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MODIFICATION OF EXPANSIVE LATERITIC SOILS OF HIGHWAY SUBGRADE WITH BLENDED COMPOSITE MATERIALS AND PERFORMANCE CHARACTERISTICS

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ABSTRACT

Susceptible degradations and excessive settlements of highway pavements has been the major issue of concerns in the Niger Delta region. Roads within this region have to undergo routine repairs seasonally to curb the menaces of unusual potholes and cracks. The research work evaluated the engineering behavioral characteristics of stabilized expansive lateritic soils with cement, lime and irvinga gabonesis fibre, their combined strength characteristics. Preliminary test results of lateritic soils as seen in table 3.1 showed that the physical and engineering properties fell 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. Percentile descriptive statistical tests of sampled roads maximum dry density (MDD) and optimum moisture content (OMC) are Odioku, 1.006% and 1.010%, Oyigba 1.012%, and 1.022%, Anakpo 1.013% and 1.014%, Upatabo 1.010% and 1.025%, Ihubuluko 1.011% and 1.024% respectively of MDD and OMC at 100% natural soils. Results obtained of California Bearing Ratio (CBR) test conducted at preliminary state of 100% are unsoaked 4.644%, 4.447%,3.696%, 4.835%, 4.467% and soaked, 4.382%, 4.321%, 3.576%, 4.921%, 4.551%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively. Unconfined compressive strength test conducted at preliminary stages of 100% natural soil from sampled roads yielded the following peak percentile results; Odioku 1.393%, Oyigba 1.483%, Anakpo 1.636%, Upatabo 1.633% and Ihubuluko 1.441% respectively. Consistency limits (Plastic index) at preliminary tests of 100% natural soil from sampled roads are Odioku 0.995%, Oyigba 0.989%, Anakpo 0.988%, Upatabo 0.997% and Ihubuluko 0.987%. Comparatively, un-stabilized and composite stabilized soils result shown in tables 3.2 –3.3 into 3.2A and 3.3 and figures 3.2 – 3.3, maximum dry density (MDD) and optimum moisture content (OMC) of compaction test parameters showed percentile increment to percentage ratios of composite stabilizers to soil. Indication confirmed the rise in MDD and OMC due to inclusion of stabilizers. Results of stabilized California bearing ratio (CBR) of sampled roads with composite materials of cement, lime and IGF showed incremental percentile values with ratio variation. Both cementitious materials showed percentile increased to optimum mix ratio of 91.75+0.75+7.5% with higher strength performance in cement than lime. Reversed values were notice beyond optimum mix ratio with crack formations in both cementitious agents. Results obtained of

unconfined compressive strength from sampled roads, stabilized with cement / lime + IGF showed incremental percentile rise to corresponding ratios of composite materials to soil. Results of consistency limits (Plastic Index) in comparison showed percentile decreased values with increased in composite materials to soil ratio. Results demonstrated that the increase in ratio variation decreases plastic index of soils. Entire results proved composite materials as good soil stabilizers with maximum values strength increase recorded in cement samples over lime.

Key Words: Lateritic soils, Irvinga Gabonesis Fibre, Cement, Lime, CBR, UCS, Consistency, Compaction

1.0 Introduction

The desired and quest to obtain cheaper additives which can be used to substitute the expensive industrially manufactured soil improving additives (bitumen, cement, lime etc) leads to the consideration of agricultural waste resources such as plantain rachis, banana rachis, ogbono fiber. Hence, the use of cheap admixtures to partially replace or supplement cement or lime stabilized soils especially wastes from agricultural products will eventually reduce the cost of construction works where expansive soils are found. This study matches the need for safe and environmental disposal of waste, for the society and the engineers need for better and cost effective construction materials (Collins and Ciesiellski, [1]); Phanikumar and Sharma [2]; Malhotra and Metha [3]; Cokca [4]).

Charles *et al.* [5] investigated the problematic engineering properties of soils with high plasticity level, high swelling and shrinkage potentials used in pavement design in the Nigerian Niger Delta region. The application of stabilizing agents of cement and costus afer bagasse fibre (Bush Sugarcane Bagaase Fibre) were mixed in single and combines actions to improved their unique properties. Results showed that inclusion stabilizing material improved strength properties of the soils. Results of tests carried out show that the optimum moisture content increased with increasing cement ratios to both soils (clay) and (laterite). Treated soils with Cement decreased in liquid limits and increased in plastic limits. Soils with Cement and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions. At 8% of lime, CBR values reached optimum, beyond this range, cracks exist and 7.5% cement + 0. 75% BSBF, optimum value are reached.

Charles *et al.* [6] 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.

Charles *et al.* [7] 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.

Kalantari *et al.,* [8] experimented the use of cement, polypropylene fibers and optimum moisture content values to strengthen peat. From their laboratory study it was observed that peat with cement and fibers can be used as the base

course in the pavement construction. It appears that the fibers prevent the formation and the development of the cracks upon loading and thus increasing the strength of the samples.

Otoko and Blessing [9] studied the engineering behavior of stabilized marine clay with cement and lime. The authors show that the strength characteristics of the marine clay was improved as unconfined compressive strength and maximum dry density increased with increase in cement and lime content with of coarse, a corresponding decrease in the optimum moisture content.

Kalkan [10] stabilized expansive clay with red mud (a waste material generated during the production of alumina) and cement-red mud and found increase in strength and decrease in swelling percentage and hydraulic conductivity.

Goyal *et al*., [11] reported that SCBA with high specific surface area, high contents of amorphous silica and calcium oxide fulfilled the principal requirements of a pozzolanic material.

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 Rds at 1.5 m depth, at Odiokwu Town Rd(CH 0+950), Oyigba Town Rd(CH 4+225), Anakpo Town Rd(CH6+950) , Upatabo Town Rd (CH8+650), Ihubuluko Town Rd, 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 Irvinga Gabonesis Fibre

The Irvinga Gabonesis, popularly called Bush mango , with Nigerian native name (Egbono) are widely spread plants across Nigerian bushes and farm land with edible fruits that bears the fibre , they are collected from at Olokuma village, a river side area in Ubie Clan, Ahoada-West, Rivers State, Nigeria.

2.1.3 Lime

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

2.1.4 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 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. 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 (UCS) values of 178kPa, 145kPa, 165kPa, 158kPa and 149kPa.

3.1 Compaction Test Results

Preliminary and stabilized tests of sampled roads maximum dry density (MDD) and optimum moisture content (OMC) percentile values from tables 3.3 and 3.3, derived into 3.2A and 3.3A are Odioku, 1.006% and 1.010%, Oyigba 1.012%, and 1.022%, Anakpo 1.013% and 1.014%, Upatabo 1.010% and 1.025%, Ihubuluko 1.011% and 1.024% respectively of MDD and OMC at 100% natural soils. Stabilized clay soil results with composites materials of Odioku samples MDD are laterite + Cement + IGF 1.123%, 1.942%, 3.323%, 8.492%, laterite + lime + IGF 0.511%, 0.716%, 1.995%, 8.341%, OMC are Laterite + Cement + IGF 1.928%, 2.896%, 4.995%, 7.093%, laterite + lime + IGF 2.247%, 3.539%, 4.991%, 7.251%. Oyigba MDD are laterite + cement + IGF 2.462%, 4.293%, 5.478%, 6.770%, laterite + lime + IGF 0.538%, 1.453%, 1.992%, 3.392%, OMC are laterite + cement + IGF 4.411%, 6.363%, 9.080%, 12.495%, laterite + lime + IGF 1.112%, 3.342%, 4.317%, 5.432%. Anakpo MDD are laterite + cement + IGF 2.659%, 3.276%, 3.482%, 5.026%, laterite + lime + IGF 1.231%, 2.209%, 3.290%, 3.805%, OMC are laterite + cement + IGF 2 2.868%, 4.312%, 7.200%, 9.366%, laterite + lime + IGF 1.008%, 3.174%, 4.402%, 6.857%. Upatabo are MDD laterite + cement + IGF 1.925%, 2.835%, 4.484%, 6.362%, laterite + lime + IGF 1.021%, 2.045%, 3.581%, 5.572%, OMC are laterite + cement + IGF 4.860%, 7.150%, 9.865%, 20.552%, laterite + lime + IGF 2.193%, 4.398%, 5.925%, 9.148%. Results of maximum dry density (MDD) and optimum moisture content (OMC) of compaction test parameters showed percentile increment to percentage ratios of composite stabilizers to soil with peak values recorded in cement over lime compositions. Indication confirmed the rise in MDD and OMC due to inclusion of cementitious stabilizers.

