Nigerian Journal of Technology (NIJOTECH)
Vol. 41, No. 6, November, 2022, pp.949 - 954
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
http://dx.doi.org/10.4314/njt.v41i6.4

EFFECT OF SUGARCANE BAGASSE ASH AND PLANTAIN LEAF ASH ON GEOTECHNICAL PROPERTIES OF CLAY SOIL FROM EFAB ESTATE, AWKA, ANAMBRA STATE

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Article history: Received 24 April, 2022. Revised 28 January, 2023. Accepted 29 January, 2023

Abstract

This study investigated the feasibility of using agricultural wastes: sugarcane bagasse ash and plantain leaves ash for clay soil stabilization. The sample was mixed using five trial mixes: 0%BA:10%PLA, 3%BA:7%PLA, 5%BA:5%PLA, 7%BA :3%PLA, 10%BA:0%PLA and a control mix. Characterization of these ashes was done using the X-ray fluorescence testing method. Specific gravity, sieve analysis, Atterberg limits, compaction and California bearing ratio tests were also assessed. The clay soil was described as A-7-6 (AASHTO). After X-ray characterization, BA and PLA possessed 61.97% and 28.27% pozzolanic content respectively. From the liquid limit results, on addition of 3%BA :7%PLA, a significant decrease in values of 47.0%, 32.0% and 15.0% to 36.0%, 26.0% and 10.0% for LL, PL and PI was documented. Also, the addition of plantain leaves alone significantly decreases atterberg limit values. For compaction, 3%BA and 7%PLA recorded the least MDD value of 18.44kN/ m^3 and peak value of 19.42kN/m^3 at 0%BA: 10%PLA. 10%PLA and 10%BA recorded CBR soaked values of 57.8% and 62.1% whilst 7%BA:3%PLA yielded best results of 51.3% CBR soaked values. These findings reveal significant improvements in strength and index properties of the clay soil. In conclusion, bagasse ash and plantain leaves ash produce an eco-friendly stabilizer that can be utilized as subbase material in the stabilization of clay soils

Keywords: Agricultural wastes, Baggase ash, Plantain leaf ash, stabilization, XRF.

1.0 INTRODUCTION

Sugar cane is one of the main crops grown in over 110 countries, and its total production is around 1500 million tons [1, 3]. The world's leading sugarcane producing countries currently are Brazil and India. Brazil produces over 719 million tons of sugarcane standing as one-third of the World's total sugarcane production [2, 3] with India producing 300 million tons of sugarcane per year and generating about 10 million tons of sugarcane bagasse ash. The resulting bagasse ash is deposited in stockpiles in waste landfill dumps and represents environmental problems to the society. When bagasse is left in the open, it ferments and decays; this brings about the need for safe disposal of the pollutant, which when inhaled in large doses can result in respiratory disease known as bagassiosis [6]. The improvement in strength and durability of clay soil in recent times has become imperative, this has geared researchers towards using stabilizing materials that can be sourced locally at a very low cost [7].

Plantain Leaf Ash (PLA) is a local additive and agricultural by-product from plantain. Disposal of these agricultural wastes is usually done either by open burning or putting into a landfill. These processes are harmful to the environment as it can lead to air or land pollution as well as global warming. The use of PLA will help reduce environmental pollution, global warming and high cost of cementitious materials albeit it is also readily available [11].

Kawade et al. [12] study revealed that up to 15% of sugarcane bagasse ash can be used favourably without compromising the primary properties of soil. Stabilization of high plasticity clayey subgrade with bagasse or plantain leaves ash may prevent the pavement from swelling [14]. Hassan et al.[8] in his findings, reported that the soaked California Bearing Ratio (CBR) results indicated that bagasse ash possessed the ability to protect treated expansive soil from harmful effect of saturation. A study on the use of bagasse ash as subgrade soil stabilizing material was successfully investigated by [15] in stepped concentrations of 5%, 10%, 15%, 20%, 25% and 30%. Results revealed reduction in Plasticity Index (PI), Swelling and Maximum Dry Density (MDD) with increase in Optimum Moisture Content (OMC) and CBR values. In another study [16], observed increased unconfined strength values by 183% at 16% optimum SBA and a 9.4% reduction in plasticity index. Research on the geotechnical properties of lateritic soils stabilized with banana leaves ash in comparison with cement by [18] revealed that banana leaves ash sufficiently serves as cheap stabilizing agents for subgrade purposes.

