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Influence of innovative technologies on the physical and mechanical properties of building materials in the construction industry

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Abstract. A multifunctional additive based on a gel-like dispersion of taunitic carbon nanomaterial (CNM) is considered. The influence of its quantitative composition on the physical and mechanical properties of fine-grained concrete is studied. The results of a study of the frost resistance of fine-grained concrete enriched with a gel-like dispersion of CNM "Taunit" are presented.The main hypotheses describing the formation of the porous structure of concrete under the action of alternate freezing and thawing are considered, and the influence features of the structure of nanomodified concrete on its frost resistance and density. Nano-modified fine-grained concrete was tested by scanning microscopy, which shows that the process of forming changes in its structure occurs not only as a result of reinforcement, but also as a result of growth crystalline hydrates, the centers of which are particles of CNM "Taunit".

1 Introduction

Today, such trends in the development of the industry as a significant acceleration in the growth of construction, the use of new knowledge-intensive resources in an innovative direction are clearly visible. However, a number of problems remain in the civil engineering sector: weak technical regulation, lack of investment and quality local building materials, slow development of the labor and capital market, resulting in difficulties with commissioning. buildings and structures on time. It becomes obvious the need to develop a cluster of building materials industry.

The priority areas in the production of building materials are the creation of mineral slabs based on porous ceramic blocks, aerated concrete, multi-layer reinforced concrete wall panels with internal insulation, basalt fiber, wood concrete, ecowool and fiberglass reinforcement, or an increase in production. New technologies are designed to increase the energy efficiency of residential buildings and industrial buildings and increase the level of environmental protection, as well as reduce the time and cost of building and operating buildings, especially in times of crisis.

In recent years, the global cement industry and the scope of its requirements have been expanding, and a number of problems have arisen, such as obtaining cheap cement products and creating a structure that will last for a long time. Therefore, the study of such problems,

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the development of effective methods and special cements have become a hot topic. Such cements were obtained by adding various natural and artificial additives to Portland cement. It is known that slags improve the properties of cement, but tripoli and diatomite slags increase the water demand of cement and, as a result, cement efficiency decreases. This, in turn, requires a close study of the process of cement hydration, hardening, and methods for obtaining special cements. Any artificial and natural additives contain active and ballast amounts. Therefore, the preparation of a high-quality cement mixture depends on the phase of their separation, individual grinding and the number of combined fractions (sizes). Based on the requirements of GOST 31178-2003 (TU), natural and artificial active mineral additives are allowed for the production of Portland cement.

2 Materials and methods

The requirements for modern concrete today directly depend on the area of their application, the climatic factors of the selected area. In the conditions of year-round construction work, concrete structures are exposed to intense effects of the aquatic environment, variable temperatures with freezing and thawing. An example is bridge, bank protection, sewerage, culvert and treatment facilities, various structures made of road concrete. The main task under these conditions is to maintain the operational properties of a concrete structure for the longest possible period of time [1].

Frost resistance of concrete - the property of concrete in a state saturated with water to withstand repeated alternating freezing and thawing. The destruction of concrete in a water-saturated state under the cyclic action of positive and negative, as well as variable negative temperatures, is due to a complex of physical corrosion processes that cause deformations and mechanical damage to products and structures.

The decrease in the strength of concrete under conditions of alternate freezing and thawing is facilitated by the formation of ice in the pores of concrete. The resulting ice creates pressure on the walls of the pores and mouths of microcracks, which leads to the destruction of the structure of the building material. Destruction does not occur immediately, since the expansion of water is prevented by the solid skeleton of concrete, in which significant tensile stresses can occur. The cyclic nature of freezing and thawing processes leads to a gradual weakening of the structure, and the destructive process itself begins with protruding faces, surface layers and spreads deep into the concrete [2].

There are several main hypotheses that explain the ways in which stresses are transferred to the elements of the concrete structure resulting from the formation of ice.

