

Utilization Of Corn Stalk Ash For The Stabilization Of Lateritic Soil For Sustainable Road Construction

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ABSTRACT : Lateritic soils are widely used as subgrade materials in tropical regions; however, their engineering performance is often limited by high plasticity and low strength characteristics. This study evaluates the effectiveness of corn stalk ash (CSA) as a sustainable stabilizing agent for improving the geotechnical properties of lateritic soil obtained from Apir, Benue State, Nigeria. CSA was incorporated at 2%, 4%, 6%, 8%, 10%, and 12% by dry weight of soil, and laboratory tests were conducted in accordance with BS 1377 (1990). Results indicate that CSA addition significantly reduces the plasticity index and enhances compaction properties, while improving strength parameters such as California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). Maximum dry density increased progressively with CSA content, reaching peak values at 12%, while optimum moisture content decreased. The California Bearing Ratio (CBR) exhibited peak values at 4% CSA for both soaked and unsoaked conditions, indicating optimal performance for load-bearing applications at lower percentages. In contrast, unconfined compressive strength (UCS) increased consistently with CSA content, with maximum values observed at 10–12% after 28 days of curing. These findings demonstrate that the optimum CSA content depends on the targeted engineering property: approximately 4% for CBR-based design and 10–12% for strength development. Overall, CSA addition proves to be an effective, sustainable, and eco-friendly stabilizer for lateritic soils in road construction.

KEYWORDS: Lateritic soil; Corn stalk ash; Soil stabilization; CBR; UCS; Sustainable construction

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I. INTRODUCTION

Lateritic soils are widely used in tropical regions as subgrade materials due to their availability and affordability. However, they often exhibit poor engineering properties, including excessive plasticity, swelling, shrinkage, and low load-bearing capacity (Otto & Eberhardt, 2021; Assefa & Sado, 2022). Conventional stabilizers such as cement and lime improve soil performance but are costly and environmentally unsustainable.

Agricultural waste ashes, including corn stalk ash (CSA), rice husk ash, and bagasse ash, have emerged as eco-friendly alternatives (James et al., 2022;

Adeyanju & Okeke, 2023). CSA, rich in silica and potassium, exhibits pozzolanic properties that enhance soil strength and durability (Hossain et al., 2019). Its utilization also addresses waste disposal challenges, reducing greenhouse gas emissions from open-field burning (Mukherjee et al., 2022).

This study investigates CSA's effectiveness in stabilizing lateritic soil for sustainable road construction.

II. MATERIALS AND METHODS

I. 2.1 SOIL AND ASH COLLECTION

Lateritic soil was collected from Apir, Benue State, Nigeria at a depth of 1 m. Corn stalks were sourced locally, sun-dried, combusted under controlled conditions, ground, and sieved through a 75 μm mesh.

Table 1: Geotechnical Properties of Lateritic Soil

Parameters	Quantity
Natural Moisture content (%)	14.40
Liquid limit (%)	47.20
Plastic limit (%)	31.00
Plasticity index (%)	16.20
Linear shrinkage (%)	12.10
Specific gravity	2.01
AASHTO Class	A-7-6
USCS	CL
Colour	Reddish-Brown
MDD	1.65
OMC (%)	18.10
UCS (kN/m^2)	53.0

The geotechnical properties of the natural lateritic soil sample were determined, and the results are summarized in Table 1. These baseline properties provide essential information for assessing the soil's suitability for stabilization and subsequent performance evaluation."

The chemical composition of the natural lateritic soil was analyzed to identify the dominant oxides

influencing its pozzolanic reactivity and stabilization potential. The results are presented in Table 2.

Table 2: Chemical composition of natural lateritic soil samples used for the study.

