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Evaluation of Sandcrete Blocks Produced from Recycled Concrete Waste and Cassava Peel Ash

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Abstract
This study assesses the engineering properties of sandcrete blocks produced using recycled aggregate from concrete waste as a partial substitute for natural river sand. Cassava peel ash blended with cement served as the binder. Cassava peels were burned at 700°C to produce ash, which replaced 20% of the cement in the binder. Recycled fine aggregate was sourced from crushed concrete waste at a demolition site. Six mixture proportions were prepared by replacing natural river sand with recycled material at 0%, 20%, 40%, 60%, 80%, and 100%, while keeping all other components unchanged. The sandcrete blocks were tested for compressive strength and water absorption at 7, 14, and 28 days of curing. Results indicated that incorporating these waste materials enhanced sustainability with minimal reduction in strength at optimal replacement levels. Mixtures containing 20% cassava peel ash and 20–40% recycled fine aggregate achieved compressive strengths comparable to the control mix and complied with relevant standards. Although water absorption increased with higher replacement levels, values remained within acceptable limits at moderate substitution rates. Overall, the findings demonstrate that agricultural and construction wastes can be effectively utilized in sustainable sandcrete block production.

Keywords: *Cassava peel ash, Compressive strength, Recycled aggregate, Sandcrete blocks, Sustainability.*

1.0 Introduction

Sandcrete blocks are commonly used for wall construction in most sub-Saharan African countries. This is due to their ease of production and installation. However, their widespread use makes them heavy consumers of natural resources. They are typically made from sand, the aggregate or bulk material, and cement, the binder.

Sand is obtained by scooping from rivers and from ongoing earth excavation, both of which pose environmental challenges. As a natural resource, sand is used unsustainably, damaging ecosystems. Conversely, cement, used as a binder, is a major source of carbon emissions. It is reported that producing 1 tonne of cement results in approximately 0.9 tonnes of carbon dioxide emissions, accounting for about 8% of global carbon emissions. Essentially, the current practice of making blocks from natural sand and Portland cement is not sustainable.

To address these challenges, interest has grown in finding alternatives to natural sand and in replacing as much clinker as possible in cement or concrete. Recycled concrete aggregates (RCA) are a potential aggregate source. Globally, around 10 billion tonnes of construction and demolition waste (CDW) are generated each year, representing a market value of approximately USD 7 billion in 2020 and a compound annual growth rate of 6.8% from 2021 to 2028 (Essomar, 2019; Wang et al., 2019). CDW also accounts for over 30% of global waste (Papargyropoulou et al., 2011). CDW typically includes concrete rubble, bricks, tiles, sand, dust, timber, plastics, and steel, among other materials. Of these, concrete rubble usually makes up the largest portion of CDW. When crushed concrete rubble is properly sorted and sieved, it can be used to replace natural sand and coarse aggregate in the production of sandcrete blocks and concrete (Bekkeri et al., 2024).

According to Menegaki and Damigos (2018), more than 35% of C&D waste is disposed of in landfills each year. Based on aggregate size, the percentage of old cement paste or mortar in RCA particles ranges from 30 to 60 percent. RCA appears to be quite angular and rough (ECCO, 1999). Compared with natural aggregate, RCA has lower specific gravity and bulk density but greater water-absorption capacity (Anderson et al., 2009; Rahal, 2007; Juan & Gutierrez, 2004). RCA's ability to reduce landfill and

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environmental waste has led to its rapid adoption worldwide (Olonade et al., 2023). Using RCA eliminates the need for conventional aggregates such as granite and gravel, thereby reducing issues associated with their mining and transportation (Tijani et al., 2019).

Numerous studies have demonstrated that the production and use of RCA are technically feasible. RCA can be used for road base and subbase, concrete production, and other applications. Its acceptability in concrete depends on the specific use case. Generally, RCA can partially replace natural aggregates in most applications (Tijani et al., 2022). However, the amount of RCA in a concrete mix depends on RCA properties and the particular application. According to Okafor (2010), the strength of RCA-produced concrete is influenced by the strength of the original concrete. When the required concrete strength is not higher than that of the original concrete, RCA can be used to produce high-quality concrete. RCA with higher water/cement ratios can achieve the same compressive strength as virgin aggregates (Aiyewalehinmi and Adeoye, 2016). Increasing the RCA proportion decreases the compressive strength and increases the voids and porosity of pervious concrete, as noted by Rizvi et al. (2010). The compressive and tensile strengths of pervious concrete decrease with increasing RCA content, although its permeability improves (Tijani et al., 2022; Kareem, 2014).

