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Waste tiles as a partial replacement of coarse aggregate in concrete

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Abstract

This research examined tile waste as a partial replacement for coarse aggregate in concrete production. The aim was to evaluate the effects of adding tile waste on concrete. Tile wastes were added to the concrete mix in varying proportions of 0%, 10%, 20%, and 30%. Cement, fine aggregate, coarse aggregate, and water are primary materials. A series of tests were conducted to assess the performance of the concrete, including a Sieve analysis to determine the grading of fine aggregates, a slump test to measure workability, a compressive strength test to evaluate load-bearing capacity, and a water absorption test to assess durability. The results were compared to a control mix of 0% tile waste, demonstrating how different percentages of tile waste affected the concrete's workability, strength, and durability. The findings showed that tile waste has the potential to be a viable alternative to conventional aggregates, contributing to sustainable construction practices by reducing waste and conserving natural resources.

Keywords: Waste tiles; Partial replacement; Coarse aggregate; Concrete; Sustainable construction**.**

1. Introduction

Concrete is the second most widely used substance in the world, after water and plays a significant role in shaping the built environment [1]. Concrete consumption is reported to be around three tons per person annually [2]. Ceramic tiles are increasingly popular for decorative purposes but become waste once they are broken [3; 4; 15; 16; 17 and 18]. When recycled into aggregate, waste ceramic tile aggregates (WCTAs) exhibit favourable properties, including high specific gravity, lower water absorption, and higher crushing, impact, and abrasion values when compared to natural crushed stone [5]. Some other waste materials like a recycled plastic waste [6], Waste or broken glasses [7], Bricks and marble [8], Palm kernel shell [9], granite powder [10], Coal ash [11], waste coconut fibre [12], locally sourced aggregates [13], etc have been researched on to see how they can be used to encourage sustainability in Civil engineering and construction materials. Other researchers are working on how to improve the quality of concrete using local materials [19 – 34].

2. Materials and method

2.1. Materials

- Cement: Ordinary Portland cement which was sourced in Egbuoma.
- Aggregate: fine and coarse aggregates were sourced in Egbuoma.
- Water: Portable water was sourced from the civil engineering laboratory.
- Waste Tile: The tile waste used in this experiment was collected from construction sites in Uli.

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2.2. Methodology

2.2.1. Batching, mixing, and Slump test

Concrete was prepared with different amounts of waste tiles replacing coarse aggregates at 0%, 10%, 20%, and 30% by weight of coarse aggregate. Mix design ratio of 1:2:4, with a water-cement ratio of 0.7. For the mixes containing waste tiles, the crushed waste tiles were thoroughly mixed with a shovel. Portable Water from the laboratory was added to improve workability [14]. Slump tests as in Figure 1 were conducted for 0%, 10%, 20%, and 30% waste tile replacement to evaluate the workability of the concrete

Figure 1 Slump test

2.2.2. Concrete compaction, Curing and testing

The concrete cubes were prepared by cleaning and applying oil to the moulds for easy removal of the cubes from the mould [12], the prepared fresh concrete was placed on the mould and compacted using a poker vibrator. The concrete cubes were left to set for 24 hours before removing it from the moulds. The curing process involved immersing the cubes in a water tank for a period of 7, 14, 21, and 28 days. After curing, the cubes were allowed to dry before conducting tests. For the water absorption test, we weighed the cubes before and after curing to determine how much water they had absorbed. For the compressive strength test, we used a universal compressive testing machine to measure the amount of pressure the cubes could withstand before cracking.

3. Results

3.1. Sieve analysis: The result for the particle size distribution of fine aggregate and the grading of the sampled material is illustrated in Table 1.

Table 1 Sieve analysis results

Sieve size	Mass Retained (g)	Cumulative mass Retained (g)	Percentage mass retained (%)	% Passing	Cumulative % Passing
8	150	5.77	5.77	94.23	94.23
10	50	7.69	1.92	98.08	88.46
12	200	15.38	7.69	92.31	80.77
20	950	51.92	36.54	63.46	44.23
30	300	63.48	11.56	88.46	32.69

40	450	80.79	17.31	82.69	15.38
80	450	98.1	17.31	82.69	0.00
Pan	50	100.02	1.92	98.08	0.00

Table 1 shows a gradual decrease, indicating a well-graded fine aggregate distribution. This grading is crucial for ensuring adequate compaction, which directly affects the concrete's strength and durability.

3.2. Slump Test

The slump test results for 0%, 10%, 20%, and 30% are shown in Figure 2.

