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# Problematic Clay Soils Modification Using Bush mango Fibre as Stabilizer

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***Abstract*: Majority of the roads within the Niger Delta regions of Nigeria constructed on black cotton soils and are prone to severe cracks, degradation and differential settlement that has led to constant rehabilitation seasonally. The soils fell below standard for its application as road constructional materials. The study experimented on the use of irvinga gabonesis fibre(Bush Mango) to stabilized clay soils with percentage ratios of 0.25%, 0.50%, 0.75% and 1.0%. Preliminary investigations revealed the soils as A – 7 – 6 /CH on the AASHTO classification schemes / Unified Soil Classification System. The soils were dark grey in colors (from wet to dry states) with plastic index of 31.10%, 24.55%, 31.05%, and 32.17% respectively for Iwofe, Chokocho, Ndoni, and Ogbele Roads. The soils has unsoaked CBR values of 7.35%, 7.75%, 8.15%, and 7.85% and soaked CBR values of 6.35%, 6.23%, 7.05% and 5.55%. Unconfined compressive strength (UCS) values of 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa. Results of compaction test determination showed decreased in MDD values while OMC values increased, both parameters adhered to corresponding percentage increase ratios. Comparably, results indicated increased in CBR altered soils with optimum mixed percentage ratios of 0.7% to soils. Similarly, results of UCS stabilized soils increased with percentages ratio variations. Results showed low values of plastic index with corresponding percentage increased ratios. Entire results showed the potential use of irvinga gabonesis fibre for expansive soils treatment.**

***Keywords:* Clay soils, Irvinga Gabonesis Fibre, CBR, UCS, Consistency, Compaction.**

## 1. INTRODUCTION

Soil stabilization depends mainly on chemical reactions between stabilizer and soil minerals to achieve the desired effect. Generally, the additions of additives such as fibres to expansive soils increase the strength, bearing capacity and durability of the soil. Natural fibres such as hey, wood and bamboo have been used for the improvement of construction materials (Khedari *et al*. [1]), the use of appropriate elements in soil improves its engineering properties such as strength, hardness and deformability. Currently, natural fibres such as kenaf, coir, banana, jute, flax, sisal, palm, reed, bamboo and wood fibres are used for soil reinforcement and stabilisation (Ramakrishna and Sundararajan [2]).

Charles *et al*. [3] investigated the effectiveness of natural fibre, costus afer bagasse (Bush sugarcane bagasse fibre (BSBF) as soil stabilizer / reinforcement in clay and lateritic soils with fibre inclusion of 0.25%, 0.50%, 0.75% and 1.0%. They concluded that both soils decreased in MDD and OMC with inclusion of fibre percentage, CRB values increased tremendously with optimum values percentage inclusion at 0.75%, beyond this value, crack was formed which resulted to potential failure state.

Ghavami *et al*. [4] 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 [5] studied on soil specimens reinforced with sisal fibres showed that both fibre content and aspect ratio have important influences in shear strength parameters (c, ∅).

Bouhicha *et al*. [6] used the shear box test method to evaluate the strength of compacted earth reinforced with barley straw. Their work was part of a wider study of the physical and mechanical properties of fibre-reinforced compressed earth blocks. Their test results are showed that a 1.5 and 3.5 % (by weight of soil) addition of straw increased the apparent cohesion by up to 50 % (from 330 to 493kPa), but decreased the angle of internal friction.

## 2. MATERIALS AND METHODS

### 2.1 Materials

#### 2.1.1 Soil

The soils used for the study were collected within failed sections of the at 1.5 m depth from Iwofe Town Road, in Obio/Akpor Local Government Area, Chokocho Town Road, in Etche Local Government Area, Ndoni Town Road, in Ogba/Egbema/Ndoni Local Government Area and Ogbele Town Road in ahoada – East Local Government Area, all in Rivers State, Nigeria.

#### 2.1.2 Irvinga Gabonesis Fibre (Bush Mango)

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.