Constituents (Oxides)	Percentages (%)
Silicon Oxide (SiO_2)	62.3167
Aluminium Oxide (Al_2O_3)	16.423
Iron Oxide (Fe_2O_3)	4.5153
Sodium Oxide (Na_2O)	0.2236
Magnesium Oxide (MgO)	1.5620
Potassium Oxide (K_2O)	1.3226
Calcium Oxide (CaO)	0.1091
Zinc Oxide (ZnO)	0.0037
Sulphur (S)	0.2122
Manganese Oxide (MnO)	0.0910
Phosphorus Oxide (P_2O_5)	0.2343
Nickel Oxide (Ni_2O)	0.0013

2.2 Soil Stabilization Procedure

Soil samples were treated with CSA at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by dry weight. Mixing was conducted in laboratory conditions to ensure uniform integration.

2.3 Laboratory Testing

Laboratory tests were conducted in accordance with BS 1377 (1990) to determine the engineering properties of the soil. The procedures included

determination of natural moisture content, specific gravity, sieve analysis, and Atterberg limits. Compaction characteristics were assessed through maximum dry density (MDD) and optimum moisture content (OMC). Strength parameters were evaluated using the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). Figure 1 illustrates the particle size distribution curve of the lateritic soil from Apir.

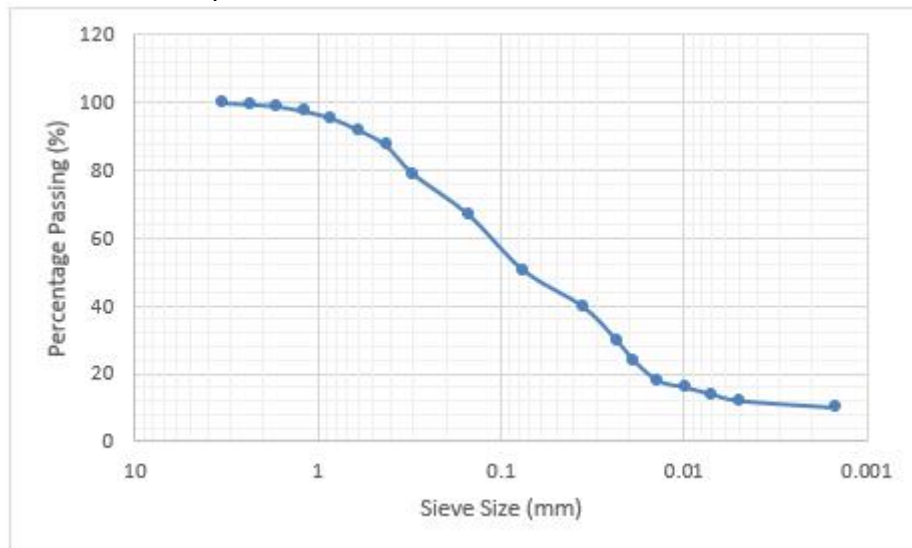


Fig 1: Particle Size Distribution Curve of Apir's Laterite soil

III. RESULTS AND DISCUSSION

3.1 Soil Plasticity

The addition of CSA resulted in a reduction in the plasticity index of the lateritic soil. This behavior can be attributed to cation exchange and flocculation

processes, where clay particles aggregate into larger structures, reducing their affinity for water and minimizing shrink-swell behavior (Bhosale & Patil, 2023). This improvement enhances the workability and stability of the soil. As shown in Figure 2, the plasticity index decreased steadily with increasing CSA content