On the other hand, clinker in cement or cement in concrete is typically replaced with various supplementary cementitious materials (SCMs). Materials such as fly ash, slag, and silica fume are well-established SCMs known for reducing the carbon footprint of Portland cement (Mugahed et al., 2021). In addition to these industrial wastes, some agricultural wastes have also been reported as potential SCMs. Among these materials are rice husk ash, sugarcane straw ash, and palm kernel shell ash (Tashima et al., 2004; Moisés et al., 2006). More recently, Salau and Olonade (2011) demonstrated the pozzolanic potential of cassava peel ash by using it to construct a pilot structure.

This study, therefore, aims to combine two potential solutions to reduce the carbon footprint of Sandcrete blocks by replacing sand with recycled fine aggregate and blending cassava peel ash with Portland cement as a binder. It also aims to evaluate the strength and durability of Sandcrete blocks made from these materials.

2.0 Materials and Methods

2.1 Materials

The materials used in this study were cement, cassava peel ash, natural river sand, recycled fine aggregate, and water. Portland Limestone Cement conforming to relevant standards was used. Natural river sand served as the control fine aggregate. Recycled fine aggregate was obtained by crushing hardened concrete cubes and sieving to obtain particles less than 4 mm. Cassava peels were air-dried, calcined at 700 °C for about 90 minutes as recommended by Salau and Olonade (2011), and then ground to produce cassava peel ash. The chemical composition, as determined by XRF, is presented in Table 1.

Table 1: Chemical and physical properties of cement and cassava peel ash (Salau and Olonade, 2011)

Properties	Portland Limestone Cement (PLC)	Cassava Peel Ash (CPA)	BS EN 196-2
Chemical Composition (%)			
Silicon Dioxide, SiO_2	19.63	42.21	18 - 24
Aluminum Oxide, Al_2O_3	2.42	9.79	2.6 - 8
Iron Oxide, Fe_2O_3	2.33	4.01	1.5 - 7
Calcium oxide, CaO	61.25	4.77	61 - 69
Magnesium Oxide, MgO	2.17	1.33	0.5 - 4
Sulphur Trioxide, SO_3	2.09	0.72	0.2 - 4
Potassium OXIDE, K_2O	0.29	9.04	0.2 - 1.0
Sodium Oxide, Na_2O	0	0.68	-

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Loss on Ignition (LOI), %	9.62	4.18	-
Fineness (Blain Value), m^3/kg	355	330	-
Specific Gravity	3.09	0.32	-

2.1.1 Cement

Portland Limestone Cement (PLC) manufactured by Dangote Cement Plc was blended with 20% cassava peel ash to serve as a binder.

2.1.2 Recycled and natural fine aggregate

Concrete cube waste was obtained from the concrete laboratory of the Department of Civil and Environmental Engineering at the University of Lagos (Figure 1a). The cubes were crushed and sieved through a 3.18 mm sieve and retained on a 150 µm sieve to ensure that the particle sizes fall within the fine aggregate range (Figure 1, b-d). For comparison, natural river sand was also used in the research. The sand used was Ogun River sand.

2.1.3 Mix proportions and sample preparation

A cement-to-sand ratio of 1:6 was used. Cement was partially replaced with 20% cassava peel ash, and river sand was replaced with recycled fine aggregate at 0%, 20%, 40%, 60%, 80%, and 100% by weight (Figure 2). A water-cement ratio of 0.55 was used. Each mix was prepared by thoroughly blending the cement and fine aggregate (recycled waste material and natural river sand) in a concrete mixer. The mixtures were batched by weight to ensure accuracy and consistency. The mix sample was cast in a 150 mm block mold, commonly known as a 6-inch block (Figure 3a). The cast blocks were cured by covering them with polythene for 7, 28, and 56 days (Figure 3b).