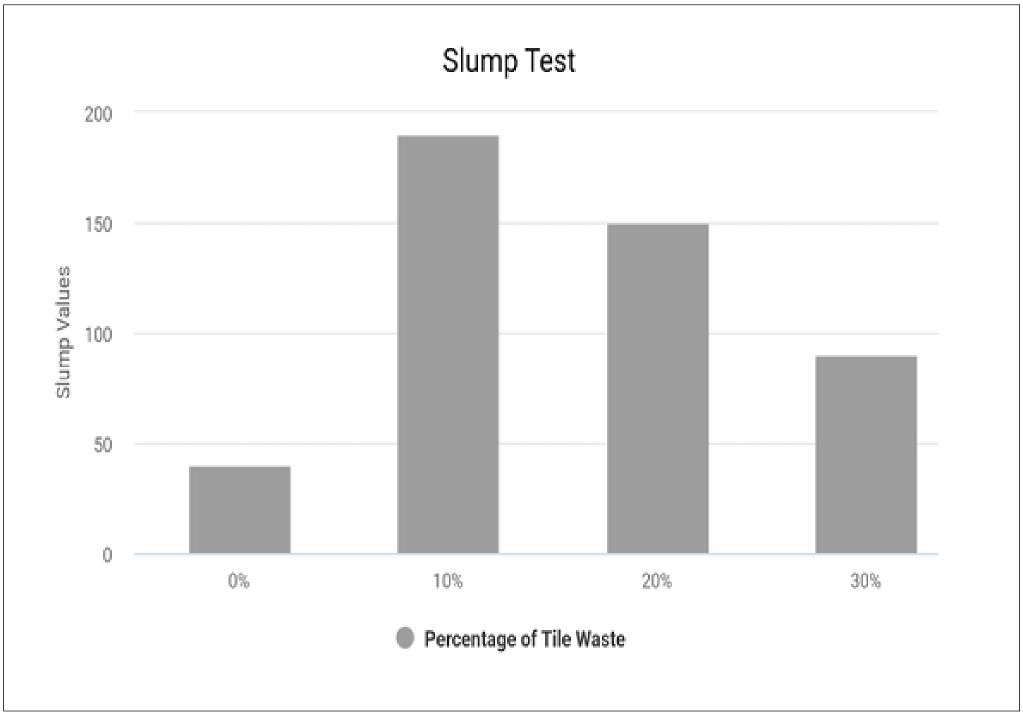

Figure 2 Slump Test bar chart

The slump values in Figure 2 indicate that the concrete has adequate workability, which gradually reduces over time as the hydration process consumes free water, leading to increased stiffness in the mix.

3.3. Water absorption test

The water absorption test was conducted, as shown in Table 2, to assess the porosity of the concrete samples by measuring the amount of water absorbed over a period of 7, 14, 21, and 28 days.

Table 2 Water Absorption Test Results

Sample Age (Days)	Initial weight (kg)	weight After immersion (kg)	Water absorbed (kg)	Water absorption (%)
7	7.00	7.5	0.5	1.02
14	7.00	7.58	0.58	8.29
21	7.10	7.70	0.6	8.45
28	7.30	8.10	0.8	10.96

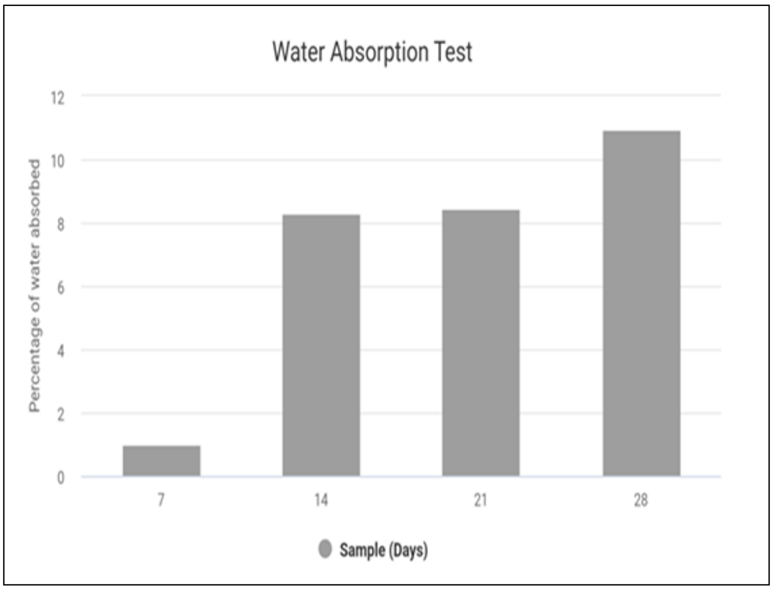

Figure 3 Bar chart of water absorption test

The water absorption results in Figure 3 showed a gradual increase over time, which may be attributed to the continued hydration process and the porous nature of the waste tiles aggregate. However, the absorption rates are within acceptable limits, indicating that the concrete will maintain sufficient durability.