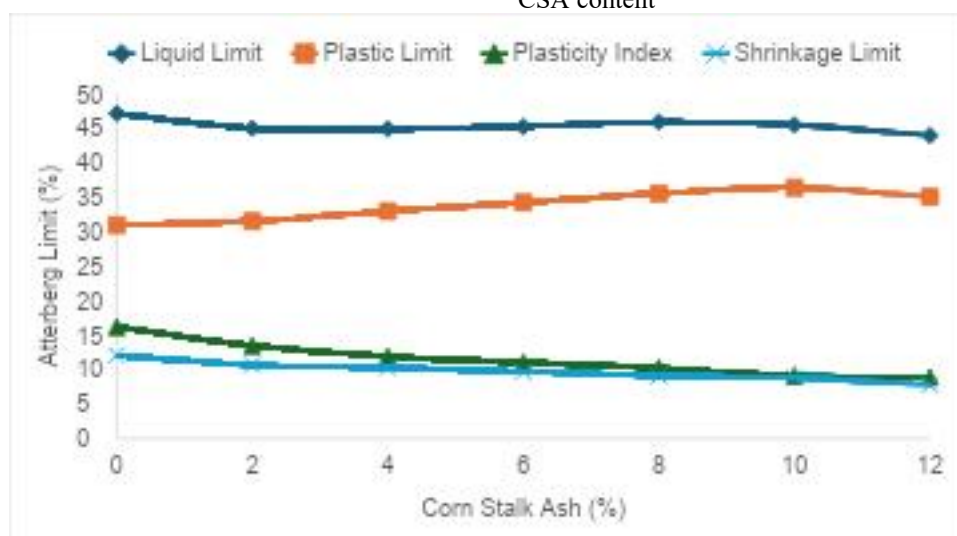


Fig. 2: Variation of Atterberg Limits with CSA Content

3.2 Compaction Characteristics

3.2.1 Maximum Dry Density (MDD)

The maximum dry density increased progressively with increasing CSA content, reaching peak values at 12% CSA. This trend is attributed to the fine nature of CSA, which fills voids within the soil matrix and enhances particle packing. Additionally, the

formation of cementitious compounds contributes to a denser soil structure.

However, it is important to note that MDD alone does not define the optimum stabilization level, as strength characteristics exhibit different trends.

Figure 3 illustrates the compaction curves, showing maximum dry density increasing with CSA content.

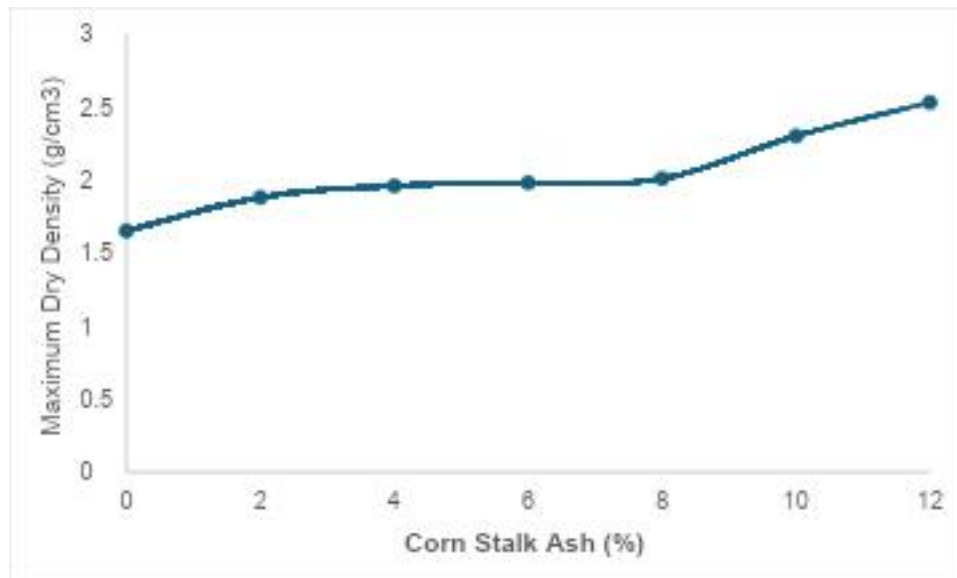


Fig. 3: Maximum Dry Density

3.2.2 Optimum Moisture Content

The optimum moisture content decreased with increasing CSA content. This reduction is due to the lower water absorption capacity of CSA compared to clay particles and the modification of soil texture,

which reduces the amount of water required for compaction (Ibrahim et al., 2022). The variation of optimum moisture content (OMC) of the lateritic soil with varying corn stalk ash (CSA) is shown in Figure 4.

