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Cement Stabilized Akwuete Lateritic Soil and the Use of Bagasse Ash as Admixture

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Abstract- The lateritic soil collected from Akwuete borrow site, Ukwa East Local Government Area of Abia State, classified as an A-2-6 soil on the AASHTO classification was stabilized using 4% and 6% cement with variations of bagasse ash ranging from 0%(control), 2%, 4%, 6%, 8%, and 10% by weight of the dry soil. The effect of bagasse (sugarcane foil) ash on the soil was investigated with respect to compaction characteristics and California bearing ratio (CBR) tests. The results obtained indicate a decrease in maximum dry density (MDD) with 4% cement content and an increase with 6% cement content. There is also an increase in optimum moisture content (OMC) for both 4% and 6% cement content all with increase in bagasse ash content of 0%, 2%, 4%, 6%, 8%, and 10% by weight of the soil on the constant cement contents of 4% and 6%. An increase was also recorded in the CBR of the soil. This shows a potential of using bagasse ash as admixture in cement stabilized lateritic soil.

Keywords- *Bagasse-Ash, California Bearing Ratio, Admixture, Lateritic Soil, Cement Stabilized Soil, Optimum Moisture Content.*

I. FORMATION OF LATERITE

Lateritic soils are soil types rich in iron and aluminum formed in wet and hot tropical areas. Nearly all lateritic soils are rusty red because of iron oxides. They develop by intensive and long lasting weathering of the underlying parent rock.

Lateritic soils cover about one third of the earth's continental land area with the majority of that in the land areas between the tropics of cancer and Capricorn, [1]. Historically, Laterite was cut into brick-like shapes and used in monument building. An example is the construction of Angkor Wat and other south east Asia sites made of Laterite, brick, and stone, [1]. Statistical analysis shows that the transition in the mean and variance levels during the middle Pleistocene was abrupt. It seems this abrupt transition was global and mainly represents an increase in ice mass at about the same time and abrupt decrease in sea surface temperatures occurred. These two changes indicate a sudden global cooling. The rate of laterization would have decreased with the abrupt cooling of the earth, [2].

Lateritic soils are formed from the leaching of parent sedimentary rocks (sandstones, clays, lime stones); volcanic rocks (schists, gneiss, migmatites); and mineralized protores which leaves the more insoluble irons, predominantly iron and aluminum, [3]. The reaction zone where rocks are in contact with water from the lowest to the highest water table is progressively depleted of the easily leached ions of sodium (Na^{++}), potassium (K^+), calcium (Ca^{++}) and magnesium (Mg^{++}), [1].

In later studies by [4], it was found that intensive chemical decomposition of rocks in a widespread phenomenon in tropical region and affects each land of rock. Obviously, tropical weathering causes an increase of iron indicated by the reddish brown color of Laterite. With the progress in chemical analysis, more and more examples were analyzed and showed the typical increase of iron and frequently, of aluminum and decrease of silica in relation to the underlying parent rock. Laterite was therefore tried to be defend by the ratio Si (Al+Fe) but a definite limit was not applicable for laterite on different parent rocks, [5]. Therefore, Laterite is a reddish soil produced by rock decay which contains insoluble deposits of Ferric and Aluminum oxides.

II. RESEARCH BACKGROUND

Bagasse ash which is used as the admixture in the stabilization of lateritic soil is the ash of an agricultural waste material gotten after squeezing out the sweet juice in sugar cane and incinerated into ash.

Sugar cane is grown in the world from latitude 36.7oN and 31.00S , from sea level to 1000m of a latitude or little more. It is considered as essentially a tropical plant. It is a long duration crop and thus it encounters all the seasons viz; wet season, winter and summer during its cycle. It is produced in commercial quantities in Nigeria in the North and the Eastern part of the country précised at Lokpanta in Umunnochi L.G.A. of Abia state.

Principal climatic components that control sugar cane growth, yield and quality are temperature, light and moisture availability. The plant thrives best in tropical hot sunny areas; the ideal climate for production of maximum sugar from sugar cane is characterized by,

1) A long warm growing season with a high incidence of solar radiation and adequate moisture (rainfall). The plant uses from 148g to 300g of water to produce 1.0g of dry substance.

2) A fairly dry, sunny and cool but frost free season for ripening and harvesting moisture percentage drops steadily throughout the life of the sugarcane plant from 83% in very young cane to 71% in mature cane, meanwhile, sucrose grows from less than 10% to more than 45% of dry weight, [2].

High humidity (80-85%) favors rapid cane elongation during ground growth period and this produces higher quantity of cane soil from where bagasse ash is gotten.

Sugar cane soil has constituted disposal problems which are highly observed and which is a major problem encountered in areas of great sugarcane production.

