Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2018, 5(6): 368-374

Research Article ISSN: 2394 - 658X

Comparative Evaluation of Cementitious Agents Composite materials on Strength Improvement Behavior of Black Cotton Clay Soil

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ABSTRACT

This research study investigated the application of cement / lime + costus afer fiber ash (bush sugarcane bagasse fibre ash) as composite material to effect changes in strength of natural black cotton marine clay to meet the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW 1997). Results of compaction relationship between optimum moisture content (OMC) and maximum dry density (MDD) at 100% clay and cement / lime + bagasse fibre ash treated soil at the ratios of 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement / lime and bagasse ash to soil. OMC results increased from 12.39% to 12.79% clay + cement + bagasse fibre ash and 12.93% to 14.37%. clay +lime + bagasse fibre ash. MDD results increased from1.640KN/m^3 and 1.78 KN/m^3 clay + cement + bagasse fibre ash and 1.640KN/m^3 and 1.73KN/m^3 (clay) clay +lime + bagasse fibre ash. CBR results of clay + lime + bagasse fibre ash (BSBFA) at 100% clay, of 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement / lime and bagasse ash to soil of lime + BSBFA, increased from 7.6% to 17.8% clay +lime + bagasse fibre ash and from 7.6% to 13.9% clay + cement + bagasse fibre ash, both showed tremendous strength increased with lime having higher values in clay cement / lime, low results of cement was attributed to hydration between cement and bagasse ash. Results of UCS of soils + cement + BSBFA with ratios ad above showed an increased values of 78.6kPa to 623kPa and 78.6kPa to 223kPa clay + lime + BSBFA treated clay. Higher strength of UCS was recorded higher in cement to lime samples. Results of clay + lime + BSBFA treated clay soil IP decreased from 33.7% to 30.8% and while clay + cement + BSBFA 36.8% to 31.2%. Composite materials improved strength of expansive soil.

Key words: Clay and lateritic CLAYs, Costus Afer ash, CBR, UCS, Consistency, Compaction

1. INTRODUCTION

Bagasse is a fibrous residue that remains after crushing the stalks of Bush Sugarcane, and contains short fibers. It consists of water, fibers, and small amounts of soluble solids. Percentage contribution of each of these components varies according to the variety, maturity, method of harvesting, and the efficiency of the crushing plant. When juice is extracted from the cane sugar, the solid waste material is known as bagasse. When this waste is burned it gives ash called as bagasse ash. .

Manikandan and Moganraj [1] had found that the combined effect of bagasse ash and lime were more effective than the effect of bagasse ash alone in controlling the consolidation characteristics of expansive clay along with the improvement in other properties.

Seco *et al.*, [2] studied the stabilization of expansive clay, consisting of the reduction of its swelling capacity and the improvement of its mechanical capacities by the addition of by-products and waste materials of industrial origin. Of the waste materials, the most notable is the behavior of Rice Husk Fly Ash, highly effective in stabilizing clay from the two aspects considered in this experiment.

Ramakrishna and Pradeep [3] studied combined effects of RHA and cement on engineering properties of black cotton clay. From strength characteristics point of view they had recommended 8 % cement and 10 % RHA as optimum dose for stabilization.

Sharma *et al*., [4] 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 clay without addition of RHA. From UCS and CBR point of view when the clay was mixed with lime or calcium chloride, RHA content of 12 % was found to be the optimum. In expansive CLAY – RHA mixes, 4% lime and 1% calcium chloride were also found to be optimum.

Goyal *et al.*, [5] reported that SCBA with high specific surface area, high contents of amorphous silica and calcium oxide fulfilled the principal requirements of a pozzolanic material.

Ganesan *et al.*, [6] studied on the use of bagasse ash (BA) as partial cement replacement material in respect of cement mortars. Up to 20 % of ordinary Portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete. Several studies have been carried out on the effectiveness of clay stabilization by RHA admixing.

Basha, *et al.*, [7] studied the stabilization of residual clay by chemically using cement and RHA. In general, 6 %, 8 % of cement and 10 %, 15 % RHA show the optimum amount to reduce the plasticity of clay. CBR value determined maximum at 4% cement and 5 % RHA mixtures with clay. According to compressive strength and PI, 6 %, 8% of cement and 15 %, 20 % RHA showed the optimum amount to improve the properties of clay. Studies have shown the effect of reinforcement on swelling behavior of clays (Puppala and Musenda, [8]); reduction of soil swell potential with fibre reinforcement (Loher *et al*. [9]), and effect of fibres on swelling characteristics of bentonite (Banu *et al*., [10]).

