# Swelling Potential Reduction of Expansive Soils using Costaceae Lacerus Bagasse Fibre Ash and Lime

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***Abstract:*** **The research examined the use of natural fibre bagasse ash (Costaceae Lacerus) and lime combinations in the alteration of expansive soils of unique characteristics of swelling, shrinkage and cracks. Stabilization with 2.5+2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% (CLBFA + Lime) to lateritic soil ratio was deployed on failed road subgrade pavement. Preliminary investigations of the engineering Properties of soils at natural state are percentage (%) passing BS sieves #200 are 28.35%, 40.55%, 36.85%, 33.45% and 39.25% (laterite) and soils deposit belonged to the group A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System. Swelling potential of treated soil decreased with the inclusion of CLBFA + Lime up to7.5% + 7.5%. Stabilized lateritic soils with additives decreased in plastic index properties with increased in additives inclusion percentages. Results showed that an increase in percentage ratio of combined stabilizers increases both MDD and OMC levels. CBR results showed and increased in values of both unsoaked and soaked with optimum level of inclusion at 7.5% + 7.5%., an adversed reduction was experienced beyond the peak giving way for cracks which led to failure. The entire results showed the potential of using CLBFA + Lime as admixtures in treatment of lateritic soils.**

***Keywords:*** **Clay and lateritic soils, Costaceae Lacerus Bagasse Ash, CBR, UCS, Consistency, Compaction.**

## 1. INTRODUCTION

Niger delta roads are susceptible to pavement degradation resulting in very many failures, potholes and cracks along the roads as a result of the type of soil found within the area which shrinks and swells on seasonal variations, they are less the minimum requirements for soils or soil-based materials usable in road pavement structures as indicated by the FMW Specifications [1]. The specified requirements can be achieved by the use of soil stabilizers to improve their strength and make them suitable for road pavement construction materials. Soil Stabilization has proved to be very economical as it provides cheap materials for the construction of low cost roads. Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. A number of stabilizers, such as lime, cement and fly ash, depend on their chemical reactions with the soil elements in the presence of water (Azadegan *et al*. [2]; Mallela *et al*. [3]). Other additives, such as geofiber and geogrid, depend on their physical effects to improve soil properties (Alawaji, [4]; Viswanadham *et al*. [5]). In addition, it can be combined both of chemical and physical stabilization, for example, by using lime and geofiber or geotextile together (Yang *et al*. [6]; Chong and Kassim, [7]). Lime is the oldest traditional chemical stabilizer used for soil stabilization (Mallela *et al*. [3]).

Charles *et al*. [8] 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 strength the failed section of the road. The preliminary investigation values indicated that the soils are highly plastic. The entire results showed the potential of using bagasse, BSBF as admixtures in cement and lime treated soils of clay and laterite. The entire results showed the potential of using bagasse BSBF as admixture in cement and lime treated soils of clay and laterite with 8 % cement and lime and 7.5% +7.5 % of cement / lime + BSBF.

Charles *et al.* [9] 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% and termed poor on remarks required subgrade and strength fo constructional works. 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.

## 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 Costaceae Lacerus Bagasse Fibre Ash

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

#### 2.1.3 Lime

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

### 2.2 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, Califonia 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 [10]; Allam and Sridharan [11]; Omotosho and Akinmusuru [12]; Omotosho [13]). 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 , 145 kPa, 165 kPa , 158kPa and 149 kPa when compacted with British Standard light (BSL), respectively.

### 3.1 Compaction Test Results

Table 3.1 showed the results of maximum dry density (MDD) and optimum moisture content (OMC) results of lateritic soils of Odiokwu, Oyigba, Anakpo, Upatabo, Ihubuluko Town Roads at 100% as 1.954KN/m$^3$, 1.857KN/m$^3$, 1.943KN/m$^3$, 1.758KN/m$^3$ and 2.105KN/m$^3$ MDD and 12.39%, 14.35%, 13.85%, 11.79 and 10.95% OMC. Tables 3.5 and figures 3.1 – 3.5 showed the results of Stabilized soils with 2.5+2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% (CLBFA + Lime) to lateritic soils corresponding ratio, MDD increased to 2.058KN/m$^3$, 1.975KN/m$^3$, 1.965KN/m$^3$, 1.940KN/m$^3$, 2.184KN/m$^3$, and OMC also increased to 13.45%, 15.45%, 14.95%, 12.45%, 11.95%. Results showed that an increase in percentage ratio of combined stabilizers increases both MDD and OMC levels.

