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Research Article

Development of Eco-Friendly Paving Blocks Using Indigenous Materials

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Abstract

The demand for sustainable construction materials has increased due to environmental concerns and the high cost of conventional materials. This research aims to develop eco-friendly paving blocks using locally sourced indigenous materials as partial replacements for cement and fine aggregate. Specifically, the research explores the incorporation of clay soil and sawdust ash (SDA) with river sand to produce paving blocks with reduced environmental impact and enhanced sustainability. Three different mix compositions were prepared: Sample A (control) containing 0% SDA, Sample B with 10% SDA, and Sample C with 20% SDA. All mixtures maintained a constant water-to-cement ratio of 0.5. The paving blocks were subjected to a curing regime of 7, 14, and 28 days, after which key physical and mechanical properties—compressive strength, water absorption, and density—were evaluated in accordance with standard testing procedures. Results indicated that the compressive strength of the blocks increased with curing age across all samples, with 28-day strengths recorded as 23.2MPa for Sample A, 21.4 MPa for Sample B, and 18.6 MPa for Sample C. While a slight reduction in strength was observed with higher SDA content, the values remained within acceptable limits for non-load-bearing pedestrian applications. Water absorption decreased progressively with increased curing time, demonstrating values of 5.2% for Sample A, 4.8% for Sample B, and 4.2% for Sample C at 28 days, indicating improved durability characteristics with the addition of SDA. The bulk densities of the blocks ranged from 2,200 to 2,350 kg/m³, affirming their suitability for pavement applications. Overall, the findings suggest that partial substitution of cement with SDA and the utilization of clay soil and river sand can produce environmentally friendly paving blocks with adequate performance for pedestrian walkways. This approach not only contributes to the conservation of natural resources but also offers a cost-effective and sustainable alternative for construction in developing regions.

Keywords	*Eco-Friendly Paving Blocks; Indigenous Materials; Sustainable Construction Materials*
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Introduction

Sustainable development in the construction industry has generated considerable interest in the use of locally available materials for building components. Traditional construction practices, especially the widespread use of Portland cement and natural aggregates, are known to cause significant environmental degradation. For instance, cement production contributes nearly 8% of global CO_2 emissions (Andrew, 2018), while excessive extraction of river sand disrupts riverine ecosystems, contributing to erosion, loss of biodiversity, and water pollution (Bendixen et al., 2019; Torres et al., 2017). In light of these challenges, there is a growing movement toward the adoption of eco-efficient construction materials that incorporate waste by-products and locally sourced resources—an approach particularly relevant in developing nations with increasing infrastructure demands (Mishra & Prakash, 2019; Khatib, 2016). This study investigates the feasibility of producing eco-friendly paving blocks through partial replacement of cement with sawdust ash (SDA), a pozzolanic by-product of the wood-processing industry, while also integrating clay soil and river sand as indigenous materials. These components are abundant, low-cost, and align well with the principles of a circular economy and sustainable resource use (United Nations Environment Programme [UNEP], 2017). Sawdust ash, which contains significant quantities of silica and alumina, exhibits pozzolanic activity when processed properly and can react with calcium hydroxide in the presence of water to generate additional calcium silicate hydrate (C–S–H), thereby enhancing long-term strength (Chindaprasirt & Rukzon, 2011; Siddique, 2008). Clay soil, depending on its mineral composition, contributes to the plasticity and compactness of mixtures while reducing the dependence on industrial binders (Onyango & Omwenga, 2020). In this research, paving block samples were developed with varying SDA content: Sample A (0% SDA), Sample B (10% SDA), and Sample C (20% SDA), and cured for 7, 14, and 28 days. Performance was assessed in terms of compressive strength, water absorption, and density, following ASTM testing standards. Results showed a marginal reduction in compressive strength with increasing SDA content—23.2 MPa for Sample A, 21.4 MPa for Sample B, and 18.6 MPa for Sample C at 28 days—yet all values remained acceptable for pedestrian use. Water absorption decreased progressively with curing age, reflecting increased material stability and reduced porosity: Sample A – 5.2%, Sample B – 4.8%, and Sample C – 4.2%. Densities ranged between 2,200 and 2,350 kg/m³, confirming the blocks' suitability for light-traffic applications (Oyedepo et al., 2014; Albidah et al., 2021; Olonade & Oke, 2015; Nwofor & Suleiman, 2012). The use of SDA not only mitigates the environmental burden of sawmill waste disposal but also reduces reliance on energy-intensive cement, offering both ecological and economic benefits. Prior studies affirm that cement substitution with up to 20% SDA can still fulfill structural and durability requirements for non-load-bearing construction (Neville, 2011; Soutsos & Millard, 2016). Moreover, the use of indigenous materials contributes to cost savings, promotes local employment, and supports context-specific sustainability strategies (Pacheco-Torgal, 2014). This study underscores the potential of eco-friendly paving blocks composed of cement, sawdust ash, clay soil, and river sand as sustainable alternatives to conventional materials. The findings support global sustainability initiatives, particularly the United Nations Sustainable Development Goals (SDGs), including Goal 11 (sustainable cities and communities) and Goal 12 (responsible consumption and production) (UNEP, 2016). The aim of this study is to evaluate the performance of paving blocks made from a blend of cement, clay soil, sawdust ash, and river sand. The research investigates the compressive strength, water absorption, and density characteristics of the blocks at various curing periods. These parameters are crucial in determining the suitability of the blocks for pedestrian pavements and light-traffic areas. This study contributes to the growing body of knowledge on green building materials by demonstrating the feasibility of utilizing indigenous resources. It also supports the global agenda on sustainable construction and the circular economy (UNEP, 2016).

