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Effect of Recycled Homogeneous Ceramic Waste Aggregates on Water Absorption of Mortar

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Abstract

Nowadays, concern for environmental issues encourages the researchers to find a solution for reducing depletion of natural resources. Utilizing the industrial wastes as a construction material is a win-win situation which has two benefits; first, will solve the problem of the landfill and on another hand by recycling and reusing the waste will increase natural materials reservation life span. Ceramic wastes are one of the by-products of ceramic manufacturing, which is directly meant for landfill ends traditionally. There have been several studies on replacement of ceramic waste with concrete admixture. However, there is no research on the effect of the using high rate of ceramic waste replacement on the rate of water absorption. This experimental work focuses on utilizing the homogeneous ceramic wastes as recycled aggregates and partial cement replacement and verifies the effect of this replacement on water absorption of mortar. River sand fully replaced by recycled ceramic aggregates and 40% of cement was replaced by fine ceramic powder. The specimens were cast in 100 x 100 x 100 mm cube for compressive strength test and water absorption test. Mortar containing the recycled ceramic wastes shows lower water absorption in compared to control specimens where the rate value, at the age of 90 days, are 1.32% and 2.11%, respectively.

Keywords: Water absorption, homogenous ceramic wastes; mortar

1. Introduction

Study on the utilizing of industrial and agricultural wastes as an alternative source for construction material started as early as 1937 [1]. In many developed countries, more than 80% of the construction materials comes from demolishing structures. Nowadays, utilizing the industrial and agricultural wastes as a construction material (such as pulverized fuel ash and palm oil fuel ash) are common. Utilizing the waste materials as construction materials depend upon the type of the wastes have some advantages and disadvantages. The waste materials that usually being used for casting mortars can be divided into two types, which are as aggregates or binder.

Limited research has been conducted on the water absorption of concrete incorporating recycled ceramic wastes [2, 3]. It is while this downstream and upstream requirement of multifunctional material is very critical for the success of and R&D activity in construction material research [4]. The previous researchers stated that the water absorption ultimate decreases will happen in the specimen with 20% ceramic powder replacement [5]. On the other hand, another researcher reported that by with replacing cement with ceramic waste powder (10, 20 and 30%), the water absorption increase if the ceramic waste content increases [6]. It was reported that the ceramic concrete shows more porous nature with higher ceramic powder content. It indicates that the concrete with higher ceramic powder content tends to absorb more water due to greater porosity. Therefore, more research works are required to investigate the water absorption of concrete containing fine ceramic powder. Furthermore, for the ceramic aggregates replacement, Tavakoli et al. [7], mentioned that by

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increasing the ceramic aggregates replacement (10, 20, 30 and 40%), the water absorption of the mortar also increased. This performance is probably due to the flakiness shape of ceramic aggregates and the existence of pore itself. However, the research findings showed that by replacing with less than 10% ceramic waste aggregates, the water absorption reduced which is similar to the study reported by previous researchers [8]. A similar result was reported where the replacement level of 20% ceramic waste aggregates led to reducing of capillary water absorption [9]. In some studies, the uses of recycled aggregates as aggregates replacement cause increasing the water absorption [10,11]. Also, some researchers reported about water absorption of recycled aggregates itself. Depend on the sources of recycled aggregates the value of water absorption is different. The water absorption of ceramic recycled aggregates is less than natural aggregates due to the smooth surface of them [12]. Therefore, it is necessary to study the effect of ceramic waste on the water absorption of mortar.

2 Materials and Test Methods

2.1 Materials

Ordinary Portland Cement (OPC) satisfying the requirement of ASTM C150-15 for cement Type I was used. OPC was obtained from local cement producer in Malaysia. The ceramic wastes were collected from a ceramic factory located in the south of Malaysia as shown in Figure 1. The ceramic waste utilized in the form of ceramic powder (as cement replacement) and fine ceramic aggregates (as fine aggregates replacement). The process for preparing the ceramic waste is similar to the previous research [13]. Normal quality Tap water (which was available in the laboratory) was used in experiments. Saturated surface dry (SSD) fine aggregates were used which had a specific gravity of 2.62 and fineness modulus of 2.85. Fine aggregates were modified according to ASTM C33-13. The well-graded aggregates usually reduce the demand for water and thereby, improve the packing density, robustness and workability of the mortar. Mix proportions of mortar are shown in Table 2.

Figure 1: Ceramic waste abandoned in manufacturer

2.2 Testing procedure

Water absorption test was conducted based upon the specification of BS 1881: Part 122. First, three specimens were kept in the oven for 72±2 hours at 110±5°C to remove the moisture content. After that, the specimens were cooled in the vacuum container for 24±0.5 hours. Next, the specimens were weighed and submerged in the water container until 25±5 mm depth water on top of the specimens. The specimens were left in water for 30±0.5 minutes to ensure the water absorption. After, the specimens were dried with a towel to remove the excessive water over the surface. The specimens were then weighed to get the weight of wet specimens. The water absorption was then calculated using the following equation as specified in Equation 1.

$$W_a = \frac{W_w - W_d}{W_d} X\ 100 \qquad \textit{Equation 1}$$

where W_a is percentage of water absorption (%), W_w is weight of wet specimen (g), W_d is weight of dry sample (g).

