Construction and Building Materials 144 (2017) 35–41

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

High performance concrete incorporating ceramic waste powder as large partial replacement of Portland cement

Dima M. Kannan [a], Sherif H. Aboubakr [b], Amr S. EL-Dieb [a], Mahmoud M. Reda Taha [b,*]

[a] Civil and Environmental Engineering Department, United Arab Emirates University, United Arab Emirates
[b] Department of Civil Engineering, University of New Mexico, USA

HIGHLIGHTS

- High performance concrete mixtures incorporating up to 40% ceramic waste powder as large partial replacement of cement can be produced.
- High performance concrete mixture incorporating large content of ceramic waste powder showed high strength and excellent durability performance.
- Ceramic waste powder acts primarily as a filler rather than pozzolanic material.
- Producing high performance concrete can be an excellent source for recylcing large quantities of ceramic waste powder.

ARTICLE INFO

Article history:
Received 22 October 2016
Received in revised form 27 February 2017
Accepted 12 March 2017

Keywords:
Ceramic waste powder (CWP)
High performance concrete
Frattini test

ABSTRACT

Ceramic waste powder (CWP) is produced during ceramic tile polishing with potential environmental pollution. CWP is silica-rich, alumina-rich and fine particle size material. High performance concrete (HPC) mixtures incorporating 10–40% CWP as replacement of Portland cement by mass were evaluated. Mechanical, durability and microstructural investigations of HPC mixtures were performed. It is shown that concrete incorporating CWP as large replacement of cement has high strength and excellent durability. Microstructure investigations showed that incorporating CWP did not make significant difference in cement hydration compared with cement without CWP. Performance improvement is explained by the low water/cement ratio of the reference mixture enabling CWP to create dense packing particles.

© 2017 Published by Elsevier Ltd.

1. Introduction

Portland cement production accounts for around 5% of the global carbon dioxide (CO_2) emissions, which is categorized as a major greenhouse gas. While increasing demand on concrete is essential and associated with rapid global development and construction industry growth, cement is the primary and most expensive component of concrete mixture. Partial or full replacement of cement is considered a sustainable solution toward decreasing the environmental impact of cement production and will also contribute to sustainable concrete. This paper investigates the possibility of utilizing ceramic waste powder (CWP) as partial replacement of cement in high performance concrete (HPC) mixture that is characterized by relatively high cement content and low water content. CWP produced during ceramic tile polishing contributes toward environmental pollution. We suggest that using CWP can enable a significant reduction of cement in HPC mixtures without detracting from the concrete's performance.

Irassar et al. [1] studied the utilization of CWP as pozzolanic materials and reported that incorporation of ceramic waste with Portland cement simulates hydration due to enhancement of effective water-to-cement ratio in the system. However, it was claimed that with replacement between 8 to 40% no pozzolan activity was observed at early ages, while good pozzolanic activity was observed at 28 days. Pokorný et al. [2] showed that incorporation of CWP reduced compressive, bending strength, and thermal properties, while improving thermal insulation. For similar ceramic waste, Vejmelková et al. [3] showed that CWP slowed compressive strength development, and the 28 days compressive strength reaching 90% of the reference concrete with no CWP. Similarly, Heidari and Tavakoli [4] and Pacheco-Torgal and Jalali [5] reported reduction in early age compressive strength of concrete with an increase of CWP content but with minor strength reduction at later ages. Wang and Tian [6] showed that pozzolanic activity and strength of concrete incorporating CWP preceded that incorporating fly ash. However, addition of CWP reduced the heat of hydration and increased

* Corresponding author.
E-mail address: mrtaha@unm.edu (M.M. Reda Taha).

http://dx.doi.org/10.1016/j.conbuildmat.2017.03.115
0950-0618/© 2017 Published by Elsevier Ltd.

shrinkage. The microstructure of mortars incorporating CWP demonstrated close-grained, dense, and reticular hydration gel. Reiterman et al. [7] reported that replacing 10% of cement by CWP reduced the mechanical properties by 3%. On the other hand, Cheng et al. [8] reported that replacing cement by 10–40% ceramic waste resulted in reduction of concrete permeability. Cheng et al. [9] also showed that carbonation resistance of concrete with CWP is reduced, while sulphate corrosion resistance is enhanced. Moreover, Mishra and Vasugi [10] showed that 67% of compressive strength of concrete incorporating CWP was achieved within 7 days, while 80% in 28 days, due to the effect of early hardening when producing concrete incorporating CWP with high silica content and ground granulated blast furnace slag. López et al. [11] showed that substituting white CWP for sand resulted in slight improvement of compressive strength. Vijayalakshmi et al. [12] also suggested replacement of sand by granite CWP up to 15%. While researchers showed that concrete incorporating CWP showed good mechanical and durability characteristics, a microstructural investigation of concrete incorporating CWP is necessary to understand the role of CWP in cement hydration and concrete strength development

In this paper, Portland cement was partially replaced in the production of HPC with CWP. An experimental program examining replacing 0, 10, 20, 30 and 40% of Portland cement in 50 MPa HPC mixtures with CWP was developed. Mechanical and durability characteristics of concrete were examined. Furthermore, microstructural analysis of the cement paste (CP) mixtures incorporating CWP and pozzolanic reactivity tests of the CWP were performed.

