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ASSESSMENT OF COMPRESSIVE STRENGTH OF A CONCRETE USING WASTE CERAMIC TILES AS FULL REPLACEMENT FOR CONVENTIONAL AGGREGATES

MOHAMMED KABIR; CHUWANG GYANG GAZU; AHMAD JIBRIN GUTO; JIBRIN ABUBAKAR; & ALI KOLO MUKTAR

Department of Building, Nigerian Army University Biu, Borno

Corresponding Author: tashkalmabiu@gmail.com

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ABSTRACT

This research evaluates the compressive strength of concrete in which ceramic waste tiles are used as a full replacement for both fine and coarse aggregates. The study was conducted to address environmental challenges posed by ceramic tile waste and the depletion of natural aggregates. A nominal mix ratio of 1:2:4 with a water-cement ratio of 0.55 was adopted. Concrete specimens were cast, cured, and tested at 7, 14, 28,

Introduction

The global demand for natural aggregates in concrete production has led to environmental degradation and depletion of quarry resources. Simultaneously, the ceramic industry generates large quantities of tile waste, which poses disposal challenges. Jwaida et al. (2024) analyzed various studies on the use of ceramic waste in concrete. The findings indicate that incorporating ceramic waste can improve compressive and flexural strengths, particularly when used as a partial replacement for fine or coarse aggregates. However, the extent of improvement depends on factors such as the type of ceramic waste and its replacement ratio. Recent studies confirm that the ceramic tile industry continues to generate significant waste, with estimates indicating that up to 30% of daily production results in waste, much of which is landfilled. For instance, Agrawal et al. (2020)

and 56 days. Results indicate that ceramic waste tile concrete exhibited higher compressive strength compared to conventional concrete at all curing ages. The findings demonstrate the potential of ceramic waste tiles as a sustainable and structurally effective alternative in concrete production.

Keywords: Ceramic waste, recycled aggregate, compressive strength, sustainable concrete, Environmental challenges.

have reported that approximately 30% of ceramic production becomes waste. This raises environmental concerns due to land usage, degradation, and contamination.

Recent studies suggest that ceramic waste tiles, due to their durability and comparable properties to natural aggregates, may serve as viable substitutes in concrete production. By utilizing ceramic waste tiles as both fine and coarse aggregates, this research explores a dual benefit: reducing environmental waste and conserving natural aggregate resources. Moreover, such an approach aligns with the global push for sustainable construction practices and the development of eco-friendly building materials.

To address both issues aggregate depletion and ceramic waste accumulation there is increasing interest in utilizing ceramic tile waste as an alternative aggregate in concrete. Ceramic waste is chemically stable, hard, and possesses high durability, making it a promising substitute for natural aggregates. The application of recycled ceramic waste in construction aligns with sustainable development goals by promoting waste recycling and reducing reliance on natural resources.

This study investigates the compressive strength of concrete in which ceramic waste tiles are fully substituted for natural aggregates, thereby contributing to waste valorization and sustainable construction.

Literature Review

Aggregate

The term aggregate is used broadly by the construction industry to refer to natural mineral materials used for various types of construction. It consists of large chunks of materials in a concrete mix which are generally sand, gravel, or crushed rocks and such as limestone or granite. Robinson et al (2004) describe the term aggregates as an industrial commodity in term of sand, gravel, and crushed rock

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materials, in their natural or processed state, that are used to provide bulk, strength, and wear resistance in construction applications. (Robinson et al, 2004) In the U.S., aggregates are primarily used in the production of Portland cement concrete, asphalt pavement, and as structural fill in the construction and maintenance of roads and buildings. Khan et al. (2024) the use of construction and demolition waste (CDW) aggregates in pavement construction offers significant environmental and economic benefits. It reduces landfill loads, conserves natural resources, and decreases energy consumption and greenhouse gas emissions associated with natural aggregate extraction. Weil et al. (2006). In Europe, the word aggregate is also used to describe recycled concrete, bricks and ceramics which are often crushed and used as fill for civil engineering projects. More recently, these recycled aggregates have begun to be used in Europe for the production of new concrete.

Between 70 to 80 percent of the total volume of concrete is occupied by aggregate, there are two types of aggregates namely fine and coarse aggregates. Manchiryal et al. (2014) Fine aggregates in concrete typically consist of particles smaller than 5mm, while coarse aggregates are larger than 5mm

Materials for Aggregates

According to Garba (2014) aggregate materials are used in concrete to increase its strength, volume and durability, reduce creep, reduce shrinkage and reduce overall cost, thermal properties and impact sound, impact density, increase chemical resistance. The materials used as aggregate include: palm kennel shells, pumice, crush rock, recycle concrete, gravel, scrap iron, lead, iron shots, barites, crush burnt bricks, etc. Almost any available material that met some basic requirement can be used as aggregate for concrete. For aggregate to be used in normal structural concrete the following characteristics should be considered; cleanness, hardness, cost, chemical inertness, availability in required sizes, and availability in good shape, availability required grading and availability in good surface textures.

