Evaluation of Expansive Lateritic Soils Stabilization with Irvinga Gabonesis Fibre and Cement Admixtures as Stabilizers

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ABSTRACT

The research work premeditated the inclusion of irvinga gabonesis fibre and cement in coalesced state to unstable subgrade (soils) of failed highway roads in five local Government Areas of Rivers State with weak and less matured in the soils vertical profile and probably much more sensitive to all forms of manipulation to meet required standard. 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%. The soils are classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System. Consistency limits (plastic index) of the soils at 100% natural state are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%. Comparative results showed maximum dry density and optimum moisture content values increased to corresponding percentage ratio of additives to soils. Results indicated continuous increased in California bearing ratio values with additives increase to optimum. Reduction in California bearing ratio values was noticed beyond 0.7% + 7.5% percentage ratio to soils. Results indicated increased in unconfined compressive strength with percentage ratio increase. Consistency limits comparative results indicated decreased values of plastic index properties to corresponding percentage ratio to sampled soils. Swelling potential of treated soil decreased with the inclusion of fibre up to 0.75% + 7.5% to soils. The entire results showed the potential of using irvinga gabonesis fibre + cement as admixtures in treated soils.

Key Words: *lateritic soils, irvinga gabonesis fibre, cement, CBR, UCS, Consistency, Compaction*

1.0 Introduction

Researches have been carried out on lateritic soil using stabilizers such as lime, cement and bitumen to improve the strength properties in the past (Ola, [1]; Bairwa *et al*., [2]). Stabilization is defined as a means by which soil properties are proved and made more suitable for construction purpose, which can be mechanical, chemical and biological. Soil stabilization is the process that involves the improvement of the engineering properties of soil to make it stable. It can be done by the use of controlled compaction, proportioning and the addition of suitable different types of admixtures and stabilizers (Bairwa *et al.,* [2]).

Ghavami *et al*. [3] observed that the addition of 4 % coconut and sisal fibres to soil causes its deformability to increase significantly. Besides, the creation of cracks in dry seasons was highly lessened.

Prabakar and Sridhar [4] studied on soil specimens reinforced with sisal fibres showed that both fibre content and aspect ratio have important influences in shear strength parameters (c, ∅). They observed that an optimum value for the fibre content exists such that the shear strength decreases with increasing fibre content above this optimum value.

Charles *et al.* [5] 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.* [6] 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. [7] 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.

Mesbah *et al*. [8] carried out tensile tests on soil specimens reinforced with sisal fibres and concluded that the fibres, length and their tensile strength are the most important factors affecting the tensile strength of the soil composite.

Sabat [9] 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.

Ramakrishna and Pradeep [10] 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*., [11] 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.

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 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 Cement

The cement used was Portland Cement, 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 (Ola [1]; Allam and Sridharan [12]; Omotosho and Akinmusuru [13]; Omotosho [14]). The soils 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

Table 3.1 outlined the results maximum dry density (MDD) as 1.954KN/m^3, 1.857 KN/m^3, 1.943 KN/m^3, 1.758 KN/m^3 and 2.105KN/m^3 at 100% soils and optimum moisture content (OMC), 12.39%, 14.35%, 13.85%, 11.79% and 10.95% at 100% lateritic soils. Table 3.4 are the results of stabilized lateritic soils of sampled roads with irvinga gabonesis fibre (IGF) + cement treated soils peak values of MDD as 2.459 KN/m^3, 1.960 KN/m^3, 2.115 KN/m^3, 1.853 KN/m^3 and 2.215 KN/m^3 while OMC are 13.15%, 15.83%, 14.95%, 13.93% and 12.06% with 0.25% + 2.5%, 0.5% + 5.0%, 0.75% + 7.5% and 1.0% +10% percentages to soils ratio. Comparative results showed MDD and OMC increased values to corresponding percentage ratio increase of additives to soils as represented graphically in figures 3.1 – 3.5.

3.2 California Bearing Ratio (CBR) Test

Obtained preliminary investigation results of CBR sampled lateritic soils at 100% are unsoaked, 8.7%, 8.5%, 7.8%, 9.4%, and 10.6% and soaked, 8.3%, 7.8%, 7.2%, 8.5% and 9.8 %. Fibre and cement treated soils with percentage ratio in table 3.4 with optimum values at 0.7% + 7.5% inclusions are unsoaked, 93.80%, 86.75%, 73.85%, 92.30% , 97.35% and soaked, 89.85%, 79.30%, 69.95%, 84.75% and 94.85%. Results indicated continuous increased in CBR values with additives increase to optimum. Reduction in CBR values was noticed beyond 0.7% + 7.5% percentage ratio to soils as presented in table 3.4 and represented in figures 3.1 – 3.5.

