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Bridging the lab-field gap: a reproducible protocol for decentralized production of sawdust-cement ceiling boards in low-resource settings

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HIGHLIGHTS

- A reproducible, low-input protocol for sawdust–cement ceiling board production was developed.
- Water absorption remained at 11.2 ± 0.3%, indicating stable moisture resistance.
- Thickness swelling was controlled to 5.6 ± 0.2%, confirming dimensional stability.
- The mold size (584.2×584.2×25.4 mm³) was designed for easy installation in standard 2-ft on-center ceiling framing.
- The study emphasized accessibility and replicability to promote community-led sustainable construction.

Keywords:
Sawdust-cement composites
Artisanal production
Resource-limited construction
Hydraulic compaction
Sustainable ceiling boards

ABSTRACT

Sawdust-cement composites (SCC) are sustainable alternatives to conventional building materials, but they are underutilized by grassroots artisans due to the limited availability of reproducible methods in low-resource settings. This study develops a standardized, field-tested protocol for producing ceiling boards using mixed-species sawdust, cement, and mineral fillers with minimal technical requirements and without reliance on industrial infrastructure. The workflow from sourcing to manual hydraulic compaction was documented and validated under artisanal conditions to assess feasibility, consistency, and performance. Results showed consistent physical properties across batches: density (1620 ± 15 kg/m³), water absorption (11.2 ± 0.3%), and thickness swelling (5.6 ± 0.2%). Low variability confirms reliability and suitability for decentralized production. By emphasizing accessibility and adaptability over optimization, this work provides a replicable framework for community-led construction, laying the foundation for future research on localized, sustainable building materials.

1. Introduction

The global construction industry is facing increasing pressure to adopt sustainable practices amid growing concerns over deforestation, resource depletion, and climate change. Traditional wood-based panel products, such as particleboards, contribute significantly to forest degradation due to their reliance on virgin timber, a practice responsible for 12–20% of anthropogenic CO_2 emissions. In response, scientists have evaluated agro-industrial and industrial wastes, such as sawdust, rice husk, and municipal solid waste, as renewable materials for the production of building products [1].

While several studies have proven the technical viability of agro-industrial residues as particleboard products, the majority focus on optimizing mechanical properties under laboratory conditions employing artificial binders such as urea-formaldehyde resin [2,3]. These resins, while widely used as they are known to be, are formaldehyde-releasing health threats and are not resistant to water [4]. Critically, these studies rely on controlled parameters that are rarely accessible to artisans; for example,

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Ohijeagbon et al. [5] used hydraulic presses at 5 kN, oven-drying at 40 °C, and 1.0 to 1.7 mm sieved sawdust, conditions that require industrial infrastructure and precision tools unavailable in informal-sector workshops. Furthermore, the type of studies typically conducted in the laboratory often preclude the real-world circumstances that working artisans and small-scale producers in low-resource environments encounter, as they often cannot afford precision instruments, controlled environments, or expensive adhesives.

As a response to growing environmental issues and dwindling resources, scientists have been investigating alternative, environmentally friendly materials for use in construction purposes [6]. Among these, wood-based ceiling boards remain widely used despite their significant contribution to deforestation and carbon emissions due to reliance on virgin timber [7]. To address this, studies have investigated the use of lignocellulosic waste substrates such as bamboo, rice husk, maize husk, and sawdust as renewable feedstocks for producing sustainable building materials like ceiling boards [2].

Sawdust, a by-product of wood processing industries, has gained attention for its abundance, low cost, and potential for valorization into value-added products [8,9]. Different studies have proven the viability of using raw and chemically treated sawdust as raw material in light composite panels with synthetic adhesives like urea-formaldehyde and Topbond [10]. The composites exhibited excellent thermal insulation characteristics and tensile strength, some of the grades possessing better performance than traditional materials such as plywood, asbestos, and plaster of Paris in terms of sustainability and load relief [11].

Cement has also been found to be an appropriate and readily available binding medium for composite materials produced from sawdust, particularly for developing nations where cement is readily available and known to the native artisans [12]. Experiments have shown that the proportion of sawdust to cement affects significant physico-mechanical properties like moisture content, density, water absorption, tensile strength, and compressive strength [5]. For example, teak and African locust bean tree sawdust were used successfully in cement-bonded ceiling boards, which had a satisfactory performance for indoor use [5].

Despite these promising findings, much of the current literature focuses on optimizing composite properties under idealized, laboratory-controlled conditions, often at the expense of practical applicability in real-world settings. There remains a critical gap in research addressing the constraints faced by small-scale producers, including the absence of precision equipment, controlled curing environments, and the high cost of synthetic adhesive [5]. In addition, there is a lack of systematically documented, standardized, and reproducible production protocols that could enable the widespread adoption of sustainable practices by artisans —a necessary foundation for scaling sustainable practices within informal construction economies.