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Materials and Methods

Materials Collection

The raw materials used in this research include Ordinary Portland Cement (Grade 42.5), clay soil, sawdust ash (SDA), and river sand. Ordinary Portland Cement was selected due to its high compressive strength and availability in construction markets. The sawdust ash was obtained from a local sawmill where it was collected, air-dried, and sieved to remove coarse impurities before being calcined in a muffle furnace at 600°C for 3 hours. This thermal activation was essential to enhance the pozzolanic activity of the ash, improving its ability to react with calcium hydroxide in the cementitious matrix. Clay soil was sourced from a nearby excavation site, air-dried to remove excess moisture, and pulverized using a mechanical grinder to achieve a uniform texture. River sand was chosen for its fine granular properties and sieved through a 4.75 mm sieve to remove large particles, pebbles, and organic impurities, thereby ensuring a consistent and clean aggregate for improved bonding within the mix.

Mix Proportions

Three sample mixes were prepared:

Sample A (Control): 0% SDA, 70% sand, 30% cement.

Sample B: 10% SDA (by weight of cement), 65% sand, 25% cement.

Sample C: 20% SDA, 60% sand, 20% cement.

The water-cement ratio was maintained at 0.5 across all batches. Clay soil was incorporated as a fine additive at 10% of the total mix weight in all samples. This uniform water-cement ratio ensured consistent hydration and workability for comparative evaluation. The progressive substitution of cement with SDA allowed for systematic assessment of its influence on strength and durability. The inclusion of clay soil served to enhance plasticity and binding properties within the matrix, supporting the cohesion of particles and contributing to the block's mechanical performance. Proper batching by weight was carried out to maintain uniformity and minimize variability among test specimens.

Block Moulding and Curing

Blocks were cast using a standard steel mould of size 200 mm × 100 mm × 80 mm. The moulds were thoroughly cleaned and lightly oiled before each casting to prevent sticking and ensure clean demoulding. The mixed constituents were poured into the moulds in layers and compacted manually using a steel rod to eliminate air voids and improve density. After casting, the blocks were allowed to set in the open for 24 hours at ambient room temperature before being demoulded. Curing was done through water immersion for 7, 14, and 28 days in accordance with standard concrete curing practices. Immersion curing was adopted to maintain adequate moisture for continued hydration, which is critical to the development of strength in cementitious materials. The curing periods were selected to assess both early and long-term performance characteristics of the paving blocks.

