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Improve the Characteristics of Concrete using Waste Ceramic as a Cement Replacement Ingredient

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A B S T R A C T

The primary component of concrete, cement, is accountable for 8% of global carbon dioxide emissions. In order to minimize the total embodied carbon in the concrete manufacturing process, it is therefore highly desired to reduce the amount of cement used in concrete. Additionally, a growing quantity of ceramic waste powder is produced during the production of ceramics, and this can lead to serious environmental issues such air, soil, and groundwater pollution. This research explores the use of ceramic waste powder as a cement replacement agent to reduce environmental pollution during concrete production. A laboratory study was conducted to replace various levels of a cement with ceramic waste powder. It was found that slump and workability of concrete can be increased by using the pozzolanic nature of ceramic materials and suitable admixtures. Adding waste ceramic to concrete reduces density, with a linear drop as ceramic percentage increases. Additionally, it was obtained that ceramic concrete had a slightly greater modulus of elasticity, split tensile strength, compressive strength, and flexural strength than conventional concrete. When 10% CWP was substituted for ceramic concrete, the strength improved by 10.45%. Concrete's strength increases when CWP is added up to 20% of the mix. Finally, for the greatest results it is advised to add 10% of CWP.

1. Introduction

Concrete has a significant impact effect on the environment, consuming materials from nature and generating one ton of carbon dioxide for every ton of (OPC) produced. Five percent of the greenhouse gases released into the atmosphere worldwide are produced during the cement making process [1, 6,16]. In 2050, it is expected that annual greenhouse gas emissions will exceed 2.34 billion tons if current conditions continue [3-4].

Cement is becoming more and more in demand as development picks up speed since it is used as a binding ingredient to create uniform mixes. The earth's carbon footprint increases as a result of this growth in demand driving up cement output; as a result, over production of (OPC) seriously harms our planet and undermines sustainable building practices [2]. New materials are required to minimize wasteful use of natural resources and to recycle industrial and agricultural waste products in order To minimize the harmful impact on the planet. Every year, enormous amounts of waste are produced, putting the environment in danger and needing large energy and financial investments to manage. Concrete might be made with waste materials partially in place of conventional ingredients, which would solve these issues.

Solid waste repurposed for mortar/concrete production can be categorized as industrial or construction trash, depending on its source. Because they have cementitious qualities, some minerals, such as slag, are frequently used as additives to cement [5]. Exploring the flip side, study has been conducted on the possible applications of solid wastes from building such as leftover concrete, rubber, bricks, and ceramic as an aggregate or supplementary cementitious material [6-9-12].

In order to create sustainable concrete, researchers are considering reusing the enormous volumes of ceramic waste that are created annually. Ceramic materials are still widely employed today to make products like high-voltage electric insulators, sanitary ware, and earthenware that have been used for a long time for a variety of purposes [7,33]. An amazing renewable material is waste ceramic in cement replacement procedure as shown in Figure (1) [8,11]. Utilizing recycled ceramic as construction supplies are widely used in actual engineering applications, with impressive results in both the economy and society [10,13,14]. CWP has sufficient pozzolanic effect after 28 days, despite its initial lack of strength. By reducing porosity and cracks. Cement motor acid resistance can be increased by using CWP in some areas instead of cement [15].

According to [16], the frost resistance of reference concrete and concrete that substitutes as much as 40 percent fine-ground ceramics for cement is comparable. Concrete's compressive strength and carbonation resistance would decrease if cement were substituted with ceramic polishing waste, as demonstrated by [17]. There is no discernible impact on mortar strength when ceramic tile polishing residue is substituted for cement up to a 25% amount [18]. Research [19] showed that while adding ceramic tile waste in place of cement would weaken mortar, doing so up to a 35% level would still meet fly ash strength activity index standards. Approximating 20% porcelain polishing residue added to the cement would result in self-consolidating concrete with similar rheological properties but more passage capacity [20]. According to [21] the use of porcelain waste by up to 9% of the aggregate will not negatively affect the resistance of concrete. The strength of concrete was found to be more than or equal to the resistance of natural concrete when ceramic waste was used as fine aggregate, replacing sand by up to 30% [22].

When ceramic waste accounts for up to 25% of the aggregate, the durability of the concrete is found to be about equal to that of the reference concrete [23]. However, the pressure resistance was observed to decrease when the proportion of ceramic waste increased to 75% [24]. Research [25] When brick concrete and ceramic waste concrete were compared, it was discovered that the ceramic waste concrete was superior to the brick concrete. According to [26], there is little impact from ceramic tile waste; therefore, it is possible to use ceramic tile waste to partially replace coarse aggregate.

