

Performance Characteristics of Stabilized Soils using Irvingia Gabonensis Fibre and Lime as Stabilizer

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Abstract: The study explored the effective use of composite soil stabilizers of irvingia gabonensis fibre + lime in combined action to improve the performance of problematic soils with swelling and shrinkage potentials and make trivial soils meet required standard of subgrade road pavement materials. Preliminary investigation results grouped the sampled lateritic soils at 100% natural state as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System and percentage (%) passing BS sieves #200, 28.35%, 40.55 %, 36.85%, 33.45% and 39.25%. Remarks on soil is poor and need to stabilize the soils paramount. Consistency limits (plastic index) of the soils at 100% natural state are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%. Comparatively, stabilized soils compaction results showed corresponding increased values to percentage ratios of both MDD and OMC of stabilized soils. CBR Results showed increased in stabilized samples with optimum percentage ratios of 0.75 + 7.5% to soil. Beyond maximum ratio, cracks were noticed. Results obtained showed increased in UCS values corresponding to additives percentage. Results showed decreased in plastic index to corresponding percentage ratio of additives. Swelling potential of treated soil decreased with the inclusion of fibre + lime up to 0.75% +7.5% for lateritic soils. The entire results showed the potential of using irvingia gabonensis fibre + lime as admixtures in treated soils.

Keywords: Lateritic soils, Irvingia Gabonensis Fibre, Lime, CBR, UCS, Consistency, Compaction.

1. INTRODUCTION

The rapid growth in development of Niger Delta has resulted in demand for effective, stronger and more durable roads. Subsequently, engineers are forced to be more proactive and 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 high cost of additives (cement, lime, fly-ash, etc) has greatly increased for modification and stabilization of soils as single or double actions. The stabilization of soils is recognized as an important process of improving the performance of problematic soils with swelling and shrinkage potentials and makes marginal soils perform better as civil engineering materials (Amadi, [1]).

Ramakrishna and Pradeep (2006) studied combined effects of RHA and cement on engineering properties of black cotton soil. From strength characteristics point of view they had recommended 8 % cement and 10 % RHA as optimum dose for stabilization.

Sharma *et al.*, [2] investigated the behavior of expansive clay stabilized with lime, calcium chloride and RHA. The optimum percentage of lime and calcium chloride was found to be 4 % and 1% respectively in stabilization of expansive soil without addition of RHA. From UCS and CBR point of view when the soil was mixed with lime or calcium chloride, RHA content of 12 % was found to be the optimum. In expansive soil – RHA mixes, 4% lime and 1% calcium chloride were also found to be optimum.

Charles *et al.* [3] evaluated the geotechnical properties of an expansive clay soil found along Odioku – Odieroke 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.* [4] 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.*[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.

Sabat [6] studied the effects of polypropylene fiber on engineering properties of RHA-lime stabilized expansive soil. Polypropylene fiber added were 0.5 % to 2 % at an increment of 0.5 %.The properties determined were compaction, UCS, soaked CBR, hydraulic conductivity and P effect of 0 day, 7 days and 28 days of curing ware also studied on UCS, soaked CBR, hydraulic conductivity and swelling pressure. The optimum proportion of Soil: RHA: lime: fiber was found to be 84.5:10:4:1.5.

Wahab *et al.* [7] stated that lime stabilization creates a number of important engineering properties in soils to improved workability, providing a working platform for subsequent construction, reducing plasticity to meet specifications, conditioning the soil for further treatment. Lime stabilization results in higher bearing capacity and lower compressibility of the treated soil mass.

(Deboucha *et al.* [8] found increase in CBR value corresponded to increase of the additives content and curing period. Furthermore, the added lime reacts with the pore water, resulting in chemical bonding between soil particles, a reduction in water content and, in turn, an increase in undrained shear strength.

