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Research Article

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Analysis of the Addition of Wood Sawdust ash on the physical and mechanical properties of stabilized earth bricks

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Abstract This study investigates the physical and mechanical properties of cement-stabilized raw earth bricks enhanced with wood sawdust ash. The physical characteristics of the materials—earth, wood sawdust ash, and cement—were rigorously analyzed to assess their compliance with relevant standards and their suitability for brick manufacturing. A cement stabilizer dosage of 10% was initially chosen based on the quality of the earth utilized. Subsequently, the cement content was systematically reduced by incorporating wood sawdust ash in increments of 10% to 40% relative to the cement mass. The primary objective was to determine the optimal blend capable of achieving robust compressive strength, acceptable drying shrinkage behavior, and satisfactory density. The findings reveal a significant enhancement in compressive strength with increasing cement content, escalating from 3.09 MPa for raw earth bricks to 10.82 MPa for stabilized earth bricks after a 28-day curing period. However, substituting cement partially with wood sawdust ash leads to a reduction in compressive strength, albeit specific ash compositions (30% and 40%) demonstrated improved strength properties. Dimensional stability of the bricks remained intact up to 20% ash content, beyond which noticeable shrinkage occurred, indicating potential necessity for supplementary treatments or additives for higher ash concentrations. Additionally, the analysis highlights a progressive reduction in brick density as ash content rises, attributed to the lower density of ash compared to cement.

Keywords Raw earth, Shrinkage, Wood sawdust ash, Stabilized earth bricks, Compressive strength.

Introduction

The use of sustainable and environmentally friendly building materials has become crucial in the current context of climate change and depletion of natural resources [1 - 2]. Raw earth bricks, one of the oldest building materials, are known for their low environmental impact and energy efficiency [3]. However, their limited mechanical properties restrict their use in modern applications [4 - 5]. To overcome these limitations, stabilizing earth bricks with cement is a commonly used method [6]. This stabilization significantly improves the compressive strength and durability of the bricks [7].

In addition to stabilization with cement, the addition of alternative materials [8 - 9] such as wood sawdust ash could potentially further enhance the properties of earth bricks. Wood sawdust is an abundant by-product of the wood industry [10 - 11], often considered as waste. When burned, it produces ashes containing siliceous and aluminous compounds capable of reacting with cement to form additional cementitious products [12]. This reaction could not only strengthen the bricks but also provide a solution for valorizing industrial waste, thus contributing to more ecological resource management [13].

This study focuses on analyzing the physical and mechanical behaviors of raw earth bricks stabilized with cement and supplemented with wood sawdust ashes. The primary goal is to determine the optimal blend of cement and wood sawdust ashes to produce bricks with high compressive strength, acceptable drying shrinkage, and satisfactory density.

Materials and Methods

The clayey soil sample used in this study was sourced from the Togo 2000 district, a suburb located northeast of Lomé, the capital of Togo. It is a plastic clay soil devoid of organic matter (Table 1), with a continuous particle size distribution ranging from 0.1 mm to 1.3 mm (Figure 1). Characterization tests were conducted following applicable standards [14 - 16].

Wood sawdust is a byproduct obtained from wood and carpentry industries during wood processing. Prior to combustion, it undergoes solar drying to eliminate moisture, thereby reducing smoke emissions, as wet sawdust tends to generate more smoke. Following drying, sawdust is incinerated on a metal surface. To optimize combustion efficiency, the surface is elevated with bricks placed around it to enhance airflow, thereby improving sawdust combustion and facilitating control over the combustion process. After approximately 24 hours of burning, ash residue forms. It is essential to allow this ash to cool before handling. Once cooled, the ash is collected and subjected to density testing for subsequent utilization.

