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Experimental Investigation of the Strength Characteristics of Lateritic Soil Stabilized with Sawdust Ash and Plantain Peel Ash

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ABSTRACT: Lateritic soils are widely used as construction materials for highways, embankments, foundations, airfields, and earth-retaining structures in Nigeria. However, these soils often exhibit inadequate engineering performance, leading to challenges such as pavement deterioration, excessive settlement, erosion, slope failure, and seepage. Soil stabilization has therefore become essential for enhancing their geotechnical characteristics and ensuring structural durability. This study investigated the effectiveness of sawdust ash (SDA) and plantain peel ash (PPA) as environmentally sustainable stabilizing agents for improving the engineering properties of lateritic soil classified as AASHTO A-2-6. The soil

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was treated with varying proportions of SDA (3%, 6%, 9%, and 12%) combined with a constant 6% PPA. Laboratory tests were conducted to evaluate the effects of stabilization on the soil's properties. These tests included moisture content determination, particle size distribution, Atterberg limits, compaction characteristics, and California Bearing Ratio (CBR). The results showed that the addition of SDA and PPA improved the index and strength properties of the soil. Maximum Dry Density (MDD) increased with increasing stabilizer content, while Optimum Moisture Content (OMC) also exhibited an upward trend. Furthermore, CBR values improved significantly, indicating enhanced load-bearing capacity suitable for use as fill material, subgrade, and subbase layers in pavement construction. Among the stabilization levels investigated, the combination of 9% SDA and 6% PPA produced the most favorable performance. The findings suggest that incorporating SDA and PPA can effectively improve weak lateritic soils while promoting the beneficial use of agricultural waste materials in geotechnical engineering applications.

Keywords: *California bearing ratio, lateritic soil, optimum moisture content, plantain peel ash, saw dust ash*

1. Introduction

Rapid technological advancement has encouraged the development of innovative and sustainable construction materials capable of improving infrastructure quality while reducing construction costs and environmental impacts. Among such materials are waste-derived pozzolanic products and agricultural by-products including rice husk ash, sawdust ash, palm kernel shell ash, and plantain peel ash (Ennio et al, 1975). These materials have attracted considerable attention in civil engineering due to their potential application in soil stabilization and other construction activities.

Soil serves as the foundation of virtually all civil engineering structures and therefore plays a critical role in determining their performance and durability. The successful design and construction of engineering facilities depend largely on a proper understanding of soil behavior and geotechnical characteristics. When soils with inadequate engineering properties are encountered during construction, engineers may choose to relocate the project, modify the design, replace the unsuitable soil, or improve the existing soil through stabilization. Among these alternatives, soil stabilization is often preferred because it can be both economical and practical.

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Soil stabilization involves modifying the physical and mechanical properties of soil to improve its strength, density, durability, compressibility, and hydraulic performance (Makusa, 2012). Traditionally, stabilizing agents such as cement, lime, and bitumen have been widely used. However, the increasing cost of conventional materials, coupled with environmental concerns associated with waste disposal, has encouraged research into the use of agricultural and industrial by-products as alternative stabilizers.

The growing generation of biomass waste presents both environmental challenges and opportunities. Rather than disposing of these materials in landfills or open dumps, they can be processed and utilized in engineering applications. The reuse of agricultural waste materials contributes to sustainable construction practices while reducing environmental pollution. Consequently, researchers have increasingly investigated the effectiveness of waste-derived materials in enhancing soil performance.

Lateritic soil is one of the most widely available natural construction materials in tropical regions, particularly in Nigeria (Mtallib et al., 2011). Owing to its abundance and relatively low cost, it is commonly used in the construction and rehabilitation of roads, embankments, foundations, airfields, and earth dams. Some lateritic soils possess naturally favorable gradation and sufficient clay content, making them suitable for use as subgrade, subbase, and base materials in pavement systems (Ackroyd, 1959).

Despite its widespread use, the engineering behavior of lateritic soil varies considerably depending on factors such as parent material, climatic conditions, weathering processes, and topography (Graham, 2011). These variations often result in challenges including excessive deformation, erosion, settlement, instability, and reduced load-bearing capacity. Such problems can adversely affect the performance and service life of transportation infrastructure and other civil engineering structures.

The design and construction of pavements require careful assessment of foundation soils because the long-term performance of pavement systems depends significantly on the strength and stability of the underlying layers. Engineers must evaluate soil properties through laboratory testing to ensure that pavement structures can withstand anticipated traffic loads, environmental conditions, and maintenance requirements throughout their design life (Brown, 1996). Improved foundation materials can enhance pavement performance and may allow for more economical pavement designs.

