Black Cotton Soil Properties Modification using Costaceae Lacerus Bagasse Fibre as Road Pavement Stabilizer

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Abstract

The research work examined the modification of expansive soils with bagasse fibre to improve its engineering properties for road pavement structures. Preliminary investigations classified the clay soils as A – 7 – 6 on the AASHTO Classification System and soils are dark grey at all conditions and percentage (%) passing BS sieves #200 are 73.85%, 67.38%, 6.35%, 82.35%, and 71.55%. Comparative results confirmed a decrease in plastic index properties of clay soils. Compaction test results showed a decreased in MDD values while OMC recorded increased values due to bagasse fibre inclusion. Results obtained showed an increase in UCS with an increase in fibre percentages to soil corresponding ratio. Relative results showed an increased in CBR values with an increase in bagasse fibre percentages to a peak ratio of 0.75% to soil ratio. The entire results showed the potential of using costaceae lacerus bagasse fibre (CLBF) as admixtures in the treatment of clay soils. The swelling potential of treated soil decreased with the inclusion of bagasse fibre up to 0.75%.

Keywords: Clay Soils, Costaceae Lacerus Bagasse Fibre, CBR, UCS, Consistency, Compaction.

INTRODUCTION

Large soils are formed by the breakdown of the original igneous rocks where seasonal variations of weather occur at the peak. Nigerian black cotton soil is formed by weathering of the Shelley and mud sediments and basaltic rocks. They contain more montmorillonite, with a later appearance of self-propelling properties and a tendency to expand [1]. Expansive soils are problematic and are commonly encountered in foundation engineering designs for highways, embankments, retaining walls, etc. These soils are found in arid and semi-arid regions of tropical/temperate regions marked with dry and wet climates, and in the Niger Delta region of the River State of Nigeria with low rainfall, poor drainage, and extreme heat. Climate conditions are such that annual evaporation exceeds precipitation ([2–4]). The vast soil found in the extensive deposits in the northeastern part of Nigeria is referred to as black cotton soil, which is dark brown to black soil with high clay content, typically from 50% more in which montmorillonite is the main clay mineral [5]. These expansion soils do not conform to the standard subgrade pavement specified by the Federal Ministry of Works FMW, 1997. Soil stabilization is an approved alternative to measure this trend.

Investigated the effectiveness of natural fiber, Cotus afer bagasse (stabilizer/reinforcement in bush sugarcane bagasse fiber (BSBF) soils with inclusion of 0.25%, 0.50%, 0.75% and 1.0% fiber). MDD and OMC decreased in both soils with the inclusion of fiber percentage. CBR values increased significantly with the optimum value percent inclusion of 0.75%, beyond this value, cracks were formed, resulting in potential failure states[6].

Studied the combined effects of RHA and cement on the engineering properties of black cotton soil. From the strength characteristics point of view, they recommended 8% cement and 10% RHA as the optimal dosage for stabilization[7].

Studied the effects of polypropylene fibers on the engineering properties of RHA-Lime. Polypropylene fibers were added 0.5% to 2% at a 0.5% increase. The determined properties were condensation, the effect of UCS, soaked CBR, hydraulic conductivity and P soaking of 0-day, 7-day and 28-day curing
vessels were also studied by UCS, CBR, hydraulic conductivity and swelling pressure. The optimum soil ratio: RHA: lime: fiber was found to be 84.5: 10: 4: 1.5[8].

Reinforced on soil samples showed that both fiber content and aspect ratio have significant effects in shear strength parameters (C, Ø)[9].

Investigated the effectiveness and application of waste agricultural products from plantain rachis fibers as stabilizers for lateritic soil amendments with unrelated and volatile characteristics. The comparative results for un-stabilized and stabilized soils showed a decrease in the values of maximum dry density and an increase in the optimum moisture content values for stabilized lateritic soil. Results on the comparison with un-stabilized soil showed a percentage of decreasing ratio with a decrease in the values of the plastic index parameters of the stabilized soils. Comparative results show increased values of unconfined compression strength tests with similar percentage ratio inclusions compared to non-stationary soils. Results on the comparison with un-stabilized soil showed a percentage of decreasing ratio with a decrease in the values of the plastic index parameters of the stabilized soils. The overall results showed the potential use of plantain rachis fibers in soil stabilization [10].