Table 1: Clay soil characteristics

Characteristics		**Value**
Sand and clay content	Sand content	60.8
	Clay content	39.2
Density	Absolute density	2.30
	Apparent density	1.29
Atterberg limits	Liquidity limit	32.8
	Plasticity limit	13.38
	Plasticity index	19.42
	Consistancy index	1.16
Water content (%)		18.76

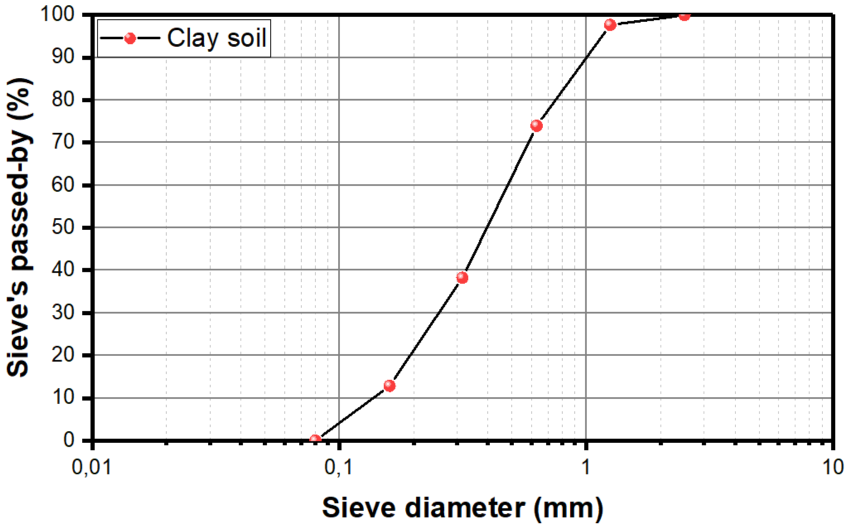

Figure 1: Clay soil grading curve

The density results for cement and ash are recorded in Table 2. It is evident that the density of cement is significantly higher than that of ash.

Table 2: Material density

Material	**Density**
Cement	2.74
Wood sawdust ash	1.92

The bricks are formulated with varying proportions of soil, cement, ash, and water. To ascertain the optimal water content for these bricks, the empirical "ball drop" or "drop test" method is employed. This method ensures that the blend of raw soil and wood sawdust attains requisite mechanical and physical properties essential for its utility as a sustainable construction material. The primary aim is to determine the precise water quantity needed to achieve the ideal consistency of the raw soil and sawdust blend, ensuring robust cohesion and adequate plasticity. Optimal water content guarantees efficient compaction of the mixture, preserving the structural integrity and shape of bricks or other fabricated components following the drying process. The procedural approach adopted is as follows:

[1]. Mixture Preparation: Blend raw soil, wood sawdust ash, and any stabilizing agent (like cement) in a dry state. Gradually incorporate water while mixing until achieving the desired consistency.

[2]. Ball Formation: Shape a small portion of the moistened mixture into a cohesive ball by hand. The ball should retain its shape without disintegration.

[3]. Drop Testing: Release the ball gently against a solid surface (e.g., ceiling, wall, or floor) and observe:
   - A. Complete disintegration indicates probable dryness; adjust by adding water and remixing.
   - B. Bursting with cohesive fragments suggests near-optimal water content, demonstrating good cohesion and plasticity.
   - C. Slight deformation while mostly intact suggests potential excess moisture; reduce water content slightly.

[4]. Final Adjustments: Continue refining water content until achieving sufficient cohesion for the ball to maintain integrity while slightly bursting upon drop testing. This consistency ensures optimal moisture for easy workability and effective compaction

For brick production, an initial stabilizer rate of 10% cement was selected based on the quality of the soil used [3]. Subsequently, cement was substituted with wood sawdust ash, varying the mass ratio of wood sawdust ash to cement from 10% to 40%, in increments of 10%. These mixtures were used to manufacture compressed earth bricks. Additionally, compressed earth bricks without cement or wood sawdust ash were also produced. Table 3 illustrates the different material proportions employed in the brick manufacturing process.

Table 3: Quantity of materials used

Designation	Wood sawdust ash rate (%)	Clay soil (kg)	Cement (kg)	Wood sawdust ash (kg)	Optimal water content (%)
WBT-0	0	50	0	0	13.43
WBC-0	0	50	5	0	11.93
WBC-10	10	50	4.5	0.5	12.81
WBC-20	20	50	4	1	15.53
WBC-30	30	50	3.5	1.5	15.29
WBC-40	40	50	3	2	14.4

WBT refers to raw earth bricks without cement or wood sawdust ash.

WBC-X denotes stabilized earth bricks containing X% of wood sawdust ash.