3.2 California Bearing Ratio (CBR) Test

Results of obtained percentile values from table 3.4 into 3.4A of California bearing ratio (CBR) test conducted at preliminary state of 100% are unsoaked 4.644%, 4.447%, 3.696%, 4.835%, 4.467% and soaked, 4.382%, 4.321%, 3.576%, 4.921%, 4.551%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively. Results of incremental percentile values recorded from Odioku stabilized unsoaked laterite + cement + IGF are 442.833%, 774.442%, 1057%, 971.224%, laterite + lime + IGF; 283.823%, 521.754%, 814.858%, 760.260%, soaked laterite + cement + IGF), 415.372%, 667.540%, 1060%, 970.552%, laterite + lime + IGF 265.997%, 474.551%, 794.913%, 735.274%. Oyigba stabilized unsoaked laterite + cement + IGF are 422.219%, 728.690%, 998.101%, 951.984%, laterite + lime + IGF, 286.812%, 502.106%, 783.283%, 648.694%, soaked laterite + cement + IGF, 408.906%, 739.034%, 993.521%, 930.060%, laterite + lime + IGF, 291.422%, 473.473%, 819.627%, 640.140%. Anakpo unsoaked laterite + cement + IGF are 342.560%, 709.483%, 919.740%, 848.586%, laterite + lime + IGF, 281.560%, 478.996%, 818.739%, 715.534%, soaked laterite + cement + IGF, 329.678%, 742.872%, 943.567%, 899.122%, laterite + lime + IGF, 290.883%, 413.383%, 818.244%, 736.300%. Upatabo unsoaked laterite + cement + IGF are 462.829%, 768.148%, 961.233%, 896.871%, laterite + lime + IGF are 279.386%, 481.726%, 796.088%, 694.492%, soaked laterite + cement + IGF, 471.797%, 832.386%, 976.738%, 936.150%, %, laterite + lime + IGF 290.686%, 521.274%, 846.568%, 717.745%. Ihubuluko unsoaked laterite + cement + IGF are 424.312%, 712.047%, 896.010%, 799.783%, laterite + lime + IGF, 270.331%, 461.841%, 785.426%, 719.860%, soaked laterite + cement + IGF 433.129%, 732.109%, 945.884%, 822.415%, laterite + lime + IGF 254.718%, 458.289%, 801.657%,744.514%. Results of stabilized California bearing ratio (CBR) of sampled roads with composite materials of cement, lime and IGF showed incremental percentile values with ratio variation. Both cementitious materials showed percentile increased to optimum mix ratio of 91.75+0.75+7.5% with higher strength performance in cement than lime. Reversed values were notice beyond optimum mix ratio with crack formations in both cementitious agents.

3.3 Unconfined Compressive Strength Test

Unconfined compressive strength test conducted at preliminary stages of 100% natural soil from sampled roads yielded the following peak percentile results; Odioku 1.393%, Oyigba 1.483%, Anakpo 1.636%, Upatabo 1.633% and Ihubuluko 1.441% respectively. Stabilized composite materials Unconfined compressive strength of Odioku laterite + cement + IGF are 67.552%, 116.990%, 217.552%, 416.990%, laterite + lime + IGF 47.293%, 136.619%, 215.833%, 335.496%, Oyigba laterite + cement + IGF are 80.834%, 144.282%, 263.593%, 439.455%, laterite + lime + IGF 53.625%, 125.349%, 230.177%, 402.591%. Anakpo laterite + cement + IGF are 102.525%, 133.434%, 240.101%, 408.586%, laterite + lime + IGF 43.755%, 143.149%, 261.936%, 347.391%. Upatabo laterite + cement + IGF are 102.051%, 204.582%, 328.000%, 555.848%, laterite + lime + IGF 65.498%, 196.510%, 281.953%, 386.384%, Ihubuluko laterite + cement + IGF 74.760%, 147.863%, 251.312%, 446.484%, laterite + lime + IGF 48.092%, 133.609%, 292.230%, 414.299%. Results obtained of unconfined compressive strength from sampled roads, stabilized with cement / lime + IGF showed incremental percentile rise to corresponding ratios of composite materials to soil.

3.4 Consistency Limits Test

Consistency limits (Plastic index) at preliminary tests of 100% natural soil from sampled roads are Odioku 0.995%, Oyigba 0.989%, Anakpo 0.988%, Upatabo 0.997% and Ihubuluko 0.987%. stabilized Odioku laterite + cement + IGF are -2.119%,-3.876%, -6.125%, -8.725%, laterite + lime + IGF -1.694%, 31.686%, -4.505%, -5.840%. Oyigba laterite + cement + IGF -2.119%, -3.876%,-6.125%, -8.725%, laterite + lime + IGF -1.694%, 31.686%, -4.505%, -5.840%. Anakpo laterite + cement + IGF laterite + cement + IGF -2.367%, -4.262%, -6.289%, -8.707%, laterite + lime + IGF -1.180%, -3.925%, -3.533%, -4.905%. Upatabo laterite + cement + IGF -0.572%, -2.687%, -4.001%, -6.401%, laterite + lime + IGF -1.376%, -2.633%, -3.319%, -4.290%. Ihubuluko laterite + cement + IGF -2.626%, -5.483%, -7.409%, -9.210%, laterite + lime + IGF -3.256%, -4.312%, -5.120%, -5.679%. Results of consistency limits (Plastic Index) in comparison showed percentile decreased values with increased in composite materials to soil ratio. Results demonstrated that the increase in ratio variation decreases plastic index of soils.