### 3.2 California Bearing Ratio (CBR) Test

Tables 3.1 showed the preliminary results of 100% of CBR values as 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 %, of the sampled sites. Stabilized samples as with 2.5+2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% (CLBFA + Lime) to lateritic soils corresponding ratio increased to 46.40%, 44.95%, 38.75%, 48.35%, 49.75% (unsoaked) and 43.35%, 40.85%, 36.60%, 44.30%, and 44.35% (soaked). Final results showed and increased in CBR values of both unsoaked and soaked with optimum level of inclusion at 7.5% + 7.5%. An adverse reduction was experienced beyond the peak giving way for cracks which led to failure.

### 3.3 Unconfined Compressive Strength Test

Results obtained of lateritic soils of sampled sites at preliminary engineering soil properties are unconfined compressive strength (UCS) values of 178kPa, 145 kPa, 165 kPa , 158kPa and 149 kPa as shown in table 3.1. Stabilized soil samples increased to 318kPa, 275kPa, 296kPa, 287kPa, and 280kPa. Results showed an increased in UCS of stabilized lateritic soils with 2.5+2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% (CLBFA + Lime) to lateritic soils corresponding percentage ratio.

### 3.4 Consistency Limits Test

Consistency limits (Plastic Index) results at 100% natural state are 17.30%, 14.23%, 15.20%, 15.50%, and 16.10% at 100% lateritic soils and 15.75%, 12.85%, 14.02%, 16.23% and 14.85% as shown in table 3.1 and figures 3.1 – 3.5. Stabilized lateritic soils with additives decreased in plastic index properties with increased in additives inclusion percentages.

**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/m³) | 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: Properties of Coataceae Lacerus bagasse fibre. (University of Uyo, Chemical Engineering Department, Material Lab.1)**

| Property | Value |
|---|---|
| Fibre form | Single |
| Average length (mm) | 400 |
| Average diameter (mm) | 0.86 |
| Tensile strength (MPa) | 68 - 33 |
| Modulus of elasticity (GPa) | 1.5 – 0.54 |
| Specific weight (g/cm$^3$) | 0.69 |
| Natural moisture content (%) | 6.3 |
| Water absorption (%) | 178 - 256 |

Source, 2018

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**Table 3.3: Composition of Bagasse. (University of Uyo, Chemical Engineering Department, Material Lab.1)**

| Item | % |
|---|---|
| Moisture | 49.0 |
| Soluble Solids | 2.3 |
| Fiber | 48.7 |
| Cellulose | 41.8 |
| Hemicelluloses | 28 |
| Lignin | 21.8 |

Source, 2018

**Table 3.4: Results of Subgrade Soil (Clay) Test Stabilization with binding cementitious Products of Different percentages and combination**