**MATERIALS AND METHODS**

**Materials**

**Soil**

Sampled soils are gotten from Ogoda Town Road, Ubie, Districts of Ekpeye, Ahoada-East and Ahoada-West Local Government Area, Bodo Town Road, Gokana Local Government Area, Ogbogu Town Road, Egbeama/Ndoni/Egbema Local Government Area, Ula-Ikata Town Road, Ahoada-East Local Government area, and Kaani Town Road, Khana Local Government Area, all of Rivers State, Niger Delta, Nigeria.

**Costaceae Lacerus Bagasse Fibre (CLBF)**

Costaceae Lacerus bagasse fibre is abundantly and widely medicinal plants gotten from bushes of Oyigba Town, Ubie Clan, Ahoada-West, and Ahoada State, Nigeria.

**Method**

**Sampling Locality**

Sampled soils are gotten from Rivers State in Ogoda Town Road, (latitude 5.04 ° 59'S and longitude 6.38 ° 42'E), Bodo Town Road, (latitude 4.65 ° 05'S and longitude 7.27 ° 15'E, Ogbogu Town Road, Latitude 5.13 ° 08'S and longitude 6.33 ° 25'E), Ula Ikata Town Road, (latitude 5.95 ° 45'S and longitude 6.66 ° 13'E) and Kanni Town Roads, latitude 4.67 ° 13'S and longitude 6.81 ° 55'E).

**Test Conducted**

Tests performed included (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;

**Moisture Content Determination**

The natural moisture content of the soil obtained from the site was determined according to BS 1377 (1990) Part 2. The freshly collected sample was dug and placed loosely in the containers and the containers were weighed together with samples at 0.01g.

**Grain Size Analysis (Sieve Analysis)**

Mechanical or sieve analysis is performed to determine the distribution of course, large-sized particles. This test is performed to determine the percentage of different grain sizes contained within the soil.

**Consistency Limits**

The liquid limit (LL) is defined as the arbitrary water content, in percentage, at which a portion of the soil in the standard cup and a groove of standard dimensions is cut, for a distance of 13 mm will flow simultaneously at the base of the drain (1 / 2in.) When subjected to 25 shocks being dropped 25 mm from the cup in a standard fluid limit mechanism operated at a rate of two shocks per second.

**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 compaction effort.

**Unconfined Compression (UC) Test**

Unconfined compressed power is taken as the maximum load achieved per unit area, or loaded at 15% axial stress per unit area, whichever occurs during the performance of a test. The primary objective of this test is to determine the undefined compressive strength, which is then used to calculate the unconsolidated shear strength of the soil under unconfined conditions.

**California Bearing Ratio (CBR) Test**

The California Bearing Ratio (CBR) test by the California Division of Ratio was developed and evaluated and evaluated the soil-sub-base and base course material for flexible pavements

**RESULTS AND DISCUSSIONS**

The soils classified as A – 7 – 6 on the AASHTO 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 [11-14]. Preliminary results on clay 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 are
reddish brown and dark grey in color (from wet to dry states) plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Town Roads. The soil has unsoaked CBR values of 8.58%, 8.83%, 8.05%, 7.38%, and 9.05% and soaked CBR values of 6.33%, 7.15%, 7.35%, 5.9% and 8.23 %, unconfined compressive strength (UCS) values of 58.85kPa, 63.35kPa, 57.75 kPa, 53.75kPa and 63.85kPa when compacted with British Standard Light (BSL), respectively.

Compaction Test Results

Table 3.1 showed the compaction test of maximum dry density (MDD) at natural state 100% clay as 1.875KN/m³, 1.923KN/m³, 1.823KN/m³, 1.795KN/m³, 1.985KN/m³ and Optimum moisture content (OMC) as 15.68%, 14.93%, 16.30%, 17.45% and 15.35%. Stabilized soil with costacea lacerus bagasse fibre (CLBF) at 0.25%, 0.50%, 0.75%, and 1.0% decreased to 1.758 KN/m³, 1.825 KN/m³, 1.794 KN/m³, 1.683 KN/m³, 1.883 KN/m³ with percentile representations from 99.58%, 98.26%, 98.75%, 98.84%, 99.35%, 109.46% to 103.15%, 111.80%, 104.06%, 105.07%, 121.31%, 128.72%. Optimum moisture content (OMC) increased to 16.48%,15.98%, 14.93%, 13.22%, 13.88%, 12.85%, 15.38% with represented percentile increased of 763.82%, 736.36%, 642.86%, 688.14%, 684.69%. Comparative results showed an increased in CBR values with increase in bagasse fibre percentages to a peak ratio of 0.75% to soil ratio.