A TERSTARAM manual press (S.P.R.L Appro-Techno), capable of generating compaction loads up to 35 bars, was used to manufacture CEBs measuring 29×14×9.5 cm^3. A total of 72 bricks were produced, with 12 bricks per formulation.

Curing is a critical stage in CEB production, ensuring their strength and durability by controlling drying and material consolidation. Curing proceeds in two phases:

- A. Wet curing: During this phase, which lasts for 7 days, the bricks are covered with a tarpaulin or plastic sheeting to prevent rapid drying that could lead to cracking. The retained moisture promotes the cement curing reaction, thereby enhancing the strength of the bricks.
- B. Dry curing: This phase also lasts for 7 days. During this period, the bricks are stored under a shed to facilitate gradual drying through moisture evaporation. This process enhances the bricks' strength and durability by promoting uniform consolidation of materials.

The tests conducted on the bricks at the 21st and 28th days of age include density measurement, shrinkage assessment, and compression strength testing in accordance with EN 772 [17] standards.

Shrinkage is measured on each face of the bricks, and an average is computed using the formula:

$$r = \frac{L_0 - L}{L_0} \quad (1)$$

where:

L0 represents is the initial dimension of bricks

L denotes the final dimension of bricks

Results

Tables 4 and 5 depict the outcomes derived from the various conducted tests, including density, compressive strength, and shrinkage.

Table 4: Results of density tests and compressive strength tests

Designation	Wood sawdust ash rate (%)	Density		Compressive strength (MPa)	
		At 21th day	At 28th day	At 21th day	At 28th day
WBT-0	0	2.01	1.98	3.09	4.16
WBC-0	0	2.08	2.02	9.92	10.82
WBC-10	10	2.01	1.96	8.82	10.03
WBC-20	20	1.98	1.95	5.89	6.18
WBC-30	30	1.95	1.93	6.20	6.49
WBC-40	40	1.89	1.87	7.30	6.98

Table 5: Results of shrinkage tests

Designation	Wood sawdust ash rate (%)	Shrinkage (%) At 28th day			
		Length	Width	Thickness	Average
WBT-0	0	0.34	0	0.68	0.34
WBC-0	0	0	0	0.34	0.11
WBC-10	10	0	0	0.34	0.11
WBC-20	20	0	0	0.68	0.23
WBC-30	30	0,68	0	0.68	0.45
WBC-40	40	0,34	0.34	0.68	0.45

A. Analysis of Density Variations

From the results in Table 4, density variation curves are plotted against the wood sawdust ash content (Figure 2). The crushed blocks after 21 days exhibit higher density compared to those crushed after 28 days. This phenomenon can be attributed to water shrinkage over time in the samples. As water evaporates or is consumed by cement hydration reactions, the samples lose mass, resulting in a decrease in density.

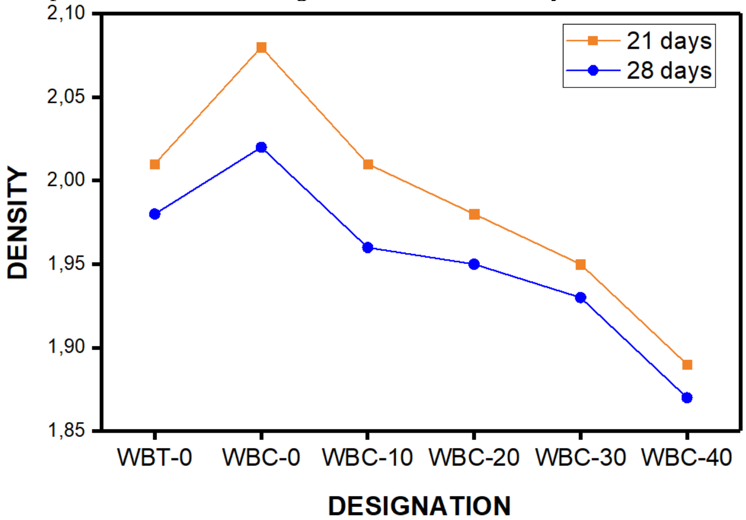

Figure 2: Bricks densities variation

Increasing the dosage of wood sawdust ash in the bricks results in a decrease in bulk density. This trend is attributed to the lower density of wood sawdust ash compared to cement. As the proportion of ash increases, a larger portion of the brick volume is occupied by a less dense material, thereby reducing the overall bulk density.

