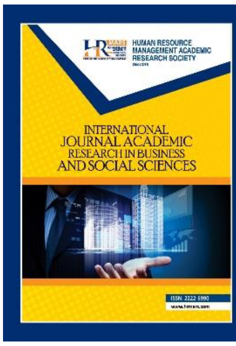

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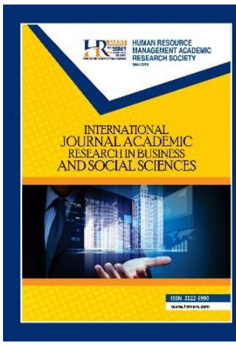

Properties of Concrete with The Inclusion of Ceramic Waste As Coarse Aggregate

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Abstract

Ceramic tile waste, which is obtained from construction sites, demolition sites, and manufacturing industries, has a negative impact on the environment. Recycling these ceramic tiles to produce concrete could be a useful strategy for preserving the environment and enhancing the concrete's inherent qualities. To lessen the impact of waste materials on the environment, this study seeks to ascertain whether it is feasible to substitute waste materials from ceramic tiles as coarse aggregates in the production of concrete. Experimental studies were conducted and the concrete grade 30 was tested for slump test, compression test, and water absorption test, at various curing times of 7, 14, and 28 days. Additional water absorption of the CTA lead to increased water demand, which then increased the levels of porosity and reduced workability. The high porosity of the CTA concrete reduces the density of the concrete and has an impact on compressive strength. CTA has the probability to be used, but precaution needs to be required, especially for higher replacements that may influence the compressive strength and thus partial replacement is suggested.

Keywords: Ceramic Tile Aggregates (CTA), Compressive Strength, Normal Concrete, Slump Test, Water Absorption, Workability

Introduction

Crushed ceramic tiles are an industrial waste that pollutes the environment. The potential use of this material would therefore lessen the environmental pollution. Additionally, there hasn't been much research on utilizing waste from conventional ceramic tiles for structural concrete production as a partial alternative for coarse aggregates. Issues regarding environmental contamination will arise when appropriate action is not taken to address this issue. The aim of this study is to determine whether it is possible to replace coarse aggregates with waste materials from ceramic tiles in the production of concrete to determine the solution of reducing the impact of waste materials on the environment. From an economic perspective, cement and coarse aggregates make up a large share of the costs in the manufacturing of concrete; therefore, substituting waste material with similar properties would be highly beneficial economically and environmentally. Ceramic wastes have been discovered to be appropriate for use as a partial replacement for coarse aggregates in the manufacturing of cement. According to research, they may be used in mortars and both structural and non-structural concrete. In terms of qualities such as density, toughness, permeability and compressive strength, they were discovered to perform better than regular concrete (Adekunle et al., 2017).

Concrete is a manufactured product consisting of cement, aggregate which is sand as fine aggregate and gravel as coarse aggregate, water, and admixture if necessary. The use of recycled aggregate in the production of concrete has been adopted to protect this resource. The common recycled aggregate that is usually used in the construction industry is Recycled Concrete Aggregate (RCA). Due to the fast growth of the infrastructure, a lot of building and demolition waste is produced. The loading and exposure conditions of the demolished structures are generally what determines the grade of the recycled aggregate. Unfortunately, these aggregates can have a wide range of compositions, and as a result, their characteristics greatly affect the characteristics of the concrete. In fact, recycled concrete aggregates (RCA) used in concrete have inferior qualities compared to natural aggregates. Since abhorred mortar is a porous substance and its porosity is dependent on the water cement ratio of the recycled concrete used, the quantity and quality of adhered mortar impacts the physical characteristics of the recycled aggregates (Otoko, 2014). According to Matar & El Dalati, in a 2012 study, it has also been demonstrated that using RCA in the production of precast concrete blocks for walls without any natural aggregates is not at all cost-effective due to the need to add a disproportionately large amount of cement to achieve the necessary compressive strength.