Figure 1: Recycled aggregate preparation (a) concrete cubes waste (b) mechanical crusher (c) crushed concrete waste (d) recycled fine aggregate

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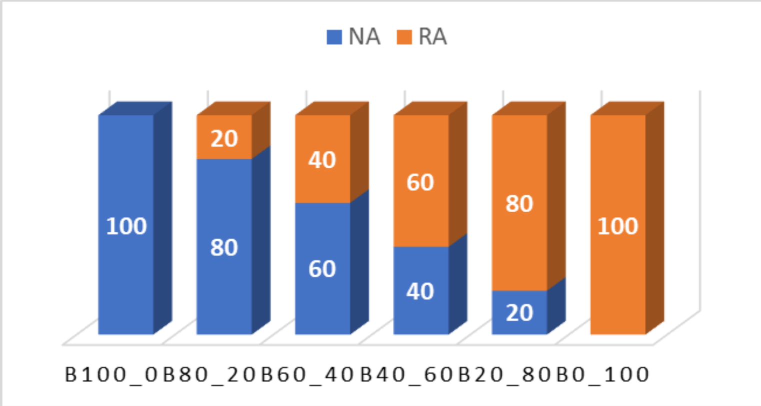

NA = Natural Aggregate, RA=Recycled Aggregate
Figure 2: Sample nomenclature

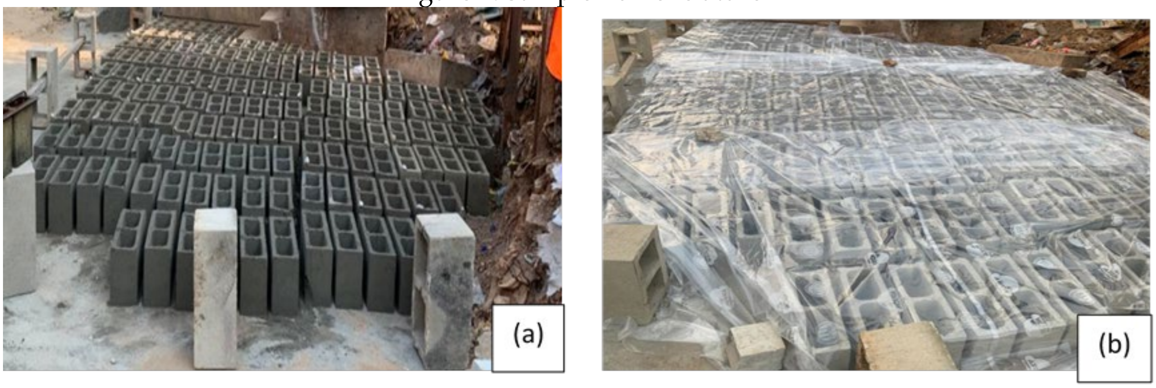

Figure 3: Block samples (a) freshly moulded blocks (b)blocks under curing

2.2 Methods

2.2.1 Determination of particle size distribution

To determine the particle size distribution of the fine aggregates, sieve analysis was performed. The fine aggregate obtained from crushed concrete cubes was sieved through a set of standard sieves ranging from 4.75 mm to 0.75 micrometers, following the procedure outlined in BS EN 933-1. The weight of material retained on each sieve and the total sample weight were recorded to calculate the percentage passing through each sieve. The particle size distribution curves were then plotted.

2.2.2 Determination of compressive strength

The cured Sandcrete blocks were subjected to two tests to evaluate their properties and performance. The primary test was the compressive strength test, performed at 7, 28, and 56 days in accordance with the procedures specified in BS EN 12390-3:2009. The blocks were placed between two plates, and a load was applied until the blocks were crushed (Figure 4). The maximum force required to crush the block was recorded, and the compressive strength was calculated by dividing the maximum crushing force by the net surface area of the block.

Figure 4: Compressive strength determination

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2.2.3 Determination of water absorption

The water absorption test is a key durability measurement that assesses how much water a block absorbs when submerged. High absorption levels often indicate high porosity, which can weaken the material and make it more susceptible to chemical damage or freeze-thaw deterioration. The test was performed in accordance with BS EN 772-11.