B. Analysis of Compression Strength Variations

The curves illustrating the evolution of compressive strength as a function of wood sawdust ash content are shown in Figure 3.

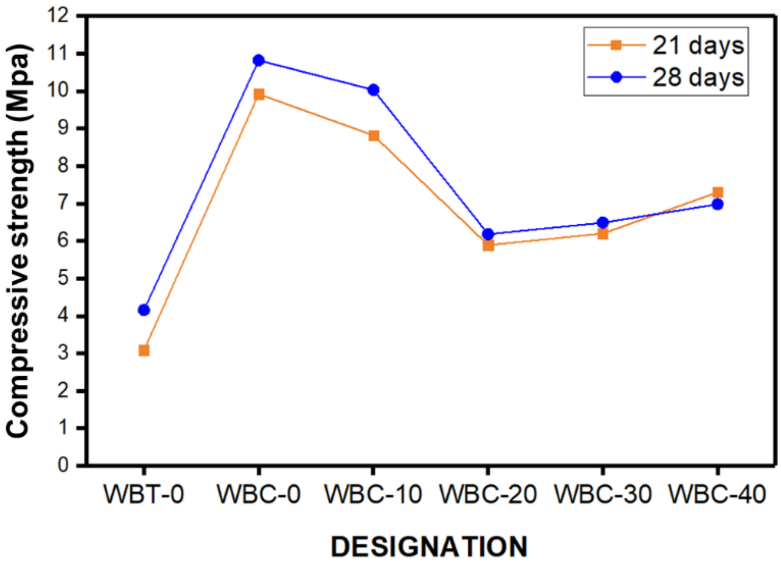

Figure 3: Bricks compressive strength variation

The compressive strengths measured at 28 days consistently exceed those measured at 21 days, indicating ongoing hardening and strength gain over time, likely due to continued hydration and reduction of residual moisture.

Cement-stabilized bricks demonstrate a significant increase in compressive strength compared to unstabilized bricks. After 21 days, strength increases from 3.09 MPa (raw earth bricks) to 9.92 MPa (stabilized earth bricks), and after 28 days, it increases from 4.16 MPa to 10.82 MPa. This enhancement can be attributed to cement hydration reactions, forming cementitious compounds that enhance cohesion and solidity of the bricks.

Partial substitution of cement with wood sawdust ash results in reduced compressive strength. At 21 days, strength decreases to 5.89 MPa for 20% ash content, and to 6.18 MPa at 28 days. However, a slight increase in strength is observed at 30% and 40% ash content, reaching 7.30 MPa and 6.98 MPa respectively at 21 days and 28 days. The strengths of bricks containing wood sawdust ash are significantly higher than those of raw earth bricks.

C. Analysis of Shrinkage Variations

The results from Table 4 indicate that shrinkage on each face of the bricks varies from 0 to 0.0068. Bricks containing 0 to 20% wood sawdust ash maintain stable dimensions, with no significant variation in width and length.

Conversely, bricks with higher ash content exhibit more pronounced shrinkage, suggesting increased dimensional instability.

Conclusion

This study examined the effects of adding cement and wood sawdust ash on the physical and mechanical properties of unfired clay bricks, using locally available materials in Lomé, Togo. The results clearly demonstrate that adding cement significantly enhances the compressive strength of the bricks, achieving sufficient values for structural applications after 28 days of curing. However, partially substituting cement with wood sawdust ash progressively reduces this strength, although it remains superior to that of unfired clay bricks.

Density analysis revealed that incorporating ash reduces the bricks' density, which may be advantageous for applications requiring lighter materials. However, careful attention is needed regarding dimensional stability, as bricks containing higher proportions of ash exhibit significant shrinkage, which could compromise their durability and structural performance.

The environmental and economic implications of using wood sawdust ash are promising. By recycling industrial waste and reducing reliance on cement, this approach contributes to construction sustainability. Nonetheless, further research is essential to refine optimal proportions of cement and ash to maximize environmental benefits while maintaining adequate mechanical performance.

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