| SAMPLE LOCATION | SOIL + FIBRE RATIO BAGASSE ASH+LIME(%) | MDD (kN/m³) | OMC (%) | UNSOAKED CBR (%) | SOAKED CBR (%) | UCS(KPa) | LL(%) | PL(%) | PI(%) | SIEVE #200 | AASHTO / USCS (Classification) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATERITE + COSTACEAE LACERUS BAGASSE FIBRE ASH (CLFA) + 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 |
| | 95+2.5+2.5% | 1.959 | 12.48 | 18.75 | 15.15 | 209 | 39.58 | 22.40 | 17.18 | 28.35 | A-2-6/SC | GOOD |
| | 90+5.0+5.0% | 1.967 | 12.52 | 29.35 | 26.33 | 225 | 39.15 | 22.13 | 17.02 | 28.35 | A-2-6/SC | GOOD |
| | 85+7.5+7.5% | 1.988 | 12.85 | 46.40 | 43.35 | 275 | 38.75 | 21.93 | 16.82 | 28.35 | A-2-6/SC | GOOD |
| | 80+10.0+10% | 2.058 | 13.45 | 42.75 | 38.37 | 318 | 38.21 | 21.72 | 16.49 | 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 |
| | 95+2.5+2.5% | 1.865 | 14.48 | 18.55 | 14.98 | 165 | 35.93 | 21.90 | 14.03 | 40.55 | A-2-4/SM | GOOD |
| | 90+5.0+5.0% | 1.887 | 14.65 | 25.85 | 22.14 | 198 | 35.65 | 21.79 | 13.86 | 40.55 | A-2-4/SM | GOOD |
| | 85+7.5+7.5% | 1.928 | 14.89 | 44.95 | 40.85 | 237 | 35.26 | 21.91 | 13.35 | 40.55 | A-2-4/SC | GOOD |
| | 80+10.0+10% | 1.975 | 15.45 | 40.15 | 37.85 | 275 | 34.88 | 20.82 | 13.03 | 40.55 | A-2-4/SM | 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 |
| | 95+2.5+2.5% | 1.952 | 14.08 | 16.35 | 16.12 | 185 | 36.45 | 21.40 | 15.05 | 36.85 | A-2-4/SM | POOR |
| | 90+5.0+5.0% | 1.967 | 14.23 | 24.40 | 22.25 | 218 | 36.15 | 20.29 | 14.86 | 36.85 | A-2-4/SM | GOOD |
| | 85+7.5+7.5% | 1.985 | 14.65 | 38.75 | 36.60 | 265 | 35.98 | 21.45 | 14.53 | 36.85 | A-2-4/SM | GOOD |
| | 80+10.0+10% | 1.965 | 14.95 | 32.45 | 30.85 | 296 | 35.23 | 21.05 | 14.18 | 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 |
| | 95+2.5+2.5% | 1.766 | 11.87 | 23.85 | 21.23 | 179 | 36.65 | 19.50 | 17.15 | 33.45 | A-2-6/SM | GOOD |
| | 90+5.0+5.0% | 1.787 | 11.93 | 33.15 | 29.30 | 195 | 36.65 | 19.50 | 17.15 | 33.45 | A-2-6/SM | GOOD |
| | 85+7.5+7.5% | 1.835 | 12.21 | 48.35 | 44.30 | 226 | 36.03 | 19.68 | 16.35 | 33.45 | A-2-6/SC | GOOD |
| | 80+10.0+10% | 1.940 | 12.45 | 43.55 | 39.77 | 287 | 35.70 | 19.65 | 16.05 | 33.45 | A-2-6/SM | 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 |
| | 95+2.5+2.5% | 2.114 | 11.08 | 26.65 | 22.30 | 112 | 37.35 | 21.47 | 15.88 | 39.25 | A-2-6/SM | POOR |
| | 90+5.0+5.0% | 2.128 | 11.25 | 34.95 | 30.35 | 193 | 37.08 | 21.55 | 15.53 | 39.25 | A-2-6/SM | GOOD |
| | 85+7.5+7.5% | 2.235 | 11.65 | 49.75 | 44.35 | 239 | 36.77 | 21.45 | 15.32 | 39.25 | A-2-6/SC | GOOD |
| | 80+10.0+10% | 2.184 | 11.95 | 45.60 | 40.80 | 280 | 36.25 | 21.20 | 15.05 | 39.25 | A-2-6/SM | GOOD |