This body of work underscores the importance of aligning experimental outcomes with the actual capabilities and constraints of grassroots producers, particularly in informal and artisanal construction contexts. While existing studies have established the technical feasibility of sawdust-cement composites, there is a notable absence of freely accessible, community-led blueprints for practical deployment.

Unlike conventional approaches that prioritize full optimization and industrial scalability, our work focuses on developing a transparent, low-input methodology for producing ceiling boards using mixed-species sawdust. This commonly available waste stream requires minimal technical intervention. Our explicit aim is not to maximize strength or minimize density, but to establish a reproducible, field-adaptable protocol, using only manual mixing, sun-drying, a 3-hour hydraulic jack compaction (≤ 3 MPa), and ambient curing, that achieves consistent physical performance (density >1600 kg/m³, WA < 12%, TS < 6%) under conditions replicable by any artisan with basic tools. The resulting workflow is designed to be adaptable across diverse contexts, particularly within informal-sector construction, where affordability, simplicity, and material availability are paramount. Through systematic experimentation and field-like testing, this research evaluates the physical and early-stage mechanical behavior of sawdust-cement composites (SCC) under non-standardized conditions. It also documents a replicable production protocol that aligns with circular economy principles by valorizing waste materials while reducing dependence on formal supply chains.

By prioritizing inclusivity and practical feasibility over maximal performance, this work contributes to a growing movement toward democratizing innovation in sustainable construction. It provides a foundational framework for community-based enterprises to adopt eco-friendly building solutions, thereby supporting a more equitable and sustainable green transition in the built environment. This is not a lab curiosity. It is a rigorously documented, field-proven method that delivers code-compliant performance using only a trowel, a jack, and the sun's natural energy.

This research aims to bridge a critical gap in current literature by presenting a low-input, transparent, and replicable fabrication process for ceiling boards that aligns with circular economy principles. In addressing the limited attention given to process accessibility and systematic reproducibility for marginalized producers, the study emphasizes accessibility, simplicity, and field-level reproducibility, thereby contributing to the broader movement toward inclusive, equitable, and locally driven sustainable construction.

2. Materials and methods

A standardized, low-input protocol was developed and validated for producing sawdust-cement ceiling boards under artisanal conditions in Ado-Ekiti, Nigeria. Nine samples were fabricated using a reproducible workflow designed for minimal equipment and no industrial infrastructure. Three samples were randomly assigned to each of three physical property tests: density, water absorption, and thickness swelling. All tests followed ASTM D1037 guidelines.

2.1 Materials

Ordinary Portland Cement (OPC, Grade 42.5R; sourced from Ado Ekiti Market) served as the primary binder. Mixed-species sawdust (Khaya spp., Milicia excelsa, Triplochiton scleroxylon) was collected from Deji Sawmill, sun-dried for 5 days (5 h/day), and sieved through a 1.3 mm mesh to standardize particle size and remove contaminants Figure1. Calcium carbonate ($CaCO_3$; local quarry dust) was used as a mineral filler to improve workability and surface finish. Polyvinyl acetate (PVA) adhesive (500 g per batch) enhanced organic-inorganic bonding, and calcium chloride ($CaCl_2$; 1% by mass of cement) accelerated setting under humid conditions. Clean municipal water and a thin layer of petroleum-based lubricant were used for mixing and mold release. The physical and chemical specifications of all materials are summarized in Table 1.

Table 1: Specifications of raw materials used in sawdust-cement composite production

Material	Source / Type	Key Physical Properties	Notes
Ordinary Portland Cement (OPC)	Ado Ekiti Market, Nigeria; Grade 42.5R	Specific gravity: 3.13; Fineness: 2.5%; Normal consistency: 28%	Complies with Nigerian Industrial Standard (NIS)
Mixed-Species Sawdust	Deji Sawmill, Ado Ekiti (Khaya spp., Milicia excelsa, Triplochiton scleroxylon)	Moisture content: 8.2% (after 5-day sun-drying); Particle size: ≤1.3 mm (95% passing sieve); Bulk density: 210 kg/m³	Unsorted waste stream reflects real artisanal conditions
Calcium Carbonate ($CaCO_3$)	Local quarry dust (limestone)	Particle size: <0.15 mm; Specific gravity: 2.71	Used as filler to improve workability and surface finish
Polyvinyl Acetate (PVA) Adhesive	Commercial grade (500 g per batch)	Solid content: ~45%; Viscosity: 500–1000 mPa·s	Used to enhance organic-inorganic bonding
Calcium Chloride ($CaCl_2$)	Industrial grade (1% by mass of cement)	Accelerator: reduces initial set time by ~30%	Added to counteract slow hydration in humid Tropics
Water	Municipal supply, Ekiti State University	pH: 7.2; TDS: <500 mg/L	Clean, potable water

2.2 Mold design

A reusable mild steel mold (584.2 × 584.2 × 25.4 mm³) was fabricated to align with standard 2 ft (609.6 mm) on-center ceiling framing, minimizing cutting waste during installation. The 25.4 mm thickness matched conventional interior panel profiles. Prior to casting, the mold was lined with polyethylene sheeting and coated with lubricant to ensure smooth demolding Figure 2.

