„Analyses of application possibilities of functional cement nanocomposites as repair and self-monitoring materials in building structures"

Abstract

Nanotechnology finds increasing use in building materials. The possibility of modifying traditional building materials on a molecular level and creating coatings based on nanomaterials allows for shaping their basic properties and employing unique functional properties. These properties contribute to the increasing safety of use of the structure and potential reduction in operation costs, while the improvement of strength and durability of building materials through the addition of nanomaterials reduced their environmental impact through reduction of natural resource consumption and frequency of renovations.

Among multiple available nanomaterials, a large attention is given to carbon nanomaterials. Thanks to a very high mechanical strength and electrical conductivity, they can be used in many branches of industry, including civil engineering. The addition of carbon nanomaterials such as carbon nanotubes, graphene or carbon nanofibers into the cement-based composites improves their strength and microstructure and allows for implementing functional properties connected with self-sensing of strain, heat generation or energy harvesting.

The presented doctoral thesis focused on the influence of commercially available carbon nanotubes on a variety of basic properties, electrical conductivity and durability of cement mortars. An attempt was made to design an optimal composition of the cement mortar with a specific focus on properties related to the possibility of using it as a material for strengthening and monitoring of building structures.

Cement mortars used in research consisted of ordinary Portland cement CEM I, standard sand and dosages of carbon nanotubes of 0,05%; 0,1%; 0,2%; 0,5% and 1,0% as referred to the mass of cement. Two sets of samples were prepared with standard proportions of components and with an increased amount of cement. Samples were tested for basic properties including: rheological properties of fresh mix, drying shrinkage, bulk density, air content, water absorption, capillary absorption, flexural and compressive strength. The influence of the nanomaterial addition on the microstructure and porosity of mortars was also tested along with durability under ageing tests, chloride ion migration, carbonation and sewer-induced biological corrosion. To test the possibility of using mortars as functional materials, electrical conductivity in various humidity conditions was measured.

The acquired results imply a significant and mostly negative influence of the carbon nanotubes addition on the basic properties of cement mortars. With an increase in nanomaterial dosage flowability and mechanical strength of the tested mortars decreased. Porosity and pore diameter decreased which was considered a positive result. Electrical conductivity, a vital property for implementing the nanocomposites as functional materials, was, as expected and found in the literature, strongly connected with sample humidity and only for the highest dosages it was possible to acquire a stable conductivity in a dry state. Tests regarding the corrosive resistance of the cement-based composites revealed positive influence of carbon nanotube addition on the durability of the mortars however more tests are required.

The acquired results are a base for further development and optimization of the mix design of cement mortars with carbon nanotubes to create functional materials for monitoring and strengthening of building structures. Further works will focus on practical use and possible applications of cement-based nanocomposites in real structural elements as strain and damage sensors. Materials of this kind have the potential to reduce the environmental impact of building materials through implementation in modern cities.

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