Natural fibres have been used to reduce shrinkage cracks in clayey soils without the least environmental nuisances and at almost low performance costs (Sivakumar *et al.* [11]). They are obtained from the waste of palm fruits and have acceptable mechanical properties and durability in natural conditions (Marandi *et al.*, [12]; Zare, [13]).

Gandhi [14] successfully worked on improving the existing poor and expansive sub grade clay using bagasse ash. Bagasse ash effectively dries wet clay and provides an initial rapid strength gain, which is useful during construction in wet, unstable ground conditions. The swell potential of expansive clay decreases by replacing some of the volume previously held by order to evaluate the possibility of their use in the industry. He conducted tests like Liquid Limit, Plastic Limit, Plasticity Index, Shrinkage Limit, Free Swell Index and Swelling Pressure with the increasing percentage of Bagasse ash at 0 %, 3 %, 5 %, 7 % and 10 % respectively .He found out that as the percentage of bagasse ash increases in the clay sample, all the properties decrease

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil

The deltaic soils (laterite) are abundant in Rivers State within the dry flat country. The soils used for the study was collected from a borrow pit at 1.5 m depth, at Odioku – Odiereke Town Road, Ubie Clan, Ahoada-West, Rivers State, Nigeria, lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Cement

The cement used was Eagle Portland Cement, purchased in the open market at Mile 3 market road, Port Harcourt, Rivers State.

2.1.3 Lime

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

2.1.4 Costus Afer (Bush Sugarcane) Bagasse Fibre

The bush sugarcane bagasse fibre are abundant in Rivers State farmlands / bushes, they are wide plants and covers larger areas, collected from at Odioku Town Farmland / Bush, 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 Odioku Community road in Ahoada West Local Government, in Rivers state, of Nigeria, (latitude 5.07° 14‘S and longitude 6.65° 80‘E), from trial borrow-pits the various earthworks within the entire roads. The top soil was removed to a depth of 0.5 m before the soil samples were taken, sealed in plastic bags and put in sacks to avoid loss of moisture during transportation. All samples were air dried for about two weeks to take advantage of the aggregating potentials of lateritic soils upon exposure (Allam and Sridharan [15]; Omotosho and Akinmusuru [16]).

These tests were conducted to prove that fibre product at varying proportions to give positive effect on the stabilization of soil and with binding cementitious inclusions. A number of tests were conducted as these tests include (1) Moisture Content Determination (2) Atterberg 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;

2.2.1 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.

2.2.2 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.

2.2.3 Atterberg Limits

This test is performed to determine the plastic and liquid limits of a fine grained soil. 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. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

2.2.4 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. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933, therefore, the test is also known as the Proctor test.

2.2.5 Unconfined Compression (UC) 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. According to the ASTM standard, the unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, 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.

2.2.6 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test was developed by the California Division of Highways as a method of classifying and evaluating soil- subgrade and base course materials for flexible pavements. CBR is a measure of resistance of a material to penetration. The CBR tests were performed in order to determine effect of fibre inclusion on CBR values of reinforced soils.

3. RESULTS AND DISCUSSIONS

3.1 Compaction Test Results

Preliminary engineering soil properties of natural state of soil are showed in table 3.1 which stood as control samples, tables 3.2,3.3 and 3.4 showed the of costus afer bagasse fibre ash properties, composition and oxides.

Table 3.5 showed the results of the compaction relationship between optimum moisture content (OMC) and maximum dry density (MDD) at 100% clay and cement / lime + bagasse fibre ash treated soil at the ratios of 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement / lime and bagasse ash to soil. OMC results increased from 12.39% to 12.79% clay + cement + bagasse fibre ash and 12.93% to 14.37%. clay +lime + bagasse fibre ash

MDD results increased from1.640kN/m^3 and 1.78 kN/m^3 clay + cement + bagasse fibre ash and 1.640 kN/m^3 and 1.73 kN/m^3 (clay) clay +lime + bagasse fibre ash.