Even though recycled aggregate is frequently used in developed countries such as the United Kingdom, South Korea, and Japan, Malaysia's use of it in the construction industry is considered new. The lack of recycled aggregate performance reviews in concrete and an adequate supply of natural resources are probably the factors that cause recycled aggregates to be less used in the construction industry. In this study, the proposed idea was to replace concrete waste with ceramic waste as a recycled aggregate. This material has been selected because it consists of some special characteristics and is beneficial to the users.

Numerous studies have compared the use of ceramic waste with concrete (Pacheco-Torgal & Jalali, 2010; Prahara & Meilani, 2014; Shruthi et al., 2016; Elci, 2016; Anderson et al., 2016; Kannan et al., 2017; Rashid et al., 2017; Chen et al., 2017; Bommisetty et al., 2019; Huseien et al., 2020; Daniel & Sangeetha, 2020; Goyal et al., 2021 have investigated the utilization of ceramic waste in different percentages of replacement for fine and coarse aggregates in concrete. The results showed that it would increase both mechanical properties and durability properties at different percentages of replacement. Another research carried out by Aly et al (2019); 2017; Bhogilal & Jayantilal (2018), resulted that mechanical properties were reduced with an increase in crushed ceramic tile in self compacting concrete. In this study, coarse aggregates were replaced by CTA to produce concrete specimens. Then, the workability, compressive strength and water absorption of the CTA concrete were examined by conducting mechanical and physical tests.

Methodology

The experiment was conducted in the concrete laboratory. The process flow is shown in Figure 1 and includes ingredients selection like cement, fine aggregates, coarse aggregates and ceramic tile aggregates.