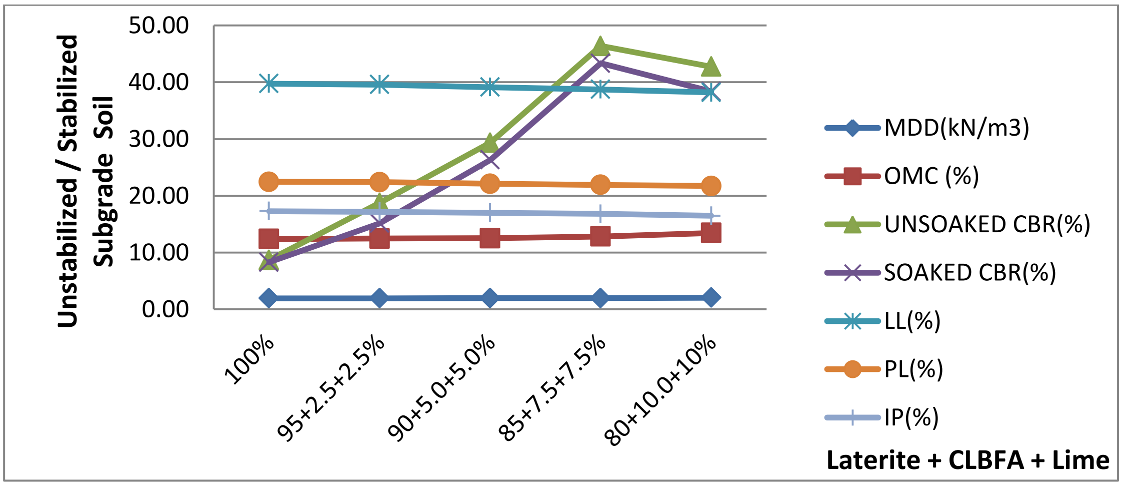


**Figure 3.1:Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination**

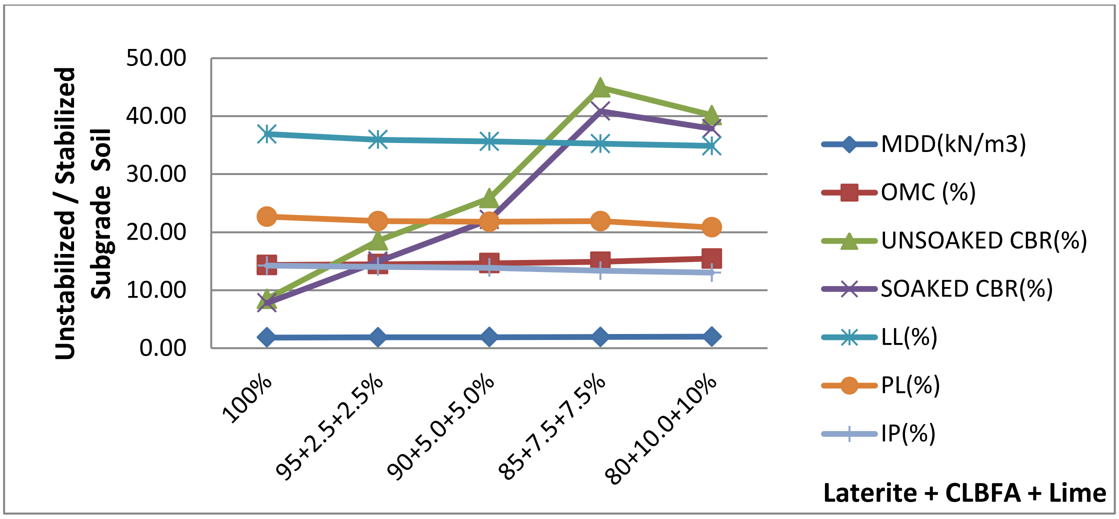


**Figure 3.2:Subgrade Stabilization Test of Lateritic Soil from Oyigba in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination**