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Given the increasing demand for sustainable and cost-effective construction materials, there is a need to explore alternative stabilizers capable of improving weak lateritic soils. Agricultural waste products such as sawdust ash and plantain peel ash offer promising prospects due to their availability, low cost, and potential pozzolanic characteristics. Their utilization not only enhances soil properties but also promotes environmental sustainability through beneficial waste management. Therefore, investigating the influence of these materials on the engineering behavior of lateritic soils is essential for developing sustainable solutions for pavement and foundation construction (Frost et al; 2001).

2. Materials and Methods

2.1 Materials

The materials utilized in this study consisted primarily of lateritic soil, sawdust ash (SDA), and plantain peel ash (PPA). In addition, standard laboratory apparatus and testing equipment were employed for sample preparation and geotechnical testing.

2.1.1 Sawdust Ash (SDA)

The sawdust used in this investigation was sourced from a local sawmill located in Gusau, Zamfara State. The material was generated from the processing of timber species such as deodar and kale wood. Upon collection, the sawdust was spread and allowed to dry naturally under ambient laboratory conditions to reduce its moisture content. The dried material was subsequently passed through a 600 µm sieve to remove coarse particles, bark fragments, gravel, and other unwanted impurities. The processed sawdust was then subjected to controlled burning at temperatures ranging from approximately 320°C to 350°C to produce sawdust ash suitable for soil stabilization purposes.

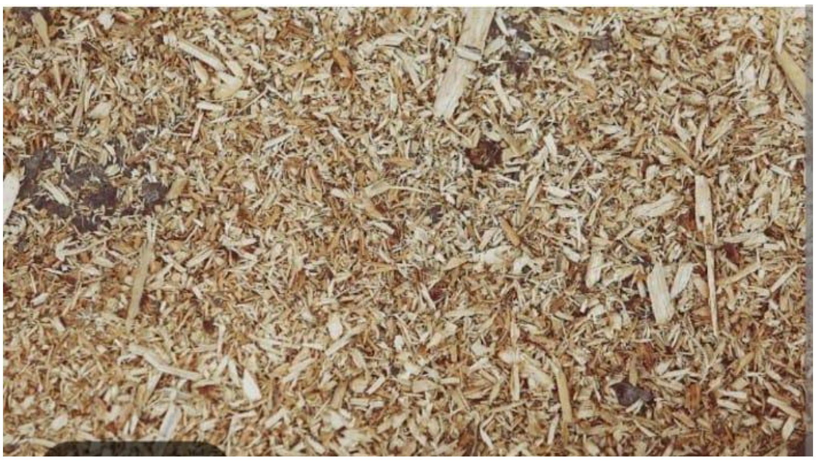

Figure 2.1: Sawdust Ash (SDA)

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2.1.2 Plantain Peel Ash (PPA)

Plantain peels were obtained from a waste disposal site in Kaduna, Kaduna State. The collected peels were air-dried to remove excess moisture before being incinerated to obtain ash. After combustion, the resulting ash was sieved through a No. 200 sieve (0.075 mm aperture) to ensure uniform particle size and eliminate larger residues. The processed ash was then stored for subsequent use in the stabilization program.

Figure 2.2: Plantain Peel Ash (PPA)

2.1.3 Lateritic Soil

The lateritic soil sample used for this study was collected from Mayanchi in Maru Local Government Area along the Gusau–Sokoto Road, Zamfara State. Sampling was carried out at depths ranging from 0.5 m to 2.5 m below the ground surface after the removal of the organic topsoil layer. The excavated soil was transported to the Triacta Construction Company Laboratory Yard located along Sokoto Road in Talata Mafara, Zamfara State, where it was stored in sealed sacks under dry conditions until testing commenced.

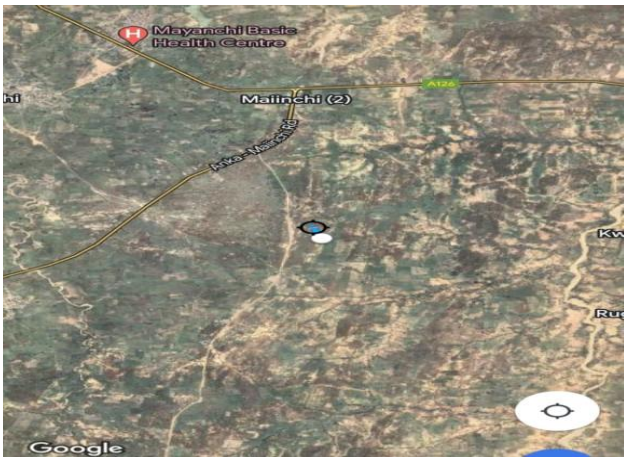

Figure 2.3: Location of Soil Sampling Site (Google map)

