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Effect of Sesame Stalk Ash Replacement on Water Absorption and Abrasion Resistance of Cement-Stabilized Compressed Earth Bricks Produced from Yobe Lateritic Clay

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Abstract

Cement-stabilized compressed earth bricks offer a sustainable alternative to conventional masonry materials; however, their durability may be influenced by the incorporation of supplementary materials. This study investigated the water absorption and abrasion resistance of cement-stabilized compressed earth bricks produced from Yobe lateritic clay using sesame stalk ash (SSA) as a partial replacement material. Four SSA replacement levels of 0%, 10%, 20%, and 30% were investigated with 10% cement stabilization. Water absorption and abrasion loss were evaluated after 28 and 56 days of curing to assess the effects of SSA content and curing duration on durability performance. At 28 days, water absorption increased from 5.46% for the control mixture to 6.56%, 8.27%, and 9.66% for bricks containing 10%, 20%, and 30% SSA, respectively. After 56 days, the corresponding values decreased to 4.54%, 5.54%, 6.96%, and 8.44%. Similarly, abrasion loss at 28 days increased from 3.58% for the control to 4.38%, 5.12%, and 6.25% at 10%, 20%, and 30% SSA replacement, respectively. At 56 days, abrasion loss decreased to 2.51%, 3.57%, 4.30%, and 5.25%, respectively. These results demonstrate that increasing SSA replacement progressively increased water absorption and abrasion loss, whereas prolonged curing from 28 to 56 days improved durability by reducing both parameters. Among the SSA-stabilized mixtures, 10% SSA provided the most favourable balance of durability performance. Nevertheless, all investigated mixtures remained within the adopted durability criteria, indicating their suitability based on the evaluated water absorption and abrasion resistance characteristics.

Keywords

Sesame Stalk Ash,
Lateritic Clay,
Compressed Earth Bricks,
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1. Introduction

Compressed earth bricks provide an alternative construction material where suitable local soils are available. Their performance depends heavily on soil characteristics, stabilizer content, compaction, moisture, and curing conditions (Jamilu & Abubakar, 2023). Lateritic clays are common across Nigeria, but their inherent sensitivity to moisture often necessitates chemical stabilization to achieve acceptable engineering standards (Omoregie & Ekpete, 2021).

Durability is particularly important because earth-based masonry can be exposed to severe water infiltration and surface abrasion during its structural service life (Cruz et al., 2024). Water absorption provides a critical indication of the tendency of a brick to absorb moisture and undergo volume changes, while abrasion loss indicates the resistance of the brick surface to physical wear from wind, rain, and human contact (Sani & Attah, 2025). Traditionally, ordinary Portland cement is utilized as the primary binder; however, its high cost and carbon footprint have led researchers to explore alternative, sustainable pozzolans (Oti & Kinuthia, 2019).

Agricultural residues such as sesame residues can be converted into ash and incorporated into cement-stabilized construction materials to reduce overall binder expenses and promote environmentally friendly matrices (Sulaiman et al., 2024). However, increasing raw agricultural ash content can also significantly affect structural density, pore structure, chemical bonding, and surface resistance if not properly proportioned. Recent assessments of sesame waste ash additions highlight distinct trends regarding increased moisture permeability and modified

surface matrix consistency at higher replacement levels (Sulaiman et al., 2024).

In the present study, sesame stalk ash was incorporated at 0%, 10%, 20%, and 30% replacement levels in cement-stabilized compressed earth bricks produced from Yobe lateritic clay. The study specifically evaluates water absorption and abrasion resistance at 28 and 56 days. The ultimate objective of this paper was to determine the effect of SSA replacement on the water absorption and abrasion resistance of cement-stabilized compressed earth bricks produced from Yobe lateritic clay.

2. Materials and Methods

2.1 Materials

The materials used were Yobe lateritic clay soil, Portland cement, sesame stalk ash (SSA), and water. The SSA was derived by burning dry agricultural residues under controlled conditions and grinding them to meet pozzolanic fineness criteria before incorporation into the brick mixture, mirroring processing mechanisms noted in modern agro-waste cement composites (Sulaiman et al., 2024).

2.2 Mix proportions

The control mixture contained 10% cement and 0% SSA. The remaining stabilized mixtures maintained a base of 10% cement with partial SSA replacement levels of 10%, 20%, and 30% by weight of the binder matrix.

2.3 Production and curing

The materials were proportioned and dry-mixed before adding the optimum moisture content required for maximum compaction. The wet mixture was compacted using a standard manual brick-making machine. The moulded bricks were allowed to stand protected for 24 hours before moist curing

commenced (Jamilu & Abubakar, 2023). Water absorption and abrasion tests were conducted systematically at 28 and 56 days.

2.4 Water absorption

Water absorption testing was conducted according to BS 1377-3:2018 guidelines. The value was determined from the change in mass of the brick after total water immersion relative to its initial oven-dry mass. The average value of three test specimens was used for each mixture and curing age. The recorded water absorption results are presented in Table 1.

Table 1. Water absorption capacity.

SSA replacement	28 days (%)	56 days (%)
0% Control	5.46	4.54
10% SSA	6.56	5.54
20% SSA	8.27	6.96
30% SSA	9.66	8.44

2.5 Abrasion resistance

Abrasion resistance was evaluated via physical surface degradation testing in accordance with standard abrasive parameters adapted from BS 1377:2018 soil testing frameworks. The percentage mass loss was calculated after executing a standardized brushing sequence using a loaded wire brush tool across the brick surface (Sani & Attah, 2025). The resulting abrasion data are reported in Table 2.