3.0 Results and Discussion

3.1 Sieve analysis

The particle-size distributions of both recycled and natural fine aggregates were evaluated using the coefficients of uniformity (Cu) and curvature (Cc), with the results shown in Figure 5. The recycled fine aggregate had a Cu of 9.23 and a Cc of 1.03, meeting the criteria for well-graded sand under the Unified Soil Classification System. In contrast, the natural fine aggregate exhibited a Cu of 2.69 and a Cc of 0.879, indicating a poorly graded material with a narrow particle-size distribution.

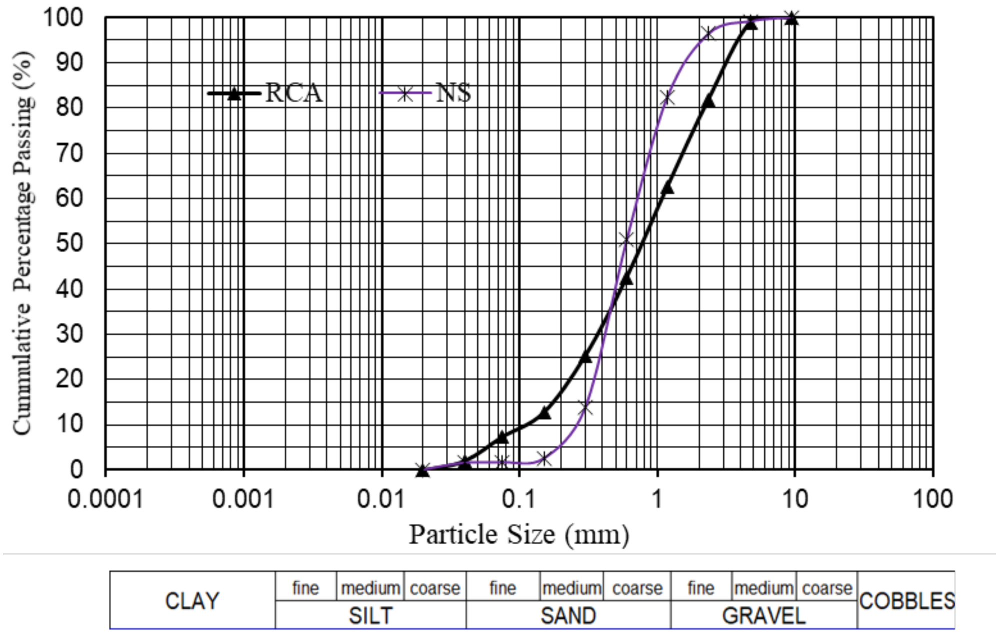

Figure 5: Particle size distribution curves for NS and RCA

3.2 Compressive strength

The development of compressive strength in sandcrete blocks containing recycled concrete aggregate (RCA) and cassava peel ash (CPA) was evaluated at 7, 28, and 56 days. For each mixture, three specimens were tested, and the mean strength was used in the statistical analysis. Percentage increases in strength and strength ratios relative to the control mix were calculated to assess performance.

Compressive strength increased with curing time across all mixes. The control mix achieved the highest strength at 28 days. However, mixes containing 20% cassava peel ash and up to 40% recycled fine aggregate reached strengths comparable to the control and met the minimum standard requirements (Figure 6).

Sample B100_0 (control mix) exhibited mean compressive strengths of 3.30 MPa at 7 days, 5.80 MPa at 28 days, and 6.50 MPa at 56 days. Strength increased by 75.8% from 7 to 28 days and by 12.1% from 28 to 56 days, for a total increase of 97.0% from 7 to 56 days. These results confirm rapid early hydration followed by slower long-term strength development, as shown in Figure 6.

For sample B80_20, as shown in Figure 6, the mean compressive strengths were 2.90 MPa at 7 days, 4.20 MPa at 28 days, and 5.20 MPa at 56 days. Strength increased by 44.8% from 7 to 28 days and by 23.8% from 28 to 56 days, for a total increase of 79.3%. The 56-day strength was 80% of the control mix (strength ratio = 0.80), indicating good mechanical performance at moderate replacement levels.