The characteristics for aggregate are cleanness, grading, hardness and shape. While the principal characteristics are important since they affect both the concrete and mortar like cost, workability, strength and durability.

Ceramic Waste as Aggregate

Ceramic wastes originate primarily from construction site discards, manufacturing defects, or demolition debris. These materials include glazed and unglazed tiles, sanitary ware, and structural ceramics. According to Torgal and Jalali (2010),

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ceramic wastes are generally divided into red ceramic (e.g., bricks, blocks) and white ceramic (e.g., tiles, sanitary ware), with both types exhibiting favorable properties for use in concrete. Numerous studies have evaluated ceramic waste as aggregate. Tamanna and Sharma (2018) studied the effect of replacing average aggregate in concrete with waste tiles as coarse aggregate and found that replacing leads to increasing compressive strength of concrete; Tavakoli A. A., Heidari, A. and Karimian, M. (2013) reported that concrete with ceramic tile aggregates achieved up to 30% higher compressive strength, particularly when tile waste replaced up to 40% of natural aggregates. Magesh (2018) used coarse and fine ceramic tiles as the replacement from average aggregate in concrete; the compressive strength increased from 28 MPa for control mix to 31 MPa for 50% replacement in his study, and the optimum dosage was 50%. Also, he gained increment in tensile and flexural strength by using waste ceramic tiles. Naveen (2018) studied the use of waste tiles as aggregate in concrete for 10, 20, 30, and 40% replacements from average aggregate and got increment in compressive, tensile, and flexural strength by using waste tiles aggregate. Cachim (2009) observed that a 15% substitution of ceramic aggregates had no negative effect on compressive strength, while higher percentages caused minor reductions depending on ceramic type.

Physical and Mechanical Properties of Ceramic Waste

Ceramic waste has shown promising potential as a sustainable alternative in construction materials. Lilesh Gautam et al. (2020) as a cement substitute, ceramic waste enhances mechanical and durability properties of concrete, contributing to reduced construction costs and environmental impact.

Ceramic waste is known for its hardness, angular shape, and high water absorption. These characteristics enhance interlocking and mechanical bonding with the cement matrix but may reduce workability. Binici (2007) showed that concrete made with ceramic and pumice aggregates exhibited good abrasion resistance and durability, although with slightly lower workability due to high absorption. Á. Pitarch et al. (2021) and S. Zito et al. (2022) recent studies have explored the potential of ceramic waste as a pozzolanic material in sustainable concrete production. Various types of ceramic waste, including tiles, bricks, and sanitary-ware, have demonstrated pozzolanic activity when used as partial cement replacements. Hamad et al. (2020) Partial replacement of fine aggregates with ceramic waste powder (25-50%) improved compressive and tensile strength.

This was echoed by Pacheco and Jalali (2010), who attributed improved durability to pozzolanic activity of ceramic fines. Research on incorporating ceramic waste

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as aggregate in concrete has shown mixed results. Peter et al. (2020) observed that concrete with 50% ceramic fine aggregates and 75% ceramic coarse aggregates exhibited higher compressive strength than conventional concrete, although modulus of elasticity decreased. They also reported decreased density while maintaining desired compressive strength.

Compressive Strength of Ceramic Aggregate Concrete

Compressive strength is a critical factor in structural concrete. While recent studies have explored the complex relationship between porosity, pore structure, and compressive strength in concrete. Fan Yu et al. (2023) increased porosity generally reduces strength, optimizing pore structure can enhance both strength and permeability. Tavakoli et al. (2013) demonstrated that up to 30% of ceramic aggregate increased compressive strength due to the aggregate's sharp edges, which improve bonding. Veera (2010), however, cautioned that substitution beyond 20% could reduce strength unless the concrete is appropriately proportioned.

In general, findings suggest that ceramic waste aggregates if properly processed and proportioned can produce concrete of comparable or even superior compressive strength to conventional mixes.

Materials and Methods

Author: (2024) Plate I: Production of ceramic waste tile aggregate

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Materials

- Cement: Dangote Ordinary Portland Cement (BS 12, 1996).
- Fine Aggregate: Crushed ceramic waste tiles and river sand (for control).
- Coarse Aggregate: Crushed ceramic waste tiles and granite (for control).
- Water: Potable tap water.