Clay soils are problematic soils owing to their low permeability and highwater retention properties. Most times this clay soils are encountered on road construction site. Sometimes sourcing for alternative soils may prove economically unwise. Hence, soil improvement by way of stabilization with locally sourced materials at very low cost to meet the desired objective becomes a viable option. Soil improvement using bagasse ash has been done extensively in literature but limited research has been carried out on the use of bagasse ash and plantain leaves ash in appropriate mix ratios for the stabilization of problematic clay soils. This study aims to bridge that gap.

2.0 MATERIALS AND METHODS

2.1 CLAY SOILS

The sample used for this work is Clay, and it was collected from Efab Estate by Amansea, Awka, Anambra state as shown in Figure 1. The location coordinates are presented in Table 1. A pit of 0.45m was excavated from which the clay soil was extracted. The estate noticeably has its water table close to the surface of the ground during the rainy season, and soil here is characterised as highly plastic clay soil.

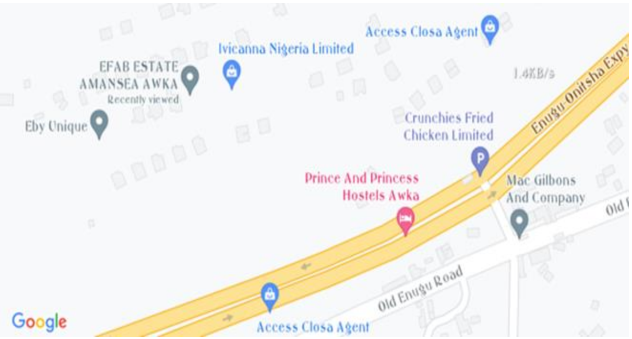

Figure 1: Map showing sample location (source: Goggle map)

2.2 SUGARCANE BAGASSE ASH (BA)

The Sugarcane bagasse waste used for this project was procured from Amansea area, Awka. It was gathered in a large quantity. The Sugarcane waste had the sugar extracted completely and sun dried for 3-4days before proceeding to the burning process. The leaves were subjected to burning and calcined into ash in a make-up container at temperature below 650°C. After it was allowed to cool for 24 hours and the ash collected. The ash was then sieved using the 600um sieve size and the ashes that passed through this sieve size were used for this research and those retained on the sieve were discarded.

2.3 PLANTAIN LEAF ASH (PLA)

The plantain leaves were gotten or collected from plantain trees. Plantain leaves (old and dry leaves) were gotten from Ifite, Awka district of Anambra Nigeria. The leaves were gathered in a large quantity. It was further sun-dried for about 12 hours to make sure it is properly dried. The leaves were subjected to burning and calcined into ash in a make-up container at temperature below 650°C. After it was allowed to cool for 24 hours and the ash collected. The ash was then sieved using the 600um sieve size and the ashes that passed through this sieve size were used for this research and those retained on the sieve were discarded.

Table 1: Sample location coordinates

S/N	Sample	Latitude	Longitude
1	Clay Soil	6.2551978N	7.1535466E

3.0 RESULTS AND DISCUSSION

3.1 CHARACTERISATION OF BAGASSE ASH AND PLANTAIN LEAF ASH

In order to evaluate the chemical composition of the baggase and plantain leaf ashes, the X-ray fluorescence testing (XRF) was done in accordance with British standards BS 4550 and EN 196 and the results analysed using the XRS-FP software. The results are shown in Table 2.