2. 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 Irvinga Gabonesis Fibre

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

2.1.3 Lime

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

2.2 Method

2.2.1 Sampling Locality

The soil sample used in this study were collected along 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 Ihubuluko 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. RESULTS AND DISCUSSIONS

Preliminary results on lateritic soils as seen in detailed test results given in Tables: 5 showed that the physical and engineering properties fall below the minimum requirement for such application and needs stabilization to improve its properties. The soils classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1 and are less matured in the soils vertical profile and probably much more sensitive to all forms of manipulation that other deltaic lateritic soils are known for (Ola [9]; Allam and Sridharan [10]; Omotosho and Akinmusuru [11]; Omotosho [12]). The soils are reddish brown and dark grey in colour (from wet to dry states) plasticity index of 17.30%, 14.23%, 15.20%, 15.50%, and 16.10% respectively for Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads. 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 when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results

Preliminary results of compaction test of 100% lateritic soils of sampled roads are maximum dry density (MDD), 1.954KN/m³, and 1.857KN/m³, 1.943KN/m³, 1.758KN/m³ and 2.105 KN/m³ and for Optimum moisture content (OMC), 12.39%, 14.35%, 13.85%, 11.79% and 10.95%. Obtained maximum results of stabilized lateritic soils with Irvingia gabonensis fibre + lime at 0.2%+2.5%, 0.5 +5.0%, 0.75 +7.5% and 1.0% +10% are MDD, 2.112 KN/m³, 1.943 KN/m³, 2.185 KN/m³, 1.847 KN/m³, 2.215 KN/m³, and OMC 13.15%, 15.05%, 14.73%, 12.74%, 11.93%. Comparatively, results showed corresponding increased values to percentage ratios of both MDD and OMC of stabilized soils.

3.2 California Bearing Ratio (CBR) Test

Obtained CBR results at 100% lateritic soils of unsoaked are 8.7%, 8.5%, 7.8%, 9.4%, 10.6% and soaked of 8.3%, 7.8%, 7.2%, 8.5% and 9.8 %. Irvingia gabonensis fibre + lime stabilized lateritic soils maximum values are unsoaked 73.65%, 69.25%, 66.35%, 77.85%, 86.75 and soaked 68.75%, 66.35%, 61.15%, 74.60%, 81.95%. Results showed increased in stabilized samples with optimum percentage ratios of 0.75 + 7.5% to soil. Beyond maximum ratio, cracks were noticed.

3.3 Unconfined Compressive Strength Test

Preliminary results obtained at 100% lateritic soils are 178kPa, 145kPa, 165kPa, 158kPa and 149kPa. Stabilized soils maximum values are 738kPa, 695kPa, 706kPa, 725kPa and 715kPa. Results obtained showed increased in UCS values corresponding to additives percentage.

3.4 Consistency Limits Test

Preliminary results obtained at 100% lateritic soils consistency limits (plastic index) are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%. Results of stabilized lateritic soils maximum values are 16.28%, 13.52%, 14.64%, 16.87% and 15.45%. Results showed decreased in plastic index to corresponding percentage ratio of additives.