3.3 Unconfined Compressive Strength Test

Results obtained of lateritic soils at preliminary engineering soil properties are unconfined compressive strength (UCS) values of 178kPa, 145kPa, 165kPa, 158kPa and 149kPa at 100% soils. Treated soils peak values are 870kPa, 735kPa, 775kPa, 975kPa and 748kPa. Results indicated increased in UCS with percentage ratio increase as presented in table 3.4 and represented graphically in figure 3.6.

3.4 Consistency Limits Test

Results of consistency limits (Plastic index) properties at 100% soils are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%.For stabilized soils, recorded peak values are 16.28%, 13.14%, 14.52%, 16.43% and 14.83%.

Comparative results of table 3.4 and figures 3.1 – 3.5 indicated decreased values of plastic index properties to corresponding percentage ratio to sampled soils.

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})	1.953	1.857	1.943	1.953	2.105
Grain Size Distribution					
Gravel (%)	6.75	5.35	5.05	8.25	7.58
Sand (%)	35.56	37.35	28.45	29.56	34.25
Silt (%)	33.45	35.65	39.45	38.85	33.56
Clay (%)	24.24	21.65	27.05	23.34	24.61
Unconfined compressive strength (kPa)	178	145	165	158	149
California Bearing capacity (CBR)					
Unsoaked (%) CBR	8.7	8.5	7.8	9.4	10.6
Soaked (%) CBR	8.3	7.8	7.2	8.5	9.8

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

SAMPLE LOCATION	SOIL + FIBRE IRVINGA GABONENSIS + CEMENT	MDD (KN/m^3)	OMC (%)	UNSOAKED CBR (%)	SOAKED CBR (%)	UCS(KPa)	LL(%)	PL(%)	PI(%)	SIEVE #200	AASHTO / USCS (Classification)	NOTES
				LATERITE + IRVINGA GABONESIS FIBRE (IGF) + CEMENT								
	100%	1.954	12.39	8.70	8.30	178	39.75	22.45	17.30	28.35	A-2-6/SC	POOR
Odiokwu	97.25+0.2+2.5	1.965	12.51	40.40	36.37	248	39.48	22.27	17.21	28.35	A-2-6/SC	GOOD
Town Road	94.5+0.5+5.0	1.981	12.63	69.25	57.30	336	39.15	22.07	17.08	28.35	A-2-6/SC	GOOD
(CH (0+950)	92.25+0.75+7.5	2.208	12.89	93.80	89.85	515	38.75	22.00	16.75	28.35	A-2-6/SC	GOOD
	89+1.0+10	2.459	13.15	86.37	82.45	870	38.20	21.92	16.28	28.35	A-2-6/SC	GOOD
Oyigba Town	100%	1.857	14.35	8.50	7.80	145	36.90	22.67	14.23	40.55	A-2-4/SM	GOOD
Road	97.25+0.2+2.5	1.880	14.67	37.80	33.70	215	36.55	22.57	14.08	40.55	A-2-6/SC	GOOD
(CH 4+225)	94.5+0.5+5.0	1.914	14.95	63.85	59.45	307	96.21	22.38	13.83	40.55	A-2-6/SC	GOOD
	92.25+0.75+7.5	1.936	15.34	86.75	79.30	480	35.93	22.32	13.51	40.55	A-2-6/SC	GOOD
	89+1.0+10	1.960	15.83	82.83	74.35	735	35.35	22.41	13.14	40.55	A-2-6/SC	GOOD
Anakpo	100%	1.943	13.85	7.80	7.20	165	36.75	21.45	15.30	36.85	A-2-4/SM	POOR
Town Road	97.25+0.2+2.5	1.969	14.05	28.83	25.75	270	36.35	21.23	15.12	36.85	A-2-4/SM	GOOD
(CH6+950)	94.5+0.5+5.0	1.981	14.25	57.45	55.50	321	36.05	21.22	14.83	36.85	A-2-4/SM	GOOD
	92.25+0.75+7.5	1.994	14.65	73.85	69.95	497	35.83	21.37	14.52	36.85	A-2-4/SM	GOOD
	89+1.0+10	2.115	14.95	68.30	66.75	775	35.46	21.37	14.15	36.85	A-2-4/SM	GOOD
Upatabo	100%	1.758	11.79	9.40	8.50	158	36.85	19.35	17.50	33.45	A-2-6/SC	POOR
Town Road	97.25+0.2+2.5	1.775	12.08	45.45	41.83	258	36.56	19.28	33.45	33.45	A-2-6/SC	GOOD
(CH8+650)	94.5+0.5+5.0	1.791	12.35	74.15	72.48	420	36.23	19.15	17.08	33.45	A-2-6/SC	GOOD
	92.25+0.75+7.5	1.820	12.67	92.30	84.75	615	35.95	19.10	16.85	33.45	A-2-6/SC	GOOD
	89+1.0+10	1.853	13.93	86.25	81.30	975	35.66	19.23	16.43	33.45	A-2-6/SC	GOOD
Ihubuluko	100%	2.105	10.95	10.60	9.80	145	37.65	21.55	16.10	39.25	A-2-6/SC	GOOD
Town Road	97.25+0.2+2.5	2.128	11.21	47.35	44.60	209	37.28	21.39	15.89	39.25	A-2-6/SC	GOOD
(CH10+150)	94.5+0.5+5.0	2.160	11.53	77.85	73.90	315	37.01	21.58	15.43	39.25	A-2-6/SC	GOOD
	92.25+0.75+7.5	2.192	11.83	97.35	94.85	465	36.79	21.67	15.12	39.25	A-2-6/SC	GOOD
	89+1.0+10	2.215	12.06	87.15	82.75	748	36.47	21.64	14.83	39.25	A-2-6/SC	GOOD

