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Mechanical Fracture Properties of Alkali-Activated Slag with Graphite Filler

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Abstract

Alkali-activated slag is a building material considered as alternative to ordinary Portland cement based materials. Addition of graphite powder increases its electric conductivity, hence, introducing new functionality to building materials such as self-sensing and self-heating properties. In this study, the effect of graphite filler on the mechanical fracture properties of alkali-activated slag composite is investigated. Graphite powder was added in the amount of 5, 10 and 15% with respect to the slag mass. Modulus of elasticity, fracture toughness and fracture energy were determined using standard three-point bending test on prismatic specimens with central edge notch. The course of fracture tests was also monitored by acoustic emission (AE) method. Compressive strength was determined on the fragments remaining after the fracture tests. Results showed that addition of graphite caused a decrease in compressive strength, fracture toughness and fracture energy but modulus of elasticity increased. Addition of graphite also caused a decrease in AE events and increase in amplitude of signals. This implies that mortars with graphite filler is more brittle than the reference mortar, and lower number of much larger cracks is formed during the fracture test.
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Keywords: Fracture test; Alkali-activation; Slag; Graphite; Acoustic emission

1. Introduction

Alkali-activated slag (AAS) is an attractive alternative to Portland cement, which is generally characterized by a comparable compressive and flexural strength, hardness, chemical stability and improved corrosion resistance. Less

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energy is consumed during its production and it also has a reduced environmental impact, as less greenhouse gases are emitted [1]. Development and assessment of alkali-activated materials have been conducted for over 70 years but an increased interest in the practical applications has taken place in the past decades [2,3]. The structural development of alkali-activated slag is a highly heterogeneous process in which dissolution of glassy phase in highly alkaline medium, nucleation and growth of initial solid phases, their interactions and finally formation of the hard structure take place. The main reaction product is aluminum-substituted C-A-S-H gel with a disordered tobermorite-like structure. This is accompanied by the formation of secondary reaction product depending on the chemical composition of the slag and the activator type used [4,5]. The mechanical properties and application possibilities of alkali activated slag composites are very similar to ordinary cement based concrete. However, in contrast to Portland cement based binders, alkali-activated slag offers superior properties such as higher corrosion resistance against acid or sulphate attack [6–8] and also higher resistance to elevated temperatures and fire [9–11].

Graphite is a polymorph of carbon. Due to its structure in which the carbon atoms are arranged in a honeycomb lattice, it is a good conductor of electricity, and therefore it opens up new application possibilities such as development of self-sensing, self-heating or snow-melting concrete [12,13]. The self-sensing concrete has both structural and sensing functions, so it replaces the need for embedded or attached sensors. On the other hand, addition of conductive filler must not negatively influence the mechanical properties of the concrete itself.

In this study, a new composite utilizing advantages of alkali-activated slag as progressive material and graphite as conductive filler was prepared. The composite was tested for the mechanical fracture properties and the effect of graphite content on the mechanical performance was assessed.

2. Materials

The alkali-activated slag was composed of granulated blast furnace slag supported by Kotouč, s.r.o. (CZ) finely ground to the specific surface of 383 m^2/kg with the mean particle size of 15.5 μm and solid sodium silicate Susil MP 2.0 (Vodní sklo, CZ) as activator. The molar Na_2O/SiO_2 ratio of the silicate activator is 2.0 and the SiO_2 content is 52.4%. Quartz sand with maximum grain size of 2.5 mm was used as aggregate in order to prepare AAS mortar. Graphite powder COND 96-8 (AMG Graphite, Germany) was used as conductive admixture. The mean particle size is 6.4 μm and the particle size distribution determined by laser granulometry is given in Fig. 1. Graphite filler was added in the amount of 5, 10 and 15% by mass of the slag. Triton X-100 (Aldrich) was used as dispersing agent for the graphite powder. It was added to the graphite suspension in the form of 0.5% solution. In order to avoid formation of foam during mixing, 1% solution of siloxane-based defoaming agent, Lukosan S (Lučební závody, CZ), was used.

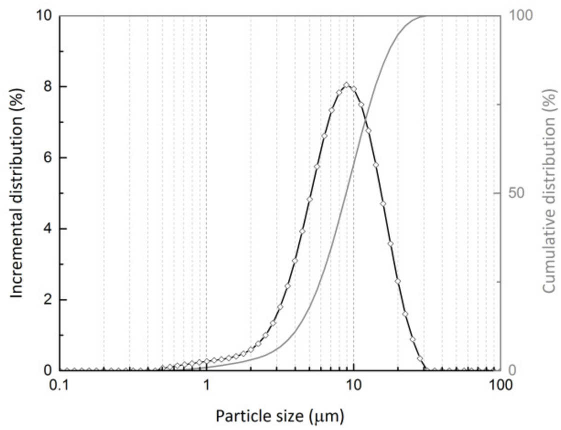

Fig. 1. Particle size distribution of graphite powder obtained by laser granulometry.

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