3.2 California Bearing Ratio (CBR) Test

Tables 3.4 and 3.5 presented the CBR results of clay + lime + bagasse fibre ash (BSBFA) at 100% clay, of 2.5% +2.5%, 5.0% + 5.0%, 7.5% + 7.5% and 10% + 10% of cement / lime and bagasse ash to soil of lime + BSBFA, increased from 7.6% to 17.8% clay +lime + bagasse fibre ash and from 7.6% to 13.9% clay + cement + bagasse fibre ash, both showed tremendous strength increased with lime having higher values in clay cement / lime, low results in cement was attributed to hydration between cement and bagasse ash.

3.3 Unconfined Compressive Strength Test

Results of UCS of soils + cement + BSBFA with ratios ad above showed an increased values of 78.6kPa to 623kPa and 78.6kPa to 223kPa clay + lime + BSBFA treated clay. Higher strength of UCS was recorded higher in cement to lime samples

3.4 Consistency Limits Test

Tables 3.4 and 3.5 presented the results of clay + lime + BSBFA treated clay soil IP decreased from 33.7% to 30.8% and while clay + cement + BSBFA 36.8% to 31.2%.

Table -3.1 Engineering Properties of Soil Samples

	(Clay)
Percentage(%) passing BS sieve #200	80.5
Colour	Grey
Specific gravity	2.65
Natural moisture content (%)	45.5
Atterberg limits	
Liquid limit (%)	56.1
Plastic limit (%)	22.4
Plasticity Index	33.7
AASHTO soil classification	A-7-6
Compaction characteristics	
Optimum moisture content (%)	12.39
Maximum dry density (kN/m$^{3)}$	1.64

Grain size distribution	
Gravel (%)	0
Sand (%)	10
Silt (%)	48
Clay (%)	42
Unconfined compressive strength (kPa)	78.6
California Bearing capacity (CBR)	
Unsoaked (%) CBR	7.6
Soaked (%) CBR	7.4

Table -3.2 Properties of Bush sugarcane bagasse fibre. (Rivers State University of Science and Technology, Chemical Engineering Department, Material Lab.1)

Property	Value
Fibre form	Single
Average length (mm)	150
Average diameter (mm)	0.5
Tensile strength (MPa)	60 – 23
Modulus of elasticity (GPa)	1.1 – 0.35
Specific weight (g/cm^3)	0.52
Natural moisture content (%)	8.8
Water absorption (%)	150 – 223

Source, 2018

Table -3.3 Composition of Bagasse. (Rivers State University of Science and Technology, 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 Oxides Composition of Bagasse Ash (Rivers State University of Science and Technology, Chemical Engineering Department, Material Lab.1)

Oxide	**Composition (%)**
SiO_2	57.95
Al_2O_3	8.23
FeO_3	3.96
CaO	4.52
MgO	4.47
K_2O	2.41
LOI*	5.0