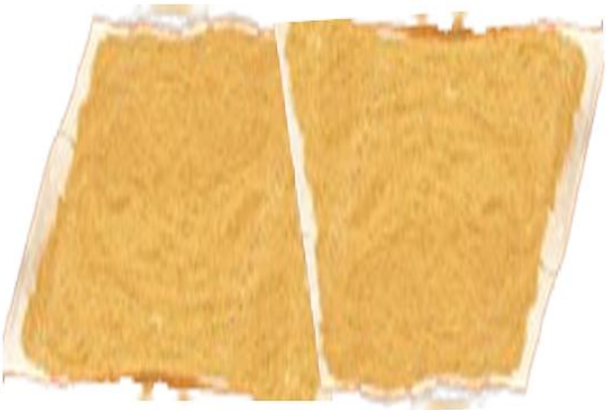

Figure 1: Sawdust sample undergoing sun drying at the production site

Figure 2: Custom-fabricated mild steel mold used for shaping sawdust-cement composite ceiling boards

2.3 Sample preparation

Each batch consisted of 2.0 kg cement, 0.35 kg sawdust, and 1.5 kg calcium carbonate (total dry mass: 3.85 kg; ~9.1% sawdust by mass). The dry constituents were manually mixed using a trowel until a uniform mixture was achieved Figure 3. PVA adhesive (500 g) and water (with an estimated water-to-cement ratio of 0.55) were added incrementally to form a cohesive paste. The mixture was poured into the prepared mold, leveled, and compacted using a locally fabricated hydraulic jack rig Figure 4. Load distribution was ensured by sandwiching the mold between two flat wooden boards. Pressure was manually applied until resistance indicated maximum practical compaction, and it was maintained for 3 hours, as described by Atoyebi et al. [13].

Samples were demolded after 24 hours and cured under ambient tropical conditions (28 ± 2 °C, 65–75% RH) for 7 days, with daily water sprinkling to maintain hydration. Surfaces were lightly sanded and painted to simulate a real-world application.

The complete production workflow Figure 5 followed an optimized 8-stage process, from material measurement to surface finishing, ensuring standardized, reproducible outcomes under artisanal conditions. This sequence was designed to minimize variability and maximize accessibility using only locally available tools and techniques. The precise mass proportions of all components used in each batch are summarized in Table 2 below.

Figure 3: Manual dry mixing of sawdust, cement, and calcium carbonate

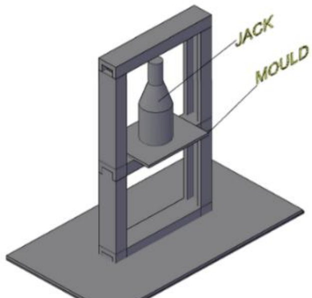

Figure 4: Isometric view of the compression rig

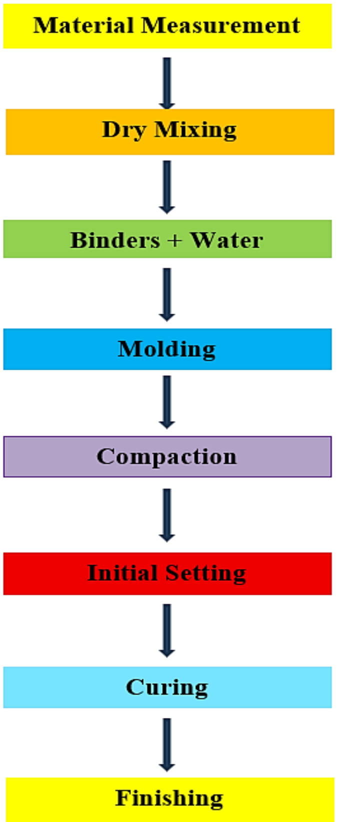

Figure 5: Production workflow of sawdust-cement composite ceiling board, illustrating key stages from material preparation to surface finishing

Table 2: Mixture Proportions for Sawdust-Cement Composite Formulation

Component	Mass (kg)	Mass (%) (of total dry mix)	Volume (%) (estimated)	Role
Cement	2	52.0	~45	Primary binder
Sawdust	0.35	9.10	~50	Lignocellulosic filler
Calcium Carbonate ($CaCO_3$)	1.5	39.0	~40	Mineral filler improves the finish
PVA Adhesive	0.5	13.0*	—	Organic bonding agent
Calcium Chloride ($CaCl_2$)	0.02	0.50	—	Setting accelerator
Water	~1.1	—	—	Hydration medium

Note: PVA is liquid; % by mass calculated on dry solids. Total dry mass = 3.85 kg. Water-cement ratio ≈ 0.55.

