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Stabilization of Deltaic Soil with Bush Sugarcane Bagasse, Cement and Lime: A Comparative Evaluation

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Abstract The research work investigated the geotechnical properties of an expansive soil of failed highway and stabilized with composite cementitious material. The Deltaic soil (laterite) was collected at failed portion of Odioku road in Ahoada West L.G.A of Rivers State. The soil was classified as A- 2 -7 on the AASHTO classification scheme. Its natural characteristics based on preliminary investigation show that they fell short of the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW 1997). Hence, there was need for stabilization to improve their properties. Laboratory tests such as Natural Moisture Content, Consistency Limits, Compaction, California Bearing Ratio (C.B.R.), and Unconfined Compressive Strength (U.C.S.) were carried out on the samples of untreated soils and treated soils with stabilizers (Cement, Lime and Bush Sugarcane Bagasse of Fibre and Ash (BSBF). The soils were treated with 3.75 %,5.5 %,7.25 % and 9 % cement and lime with variations (BSBF) ranging from 0 %, 0.25 %,0.5 %,0.75 %, and 1.0 % by weight of soils. Compaction results obtained of Optimum moisture content (OMC) and maximum dry density (MDD) of clay soils + cement + bush sugarcane bagasse fibre (BSBF) reinforced soils at combined actions to soil, cement, lime and BSBF combined percentages.OMC of Soil + cement + BSBF treated soils increased from 11.79% to 12.992% and Soil + lime + BSBF treated soils increased 11.79% to 14.32% , lime treated samples with higher values of 10.2% against cement treated samples. MDD of soil + cement + BSBF treated soil increased from 1.803kN/m^3 and 1.868kN/m^3 and soil + lime + BSBF treated increased from 1.803KN/m^3 to 1.841kN/m^3, with higher differential value 1.467% of cement to lime treated samples. CBR test results of soil + cement + bagasse fibre (BSBF) increased from 9.8% to 90.84%, and soil + lime + bagasse fibre (BSBF) increased from 9.8% to 46.81% with differential value of 94.06% of cement to lime treated samples and with an optimum inclusion percentage ratio of soils 92% + cement 7.25 + BSBF 0.75%. UCS results of soil + cement + BSBF increased from 155kPa to 1015kPa while soil + lime + BSBF increased from 155kPa to 356kPa, with 185.1% higher in cemented to lime treated samples. Entire results showed the potential of using the cement / lime and BSBF in combined actions to stabilized and strengthened failed and new roads.

Keywords Clay and lateritic Soils, Costus Afer ash, CBR, UCS, Consistency, Compaction

1. Introduction

Expansive and Soft soil formations, especially those with high in situ water contents, are susceptible to large settlements and possess low shear strength unless they are naturally cemented. Pre-compression of such deposits with geodrains can prevent this large settlement and thus enhance shear strength. But this mode of attacking the problem often requires more time than is practically available. An alternative to this is cementation of the soft soil with supplementary cementing materials such as lime and cement [1]. The principle mechanism of ground improvement is done by forming chemical bonds between the Soil particles. When the SOIL particles are bonded, it will be strengthened and become more stable physically and mechanically. Soft soil, when mixed with cement, will be stabilized because cement and water react to form cementitious calcium silicate and aluminate hydrates, which bind the Soil particles together [2]. The study of the treatment of soils using several methods of stabilization (addition of NaCl salt, lime, cement, and association lime+ cement, and association lime + salt) show that for certain combinations the reduction rate in swelling potential more than 90% [2].

Ordinary Portland Cement (OPC) is one of the most successfully used Soil stabilization. It will reduce Soil plasticity with resultant effects on swelling and similar behavior [3]. They found that the improvement of Soil L characteristics depended on the chemical components of cementing agent and the properties of the Soil. OPC and Soil mixed at the proper moisture content has been used increasingly in recent years to stabilize Soils in special situations. The hardening process of cement stabilized Soils happens immediately upon mixing Soil with cement slurry. The hardening agent produces the hydrated calcium silicates, hydrated calcium aluminates, and calcium hydroxide and forms hardened cement bodies.

Saadeldin *et al*. [4] evaluated the performance of a road embankment constructed on cement-stabilized soft soil (CSC). The undrained shear strength of the soft soil was experimentally determined before and after stabilization with cement. The results of the experimental work were used to simulate the behavior of the foundation Soil under the road embankment using a 2-D finite element model. The foundation Soil consisted of two layers: CSC having a variable thickness ranging from 1 to 5m, followed by soft soil layer extending to 15m below ground surface. The performance of the embankment founded on CSC was compared to that obtained if the CSC was replaced with compacted sand fill. Cement stabilization enhanced the performance of the embankment with respect to safety against shear failure more than sand soil replacement. It also found, the unconfined compressive strength of cement-stabilized soft soil increased as the cement content increased. The unconfined compressive strength increased as the curing time increased up to about 28 days, after which the compressive strength practically stabilized.