Source, 2018

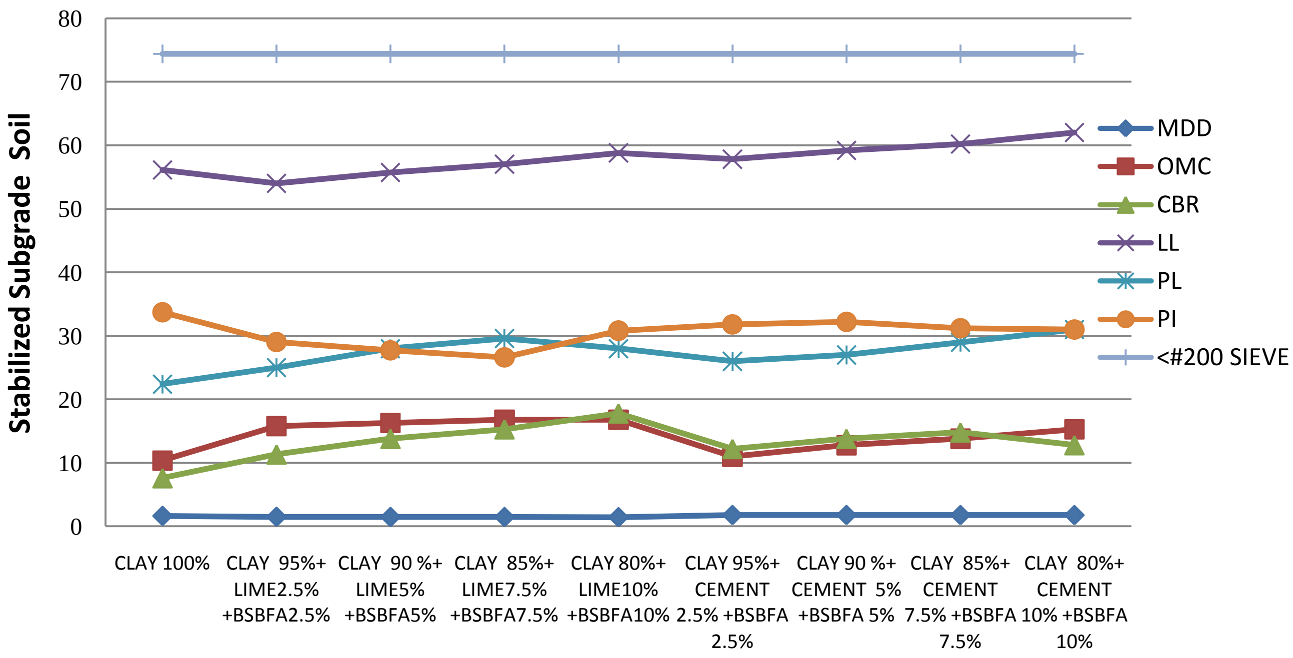
Table -3.5 Results of Subgrade Soil (Clay) Test Stabilization with Binding Cementitious Products at Different percentages and Combination

`S/no	**Description of materials Bush sugarcane bagasses fibre products**	**MDD (kN/m$^{3)}$**	**OMC (%)**	**CBR (%)**	**LL (%)**	**PL (%)**	**PI (%)**	**SIEVE #200**	**AASHTO Class**	**Remarks**
	CLAY									
1	CLAY 100%	1.64	12.39	7.6	56.1	22.4	33.7	74.4	A-7-6.	POOR
	CLAY + CEMENT + BSBFA									
7	CLAY 95%+ CEMENT 2.5% +BSBFA 2.5%	1.778	10.96	12.2	57.8	26	31.8	74.4	A-7-6.	GOOD
8	CLAY 90 %+ CEMENT 5% +BSBFA 5%	1.780	12.79	13.8	59.2	27	32.2	74.4	A-7-6.	GOOD
9	CLAY 85%+ CEMENT 7.5% +BSBFA 7.5%	1.770	13.81	14.8	60.2	29	31.2	74.4	A-7-6.	GOOD

10	CLAY 80%+ CEMENT 10% +BSBFA 10%	1.768	15.29	12.8	62	31	31	74.4	A-7-6.	GOOD
	CLAY + LIME + BSBFA									
7	CLAY 95%+ LIME 2.5% +BSBFA 2.5%	1.50	15.8	11.34	54	25	29	74.4	A-7-6.	GOOD
8	CLAY 90 %+ LIME 5% +BSBFA 5%	1.47	16.3	13.8	55.7	28	27.7	74.4	A-7-6.	GOOD
9	CLAY 85%+ LIME 7.5% +BSBFA 7.5%	1.46	16.8	15.3	57	29.6	26.6	74.4	A-7-6.	GOOD
11	CLAY 80%+ LIME 10% +BSBFA 10%	1.43	16.8	17.8	58.8	28	30.8	74.4	A-7-6.	GOOD