### 2.2 Method

#### 2.2.1 Sampling Locality

The soil sample used in this study were collected along Iwofe Town, (latitude 4.49° 41‘S and longitude 6.57° 24‘E), Chokocho Town, ( latitude 4.9882° N ° 34‘S and longitude 7.0525° ° 13‘E), Ndoni Town, latitude 5.5487 ° 21‘S and longitude 6.5917° ° 39‘E), Ogbele Town, (latitude 4.9198 ° 23‘S and longitude 6.6751 ° 34‘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 clay 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 and needs stabilization to improve its properties. The soils classified as A – 7 – 6 /CH 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 [7]; Allam and Sridharan [8]; Omotosho and Akinmusuru [9]; Omotosho [10]). The soils are dark grey in colour (from wet to dry states) plastic index of 31.10%, 24.55%, 31.05%, and 32.17% respectively for Iwofe, Chokocho, Ndoni, and Ogbele Town Roads. The soil has unsoaked CBR values of 7.35%, 7.75%, 8.15%, and 7.85% and soaked CBR values of 6.35%, 6.23%, 7.05% and 5.55%, unconfined compressive strength (UCS) values of 87.85kPa , 78.75kPa, 105.75kPa , and 85.35kPa when compacted with British Standard light (BSL), respectively.

### 3.1 Compaction Test Results

Natural clay soils compaction test results at 100% are maximum dry density (MDD) 1.685KN/m$^3$, 1.635KN/m$^3$, 1.657KN/m$^3$, 1.697KN/m$^3$ and optimum moisture content (OMC) are 15.28%, 16.28%, 16.05% and 15.73%. In contrast, stabilized clay soils of Iwofe, Chokocho, Ndoni and Ogbele roads with 0.25%. 0.5%, 0.75 and 1.0% to clay soils percentage ratios maximum values are (MDD) 1.550KN/m$^3$ 1.493KN/m$^3$ 1.518KN/m$^3$ 1.542KN/m$^3$ and (OMC) 16.60%, 17.55%, 17.28% and 17.05% . Results of compaction test determination showed decreased in MDD values while OMC values increased, both parameters adhered to corresponding percentage increase ratios.

### 3.2 California Bearing Ratio (CBR) Test

Clay soils at 100% results of CBR values soils has unsoaked 7.35%, 7.75%, 8.15%, 7.85% and soaked 6.35%, 6.23%, 7.05% and 5.55%. Altered clay soils with Irvinga Gabonesis fibre with 0.25%. 0.5%, 0.75% and 1.0% values at maximum are unsoaked 15.25 %, 15.35%, 15.35%, 15.85%, and unsoaked 14.80%, 13.65%, 14.83% and 13.85%. Comparably, results indicated increased in CBR altered soils with optimum mixed percentage ratios of 0.7% to soils.

### 3.3 Unconfined Compressive Strength Test

Results obtained of clay soils at preliminary tests are 87.85kPa, 78.75kPa, 105.75kPa and 85.35kPa. Fibre treated soil results maximum values are 286kPa, 245kPa, 295kPa and 274kPa. Comparably, results of UCS stabilized soils increased with percentages ratio variations.

### 3.4 Consistency Limits Test

Results of consistency limits (Plastic index) at 100% soils are 31.10%, 24.55%, 31.05%, and 32.17%. Fibre stabilized clay soils yielded 28.93%, 23.25%, 28.85% and 29.93%. Results showed low values of plastic index with corresponding percentage increased ratios.

**Table 3.1: Engineering Properties of Soil Samples**

| Location Description | Iwofe Road Obio/Akpor L.G.A | Chokocho Road Etche L.G.A | Ndoni Road Ogba/Egbema/ Ndoni L.G.A | Ogbele Road Ahoda East L.G.A |
|---|---|---|---|---|
| Depth of sampling (m) | 1.2 | 1.2 | 1.2 | 1.2 |
| Percentage(%) passing BS sieve #200 | 76.35 | 80.25 | 83.65 | 78.25 |
| Colour | greenish | Greenish | greenish | greenish |
| Specific gravity | 2.52 | 2.58 | 2.45 | 2.44 |
| Natural moisture content (%) | 42.58 | 48.35 | 44.65 | 44.30 |
| Consistency Limits | | | | |
| Liquid limit (%) | 68.35 | 53.85 | 62.40 | 58.75 |
| Plastic limit (%) | 37.25 | 29.30 | 31.35 | 26.58 |
| Plasticity Index | 31.10 | 24.55 | 31.05 | 32.17 |
| AASHTO soil classification<br>Unified Soil Classification System | A-7-6<br>CH | A-7-6<br>CH | A-7-6<br>CH | A-7-6<br>CH |
| Optimum moisture content (%) | 15.28 | 16.28 | 16.05 | 15.73 |
| Maximum dry density (kN/m$^{3)}$ | 1.685 | 1.635 | 1.657 | 1.697 |