Table 2. Abrasion loss.

SSA replacement	28 days (%)	56 days (%)
0% Control	3.58	2.51
10% SSA	4.38	3.57
20% SSA	5.12	4.30
30% SSA	6.25	5.25

3. Results and Discussion

3.1 Water absorption

Water absorption increased significantly with the increase in sesame stalk ash (SSA) replacement across both testing ages (Table 1). At 28 days of curing, the water absorption capacity rose from 5.46% for the control mixture (0% SSA) to 6.56%, 8.27%, and 9.66% for the 10%, 20%, and 30% SSA replacement levels, respectively.

This upward trend indicates that the introduction of SSA alters the microstructure of the compressed earth bricks, increasing the volume of capillary pores. Because agricultural biomass ashes generally possess a higher specific surface area and greater water demand than cement, their inclusion can introduce more voids if compaction energy remains constant, leading to higher water intake. This baseline rise in moisture permeability directly aligns with findings established by Sulaiman et al. (2024), who observed that adding escalating percentages of sesame waste ash systematically increases the baseline water absorption of blended cementitious composites.

Prolonged curing from 28 days to 56 days resulted in a noticeable reduction in water absorption for all mixtures. At 56 days, the water absorption capacity dropped to 4.54% for the control, 5.54% for 10% SSA, 6.96% for 20% SSA, and 8.44% for 30% SSA. This improvement over time is driven by the progress of cement hydration and subsequent secondary pozzolanic reactions between the silica in the SSA and the calcium hydroxide (Ca(OH)_2) liberated during cement hydration (Cruz et al., 2024). These reactions generate additional calcium silicate hydrate (C-S-H) gels, which gradually infill pore spaces, refine the capillary network, and densify the matrix

(Omoregie & Ekpote, 2021). This strength and permeability enhancement over extended curing durations maps closely to behavior seen in targeted sesame ash durability testing (Sulaiman et al., 2024).

NBRRI Standard Justification: The Nigerian Building and Road Research Institute (NBRRI) dictates a maximum water absorption limit of 12.5% for compressed stabilized earth bricks. Even at the highest substitution rate (30% SSA), the values (9.66% at 28 days and 8.44% at 56 days) sit below this national threshold.

ARSO Standard Justification: Under the continental African Organisation for Standardisation (ARSO) framework (ARS 965:2021), the standard ceiling for compressed earth blocks exposed to standard environmental weather conditions is capped between 12% and 15%. All SSA-blended blocks satisfy these requirements.

3.2 Abrasion resistance

The surface wear characteristics, evaluated via wire-brush abrasion loss, followed a trend similar to that of water absorption. At 28 days, mass loss increased from 3.58% in the control brick to 4.38%, 5.12%, and 6.25% for bricks containing 10%, 20%, and 30% SSA, respectively. The increase in abrasion loss with higher ash contents reveals a reduction in early surface interparticle bonding. Higher concentrations of unreacted ash at early stages weaken the cohesive matrix of the clay-cement skeleton, making the outer skin of the brick more susceptible to physical scouring (Sani & Attah, 2025).

By extending the curing period to 56 days, abrasion resistance improved across the board, as evidenced by a decline in percentage weight loss. The values fell to

2.51% (control), 3.57% (10% SSA), 4.30% (20% SSA), and 5.25% (30% SSA). The extended curing age allows the surface layers of the brick to develop higher cohesion through continuous microstructural densification (Jamilu & Abubakar, 2023).

NBRRI and ARSO Compliance: NBRRI standard parameters require a durability/abrasion mass loss threshold strictly under 6.9% for structural building use. Concurrently, continental ARSO benchmarks demand high surface durability to prevent wind-driven rain erosion (ARS 965:2021). All investigated SSA mixtures fall within these stated limits, confirming satisfactory durability performance. Among the ash-blended specimens, the 10% SSA mixture demonstrated the most favourable durability profile, mimicking the performance of the pure cement-stabilized control while incorporating agricultural waste. This 10% maximum substitution level is consistent with the range reported by Sulaiman et al. (2024).

4. Conclusion

Based on the laboratory evaluation of cement-stabilized compressed earth bricks produced from Yobe lateritic clay and modified with sesame stalk ash (SSA), the following conclusions are drawn:

Methodological Framework: The testing criteria were based on the standards adopted in the study for water absorption and surface abrasion.

Porosity and Wear Trends: Increasing the sesame stalk ash replacement level increased both water absorption and wire-brush abrasion loss in the compressed earth bricks.

Curing Enhancements: Prolonged moist curing from 28 to 56 days reduced water absorption and abrasion loss across all mixtures.

Standard Compliance: All investigated formulations remained within the durability criteria adopted in the study.

Engineering Recommendation: The 10% SSA replacement level represents the most favourable tested replacement level for balancing durability performance and agricultural waste utilization.

5. Recommendations

Field Implementation Limit: For practical masonry projects within the Yobe region, the sesame stalk ash content should be limited to 10% replacement based on the durability results obtained in this study.

Curing Requirements: Extended moist curing should be maintained where practical to allow continued hydration and pozzolanic reactions.

Protective Surface Coatings: For structures exposed to severe driving rain or high humidity, suitable protective surface treatment may be considered.

Processing Standardization: SSA production should follow controlled burning and processing conditions to improve consistency of the material.

Policy Integration: Further research should provide evidence for the development of locally appropriate guidelines for agro-waste stabilized earth masonry.

Future Research: Further microstructural studies such as SEM and XRD may be conducted to evaluate long-term chemical bonding and mineral transformations.

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