The physical properties of Soil cement depend on the nature of Soil treated, the type and amount of cement utilized, the placement and cure conditions adopted. Soil -cement content varying from 5 % to 20 % for satisfactory stabilization. For soils, cement content may range from 3 % to 16 % by dry weight of soil, depending on the type of Soil and properties required. Generally as the soil content of soil increases, so does the quantity of cement required.

Sabat and Pradhan [5] investigated the effect of polypropylene fiber (content and length) on compaction properties, unconfined compressive strength (UCS), soaked CBR, and PS of an expansive soil stabilized with optimum percentage (20 %) of fly ash and had found the optimum percentage and optimum length of fiber as 1% and 12 mm respectively with improvement in strength and swelling behavior.

Kalkan [6] stabilized expansive clay with red mud (a waste material generated during the production of alumina) and cement-red mud and found increase in strength and decrease in swelling percentage and hydraulic conductivity.

Rao *et al*., [7] studied the effects of RHA, lime and gypsum on engineering properties of expansive soil and found that UCS increased by 548 % at 28 days of curing and CBR increased by 1350 % at 14 days curing at RHA- 20%, lime -5 % and gypsum -3%.

Sabat [8] studied the effect of lime sludge (from paper manufacturing industry) on compaction, CBR, shear strength parameters, coefficient of compression, Ps and durability of an expansive soil stabilized with optimum percentage of RHA after 7days of curing. The optimum proportion soil: RHA: lime sludge was found to be 75:10:15.

Sharma and Gupta [9] investigated the effect of fly ash(class-F) on sand stabilized black cotton soil based on compaction and CBR test the optimum proportion of soil: sand :fly ash was found to be 63:27:15.

Gopala *et al*., [10] studied the effect of fly ash (class-F) and zycosil on soaked and unsoaked CBR of black cotton soil, the highest unsoaked CBR was obtained at 2 % zycosyl with 3% fly ash and highest soaked CBR was obtained at 2 % zycosil with 4 % fly ash.

Radhakrishnan *et al.,* [11] studied the combined effect of (class-F) fly ash - Magnesium chloride and fly ash-Aluminum chloride on swelling pressure (Ps), swelling potential (Sp) and differential free swell (DFS) of expansive soil and found that the swelling properties decreases substantially with increase in percentage of stabilizer but remain stable after certain percentage of the stabilizers.

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 Lime

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

2.1.3 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.

2.1.4 Cement

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

2.2. Methods

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 [12-13].

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;

2.2.2 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.

2.2.3 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.

2.2.4 Consistency 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.

2.2.5 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.

2.2.6 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.

2.2.7 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

The Deltaic soil (laterite) was collected at failed portion of Odioku road in Ahoada West L.G.A of Rivers State. The soil is classified as A- 2 -7 on the AASHTO classification scheme. Its natural characteristics based on preliminary investigation show that they fell short of the minimum requirements for such applications on Specifications for road pavement structural materials (after FMW 1997). Hence, there was need for stabilization to improve their properties. Laboratory tests such as Natural Moisture Content, Consistency Limits, Compaction, California Bearing Ratio (C.B.R.), and Unconfined Compressive Strength (U.C.S.) were carried out on the samples of untreated soils and treated soils with stabilizers (Cement, Lime and Bush Sugarcane Bagasse of Fibre and Ash (BSBF). The soils were treated with 3.75 %,5.5 %,7.25 % and 9 % cement and lime with variations (BSBF) ranging from 0 %, 0.25 %,0.5 %,0.75 %, and 1.0 % by weight of soils.

3.1 Compaction Test Results

Table 3.4 showed the results obtained of Optimum moisture content (OMC) and maximum dry density (MDD) of clay soils + cement + bush sugarcane bagasse fibre (BSBF) reinforced soils at combined actions to soil, cement , lime and BSBF combined percentages.

OMC of Soil + cement + BSBF treated soils increased from 11.79% to 12.992% and Soil + lime + BSBF treated soils increased 11.79% to 14.32%, lime treated samples with higher values of 10.2% against cement treated samples.

MDD of soil + cement + BSBF treated soil increased from 1.803kN/m^3 and 1.868kN/m^3 and soil + lime + BSBF treated increased from 1.803KN/m^3 to 1.841kN/m^3, with higher differential value 1.467% of cement to lime treated samples.