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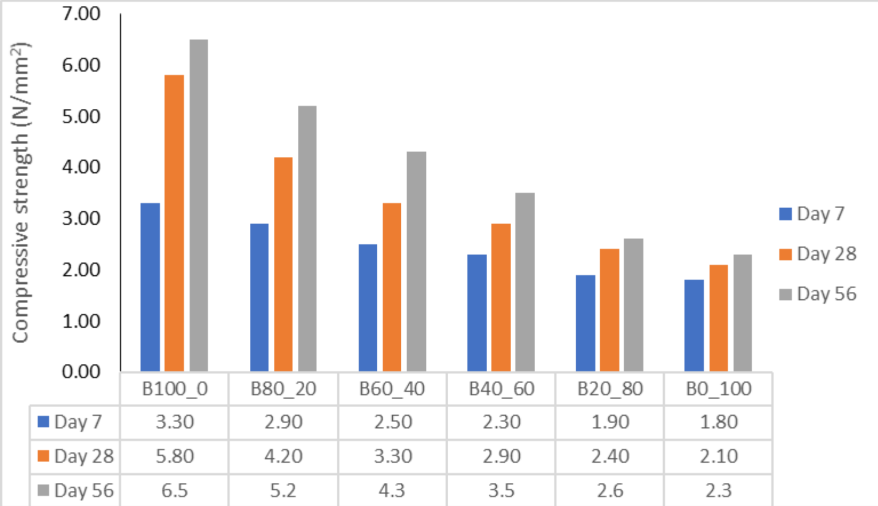

Figure 6: Compressive strength of block samples at different ages.

Sample B60_40 exhibited mean strengths of 2.50 MPa at 7 days, 3.30 MPa at 28 days, and 4.30 MPa at 56 days. Strength increased by 32.0% from 7 to 28 days and by 30.3% from 28 to 56 days, for a total increase of 72.0%. The 56-day strength was 66% of the control mix (strength ratio = 0.66), indicating continued strength gain from secondary reactions.

Sample B40_60 has mean compressive strengths of 2.30 MPa (7 days), 2.90 MPa (28 days), and 3.50 MPa (56 days). Strength increased by 26.1% from 7 to 28 days and by 20.7% from 28 to 56 days, for a total increase of 52.2%. The 56-day strength is 54% of the control mix (strength ratio = 0.54), indicating reduced load-bearing capacity at higher replacement levels.

Similarly, Figure 6 shows the strength of Sample B20_80, with mean strengths of 1.90 MPa at 7 days, 2.40 MPa at 28 days, and 2.60 MPa at 56 days. Strength increased by 26.3% from 7 to 28 days and by 8.3% from 28 to 56 days, for a total increase of 36.8%. The 56-day strength is 40% of the control strength (strength ratio = 0.40), indicating a significant reduction in structural performance.

Sample B0_100 recorded mean strengths of 1.80 MPa, 2.10 MPa, and 2.30 MPa at 7, 28, and 56 days, respectively. Strength increased by 16.7% from 7 to 28 days and by 9.5% from 28 to 56 days, for a total increase of 27.8%. The 56-day strength was 35% of the control mix (strength ratio = 0.35), indicating the lowest performance among all mixes.

Generally, all mixes demonstrated age-dependent strength development, with more pronounced gains occurring between 7 and 28 days for lower replacement levels and diminishing gains at higher replacement ratios. The control and lower RCA mixes exhibited stronger early hydration, whereas higher replacement mixes showed slower, more limited strength development. Although the control mix achieved the highest overall strength, mixes with moderate replacement levels (e.g., B80_20 and B60_40) displayed relatively competitive performance, supporting the potential for partial replacement in sustainable sandcrete production.

3.3 Water absorption

The water absorption behavior of the sandcrete blocks showed a consistent dependence on curing age and mix composition. Across all mixes, water absorption peaked at 7 days, decreased at 28 days, and reached its lowest levels at 56 days, indicating progressive densification of the matrix with curing time (Figure 7).