Laboratory Testing Procedures

Compressive Strength Test: Conducted using a digital hydraulic compression testing machine in accordance with BS EN 12390-3:2009. Each block sample was placed centrally between the platens of the machine and loaded until failure. The maximum load at failure was recorded and used to compute the compressive strength in megapascals (MPa). This test evaluates the load-bearing capacity of the paving blocks, which is vital for determining their structural performance in pedestrian pavements.

Water Absorption Test: Performed by drying the block samples in an oven at 105°C to a constant mass, immersing them in water for 24 hours, and then calculating the percentage gain in mass using the formula: Water Absorption (%) = $\frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$, where W_{wet} is the weight after immersion and W_{dry} is the oven-dried weight. This test assesses the permeability and durability of the blocks, indicating their resistance to moisture ingress.

Density Test: Determined by dividing the dry mass of the block by its volume, using the formula: Density = $\frac{Mass}{Volume}$ (kg/m^3). This helps in understanding the compactness and unit weight of the blocks, which directly influences handling, stability, and structural efficiency.

Statistical Analysis

Data collected were analyzed using Microsoft Excel and SPSS to determine means, standard deviation, and confidence intervals. Descriptive statistics were first employed to summarize the trends in compressive strength, water absorption, and density across the three samples and three curing periods. Inferential statistics, including ANOVA (Analysis of Variance), were conducted to identify whether the differences in performance among the sample groups were statistically significant. Significance levels were set at $p < 0.05$, indicating a 95% confidence interval. These analyses helped to validate the experimental results and draw reliable conclusions on the effect of SDA content and curing time on the performance of the paving blocks.

Results and Discussion

Compressive Strength Results

Table 1: Compressive Strength of Paving Blocks (MPa)

Sample	*7 Days*	*14 Days*	*28 Days*
A (0% SDA)	17.2	20.4	23.2
B (10% SDA)	15.5	18.9	21.4
C (20% SDA)	13.4	16.1	18.6