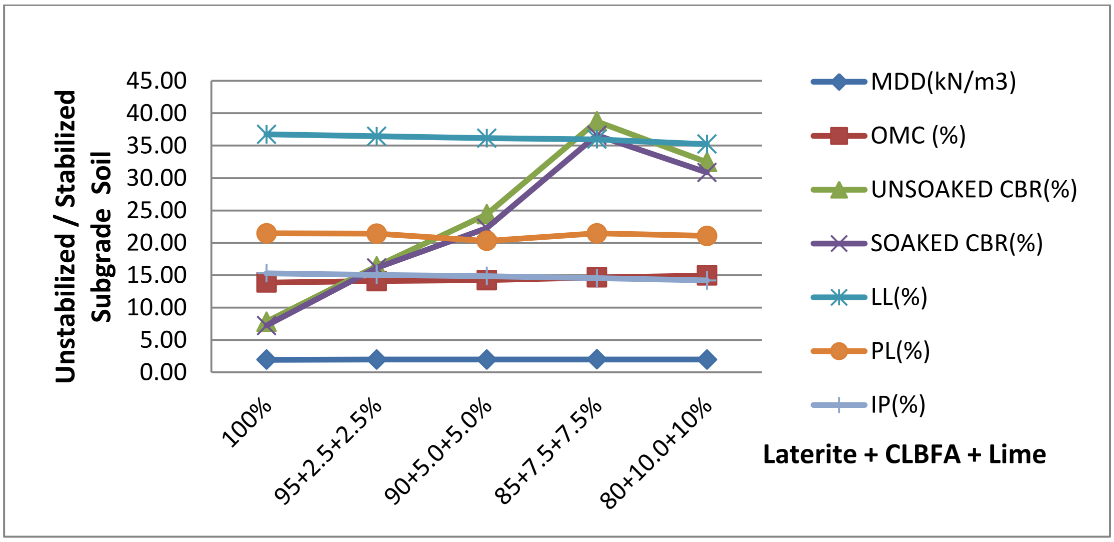


**Figure 3.3:Subgrade Stabilization Test of Lateritic Soil from Anakpo in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination**

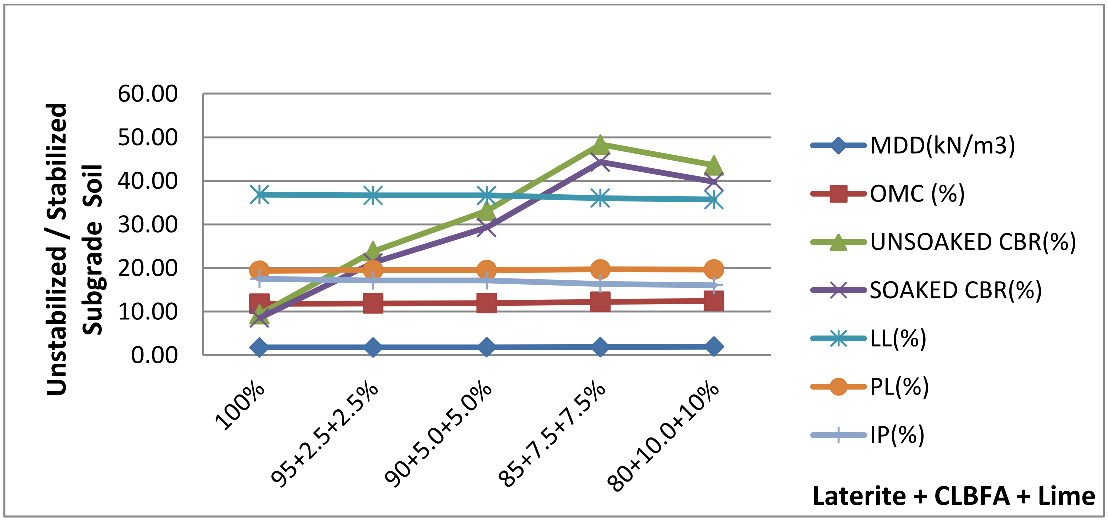


**Figure 3.4:Subgrade Stabilization Test of Lateritic Soil from Upatabo in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination**