In Nigeria, the cities of Jos, Benue, Sokoto and the above unmentioned locations in Eastern Nigeria have a good share of this disposal problem caused by bagasse, [6].

III. LATERITIC SOIL BED IN NIGERIA

Laterites are formed mostly in the sub-tropical regions of the world between 25o N and 25o S latitude. And it is basic that Nigeria's climate is tropical, which refers to any region falling between the tropics of cancer and Capricorn. Nigeria as the case may be is safely within the region, ranging from 4-11o S latitude, [2]. The red beds of lateritic soil are present in the dominantly Drah Binna sandstone at two locations in south eastern Nigeria. It is deduced that the climate in the source area was conducive for the production of the red soils. Alternating humid and dry periods are believed to have provided the conditions for the accelerated metamorphic rocks of marked relief due to her climatic and geological position in the world, Nigeria is endowed with high qualities of Laterite. This is especially seen in both northern and eastern parts of the country. Also due to the climatic and geological position of Abia state and her alternating humid and dry periods, Akwuete in Ukwa East local government area of the state has her share in Laterite deposition and formation. Materials from this soil deposit are usually used by the people of this area in the construction of earth roads. Lateritic soils in this area are used as filling materials in road construction and at the foundation stages of buildings.

IV. RESEARCH OBJECTIVE E

The objective of this work is to examine the effects of bagashe ash on the compaction and strength characteristics of cement stabilized lateritic soil which is the test requirements for stabilized materials. This is done by the addition of 0% (control, 2%, 4%, 6%, 8% and 10% bagashe ash to constant cement contents of 4% and 6%).

V. RESEARCH LIMITATION AND JUSTIFICATION

Research is limited to Akwuete lateritic soil which is stabilized with ordinary Portland cement (binder) and bagasse ash (admixture). In a bid to achieve alternative low cost roads where the production of aggregates for road work is very expensive, bagasse ash, a waste product is substituted as a percentage for cement stabilized soil. It has also been established that bagasse ash is a good pozzolana, [7]. Over the years it has shown a remarkable ability of improving the engineering properties of cement stabilized soil materials because it continues to react with calcium hydroxide -$Ca(OH)_2$- which is a product of hydration reaction with calcium oxide (CaO) forming cementitious substances in the stabilized matrix and subsequently improve the strength properties of the stabilized matrix.

VI. RESEARCH REVIEW OF RELATED WORKS

- Purpose of soil stabilization

Soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become more suitable for construction beyond their original classification, [8] and [9].

The process may include the blending of soils to achieve a required gradation or the mixing of commercially available additives that may alter gradation, texture or plasticity or act as a binder for cementation of the soil, [10]. In addition, soil stabilization is any treatment applied to a soil to improve its strength and reduce its vulnerability to water, [11]. Soil stabilization is important as it improves the engineering properties of a soil, thus making it more stable [5].

- Constituent Elements of Present Work

1. Portland Cement

Table I: Constituents of Portland Cement

Name of Compound	Chemical Composition	Abbreviation
Tri-calcium Silicate	$3CaO.SiO_2$	C_3S
Di-calcium Silicate	$2CaO.SiO_2$	C_2S
Tri-calcium Aluminate	$3CaO.Al_2O_3$	C_3A
Tetra-calcium Alumino Ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

2. Bagasse Ash

Table II: Constituents of Bagasse Ash

Name of Compound	Chemical Composition	Percentage (%)
Cellulose	C2H12O6	45-55
Hemi-cellulose	6C6H12O6	20-25
Lignin		13-24
Ash	Al_2O_3,SiO_2,CaO	1-4
Water	H_2O	‹ 1

Table III: Oxide Composition of Bagasse Ash

Constituents	Composition (%)
SiO_2	57.65
Al_2O_3	8.23
Fe_2O_3	3.96
CaO	4.52
MgO	1.17
H_2O	2.41
Loss on ignition	5.00

3. Laterite

Table IV: Chemical Compound Composition of Laterite

Name of Compound	Chemical Composition
Alumina	Al_2O_3
Silica	SiO_2
Ferrite	Fe_2O_3
Water	H_2O

Mohammed carried out a work to study the influence of competitive effort on bagasse ash with cement treated lateritic soil, [12]. An increase in optimum moisture content (OMC) and decrease in maximum day density (MDD) was observed with increase in the percentage of bagasse ash and cement. [13] Studied the effect of up to 12% bagasse ash by weight of dry soil on the geotechnical properties of deficient lateritic soil. It was concluded that bagasse ash cannot be used as a standalone stabilizer but should be employed as admixture.

