Influence of Waste Agricultural Fibre Products Material and Lime on Geotechnical Characteristics of Expansive Soils

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ABSTRACT

The study evaluated the failures associated with the sampled roads of Ebiriba, Ochihga, Eneka and Isiokpo in the Niger Delta of Nigeria with the application of composite materials of plantain rachis fibre ash + lime as soil stabilizer to strengthened the poor state of the failed sections. First stage of investigations classified the clay soils as A-7-6/CH on the AASHTO classification schemes / Unified Soil Classification System with percentage passing sieve #200 as 75.55%, 75.05%, 82.85% and 69.55%, unsoaked CBR values of 6.38%, 7.75%, 8.24% and 7.85%, and soaked CBR values of 5.25%, 6.03%, 6.35% and 6.30%, unconfined compressive strength (UCS) values of 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa. Soils fell below the minimum requirement for such application as road embankment and needs stabilization to improve their properties. Comparatively results shown in table 3.1 and 3.2 on compaction test parameters indicated increased values of maximum dry density (MDD) and optimum moisture content (OMC) relative to percentage inclusion increase. In contrast to results of tables 3.1 and 3.2, stabilized clay soils California bearing ratio of unsoaked and soaked values increased with respect to composite materials of plantain rachis fibre + lime percentile ratio with the optimum percentage of 0.75% + 7.5%. Cracks and values reduction were confirmed outside optimum percentile. Comparative results are shown in table 3.2 and figure 3.5 illustrated unconfined compressive strength tests increased relative to inclusion percentile increase. Comparative results shown in table 3.1, 3.2 and figures 3.1 – 3-4 showed decreased values of the plastic index with respect to additives inclusion percentages. The entire results showed the good potential of using plantain rachis fibre ash + limet as the soil stabilizer

Key Words: Clay, Plantain Rachis Fibre Ash, Lime, CBR, UCS, Consistency, Compaction

1.0 INTRODUCTION

Expansive soils with unique potentials of swelling, shrinkage and with excessive in situ water contents are susceptible to massive settlements and possess low shear strength until they attained cemented. An alternative to that is cementation of the smooth clay with supplementary cementing substances together with lime and cement (Horpibulsuk et al. [1]).

Charles et al. [2] 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% BSBF, 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.

Sharma et al., [3] 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.

Ramakrishna and Pradeep [4] 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.

Sabat [5] 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 were 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.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil
The soils used for the study were collected from Ebiriba Town Road, in Ahoada-West Local Government, Ochigba Town Road, in Ahoada-East Local Government Area, Eneka Town Road, in Obio/Akpor Local Government Area and Isiokpo Town Road, in Ikwere Local Government area, all in Rivers State, Niger Delta region, Nigeria. It lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Plantain Rachis Fibre
The Plantain Rachis fibres are obtained from Iwofe markets, in Obio/Akpor Local Area of Rivers State, they are abundantly disposed as waste products both on land and in the river.

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 Ebiriba Town, (latitude 5.10° 31'N and longitude 6.38° 8'E), Ochigba a Town, (latitude 5.1° 30'N and longitude 6.35° 55'E), Eneka Town, latitude 4.90° 28'N and longitude 7.03° 15'E), and Isiokpo Town, latitude 5.05° 41'N and longitude 6.92° 33'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 (1/2 in.) 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 regulating 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 [6] Allam and Sridharan [7]; Omotosho and Akimnusuru [8]; Omotosho [9]). The soils are reddish brown and dark grey in colour (from wet to dry states) plasticity index of 28.55%, 25.97%, 33.50%, and 28.40% respectively for Ebiriba, Ochigba, Eneka and Isiokpo Town Roads. The soil has unsoaked CBR values of 6.38%, 7.75%, 8.24% and 7.85%, and soaked CBR values of 5.25%, 6.03%, 6.35% and 6.30%, unconfined compressive strength (UCS) values of 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa when compacted with British Standard light (BSL), respectively.

3.1 Compaction Test Results
Compaction test results of sampled roads preliminary geotechnical investigation are maximum dry density (MDD) values 1.685 KN/m$^3$, 1.705 KN/m$^3$, 1.663 KN/m$^3$, 1.605 KN/m$^3$ and optimum moisture content (OMC) 16.38%, 17.45%, 16.75% and 15.87%. Stabilized clay soils with plantain rachis fibre ash + lime at 2.5% + 2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% to soils ratio peak values are maximum dry density (MDD) values are 1.762KN/m$^3$, 1.785KN/m$^3$, 1.735KN/m$^3$, 1.684KN/m$^3$ and optimum moisture content (OMC) 18.43%, 18.98%, 18.43% and 17.34%.

Results from table 3.2 and figures 3.1 - 3.4 illustrated results of un-stabilized and stabilized clay soils compaction test results which showed increased in both maximum dry density (MDD) and optimum moisture content (OMC) relative to ratio percentage increase.