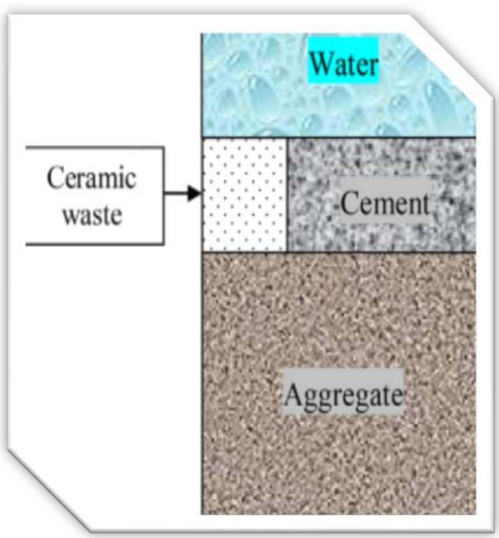

Figure 1 Ceramic Waste as a cement replacement

2. Materials and Methods

2.1. Materials

Every substance employed. It was obtained from local Egyptian sources and is widely utilized in Egyptian building. The materials used were basalt (coarse aggregate), sand (fine aggregate), ordinary Portland cement (OPC), and regular drinking water.

The final cutting of ceramic goods produced the ceramic waste powder. Over 40% of the CW particles by volume were in the size range of 4 t0 10 µm as shown in Figure (2). Silicon dioxide (SiO2) makes up 69.30 % of CWP, while aluminum oxide (Al2O3) makes up 18.10%, CaO (1.85%), and MgO (2.98%). Other oxides with the specific elemental composition, sodium oxide (Na2O) (2.89%), and potassium oxide (K2O) (2.85%) as shown in table (1). For physical properties of CWP specific gravity 2.6.

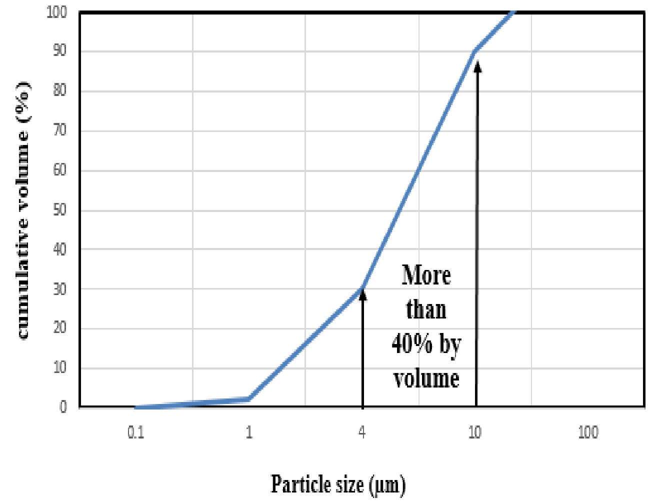

Figure 2 Distribution of cumulative particle sizes for CWP

Table 1 Chemical components of CWP used in study for concrete manufacture

Chemical composition	Weight percentage (%)
SiO_2	69.30%
Al_2O_3	18.10%
Na_2O	2.89%
K_2O	2.85%
MgO	2.98%
CaO	1.85%

2.2. Methods

Five mixes with varied CWP ratios were created according to Egyptian code and tested. Slump test for fresh concrete, and compressive, indirect splitting, and flexural strengths for hundred concrete. Test specimens were assembled into five groups. Mixture (1) has no ceramic waste powder, which is known as the control mixture (M1), mixture (2) includes 5% of CWP (M2), mixture (3) contains 10% of CWP (M3), mixture (4) contains 15% of CWP (M4), and mixture (5) contains of 20%. Superplasticizer had been added to the concrete to improve its workability. Table (2) displays the mixing design for concrete mixtures.

Table 2 Mix design of all concrete specimens

No.	W	C	F.A	C.A	CWP	S.P
X1	150.8	350	675.5	1340.2	0	3.5
X2	150.8	332.5	675.5	1340.2	17.5	3.5
X3	150.8	315	675.5	1340.2	35	3.5
X4	150.8	297.5	675.5	1340.2	52.5	3.5
X5	150.8	280	675.5	1340.2	70	3.5

All quantities of material in kg/m3

3. Results and Discussion

3.1. Slump Result

The test followed ASTM C143 guidelines. The slump test apparatus consists primarily of a metal mold in the shape of a cone measuring twenty centimeters at the bottom, ten centimeters at the top, and thirty centimeters at the height inside. The mold is put on a flat, non-absorbent surface. The new test sample of concrete is taken from the pan mixer immediately after mixing and inserted into the cone mold in three layers; each layer It has been crushed 25 times with a normal tamping rod. The cone mold is released, this allows the concrete to settle. The average height between the mold and the highest point of the falling concrete is measured in order to get the slump value.

Figure 3 illustrates how workability is declining. The workability decreases when waste ceramic powder is used in place of cement. The slump value of mixes continues to decrease as CWP substitution increases. This is a result of the CWP particles' asymmetrical and angular shapes. According to Kanaan1a and EL-Dieb [29], CWP has 1.5 times the specific surface area of cement. Furthermore, Cement particle gaps can be filled by CWP. The outcome is an increase in the friction between the particles of concrete which might reduce the slump value.