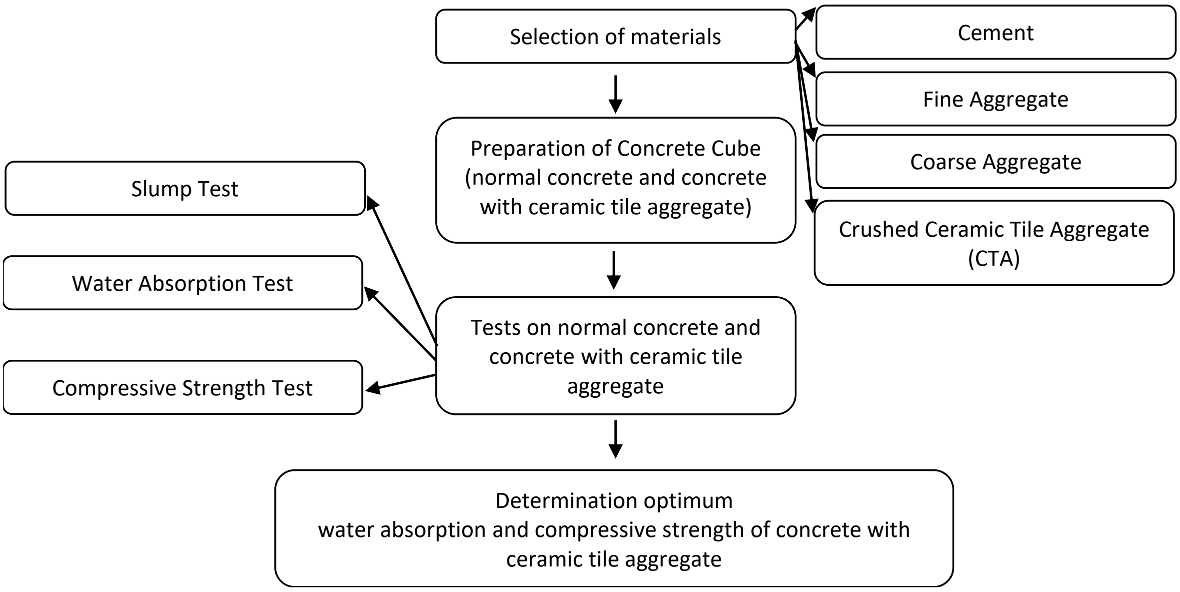

Figure 1: Flowchart of the processes involved

The concrete is prepared for the grade 30 prescribed mix design. In place of coarse aggregate, CTA is used as 100% coarse aggregates. Figure 2 shows the materials used for the cube preparation. Materials are combined by taking the quantities into account according to the mix design. For the workability test, a slump test was conducted as per Standard Specifications for Building Works 2020 (PWD, 2020). The mould has a dimension of 100x100x100 mm in three (3) approximate equal layers. In each layer, compaction is done by using a tamping rod. Moulds are prepared for different proportions as per the design. The moulds are cured for 7, 14 & 28 days under no dry conditions until they are tested. The concrete cube specimens are tested at the ages of 7, 14 and 28 days of the curing period for the compression test and water absorption test. For the water absorption test, the weight of the concrete cubes is recorded before the cubes are dried in the oven. After 24 hours in the oven, the dried cubes are weighed and recorded (BS 1881-122, 1983). For the compression test, concrete cubes are placed on a compression test rig and the maximum load is applied to the cube. The compression test measures the capacity of the concrete to withstand load before experiencing failure (BS EN 12390-3:2001, 2001).

Characteristic of Materials

- Cement: Cement is a fine powder that can create a mechanically strong material when mixed with water and allowed to set and harden. Ordinary Portland cement grade 33 is the type of cement that is most frequently used.
- Fine aggregates: Sand that is close to the riverbed quality and is readily available locally is used as fine aggregates. The term "fine aggregates" refers to fractions with a size between 4.75 mm and 150 microns.
- Coarse aggregates: The term "coarse aggregates" refers to fractions larger than 4.75 mm. The used crushed aggregates or gravel has a nominal maximum size of 20 mm.
- Ceramic tile aggregates: CTA are ceramic tiles crushed uniformly to about 20mm in size done manually using a hammer and sieved through 20mm.
- Water: Water that is readily available from local sources and meets the requirements of water for curing and concreting.