3.2 California Bearing Ratio (CBR) Test
Results from table 3.1, illustrated the California bearing ratio (CBR) of clay soils at 100% natural state are unsoaked 6.38%, 7.75%, 8.24% and 7.85%, and soaked 5.25%, 6.03%, 6.35% and 6.30%. Stabilized clay soils with plantain rachis fibre ash + lime to soils peak values of California bearing ratio (CBR) unsoaked are 48.35%, 52.48%, 54.38%, 49.85%, and soaked 46.80%, 51.05%, 52.80% and 47.35%.

Results computed in table 3.2 and figure 3.1 – 3.4, illustrated California bearing ratio (CBR) values increased of unsoaked and soaked of stabilized clay soils as against un-stabilized with optimum inclusion of 7.5% + 7.5%. Mixed ratio beyond optimum experienced value reduction and cracks.

3.3 Unconfined Compressive Strength Test
From table 3.1, results obtained of un-stabilized clay soils at 100% of unconfined compressive strength test are 68.85kPa, 77.35kPa, 79.85kPa and 65.57kPa. Stabilized plantain rachis fibre ash + lime to clay soils unconfined compressive strength test maximum yielded values are 436kPa, 456kPa, 483kPa and 415kPa. Comparative results shown in table 3.2 and figure 3.5 illustrated unconfined compressive strength tests increased relative to inclusion percentile increase.

3.4 Consistency Limits Test
Results of consistency limits (Plastic index) of clay soils at zero percentage inclusion are 28.55%, 25.97%, 33.50%, and 28.40%. Results of modified plastic index of clay soils are 27.36%, 28.56%, 36.65% and 27.43%. Comparative results shown in table 3.1, 3.2 and figures 3.1 – 3.4 showed decreased values of plastic index with respect to additives inclusion percentages.
| Location Description | Ebiriba Road Ahoada West L.G.A | Ochigba Road Ahoada East L.G.A | Eneka Road Obio/Akpor L.G.A | Isiokpo Road Ikwerre L.G.A |
|----------------------|--------------------------------|-------------------------------|-----------------------------|-------------------------|
| Depth of sampling (m) | 1.0                            | 1.0                           | 1.0                         | 1.0                     |
| Percentage(%) passing BS sieve #200 | 75.55                          | 75.05                         | 82.85                        | 69.55                   |
| Colour               | Greyish/black                   | Grey                          | Greyish                     | Greyish                 |
| Specific gravity     | 2.45                            | 2.68                          | 2.62                         | 2.48                    |
| Natural moisture content (%) | 47.36                        | 43.85                         | 47.80                        | 48.15                   |
| Consistency limits   |                                 |                               |                             |                         |
| Liquid limit (%)     | 57.30                           | 56.35                         | 63.30                        | 57.75                   |
| Plastic limit (%)    | 28.75                           | 30.38                         | 29.80                        | 29.35                   |
| Plasticity Index     | 28.55                           | 25.97                         | 33.50                        | 28.40                   |
| AASHTO soil classification | A-7-6/CH                    | A-7-6/CH                      | A-7-6/CH                     | A-7-6/CH                |
| Unified Soil Classification System |                   |                               |                             |                         |
| Compaction characteristics |                               |                               |                             |                         |
| Optimum moisture content (%) | 16.38                       | 17.45                         | 16.75                        | 15.87                   |
| Maximum dry density (kN/m³) | 1.685                       | 1.705                         | 1.663                        | 1.665                   |
| Grain size distribution |                               |                               |                             |                         |
| Gravel (%)           | 0                               | 0                             | 0                            | 0                       |
| Sand (%)             | 16.25                           | 12.35                         | 12.80                        | 14.35                   |
| Silt (%)             | 43.83                           | 39.85                         | 41.85                        | 42.35                   |
| Clay (%)             | 39.92                           | 46.80                         | 45.35                        | 56.70                   |
| Unconfined compressive strength (kPa) | 68.85                    | 77.35                         | 79.85                        | 65.57                   |
| California Bearing Capacity (CBR) |                       |                               |                             |                         |
| Unsoaked (%) CBR     | 6.38                            | 7.75                          | 8.24                         | 7.85                    |
| Soaked (%) CBR       | 5.25                            | 6.03                          | 6.35                         | 6.30                    |
| SAMPLE LOCATION | SOIL + FIBRE PLANTAIN RACHIS ASH + LIME | CLAY SOIL + PLATAIN RACHIS FIBRE ASH (PRFA) + LIME |
|-----------------|----------------------------------------|--------------------------------------------------|
| EBITIBA ROAD AHOADA WEST L.G.A | 100% 1.685 16.38 6.38 5.25 68.85 57.30 28.75 28.55 79.55 A – 7 – 6/CH POOR | 95 +2.5 +2.5% 1.692 16.83 25.50 22.45 88.85 57.83 29.41 28.41 79.55 A – 7 – 6/CH GOOD |
| 90 +5.0 +5.0% 1.708 17.53 32.68 29.65 197 58.30 30.12 28.18 79.55 A – 7 – 6/CH GOOD |
| 85 +7.5 +7.5% 1.741 17.98 48.35 46.80 380 58.62 30.19 27.83 79.55 A – 7 – 6/CH GOOD |
| 80 +10 +10% 1.762 18.43 41.85 38.23 436 58.93 31.07 28.75 79.55 A – 7 – 6/CH GOOD |
| OCHIGBA ROAD AHOADA EAST L.G.A | 100% 1.705 17.45 7.75 6.03 77.35 56.35 25.97 28.56 75.05 A – 7 – 6/CH POOR | 95 +2.5 +2.5% 1.718 17.85 28.35 26.89 96 59.71 27.26 29.45 75.05 A – 7 – 6/CH GOOD |
| 90 +5.0 +5.0% 1.733 18.23 36.81 33.45 216 57.18 28.18 29.00 75.05 A – 7 – 6/CH GOOD |
| 85 +7.5 +7.5% 1.755 18.67 52.48 51.05 338 57.45 28.57 28.88 75.05 A – 7 – 6/CH GOOD |
| 80 +10 +10% 1.785 19.88 48.25 46.30 456 57.93 29.37 28.56 75.05 A – 7 – 6/CH GOOD |
| ENEKA ROAD OBIO/AKOPO R L.G.A | 100% 1.663 16.75 8.24 6.35 79.85 63.30 29.80 38.50 82.85 A – 7 – 6/CH POOR | 95 +2.5 +2.5% 1.672 17.23 33.30 29.65 108 63.57 25.27 38.30 82.85 A – 7 – 6/CH GOOD |
| 90 +5.0 +5.0% 1.683 17.74 41.40 38.83 263 63.93 25.87 38.06 82.85 A – 7 – 6/CH GOOD |
| 85 +7.5 +7.5% 1.718 18.05 54.38 52.80 347 64.13 26.18 37.95 82.85 A – 7 – 6/CH GOOD |
| 80 +10 +10% 1.735 18.43 46.05 44.15 483 58.53 25.93 31.65 82.85 A – 7 – 6/CH GOOD |
| ISIOKPO ROAD IKWERRE L.G.A | 100% 1.605 15.87 7.85 6.30 65.75 57.75 29.35 28.40 69.55 A – 7 – 6/CH POOR | 95 +2.5 +2.5% 1.618 16.18 31.35 29.10 85 57.53 29.32 28.21 69.55 A – 7 – 6/CH GOOD |
| 90 +5.0 +5.0% 1.643 16.48 38.23 37.05 163 57.81 29.78 29.03 69.55 A – 7 – 6/CH GOOD |
| 85 +7.5 +7.5% 1.663 16.87 49.85 47.35 296 58.08 30.22 29.86 69.55 A – 7 – 6/CH GOOD |
| 80 +10 +10% 1.684 17.34 43.40 39.38 415 58.53 30.10 27.43 69.55 A – 7 – 6/CH GOOD |
Figure 3.1: Subgrade Stabilization Test of Clay Soil from Ebiriba in Ahoada - West L.G.A of Rivers State with PRFA + Lime at Different Percentages and Combination