3.4. Compressive Strength Test

The compressive strength test was conducted on concrete cubes made with tiles as coarse aggregate. The cubes were tested after curing for 7, 14, 21, and 28 days to assess the strength development over time. The results of crushed concrete cubes after curing are shown in Figure 4.

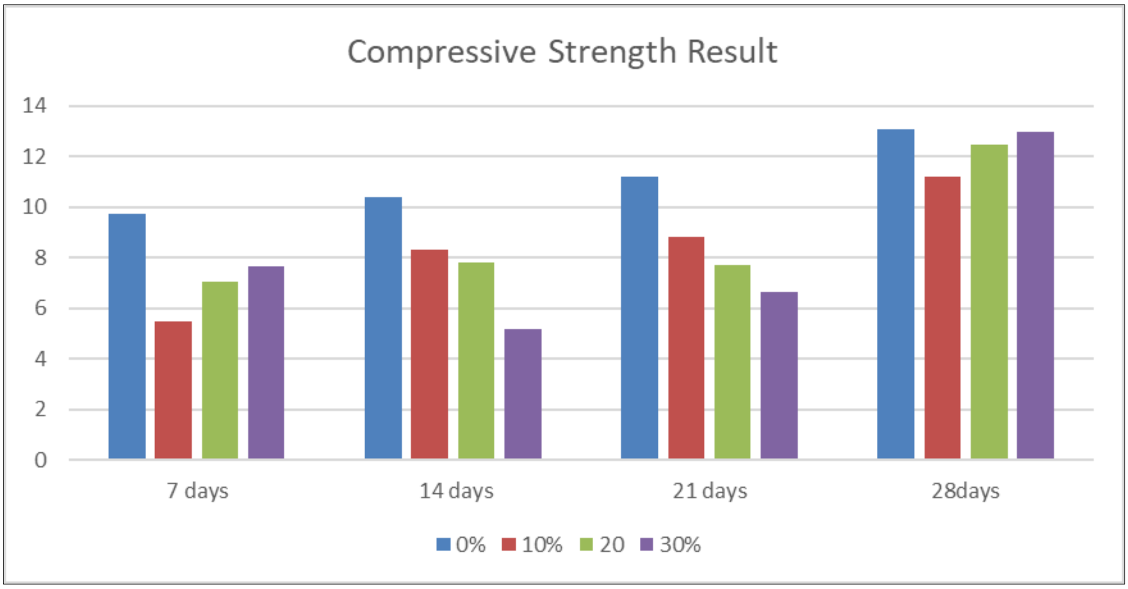

Figure 4 Bar chart for compressive strength Test

From Figure 4, concrete with 0% Tile Waste (Control Sample) has the highest strength at 28 days, 13.06MPa, this is the standard for comparison. The 10% Tile Waste at 28-day strength was 11.19MPa this shows a noticeable drop in strength compared to the control, indicating weaker concrete. 20% Tile Waste at 28-day strength,12.45MPa Slightly lower than the control but better than the 10% mix. It suggests acceptable performance with moderate tile waste usage. 30% Tile Waste at 28-day strength. 12.99MPa nearly matches the control strength, indicating that a higher percentage of tile waste might still produce strong concrete. Strength of Concrete with up to 30% tile waste can still achieve near-standard strength, making it viable for many applications. The results suggest that using tile waste, especially at 20-30%, could be a sustainable option without severely compromising structural integrity.

4. Conclusion

This study investigated the feasibility of utilizing tiles as a coarse aggregate in concrete production. The primary objective was to evaluate the concrete's workability, durability, and compressive strength when waste tiles are employed as a substitute for conventional aggregates. The slump test results indicated that the concrete mixes containing tiles maintained satisfactory workability, with an expected reduction in slump values over time. This decrease is typical in concrete as it undergoes hydration, leading to a gradual stiffening of the mix. The slump values obtained were within acceptable limits, demonstrating that the addition of waste does not compromise the mix's workability. The water absorption test revealed a slight increase in the porosity of the concrete samples over time. However, the absorption values remained within permissible limits, suggesting that the concrete possesses adequate durability. The tile's waste aggregate contributed to the overall performance without significant adverse effects on the concrete's water resistance.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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