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

Location Description	Odiokwu Town Rd (CH 0+950)	Oyigba Town Rd (CH 4+225)	Anakpo Town Rd (CH6+950)	Upatabo Town Rd (CH8+650)	Ihubuluko Town Rd (CH10+150)
	(Laterite)	(Laterite)	(Laterite)	(Laterite)	(Laterite)
Depth of sampling (m)	1.5	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 soil 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 IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo,Ihubuluko Towns), Rivers State

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
MDD (Laterite + Cement + IGF) Odiokwu Town Road	1.95	1.97	1.98	2.01	2.11
MDD (kN/m3) (Laterite + Lime + IGF)Odiokwu Town Road	1.95	1.96	1.96	1.99	2.11
MDD (Laterite + Cement + IGF) Oyigba Town Road	1.86	1.88	1.91	1.94	1.96
MDD (kN/m3) (Laterite + Lime + IGF)Oyigba Town Road	1.86	1.86	1.88	1.89	1.92
MDD (Laterite + Cement + IGF) Anakpo Town Road	1.94	1.97	1.98	1.99	2.02
MDD (kN/m3) (Laterite + Lime + IGF)Anakpo Town Road	1.94	1.96	1.97	2.00	2.01
MDD (Laterite + Cement + IGF) Upatabo Town Road	1.76	1.78	1.79	1.82	1.85
MDD (kN/m3) (Laterite + Lime + IGF) Upatabo Town Road	1.76	1.77	1.79	1.81	1.85
MDD (Laterite + Cement + IGF) Ihubuluko Town Road	2.11	2.13	2.16	2.19	2.22
MDD (kN/m3) (Laterite + Lime + IGF)Ihubuluko Town Road	2.11	2.13	2.15	2.19	2.22

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
MDD (Laterite + Cement + IGF) Odiokwu Town Road	1.01%	1.12%	1.94%	3.32%	8.49%
MDD (kN/m3) (Laterite + Lime + IGF)Odiokwu Town Road	1.00%	0.51%	0.72%	2.00%	8.34%
MDD (Laterite + Cement + IGF) Oyigba Town Road	1.01%	2.46%	4.29%	5.48%	6.77%
MDD (kN/m3) (Laterite + Lime + IGF)Oyigba Town Road	1.00%	0.54%	1.45%	1.99%	3.39%
MDD (Laterite + Cement + IGF) Anakpo Town Road	1.01%	2.66%	3.28%	3.48%	5.03%
MDD (kN/m3) (Laterite + Lime + IGF)Anakpo Town Road	1.01%	1.23%	2.21%	3.29%	3.80%
MDD (Laterite + Cement + IGF) Upatabo Town Road	1.01%	1.92%	2.83%	4.48%	6.36%
MDD (kN/m3) (Laterite + Lime + IGF) Upatabo Town Road	1.01%	1.02%	2.05%	3.58%	5.57%
MDD (Laterite + Cement + IGF) Ihubuluko Town Road	1.01%	2.17%	3.69%	5.21%	6.31%
MDD (kN/m3) (Laterite + Lime + IGF)Ihubuluko Town Road	1.01%	2.08%	3.36%	4.98%	6.26%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
OMC%(Laterite + Cement + IGF) Odiokwu Town Road	12.39	12.51	12.63	12.89	13.15
OMC%(Laterite + Lime + IGF) Odiokwu Town Road	12.39	12.53	12.69	12.87	13.15
OMC%(Laterite + Cement + IGF) Oyigba Town Road	14.35	14.67	14.95	15.34	15.83
OMC%(Laterite + Lime + IGF) Oyigba Town Road	14.35	14.43	14.75	14.89	15.05
OMC%(Laterite + Cement + IGF) Anakpo Town Road	13.85	14.05	14.25	14.65	14.95
OMC%(Laterite + Lime + IGF) Anakpo Town Road	13.85	13.92	14.22	14.39	14.73
OMC%(Laterite + Cement + IGF) Upatabo Town Road	11.79	12.08	12.35	12.67	13.93
OMC%(Laterite + Lime + IGF) Upatabo Town Road	11.79	11.92	12.18	12.36	12.74
OMC%(Laterite + Cement + IGF) Ihubuluko Town Road	10.95	11.21	11.53	11.83	12.06
OMC%(Laterite + Lime + IGF) Ihubuluko Town Road	10.95	11.21	11.48	11.66	11.93

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
OMC%(Laterite + Cement + IGF) Odiokwu Town Road	1.01%	1.93%	2.90%	4.99%	7.09%
OMC%(Laterite + Lime + IGF) Odiokwu Town Road	1.01%	2.25%	3.54%	4.99%	7.25%
OMC%(Laterite + Cement + IGF) Oyigba Town Road	1.02%	4.41%	6.36%	9.08%	12.49%
OMC%(Laterite + Lime + IGF) Oyigba Town Road	1.01%	1.11%	3.34%	4.32%	5.43%
OMC%(Laterite + Cement + IGF) Anakpo Town Road	1.01%	2.87%	4.31%	7.20%	9.37%
OMC%(Laterite + Lime + IGF) Anakpo Town Road	1.01%	1.01%	3.17%	4.40%	6.86%
OMC%(Laterite + Cement + IGF) Upatabo Town Road	1.02%	4.86%	7.15%	9.86%	20.55%
OMC%(Laterite + Lime + IGF) Upatabo Town Road	1.01%	2.19%	4.40%	5.93%	9.15%
OMC%(Laterite + Cement + IGF) Ihubuluko Town Road	1.02%	4.69%	7.62%	10.36%	12.46%
OMC%(Laterite + Lime + IGF) Ihubuluko Town Road	1.02%	4.69%	7.16%	8.80%	11.27%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
UNSOAKED (Laterite + Cement + IGF) Odiokwu Town Road	8.70	40.40	69.25	93.80	86.37
UNSOAKED (Laterite + Lime + IGF) Odiokwu Town Road	8.70	27.45	48.15	73.65	68.90
SOAKED(Laterite + Cement + IGF) Odiokwu Town Road	8.30	36.37	57.30	89.85	82.45
SOAKED (Laterite + Lime + IGF) Odiokwu Town Road	8.30	24.85	42.16	68.75	63.80
UNSOAKED (Laterite + Cement + IGF) Oyigba Town Road	8.50	37.80	63.85	86.75	82.83
UNSOAKED (Laterite + Lime + IGF) Oyigba Town Road	8.50	27.05	45.35	69.25	57.81
SOAKED(Laterite + Cement + IGF) Oyigba Town Road	7.80	33.70	59.45	79.30	74.35
SOAKED (Laterite + Lime + IGF) Oyigba Town Road	7.80	25.15	39.35	66.35	52.35

UNSOAKED (Laterite + Cement + IGF) Anakpo Town Road	7.80	28.83	57.45	73.85	68.30
UNSOAKED (Laterite + Lime + IGF) Anakpo Town Road	7.80	24.45	39.85	66.35	58.30
SOAKED(Laterite + Cement + IGF) Anakpo Town Road	7.20	25.75	55.50	69.95	66.75
SOAKED (Laterite + Lime + IGF) Anakpo Town Road	7.20	23.18	32.00	61.15	55.25
UNSOAKED (Laterite + Cement + IGF) Upatabo Town Road	9.40	45.45	74.15	92.30	86.25
UNSOAKED (Laterite + Lime + IGF) Upatabo Town Road	9.40	29.28	48.30	77.85	68.30
SOAKED(Laterite + Cement + IGF) Upatabo Town Road	8.50	41.83	72.48	84.75	81.30
SOAKED (Laterite + Lime + IGF) Upatabo Town Road	8.50	27.35	46.95	74.60	63.65
UNSOAKED (Laterite + Cement + IGF) Ihubuluko Town Road	10.60	47.35	77.85	97.35	87.15
UNSOAKED (Laterite + Lime + IGF) Ihubuluko Town Road	10.60	32.15	52.45	86.75	79.80
SOAKED(Laterite + Cement + IGF) Ihubuluko Town Road	9.80	44.60	73.90	94.85	82.75
SOAKED (Laterite + Lime + IGF) Ihubuluko Town Road	9.80	28.35	48.30	81.95	76.35