VII. MATERIALS AND METHOD

- Materials and Sampling

The lateritic soil sample used for this research work was collected using disturbed sampling technique from a soil deposit called Basic Borrow Site in Akwuete, Ukwa East Local Government Area of Abia State, Nigeria. The sample was collected at a depth below 1.5m to avoid the top soil. Ordinary Portland cement was used as a binder and Bagasse Ash was used as an admixture in the stabilization of the lateritic soil. Distilled water was used for mixing, [14] and [15].

- Properties of Akwuete Lateritic soil before stabilization

This is summarized in Table V shown below.

Table V: Properties of Lateritic Soil before Stabilization

Properties	Quantity
Natural Moisture Content (%)	45.30
Percentage Passing BS Sieve No.200	9.27
Liquid Limit (%)	74.76
Plastic Limit (%)	50.25
Plasticity Index (%)	24.51
AASHTO Classification	A-2-6
Maximum Dry Density (g/cm3)	1.78
Optimum Moisture Content (%)	15.80
California Bearing Ratio (%)	11.25
Specific Gravity	2.75

VIII. RESULTS AND DISCUSSIONS

The results of the optimum moisture content, maximum dry density and California bearing ratio for the 4% and 6% cement content for the varying percentages of bagasse ash are summarized in Tables VI, VII, VIII, IX, X, and XI as follows;