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2.2 Sample Preparation and Testing Procedure

The stabilization program involved blending the lateritic soil with varying percentages of sawdust ash while maintaining a constant plantain peel ash content of 6%. The mixtures prepared were:

- 3% SDA + 6% PPA
- 6% SDA + 6% PPA
- 9% SDA + 6% PPA
- 12% SDA + 6% PPA

The percentages were determined based on the dry weight of the soil. Following thorough mixing, laboratory tests were conducted to assess the influence of the additives on the engineering behavior of the soil. The tests included Atterberg limits, compaction characteristics, and California Bearing Ratio (CBR) determinations.

The effectiveness of stabilization was evaluated by comparing the geotechnical properties of the treated soils with those of the untreated soil. Particular attention was given to variations in maximum dry density (MDD) and CBR values, which were used as indicators of strength improvement and load-bearing capacity. The optimum stabilizer content was identified based on the mix that produced the most favorable engineering performance.

3. Results and Discussion

3.1 Index Properties

3.1.1 Properties of the Natural Soil

Preliminary laboratory tests were conducted on the lateritic soil obtained from the borrow pit located in Gusau, Zamfara State. The tests were performed in accordance with the procedures specified in BS 1377 (1990). The results obtained from the characterization of the untreated soil are presented in Table 3.1.

The natural soil exhibited a greyish-brown coloration and was classified as A-2-6 under the AASHTO soil classification system and CL under the Unified Soil Classification System (USCS). The classification indicates a predominantly granular soil containing a moderate

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proportion of fines. The particle-size distribution curve is presented in Figure 3.1, while detailed sieve analysis results are provided at the end of this research.

Table 3.1: Properties of the Borrow pit Soil (Control Sample)

Properties	**Values**
Percentage Passing B.S No 200 (%)	29.0
Liquid Limit, %	36.0
Plastic Limit, %	24.0
Plasticity Index, %	12.0
AASHTO Classification	A-2-6
Maximum Dry Density, Mg/m³ (B.S Light)	1.780
Optimum Moisture Content % (B.S Light)	13.30
48 Hours-Soaked California Bearing Ratio % (B.S Light)	10.80
Colour	Greyish-Brown

3.1.2 Properties of the Stabilized Soil

The effects of sawdust ash (SDA) and plantain peel ash (PPA) on the index properties of the lateritic soil were investigated by incorporating varying percentages of SDA while maintaining a constant 6% PPA content. The results are summarized in Table 3.2.

Table 3.2: Index Properties of SDA–PPA Stabilized Lateritic Soil

Property	**3% SDA + 6% PPA**	**6% SDA + 6% PPA**	**9% SDA + 6% PPA**	**12% SDA + 6% PPA**
Percentage Passing BS No. 200 Sieve (%)	22.8	26.7	30.7	45.2
Liquid Limit (%)	29.0	34.0	35.0	40.5
Plastic Limit (%)	20.0	26.0	19.7	22.8
Plasticity Index (%)	9.0	8.0	15.3	17.7
AASHTO Classification	A-2-4	A-2-4	A-2-6	A-2-7
Maximum Dry Density (Mg/m³)	1.835	1.770	1.875	1.798

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Optimum Moisture Content (%)	11.8	12.4	12.8	12.5
48-Hour Soaked CBR (%)	10.2	15.3	17.6	13.0

The results indicate that the addition of SDA and PPA modified the engineering characteristics of the soil. Improvement was observed in the classification and strength properties of the stabilized specimens compared with the untreated soil. The blend containing 9% SDA and 6% PPA produced the highest improvement, recording a CBR value of 17.6%, which represents a significant increase over the natural soil value of 10.8%.

The mixture containing 3% SDA and 6% PPA showed only marginal improvement in strength, while the 6% SDA and 6% PPA blend produced a noticeable increase in CBR. Although stabilization with 12% SDA and 6% PPA resulted in a higher CBR than the untreated soil, its performance was lower than that of the 9% SDA mixture. This suggests that excessive ash content may not necessarily result in further strength enhancement.

3.2 Compaction Characteristics

3.2.1 Maximum Dry Density (MDD)

The influence of SDA and PPA on the compaction behavior of the soil was evaluated through Maximum Dry Density (MDD) measurements. The results show that stabilization generally improved the compacted density of the soil.