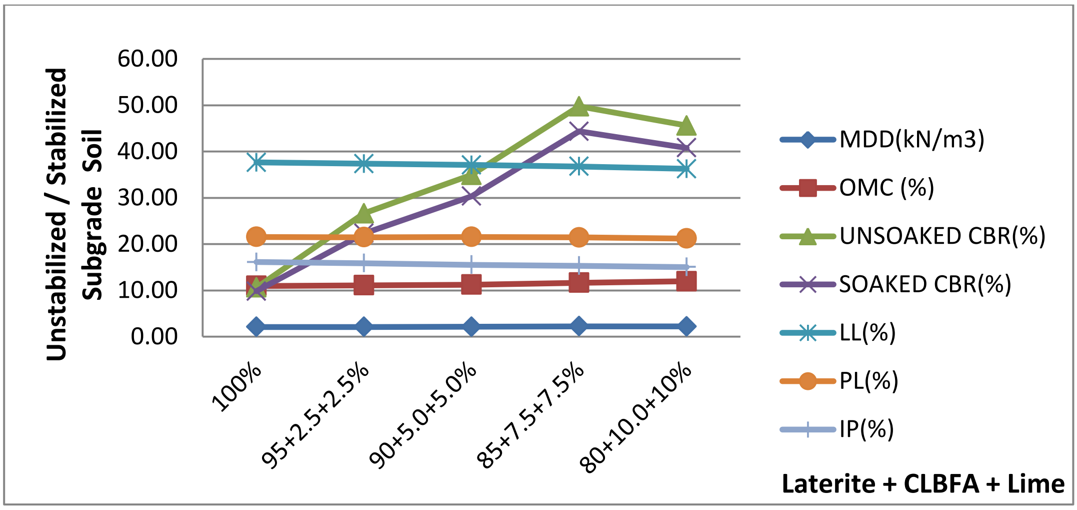


**Figure 3.5:Subgrade Stabilization Test of Lateritic Soil from Ihubuluko in Ahoada-West L.G.A of Rivers State with CLBFA + Lime at Different Percentages and Combination**

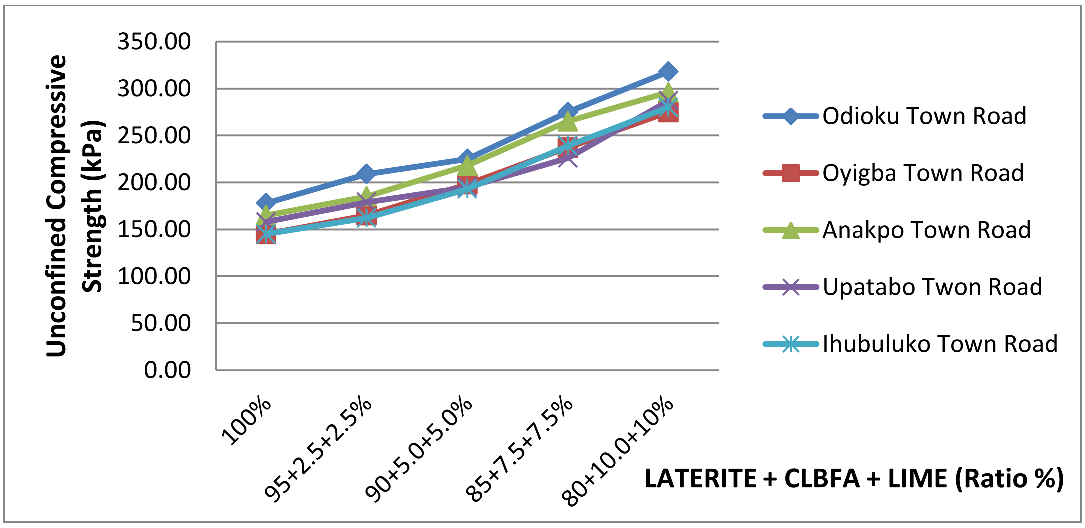


**Figure 3.6: Unconfined Compressive Strength (UCS) of Niger Deltaic Laterite Soils Subgrade with CLBFA + Lime of ( Odioku, Oyigba, Anakpo, Upatabo and Ihubuluko Towns), Ahoad-West L.G.A, Rivers State**

Plate i. **Costaceae Lacerus** plant

Plate ii. **Costaceae Lacerus** stem

Plate iii. **Costaceae Lacerus** dry bagasses/fibre

Plate iv. **Costaceae Lacerus** Bagasses Fibre ash

## 4. CONCLUSIONS

The following conclusions were made from the experimental research results.

i. The soils deposit belonged to the group A-2-6 SC and A-2-4 SM on the AASHTO classification schemes / Unified Soil Classification System as shown in table 3.1.
ii. Preliminary investigations of the engineering Properties of soils at natural state are percentage (%) passing BS sieves #200 are 28.35%, 40.55%, 36.85%, 33.45% and 39.25% (laterite),
iii. The entire results showed the potential of using CLBFA + Lime as admixtures in treated soils laterite.
iv. Swelling potential of treated soil decreased with the inclusion of CLBFA + Lime up to7.5% + 7.5%
v. Stabilized lateritic soils with additives decreased in plastic index properties with increased in additives inclusion percentages.
vi. Results showed that an increase in percentage ratio of combined stabilizers increases both MDD and OMC levels.
vii. Final results showed and increased in CBR values of both unsoaked and soaked with optimum level of inclusion at 7.5% + 7.5%. An adverse reduction was experienced beyond the peak giving way for cracks which led to failure.

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