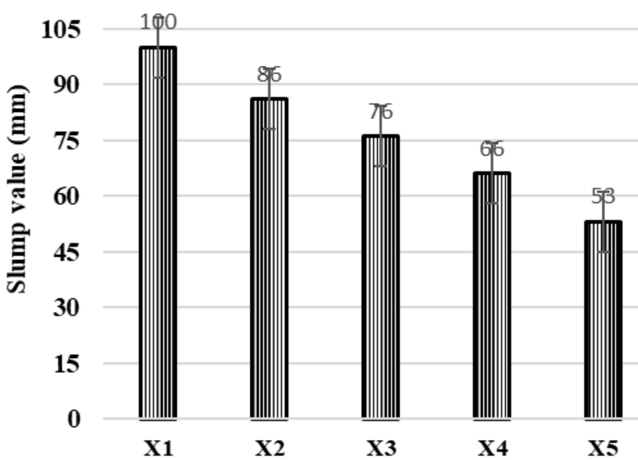

Figure 3 Slump Value of mixes

3.2. Compressive strength test

It refers to the ability to carry weights on a surface without cracking or distortion. On the seventh and 28th days following casting, cube specimens measuring 150X150 mm were compressed in line with ECP 203. Each concrete mix design's outcomes are provided in Figure 4. It observed a 9.85% improvement in compressive strength of concrete containing 10% CWP compared to the reference concrete. Concrete's strength is increased by the presence of silica and aluminum, which react with cement to generate more cement compounds, this chemical reaction is known as the pozzolanic reaction [30].

When 20% of cement was substituted with CWP, the strength decreased by 7.35%. Further increases in CWP content often degrade cement-aggregate connections [32]. When replacing cement with large volumes of ceramic waste powder, there is an absence in calcium hydroxide caused by hydration the cement and reacting with the silica in the powder [33].

3.3. Tensile and flexural strength test

Ceramic mortar's tensile strength increased over time in comparison to cement mortar. It was discovered after 28 days that, under the same conditions and treatment, the ceramic's tensile strength is equal to 4.34 MPa, or 14% more than the cement's tensile strength. as shown in Figure 5.

On the same approach, it was found that the bending strength of the ceramic mortar is 3.85 MPa, so it is more than the cement mortar approximately 12%.

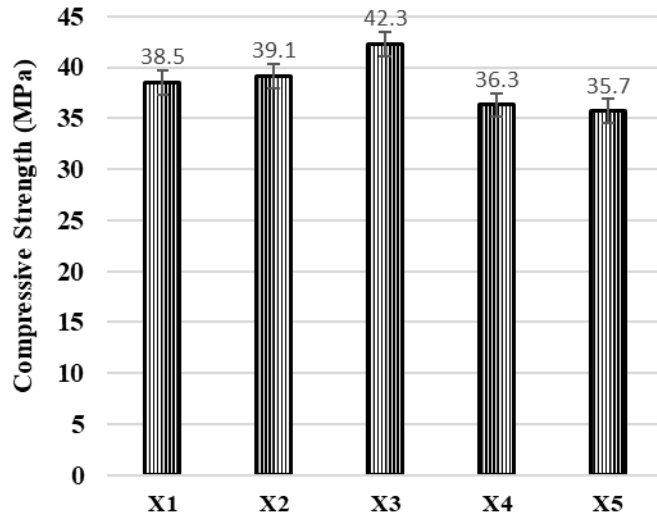

Figure 4 Compressive Strength Value of mixes

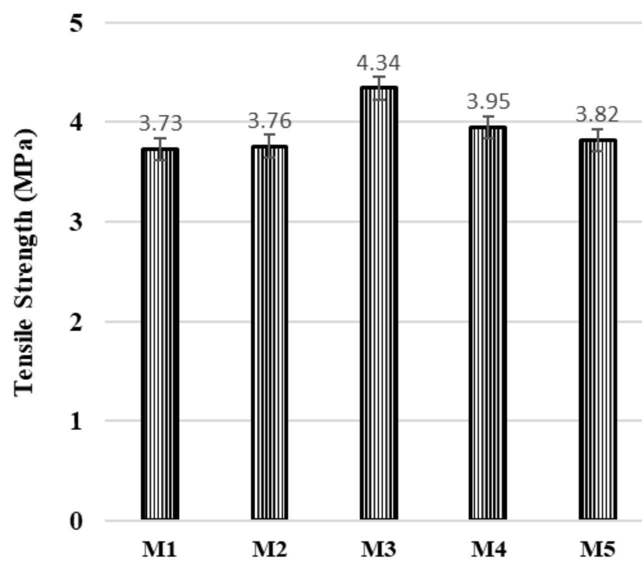

Figure 5 Tensile Strength Value of mixes

4. Conclusions

- One of the most effective, economical, creative, and ecologically responsible ways to raise the performance of concrete structures is through the use of green concrete. It is advised that green concrete be used in significant infrastructure projects across the globe.

- Concrete workability decreased with CWP due to the CPW is angular in shape and has continuously graded particle size distribution. Moreover, the primary constituents are SiO_2, Al_2O_3, Fe_2O_3, and CaO.
- It was found that using ceramic waste powder in place of cement improved the strength properties of concrete.

Conflict of Interest

The authors declare no conflict of interest.

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