Table 3.1: Engineering Properties of Soil Samples

Location Description	Odiokwu Town Road (CH 0+950) (Laterite)	Oyigba Town Road (CH 4+225) (Laterite)	Anakpo Town Road (CH6+950) (Laterite)	Upatabo Town Road (CH8+650) (Laterite)	Ihubuluko Town Road (CH10+150) (Laterite)
Depth of sampling (m)	1.5	1.5	1.5	1.5	
Percentage(%) passing BS sieve #200	28.35	40.55	36.85	33.45	39.25
Colour	Reddish	Reddish	Reddish	Reddish	Reddish
Specific gravity	2.65	2.50	2.59	2.40	2.45
Natural moisture content (%)	9.85	11.25	10.35	11.85	8.95
Consistency Limits					
Liquid limit (%)	39.75	36.90	36.75	36.85	37.65
Plastic limit (%)	22.45	22.67	21.45	19.35	21.55
Plasticity Index	17.30	14.23	15.20	15.50	16.10
AASHTO soil classification	A-2-6	A-2-4	A-2-4	A-2-6	A-2-4
Unified Soil Classification System	SC	SM	SM	SC	SM
Compaction Characteristics					
Optimum moisture content (%)	12.39	14.35	13.85	11.79	10.95
Maximum dry density (kN/m ³)	1.954	1.857	1.943	1.953	2.105
Grain Size Distribution					
Gravel (%)	6.75	5.35	5.05	8.25	7.58
Sand (%)	35.56	37.35	28.45	29.56	34.25
Silt (%)	33.45	35.65	39.45	38.85	33.56
Clay (%)	24.24	21.65	27.05	23.34	24.61
Unconfined compressive strength (kPa)	178	145	165	158	149
California Bearing capacity (CBR)					
Unsoaked (%) CBR	8.7	8.5	7.8	9.4	10.6
Soaked (%) CBR	8.3	7.8	7.2	8.5	9.8

Table 3.2: Results of Subgrade Soil (Clay) Test Stabilization with Binding Cementitious Products at Different percentages and Combination

SAMPLE LOCATION	SOIL + FIBRE IRVINGA GABONENSIS + LIME	MDD (KN/m ³)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
LATERITE + IRVINGA GABONENSIS FIBRE (IGF) + LIME												
Odiokwu Town Road (CH 0+950)	100%	1.954	12.39	8.70	8.30	178	39.75	22.45	17.30	28.35	A-2-6/SC	POOR
	97.25+0.2+2.5%	1.959	12.53	27.45	24.85	225	39.87	22.79	17.08	28.35	A-2-6/SC	GOOD
	94.5+0.5+5.0%	1.963	12.69	48.15	42.16	384	39.98	23.15	16.83	28.35	A-2-6/SC	GOOD
	92.25+0.75+7.5%	1.988	12.87	73.65	68.75	525	40.25	23.70	16.55	28.35	A-2-6/SC	GOOD
	89+1.0+10%	2.112	13.15	68.90	63.80	738	40.45	24.17	16.28	28.35	A-2-6/SC	GOOD
Oyigba Town Road (CH 4+225)	100%	1.857	14.35	8.50	7.80	145	36.90	22.67	14.23	40.55	A-2-4/SM	POOR
	97.25+0.2+2.5%	1.862	14.43	27.05	25.15	189	37.08	22.97	14.11	40.55	A-2-6/SC	GOOD
	94.5+0.5+5.0%	1.879	14.75	45.35	39.35	293	37.23	23.37	18.86	40.55	A-2-6/SC	GOOD
	92.25+0.75+7.5%	1.889	14.89	69.25	66.35	445	37.45	23.74	13.71	40.55	A-2-6/SC	GOOD
	89+1.0+10%	1.195	15.05	57.81	52.35	695	37.59	24.07	13.52	40.55	A-2-6/SC	GOOD
Anakpo Town Road (CH6+950)	100%	1.943	13.85	7.80	7.20	165	36.75	21.45	15.30	36.85	A-2-4/SM	POOR
	97.25+0.2+2.5%	1.195	13.92	24.45	23.18	205	36.84	21.63	15.21	36.85	A-2-4/SM	GOOD
	94.5+0.5+5.0%	1.974	14.22	39.85	32.50	369	36.88	22.09	14.74	36.85	A-2-4/SM	GOOD
	92.25+0.75+7.5%	1.995	14.39	66.35	61.15	565	37.17	22.32	14.85	36.85	A-2-4/SM	GOOD
	89+1.0+10%	2.185	14.73	58.30	55.25	706	37.35	22.71	14.64	36.85	A-2-4/SM	GOOD
Upatabo Town Road (CH8+650)	100%	1.758	11.79	9.40	8.50	158	36.85	19.35	17.50	33.45	A-2-6/SC	POOR
	97.25+0.2+2.5%	1.767	11.92	29.28	27.35	218	36.94	19.56	17.38	33.45	A-2-6/SC	GOOD
	94.5+0.5+5.0%	1.785	12.18	48.30	46.95	425	37.21	20.05	17.16	33.45	A-2-6/SC	GOOD
	92.25+0.75+7.5%	1.812	12.36	77.85	74.60	560	37.38	20.34	17.04	33.45	A-2-6/SC	GOOD
	89+1.0+10%	1.847	12.74	68.30	63.65	725	37.56	20.69	16.87	33.45	A-2-6/SC	GOOD
Ihubuluko Town Road (CH10+150)	100%	2.105	10.95	10.60	9.80	145	37.65	21.55	16.10	39.25	A-2-6/SC	GOOD
	97.25+0.2+2.5%	2.127	11.21	32.15	28.35	184	37.85	22.01	15.84	39.25	A-2-6/SC	GOOD
	94.5+0.5+5.0%	2.154	11.48	52.45	48.30	308	38.08	22.14	15.67	39.25	A-2-6/SC	GOOD
	92.25+0.75+7.5%	2.188	11.66	86.75	81.95	538	38.26	22.74	15.54	39.25	A-2-6/SC	GOOD
	89+1.0+10%	2.215	11.93	79.80	76.35	715	38.52	23.09	15.45	39.25	A-2-6/SC	GOOD