The untreated soil recorded an MDD of 1.780 Mg/m^3 under British Standard Light (BSL) compaction. Following stabilization, MDD values of 1.835 Mg/m^3, 1.770 Mg/m^3, 1.875 Mg/m^3, and 1.798 Mg/m^3 were obtained for 3% SDA + 6% PPA, 6% SDA + 6% PPA, 9% SDA + 6% PPA, and 12% SDA + 6% PPA respectively.

The highest dry density was achieved at 9% SDA and 6% PPA, indicating improved particle packing and enhanced soil structure. The slight reduction observed at 12% SDA content may be attributed to the increased proportion of lighter ash particles replacing soil particles within the mixture.

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3.2.2 Optimum Moisture Content (OMC)

Following stabilization, OMC values of 11.8%, 12.4%, 12.8%, and 12.5% were recorded for 3%, 6%, 9%, and 12% SDA additions respectively, each combined with 6% PPA.

The results indicate that the moisture requirement of the soil changed after stabilization. This behavior may be associated with the water absorption characteristics of the ash materials and the reactions occurring between the soil particles and the stabilizing agents. The observed values suggest that adequate moisture is required to facilitate proper compaction and interaction between the soil and additives.

3.3 California Bearing Ratio (CBR)

The California Bearing Ratio test was conducted to assess the load-bearing capacity of the stabilized soil. CBR is widely used in pavement design because it provides a measure of the resistance of soil to penetration under controlled conditions.

According to the Nigerian General Specifications (1997), minimum laboratory CBR values of 80%, 30%, and 15% are generally required for base, sub-base, and subgrade materials respectively when stabilized materials are used.

3.3.1 Unsoaked CBR

The CBR values obtained for the untreated and stabilized soil samples are presented in Figure 3.2. The natural lateritic soil recorded a CBR value of 10.8%. After stabilization, values of 10.2%, 15.3%, 17.6%, and 13.0% were obtained for the mixtures containing 3%, 6%, 9%, and 12% SDA respectively, each with 6% PPA.

The results reveal that the inclusion of SDA and PPA enhanced the bearing capacity of the soil up to an optimum level. The highest CBR value of 17.6% was achieved at 9% SDA and 6% PPA, representing the best performance among all the mixtures tested.

The increase in strength may be attributed to the formation of cementitious compounds resulting from interactions between the soil and the ash materials, leading to improved particle bonding. However, beyond the optimum content, a reduction in CBR was observed, suggesting that excessive ash addition may weaken inter-particle cohesion and adversely affect strength development.

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Based on the CBR results, the optimum stabilization level was identified as 9% SDA combined with 6% PPA. At this proportion, the stabilized soil satisfies the requirements for use as fill material, subgrade, and in certain sub-base applications. The findings therefore demonstrate that the combined use of sawdust ash and plantain peel ash can effectively improve the engineering performance of weak lateritic soils.

4. Conclusion

Based on the laboratory investigations carried out on lateritic soil stabilized with sawdust ash (SDA) and plantain peel ash (PPA), the following conclusions were drawn:

The incorporation of SDA and PPA resulted in noticeable changes in the index properties of the lateritic soil. The observed improvements indicate that both materials possess the potential to enhance the engineering characteristics of weak lateritic soils.

The stabilization process influenced the compaction characteristics of the soil. Generally, the addition of SDA and PPA improved the Maximum Dry Density (MDD) values of the treated samples. Variations in the Optimum Moisture Content (OMC) were also observed, indicating that the presence of the stabilizing agents affected the moisture requirement necessary for effective compaction.

The California Bearing Ratio (CBR) values of the stabilized soils were higher than that of the untreated soil, demonstrating an improvement in load-bearing capacity. Among the mixtures investigated, the combination containing 9% SDA and 6% PPA produced the highest CBR value and exhibited the best overall performance.

The optimum stabilization level was found to be 9% sawdust ash combined with 6% plantain peel ash. At this proportion, the treated soil satisfied the requirements for use as fill material, subgrade, and certain sub-base applications in road construction.

4.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

The use of a stabilizer blend consisting of 9% sawdust ash and 6% plantain peel ash is recommended for improving the engineering properties of weak lateritic soils intended for pavement and foundation applications.

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The utilization of SDA and PPA should be encouraged as a sustainable and cost-effective alternative to conventional stabilizing materials, particularly in areas where these agricultural wastes are readily available.

Further research should be conducted to investigate the chemical interactions and cation exchange mechanisms occurring between lateritic soil and the SDA–PPA stabilizing system, as this would provide a deeper understanding of the strength development process.