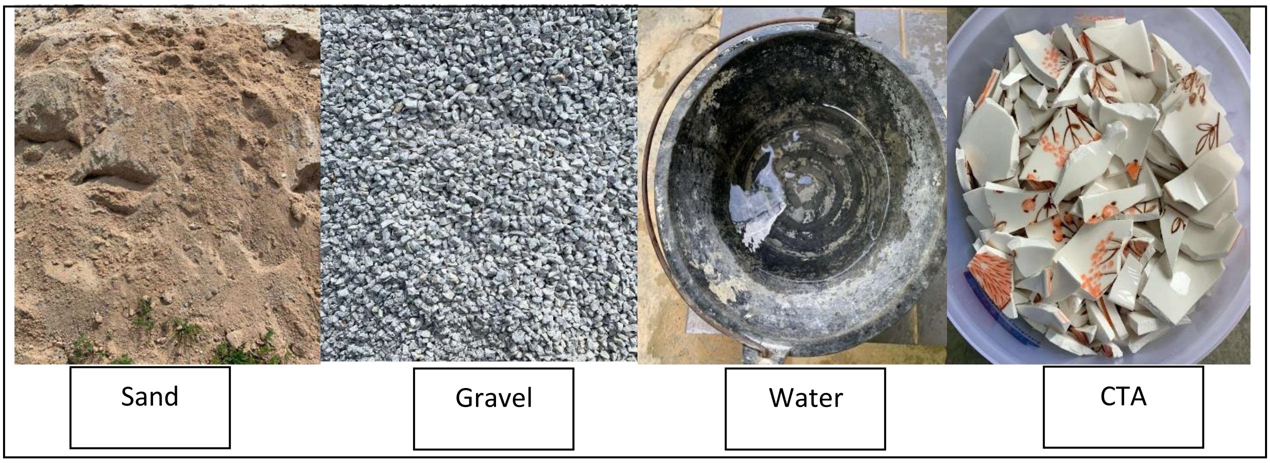

Figure 2: Materials used for cube preparation

Table 1
Mix Proportion of samples

QUANTITIES	**CEMENT (kg)**	**WATER (kg or litre)**	**FINE AGGREGATE (kg)**	**COARSE AGGREGATE (kg)**
Per m³ (to nearest 5kg)	352	190	680	**1208**
Normal Cube Concrete for testing **Size: 100 x 100 x 100 mm (9 cubes)** **Convert mm to m = 0.1 x 0.1 x 0.1 (9) = 9 x 10⁻³ = 0.009 m³**				
Per trial mix of 0.009 m³	352 x 0.009 = 3.17	190x 0.009 = 1.71	680 x 0.009 = 6.12	**1208 x 0.009** **= 10.87(Gravel)**
Product Cube Concrete for testing **Size: 100 x 100 x 100 mm (9 cubes)** **Convert mm to m = 0.1 x 0.1 x 0.1 (9) = 9 x 10⁻³ = 0.009 m³**				
Per trial mix of 0.009 m³	**352 x 0.009** **= 3.17**	**190x 0.009** **= 1.71**	**680 x 0.009** **= 6.12**	**1208 x 0.009** **= 10.87(CTA)**

The mixed proportion of concrete grade 30 was prepared in the laboratory. The following materials shown in Table 1 were used: cement, fine aggregates, and coarse aggregates/cement tile aggregates and mixed in a particular ratio in the form of a dry state.

Analysis and Discussion

Slump Test

Figure 3: The result of the Slump Test

Slump tests were performed to assess workability by measuring the slump value. The workability of the fresh concrete and CTA concrete are judged by its suitability in the conditions of handling and placing so that, after compaction, it surrounds all reinforcement, tendons and ducts and completely fills the formwork. Workability of the concrete shall be within ± 25mm or ± one third of the designed workability (75mm), whichever is greater (PWD, 2020). From Figure 3, the result of the slump test for CTA concrete was 50mm. While the slump test result for normal concrete was 100mm. It showed that the slump test result of CTA concrete was less than normal concrete due to 100% replacement of CTA and it became less workable.

Compressive Strength Test

The cubes were cast and kept for curing in a water tank at three different ages, 7 days, 14 days, and 28 days. Then, the concrete cubes were tested with a compression testing machine (CTM). The concrete cube specimens were loaded until they reached the failure mode(BS EN 12390-3:2001, 2001).

The comparative study of normal concrete and CTA concrete is shown in Figure 4. Based on Figure 5, the average compressive strength data for Days 7, 14, and 28 of curing reveals that normal concrete provides more strength in comparison to CTA concrete. According to the overall compressive strength test findings, both normal concrete and CTA concrete meet the compressive strength specifications (JKR Standards Specification for Building Works) for the prescribed mix.

It can be observed that there is a significant decrease (of about 6 Mpa) for the concrete mixture with CTA. It is predicted that the concrete compressive strength will become lesser when the density of the specimen is low. The high porosity of the CTA specimens reduces the density of the concrete and creates an impact on compressive strength, which is align with the findings from Prahara & Meilani, 2014. Figure 5 shows the samples of normal concrete and CTA concrete specimens after running the Compressive Strength Test.