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
UNSOAKED (Laterite + Cement + IGF) Odiokwu Town Road	4.644%	442.833%	774.442%	1056.626%	971.224%
UNSOAKED (Laterite + Lime + IGF) Odiokwu Town Road	3.155%	283.823%	521.754%	814.858%	760.260%
SOAKED(Laterite + Cement + IGF) Odiokwu Town Road	4.382%	415.372%	667.540%	1059.709%	970.552%
SOAKED (Laterite + Lime + IGF) Odiokwu Town Road	2.994%	265.997%	474.551%	794.913%	735.274%
UNSOAKED (Laterite + Cement + IGF) Oyigba Town Road	4.447%	422.219%	728.690%	998.101%	951.984%
UNSOAKED (Laterite + Lime + IGF) Oyigba Town Road	3.182%	286.812%	502.106%	783.283%	648.694%
SOAKED(Laterite + Cement + IGF) Oyigba Town Road	4.321%	408.906%	739.034%	993.521%	930.060%
SOAKED (Laterite + Lime + IGF) Oyigba Town Road	3.224%	291.422%	473.473%	819.627%	640.140%
UNSOAKED (Laterite + Cement + IGF) Anakpo Town Road	3.696%	342.560%	709.483%	919.740%	848.586%
UNSOAKED (Laterite + Lime + IGF) Anakpo Town Road	3.135%	281.560%	478.996%	818.739%	715.534%
SOAKED(Laterite + Cement + IGF) Anakpo Town Road	3.576%	329.678%	742.872%	943.567%	899.122%
SOAKED (Laterite + Lime + IGF) Anakpo Town Road	3.219%	290.883%	413.383%	818.244%	736.300%
UNSOAKED (Laterite + Cement + IGF) Upatabo Town Road	4.835%	462.829%	768.148%	961.233%	896.871%
UNSOAKED (Laterite + Lime + IGF) Upatabo Town Road	3.115%	279.386%	481.726%	796.088%	694.492%
SOAKED(Laterite + Cement + IGF) Upatabo Town Road	4.921%	471.797%	832.386%	976.738%	936.150%
SOAKED (Laterite + Lime + IGF) Upatabo Town Road	3.218%	290.686%	521.274%	846.568%	717.745%
UNSOAKED (Laterite + Cement + IGF) Ihubuluko Town Road	4.467%	424.312%	712.047%	896.010%	799.783%
UNSOAKED (Laterite + Lime + IGF) Ihubuluko Town Road	3.033%	270.331%	461.841%	785.426%	719.860%
SOAKED(Laterite + Cement + IGF) Ihubuluko Town Road	4.551%	433.129%	732.109%	945.884%	822.415%
SOAKED (Laterite + Lime + IGF) Ihubuluko Town Road	2.893%	254.718%	458.289%	801.657%	744.514%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
LL(Laterite + Cement + IGF) Odiokwu Town Road	39.75	39.48	39.15	38.75	38.20
LL (Laterite + Lime + IGF)Odiokwu Town Road	39.75	39.87	39.98	40.25	40.45
LL(Laterite + Cement + IGF) Oyigba Town Road	36.90	36.55	36.21	35.93	35.35
LL (Laterite + Lime + IGF)Oyigba Town Road	36.90	37.08	37.23	37.45	37.59
LL(Laterite + Cement + IGF) Anakpo Town Road	36.75	36.35	36.05	35.83	35.46
LL (Laterite + Lime + IGF) Anakpo Town Road	36.75	36.84	36.88	37.17	37.35
LL(Laterite + Cement + IGF) Upatabo Town Road	36.85	36.56	36.23	35.95	35.66
LL (Laterite + Lime + IGF) Upatabo Town Road	36.85	36.94	37.21	37.38	37.56
LL(Laterite + Cement + IGF) Ihubuluko Town Road	37.65	37.28	37.01	36.79	36.47
LL (Laterite + Lime + IGF)Ihubuluko Town Road	37.65	37.85	38.08	38.26	38.52

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0 +10%
LL(Laterite + Cement + IGF) Odiokwu Town Road	0.99%	-1.36%	-2.19%	-3.20%	-4.58%
LL (Laterite + Lime + IGF)Odiokwu Town Road	1.00%	0.60%	0.88%	1.56%	2.06%
LL(Laterite + Cement + IGF) Oyigba Town Road	0.99%	-1.91%	-2.83%	-3.59%	-5.16%
LL (Laterite + Lime + IGF)Oyigba Town Road	1.00%	0.97%	1.38%	1.98%	2.36%
LL(Laterite + Cement + IGF) Anakpo Town Road	0.99%	-2.19%	-3.01%	-3.60%	-4.61%
LL (Laterite + Lime + IGF) Anakpo Town Road	1.00%	0.49%	0.60%	1.39%	1.88%
LL(Laterite + Cement + IGF) Upatabo Town Road	0.99%	-1.58%	-2.48%	-3.24%	-4.02%
LL (Laterite + Lime + IGF) Upatabo Town Road	1.00%	0.49%	1.22%	1.68%	2.17%
LL(Laterite + Cement + IGF) Ihubuluko Town Road	0.99%	-1.98%	-2.69%	-3.28%	-4.13%
LL (Laterite + Lime + IGF)Ihubuluko Town Road	1.01%	1.06%	1.67%	2.15%	2.84%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0+10%
PL(Laterite + Cement + IGF) Odiokwu Town Road	22.45	22.27	22.07	22.00	21.92
PL (Laterite + Lime + IGF) Odiokwu Town Road	22.45	22.79	23.15	23.70	24.17
PL(Laterite + Cement + IGF) Odiokwu Town Road	22.67	22.57	22.38	22.32	22.41
PL (Laterite + Lime + IGF) Oyigba Town Road	22.67	22.97	23.37	23.74	24.07
PL(Laterite + Cement + IGF) Anakpo Town Road	21.45	21.23	21.22	21.37	21.37
PL (Laterite + Lime + IGF) Anakpo Town Road	21.45	21.63	22.09	22.32	22.71
PL(Laterite + Cement + IGF) Upatabo Town Road	19.35	19.28	19.15	19.10	19.23
PL (Laterite + Lime + IGF) Upatabo Town Road	19.35	19.56	20.05	20.34	20.69
PL(Laterite + Cement + IGF) Ihubuluko Town Road	21.55	21.39	21.58	21.67	21.64
PL (Laterite + Lime + IGF) Ihubuluko Town Road	21.55	22.01	22.14	22.74	23.09