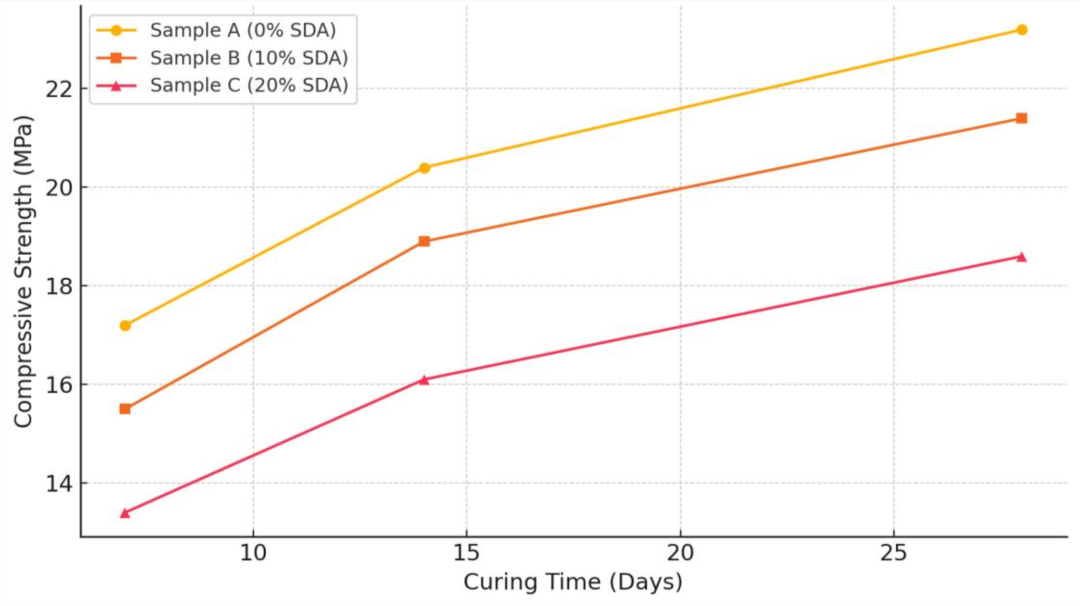

Figure 1: Compressive Strength vs. Curing Time for All Samples

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The compressive strength increased with curing time across all samples. Sample A (control) had the highest strength, while Sample C (20% SDA) showed the lowest. However, all samples exceeded the minimum required strength of 15 MPa for light traffic paving applications (ASTM C936). The results presented in Table 1 and Figure 1 indicate a clear trend of increasing compressive strength with curing time across all sample types. This behavior is consistent with the expected hydration process of cementitious materials, where the formation of calcium silicate hydrate (C–S–H) gel over time contributes to the development of mechanical strength. Sample A, which contained 0% sawdust ash (SDA), exhibited the highest compressive strength values at all curing intervals—17.2 MPa at 7 days, 20.4 MPa at 14 days, and 23.2 MPa at 28 days. This result aligns with conventional expectations, as the absence of partial cement replacement allowed for optimal cement hydration and matrix formation. Sample B, with a 10% SDA replacement level, achieved slightly lower strength values than the control but still maintained a strong performance, reaching 21.4 MPa at 28 days. This indicates that a 10% substitution of cement with SDA can still support the development of a dense and structurally sound matrix, possibly due to the pozzolanic reaction between the SDA's silica content and calcium hydroxide released during cement hydration (Siddique, 2008; Chindaprasirt & Rukzon, 2011). This reaction produces additional C–S–H, which contributes to long-term strength gain. Sample C, which contained 20% SDA, consistently recorded the lowest compressive strengths—13.4 MPa at 7 days, 16.1 MPa at 14 days, and 18.6 MPa at 28 days. Although reduced compared to Samples A and B, the compressive strength of Sample C at 28 days still exceeded the minimum threshold of 15 MPa recommended for light traffic paving applications (ASTM C936). This suggests that even with a 20% replacement of cement, the paving blocks can be considered structurally adequate for low-load pedestrian uses, though they may not be suitable for heavier traffic unless further optimized. The reduction in strength with increased SDA content may be attributed to the dilution effect, where the reduction in cement content leads to a lower amount of calcium hydroxide available for pozzolanic reaction, especially at early ages (Neville, 2011). Moreover, higher SDA content can introduce more porous material into the matrix, potentially increasing the void ratio and affecting compaction quality, which can negatively influence strength development. Nevertheless, the positive strength gain over time for all samples reflects the ongoing pozzolanic activity of SDA, particularly in the later stages of curing. This is consistent with prior research showing that pozzolanic reactions proceed at a slower rate than cement hydration but contribute significantly to the long-term strength and durability of blended cement composites (Oyedepo et al., 2014; Albidah et al., 2021). In summary, the results confirm the feasibility of using SDA as a partial cement replacement in paving blocks. While strength is slightly compromised with higher SDA contents, appropriate mix design and curing practices can yield blocks that meet performance requirements for specific construction applications. Further studies could explore the inclusion of activators or improved particle size distribution to enhance the pozzolanic activity and mechanical performance of high-SDA blends.