Unconfined Compressive Strength Test

Results obtained of clay soils at preliminary engineering soil properties of Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Town Roads at 100% soils unconfined compressive strength (UCS) values of 58.85kPa, 63.35kPa, 57.75kPa, 53.75kPa and 63.85kPa, with percentile values of 87.38%, 92.75%, 70.90%, 78.64%, 80.52%. Stabilized clay soils with inclusion as represented in figures 3.5 increased to 138.18kPa, 158.75kPa, 150.45kPa, 127.38kPa, and 163.10kPa with percentile representation of 234.80%, 250.59%, 260.52%, 236.99%, and 255.44%. Results obtained showed increased in CBR values with increase in fibre percentages to soil corresponding ratio.

Consistency Limits Test

Results of consistency limits (Plastic Index) at 100% clay soils are 20.33%, 20.35%, 21.85%, 26.30% and 21.35%, with percentile representation of 101.04%, 102.62%, 105.30%, 101.39%, 101.50%. At Stabilized conditions, the obtained values are 15.08%, 17.65%, 18.85%, 19.23% and 17.16% with percentile values representation of 94.69%, 92.78%, 90.71%, 93.17%, and 93.22%. Comparative results showed decreased in plastic index properties of clay soils.

Table 3.1: Engineering Properties of Soil Samples

| LOCATION DESCRIPTION | OGDONA TOWN ROAD, AHOADA-WEST L.G.A RIVERS STATE | BODO TOWN ROAD, GOKANA L.G.A RIVERS STATE | OGBOGU TOWN ROAD, OGBEGILLA L.G.A RIVERS STATE | ULA-IKATA TOWN ROAD, AHOADA-BEMA EAST L.G.A RIVERS STATE | KAAI TOWN ROAD, KHANNA L.G.A RIVERS STATE |
|----------------------|--------------------------------------------------|-------------------------------------------|-----------------------------------------------|--------------------------------------------------|----------------------------------|
| Depth of sampling (m) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Percentage (%) passing BS sieve #200 | 73.85 | 67.38 | 76.35 | 82.35 | 71.55 |
| Colour | Grey | Grey | Grey | Grey | Grey |
| Specific gravity | 2.71 | 2.68 | 2.1 | 2.63 | 2.63 |
| Natural moisture content (%) | 46.25 | 45.38 | 45.86 | 49.30 | 46.85 |
| Consistency Limits | | | | | |
| Liquid limit (%) | 58.85 | 59.45 | 58.35 | 56.67 | 48.25 |
| Plastic limit (%) | 38.52 | 39.10 | 37.50 | 30.37 | 24.90 |
| Plasticity Index | 20.33 | 20.35 | 21.85 | 26.30 | 21.35 |
| AASHTO soil classification | A - 6 | A - 6 | A - 6 | A - 6 | A - 6 |
| Optimum moisture content (%) | 15.68 | 14.93 | 16.30 | 17.45 | 15.35 |
| Maximum dry density (kN/m³) | 1.875 | 1.923 | 1.823 | 1.795 | 1.985 |
| Gravel (%) | 1.85 | 0.85 | 2.45 | 0.53 | 1.95 |
| Sand (%) | 12.35 | 11.08 | 9.75 | 7.34 | 13.25 |
| Silt (%) | 32.35 | 47.35 | 47.85 | 33.68 | 48.23 |
| Clay (%) | 33.45 | 40.72 | 39.95 | 38.45 | 36.55 |
| Unconfined compressive strength (kPa) | 58.85 | 63.35 | 57.75 | 53.75 | 63.85 |
| California Bearing Capacity (CBR) | Unsoaked (%) CBR | 8.58 | 8.83 | 8.05 | 7.38 | 9.05 |
| Soaked (%) CBR | 6.33 | 7.15 | 7.35 | 5.9 | 8.23 |
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/cm³)         | 0.69        |
| Natural moisture content (%)    | 6.3         |
| Water absorption (%)            | 178 - 256   |