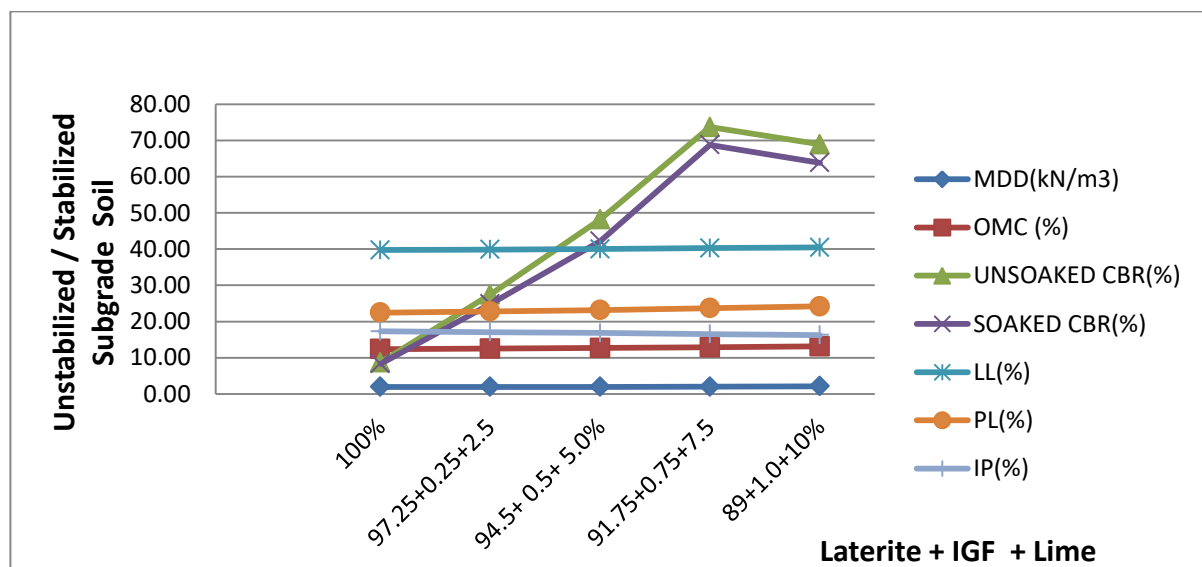


Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

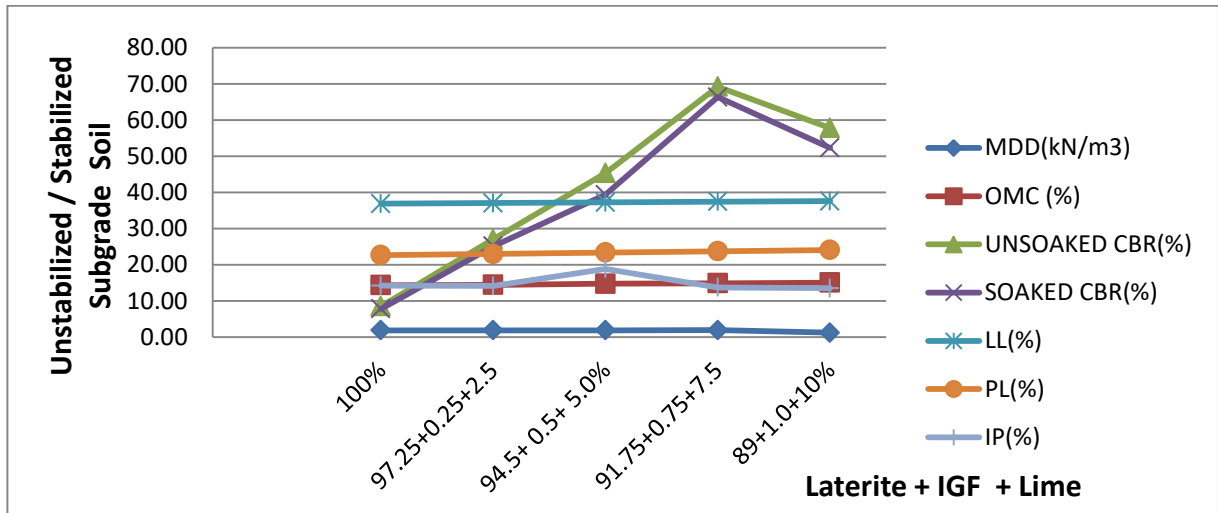


Figure 3.2: Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoda-West