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Role of polyfunctional admixture based on silica fume and carbon nanotubes in forming the structure of gypsum cement composition

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Abstract

One of the topical areas of regulating the structure of gypsum cement compositions is modifying the morphology with ultrafine and nanodisperse systems. The study has analyzed the possibility of changing the structure and properties of new formations of gypsum cement pozzolanic matrix by adding multifunctional admixture based on silica fume and multi-walled carbon nanotubes (MWCNTs) dispersed in a surfactant medium. The optimum content of complex admixture has been determined as 0.006% of MWCNTs and 10% volume content of silica fume as part of modified gypsum cement pozzolanic binder (GCPB) providing the increase of compressive strength by 55% and water resistance by 32%. Studying the structure of modified GCPB by means of physico-chemical analysis (scanning electron microscopy, infrared-spectral analysis and differential scanning calorimetry) has proved the improvement of physical and mechanical properties due to changes in mineralogical composition of new formations in hardening composition and morphology of the forming crystal hydrates in the structure of modified gypsum cement pozzolanic matrix. At the same time, it is noted that gypsum crystalline hydrates are coated with calcium silicate hydrates compacting the structure of the composition and increasing the total contact surface of the new formations. At the same time calcium silicate hydrates prevent water from the surface of crystals of calcium sulfate dihydrate, thereby increasing the water resistance of the composition.

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1. Introduction

Berenfeld [1] indicate that one of the current priorities of the gypsum industry is improving product quality and producing materials with the predetermined properties. According to Volgenskiy et al. [2] producing gypsum-cement pozzolanic binder (GCPB) due to the simplicity of its production, environmental friendliness, rapid hardening and better water resistance in comparison with gypsum binder has improved the strength characteristics of materials and expanded the application range of products based on calcium sulfate. Ferronskaya [3] set that materials based on gypsum binder are attractive due to the resource-saving manufacturing technology because it does not require a lot of energy. At the same time, the effective use of such binders in the construction has not exhausted its possibilities. Mahmoud and Rashad [4] proved that applying fine pozzolanic additives including technogenic wastes in the form of silica fume for stabilizing new formations in order to exclude the formation of ettringite.

Korolev and Bazhenov [5] suppose that one of the priority areas of controlling the properties of GCPB is adding modifying ultra- and nanodispersed additives with high-surface area into its composition. Gaiducis et al. [6] and Izryadnova [7] indicate that GCPBs have significant potential, their physical and mechanical properties being enhanced due to the directed changing of the structure of binding matrix in the process of modifying with a polyfunctional additive which consists of silica fume (SF-85) and extended carbon nanosystems (CN). The relevance of the research in this area is confirmed with the insufficiency of the previous studies of the interaction mechanism of the structuring ultra and nano-disperse additives and the original binder matrix.

2. Materials and research methods

The binder used is gypsum G-4 of the average fineness grade meeting the requirements of GOST 125-79 and Portland cement CEM I 32.5B. The quantitative content of gypsum and Portland cement varies within 55-75% and 5-35%, correspondingly.

The pozzolanic additive used is silica fume SF-85 produced by Chelyabinsk electrometallurgical plant with the average particle size of 300 nm, with the content of more than 90% of amorphous silicon oxide with the specific surface of the particles 20 m²/g (Fig. 1c). According to TC 14-106-709-2004 [8] silica fume SF-85 is a man-made metallurgical product of ferrosilicon smelting. The chemical composition is shown in Table 1.

Table 1. The chemical composition of silica fume SF -85.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	C	S
90-92%	0.68%	0.69%	0.85%	1.01%	0.61%	1.23%	0.98%	0.26%

MWCNT dispersion C-100 produced by Arkema French corporation prepared in hydrodynamic cavitator is applied as a nano-dispersed component for producing a polyfunctional additive according to Korzhenko et al. [9] technology. The dispersion is a mixture of MWCNTs in the medium of Relamix superplasticizer containing 0.5 g of MWCNT per 1 l of suspension.

During the research bar samples with the edge size 4*4*16 cm were studied. Water-binder ratio was selected in accordance with the normal density of GCPB (150-210 mm) which meets GOST 31376-2008. The control and modified samples were tested at the age of 7 days.