Source, 2018

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 at Different Percentages and Combination

| SAMPLE LOCATION | SOIL + FIBRE RATIO | MDD (kN/m²) | OMC (%) | UNSOAKED CBR (%) | SOAKED CBR (%) | UCS (kPa) | LL (%) | PI (%) | PI (%) | SIEVE #200 | ANSIIF / USCS (Classification) | NOTES |
|-----------------|--------------------|-------------|--------|------------------|----------------|------------|--------|--------|--------|------------|--------------------------------|-------|
| OGODA TOWN ROAD, AHOADA-WEST L.G.A | 100% | 1.875 | 15.68 | 8.56 | 6.33 | 58.85 | 58.85 | 38.52 | 20.33 | 73.85 | A – 7 – 6 | POOR | |
| 99.75+0.25 %    | 1.858 | 15.77 | 10.25 | 10.05 | 67.35 | 58.58 | 40.33 | 18.25 | 73.85 | A – 7 – 6 | GOOD | |
| 99.50+0.50 %    | 1.838 | 15.93 | 12.85 | 11.35 | 82.30 | 58.21 | 41.96 | 17.25 | 73.85 | A – 7 – 6 | GOOD | |
| 99.25+0.75 %    | 1.758 | 16.28 | 14.30 | 13.45 | 118.15 | 57.93 | 42.25 | 16.38 | 73.85 | A – 7 – 6 | GOOD | |
| 99.0+1.0%       | 1.758 | 16.48 | 13.18 | 12.35 | 138.18 | 57.72 | 42.64 | 15.08 | 73.85 | A – 7 – 6 | GOOD | |
| BODO TOWN ROAD, GOKANA L.G.A | 100% | 1.923 | 14.93 | 8.88 | 7.15 | 63.35 | 59.45 | 39.10 | 20.35 | 67.38 | A – 7 – 6 | POOR | |
| 99.75+0.25%     | 1.904 | 15.21 | 10.38 | 10.15 | 68.30 | 59.18 | 39.23 | 19.95 | 67.38 | A – 7 – 6 | GOOD | |
| 99.50+0.50%     | 1.886 | 15.38 | 12.58 | 11.86 | 89.50 | 58.83 | 40.08 | 18.75 | 67.38 | A – 7 – 6 | GOOD | |
| 99.25+0.75%     | 1.866 | 15.78 | 14.88 | 13.22 | 127.30 | 58.55 | 40.37 | 18.18 | 67.38 | A – 7 – 6 | GOOD | |
| 99.0+1.0%       | 1.825 | 15.98 | 12.35 | 12.05 | 158.75 | 58.17 | 40.54 | 17.65 | 67.38 | A – 7 – 6 | GOOD | |
| OGBOGU TOWN ROAD OGBA EGE/ ELEANA NDONI L.G.A | 100% | 1.823 | 16.30 | 8.25 | 7.35 | 57.75 | 58.35 | 37.50 | 21.85 | 76.35 | A – 7 – 6 | POOR | |
| 99.75+0.25%     | 1.785 | 16.81 | 11.25 | 10.86 | 81.45 | 58.13 | 36.18 | 19.95 | 76.35 | A – 7 – 6 | GOOD | |
| 99.50+0.50%     | 1.733 | 16.93 | 13.45 | 12.98 | 117.40 | 57.85 | 38.07 | 19.78 | 76.35 | A – 7 – 6 | GOOD | |
| 99.25+0.75%     | 1.718 | 17.15 | 14.15 | 13.88 | 138.53 | 57.53 | 38.28 | 19.25 | 76.35 | A – 7 – 6 | GOOD | |
| 99.0+1.0%       | 1.794 | 17.45 | 12.38 | 12.08 | 150.45 | 57.15 | 38.30 | 18.85 | 76.35 | A – 7 – 6 | GOOD | |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A | 100% | 1.794 | 17.45 | 7.38 | 5.90 | 53.75 | 56.67 | 38.37 | 18.30 | 82.35 | A – 7 – 6 | POOR | |
| 99.75+0.25%     | 1.769 | 17.17 | 9.25 | 8.75 | 68.35 | 56.45 | 38.60 | 17.85 | 82.35 | A – 7 – 6 | POOR | |
| 99.50+0.50%     | 1.740 | 17.78 | 11.15 | 10.38 | 79.30 | 56.18 | 38.58 | 17.66 | 82.35 | A – 7 – 6 | GOOD | |
| 99.25+0.75%     | 1.762 | 18.15 | 13.55 | 12.85 | 107.85 | 55.89 | 38.56 | 17.33 | 82.35 | A – 7 – 6 | GOOD | |
| 99.0+1.0%       | 1.683 | 18.38 | 12.85 | 12.05 | 137.38 | 55.52 | 38.36 | 17.16 | 82.35 | A – 7 – 6 | GOOD | |
| KANI TOWN ROAD, KHANA L.G.A | 100% | 1.985 | 15.35 | 9.05 | 8.23 | 63.85 | 48.25 | 27.90 | 20.35 | 71.55 | A – 7 – 6 | POOR | |
| 99.75+0.25%     | 1.962 | 15.61 | 11.65 | 10.95 | 79.30 | 48.03 | 27.94 | 20.09 | 71.55 | A – 7 – 6 | GOOD | |
| 99.50+0.50%     | 1.938 | 15.38 | 12.93 | 12.38 | 93.28 | 47.88 | 28.05 | 19.83 | 71.55 | A – 7 – 6 | GOOD | |
| 99.25+0.75%     | 1.908 | 16.15 | 15.38 | 14.95 | 125.78 | 47.65 | 28.02 | 19.63 | 71.55 | A – 7 – 6 | GOOD | |
| 99.0+1.0%       | 1.883 | 16.42 | 13.93 | 13.25 | 163.10 | 47.28 | 28.05 | 19.23 | 71.35 | A – 7 – 6 | GOOD |
### Table 3.5: Percentile Combination of Soft Clay + Costaceae Lacerus Bagasses Fibre (CLBF)