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5 + 5.0%	91.75+0.75 +7.5%	89+1.0+10%
PL(Laterite + Cement + IGF) Odiokwu Town Road	0.99%	-1.61%	-2.50%	-2.81%	-3.17%
PL (Laterite + Lime + IGF) Odiokwu Town Road	1.02%	3.01%	4.61%	7.06%	9.15%
PL(Laterite + Cement + IGF) Odiokwu Town Road	1.00%	-0.88%	-1.72%	-1.99%	-1.59%
PL (Laterite + Lime + IGF) Oyigba Town Road	1.01%	2.63%	4.39%	6.03%	7.48%
PL(Laterite + Cement + IGF) Anakpo Town Road	0.99%	-2.06%	-2.11%	-1.41%	-1.41%
PL (Laterite + Lime + IGF) Anakpo Town Road	1.01%	1.67%	3.82%	4.89%	6.71%
PL(Laterite + Cement + IGF) Upatabo Town Road	1.00%	-0.72%	-1.40%	-1.66%	-0.98%
PL (Laterite + Lime + IGF) Upatabo Town Road	1.01%	2.16%	4.69%	6.19%	8.00%
PL(Laterite + Cement + IGF) Ihubuluko Town Road	0.99%	-1.49%	-0.61%	-0.19%	-0.33%
PL (Laterite + Lime + IGF) Ihubuluko Town Road	1.02%	4.22%	4.83%	7.61%	9.24%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0+10%
PI (Laterite + Cement + IGF) Odiokwu Town Road	0.99%	-1.04%	-1.79%	-3.70%	-6.42%
PI (Laterite + Lime + IGF) Odiokwu Town Road	0.99%	-2.56%	-4.00%	-5.62%	-7.18%
PI (Laterite + Cement + IGF) Oyigba Town Road	0.99%	-2.12%	-3.88%	-6.13%	-8.73%
PI (Laterite + Lime + IGF) Oyigba Town Road	0.99%	-1.69%	31.69%	-4.50%	-5.84%
PI (Laterite + Cement + IGF) Anakpo Town Road	0.99%	-2.37%	-4.26%	-6.29%	-8.71%
PI (Laterite + Lime + IGF) Anakpo Town Road	0.99%	-1.18%	-3.93%	-3.53%	-4.91%
PI (Laterite + Cement + IGF) Upatabo Town Road	1.00%	-0.57%	-2.69%	-4.00%	-6.40%
PI (Laterite + Lime + IGF) Upatabo Town Road	0.99%	-1.38%	-2.63%	-3.32%	-4.29%
PI (Laterite + Cement + IGF) Ihubuluko Town Road	0.99%	-2.63%	-5.48%	-7.41%	-9.21%
PI (Laterite + Lime + IGF) Ihubuluko Town Road	0.98%	-3.26%	-4.31%	-5.12%	-5.68%

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0+10%
PI (Laterite + Cement + IGF) Odiokwu Town Road	17.30	17.21	17.08	16.75	16.28
PI (Laterite + Lime + IGF) Odiokwu Town Road	17.30	17.08	16.83	16.55	16.28
PI (Laterite + Cement + IGF) Oyigba Town Road	14.23	14.08	13.83	13.51	13.14
PI (Laterite + Lime + IGF) Oyigba Town Road	14.23	14.11	18.86	13.71	13.52
PI (Laterite + Cement + IGF) Anakpo Town Road	15.30	15.12	14.83	14.52	14.15
PI (Laterite + Lime + IGF) Anakpo Town Road	15.30	15.21	14.79	14.85	14.64
PI (Laterite + Cement + IGF) Upatabo Town Road	17.50	17.45	17.08	16.85	16.43
PI (Laterite + Lime + IGF) Upatabo Town Road	17.50	17.38	17.16	17.04	16.87
PI (Laterite + Cement + IGF) Ihubuluko Town Road	16.10	15.89	15.43	15.12	14.83
PI (Laterite + Lime + IGF) Ihubuluko Town Road	16.10	15.84	15.67	15.54	15.45

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

RATIO %	100%	97.25+0.25 +2.5	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5	89+1.0 +10%
UCS (Laterite + Cement + IGF) Odiokwu Town Rd	178.00	248.00	336.00	515.00	870.00
UCS(Laterite + Lime + IGF) Odiokwu Town Rd	178.00	225.00	384.00	525.00	738.00
UCS (Laterite + Cement + IGF) Oyigba Town Rd	145.00	215.00	307.00	480.00	735.00
UCS(Laterite + Lime + IGF) Oyigba Town Rd	145.00	189.00	293.00	445.00	695.00
UCS(Laterite + Cement + IGF) Anakpo Town Rd	165.00	270.00	321.00	497.00	775.00
UCS (Laterite + Lime + IGF) Anakpo Town Rd	165.00	205.00	369.00	565.00	706.00
UCS (Laterite + Cement + IGF) Upatabo Town Rd	158.00	258.00	420.00	615.00	975.00
UCS(Laterite + Lime + IGF) Upatabo Town Rd	158.00	218.00	425.00	560.00	725.00
UCS (Laterite + Cement + IGF) Ihubuluko Town Rd	145.00	209.00	315.00	465.00	748.00
UCS(Laterite + Lime + IGF) Ihubuluko Town Rd	145.00	184.00	308.00	538.00	715.00

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

RATIO %	100%	97.25+0.25 +2.5%	94.5+ 0.5+ 5.0%	91.75+0.75 +7.5%	89+1.0+10%
UCS (Laterite + Cement + IGF) Odiokwu Town Rd	1.393258	67.55165	116.9899	217.5516	416.9899
UCS(Laterite + Lime + IGF) Odiokwu Town Rd	1.264045	47.29338	136.6192	215.8327	335.4956
UCS (Laterite + Cement + IGF) Oyigba Town Rd	1.482759	80.834	144.2823	263.5926	439.4547
UCS(Laterite + Lime + IGF) Oyigba Town Rd	1.303448	53.62525	125.3494	230.177	402.5908
UCS(Laterite + Cement + IGF) Anakpo Town Rd	1.636364	102.5253	133.4343	240.101	408.5859
UCS (Laterite + Lime + IGF) Anakpo Town Rd	1.242424	43.75462	143.1486	261.9364	347.391
UCS (Laterite + Cement + IGF) Upatabo Town Rd	1.632911	102.0508	204.5825	328.0002	555.8483
UCS(Laterite + Lime + IGF) Upatabo Town Rd	1.379747	65.49762	196.5103	281.9533	386.3837
UCS (Laterite + Cement + IGF) Ihubuluko Town Rd	1.441379	74.75994	147.8634	251.3117	446.4841
UCS(Laterite + Lime + IGF) Ihubuluko Town Rd	1.268966	48.0922	133.6094	292.2301	414.2991

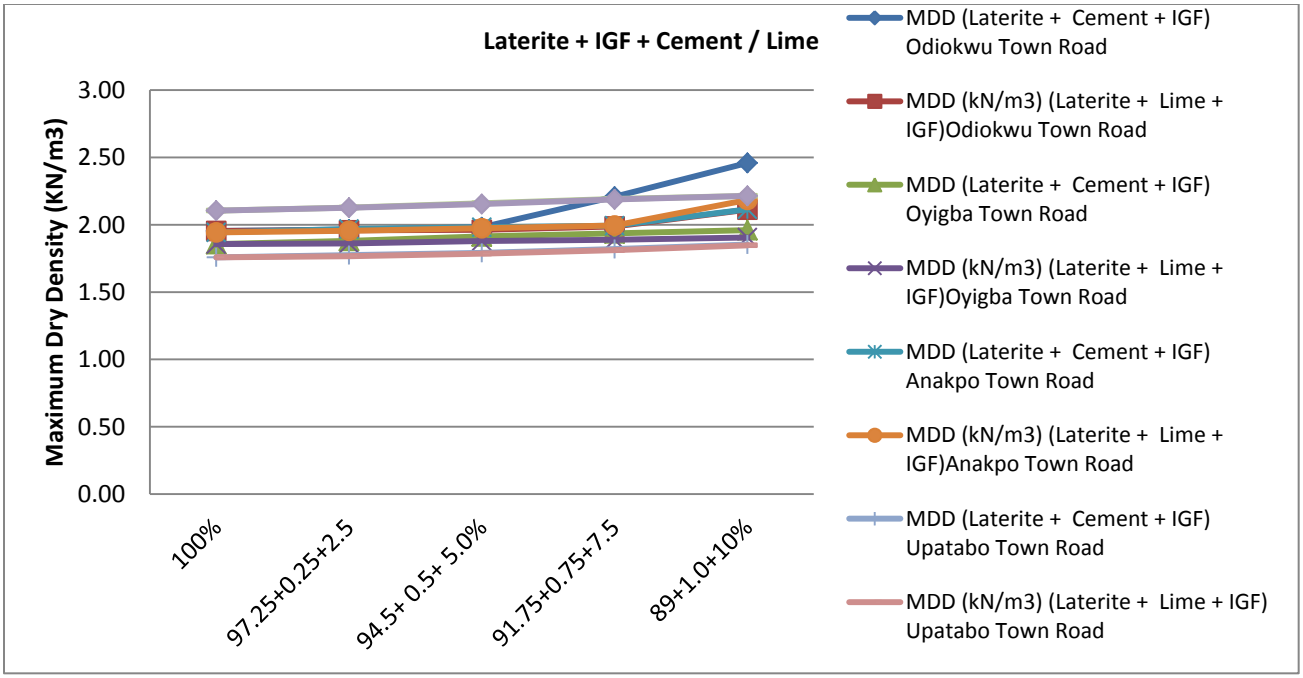

Figure 3.1: Maximum Dry Density (MDD of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

