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Utilizing of waste ceramic powders as filler material in self-consolidating concrete

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HIGHLIGHTS

- Reuse of waste materials in concrete mixes is a way of waste management.
- Waste ceramics were finely grounded for possible evaluation in SCC as filler material.
- Cement was substituted with waste ceramic powders finer than 125 μm in SCC mixes.
- An improvement was observed on flowability of the fresh SCC up to 15% WCP ratio.
- WCPs has potential to evaluate in self-consolidating concrete mixes as filler material.

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ABSTRACT

Using filler materials finer than 0.125 mm is quite effective on the fresh state properties, strength and durability of self-consolidating concretes. Most common filler materials used in self-consolidating concretes are minerals, blended cements and natural or artificial pozzolans. In this study, usability of granulated waste ceramic powder as filler material in self-consolidating concretes was investigated. Properties of self-consolidating concretes produced with 550 kg/m^3 dosage and cement was replaced with (WCP) in the amounts of 5%, 10%, 15% and 20% (by weight) were determined in the fresh and hardened phases. As a result, it is determined that use of WCP has some positive effect on viscosity of the mixes. However, a slight decrease was observed on the strength values based on the substitution of cement with ceramic powder. It can be concluded that finely ground WCPs could be evaluated up to 15% for production of self-consolidating concretes as a filler material if the strength and flowability parameters are evaluated together.

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1. Introduction

Some of the concrete types need high amounts of cement and consequently several disadvantages can be encountered such as potential of high hydration heat, risk of quick setting, shrinkage and high cost etc. In addition to that one of the big problems of cement production is high carbon emission during raw material procurement and production of cement [1,2]. Recently, various studies have been performed in different laboratories in an attempt to find alternative raw materials can be used instead of cement. Use of some natural and/or artificial pozzolans and minerals such as fly ash [3–7], ground granulated blast furnace slag [8–14], silica fume [15–23], calcite [8,24,25], metakaolin [26–30], diatomite [31–34], zeolite [35], brick powder [36–38], and waste marble dust [39–42] are widely evaluated for use them in the production of different types of concretes.

Self-consolidating concretes (SCCs), one of the most popular concrete types, have high durability performance and fresh state characteristics of SCCs are not available in traditional concretes. In addition to their systematic mix proportion, filler materials are essential for production of SCC. In the text drafted by EFNARC describes the function of inert or semi inert, pozzolanic and hydraulic additives/fillers materials of particle sizes smaller than 0.125 mm as to improve and maintain the cohesion and segregation resistance of SCC [43,44]. In earlier studies, fly ash, silica fume, ground granulated blast furnace slag, limestone powder and blended cements are commonly preferred to manufacture of SCC [7,15,17,45–49]. As a matter of fact that the effects of these fillers on strength and durability performance of SCC are non-negligible.

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However, usability of different kind of filler materials has been investigated and some of the alternatives have been asserted recently. Some of the materials such as calcite, brick powder, waste marble powder, metakaolin etc. are highly interest by the researchers [8,26,37,42].

Ceramic is a product made of clay, feldspar and quartz as basic raw materials which are processed through mixing, molding, drying and burning. When it is applied to building projects, it is called building ceramic which is a popular materials preferred in walls and floors in construction industry [50]. Senthamarai and Manoharan (2005) have indicated that 30 percent of daily production of ceramic industry goes to waste. This waste is not recycled in a sufficient way at present [51]. A huge amount of ceramic wastes arose from both manufacturing and application and also maintenance stages. Although there are no realistic solutions of the management of these wastes, some of the researchers have been used ceramic waste as aggregate or filler in traditional concrete mixes [51–55]. As the ceramic waste is piling up every day, there is pressure on the ceramic industries to find a solution for its disposal [51]. There are some of the studies focused the reuse of ceramic wastes in construction industry. Ceramic wastes have been used as road fill, as a partial substitute instead of fine or coarse natural aggregate, and cement replacement in the mortar and pavement in the previous studies [56–61]. Torkittikul, and Chaipanich (2010) investigated the feasibility of using ceramic waste and fly ash to produce mortar and concrete, and they indicated that the compressive strength of ceramic waste concrete was found to increase with ceramic waste content and was optimum at 50% for the control concrete [62]. Medina Martinez et al. (2009) reported that, ceramics industry wastes (recycled ceramic aggregates) are suitable for the manufacture of concrete [56]. Alves et. al. (2014) pointed out that, regarding the mechanical performance, in terms of compressive and tensile strength, the use of ceramic recycled aggregates for concrete is suitable [63,64].