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|---|---|---|---|---|
| Compaction Characteristics | | | | |
| Gravel (%) | 0.0 | 0 | 0 | 0 |
| Sand (%) | 13.18 | 12.3 | 12.8 | 16.5 |
| Silt (%) | 42.3 | 48.5 | 42.3 | 48.2 |
| Clay (%) | 44.6 | 38.2 | 44.9 | 35.3 |
| Unconfined compressive strength (kPa) | 87.85 | 78.75 | 105.75 | 85.35 |
| California Bearing Capacity (CBR) | | | | |
| Unsoaked (%) CBR | 7.35 | 7.75 | 8.15 | 7.85 |
| Soaked (%) CBR | 6.35 | 6.23 | 7.05 | 5.55 |

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

| SAMPLE LOCATION | SOIL + FIBRE RATIO | MDD (kN/m³) | OMC (%) | UNSOAKED CBR (%) | SOAKED CBR (%) | UCS(Kpa) | LL(%) | PL(%) | PI(%) | SIEVE #200 | AASHTO/ USCS (Classification) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY SOIL+IRVINGA GARBONESIS FIBRE | | | | | | | | | | | |
| IWOFE ROAD OBIO/AKPO L.G.A | 100(%) | 1.685 | 15.28 | 7.35 | 6.35 | 87.85 | 68.35 | 37.25 | 31.10 | 76.35 | A – 7 – 6 /CH | POOR |
| | 99.75 +0.25(%) | 1.645 | 15.50 | 10.25 | 8.89 | 120 | 68.05 | 38.20 | 29.85 | 76.35 | A – 7 – 6 /CH | POOR/ GOOD |
| | 99.50 +0.50(%) | 1.602 | 15.85 | 13.35 | 12.45 | 175 | 67.83 | 38.20 | 29.63 | 76.35 | A – 7 – 6 /CH | GOOD |
| | 99.25 +0.75(%) | 1.584 | 16.25 | 15.25 | 14.80 | 225 | 67.45 | 38.17 | 29.28 | 76.35 | A – 7 – 6 /CH | GOOD |
| | 99 +1.0(%) | 1.550 | 16.60 | 14.65 | 13.65 | 286 | 66.96 | 38.03 | 28.93 | 76.35 | A – 7 – 6 /CH | GOOD |
| CHOKOCHO ROAD ETCHE L.G.A | 100(%) | 1.635 | 16.28 | 7.75 | 6.23 | 78.75 | 53.85 | 29.30 | 24.55 | 80.25 | A – 7 – 6 /CH | POOR |
| | 99.75 +0.25(%) | 1.606 | 16.62 | 10.85 | 8.62 | 94 | 53.45 | 28.90 | 24.15 | 80.25 | A – 7 – 6 /CH | POOR/ GOOD |
| | 99.50 +0.50(%) | 1.573 | 16.98 | 12.96 | 10.85 | 165 | 53.08 | 29.28 | 23.80 | 80.25 | A – 7 – 6 /CH | GOOD |
| | 99.25 +0.75(%) | 1.525 | 17.24 | 15.35 | 13.65 | 195 | 52.85 | 29.21 | 23.64 | 80.25 | A – 7 – 6 /CH | GOOD |
| | 99 +1.0(%) | 1.493 | 17.55 | 13.65 | 12.40 | 245 | 52.40 | 29.20 | 23.25 | 80.25 | A – 7 – 6 /CH | GOOD |
| NDONI ROAD OGBA/EGBEMA/NDONI L.G.A | 100(%) | 1.657 | 16.05 | 8.15 | 7.05 | 105.75 | 62.15 | 31.35 | 31.05 | 83.65 | A – 7 – 6 /CH | POOR |
| | 99.75 +0.25(%) | 1.618 | 16.35 | 11.30 | 9.35 | 167 | 61.80 | 32.33 | 31.82 | 83.65 | A – 7 – 6 /CH | POOR/ GOOD |
| | 99.50 +0.50(%) | 1.595 | 16.67 | 14.25 | 11.80 | 198 | 61.53 | 32.25 | 29.55 | 83.65 | A – 7 – 6 /CH | GOOD |
| | 99.25 +0.75(%) | 1.553 | 16.93 | 15.35 | 14.83 | 234 | 61.15 | 32.30 | 29.23 | 83.65 | A – 7 – 6 /CH | GOOD |
| | 99 +1.0(%) | 1.518 | 17.28 | 15.15 | 13.35 | 295 | 58.75 | 32.30 | 28.85 | 83.65 | A – 7 – 6 /CH | GOOD |
| OGBELE ROAD AHODA EAST L.G.A | 100(%) | 1.697 | 15.73 | 7.85 | 5.55 | 85.35 | 58.33 | 26.58 | 32.17 | 78.45 | A – 7 – 6 /CH | POOR |
| | 99.75 +0.25(%) | 1.665 | 16.18 | 10.05 | 8.20 | 123 | 58.08 | 26.47 | 31.86 | 78.45 | A – 7 – 6 /CH | POOR/ GOOD |
| | 99.50 +0.50(%) | 1.610 | 16.45 | 13.73 | 10.35 | 185 | 57.81 | 26.66 | 31.42 | 78.45 | A – 7 – 6 /CH | GOOD |
| | 99.25 +0.75(%) | 1.585 | 16.83 | 15.85 | 13.85 | 222 | 57.55 | 26.73 | 31.08 | 78.45 | A – 7 – 6 /CH | GOOD |
| | 99 +1.0(%) | 1.542 | 17.05 | 13.98 | 12.73 | 274 | 57.72 | 27.62 | 29.93 | 78.45 | A – 7 – 6 /CH | GOOD |