L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

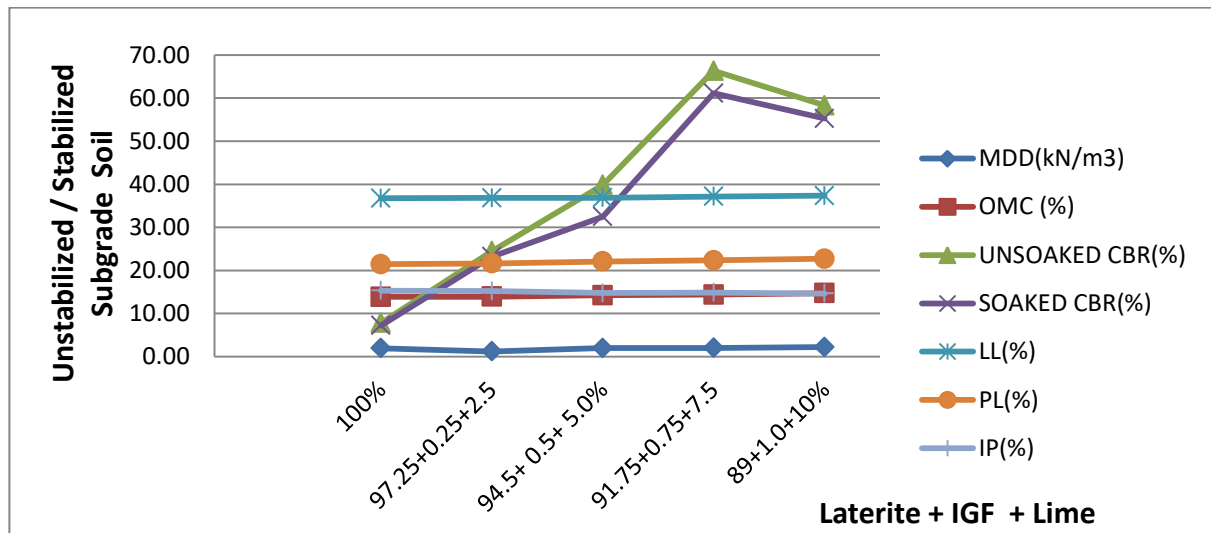


Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoda-West L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