3.2 California Bearing Ratio (CBR) Test

CBR test results of soil + cement + bagasse fibre (BSBF) increased from 9.8% to 90.84%, and soil + lime + bagasse fibre (BSBF) increased from 9.8% to 46.81% with differential value of 94.06% of cement to lime treated samples and with an optimum inclusion percentage ratio of soils 92% + cement 7.25 + BSBF 0.75%.

3.3 Unconfined Compressive Strength Test

Results of soil + cement + BSBF increased from 155kPa to 1015kPa while soil + lime + BSBF increased from 155kPa to 356kPa, with 185.1% higher in cemented to lime treated samples.

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: Results of Subgrade Soil (Lateritic) 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
					LATERITE					
1	LATERITE 100%	1.803	11.78	9.8	39	22	17	36.8	A-2-6	POOR
					LATERITE + CEMENT + BSBF					
2	LATERITE 96%+ CEMENT 3.75% +BSBF 0.25%	1.861	10.97	28.08	43.9	23	20.9	36.8	A-2-6	GOOD
3	LATERITE 94%+ CEMENT 5.5% +BSBF 0.50%	1.866	11.85	53.15	42.4	23.6	18.8	36.8	A-2-6	GOOD
4	LATERITE 92%+ CEMENT 7.25% +BSBF 0.75%	1.869	12.92	90.84	41.6	24.8	16.8	36.8	A-2-6	GOOD
5	LATERITE 90%+ CEMENT 9% +BSBF1.0%	1.863	13.75	56.30	40.7	26	14.7	36.8	A-2-6	GOOD
					LATERITE + LIME + BSBF					
6	LATERITE 96%+ LIME 3.75% +BSBF 0.25%	1.834	10.99	22.50	42.7	23	18.3	36.8	A-2-6	GOOD
7	LATERITE 94%+ LIME 5.5% +BSBF 0.50%	1.847	11.36	25.40	42	23	19	36.8	A-2-6	GOOD
8	LATERITE 92%+ LIME 7.25% +BSBF 0.75%	1.854	12.08	46.81	40	24	16	36.8	A-2-6	GOOD
9	LATERITE 90%+ LIME 9% +BSBF 1.0%	1.841	14.32	34.60	41.6	25	16.6	36.8	A-2-6	GOOD

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

S/NO	DESCRIPTION OF MATERIALS BUSH SUGARCANE BAGASSES FIBRE PRODUCTS	2 DAYS CURING PERIODS	7 DAYS CURING PERIODS	14 DAYS CURING PERIODS	21 DAYS CURING PERIODS	28 DAYS CURING PERIODS
	LATERITE					
1	LATERITE 100% + CEMENT 0%	155	155	155	155	155
	LATERITE + CEMENT + BSBF					
2	LATERITE 96%+ CEMENT 3.75% + BSBF 0.25%	503	531	550	573	598
3	LATERITE 94%+ CEMENT 5.5% + BSBF 0.50%	765	790	825	848	863
4	LATERITE 92%+ CEMENT 7.25% + BSBF 0.75%	938	954	977	991	1015
5	LATERITE 90%+ CEMENT 9% + BSBF1.0%	809	826	841	866	885
	LATERITE					
6	LATERITE 100% + LIME 0%	155	155	155	155	155
	LATERITE + LIME + BSBF					
7	LATERITE 96%+ LIME 3.75% + BSBF 0.25%	256.1	264.3	281.2	298	318
8	LATERITE 94%+ LIME 5.5% + BSBF 0.50%	274.3	286.1	295.1	306.2	313
9	LATERITE 92%+ LIME 7.25% + BSBF 0.75%	296.6	308	322	336	356
10	LATERITE 90%+ LIME 9% + BSBF1.0%	234.1	256.1	273.1	293.7	301.5