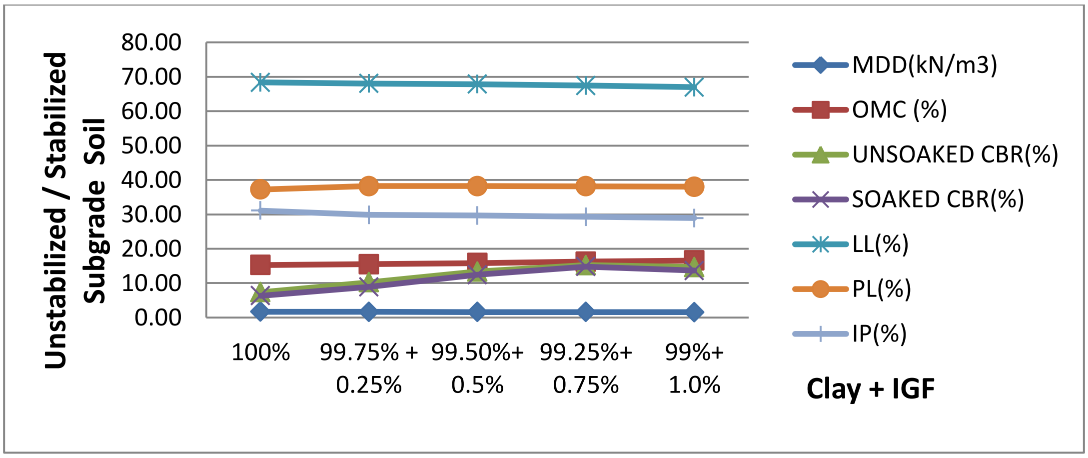


**Figure 3.1:Subgrade Stabilization Test of Clay Soil from Iwofe,in Obio/Akpor L.G.A of Rivers State with IGF at Different Percentages and Combination**