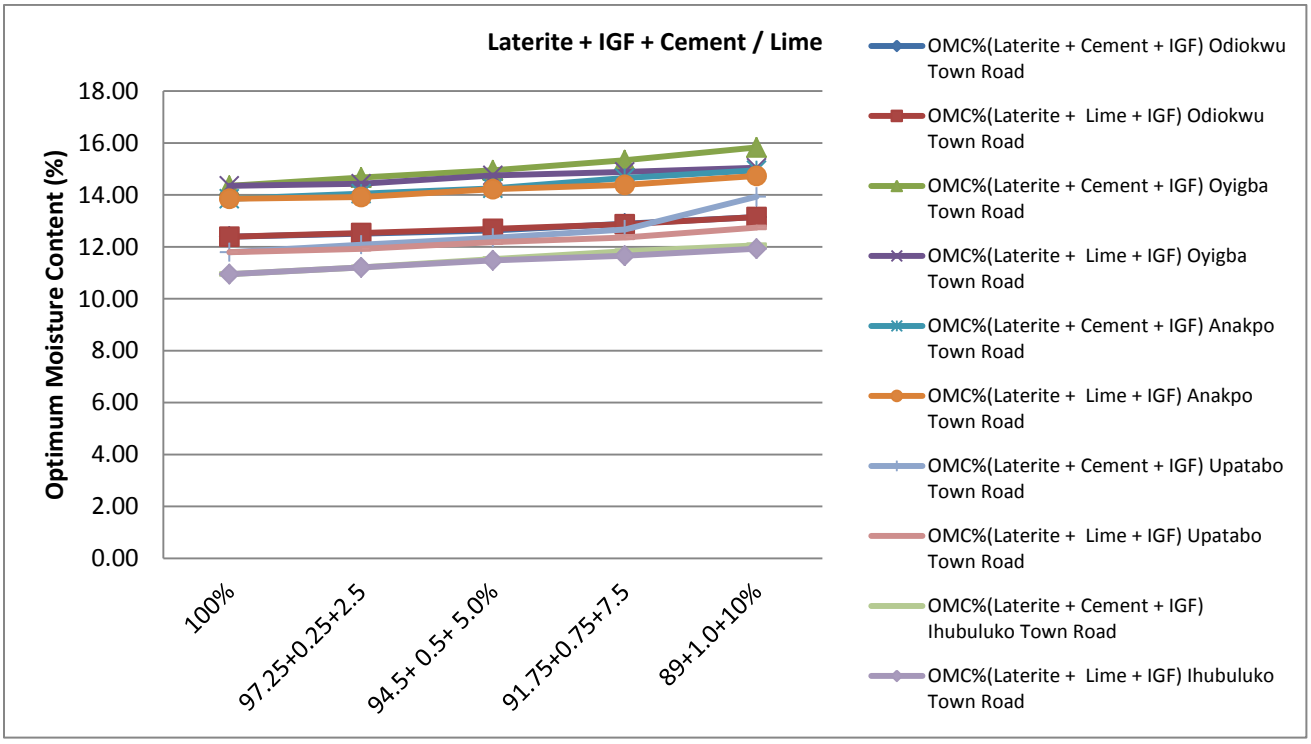

Figure 3.2: Optimum Moisture Content (OM) of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

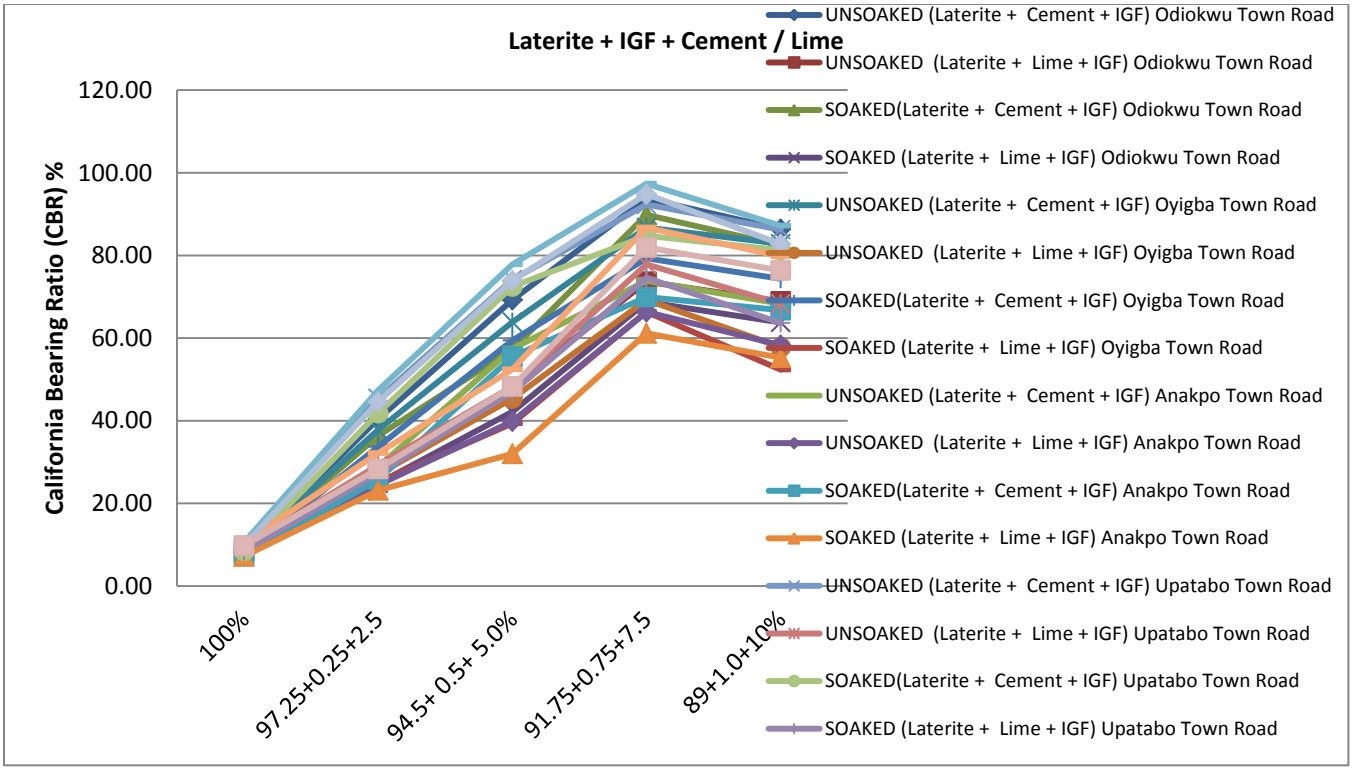

Figure 3.3: California Bearing Ratio (CBR)of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