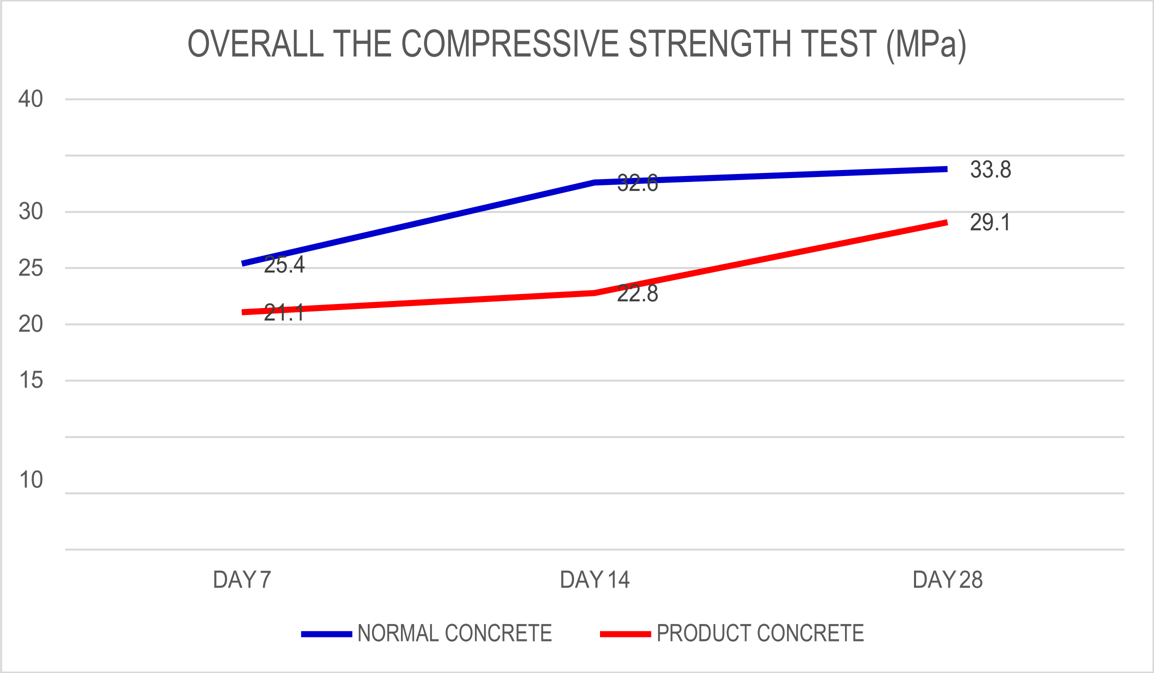

Figure 4: Graph of the overall results of the Compressive Strength Test

Figure 5: Samples of the normal concrete and CTA concrete specimens after running The Compressive Strength Test