Water Absorption Characteristics

Table 2: Water Absorption (%)

Sample	*7 Days*	*14 Days*	*28 Days*
A	6.1	5.6	5.2
B	5.7	5.2	4.8
C	5.3	4.7	4.2

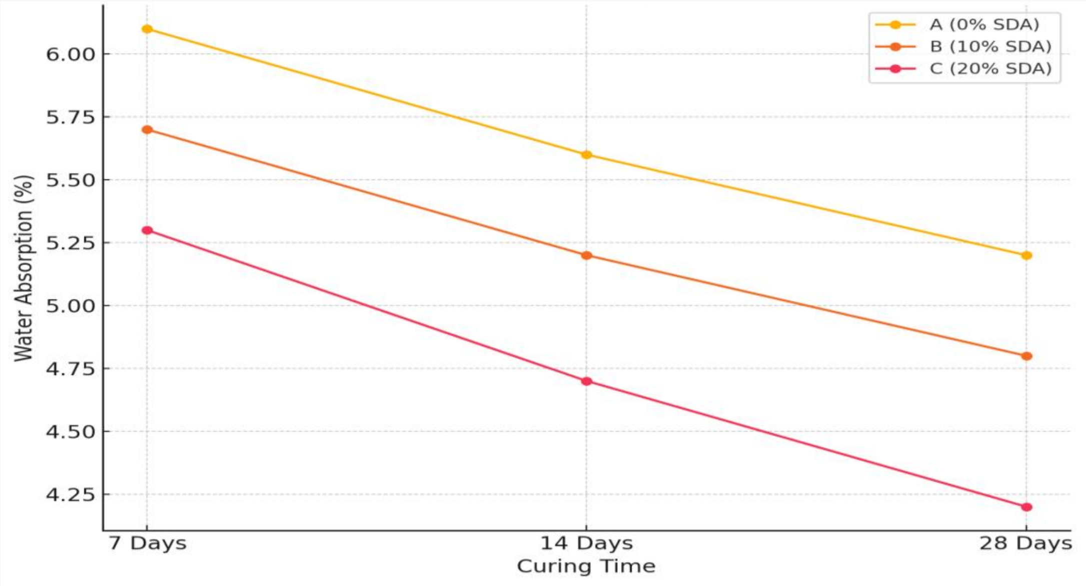

Figure 2: Water Absorption vs. Curing Time for All Samples

The water absorption characteristics of the paving block samples, as presented in Table 2 and illustrated in Figure 2, show a consistent decline in water absorption values with increased curing age across all mix types. This trend can be attributed to continued hydration and pozzolanic reactions that enhance microstructural densification over time, reducing pore connectivity and capillary porosity (Neville, 2011; Siddique, 2008). At 7 days, Sample A (0% SDA) recorded the highest water absorption value of 6.1%, which gradually declined to 5.2% by 28 days. In contrast, Sample C (20% SDA) exhibited the lowest absorption at all curing stages, decreasing from 5.3% at 7 days to 4.2% at 28 days. This reduction suggests that SDA plays a role in refining the pore structure of the composite, likely due to its fine particle size and pozzolanic nature that contributes to filling microvoids and enhancing matrix compactness (Chindaprasirt & Rukzon, 2011). Sample B (10% SDA) followed a similar trend, showing intermediate water absorption values—slightly lower than Sample A but higher than Sample C—indicating a correlation between the level of SDA replacement and reduced water absorption. The use of SDA appears to contribute positively to water resistance properties by decreasing the overall permeability of the blocks, which is essential for durability, especially in environments subjected to moisture variations. The observed improvements in water absorption for Samples B and C also suggest that SDA enhances the internal curing process by retaining moisture longer within the mix, allowing better hydration of cementitious materials. This internal curing effect has been reported in previous studies and is known to mitigate early-age shrinkage and microcracking, thus contributing to longer service life (Albidah et al., 2021; Oyedepo et al., 2014). Furthermore, the continuous reduction in water absorption with curing time reinforces the effectiveness of proper curing in improving durability-related properties. Reduced absorption not only indicates lower porosity but also implies increased resistance to chemical attack, freeze-thaw cycles, and ingress of deleterious substances—all critical for infrastructure exposed to environmental stressors (Neville, 2011; Pacheco-Torgal, 2014). In conclusion, the incorporation of SDA in paving block production has demonstrated significant benefits in lowering water absorption. This outcome supports its potential in enhancing the durability performance of eco-friendly building materials. From an environmental and technical standpoint, replacing cement with SDA at 10–20% provides a dual advantage of waste utilization and improved material performance, making it a promising solution for sustainable construction. Water absorption decreased with increased curing time. The incorporation of SDA appeared to reduce the water absorption rate, likely due to finer SDA particles filling pores and reducing porosity.