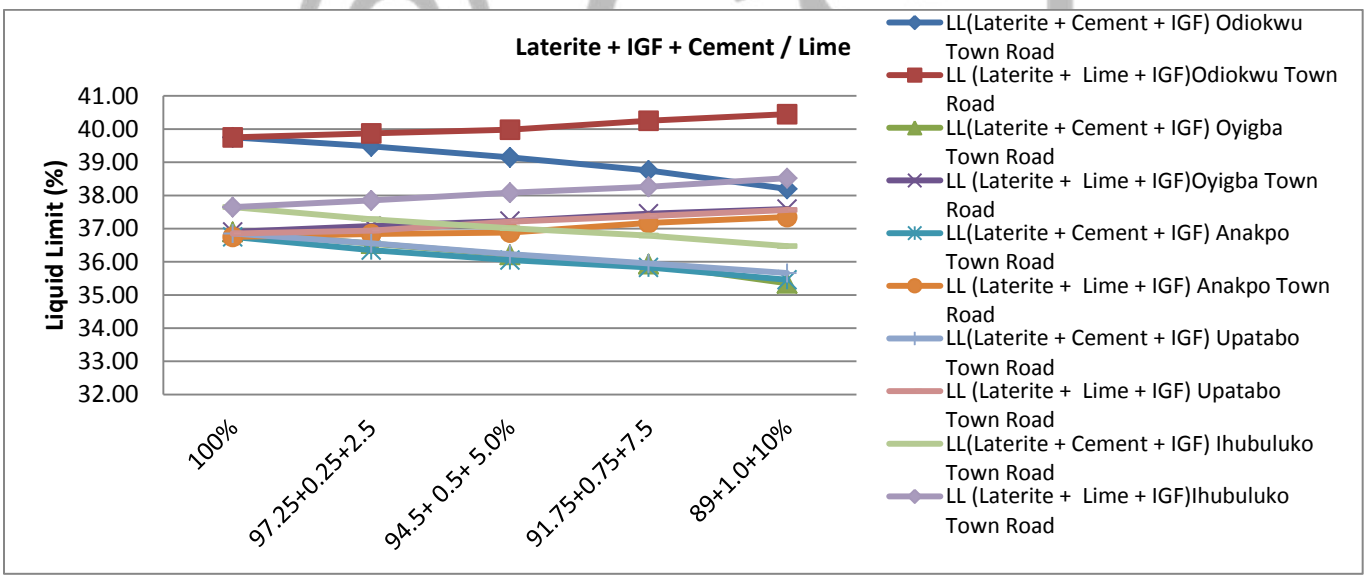

Figure 3.4: Liquid Limit (LL)of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

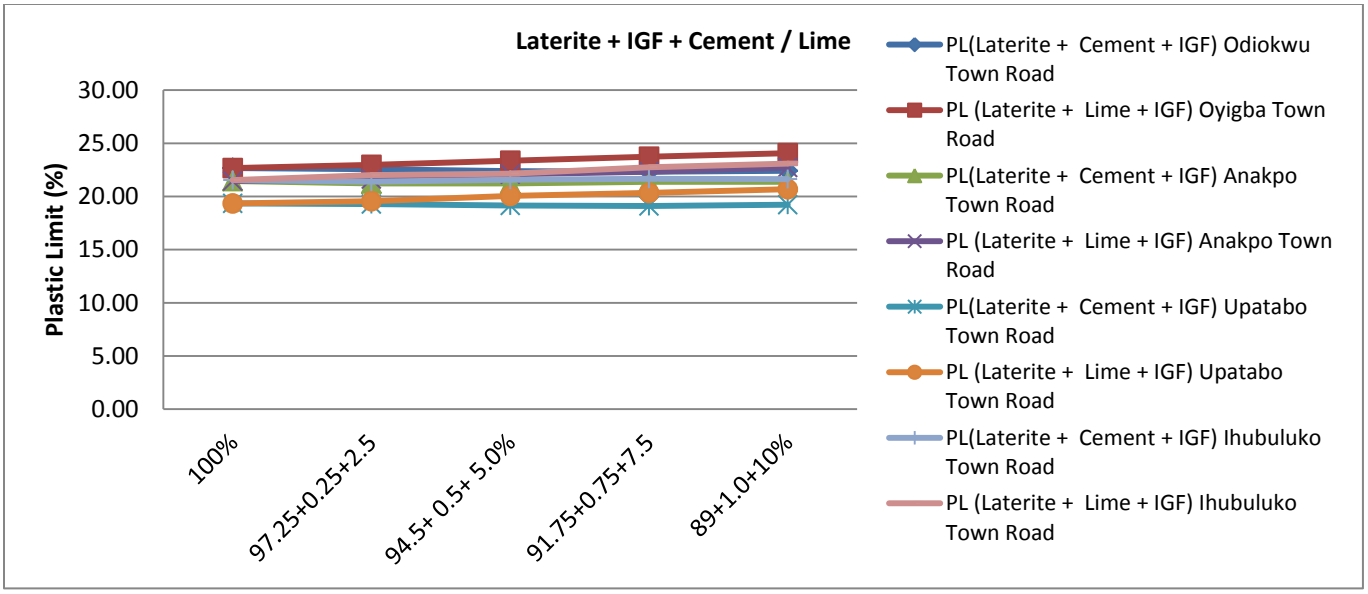

Figure 3.5: Plastic Limit (PL) of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

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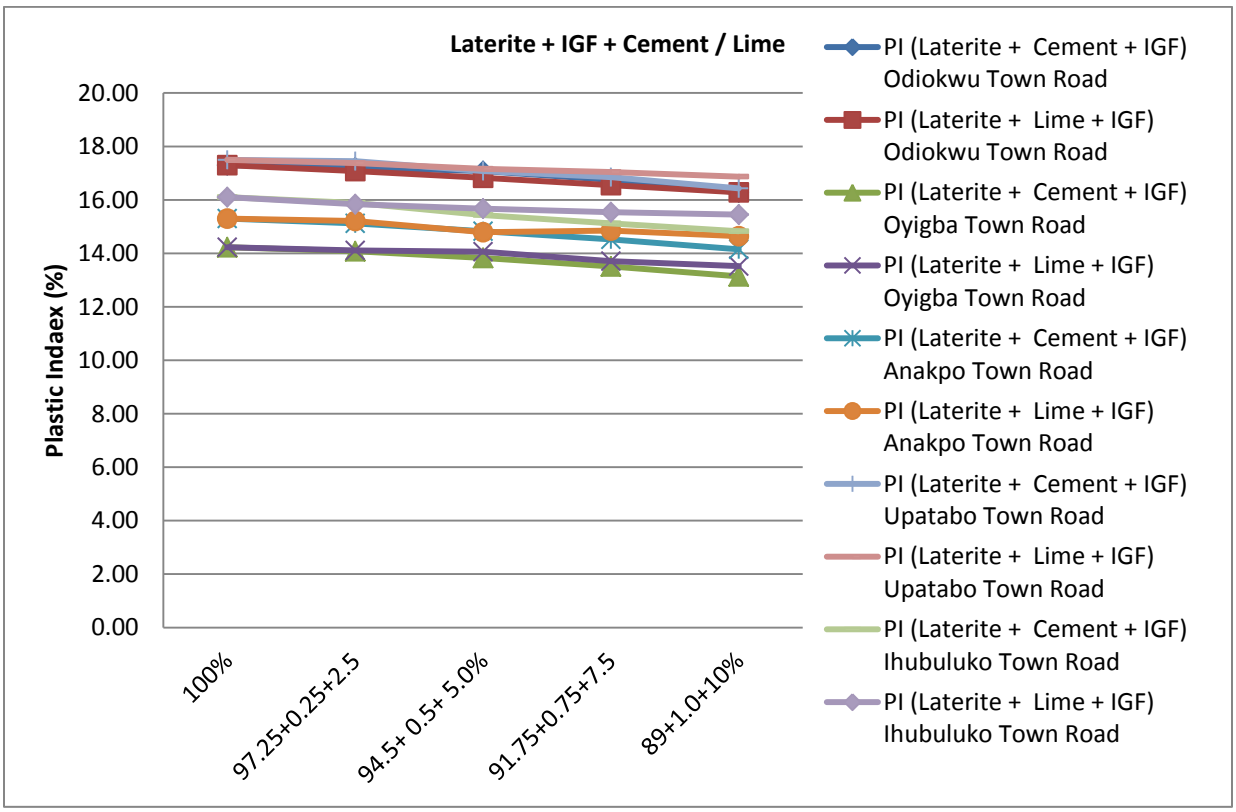