Figure 3.2: Subgrade Stabilization Test of Clay Soil from Ochiga in Ahoada - East L.G.A of Rivers State with PRFA + Lime at Different Percentages and Combination
Figure 3.3: Subgrade Stabilization Test of Clay Soil from Eneka in Obio/Akpor L.G.A of Rivers State with PRFA + Lime at Different Percentages and Combination

Figure 3.4: Subgrade Stabilization Test of Clay Soil from Isiokpo in Ikwerre L.G.A of Rivers State with PRFA + Lime at Different Percentages and Combination
Figure 3.5: Unconfined Compressive Strength (UCS) of Niger Deltaic Clay Soils Subgrade with PRFA + Lime of (Ebiriba, Ochigba, Eneka and Isiokpo Towns) all in Rivers State

4.0 CONCLUSIONS

The following conclusions were made from the experimental research results.

i. Soils are classified as A-7-6/CH on the AASHTO classification schemes / Unified Soil Classification System.

ii. Comparatively, results shown in table 3.1 and 3.2 on compaction test parameters indicated increased values of maximum dry density (MDD) and optimum moisture content (OMC) relatively to percentage inclusion increase.

iii. In contrast to results of tables 3.1 and 3.2, stabilized clay soils California bearing ratio of unsoaked and soaked values increased with respect to composite materials of plantain rachis fibre + lime percentile ratio with optimum percentage of 0.75% + 7.5%. Cracks and values reduction were confirmed outside optimum percentile.

iv. Comparative results shown in table 3.2 and figure 3.5 illustrated unconfined compressive strength tests increased relative to inclusion percentile increase.

v. Comparative results shown in table 3.1, 3.2 and figures 3.1 – 3-4 showed decreased values of plastic index with respect to additives inclusion percentages.

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