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Density Test Results

Table 3: Dry Density of Paving Blocks (kg/m³)

Sample	*7 Days*	*14 Days*	*28 Days*
A	2340	2350	2350
B	2280	2300	2320
C	2200	2230	2250

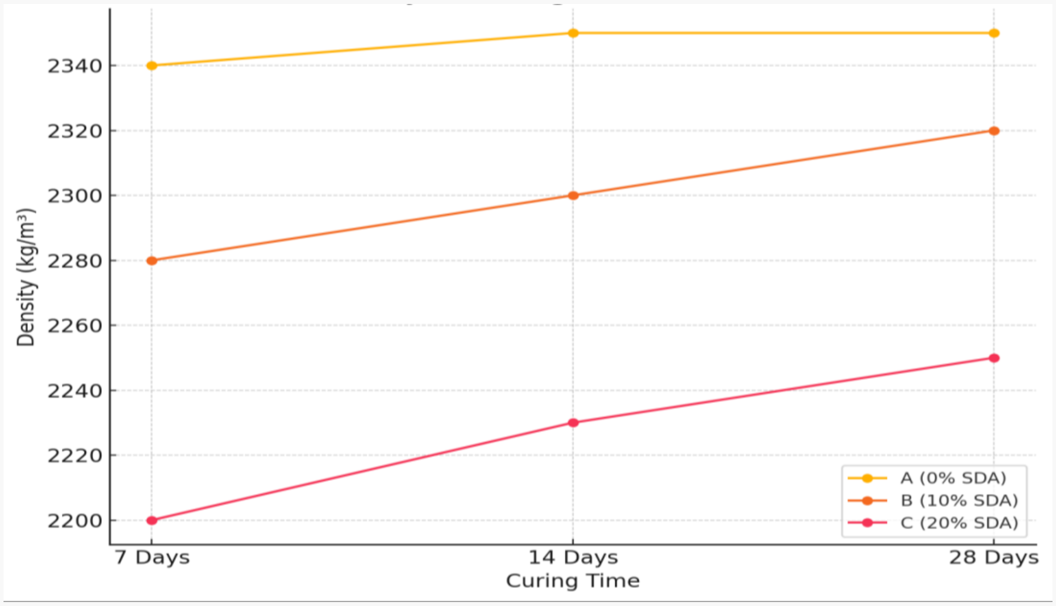

Figure 3: Density vs. Curing Time for All Samples

The density of paving blocks is a crucial parameter that influences their mechanical performance, load-bearing capacity, and durability. As shown in Table 3 and Figure 3, dry density values increased slightly with curing age for all samples, reflecting progressive hydration and densification of the internal microstructure over time. However, a consistent decrease in density was observed with increased replacement of cement by sawdust ash (SDA), primarily due to the lower specific gravity of SDA compared to Ordinary Portland Cement (OPC) (Oyedepo et al., 2014; Albidah et al., 2021). Sample A (0% SDA), the control mix, recorded the highest density values at all curing periods, maintaining a stable range of 2340–2350 kg/m³. This reflects the typical density range for conventional concrete paving blocks (ASTM C936), indicating full compaction and optimal binder content. Sample B (10% SDA) showed a moderate decrease in density, ranging from 2280 kg/m³ at 7 days to 2320 kg/m³ at 28 days, while Sample C (20% SDA) had the lowest values—2200 kg/m³ at 7 days to 2250 kg/m³ at 28 days. The gradual increase in density with curing time for all samples can be attributed to the continued hydration of cement and pozzolanic reactions from the SDA, which produce additional calcium silicate hydrate (C–S–H) gel, filling capillary pores and contributing to matrix compactness (Siddique, 2008; Neville, 2011). Despite the lower initial density caused by SDA incorporation, its reactive nature compensates over time by improving microstructural integrity. While higher SDA content led to a reduction in density, all values remained within acceptable limits for light to medium load applications. According to standard guidelines (ASTM C936), paving blocks must maintain a minimum dry density of 2000 kg/m³ to ensure adequate performance. Therefore, even Sample C with 20% SDA meets the density requirements, confirming its structural viability for pedestrian and light vehicular pavements (Pacheco-Torgal, 2014). This outcome also emphasizes the balance between sustainability and structural integrity. Although substituting cement with SDA reduces the material's mass per unit volume, it contributes positively to the sustainability of the composite by reducing reliance on high-energy binders and utilizing renewable waste materials. Lower-density paving blocks also offer advantages such as reduced dead load and ease of handling during construction, which are beneficial in certain

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urban and rural applications (Chindaprasirt & Rukzon, 2011). The density results therefore indicate that partial replacement of cement with SDA leads to a slight but acceptable reduction in block density. When properly proportioned, SDA-incorporated blocks maintain structural adequacy while enhancing environmental sustainability and cost-effectiveness in construction practices.