| RATIO (%) | 100% | 97.25±0.25+2.5 | 94.5+0.5+5.0% | 91.75±0.75+7.5% | 89+1.0+10 |
|-----------|------|----------------|---------------|-----------------|-----------|
| **MAXIMUM DRY DENSITY (MDD) (kN/m³)** | | | | | |
| OGA TOWN ROAD, AHOADA-WEST L.G.A | 1.88 | 1.88 | 1.94 | 1.93 | 1.99 |
| BODO TOWN ROAD GOKANA L.G.A MDD (kN/m³) | 1.92 | 1.96 | 1.99 | 2.15 | 2.11 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A MDD (kN/m³) | 1.82 | 1.85 | 1.88 | 1.90 | 1.94 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A MDD (kN/m³) | 1.79 | 1.82 | 1.87 | 1.89 | 1.91 |
| KAA NJI TOWN ROAD, KHANA L.G.A MDD (kN/m³) | 1.99 | 2.00 | 2.12 | 2.41 | 2.56 |
| **OPTIMUM MOISTURE CONTENT (%)** | | | | | |
| OGA TOWN ROAD, AHOADA-WEST L.G.A OMC (%) | 16.68 | 16.08 | 16.35 | 16.85 | 17.20 |
| BODO TOWN ROAD GOKANA L.G.A OMC (%) | 14.93 | 15.21 | 15.31 | 15.78 | 16.15 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A OMC (%) | 16.30 | 16.59 | 16.83 | 17.05 | 17.38 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A OMC (%) | 17.45 | 17.82 | 18.15 | 18.52 | 18.83 |
| KAA NJI TOWN ROAD, KHANA L.G.A OMC (%) | 15.35 | 15.70 | 15.96 | 16.12 | 16.47 |
| **CONSISTENCY LIMITS (%)** | | | | | |
| OGA TOWN ROAD, AHOADA-WEST L.G.A LL (%) | 58.85 | 58.93 | 59.83 | 59.83 | 60.15 |
| OGA TOWN ROAD, AHOADA-WEST L.G.A PL (%) | 38.52 | 38.91 | 40.21 | 40.21 | 40.90 |
| OGA TOWN ROAD, AHOADA-WEST L.G.A IP (%) | 20.33 | 20.12 | 19.62 | 19.62 | 19.25 |
| BODO TOWN ROAD GOKANA L.G.A LL (%) | 59.45 | 59.78 | 60.15 | 61.48 | 62.65 |
| BODO TOWN ROAD GOKANA L.G.A PL (%) | 39.10 | 39.95 | 40.53 | 43.87 | 43.77 |
| BODO TOWN ROAD GOKANA L.G.A IP (%) | 20.35 | 19.83 | 19.62 | 19.30 | 18.88 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A LL (%) | 58.35 | 59.85 | 60.18 | 60.66 | 60.97 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A PL (%) | 37.50 | 39.10 | 39.82 | 40.63 | 41.15 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A IP (%) | 21.85 | 20.75 | 20.36 | 20.03 | 19.82 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A LL (%) | 56.67 | 57.15 | 57.65 | 58.15 | 58.65 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A PL (%) | 38.37 | 34.10 | 39.83 | 40.72 | 41.60 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A IP (%) | 18.30 | 18.05 | 17.82 | 17.43 | 17.05 |