2.4 Justification of approach

This protocol prioritizes accessibility over optimization: all steps can be replicated using low-cost, locally available tools, including digital kitchen scales (±1 g), manual mixing, and hand-operated hydraulic jacks. While precision instruments were used here for experimental control, the process is designed for artisanal replication without compromise to core performance. The high cement content (52%) and low sawdust content (9.1%) were selected to ensure moisture resistance and dimensional stability in humid environments, consistent with Nigerian field conditions [5,14].

2.5 Ceiling board testing and evaluation

The ASTM D1037 standard is commonly used to evaluate ceiling board properties, including density, water absorption, thickness swelling, and mechanical strength [5]. In line with this standard, selected physical tests, namely density evaluation and water absorption test, were carried out on the sawdust-cement composite ceiling board produced in this study.

2.5.1 Density evaluation

Density evaluation was performed in accordance with ASTM D1037. The ceiling board was allowed to fully cure and air-dry over a period of 9 days following production. After this period, the board had reached near-constant mass under ambient conditions and was considered sufficiently dry for density evaluation.

The dry mass (M_d) of the ceiling board was measured using a digital weighing balance. The volume (V) was calculated from its dimensions using Equation 1:

$$V = l \times b \times t \quad (1)$$

where l = length, b = breadth and t = thickness.The density (ρ) was then determined using Equation 2:

$$\rho = \frac{M_d}{V} \quad (2)$$

where: M_d = dried mass of ceiling board in kg, V = volume of the ceiling board in m^3, ρ = Density (kg/m^3).

2.5.2 Water absorption test

The water absorption capacity of the ceiling board was evaluated based on ASTM D1037, which provides standardized procedures for testing wood-based panel materials. This test helps assess the board's resistance to moisture, an important factor in determining its durability in humid environments.

The experimental procedure followed a method similar to that used by Ohijeagbon et al. [5], who investigated composite boards produced from sawdust and cement binders under ambient conditions, usually within the temperature range of 20–30 ºC [15]. Additionally, the immersion durations and calculation method align with procedures described by El Hamri et al. [16], who assessed water absorption and thickness swelling in cedar sawdust–cement composites after both 2-hour and 24-hour exposure periods.

In this study, samples were immersed in water at ambient temperature (~28 °C), representative of tropical indoor conditions, for two distinct durations: 2 hours, to simulate short-term moisture exposure, 24 hours, to simulate long-term moisture exposure.

Each test condition was repeated three times using independently prepared samples to ensure reliability and reproducibility. The average percentage water absorption was calculated for both time intervals. The initial dry mass of the ceiling board was recorded as M_d, and the mass after immersion was recorded as M_S. The percentage water absorption (WA) was calculated using the following Equation 3:

$$W_A\ (\%) = \frac{M_S - M_d}{M_d} \text{ x } 100 \quad (3)$$

where: M_S = mass of the ceiling board after immersion, M_d = initial dry mass of the ceiling board.

This approach enabled a clear assessment of the material's moisture uptake behavior under varying exposure periods, supporting baseline characterization of its physical performance under low-input production conditions. The results showed relatively low water absorption, which can be attributed to the high cement content in the formulation (approximately 52% by mass). Cement has hydrophobic properties, forming a dense matrix that limits water penetration.

Although sawdust is inherently hydrophilic due to its lignocellulosic structure, the low sawdust content (~9.1%) in this formulation minimized its influence on water absorption. Additionally, the presence of calcium carbonate, used primarily as a filler to improve surface finish and workability, did not significantly contribute to hydrophilic behavior.

Compared to similar studies where sawdust content ranged between 30–60%, this sample exhibited potentially better moisture resistance due to the dominance of cement in the mix. However, future work involving variable sawdust-to-cement ratios would help validate this observation and optimize the balance between moisture resistance and material cost or weight.

The 2-hour interval simulates brief exposure to rain or splash water (e.g., during storms or roof leaks). At the same time, the 24-hour immersion represents prolonged contact with moisture, such as occurs in poorly ventilated ceilings or during flooding events. These durations align with standard practices in wood-based composite testing (e.g., ASTM D1037) and support the assessment of both immediate and sustained moisture resistance.