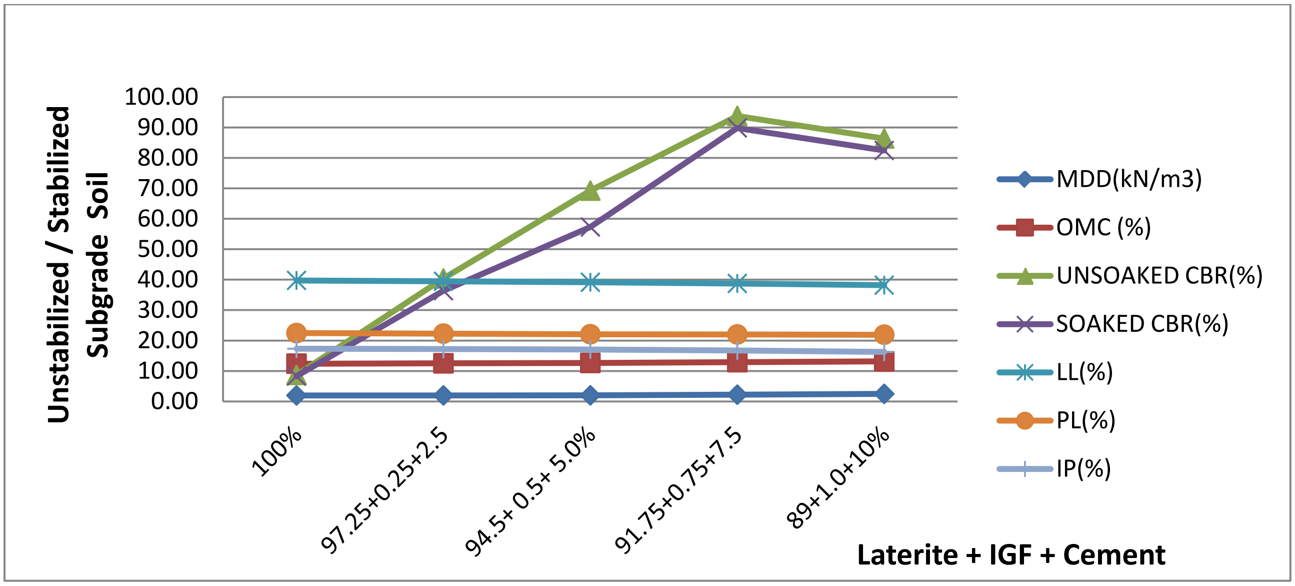

Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with IGF + Cement at Different Percentages and Combination

