Construction and Building Materials 124 (2016) 866–877

Contents lists available at ScienceDirect

Construction and Building Materials

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

Utilization of waste glass powder in the production of cement and concrete

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HIGHLIGHTS

- Waste glass powder was added up to 25.0% as cement replacement and cement addition.
- The pozzolanic activity of waste glass powder was detected according to ASTM C311.
- Waste glass powder has a significant effect on concrete properties.
- Results are expected to provide a motivation to use waste glass powder on concrete.

ARTICLE INFO

Article history:
Received 19 March 2016
Received in revised form 4 August 2016
Accepted 5 August 2016

Keywords:
Waste glass powder
Strength activity index
Cements replacement
Cement addition mechanical and physical properties

ABSTRACT

The aim objective of this work is to study of the use of waste glass powder obtained from grinding of crushed containers and building demolition to produce glass powder blended cement as concrete additives. The pozzolanic activity of glass powder and properties of glass powder blended cement were evaluated. Also, the effect of using glass powder as cement replacement and as cement addition was studied in the term of physical and mechanical properties. The considered glass powder contents were 0.0%, 5.0%, 10.0%, 15.0%, 20.0% and 25.0% by weight of cement. The test results showed that the glass powder had pozzolanic characteristic and the use of glass powder had insignificant effect on setting time and cement expansion. The use of 10% glass powder as cement replacement enhanced the mortar compressive strength by about 9.0%. Also, generally, the use of glass powder as cement replacement up to 15.0% enhanced the properties of concrete modified with glass powder. Finally, the use of 15% glass powder as cement addition increased concrete compressive strange by 16.0% in average and achieved better performance compared with as cement replacement.

1. Introduction

Concrete, a primary building construction material, is the world's most consumed man-made material. About 800 million tons of concrete was consumed in the U.S. in 2007, and the world consumption was estimated at 11 billion tons, or approximately 1.7 tons for every living human being [1]. Production of cement (the binder in concrete) is an energy-intensive and highly polluting process, which contributes about 5–8% to global CO_2 emissions [2]. This high contribution is due to that production of each ton of cement emits one ton of carbon dioxide (CO_2) to the atmosphere from both of fuel and cement raw material burning [3–6]. The use of solid waste materials or industrial by-products as partial replacement for cement in concrete is a viable strategy for reducing the use of Portland cement, and thus reducing the environmental and energy impacts of concrete production [7].

In Egypt, about 3.45 million tons of waste glass is generated annually and 84% of which is lift in landfills [6]. Fig. 1 shows the wastes of glass in solid resulted from crushed containers, constructions and demolishing in Egypt. Waste glass can be cost-effectively collected in mixed colors. According to Federico and Chidiac, and Jin et al. [8,9], mixed-color waste glass offers desired chemical composition and reactivity for use as a supplementary cementitious material which can benefit the chemical stability, moisture resistance and durability of concrete. To realize this potential, waste glass needs to be milled to micro-scale particle size in order to accelerate its beneficial chemical reactions in concrete.

According to the previous studies in the use of glass powder in concrete production, there were contradictions in the available test results. These contradictions involved fresh and hardened proprieties of concrete modified with glass powder.

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http://dx.doi.org/10.1016/j.conbuildmat.2016.08.016
0950-0618/

Fig. 1. Wastes of glass in solid form resulted from crushed containers and construction demolishing in Egypt.

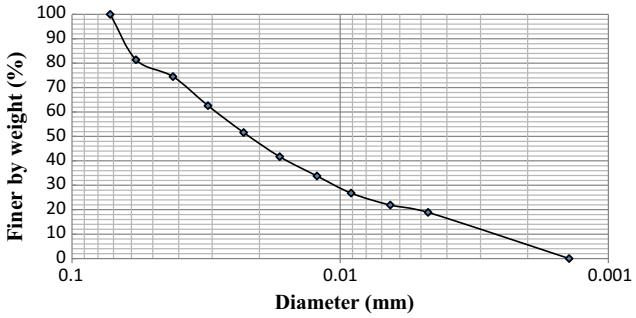

Fig. 2. Grain size analysis of used glass powder.

For fresh state of concrete, Kumarappan [10] presented that there is a systematic increase in the concrete slump as the glass powder passed through 300 μm sieve in the mix increase. The slump ranged from around 40 mm for the reference mix from 0% glass powder to 160 mm at 40% glass powder. Khatib [11] showed that there was a systematic increase in the slump as the glass powder content in the mix increase. Khatib did not mention the size distribution of used glass powder. Chikhalikar [12] investigated on the characteristics properties of fiber reinforced concrete containing 600 μm waste glass powder. Chikhalikar concluded that there is an enhancement in concrete slump is observed up to 40% glass powder as cement replacement. Soroushian [13] utilized milled 13 μm waste glass powder and resulted that slump is

Table 1
Grading and ASTM C33-04 specification limits of used aggregates.

Sieve size (mm)		25.00	19.00	12.0	9.50	4.75	2.36	1.18	0.60	0.30	0.10
Sand	Used sand	100	100	100	100	99	96	80	58	22	5
	Specification limits	100	100	100	100	95:100	80:100	50:85	25:60	5:30	0:10
Coarse aggregate	Used coarse aggregate	100	100	96	45	9	0	0	0	0	0
	Specification limits	100	100	90:100	40:70	0:15	0	0	0	0	0

Table 2
Chemical analysis of Portland cement and glass powder.

Component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	CL^-	L.O.I
Cement	21.73	3.60	1.50	63.20	3.20	2.50	0.27	0.96	0.03	1.90
Glass powder	71.40	2.54	0.37	11.2	1.60	0.16	0.36	12.25	0.04	0.82

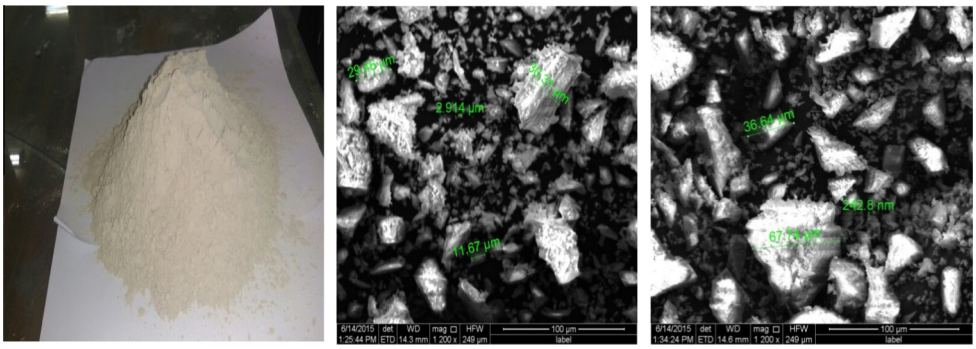

Fig. 3. Particle shape and size of glass powder grains.