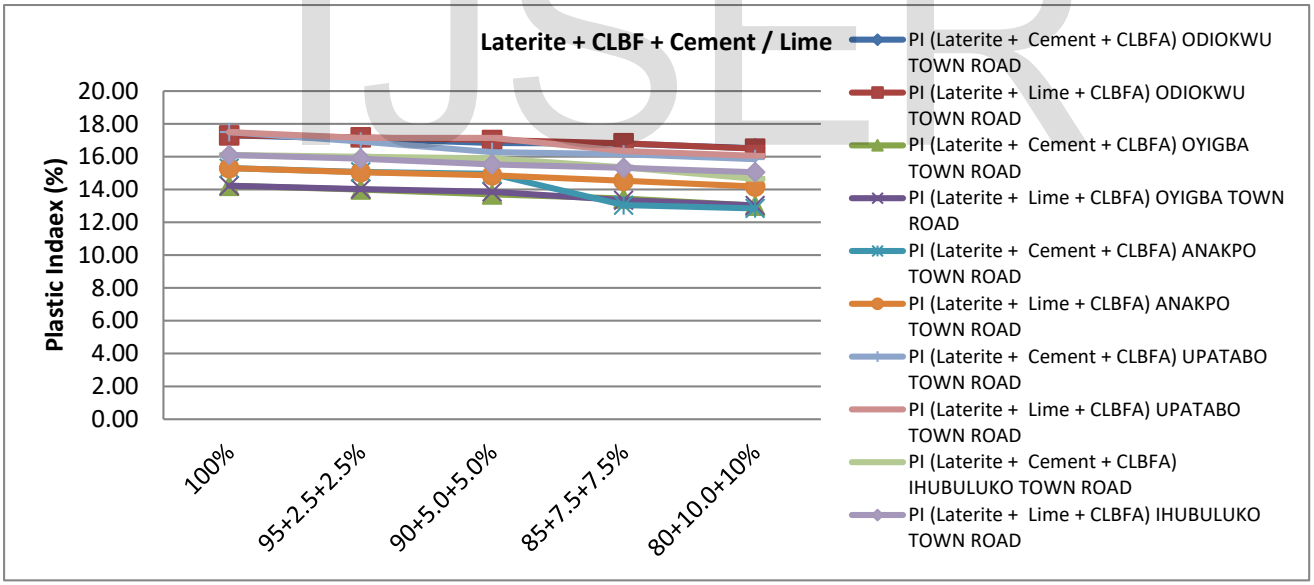

Figure 3.6: Plastic Index (PI) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

