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Influence of silicon carbide and electrocorundum on the thermal resistance of cement binders with granulated blast-furnace slag

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Abstract

The aim of this work was to compare the influence of the electrocorundum and silicon carbide on the strength and the microstructure of the cement composite with the addition of granulated blast-furnace slag, before and after exposition to higher and high temperature. Research proved that compressive strength of the cement composite with addition of Al_2O_3 in the amount of at least 2 wt.% increased in comparison to the referential samples, regardless of the high temperature, by about 25%, and the best results in the whole temperature range were obtained in case of cement binder with 6 wt.% addition of electrocorundum. On the other hand, addition of silicon carbide resulted in a relevant increase of the sample resistance (by 20-30%) only when added in the amount of at least 10 wt.%.

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Keywords: cement; silicon carbide; electrocorudnum; XRD analyses; laboratory experiments.

1. Introduction

High temperatures cause changes in the cement mortar and in the aggregate, which results usually in deterioration of physical and mechanical properties of the cement composite. The resistance of the cement composites to short term exposition to temperature oscillates around 200 to 300^{o}C. With gradual heating of the cement matrix, the water bound in it is gradually removed, which leads further to physical and mechanical changes in the structure of the cement

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mortar and destruction of the structure created during the hydration of the cement. After crossing the 400°C a degradation of the hydrated calcium silicate of the so-called C-S-H phase takes place, which is manifested in a sharp deterioration of the compressive strength of the matrix. In the temperature of 900°C the C-S-H phase undergoes a total disintegration. Thus, the critical temperature range defining the mechanical durability of the matrix equals 400-800°C. The influence of the high temperatures on the cement matrix durability has been a subject of many publications of local and international range for years. The authors draw attention to the influence of the aggregate type, the cement and the additions on the thermal resistance of composites based on cement binders. The application of the additions used for production of fireproof materials, characterised by high mechanical strength, durability and exceptionally high thermal conductivity, may result in improvement of the resistance of the cement composite in high temperatures. However, most of the research on the influence of those additions on the properties of the cement matrix concentrated on defining its physico-mechanical properties [1,2]. For example, it was proved that concretes with addition of SiC were characterised by high wear resistance, thermal shock resistance, slag corrosion and low porosity and high thermal conductivity [3]. On the other hand, the research conducted by [4] proved, that the cement composites containing significant amount of alumina, or based on aluminium cements, were more resistant to high temperatures, than Portland cements. Reports on the impact of Al_2O_3 and SiC on cement composites with addition of granulated blast-furnace slag are a real rarity in the literature. Partial replacement of the clinker with the blast-furnace slag contributes to improvement of the cement binder resistance to higher temperatures, and addition of the fireproof materials enhances this effect even further. Therefore, the aim of this work was to compare the influence of the electrocorundum and silicon carbide on the strength and the microstructure of the cement composite with the addition of granulated blast-furnace slag, before and after exposition to higher and high temperature.

2. Materials and research methods

In the research the metallurgical cement CEM III/A 52.5 N was applied, meeting the requirements of the norm PN-EN 197-1. Its main ingredients are the Portland clinker (35÷64%), granulated blast-furnace slag (36÷65%) and a regulator of the binding time (calcium sulphate). As the additions that improve the temperature resistance of the cement binder a regular electrocorundum and silicon carbide were applied, both with granulation of 250-300 μm. Regular electrocorundum is a synthetic abrasive material consisting of crystalline aluminium oxide in the amount of 94.5 - 97% and a small admixtures of oxides: TiO_2, SiO_2, Fe_2O_3, CaO, MgO, that shows a relatively high thermal conductivity and low thermal expansion. It is the less brittle and the most tensile (elastic) electrocorundum. It finds application in metalworking of steel, cast steel, malleable iron and non-ferrous materials in cutting, as well as in the fireproof industry and ceramics. The silicon carbide consisting in 95 – 98% of silicon carbide and chemical admixtures of oxides such as Fe_2O_3, Al_2O_3, CaO, SiO_2, MnO_2 is an abrasive grain of the highest cutting properties, very high toughness and durability. It is characterised by high mechanical resistance and an exceptionally high thermal and electrical conductivity. It can be applied in the treatment of brittle and hard materials (such as glass), in the production of abrasive tools and bulk materials, as well as the fireproof materials.

In order to test the influence of those additions on the physico-mechanical properties of the cement composites in different temperatures, three series of cement binders were prepared. Mixtures from the first series were prepared from the blast-furnace cement and water with the water-binder index of 0.48. In the two further series electrocorundum or silicon-carbide was added to the cement binder in the amounts of: 2%, 4%, 6% and 10% of the cement mass.

Homogenization of the mixtures begun by stirring the binder with an addition for 1 minute, and then the water was added. Total time of stirring equalled 4 minutes. The binders were formed into cylinders, which were concentrated on a vibration table, and after 48 hours of maturation they were deformed and kept in 20°C water for 90 days. Samples prepared in this way underwent a treatment in higher and high temperature, within the range of 225°C to 900°C, where the temperature increased by 2.5°C every minute. The samples were kept in the given temperature for 30 minutes. Next, the cement mortars with and without modifying additions for given temperatures, respectively: 225, 450 and 900°C, underwent compressive strength tests in the air-dry state. Phase composition of the cement mortars, with and without modifying additions after the influence of 225°C and 900°C was described with the use of a Bruker X-ray diffractometer, model AXS D8 Advance; and the analysis of the microstructure was conducted with the use of scanning electron microscopy, with the Hitachi S-3400N microscope.