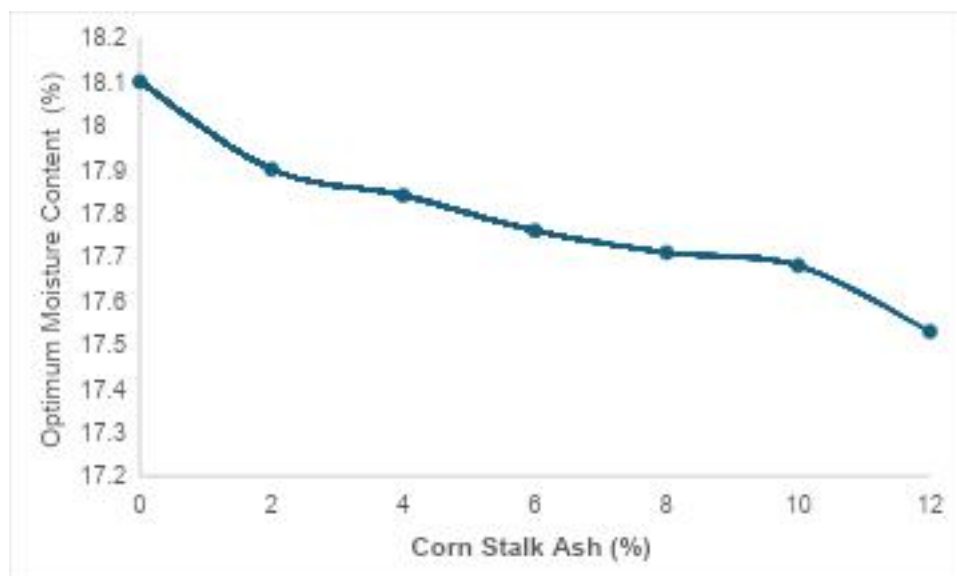


Fig. 4: Optimum Moisture Content

3.3 Strength (CBR and UCS)

3.3.1 California Bearing Ratio (CBR)

The CBR values increased with CSA addition up to an optimum of 4%, after which they declined. The peak unsoaked and soaked CBR values were 42.79% and 27.51%, respectively.

The initial increase is attributed to pozzolanic reactions that improve interparticle bonding and load-bearing capacity. The subsequent decline

beyond 4% is due to excess ash disrupting the soil matrix and reducing cohesion (Ojedokun & Aderinola, 2015) [11].

The obtained values satisfy the recommended CBR range for subgrade and subbase materials (Bowles, 1992).