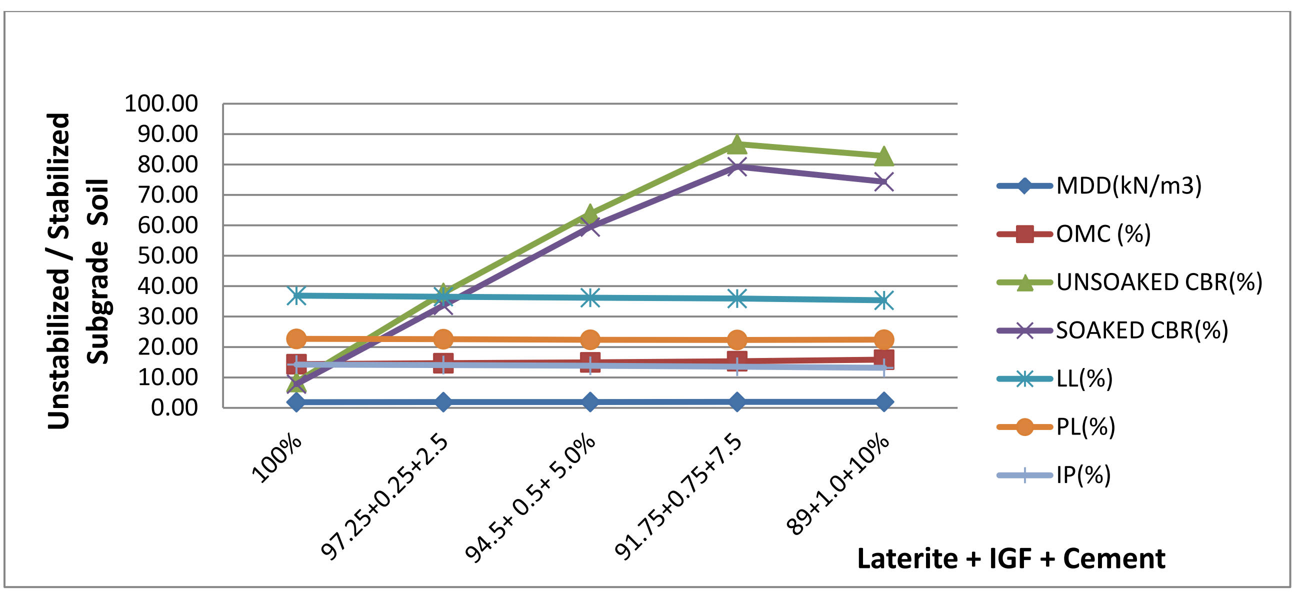

Figure 3.2: Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoada-West L.G.A of Rivers State with IGF + Cement at Different Percentages and Combination

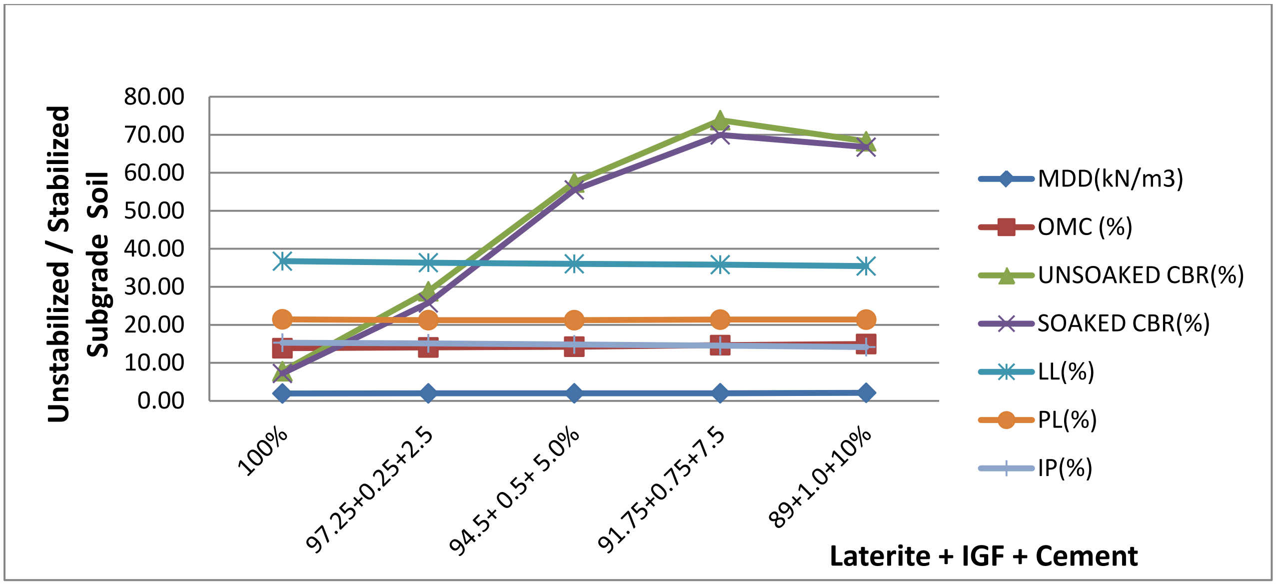

Figure 3.3: Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoada-West L.G.A of Rivers State with IGF + Cement at Different Percentages and Combination