Table 2: Chemical Composition of Baggase Ash and Plantain Leaf Ash

Chemical Compound	Bagasse Ash Concentration (%)	Plantain Leaf Ash Concentration (%)
SiO_2	40.689	19.323
Fe_2O_3	11.065	3.910
CaO	22.927	46.409
K_2O	7.136	15.746
Al_2O_3	10.216	5.040
TiO_2	2.665	0.627
MgO	0.00	0.503
SO_3	0.819	2.267
P_2O_5	2.075	2.115

Chemical Compound	Bagasse Ash Concentration (%)	Plantain Leaf Ash Concentration (%)
ZnO	0.108	0.042
Cl	1.418	1.981

From Table 2, the bagasse ash exhibits good pozzolanic properties having a total percentage combination of SiO_2, Fe_2O_3 and Al_2O_3 as 61.97% and is categorized in accordance with ASTM C618-12 [20] as class C pozzolans. The high silica in the sugarcane bagasse ash (SCBA) maybe attributed to the absorption of silicic acid from the soil deposit in amorphous state in the plant [3, 4]. In accordance with ASTM C618 [5], if the total sum of SiO_2, Al2O_3 and Fe2O_3 is above 50% of the total mass, then the matter can be considered as a pozzolanic material. Plantain leaf ash on the other hand has 28.27% when the percentages of SiO_2, Fe_2O_3 and Al_2O_3 are summed. Its pozzolanic properties are poor but it possesses good cementitious properties containing 46.409% of CaO which is similar in composition to cement, lime or sisal fibre as recorded in Etim et al.[19], Yohanna et al.[21] , Ekpo et al. [22] and Sani et al.[24].

3.2 PHYSICAL PROPERTIES OF CLAY SOIL

Table 3 represents the summary of physical properties of the clay soil. It can be seen that the liquid and plastic limit values for the clay soil is high and above the limit specified for use in pavement construction.

Table 3: Summary of the Physical Properties of Clay Soil

Properties	Values
Specific gravity	2.10
%Passing 0.075mm	64.80
Liquid limit (%)	47.0
Plastic limit (%)	32.0
Plasticity index (%)	15.0
Classification AASHTO	A-7-6
Optimum moisture content (%)	12.0
Maximum dry density (kN/m^3)	18.15
CBR (Unsoaked/soaked) (%)	19.0/10.6

The sieve analysis result for the control sample is shown in Figure 2. The soil is classified as clayey soil (A-7-6) having more than 35% passing through sieve 0.075mm. For use as subgrade soils, these soils are regarded as poor hence the need for stabilization.

3.3 ATTERBERG LIMIT CHARACTERISTICS

The test done here include liquid limit (LL), plastic limit (PL) and plasticity index (PI) and were conducted in accordance to BS 1377-2-1990. From the liquid limit results, on addition of 3%BA : 7%PLA, the Atterberg limit values noticed a significant decrease from control values of 47.0%, 32.0% and 15.0% to 36.0%, 26.0% and 10.0% for LL, PL and PI values respectively. At 5%BA : 5%PLA, a slight rise was noticeable in the Atterberg limit values when compared with the values observed at 3%BA : 7%PLA. Also, similar results observed for 3%BA : 7%PLA were obtained for 7%BA and 3%PLA.