Figure 5, illustrates the CBR values for Soaked and Unsoaked Samples

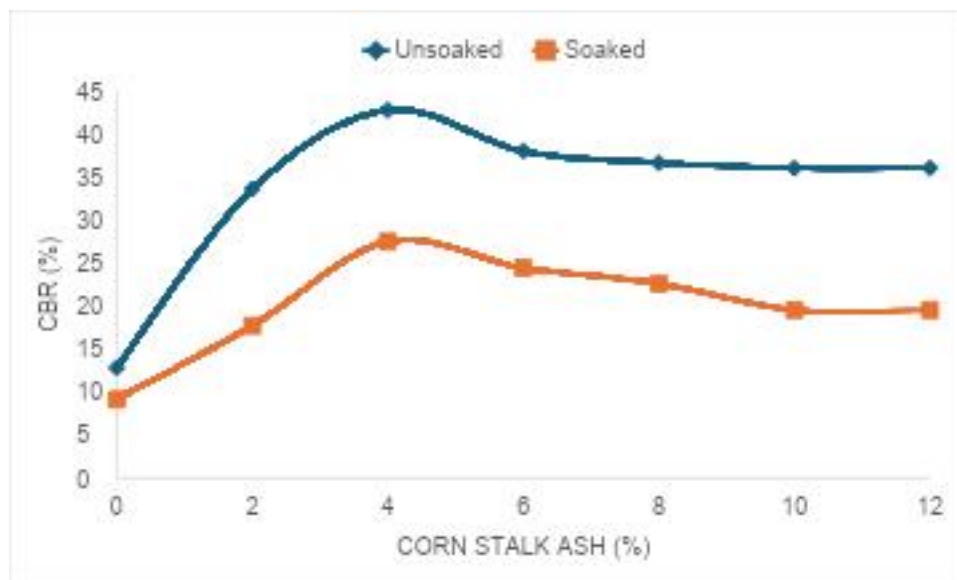


Fig. 5: CBR values for Soaked and Unsoaked Soil Samples

3.3.2 Unconfined Compressive Strength (UCS)

The UCS increased consistently with CSA content and curing time. At 28 days, peak values were recorded at 10–12% CSA.

This trend is attributed to continued pozzolanic reactions, leading to the formation of cementitious

compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which enhance bonding and strength (Khan et al., 2021)

Figure 6, illustrates the UCS values for 7, 14 and 28 days respectively

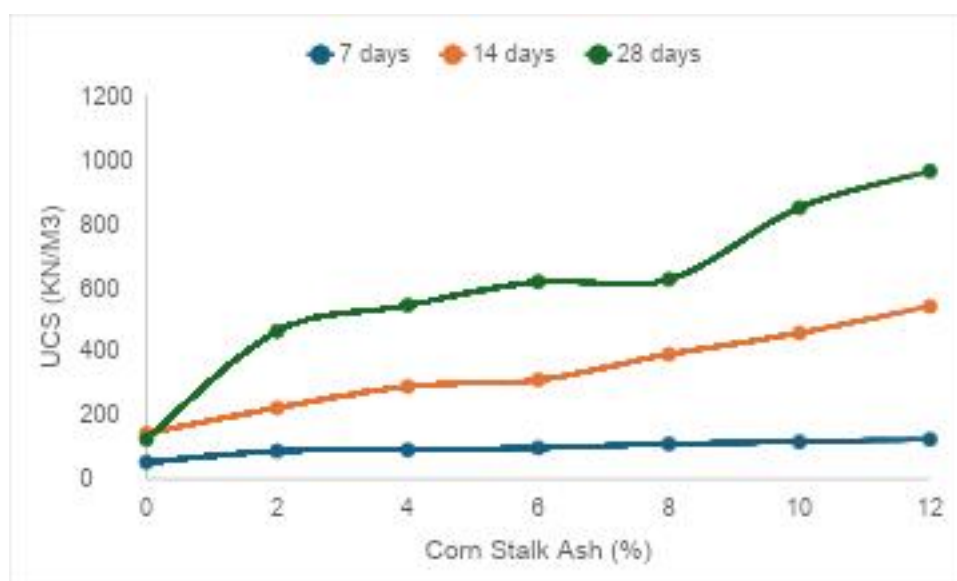


Fig. 6: Unconfined Compressive Strength Result

The observed improvements are consistent with findings from previous studies on agricultural waste stabilization, including rice husk ash and bagasse ash, confirming the effectiveness of CSA as a pozzolanic stabilizer (Phan et al., 2024; Yusuf et al., 2024)

The use of CSA as a stabilizer reduces dependence on conventional materials such as cement, thereby lowering carbon emissions. It also promotes the utilization of agricultural waste, contributing to sustainable construction practices and environmental conservation (Gupta & Kumar, 2023)

The optimum CSA content depends on the engineering property considered:

The optimum content of corn stalk ash (CSA) depends on the targeted engineering property. For pavement applications, approximately **4% CSA** is most effective, as it maximizes the California Bearing Ratio (CBR). In contrast, higher CSA contents in the range of **10–12%** are more suitable for strength development, since they yield the highest values of Unconfined Compressive Strength (UCS) after 28 days of curing. This distinction highlights the importance of tailoring CSA dosage to the specific performance requirement of the soil stabilization project.