Figure 3.6: Plastic Index (PI)of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

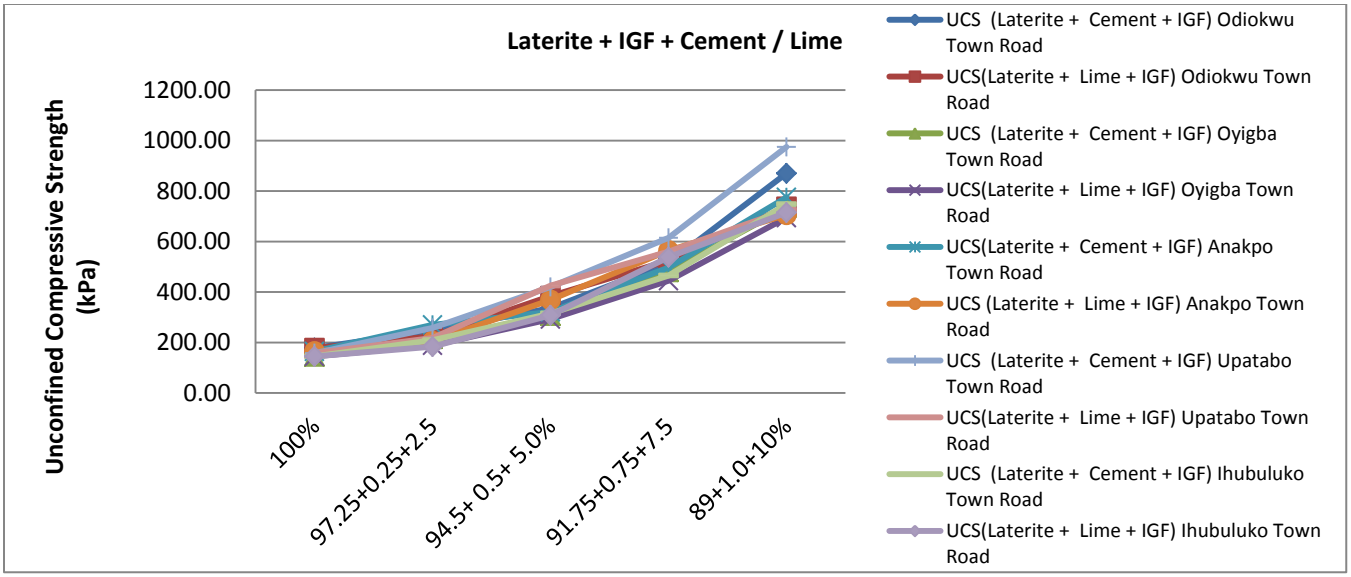

Figure 3.7: Unconfined Compressive Strength (UCS) of Niger Deltaic Lateritic Soils Subgrade with IGF + Cement / Lime of (Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Towns), Rivers State

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. Percentile descriptive statistical tests of sampled roads maximum dry density (MDD) and optimum moisture content (OMC) are Odioku, 1.006% and 1.010%, Oyigba 1.012%, and 1.022%, Anakpo 1.013% and 1.014%, Upatabo 1.010% and 1.025%, Ihubuluko 1.011% and 1.024% respectively of MDD and OMC at 100% natural soils..

iii. Results obtained of California Bearing Ratio (CBR) test conducted at preliminary state of 100% are unsoaked 4.644%, 4.447%,3.696%, 4.835%, 4.467% and soaked, 4.382%, 4.321%, 3.576%, 4.921%, 4.551%, for Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko respectively.

iv. Unconfined compressive strength test conducted at preliminary stages of 100% natural soil from sampled roads yielded the following peak percentile results; Odioku 1.393%, Oyigba 1.483%, Anakpo 1.636%, Upatabo 1.633% and Ihubuluko 1.441% respectively. Consistency limits (Plastic index) at preliminary tests of 100% natural soil from sampled roads are Odioku 0.995%, Oyigba 0.989%, Anakpo 0.988%, Upatabo 0.997% and Ihubuluko 0.987%.

v. Comparatively, unstabilized and composite stabilized soils result shown in tables 3.2 – 3.16 and figures 3.1 – 3.6, maximum dry density (MDD) and optimum moisture content (OMC) of compaction test parameters showed percentile increment to percentage ratios of composite stabilizers to soil.

vi. . Indication confirmed the rise in MDD and OMC due to inclusion of stabilizers. Results of stabilized california bearing ratio (CBR) of sampled roads with composite materials of cement, lime and IGF showed incremental percentile values with ratio variations, both cementitious materials showed percentile increased to optimum mix ratio of 91.75+0.75+7.5%.

References

[1] R. J. Collins, and S. K. Ciesiellski, "Recycling and use of Waste Materials or By- Products in Highway Construction", 1 and 2, 1-20, 1993

[2] B. R. Phanikumar, and R. S. Sharma, " Effect of Fly-Ash on Engg Properties of Expansive Soil", *Journal of Geotechnical and Geoenvironmental Engineering, vol.*130, no.7, pp.464-767, 2004.

[3] V. M. Malhotra, and P. K. Mehta, "Pozzolanic and Cementitious Materials. Gordon and Breach" Amsterdam, Netherlands, 1996

[4] E. Cokca, " Use of class C fly ashes for the stabilization- of an expansive soill", *Journal of Geotechnical and Geoenvironmental Engineering*, no.127, pp. 568-573, 2004

[5] 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

[6] 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.

[7] 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.

[8] B. Kalantari, "Civil Engineering Significant of Peat,"*Global Journal of Researches in Engineering Civil and Structural Engineering",* vol.13, no. 2, pp. 24-28, 2013

[9] G. R. Otoko, O. C. Blessing, "Cement and Lime Stabilization of a Nigerian Deltaic Marine Clay (CHIKOKO)". *European International Journal of Science and Technology vol.*3, no.4, pp. 53-60, 2014

[10]E. Kalkan, "Utilization of Red Mud as a Stabilization Material for the Preparation of Clay Liners,"*Engineering Geology, vol. 87, no.3-4, pp. 220-229,* 2006