Mix Proportion and Casting

A nominal mix of 1:2:4 with a water-cement ratio of 0.55 was employed. A total of 24 cube specimens ($100mm^3$) were cast, equally divided into control and test specimens.

Testing Procedures

- Workability: Slump and compacting factor tests (BS 1881-102:1983).
- Compressive Strength: Compressive strength tests at 7, 14, 28, and 56 days using standard procedures (BS EN 12390-3:2000).

Results and Discussion

Workability

Slump values for ceramic waste concrete were lower (4 mm) compared to control (7 mm), indicating reduced workability due to high water absorption of ceramic aggregates, as supported by Pacheco and Jalali (2010).

Compressive Strength

Table 1: **Average Compressive Strength of Ceramic Waste Concrete and Control Concrete**

Curing Day	Control Concrete (N/mm^2)	Ceramic Tile Concrete (N/mm^2)
7 Days	12.55	14.69
14 Days	15.67	19.72
28 Days	19.46	22.27
56 Days	23.70	26.03

As shown in Table 1, ceramic waste concrete exhibited consistently higher compressive strength than the control concrete: The compressive strength of ceramic waste tile concrete for each of the four curing period is higher than the control concrete. The compressive strength of both ceramic waste tile and control concrete varied from 12.55 to 23.70 N/mm^2. This shows that using 100% replacement of ceramics waste tiles as both fine and coarse aggregate, there was increase in the compressive strength beyond those that obtained from granite

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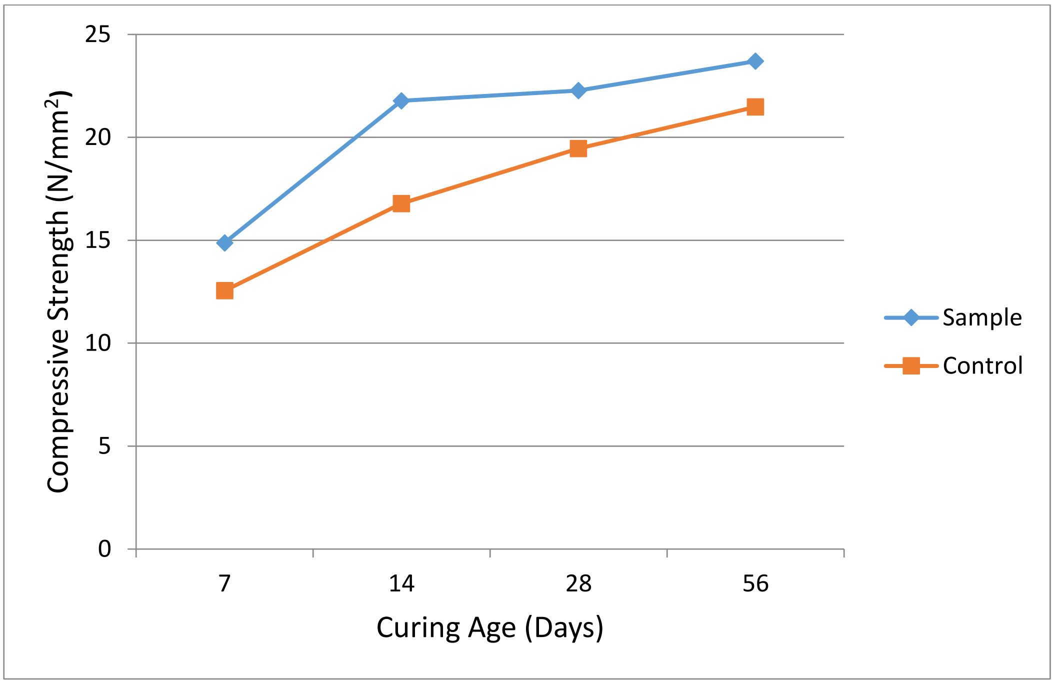
aggregate concrete (control specimen). This could be due to the rough and angular edges of the ceramic waste tile aggregate.



Author: (2024)

Figure 1: Compressive Strength of Control Concrete and Sample Concrete

Figure 1 shows the compressive strength of concrete specimens cured in water at 7, 14, 28 and 56 days of curing period which also presents the relationship between compressive strength and curing age (days). The detail results shows in Table 1 above.

Conclusion

The experimental study confirms that ceramic waste tiles, when used as a full replacement for both fine and coarse aggregates, can produce concrete with superior compressive strength compared to conventional concrete. These findings support the adoption of ceramic waste tiles as a viable alternative aggregate, contributing to sustainable construction practices.

Recommendations

- Further research should evaluate the long-term durability of ceramic waste concrete under aggressive environmental conditions.
- Future studies could explore partial substitution scenarios or combinations with other industrial by-products.

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