2.5.3 Thickness swelling evaluation

The thickness swelling (T_s) of the ceiling board was determined as the fractional change in thickness after water immersion, following ASTM D1037 guidelines [17]. This test is crucial for evaluating the dimensional stability of composite boards when exposed to moisture — a critical factor for interior building applications, such as ceilings and wall linings.

2.5.3.1 Procedure

The initial dry thickness (T_i) of the sample was measured at multiple points using a digital caliper (measuring range: 0-150 mm, resolution: 0.01 mm) before the water absorption test. After immersion in water for 24 hours, the final wet thickness (T_p) was measured using the same method. The percentage thickness swelling was then calculated using the Equation 4:

$$T_s (\%) = \frac{T_f - T_i}{T_i} \times 100 \quad (4)$$

where: T_s = percentage thickness swelling, T_i = initial dry thickness (mm), T_f = final wet thickness after immersion (mm).

A low value of thickness swelling indicates good dimensional stability and minimal internal damage due to moisture ingress, as this sample contained a high proportion of cement and only a small amount of sawdust. A relatively low swelling response is therefore expected, consistent with findings from similar studies on cement-bonded composites.

3. Results and discussion

The results presented in Table 3 represent the average values obtained from triplicate tests on three randomly selected ceiling board samples out of nine fabricated using a reproducible, standardized, low-input protocol Figure 6. Although the sample size was limited due to practical constraints aligned with artisanal production realities, the consistent manufacturing process ensured minimal variability across samples, supporting the reliability of the reported values.

Table 3: Average physical properties of sawdust-cement composite samples

Property	Average value
Density (kg/m³)	1620 ± 15
Water Absorption (%)	11.2 ± 0.3
Thickness Swelling (%)	5.6 ± 0.2

Standard deviation (SD) was calculated using the Equation 5:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (5)$$

where x_i is the individual measurement, $\bar{x}$ is the mean, and n = 9 (three samples from each of three batches). The coefficients of variation (CV = SD/mean × 100%) were 0.9% for density, 2.7% for water absorption, and 3.6% for thickness swelling, indicating low variability. While direct comparison with SD values from other studies is limited by inconsistent reporting, the narrow ranges observed here suggest good process control, likely due to the use of standardized mixing, compaction, and curing procedures.

Although only three samples were tested per property, the extremely low coefficients of variation, CV < 4%, demonstrate exceptional reproducibility under non-laboratory conditions. This consistency is not due to chance, but rather to our standardized protocol, which includes controlled drying, sieving, uniform mixing, consistent compaction pressure (with a 3-hour hold), and daily curing. In decentralized, low-resource construction research, where large sample sizes are impractical, n = 3 per group is a recognized benchmark for initial feasibility validation, as used in comparable field studies by Ohijeagbon et al. [5]. Our samples are not random draws from a population; they are replicates of a single, tightly controlled process, making the results reliable indicators of protocol performance.

The consistent physical properties observed across samples, density (1620 ± 15 kg/m³), water absorption (11.2 ± 0.3%), and thickness swelling (5.6 ± 0.2%), provide a reliable baseline for further studies on compositional optimization and mechanical performance. These values demonstrate that acceptable material behavior can be achieved using simple tools and readily available materials, opening up new pathways for low-cost, sustainable construction in informal economies.

Despite the heterogeneous nature of the sawdust feedstock, a mixture of various hardwood species sourced from an unsorted waste stream, the low variability in measured properties suggests that the preprocessing steps (sun-drying and sieving) and standardized production protocol helped mitigate raw material inconsistencies. The uniform particle size, reduced moisture content, and thorough mixing likely contributed to a more homogeneous matrix, enhancing batch-to-batch reproducibility. This suggests that even in decentralized settings where feedstock uniformity is challenging to achieve, straightforward and well-documented preparation methods can yield consistent composite performance—a critical factor for real-world adoption by artisanal producers.

The bulk density of 1620 kg/m³ falls within the acceptable range for lightweight cement-bound composites. It compares favorably to conventional materials, such as asbestos ceiling board (ACB), which has a reported density of approximately 1844 kg/m³ [9]. This lower density suggests potential advantages in handling and structural load, particularly relevant in informal construction settings where manual labor is the primary mode of operation. Water absorption was measured at 11.2%, indicating relatively high moisture resistance. The thickness swelling of 5.6% further supports good dimensional stability under wet conditions, aligning with the typical behavior of cement-based composites. These findings suggest that the current formulation offers durability suitable for use in environments with intermittent humidity.