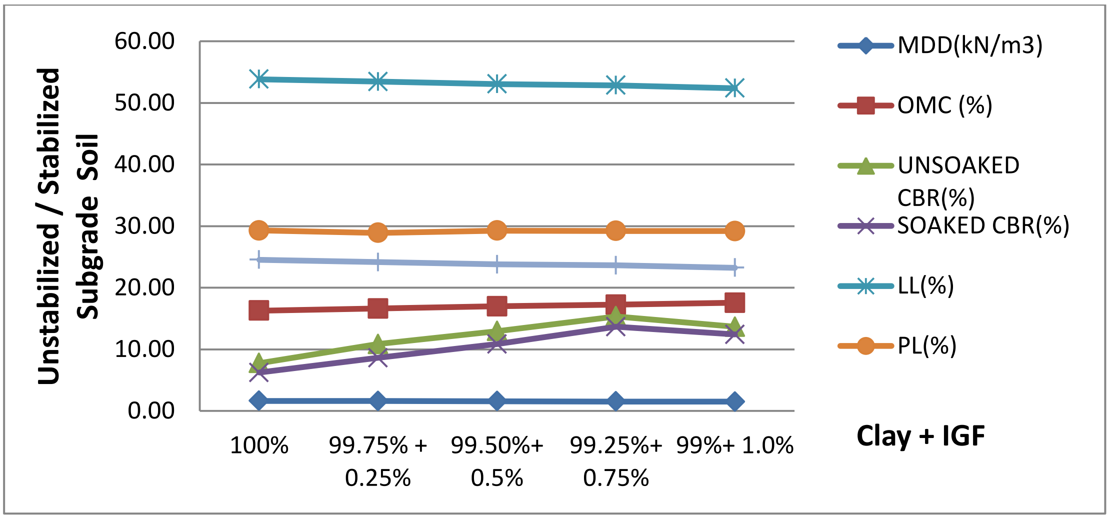


**Figure 3.2:Subgrade Stabilization Test of Clay Soil from Chokocho in Etche L.G.A of Rivers State with IGF at Different Percentages and Combination**

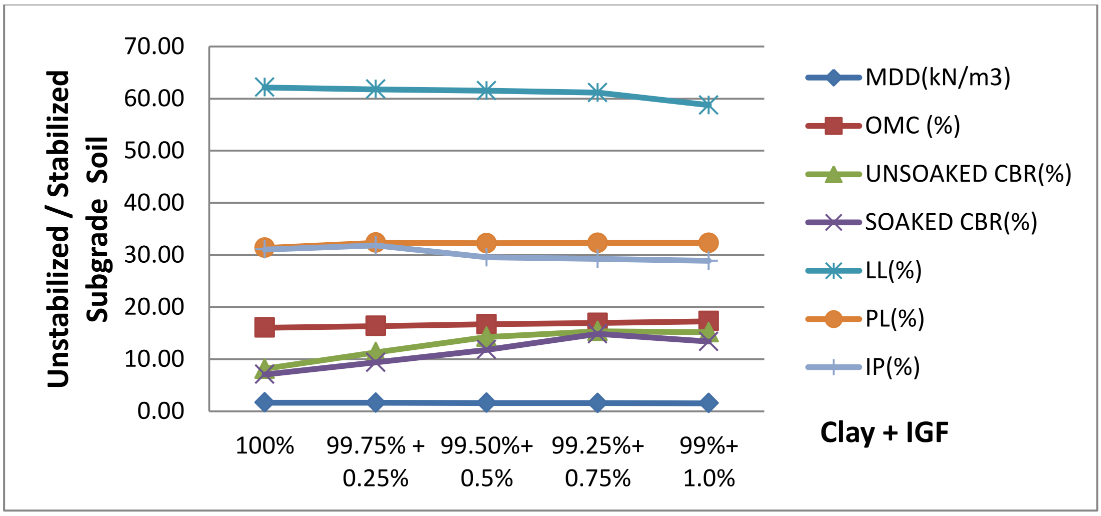


**Figure 3.3:Subgrade Stabilization Test of Clay Soil from Ndoni in Ogna/Egbema/Ndoni L.G.A of Rivers State with IGF at Different Percentages and Combination**