| KAA NJI TOWN ROAD, KHANA L.G.A LL (%) | 48.25 | 48.53 | 48.96 | 49.23 | 49.75 |
| KAA NJI TOWN ROAD, KHANA L.G.A PL (%) | 27.90 | 28.48 | 29.14 | 29.88 | 30.98 |
| KAA NJI TOWN ROAD, KHANA L.G.A IP (%) | 20.35 | 20.05 | 19.82 | 19.35 | 18.97 |
| **CALIFORNIA BEARING RATIO (%)** | | | | | |
| OGA TOWN ROAD, AHOADA-WEST L.G.A | 8.65 | 23.45 | 37.55 | 51.85 | 46.33 |
| OGA TOWN ROAD, AHOADA-WEST L.G.A SOAKED CBR (%) | 6.33 | 21.15 | 32.80 | 48.35 | 41.60 |
| BODO TOWN ROAD GOKANA L.G.A UNSOAKED CBR (%) | 8.83 | 29.60 | 41.30 | 56.30 | 48.36 |
| BODO TOWN ROAD GOKANA L.G.A SOAKED CBR (%) | 7.15 | 26.85 | 38.15 | 52.65 | 39.30 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A UNSOAKED CBR (%) | 8.25 | 27.35 | 34.30 | 49.75 | 37.37 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A SOAKED CBR (%) | 7.35 | 24.40 | 29.88 | 47.25 | 32.35 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UNSOAKED CBR (%) | 7.38 | 23.40 | 31.45 | 45.80 | 36.35 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A SOAKED CBR (%) | 5.90 | 19.05 | 27.35 | 40.60 | 31.78 |
| KAA NJI TOWN ROAD, KHANA L.G.A UNSOAKED CBR (%) | 9.05 | 28.25 | 48.35 | 57.30 | 53.45 |
| KAA NJI TOWN ROAD, KHANA L.G.A SOAKED CBR (%) | 8.23 | 26.55 | 46.85 | 56.35 | 49.75 |
| **UNCONFINED COMPRESSIVE STRENGTH (KPa)** | | | | | |
| OGA TOWN ROAD, AHOADA-WEST L.G.A UCS (Kpa) | 58.85 | 67.35 | 82.30 | 118.15 | 138.18 |
| BODO TOWN ROAD GOKANA L.G.A UCS (Kpa) | 63.35 | 68.30 | 89.50 | 127.30 | 158.75 |
| OGBOGU TOWN ROAD OGBA/EGBEMA/NDONI L.G.A UCS (Kpa) | 57.75 | 81.45 | 117.40 | 138.53 | 150.45 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UCS (Kpa) | 53.75 | 68.35 | 79.30 | 107.85 | 127.38 |
| KAA NJI TOWN ROAD, KHANA L.G.A UCS (Kpa) | 63.85 | 79.30 | 93.28 | 125.78 | 163.10 |
### Table 3.6: Percentile Decrease / Increase of Soft Clay + Costaceae Lacerus Bagasses Fibre (CLBF)