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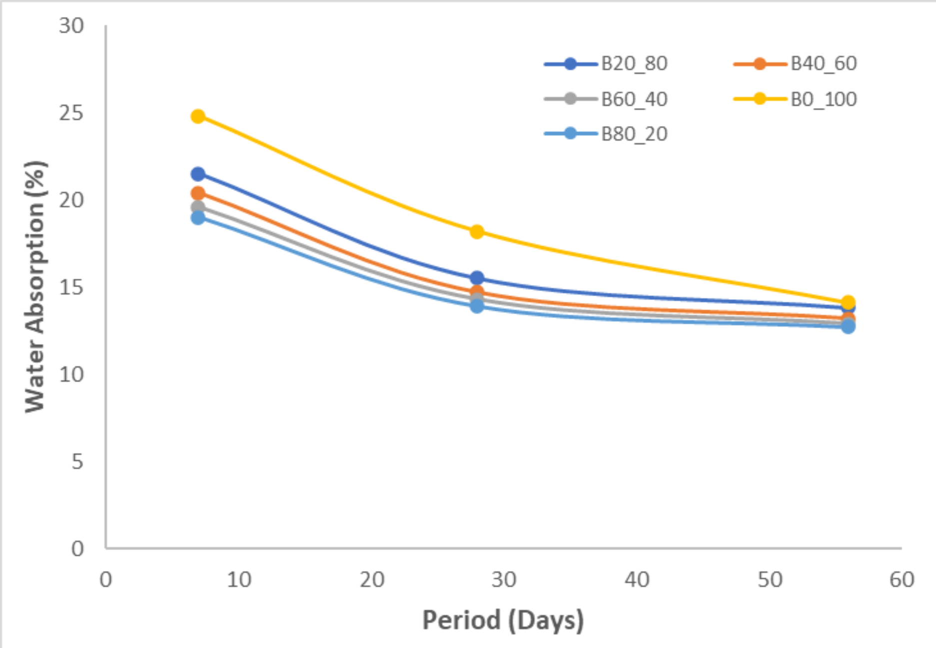

Figure 7: Water absorption of the block samples at different curing ages

The control mix containing 100% river sand (B100_0) showed moderate water absorption, decreasing from approximately 18–19% at 7 days to about 11–13% at 56 days. This reduction reflects improved matrix densification during curing. In contrast, the mix with 100% recycled fine aggregate (B0_100) exhibited the highest initial absorption (24.8% at 7 days), which decreased to 18.2% at 28 days and further to 14.1% at 56 days, indicating delayed pore refinement due to the recycled aggregates' higher initial porosity.

Blended mixes incorporating recycled aggregate and cassava peel ash (CPA) showed improved long-term performance. The B80_20 mix decreased from 19.0% at 7 days to 13.9% at 28 days and further to 12.7% at 56 days, indicating enhanced refinement of the pore structure due to pozzolanic activity. Similarly, the B60_40 mix showed a gradual reduction from 19.6% to 14.3% and finally to 12.9% at 56 days, reflecting moderate densification.

However, higher replacement levels, such as B40_60, showed elevated water absorption values of 20.4%, 14.7%, and 13.2% at 7, 28, and 56 days, respectively, indicating increased porosity associated with higher recycled aggregate content. The B20_80 mix followed a similar trend, decreasing from 21.5% at 7 days to 15.5% at 28 days and 13.8% at 56 days, but still maintained relatively higher absorption than lower-replacement mixes.

Overall, the results indicate that increasing recycled aggregate content increases water absorption at early ages due to higher porosity. However, the inclusion of CPA and extended curing significantly reduces water absorption over time through secondary pozzolanic reactions and matrix densification. Optimal performance was observed at lower to moderate replacement levels, where improved particle packing and cementitious reactions reduced porosity and enhanced the durability of the sandcrete blocks.

4.0 Conclusion

The findings of this study show that partially replacing natural aggregates and cement with recycled concrete aggregate (RCA) and cassava peel ash (CPA) is technically feasible for producing sandcrete blocks. Although early-age compressive strength decreased with higher recycled content, notable strength gains occurred at later ages due to continued hydration and the pozzolanic activity of CPA.

From a structural performance standpoint, sandcrete mixes with up to 40% RCA achieved satisfactory long-term compressive strength, although higher replacement levels may require further optimization to improve early-age mechanical properties. Likewise, CPA was found to effectively replace up to 20% of cement without affecting overall performance.

Compressive strength in all mixes consistently increased with curing age, indicating normal strength development. Although water absorption tended to rise with higher RCA content, the values remained within acceptable limits at moderate replacement levels.

Overall, the findings confirm that sustainable sandcrete blocks made with recycled materials can achieve long-term strength and durability that is competitive. This supports the use of waste-derived materials in sandcrete production, promoting resource efficiency and advancing circular economy strategies in construction materials engineering.

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