Table 1: Mix design of OPC and ceramic mortars

Mortar mixes	Cement	Ceramic powder	Sand	Ceramic fine aggregates	w/c Ratio
OPC	550	-	1460	-	0.48
Ceramic	330	220	-	1460	0.48

*all units are in kg/m^3

3 Result and Discussion

3.1 Water Absorption

The volume of porosity in a mortar, as distinct from the ease with which a fluid can penetrate it, is measured by water absorption test. The water absorption cannot be used as a parameter to measure the quality of mortar, but in general, the best quality concrete or mortar have an absorption below 10% [14]. Figure 2 shows the water absorption of the control specimens and ceramic mortars up to the age of 90 days.

The water absorption for control specimens and ceramic mortars at 90 days were 2.11% and 1.32%, respectively. At 90 days, ceramic mortar shows lower water absorption compared to control specimens by 37%. This performance was most likely due to the decreasing in the porosity of mortar with the formations of calcium silicate hydrate gel from the pozzolanic reaction that gradually fills the pore. Another possible reason is that higher fineness of unreacted ceramic powder that would act as filler. Besides, it is evidenced that more C-S-H gels were produced at an early age resulting in the higher compressive strength of the mortar.

At 7 days of curing, the water absorption for ceramic mortar was high, possibly due to the small particles size of ceramic powder that has larger surface area thus, and tends to absorb more water. However, as the age of water curing increases, the water absorption was reduced. The application of continuous water curing for 28 days has enabled ceramic particles in the mix to be actively involved in the pozzolanic reaction. Thus, it is successfully modifying the internal microstructure of mortar to be denser. Therefore, the use of ceramic wastes can successfully reduce the water absorption of mortar with prolonging curing age.

Figure 3 shows the relationship between water absorption and compressive strength of control specimen and ceramic mortars. The R2 values obtained for control specimen and ceramic mortars were 92% and 96%, respectively for the linear equation showing a good correlation between water absorption and compressive strength of ceramic mortar. The compressive strength of control specimen and ceramic mortars increases with the decrease in water absorption due to less porosity inside the mortar.

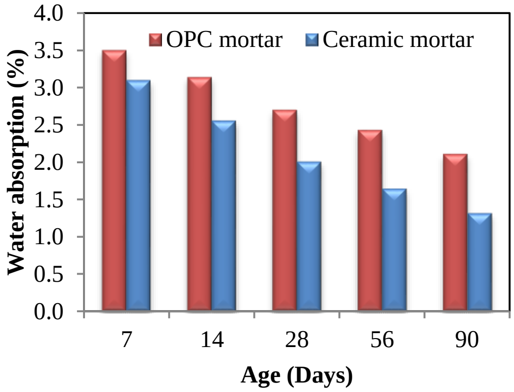

Figure 2: Water absorption of control specimen and ceramic mortars

The correlation was determined for compressive strength and water absorption values within the range of 40.34 MPa to 58.73 MPa and 1.3% to 3.1%, respectively. Hence, the reactive silica content and fineness of the ceramic powder act as an important factor for the water absorption and compressive strength of ceramic mortar. Also, fine ceramic aggregates itself have less water absorption compared to the river sand, which is played a positive role in the reduction of water absorption of ceramic mortar.

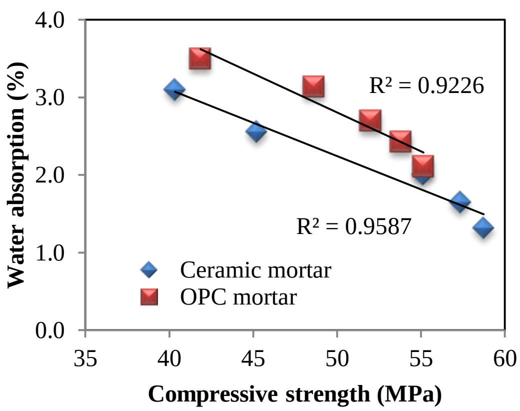

Figure 3: Relationships between water absorption and compressive strength of control specimen and ceramic mortars

Furthermore, the hardened state properties of ceramic mortar were improved at later ages due to the greater hydration cement and enhanced pozzolanic activity of ceramic powder. In general, strength properties of the mortar increased as the age of curing increased. At an early age, ceramic mortar developed lower strength properties such as compressive strength, flexural strength and splitting tensile strength but gradually increased with the increasing age of curing. The hardened state properties of ceramic mortar were improved with higher content of binder due to the micro-filling characteristics and pozzolanic reactions that improved the paste densification. The water absorption was decreased with prolonging curing time resulting in an increased compressive strength.

4 Conclusions

Ceramic waste can be used as cement replacement and fine aggregates replacement in mortar production. The result from this study shows that the ceramic waste increased the compressive strength and reduced the pore within the mortar. Ceramic mortar shows lower water absorption rate in compared with OPC mortar where the values at the age of 90 days are 1.32% and 2.11%, respectively.

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