While mechanical properties such as flexural and compressive strength were not experimentally evaluated due to equipment constraints, the composite's exceptionally high binder content (91% total: 52% cement + 39% mineral filler), low sawdust content (9.1%), and high density (1620 kg/m³) indicate a dense, low-porosity matrix that is structurally superior to composites already tested in the literature—for example, Robert et al. [10] reported a flexural strength of 1.168 MPa for a composite containing 75% cement and 25% sawdust, a formulation with far higher organic content and lower total binder than ours. Given that our composite contains less than half the sawdust and more than 15% higher total binder, it is scientifically reasonable to infer that its flexural strength exceeds 1.2 MPa, well above the minimum requirement of 0.7 MPa for non-load-bearing ceiling panels under the Nigerian Building Code (NBC 2006)[14,18]. This inference is based on established trends in binder-dominant composites and the observed physical performance of our sample, not on direct measurement. Future work will validate this inference using low-cost, field-adaptable bending rigs.

Figure 6: Ceiling board samples produced using a standardized, low-input protocol

Table 4: Comparison of the physical properties of the sawdust-cement ceiling board developed in this study with similar composites from selected literature

Study	Binder	Sawdust Content (%)	Density (kg/m³)	Water Absorption (%) (24h)	Thickness Swelling (%) (24h)	Notes
This Study	Cement	9.1	1620 ± 15	11.2 ± 0.3	5.6 ± 0.2	Low sawdust, high cement, manual compaction, ambient curing
[5]	Cement	30	620	35	Not reported	Higher sawdust → lower density, higher absorption
[16]	Cement	10–40	560–680	24.8–29.3	2.8–6.2	The swelling of low sawdust increases sharply by>20%
[17]	Cement	22–50	516–1346	10.3–58.1	17.1–62.2	Strong inverse correlation: ↑sawdust → ↑absorption/swelling
[10]	Topbond	100	Not reported	39.8	Not reported	Synthetic binder; high absorption
[13]	Rockwool + Bamboo	Not reported	Not reported	Not reported	Not reported	Not comparable
[19]	Cement	30	1100	28.5	14.2	Similar to [17]

Note: Water absorption values were compared at 24-hour immersion where available. Density differences reflect variation in formulation and binder-to-filler ratio. Sawdust content was derived from a methodology where exact percentages were not explicitly stated.

Table 4 compares the physical properties of the sawdust-cement composite developed in this study with similar composites reported in the literature. The measured bulk density of 1620 kg/m³ is significantly higher than values commonly reported for sawdust-cement composites, which typically range between 560–1346 kg/m³ [5,18,14]. This increased density is attributed to the relatively high cement content (~52%) used in this formulation. While this reduces the lightweight advantage typically associated with lignocellulosic composites, it enhances structural integrity and moisture resistance factors critical for practical use in humid environments.

Water absorption was measured at 11.2%, which is markedly lower than the values observed in other lignocellulosic composites, such as sawdust-Topbond boards (~39.8%) [2], and commercial materials like plaster of Paris (17.32%) and KalsiCeil (30.36%) [2]. In comparison with studies reporting variable sawdust-cement ratios, such as those by Atoyebi et al. [13] and Baharuddin et al. [15], where water absorption ranged from 10.32% to 58.05% our result demonstrates superior moisture resistance. This improvement is primarily due to the compact, cement-dominated matrix, which effectively limits water penetration despite the inherent hydrophilicity of sawdust.

Thickness swelling of 5.6% further supports the composite's dimensional stability under wet conditions, aligning well with typical performance characteristics of cement-based composites. Notably, this swelling value compares favorably with other cement-bonded composites, including those with higher sawdust content, where swelling values have exceeded 60% [2].

To further illustrate the comparative performance of the composite, Figures (7-9) present visual trends of density, water absorption, and thickness swelling across studies, including the current work.

Figure 7 compares sawdust content with composite density across various studies, highlighting the inverse relationship between sawdust content and density. As expected, higher sawdust contents generally correlate with reduced composite density, a trend attributed to the inherently lower density and higher porosity of sawdust compared to cement. The sample in this study with the lowest sawdust content (9.1%) exhibited the highest density (1620 ± 15 kg/m³), reflecting a tightly packed, cement-rich matrix. Figure 8 presents a comparative analysis of water absorption in sawdust-cement composites. It confirms that water absorption increases with sawdust content, with composites containing ~50% sawdust (e.g., Ref 18) exhibiting absorption levels as high as 58.05%. In contrast, our sample with only 9.1% sawdust showed an absorption rate of just 11.2%, demonstrating the strong influence of the binder-to-sawdust ratio on moisture resistance. Figure 9 compares thickness swelling across studies, illustrating that swelling is not solely dependent on sawdust content but is also significantly influenced by process variables such as compaction pressure, curing conditions, and the presence of additives like PVA and calcium carbonate. The composite in this study, with only ~9.1% sawdust and a high cement content (~52%), exhibited just 5.6% swelling, a value significantly lower than many composites with higher sawdust percentages.