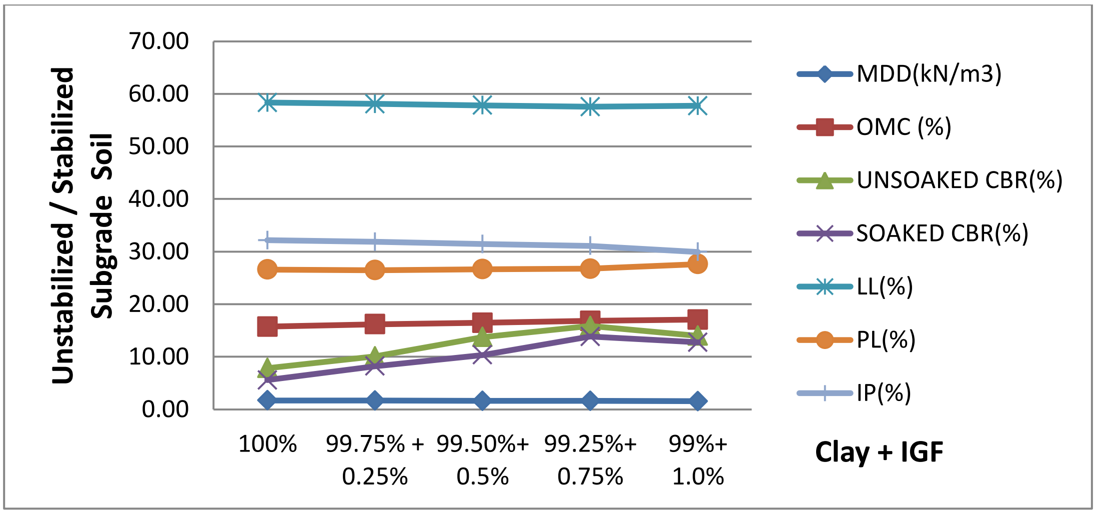


**Figure 3.4:Subgrade Stabilization Test of Clay Soil from Ogbele in Ahoada-East L.G.A of Rivers State with IGF at Different Percentages and Combination**

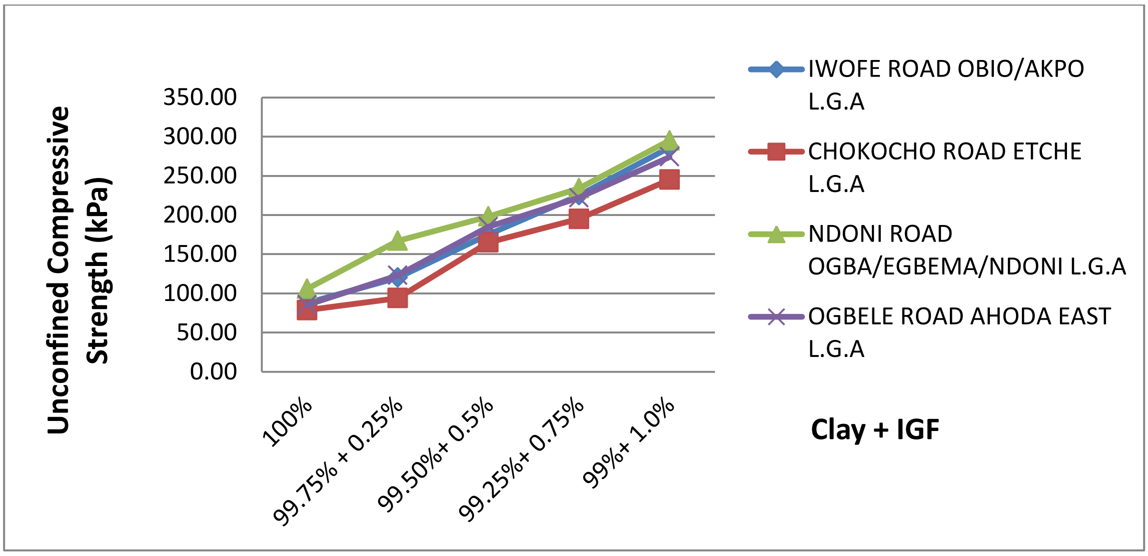


**Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with IGF of (Iwofe, Chokocho, Ndoni, and Ogbele Towns), Rivers State**

## 4. CONCLUSIONS

The following conclusions were made from the experimental research results.

i. The soils are classified as A – 7 – 6 /CH on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1

ii. The soils are dark grey in colour (from wet to dry states) with plastic index of 31.10%, 24.55%, 31.05%, and 32.17% respectively for Iwofe, Chokocho, Ndoni, and Ogbele Town Roads.

iii. Results of compaction test determination showed decreased in MDD values while OMC values increased, both parameters adhered to corresponding percentage increase ratios.

iv. Comparably, results indicated increased in CBR altered soils with optimum mixed percentage ratios of 0.75% to soils.

v. Comparably, results of UCS stabilized soils increased with percentages ratio variations.

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