Table -3.5 Unconfined Compressive Strength (UCS) Test Summary Results

S/NO	DESCRIPTION OF MATERIALS BUSH SUGARCANE BAGASSES FIBRE PRODUCTS	CURING PERIODS				
		2 DAYS	7 DAYS	14 DAYS	21 DAYS	28 DAYS
	CLAY					
1	CLAY 100% + LIME 0%	78.6	78.6	78.6	78.6	78.6
	CLAY + LIME + BSBFA					
2	CLAY 95%+ LIME 2.5% +BSBFA 2.5%	136.4	144.8	163.8	173.1	183.8
3	CLAY 90 %+ LIME 5% +BSBFA 5%	154.8	161.3	174.3	191.3	208
4	CLAY 85%+ LIME 7.5% +BSBFA 7.5%	184.2	189.4	196.6	212	223
5	CLAY 80%+ LIME 10% +BSBFA 10%	138.8	149.6	154.1	156.3	181.1
6	CLAYS 100% + CEMENT 0%	78.6	78.6	78.6	78.6	
7	CLAY 95%+ CEMENT 2.5% +BSBFA 2.5%	262	281	301	318	328
8	CLAY 90 %+ CEMENT 5% +BSBFA 5%	448	460	481	495	518
9	CLAY 85%+ CEMENT 7.5% +BSBFA 7.5%	438	453	470	419	506
10	CLAY 80%+ CEMENT 10% +BSBFA 10%	563	580	597	609	623



Clay + Cement / Lime +BSBFA

Fig. 3.1 Subgrade Stabilization Test of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement / Lime + BSBFA at Different Percentages and Combination

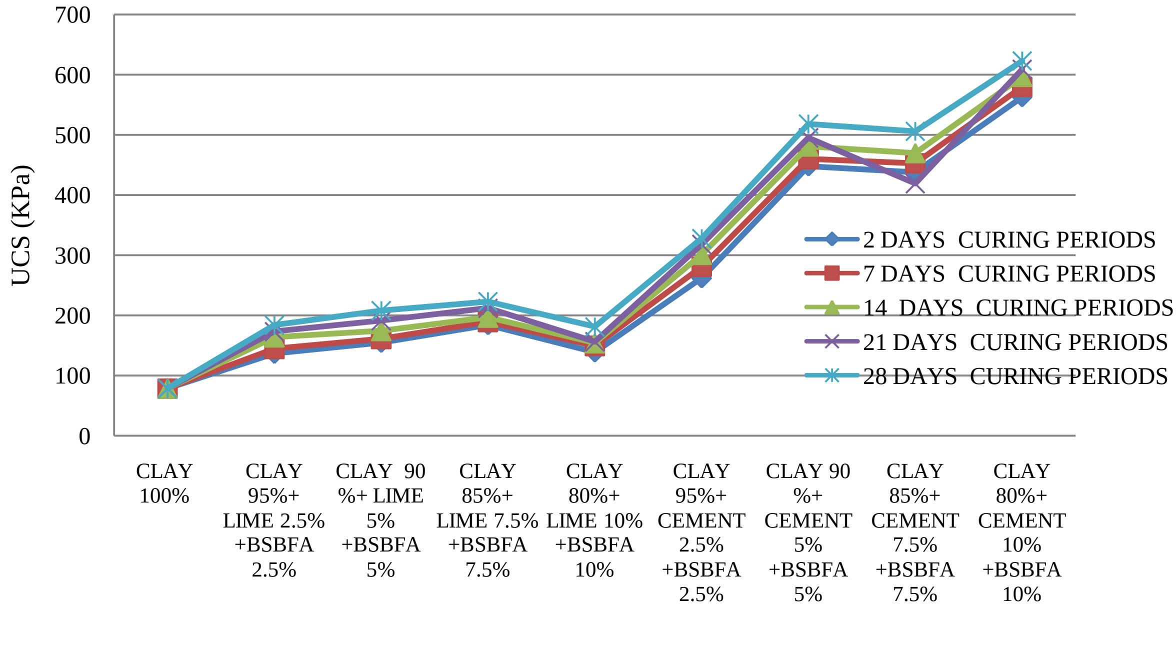


Fig. 3.2 Unconfined Compressive Strength (UCS) of Clay Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement / Lime and BSBFA at Different Percentages and Combinations

4.0 CONCLUSIONS

The following conclusions can be made from the final investigations:

- Results of tests carried out show that the optimum moisture content increased with increasing cement and lime.
- Treated soils with Cement and Lime decreased in liquid limits and increased in plastic limits. Soils with Cement, Lime and fibre products in combinations increased CBR values appreciably both at soaked and unsoaked conditions.
- The entire results showed the potential of using bagasse, BSBF and BSBFA as admixtures in cement and lime treated soils of clay and laterite.
- Bagasse ash proved to be a good pozzolana in soil stabilization and modification.
- 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. 75% BSBF, optimum value are reached.

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