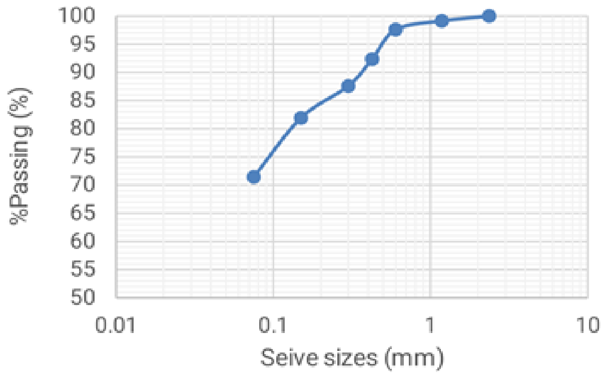

Figure 2: Sieve Analysis graph

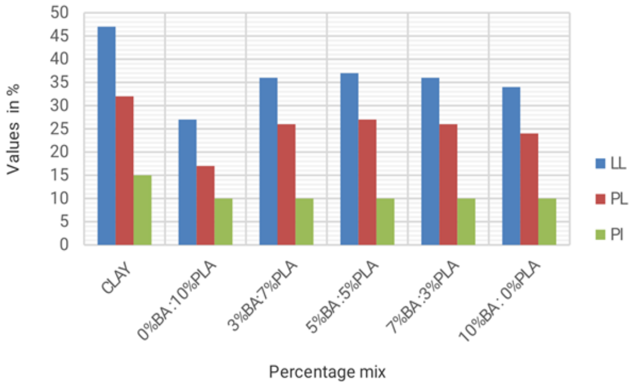

Figure 3: Atterberg limit values

Furthermore, at 10%BA : 0%PLA, the LL, PL and PI values observed were 34%, 24% and 10% indicating a decrease from the control as shown in figure 3. [13] also reported similar findings. The lowest Atterberg limit values were noticed at 0%BA : 10%PLA having 21% for LL, 17% for PL and 10% for PI. This behaviour may be attributed to the fact that plantain leaves ash from the characterization analysis as seen in Table 1 has higher cementitious content i.e., high percentage of CaO which could initiate a colloidal structure phase due to increased ionic concentration and pH of the mixture. Hence the significant decrease in liquid and plastic limit values. Similar findings have been documented [19, 21, 22].

3.4 COMPACTION CHARACTERISTICS

The compaction results portrayed a rise in the Maximum Dry Density (MDD) values when compared to the control sample value. The clay soil had recorded an OMC value of 12.0% and MDD of 18.15%. The highest MDD value of 19.42% was recorded at 0% BA and 10%PLA as seen in figure 4. These increments in MDD values after treatment may be ascribed to cementitious and pozzolanic content of the ashes occupying empty void spaces inside the blended soil matrix giving rise to the agglomeration and flocculation of the clay particles. Similar findings by Annafi et al. [25], Yohanna et al. [21] and Kumar and Puri [26] have been reported. The least was recorded at 3%BA and 7%PLA with a value of 18.44%. The OMC remained increased from control value of 12.0% to 14.0% for all trial mixes.

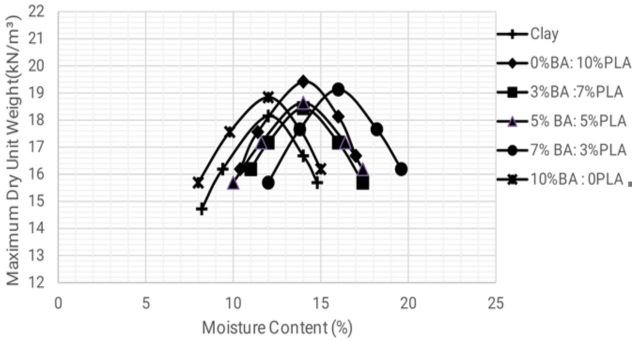

Figure 4: Compaction Characteristics

3.5 STRENGTH CHARACTERISTICS

The California Bearing Ratio (CBR) test was conducted in accordance with BS 1377-part 4. The results of this test are presented in Table 4.

Table 4: Deductions from CBR test

S/N	Description of Sample	CBR (%)	
		Unsoaked	Soaked
Control	CLAY	19.0	10.6
1	0%BA + 10%PLA	62.1	57.8
2	3%BA + 7%PLA	64.0	50.6
3	5%BA + 5%PLA	39.6	34.6
4	7%BA + 3%PLA	59.7	51.3
5	10%BA + 0%PLA	71.6	62.1

From Table 4, it can be seen that there is a significant rise in CBR values both for soaked and unsoaked. At 10% BA : 0%PLA, CBR value of 71.6% and 62.1% were documented for unsoaked and soaked respectively. This result may be attributed to the presence of higher percentage of SiO_2 in baggase ash when compared to plantain leave ash and also the formation of cementitious compounds [17]. Similar results have been obtained in [9, 10]. When acting together 3%BA : 7%PLA gave the best result of 64% and 50.6% for unsoaked and soaked values.