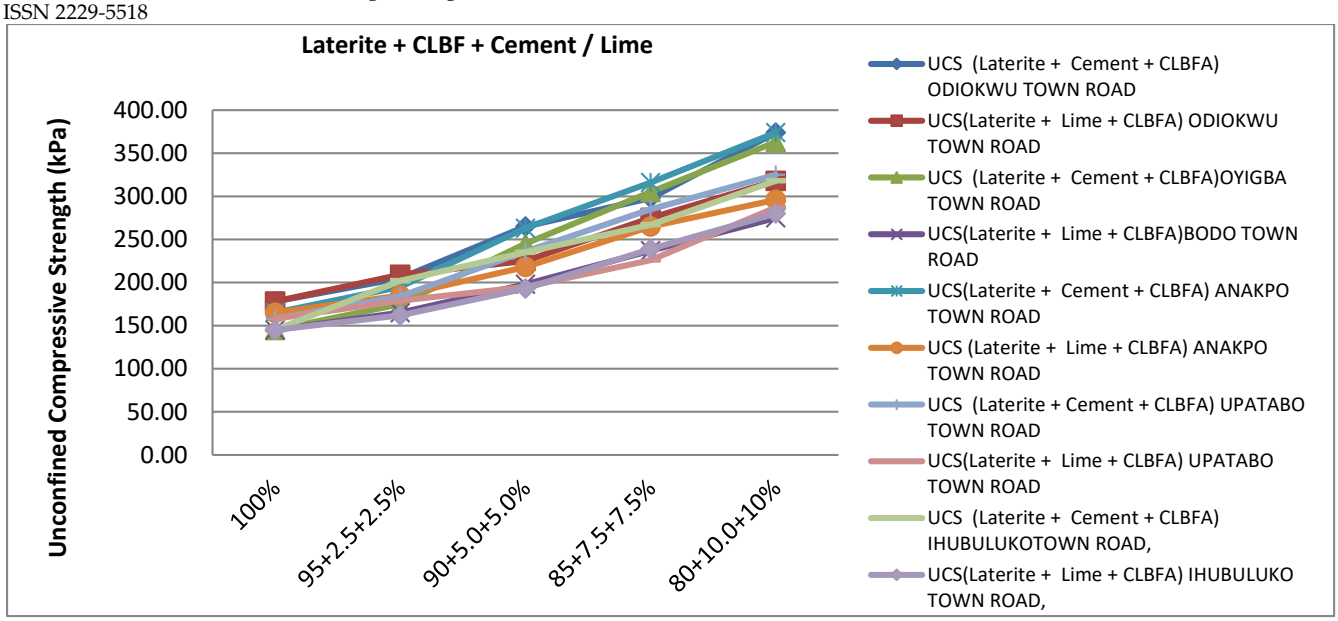

Figure 3.7: Unconfined Compressive Strength (UCS) of Niger Deltaic Lateritic Soils Subgrade with CLBFA + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. The soils classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System

ii. Computed statistical descriptive percentile comparative compaction test results of maximum dry density (MDD) and optimum moisture content (OMC) from sampled roads are, Odioku, 1.015% and 1.021%, Oyigba 1.027% and 1.056%, Anakpo 1.024% and 1.043%, Upatabo 1.101% and 1.016%, Ihubuluko 1.038% and 11.037%, respectively of MDD and OMC.

iii. Results of California bearing ratio (CBR) test results of unsoaked are 2.626%, 3.724%, 3.635%, 3.048%, 3.014%, and soaked, 3.410%, 3.199%, 3.215%, 2.782%, 2.842%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively at 100% clay natural conditions

iv. Unconfined compressive strength test of sampled roads are Odioku 1.275%, Oyigba 1.414%, Anakpo 1.303%, Upatabo 1.316% and Ihubuluko 1.483% respectively at 100% natural state.

v. California bearing ratio (CBR) of unsoaked and soaked stabilized soils with composite materials of cement, lime and CLBFA yielded incremental percentile values relatively to inclusion percentages ratio variations with optimum mix ratio of 85+7.5+7.5%.

vi. Obtained results showed decreased percentile values of consistency limits (Plastic index) with rate of decreased in stabilizer agents percentages to soils ratio. Results showed potential use of additives as soil stabilizers.

References

[1] K. Charles, L. P. Letam, O. Kelechi, "Comparative on Strength Variance of Cement / Lime with Costus Afer Bagasse Fibre Ash Stabilized Lateritic Soil", *Global Scientific Journal*, vol.6, no.5, pp. 267-278, 2018

[2] K. Charles, O. A. Tamunokuro, T. T. W. Terence, "Comparative Evaluation of Cement Effectiveness of Cement/Lime and Costus Afer Bagasse Fiber Stabilization of Expansive Soil", *Global Scientific Journal*, vol. 6, no.5, pp. 97-110, 2018.

[3] K. Charles, T.T.W. Terence, S. K. Gbinu,"Effect of Composite Materials on Geotechnical Characteristics of Expansive Soil Stabilization Using Costus Afer and Lime", *Journal of Scientific and Engineering Research*, vol.5, no.5, pp. 603-613, 2018.

[4] D. K. Rao, P. R, T. Pranav and M. Anusha, "Stabilisation of Expansive Soil using Rice Husk Ash, Lime and Gypsum-an Experimental Study", *International Journal of Engineering Science and Technology*, vol.3, no.11, pp. 8076-8085, 2011.

[5] A. Goyal, A.M. Anwar, H. Kunio, O. Hidehiko," Properties of sugarcane bagasse ash and its potential as cement – Pozzolana binder", Twelfth International Colloquium on Structural and Geotechnical Engineering, 10-12 Dec. 2007. Cairo Egypt

[6] K.Ganesan, K. Rajagopal, and K. Thangavel, "Evaluation of Bagasse Ash as Supplementary Cementitious Material", Cement and Concrete Composites, no.29, pp. 515-524, 2007.

[7] E. A. Basha, R. Hashim, H. B. Mahmud and A. S. Muntohar, "Stabilization of Residual Soil with Rice Husk Ash and Cement Stabilization of Residual Soil With Rice Husk Ash and Cement", Construction and Building Materials, vol.19, pp. 448 – 453, 2005.

[8] J. N. Jha and K. S. Gill, "Effect of rice husk ash on lime stabilization", *Journal of the Institution of Engineers (India)*, no.87, pp. 33-39, 2006.

[9] A. K. Sabat, "Effect of Polypropylene Fiber on Engineering Properties of Rice Husk Ash – Lime Stabilized Expansive Soil", *Electronic Journal of Geotechnical Engineering*, no.17(E), pp. 651-660, 2012.