Additional studies may also examine the long-term durability, permeability characteristics, and field performance of SDA–PPA stabilized lateritic soils under varying environmental and loading conditions.

References

1. Amu, O. O., and Adetuberu, A. A. (2010). Characteristics of Bamboo Leaf Ash Stabilization on Lateritic Soil in Highway Construction. *International Journal of Engineering and Technology*, 2(4), pp. 212-219

2. Bello, A.A., Ige, J. A. and Ayodele, H. (2015). Stabilization of Lateritic Soil with Cassava Peels Ash British. *Journal of Applied Science and Technology*, 7(6), pp. 642-650.

3. British Standard (BS) 1377 (1990). *Method of Testing Soils for Civil Engineering Purpose*. British Standard Institute, BSI, London.

4. British Standard (BS) 1924 (1990). Method of Tests for Stabilized Soils. British Standard Institute (BSI) London.

5. Dowling, J. W. F. (1966). The Mode of Occurrence of Laterites in Northern Nigeria and their Appearance in Aerial Photography. *Engineering Geology,* 1(3), pp. 221–233.

6. Eberemu, A. O. (2011). Consolidation Properties of Compacted Lateritic Soil Treated with Rice Husk Ash. *Geomaterials*, 1, pp. 70-78.

 DOI: ***10.5281/zenodo.22198534***

7. Etim, R.K., Eberemu, A.O. and Osinubi, K.J. (2017). Stabilization of Black Cotton Soil with Lime Iron Ore Tailings Admixture. *Journal of Transportation Geotechnics*, 10, pp. 85 – 95.

8. George, M. and Oriola, F. (2010). Groundnut Shell Ash Stabilization of Black Cotton Soil Groundnut Shell Ash Stabilization of Black Cotton Soil. *Electronic Journal of Geotechnical Engineering,* 15, pp. 415-428

9. Gidigasu, M. D. (1976). *Laterite Soil Engineering Pedo-Genesis and Engineering Principles*. Elsevier Scientific, New York, 1976, p. 554.

10. Habeeb, A.Q., Olabambo, A. A. and Olafusi, O.S. (2012). Investigation of the Geotechnical Engineering Properties of Laterite as a Subgrade and Base Material for Road Constructions in Nigeria *Civil and Environmental Research,* 2(8), pp. 23-31.

11. Ishola, K. (2014). Modification of Laterite Soil with Iron Ore Tailing. Unpublished M.Sc. thesis, Civil Engineering Department, Ahmadu Bello University, Zaria.

12. Koteswara Rao., D., Anusha, M., Pranav, P.R.T. and Venkatesh, G. (2012). A Laboratory Study on Stabilization of Marine Clay using Sawdust Ash and Lime. *International Journal of Engineering science,* 2(4), pp. 851 – 862.

13. Krishma, R. R. (1997). Use of Glass Cullet as Backfill Material for Retaining Lambe, Structures. University of Illinois, Chicago, U. S. A. pp. 5-8.

14. Kumar, B. and Puri, N. (2013). Stabilization of weak pavement subgrades using cement kiln dust. *International Journal of Civil Engineering and Technology*, 1(4), pp. 26–37.

15. Moses, G. (2008). Stabilization of black cotton soil with ordinary Portland Cement Using Bagasse ash as admixture. *IRJI Journal of Research in Engineering* 5(3), pp. 107-115.

16. Moses, G. and Folagbade, O. (2010). Groundnut Shell Ash Stabilization of Black Cotton Soil. *Electronic Journal of Geotechnical engineering*, 15, pp. 415-42.

 DOI: ***10.5281/zenodo.22198534***

17. Nigerian General Specifications (1997). *Road and Bridges Federal Ministry of Works*. Abuja, Nigeria.

18. Osinubi, K.J. and Stephen, T.A. (2006). Effect of curing period on bagasse ash stabilized black cotton soil. Book of Proceedings, Bi-monthly Meetings/Workshop, Material Society of Nigeria., Zaria. pp. 1-8.

19. Osinubi, K. J., Yohanna, P and Eberemu, A. O. (2015). Cement Modification of Tropical Black Clay Using Iron Ore Tailing as Admixture. *Journal of Transportation Geotechnics*, 5, pp. 35-49.

20. Phanikumar, B.R. and Sharma, R. S. (2004). Effect of fly ash on engineering properties of expansive soil. *Journal of Geotechnical and Geoenvironmental Engineering,* 130 (7), pp. 764–7.

 DOI: ***10.5281/zenodo.22198534***