IV. CONCLUSION AND RECOMMENDATION

Corn stalk ash (CSA) significantly improves the engineering properties of lateritic soil by reducing plasticity and enhancing strength. The study reveals that the California Bearing Ratio (CBR) attains its peak value at about 4% CSA, indicating suitability for subgrade and subbase applications. In addition, the Unconfined Compressive Strength (UCS) increases progressively with CSA content, reaching maximum values at 10–12%, which highlights its potential for long-term strength development. Compaction characteristics also improve with increasing CSA content, although they do not solely determine the optimum stabilization level. Therefore, the selection of CSA content should be guided by the specific engineering requirement, whether for pavement design or strength enhancement, underscoring CSA's role as a sustainable and eco-friendly stabilizer for lateritic soils in road construction.

5. RECOMMENDATION

Future research should focus on evaluating the long-term durability performance of corn stalk ash (CSA) stabilized lateritic soils under varying environmental and traffic conditions. In addition, field-scale validation is necessary to confirm laboratory findings and establish practical guidelines

for implementation in road construction projects. Comparative studies with other agricultural waste stabilizers, such as rice husk ash and bagasse ash, are also recommended to benchmark CSA's effectiveness and broaden the scope of sustainable soil stabilization practices.

REFERENCES

1. Adeyanju, A., & Okeke, P. (2023). Sustainable stabilization of lateritic soils using agricultural waste ash. *Journal of Geotechnical Engineering*, 15(2), 45–58.
2. Ali, M., & Imran, A. (2017). Stabilization of expansive clay soils using corn stalk ash. *International Journal of Civil Engineering*, 9(3), 112–120.
3. BS 1377. (1990). *Methods of Test for Soils for Civil Engineering Purposes*. British Standards Institution, London.
4. Bhosale, V., & Patil, R. (2023). The Influence Of Agricultural Waste on Soil Behavior: An Overview. *Advances in Civil Engineering Materials*, 10(2), 150–165.
5. Gupta, R., & Kumar, V. (2023). Innovative Materials for sustainable civil engineering practices. *Journal of Sustainable Materials and Technologies*, 29, 100–115.
6. Ibrahim, T., Musa, S., & Ahmed, K. (2022). Effect of biomass ash on the engineering properties of tropical soils. *Construction Materials Review*, 18(4), 201–214.
7. James, J., Pandian, P., & Kumar, R. (2022). Agricultural waste utilization in soil stabilization : A review. *Sustainable Infrastructure Journal*, 10(1), 55–70.
8. Khan, N., Khan, M., & Khosravi, A. (2021). Assessment of geomaterials for sustainable road construction: A review. *Materials Today: Proceedings*, 71, 2345–2351.
9. Mukherjee, S., & Dutta, S. (2022). Management of agricultural residue to reduce greenhouse emissions: A case for sustainable practices. *Environmental Science and Pollution Research*, 29(14), 20850–20860.
10. Ojedokun, A. T., & Aderinola, O. S. (2015). Utilization of corn stalk ash for lateritic soil stabilization. *Nigerian Journal of Engineering Research*, 7(1), 33–41.
11. Onwuka, C., Edeh, J., & Okafor, M. (2023). Eco-friendly soil stabilization using agricultural waste products. *International Journal of Pavement Engineering*, 14(5), 320–336.

12. Phan, H., et al. (2024). Soil stabilization with agricultural by-products: An overview. *Geoengineering Journal*, 64, 213-225.
13. Yusuf, A., Bello, M., & Hassan, U. (2024). Performance evaluation of stabilized lateritic soils using agricultural residues. *Journal of Sustainable Construction Materials*, 6(1), 77-92.