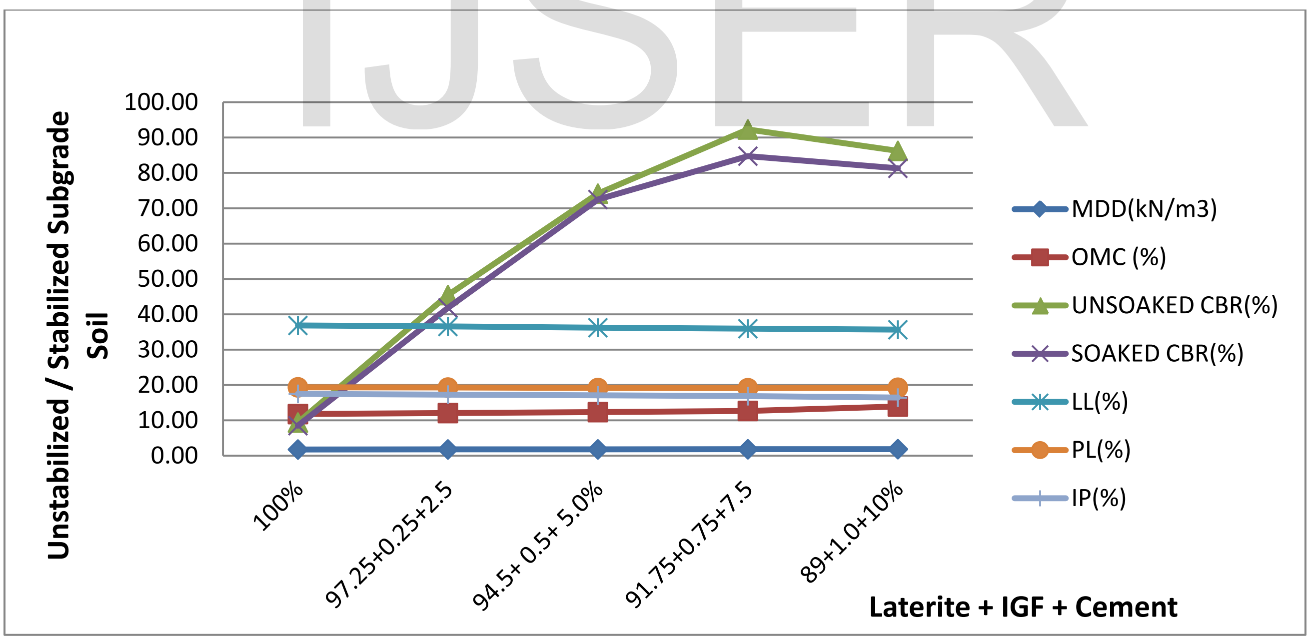

Figure 3.4: Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoada-West L.G.A of Rivers State with IGF + Cement at Different Percentages and Combination