| RATIO (%) | 1.000 | 97.25+0.25 | 94.5+0.5 | 91.75+0.75 | 89+1.0 |
|-----------|-------|------------|----------|------------|---------|
|           | MDD(kN/m³) | MDD(kN/m³) | MDD(kN/m³) | MDD(kN/m³) | MDD(kN/m³) |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A | 99.575 | 100.427 | 103.253 | 103.147 | 105.867 |
| BODO TOWN ROAD GOKANA L.G.A MDD(kN/m3) | 98.263 | 101.768 | 103.328 | 111.804 | 109.464 |
| OGBBOGU TOWN ROAD OGBA/EBEMA/NDONI L.G.A MDD(kN/m3) | 98.754 | 101.262 | 102.852 | 104.059 | 106.144 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A MDD(kN/m3) | 98.843 | 101.171 | 103.958 | 105.072 | 106.466 |
| KAANI TOWN ROAD, KHANA L.G.A MDD(kN/m3) | 99.349 | 100.655 | 106.801 | 121.310 | 128.715 |

### Optimum Moisture Content (%)

| RATIO (%) | 1.000 | 97.25+0.25 | 94.5+0.5 | 91.75+0.75 | 89+1.0 |
|-----------|-------|------------|----------|------------|---------|
|           | OMC (%) | OMC (%) | OMC (%) | OMC (%) | OMC (%) |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A | 97.512 | 102.551 | 104.273 | 107.462 | 109.694 |
| BODO TOWN ROAD GOKANA L.G.A OMC (%) | 98.159 | 101.875 | 102.545 | 105.693 | 108.171 |
| OGBBOGU TOWN ROAD OGBA/EBEMA/NDONI L.G.AOMC (%) | 98.252 | 101.779 | 103.252 | 104.601 | 106.626 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A OMC (%) | 97.924 | 102.120 | 104.011 | 106.132 | 107.908 |
| KAANI TOWN ROAD, KHANA L.G.A OMC (%) | 97.771 | 102.280 | 103.974 | 105.016 | 107.296 |

### Consistency Limits (%)

| RATIO (%) | 1.000 | 97.25+0.25 | 94.5+0.5 | 91.75+0.75 | 89+1.0 |
|-----------|-------|------------|----------|------------|---------|
|           | LL(%) | LL(%) | LL(%) | LL(%) | LL(%) |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A | 99.864 | 100.136 | 101.665 | 101.665 | 102.209 |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A PL(%) | 98.998 | 101.012 | 104.387 | 104.387 | 106.179 |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A IP(%) | 101.044 | 98.967 | 96.508 | 96.508 | 94.688 |
| BODO TOWN ROAD GOKANA L.G.A LL(%) | 99.448 | 100.555 | 101.177 | 103.415 | 105.383 |
| BODO TOWN ROAD GOKANA L.G.A PL(%) | 97.872 | 102.174 | 103.657 | 112.199 | 111.944 |
| BODO TOWN ROAD GOKANA L.G.A IP(%) | 102.622 | 97.445 | 96.413 | 94.840 | 92.776 |

### California Bearing Ratio (%)

| RATIO (%) | 1.000 | 97.25+0.25 | 94.5+0.5 | 91.75+0.75 | 89+1.0 |
|-----------|-------|------------|----------|------------|---------|
|           | CLBF (%) | CLBF (%) | CLBF (%) | CLBF (%) | CLBF (%) |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A | 36.887 | 271.098 | 434.104 | 599.422 | 535.607 |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A SOAKED CBR (%) | 29.929 | 334.123 | 518.167 | 763.823 | 657.188 |
| BODO TOWN ROAD GOKANA L.G.A UNSOAKED CBR (%) | 29.831 | 335.221 | 467.724 | 637.599 | 547.678 |
| BODO TOWN ROAD GOKANA L.G.A SOAKED CBR (%) | 26.629 | 375.524 | 533.566 | 736.364 | 549.650 |
| OGBBOGU TOWN ROAD OGBA/EBEMA/NDONI L.G.A UNSOAKED CBR (%) | 30.165 | 331.515 | 415.758 | 603.030 | 452.970 |
| OGBBOGU TOWN ROAD OGBA/EBEMA/NDONI L.G.A SOAKED CBR (%) | 30.123 | 331.973 | 406.531 | 642.857 | 440.136 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A | 31.538 | 317.073 | 426.152 | 620.596 | 492.547 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A SOAKED CBR (%) | 30.971 | 322.881 | 463.559 | 688.136 | 538.644 |
| KAANI TOWN ROAD, KHANA L.G.A UNSOAKED CBR (%) | 32.035 | 312.155 | 534.254 | 633.149 | 590.608 |
| KAANI TOWN ROAD, KHANA L.G.A SOAKED CBR (%) | 30.998 | 322.600 | 569.259 | 684.690 | 604.496 |

### Unconfined Compressive Strength (KPa)

| RATIO (%) | 1.000 | 97.25+0.25 | 94.5+0.5 | 91.75+0.75 | 89+1.0 |
|-----------|-------|------------|----------|------------|---------|
|           | UCS (Kpa) | UCS (Kpa) | UCS (Kpa) | UCS (Kpa) | UCS (Kpa) |
| OGOODA TOWN ROAD, AHOADA-WEST L.G.A UCS (Kpa) | 87.379 | 114.444 | 139.847 | 200.765 | 234.800 |
| BODO TOWN ROAD GOKANA L.G.A UCS (Kpa) | 92.753 | 107.814 | 141.279 | 200.947 | 260.792 |
| OGBBOGU TOWN ROAD OGBA/EBEMA/NDONI L.G.A UCS (Kpa) | 70.902 | 141.039 | 203.290 | 239.879 | 260.519 |
| ULA-IKATA TOWN ROAD, AHOADA-EAST L.G.A UCS (Kpa) | 78.639 | 127.163 | 147.355 | 200.651 | 236.986 |
| KAANI TOWN ROAD, KHANA L.G.A UCS (Kpa) | 80.517 | 124.197 | 146.092 | 196.993 | 255.442 |