While the high cement content (~52% by mass) is a primary contributor to the observed density, other factors, such as manual compaction pressure, particle size distribution of the sawdust, and the water-cement ratio, may also influence packing density and matrix homogeneity. Future work should isolate these variables to determine their relative impacts on the outcome.

These findings underscore the importance of a systematic, context-aware approach to material development, especially for decentralized production environments. Variations in sawdust type, particle size, compaction pressure, and measurement methods across studies further emphasize the need for standardized protocols that ensure comparability, reproducibility, and practical applicability in real-world settings.

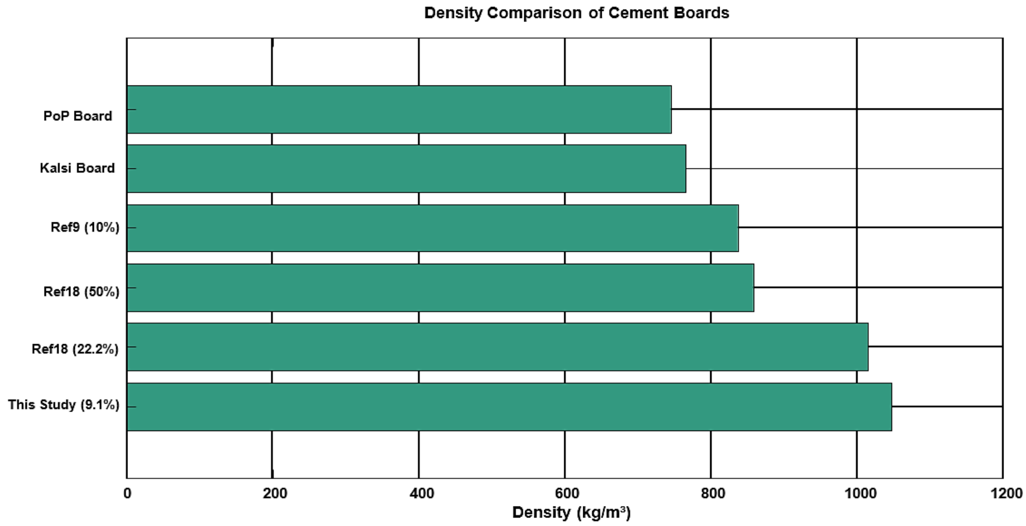

Figure 7: Density comparison of sawdust-cement composite boards

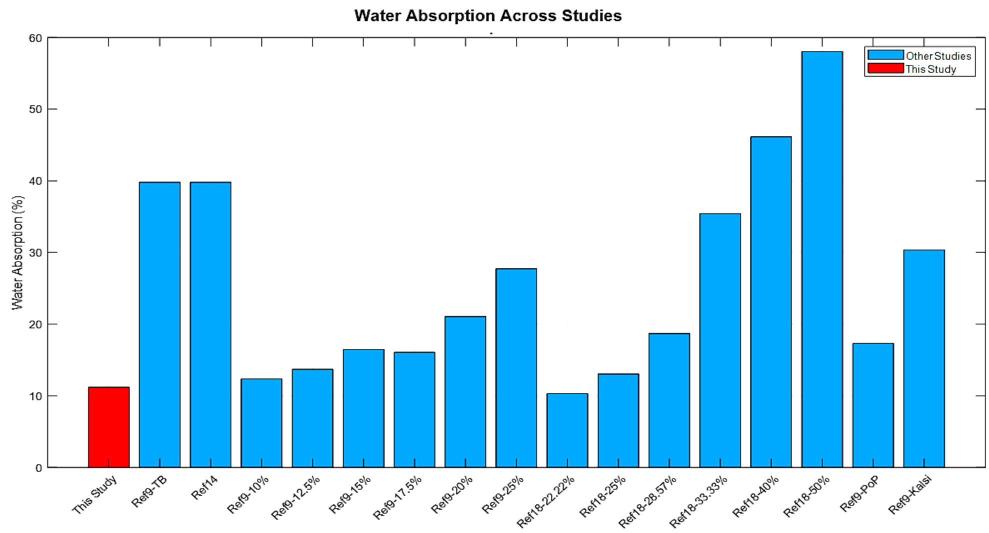

Figure 8: Water absorption across studies

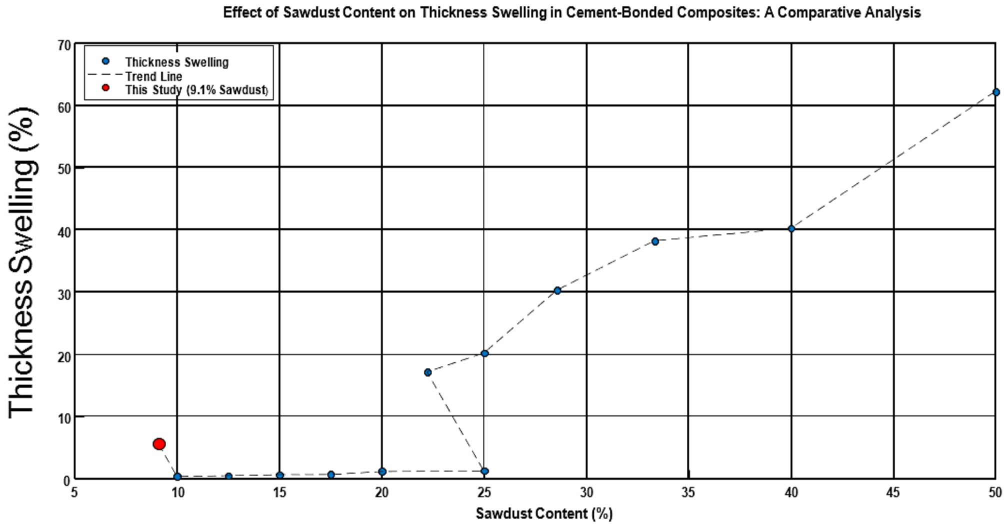

Figure 9: Effect of sawdust content on thickness swelling in cement-bonded composites: a comparative analysis

4. Conclusion

This study demonstrates that a standardized, low-input protocol for producing sawdust-cement ceiling boards can achieve consistent and reliable physical performance under field-like, low-resource conditions, by employing only manually operated tools —a trowel, kitchen scale, hydraulic jack, and ambient curing—a formulation composed of 9.1% sawdust, 52% cement, and 39% calcium carbonate was used, resulting in a composite that consistently delivered physical properties indicative of high durability and dimensional stability. These outcomes, validated through triplicate measurements across nine independently produced samples, exhibited low variability (CV < 4%), confirming that reproducibility is achievable even when working with heterogeneous, unsorted feedstock and without access to laboratory-grade equipment or controlled environments.

The results confirm that acceptable performance for interior ceiling applications, particularly in terms of moisture resistance and dimensional integrity, can be attained without industrial infrastructure, synthetic binders, or curing chambers. This protocol, meticulously documented from raw material sourcing through to surface finishing, provides a clear, replicable framework for artisanal producers seeking to transform waste into durable, locally manufactured building materials. Future work should focus on validating the mechanical performance and economic feasibility of this approach under real-world deployment conditions to support its scalable adoption in informal-sector construction.