Water Absorption Test

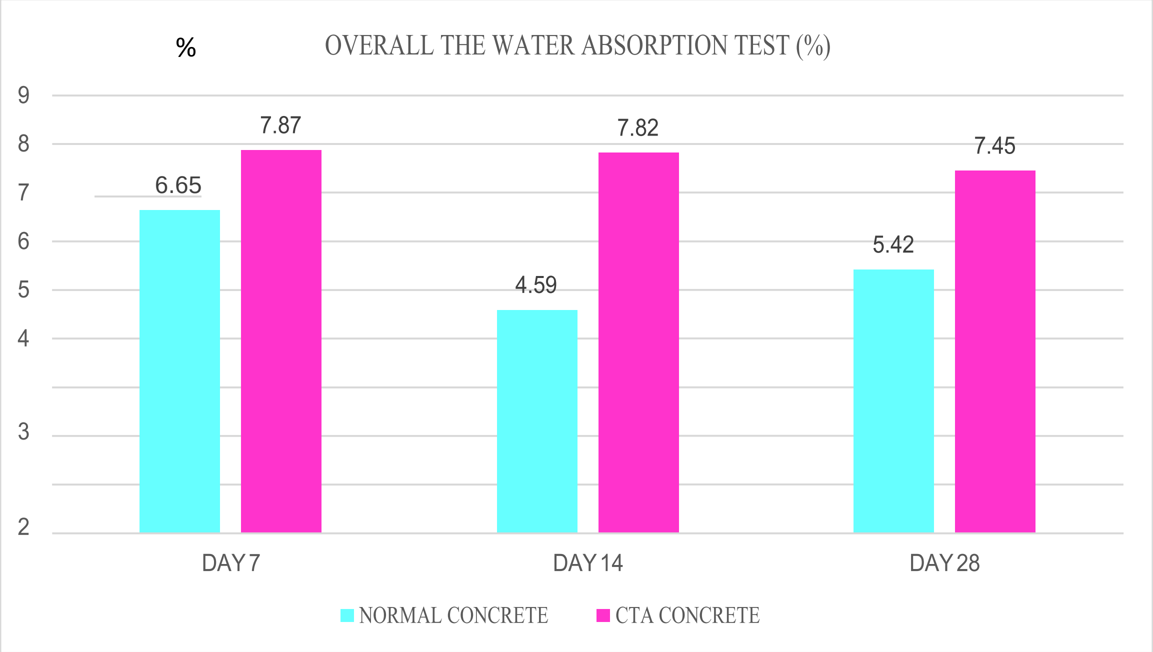

Figure 6: Graph of the Overall Results of the Water Absorption Test

The graph in Figure 6 above shows the overall results of the water absorption test for day 7, day 14 and day 28. On day 7, the average water absorption for normal concrete is 6.65%. While for the CTA concrete, the average water absorption obtained is 7.87%. Following, for day 14, the average water absorption for normal concrete is 4.59%. While for the CTA concrete, the average water absorption obtained is 7.82%. In addition, for day 28, the average water absorption based on the water absorption test for normal concrete is 5.42%. While for the CTA concrete, the average water absorption obtained is 7.45%. From the findings, it can be deduced that water absorption by the ceramic tiles aggregates is greater which leads to higher water demands and decreases its workability. Considering that water absorption of the specimen is high, the level of porosity becomes high whilst the density of the specimen becomes low and these results align with the findings from Prahara & Meilani, 2014.

The Potential of CTA Concrete

In essence, marketability refers to a brand's, product's, or service's capacity to compete in a specific market. To put it another way, it has the probability on whether a product will sell as well as the risk that it won't. In terms of marketability, further factors to be considered are customer needs, product quality, cost, price, usability and performance, as well as reputation and recognition to compete in a crowded market and the ability to reach customers (Spacey, 2017).

According to the research that has been done, the production of CTA concrete made from recycled ceramic materials has the ability to compete in the local market. This is due to the fact that CTA concrete has several distinctive properties that provides value that is not found in other types of normal concrete. It is therefore not improbable that customers, particularly those involved in construction, to prioritize CTA concrete in future projects.

The main component, ceramic, which is widely accessible in Malaysia, is one of the distinctive qualities of CTA concrete, that enables this product to compete in the market. This is because Malaysia is a major manufacturer of ceramic materials in Asia. Due to being the primary material that is always readily available, obtaining it for use in the construction industry does not provide an issue. Additionally, as the primary component is readily available in Malaysia, there is no need to rely on manufacturers from other nations to obtain the necessary raw materials, thus reduces costs. If ceramic is to be utilized in the building industry, it may be purchased from local suppliers for a relatively low price.

Due to the use of CTA concrete which is based on ceramic that is easily available and the cost is relatively low, it may become a high customer requirement, especially for the construction sector. This is because it is certain that they are searching for materials that are easy to find compared to materials that are difficult to obtain. In addition, it is sure that they prefer to select materials that are cheaper and deliver them profit instead of choosing expensive materials that will only cost more expenditure. As a result, due to the existence of this CTA concrete, it can satisfy customer needs while competing with other local businesses.

Conclusion

The following conclusion can be drawn from the subjective measurement:

- The result of the slump test of CTA concrete showed it has less workability compared with normal concrete.
- 100% replacement of CTA as coarse aggregates is not appropriate because it decreases the compressive strength by around 6 MPa compared to normal concrete.
- CTA has the probability to be used, but precaution needs to be required, especially for higher replacements that may influence the compressive strength. Therefore, it’s been suggested that CTA be used as partial replacements which indicates that CTA has the potential to be used as coarse aggregates for concrete.
- It can be concluded that additional water absorption from the CTA leads to increased water demand, which then leads to increase levels of porosity and thus reduces workability. The high porosity of the CTA specimens reduces the density of the concrete and partakes an impact on compressive strength.

The experimental findings demonstrate that ceramic wastes can be reused as an alternative building material in the construction industry. It reduces the impact of contamination and the risk of environmental pollution while also boosting the country's economy. These concepts may be useful in directing the activities of those parties participating in the construction sector, especially in green building material businesses.

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