2. Experimental methods

2.1. Materials

The CWP was obtained from the final polishing process of ceramic products from a ceramic factory in Abu Dhabi, United Arab Emirates (UAE). The CWP was dried and ground to an average specific surface area 555 m^2/kg. Scanning electron microscope (SEM) image of the ceramic powder showed that it consisted of irregular and angular particles that resemble the shape of cement particles Fig. 1(a). Chemical analysis proved that CWP consists mainly of 69.4% SiO_2 and 18.2% Al_2O_3 by mass, as shown in Fig. 1 (b). The remaining 12.4% were other oxides including magnesium oxide (MgO), sodium oxide (Na_2O), potassium oxide (K_2O), and calcium oxide (CaO) at relatively small content of 3.53%, 3.19%, 1.89%, and 1.24%, respectively. The remaining 2.55% by mass represents other relatively insignificant compounds, each with content less than 1%. Chemical analysis was performed using Rigaku ZSX Primus II wavelength dispersive X-ray fluorescence (XRF) spectrometer.

Type I Portland cement was used. The coarse aggregate (CA) was natural crushed stone with nominal size of 19 mm, with a specific gravity of 2.65, and absorption of 1.0%. Two types of fine aggregate (FA) were used in the mixture namely crushed natural sand (FA, Crushed Stone) with a fineness modulus of 3.9 and specific gravity of 2.63, and dune sand (FA, Dune Sand) with a fineness modulus of 1.0 and specific gravity of 2.63. The two types of fine aggregates were mixed to achieve a combined fineness modulus of the fine aggregate ranging from 2.7 to 2.8. Mixing two types of sand was necessary as neither type solely meets ASTM standards and thus cannot be used to produce concrete. A sand mixture ratio was determined to meet ASTM standards.

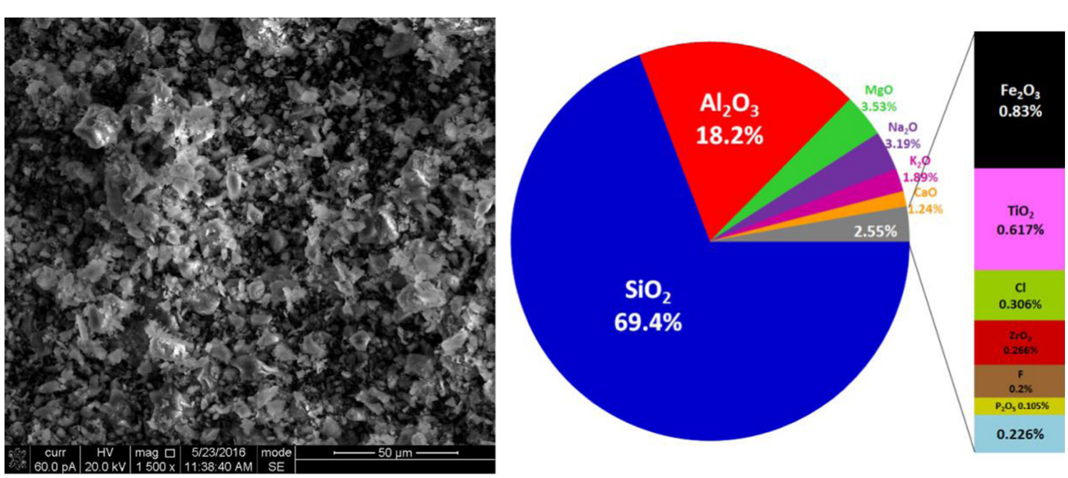
The reference concrete mixture was designed to achieve a slump value of 50 ± 10 mm. The measured slump of the reference mixture was 55 mm. Mixture proportions for the 50 MPa concrete grade (HPC-0, HPC-10, HPC-20, HPC-30, and HPC-40) with CWP as cement replacement with different mass replacement of 0, 10, 20, 30 and 40% of the Portland cement, respectively, are given in Table 1.

2.2. Fresh and hardened concrete testing

The effect of using CWP on fresh and hardened concrete properties was studied. For fresh concrete, slump, slump loss and setting time were measured. For hardened concrete, compressive strength development at age of 28 and 90 days were measured using 100 × 100 × 100 mm cubes. The rapid chloride permeability test (RCPT) was conducted on concrete discs with a thickness of 50 mm cut from 100 mm diameter cylinders following ASTM C1202 [13]. Bulk electrical resistivity was measured using concrete cylinders 100 × 200 mm. Chloride ion permeability and electrical resistivity were used as durability indices [14]. Permeable pores were measured at 90 days of age using ASTM C642 [15].

2.3. Frattini test for pozzolanic activity

Frattinit test [16] was performed to identify the pozzolanic activity of CWP following BS EN 196-5:2011 [17]. In this test,



(a) (b)

Fig. 1. CWP (a) SEM of CWP particles (b) Chemical analysis of CWP.

Download English Version:

https://daneshyari.com/en/article/4913143

Download Persian Version:

https://daneshyari.com/article/4913143

Daneshyari.com