Ceramics are construction materials, made of mixing and heating of feldspar and quartz. In this study, fine grounded WCPs were used to product self-consolidating concrete with the idea of having a high potential of filler effect. Fresh and hardened state properties of self-consolidating concretes including 5 different ratios of ceramic powders (0%, 5%, 10%, 15% and 20% by weight of cement) substituted with cement have been investigated.

2. Materials and method

2.1. Materials

CEM I 42.5 R type cement obtained from Oyak Bolu Cement Inc., limestone aggregate with 0–5, 5–12 and 12–20 mm grain sizes, Sika Viscocrete BT8 trade mark superplasticizer was obtained from Sika Construction Chemical Company in Turkey and ground granulated waste ceramic wastes were used to produce self-consolidating concrete mixtures. Chemical compositions and particle size distributions of cement and ceramic powders used in this study are summarized in Table 1 and Fig. 1 respectively. Waste ceramics were firstly grounded in Los Angeles abrasion machine and then sieved (<0.125 mm).

Based on the Fig. 1 cement is finer than WCP used in this study. It is determined from particle size distribution analysis that 7.1%, 65.2% and 86.6% of WCP particles (by weight) were passed through the 3 μm, 45 μm and 90 μm sieves respectively. Specific gravity and specific surface area of the WCP are 2.7 and 151.8 m^2/kg respectively while specific gravity and specific surface area of cement are 3.12 and 325.2 m^2/kg respectively. To investigate morphology of the WCPs SEM analysis is performed (Fig. 2).

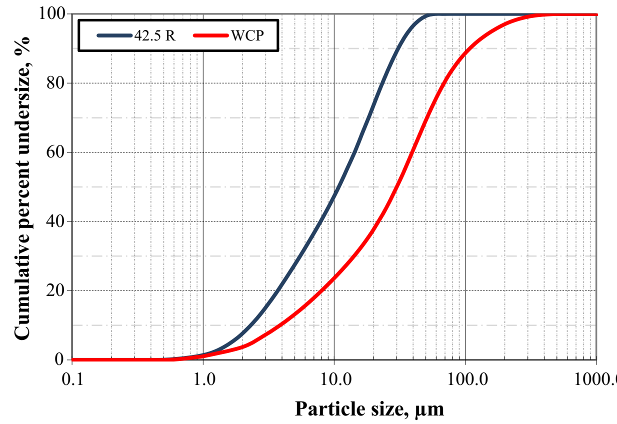

Fig. 1. Particle size distribution of Portland cement and WCP.

When we examine Fig. 2, hard and angular-shaped particle morphology is observed in small quantities. Besides, WCP particles mostly have an irregular shape with high percentage of finer materials (most of the particles less than 10 μm). Based on the EDS analysis main elemental peaks of waste ceramic particles are Si, Ca, Al, Fe and Mg.

2.2. Method

In this study, finely grounded WCPs were substituted for Portland cement at a level of 0%, 5%, 10%, 15% and 20% (by weight). Mix design of self-consolidating concretes including WCPs were given in Table 2.

Production of the self-consolidating concrete mixtures were implemented by using 110 liter drum type concrete mixer and mixture process was as the following. Different grain sizes of aggregates with saturated surface dry conditions were stirred in the mixer about one minute, consequently cement and ceramic powders were added the mixer and stirring was continued for one minute. Then, 75% of the mixing water were gradually added then stirred for a further 1 min. Finally, superplasticizer with the remaining water was added to mixer and left stirring for 4 min before fresh concrete tests.

After the mixing process unit weight, slump flow, j-ring and L-box tests were immediately conducted according to Efnarc 2005. Then the mixes were casted into the 100 × 100 × 100 mm molds for unit weight, ultrasonic pulse velocity, compressive strength and splitting tensile strength tests, and 100 × 100 × 150 mm molds for bond strength tests. A day later after the casting all the specimens were demolded. After then, specimens were placed into a water curing room during 7 and 28 days before testing.

100 × 100 × 150 mm prismatic specimens are used for the bond strength tests. The bonded length of each bar was properly

Table 1
Chemical composition of ceramic powder and Portland cement.

Compounds	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	TiO_2	KO_2	SO_3	L.O.I.*
Ceramic Powder	62.3	16.5	2.37	5.94	0.72	0.31	6.78	0.65	0.01	3.65
Cement	18.37	4.26	3.89	64.04	1.52	0.12	–	–	3.01	4.23

* L.O.I: Loss on Ignition.

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