This makes it suitable for subgrade and subbase in pavement construction being above the minimum specified standard by Federal Ministry of works and Housing [23] of 30% and 60% respectively.

4.0 CONCLUSION

1. There was also significant improvement in the strength characteristics of the sample when stabilized with bagasse ash and plantain leaves ash, compared with the natural strength characteristics of the natural clay.
2. The maximum dry unit weight (MDUW) of the soil increased with the addition of bagasse ash and plantain leaves ash compared with the control value. The peak value of 19.42kn/m^3 recorded at 0%BA: 10%PLA. Also, appreciable changes were also observed for the optimum moisture content (OMC).
3. The addition of plantain leaves ash alone for the stabilization caused a significant decrease in the Liquid limit and Plastic limit values of 27.0% and 17.0% respectively when compared to the control values.
4. In terms of strength, when both stabilizing materials act together, 3%BA : 7%PLA gave the best result of 64.0% and 50.6% for unsoaked and soaked CBR values.
5. The use of bagasse ash and plantain leaves ash produces an eco-friendly stabilizer that can be used as subbase material to stabilize clay soil.

5.0 RECOMMENDATIONS

1. The engineering performance of the clay soil sample can be improved for use in low traffic roads by modifying and stabilizing the sample with bagasse ash and plantain leaves ash respectively.
2. The percentage mix ratios for Bagasse ash and Plantain leaves ash can be increased for future research to observe its effect on natural clay soil.
3. Characterisation of the stabilizing agents should be done in order to fully understand its chemical compositions and reactions.
4. More geotechnical laboratory tests can be done in investigating the effect of bagasse ash and plantain leaves ash on clay like; triaxial test, permeability test, etc.

REFERENCES

[1] Patel, J. A and Raijiwala, D. B. “Use of sugar cane bagasse ash as partial replacement of cement in concrete”, Glob. J. Res. Eng. Volume15, 2015, pp 13–18.

[2] Lathamaheswari, R., Kalaiyarasan,V., and Mohankumar, G. “Study on bagasse ash as partial replacement of cement in concrete”, Int. J. Eng. Res. Dev. Vol.13, 2017, pp 01–06.

[3] Quedom, P. G., Wirquin, E., and Bokhoree, C. “Sustainable Concrete: Potency of sugarcane bagasse ash as a cementitious material in the construction industry”, Case studies in construction materials, Vol. 14, 2021, pp 1-18.

[4] Norsuraya, S., Fazlena, H., and Norhasyimi, R. “Sugarcane bagasse as a renewable source of silica to synthesise santa barbara amorphous-15 (SBA-15)”, Pro. Eng.148 (2016) 839–846.

[5] American Society for Testing and Materials, Philadelphia, ASTM C618. “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”, (2012).

[6] Misari, S. M., Busari, I. O., and Gbiore, S. “Current status of sugar cane research and development in Nigeria”, Proceedings of the Inaugural Meeting and Planning Workshop for Collaborations of National Co-ordinated Research Program on Sugar Cane (NCRPSC), 1998, pp 2-12.

[7] Bello, A. A., Ige, J. A. and Ayodele, H. “Stabilization of lateritic soil with cassava peel ash”, British Journal of Applied Science and Technology, 7(6), 2015, pp 642-650.

[8] Hassan, H., Dang, L., Khabbaz, H., Fatahi, B., and Terzaghi, S. “Remediation of expansive soils using agricultural waste Bagasse ash”, Procedia Engineering, Vol. 143, 2016, pp 1368-1375.

[9] Chittaranjan, M., Vijay, M and Keerthi, D. “Agricultural wastes as soil stabilizers”, International Journal of Earth Sciences and Engineering, 2011, Vol-04(06), pp. 50-51.

[10] Kiran R. G. and Kiran L. “Analysis of Strength Characteristics of Black Cotton Soil Using Bagasse Ash and Additives as Stabilizer”, International Journal of Engineering Research & Technology, 2013, Issue 7.

[11] Ugwu, J. N., and Ugwuanyi, D. C. “Sustainability Performance of Plantain Leaf Ash and the Compressive Strength of Concrete”, IOP Conference Series: Earth and Environmental Science, Vol. 410,2020, pp 1-9.