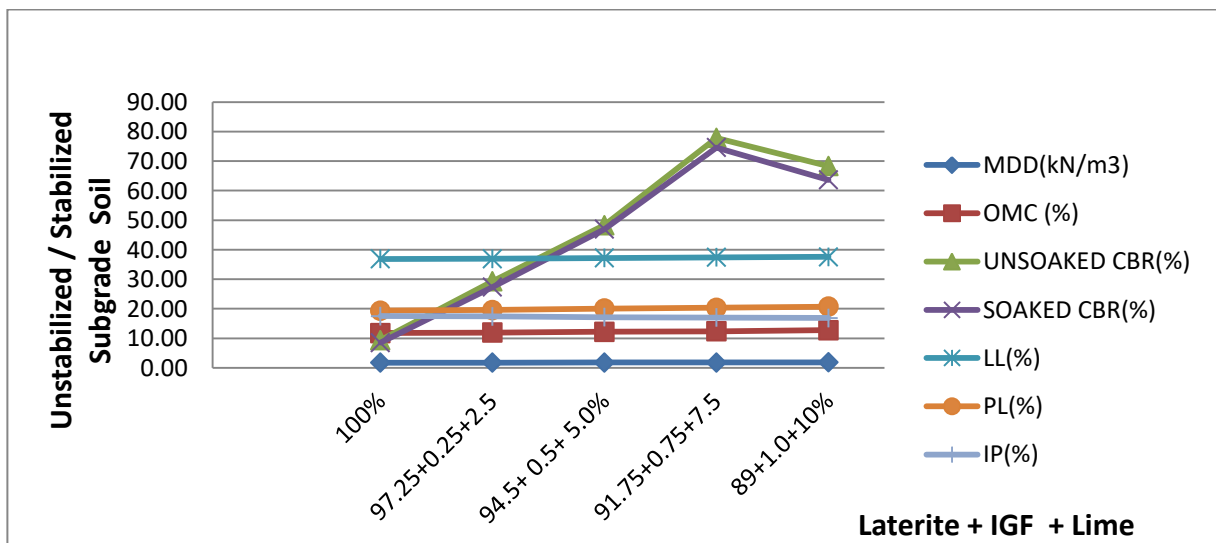


Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoda-West L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