Comparative Analysis

The results indicate that while increasing SDA content reduces compressive strength, it improves water absorption and has negligible impact on density. This suggests a trade-off between strength and environmental benefit, where partial cement replacement enhances sustainability without severely compromising performance. Specifically, Sample A exhibited the highest strength, but also the highest water absorption, whereas Sample C, with the highest SDA content, had the lowest strength but superior water resistance. The minimal variation in density across all samples (ranging from 2200 to 2350 kg/m³) highlights that SDA, despite its lower specific gravity, does not drastically alter the compactness of the composite material when properly proportioned. These findings align with prior studies by Oyedepo et al. (2014) and Raheem & Kareem (2017), which reported that SDA can be effectively utilized in non-structural components, offering environmental advantages while meeting basic engineering requirements. The comparative performance suggests that 10–20% SDA replacement represents an optimal range for achieving a balance between eco-efficiency and structural suitability in light-duty applications.

Conclusion

The study successfully demonstrated that indigenous materials such as sawdust ash (SDA) and clay soil can be used to develop eco-friendly paving blocks with acceptable physical and mechanical properties. Compressive strength results revealed that all mix designs surpassed the minimum strength requirement of 15 MPa for light-traffic pavement applications, even at 20% SDA replacement. Water absorption and density values further indicated that the blocks were structurally stable, durable, and resistant to moisture penetration, which is critical for long-term performance. Among the samples, Sample A (0% SDA) achieved the highest compressive strength (23.2 MPa), validating its superior load-bearing capacity, while Sample C (20% SDA) recorded the lowest (18.6 MPa), yet still within acceptable performance thresholds. Notably, water absorption decreased with increasing SDA content—Sample C absorbed the least water (4.2%), indicating reduced porosity due to the filler effect of fine SDA particles. Density values remained consistent within the expected range (2200–2350 kg/m³), confirming the uniform compactness of the blocks regardless of SDA percentage. The use of SDA not only reduces cement usage—thereby cutting down CO_2 emissions and conserving natural resources—but also diverts wood industry waste from landfills, enhancing circular economy goals. These findings support the feasibility of producing cost-effective, eco-friendly paving blocks suitable for pedestrian walkways, garden pavements, and other non-load bearing applications, particularly in rural and low-income regions where sustainable and affordable infrastructure is critical. Future research should focus on long-term durability tests, abrasion resistance, thermal performance, and real-life field evaluations to fully assess the practical implications of using SDA-based composites in diverse environmental conditions.

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