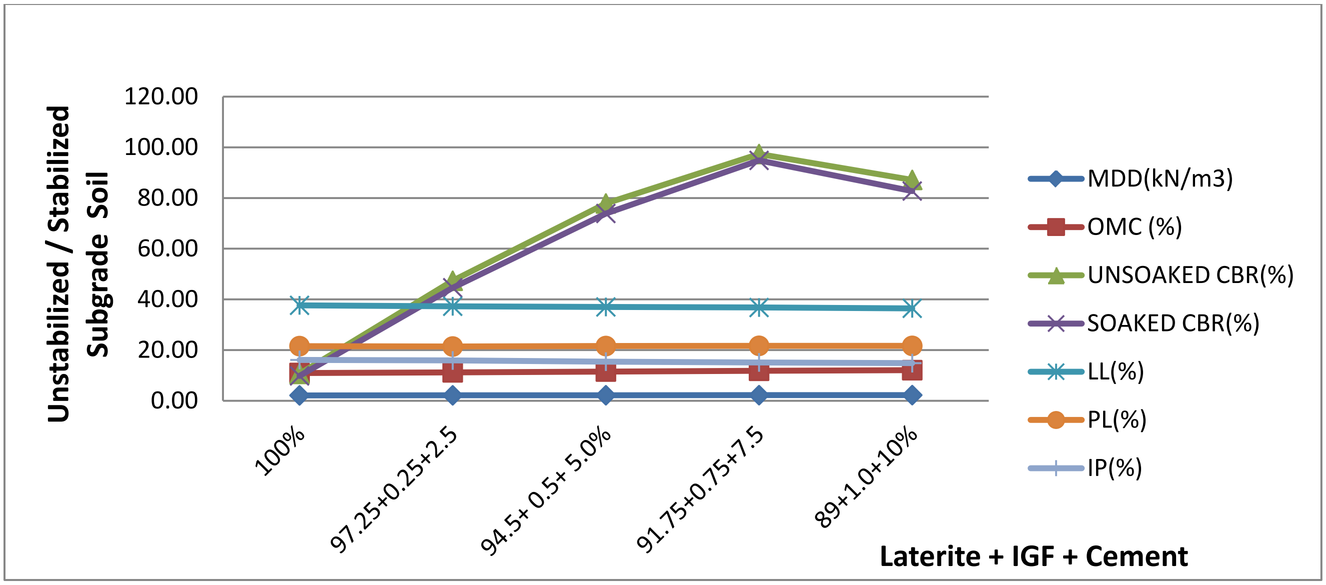

Figure 3.5: Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with IGF + Cement at Different Percentages and Combination

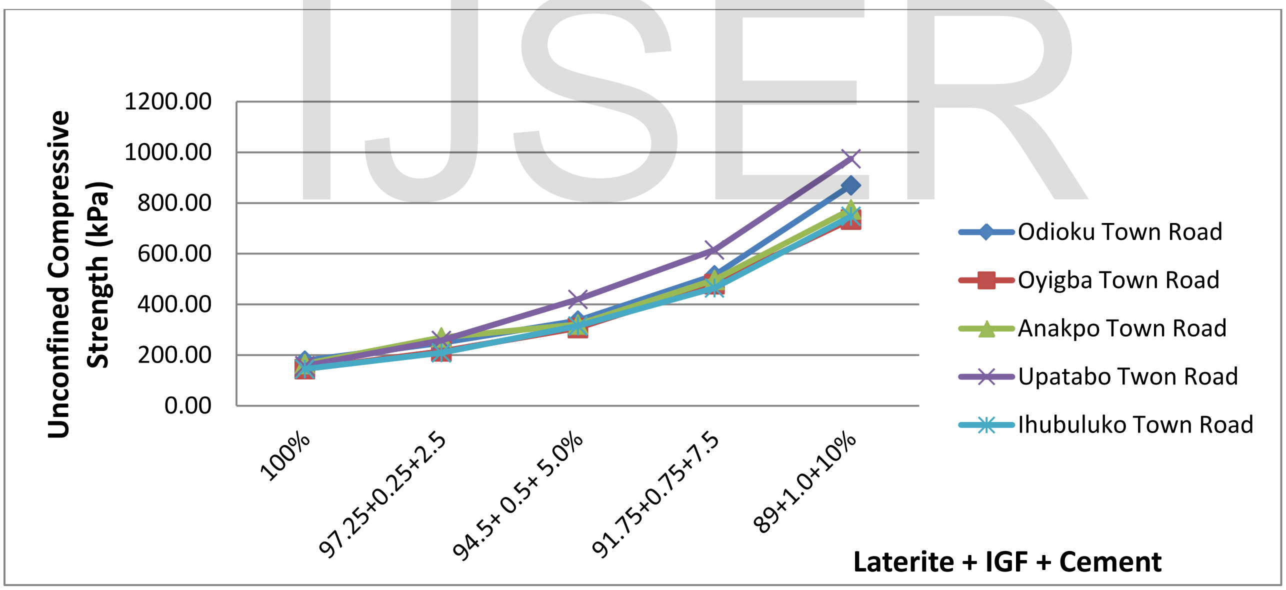

Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with IGF + Cement of (Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoad-West L.G.A, Rivers State

4.0 Conclusions

The following conclusions were made from the experimental research results.

i. 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%.
ii. The soils classified as A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System
iii. Consistency limits (plastic index) of the soils at 100% natural state are 17.30%, 14.23%, 15.20%, 15.50% and 16.10%
iv. Swelling potential of treated soil decreased with the inclusion of fibre ash up to 0.75% + 7.5% for both soils
v. The entire results showed the potential of using irvinga gabonesis fibre + cement as admixtures in treated soils

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