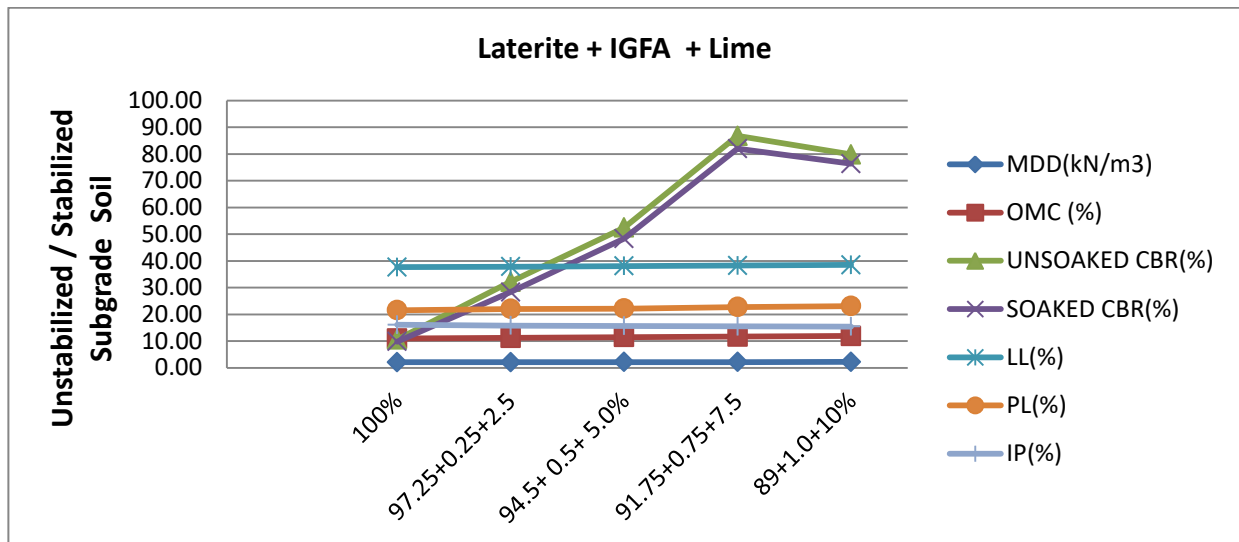


Figure 3.5: Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with IGF + Lime at Different Percentages and Combination

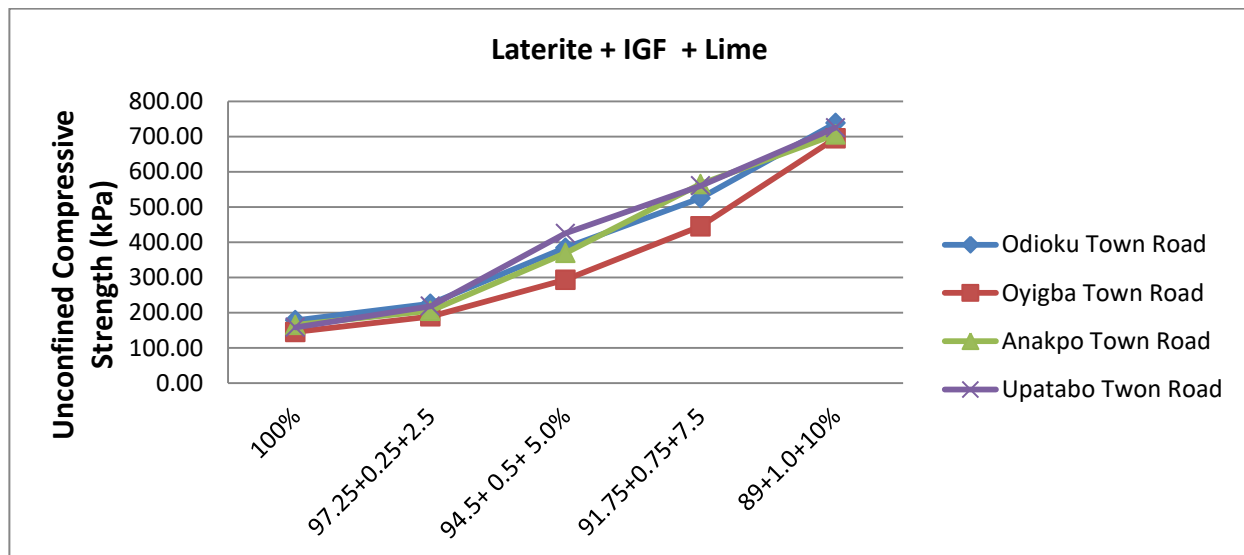


Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with IGF + Lime of (Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoada-West L.G.A, Rivers State

4. 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. Preliminary investigations of the engineering Properties of soils at natural state are percentage (%) passing BS sieves #200, 28.35%, 40.55 %, 36.85%, 33.45% and 39.25%.
- iii. Results showed decreased in plastic index to corresponding percentage ratio of additives.
- iv. Comparatively, results showed corresponding increased values to percentage ratios of both MDD and OMC of stabilized soils.
- v. Consistency limits (plastic index) of the soils at 100% natural state are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%
- vi. The entire results showed the potential of using irvinga gabonesis fibre + lime as admixtures in treated soils
- vii. Swelling potential of treated soil decreased with the inclusion of fibre + lime up to 0.75% +7.5% for lateritic soils

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