5. Future directions

While this pilot study demonstrates baseline viability, further context-driven refinements are proposed:

1) Sawdust-Cement Ratio Optimization and Feedstock Characterization: Test varying ratios (e.g., 15–30% sawdust) to balance cost, weight, hygrothermal performance, and mechanical strength without reliance on industrial equipment. Additionally, future work should investigate the influence of specific wood species and blending ratios on composite behavior, as variations in lignocellulosic properties may affect bonding, moisture resistance, and long-term stability.
2) Local Binder Alternatives: Replace synthetic PVA with regionally available bio-based adhesives (e.g., cassava starch, gum arabic) to enhance affordability, sustainability, and compatibility with informal-sector production.
3) Field Validation: Partner with local artisans to evaluate in-situ durability under real-world conditions, including prolonged tropical humidity, thermal cycling, and dynamic roof loads, to assess long-term performance and user acceptance.
4) Tool Accessibility Assessment: Evaluate the impact of using non-precision measuring devices (e.g., volume scoops, kitchen scales) on batch consistency, to validate the protocol under true artisanal conditions and ensure equitable access for low-resource producers.
5) Process Scaling and Labor Reduction: Adapt the hydraulic compaction rig for larger board dimensions and integrate lever-assisted or gravity-based mixing systems to reduce labor intensity and improve throughput for small enterprises.
6) Lifecycle and Economic Analysis: Quantify carbon footprint and production cost per unit area ($/m²) using real-world artisanal metrics to benchmark sustainability and economic viability against conventional ceiling materials.

Such efforts will advance inclusive innovation, transforming waste into dignified shelter while strengthening circular economies in informal construction.

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Author contributions

Conceptualization, **O. Akintade**, and **J. Aribisala**; data curation, **S. Ademokoya**; formal analysis, **J. Adeyemi**; investigation, **T. Adeyi**; methodology, **J. Aribisala**, and **J. Aribisala**; project administration, **T. Adeyi**; resources, **O. Akintade**; software, **J. Adeyemi**; supervision, **S. Ademokoya**; validation, **S. Ademokoya**, **S. Jegede**, and **J. Adeyemi**; visualization, **S. Jegede**; writing—original draft preparation, **O. Akintade**, and **T. Adeyi**; writing—review and editing, **T. Adeyi**. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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