Table VI: Optimum Moisture Content and Bagasse Ash Content at 4% Cement

OMC (%)	Bagasse Ash (%)
20.51	0
20.71	2
21.20	4
21.80	6
22.64	8
22.88	10

Table VII: Maximum Dry Density and Bagasse Ash Contents at 4% Cement

MDD (g/cm3)	Bagasse Ash (%)
1.78	0
1.79	2
1.74	4
1.69	6
1.50	8
1.50	10

Table VIII: California Bearing Ratio and Bagasse Ash Contents at 4% Cement

CBR (%)	Bagasse Ash (%)
58.77	0
85.66	2
86.10	4
94.20	6
112.18	8
128.05	10

Table IX: Optimum Moisture Content and Bagasse Ash Content at 6% Cement

OMC (%)	Bagasse Ash (%)
17.90	0
14.02	2
15.96	4
16.01	6
16.22	8
16.40	10

Table X: Maximum Dry Density and Bagasse Ash Contents at 6% Cement

MDD (%)	Bagasse Ash (%)
1.88	0
1.96	2
1.98	4
2.10	6
2.30	8
2.50	10

Table XI: California Bearing Ratio and Bagasse Ash Contents at 6% Cement

CBR (%)	Bagasse Ash (%)
85.30	0
98.60	2
106.70	4
119.02	6
126.75	8
137.62	10

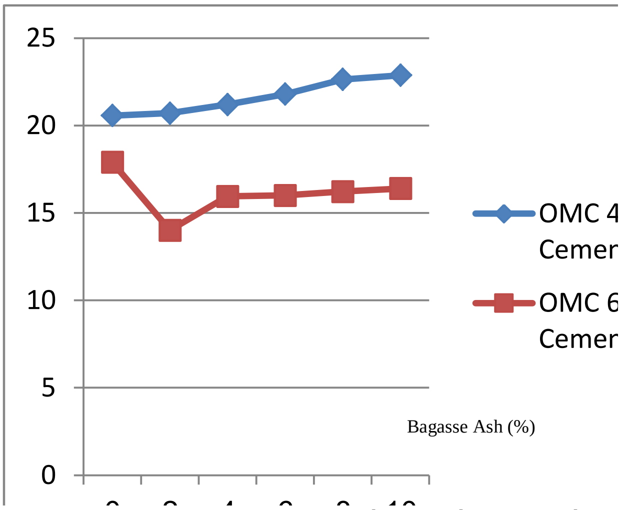

Figure I: Optimum Moisture Content Behavior with Bagasse Ash

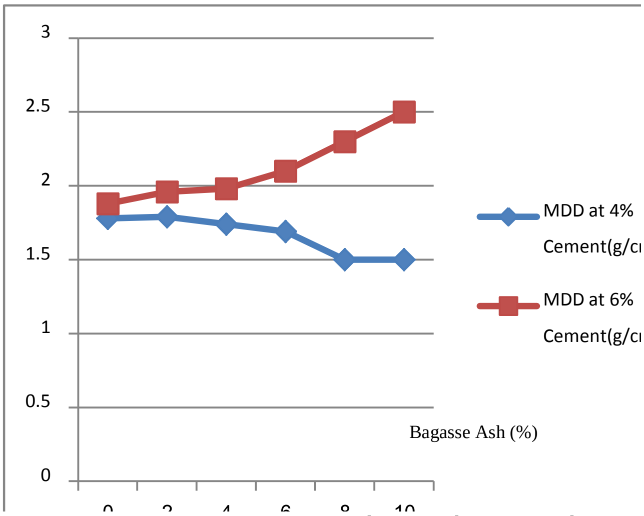

Figure II: Maximum Dry Density Behavior with Bagasse Ash

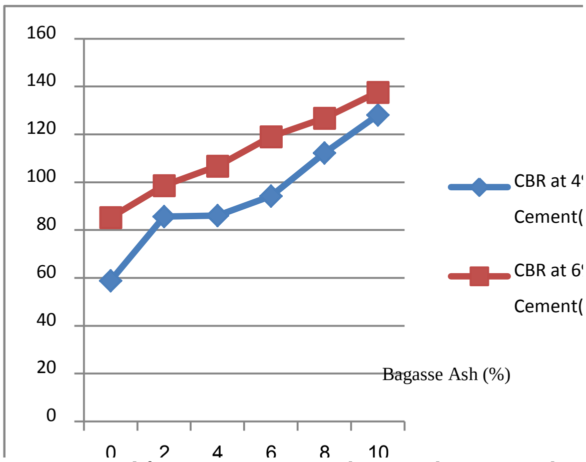

Figure III: California Bearing Ratio Behavior with Bagasse Ash

IX. CONCLUSION

At the end of this laboratory investigation, the results from the experiments show that:

1. The lateritic soil was identified to be an A-2-6 soil based on AASHTO classification system, [16].
2. At 4% cement content, with bagasse ash as admixture, there is a general reduction in the maximum dry density (Table VII) while there is an increase in the maximum dry density with increase in bagasse ash content at 6% cement content (Table X). The optimum moisture content generally increased with increase in the bagasse ash content (Tables VI and IX).
3. There was also a tremendous improvement in the CBR with bagasse ash compared to the natural soil (Tables VIII and XI). From the foregoing and tests carried out, bagasse ash is proved to be a good pozzolana in soil stabilization and modification.

REFERENCES

[1] Bureau of Reclamation, *Earth Manual*, 3rd Edition, Technical Science Center, Colorado, USA, 1998, pp. 21-67.

[2] Ekpo, A.D. and Ihedioha, N.A., *The Use of Bagasse Ash as Admixture in Cement Stabilized Oboro Lateritic Soil*, Unpublished Project Work Submitted to Department of Civil Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria, 2010.

[3] Smith, G.N. and Smith, I.G.N., *Elements of Soil Mechanics*, 7th Edition, Blackwell Science, UK, 1998, chapter 6.

[4] Gulati, S.K., *Engineering Properties of Soil*, McGraw Hill Publishing Co., New Delhi, 1978.

[5] Arora, K.R., *Soil Mechanics and Foundation Engineering*, 6th Edition, Standard publishers, Delhi, 2003.

[6] Ahawike, J. and Stephen, C., *The Effect of Bagasse Ash on the Properties of Cement Stabilized Oboro Lateritic Soil*, Unpublished Project Work Submitted to Department of Civil Engineering, Michael Okpara University of Agriculture Umudike, 2009.

[7] Mustapha, M., *Effect of Rice Husk Ash (RHA) on Cement stabilized Laterite, Seminar Paper Presented to the Department of Civil Engineering*, ABU, Zaria, Nigeria, 2005.

[8] Neville, A.M., *Properties of Concrete*, 4thdition, Pearson Education, Malaysia, 2000.

[9] Onyelowe, Ken.C., "Geosynthetics and Geotechnical Properties of Soil in a Developing Country: A Lesson for Nigeria", *Electronic Journal of Geotechnical Engineering, (EJGE), USA*, Vol. 16, 2011, pp 1481-1487, ISSN: 1089-3032.

[10] United States Army, "Soil Stabilization for Pavements", *Technical Manual No. 5-822-14*, Washington, 1994.

[11] O'Flaherty, C.A., *Soil Stabilized Pavements; Design, Construction, and Maintenance*, Butterworth-Heinemann, Malta, 2002.

[12] Mohammed, A.M., "Evaluation of Plasticity and Particle Size Distribution Characteristics of Bagasse Ash on Cement Treated Lateritic Soil", *Leonardo Journal of Sciences, USA, 2007, Issue 10.*

[13] Osinubi, K.J., "Bagasse Ash Stabilization of Lateritic Soil", *Springer Link Sciences and Business Media*, USA, 2009.

[14] BS 1924, *Methods of Testing for Stabilized Soils*, BSI London, 1990.

[15] BS 1377, *Methods of Testing Soil for Civil Engineering Purposes*, BSI London, 1990.

[16] AASHTO, "Standard Specification for Transportation materials and Method of Testing and Sampling", *American Association of State Highway and Transportation Officials*, Washington D.C, USA, 1986.

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