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Fig-3.1: Maximum Dry Density of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State with CLBF at Different Percentages and Combinations

Fig-3.2: Optimum Moisture Content of Subgrade Stabilization Test of Clay Soil Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State with CLBF at Different Percentages and Combinations

Fig-3.3: Consistency Limits of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State with CLBF at Different Percentages and Combination

Fig-3.4: California Bearing Ratio of Subgrade Stabilization Test of Clay Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaani Towns), Rivers State with CLBF at Different Percentages and Combination
Fig-3.5: Unconfined Compressive Strength (UCS) of Subgrade Soil from Ogoda, Bodo, Ogbogu, Ula-Ikata, Kaaani Towns, Rivers State with CLBF at Different Percentages and Combinations

Plate i. Costaceae Lacerus plant

Plate ii. Costaceae Lacerus stem

Plate iii. Costaceae Lacerus piled stem

Plate iv. Costaceae Lacerus pulverized stage
CONCLUSIONS

The following conclusions were made from the experimental research results.

i. The soils classified as A – 7 – 6 on the AASHTO Classification System and soils are dark grey in color (from wet to dry states) plasticity index of 20.33%, 20.35%, 21.85%, 26.30%, and 21.35% respectively for Ogoda, Bodo, Ogbogu, Ula-Ikata, and Kaani.

ii. The entire results showed the potential of using CLBF as admixtures in the treatment of clay soils

iii. The swelling potential of treated soil decreased with the inclusion of bagasse fibre up to 0.75%.

iv. Preliminary investigations of the engineering properties of soils at natural state are percentage (%) passing BS sieves #200 are 73.85%, 67.38%, 6.35%, 82.35%, and 71.55%.

v. Comparative results showed decreased in plastic index properties of clay soils

vi. Results obtained showed increased in UCS with an increase in fibre percentages to soil the corresponding ratio

vii. Comparative results showed an increased in CBR values with increase in bagasse fibre percentages to a peak ration of 0.75% to soil ratio

REFERENCES

1. Chen, F. H. (1988). Foundation on Expansive Soils. Elsevier Scientific Publication Company, Amsterdam.

2. Nelson, D., & Miller, J. (1992). Expansive Soils: Problems and Practices in Foundation and Pavement Engineering. John Wiley and Sons, Inc. New York.

3. Warren, K. W., & Kirby, T. M. (2004). Expansive Clay Soil: A Widespread and Costly Geohazard. Geostrata, Geo-Institute of the American Society Civil Engineers, Jan 24-28

4. Morin, W. J. (1971). Properties of African tropical black clay soils. Proceedings 5th Regional Conference for Africa on Soil Mechanics and Foundation Engineering Luanda, 1(5):1-59.

5. Charles, K., Essien, U., Gbinu, S. K. (2018). Stabilization of Deltaic Soils using Costus Afer Bagasse Fiber. International Journal of Civil and Structural Engineering Research, 6(1): 148-156

6. Ramakrishna, A.N., & Pradeepkumar, A.V. (2006). Stabilization of Black Cotton Soil using Rice Husk Ash and Cement, Proc. of National conference, Civil Engineering meeting the challenges of tomorrow, 215-220

7. Sabat, A. K. (2013). Engineering Properties of an Expansive Soil Stabilized with Rice Husk Ash and Lime sludge, International Journal of Engineering and Technology, 5(6): 4826-4833

8. Prabakar, J., & Sridhar, R.S. (2002). Effect of random inclusion of Sisal Fibre on Strength Behaviour of Soil," Constr Build Mater, 16:123–131.

9. Ola, S. A. (1974). Need for Estimated Cement Requirements for Stabilizing Lateritic Soils. Journal of Transportation Engineering, ASCE, 100(2):379–388

10. Allam, M. M., & Sridhara, A. (1981). Effect of wetting and drying on shear strength. Journal of the Soil Mechanics and Foundations Division, 107(4), 421-438.

11. Omotosho, P. O. (1993). Multi-Cyclic Influence on Standard Laboratory Compaction of Residual Soils, Engineering Geology, 36, 109–115.

12. Omotosho, P.O., & Akinmusuru, J. O. (1992). Behavior of Soils (Lateritic) Subjected to Multi-Cyclic Compaction. Engineering Geology, 32, 53–58.