[12] Kawade, U. R., Rathi, V. R., and Vaishali, D. G. “Effect of use of bagasse ash on strength of concrete”, International Journal of Innovation Resources, Science and Engineering Technology. Vol. 2, 2013, pp 2997–3000.

[13] Ganhi, K. S. “Expansive soil stabilization using Bagasse ash”. International Journal of Engineering Research and Technology, Vol. 1,2012, pp 1-3.

[14] Cemen, O., Saltan, M., and Kesin, S. “Stabilization of clayey subgrade with pumice for road infrastructure”, Science and Engineering of composite Materials, Vol. 22 (5), pp 2015, 583-590. Doi.org/10.15151secm-2013-0315

[15] Wubshet, M. “Bagasse Ash as a subgrade soil stabilizing Material”, Published masters Thesis, Addis Ababa Institute of Technology, Ethiopia, 2013.

[16] Hanna Saroash, Z. A., Ameer Suhail, K, Mariyan, R, Tishana, K. N and Rashida, P. K. “Soil Stabilization using Lime and sugar cane Bagasse Ash”, International Journal of Engineering Research and Technology. Vol. 10(6), 2021, 1014-1019.

[17] Okafor, O. F. and Okonkwo, U. N. “Effects of Rice Husk Ash on some Geotechnical Properties of Lateritic Soil”, Leonardo Electronic Journal of Practices and Technologies. Vol. 8(15) 2009, 67-74.

[18] Nnochiri, E. S and Aderinlewo, O. O. “Geotechnical Properties of Lateritic Soil Stabilized with Banana Leaves Ash”, FUOYE Journal of Engineering and Technology, Vol 1, Issue 1, 2016, 116-119.

[19] Etim, R. K., Attah, I. C., Ekpo, D. U., Usanga, I. N. “Evaluation on Stabilization Role of Lime and Cement in Expansive Black Clay - Oyster Shell Ash Composite”, Transportation Infrastr-ucture Geotechnology, 2021, 1-36

[20] ASTM C618–12: “Standard specification for coal fy ash and raw or calcined natural pozzolan for use in concrete”, ASTM International, West Conshohocken, PA, USA (2012)

[21] Yohanna, P., Kanyi, M. I., Etim, R. K., Eberemu, O. A., and Osinubi, K. J. “Experimental and statistical study on black cotton soil modifed with cement-iron ore tailings”, FUOYE J. Eng. Technol. (FUOYEJET),2021, Vol 6(1), 2579–0617. https://doi.org/10.46792/fuoyejet.vAiB.C

[22] Ekpo, D. U., Fajobi, A. B., Ayodele, A. L., Etim, R. K. “Potentials of cement kiln dust-periwinkle shell ash blends on plasticity properties of two selected tropical soils for use as sustainable construction materials”, IOP Conf. Ser. Mater. Sci. Eng, 2021, 1036, 012033 https://doi.org/10.1088/1757-899X/1036/1/012033

[23] Federal Ministry of Works and Housing. “General Specification for Roads and Bridges”, Abuja, 1997.

[24] Sani, J. E, Moses, G., Etim, R. K., Wilson, U. N., and Babatunde, A. O. “Stabilization of Lateritic soil with cement and treated sisal fibre”, ACTA TECHNICA CORVINIENSIS-

Bulletin of Engineering, 2022, Tome XV , 41-47.

[25] Annafi, Q. B., Eberemu, A. O., Yohanna, P. and Osinubi, K. J. "Effect of Elapsed Time After Mixing on the Strength Properties of Lime – Iron Ore Tailings Treated Black Cotton Soil as a Road Construction Material", Journal of Infrastructure, 2020, Vol. 5, 89; doi:10.3390/infrastructures5110089

[26] Kumar, B. and Puri, N. "Stabilization of Weak Pavement Subgrades using Cement Kiln Dust", International Journal of Civil Engineering and Technology, 2013, Vol. 4(1): 26-37.