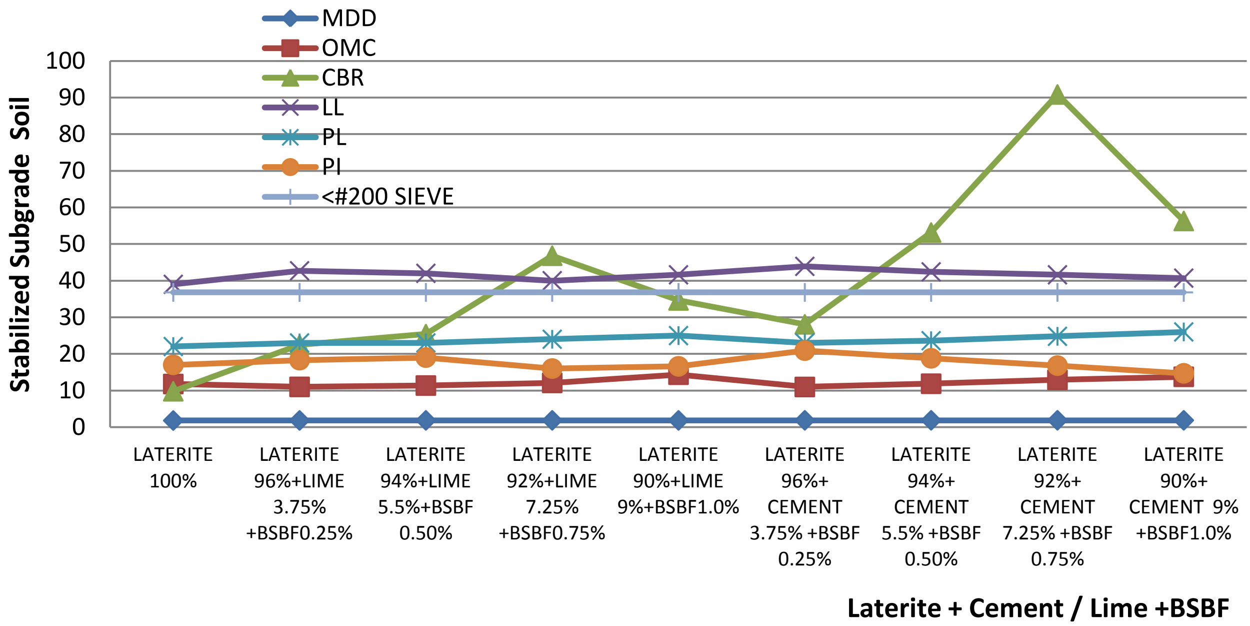

Figure 3.1: Subgrade Stabilization Test of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement / Lime + BSBF at Different Percentages and Combination

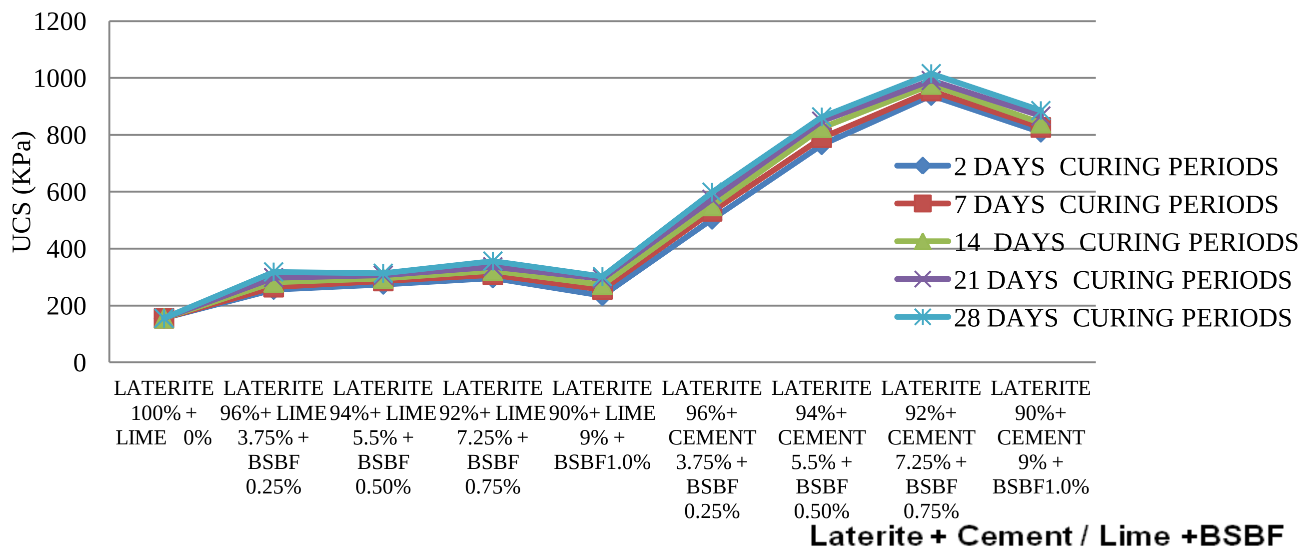

Figure 3.2: Unconfined Compressive Strength (UCS) of Lateritic Soil from Odioku in Ahoada-West L.G.A of Rivers State with Cement / Lime and BSBF at Different Percentages and Combinations

4. Conclusions

The following conclusions can be made from the final investigations:

- Bagasse ash proved to be a good in soil stabilization and modification.
- Results of tests carried out show that the optimum moisture content increased with increasing cement, lime and fibre.
- The entire results showed the potential of using bagasse BSBF as admixture in cement and lime treated soils of laterite .
- 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.

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