According to the hypothesis of T. Powers, the main reason for the destruction of concrete during alternate freezing and thawing is the hydraulic pressure created in the pores and capillaries of concrete under the influence of freezing water as a result of the resistance of the gel component of the cement stone. A convincing argument in favor of this hypothesis is that it explains the mechanism of the protective action of air pores. With a sufficient amount of them, "excessive" water is pushed back into these pores without violating the concrete structure.

The destruction of concrete occurs when the volume of conditionally closed pores is gradually filled with water, and they cannot perform the functions of reserve (damping). According to the hydraulic pressure hypothesis, the stresses that occur in concrete are proportional to the freezing rate, the amount of liquid phase displaced and its viscosity, and inversely proportional to the permeability of the cement stone. The frost resistance of concrete is influenced by many factors. For example, the storage (staleness) of cement has a much greater effect on its frost resistance than on its activity. The presence of a shell of new formations of hydrated minerals on cement grains is one of the main reasons for reducing the durability of concrete [3].

The frost resistance of the initial components and their water demand determine the frost resistance of the building material as a whole. The frost resistance of aggregates is ambiguously related to their strength. Non-frost-resistant grains can be quite strong and dense with water absorption of 0.7–2.0%, but the degree of adhesion of the filler with cement stone and the modulus of elasticity are decisive for frost resistance [4].

Experimental studies have been carried out on the effect of a polyfunctional modifier based on gel-like dispersions of carbon nanomaterial (CNM) of the Taunit brand produced by NanoTechCenter LLC (Tambov) on the strength characteristics of building materials. A polyfunctional nanomodifier is a black gel that, when interacting with water, forms a stable colloidal solution with uniformly distributed CNM particles, which is a mixture of carbon nanotubes (CNTs) and carbon nanofibers (CNFs) with an outer diameter of 2–70 nm and a length of more than 2 μm. The multilayer tubes have a density of 560 kg/m^3 and a specific geometric surface area of 110 m^2/g. The average pore volume is about 0.22 cm^3/g. The content of non-carbon impurities is not more than 1% wt. The specific geometric surface determined using the multipoint BET method (Brunauer-Emmett-Taylor), 90...130 m^2/g [5].

Experimental studies were carried out on samples of fine-grained concrete. Portland cement without additives PC 500-D0 [6] was used as a binder, and sand from the Tambov deposit was used as a fine aggregate. The results of the study of the physical and mechanical characteristics of sand: fineness modulus Mk = 1.00 ... 1.55; bulk density on average 1.25 g/cm^3; true sand density 2.65…2.70 g/cm^3; voidness of sand 0.47; bulk density, at natural humidity of 1270 kg/m^3. According to the granulometric composition of the bulk material, the quantitative distribution of its constituent particles by linear dimensions was estimated.

The analysis showed that the main weight fraction of sand particles is in the range of 45…300 μm. The quality of Portland cement corresponds to the properties of cement according to [7, 8].

The weight fraction of the CNM fraction is in the range of 20…15 μm. Based on the results of the tests, histograms of the influence of the content of nanomodifying additives based on gel-like dispersions of CNM "Taunit" on the strength characteristics of fine-grained concrete were constructed (Figure 1).

3 Results and discussion

An analysis of the results of experimental studies showed that the greatest increase in bending strength (50%) is observed at a CNM concentration of 0.0065% by weight of cement, and in compression (13%) - at 0.0005%. Structural analysis of nanomodified concrete, tested by scanning microscopy (Figure 2), showed that the formation of the structure of nanomodified concrete occurs not only due to reinforcement, but also as a result of the growth of crystalline hydrates, the centers of which are particles of CNM "Taunit".

As a result of the modification of the structure of concrete, its pore space and density change. The results of experimental studies on the effect of a polyfunctional modifier based on gel-like dispersions of CNM "Taunit" on the density of fine-grained concrete are shown in the histogram in Figure 3, from which it can be seen that the nanomodification of concrete contributes to an increase in its density (at a nanomodifier concentration of 0.0006% of the mass of cement) and, accordingly, a decrease in the pore space. Note that even a slight variation in porosity in materials leads to a sharp change in their properties. With the ability to control the pore structure, it is possible to increase the properties and durability of concrete.

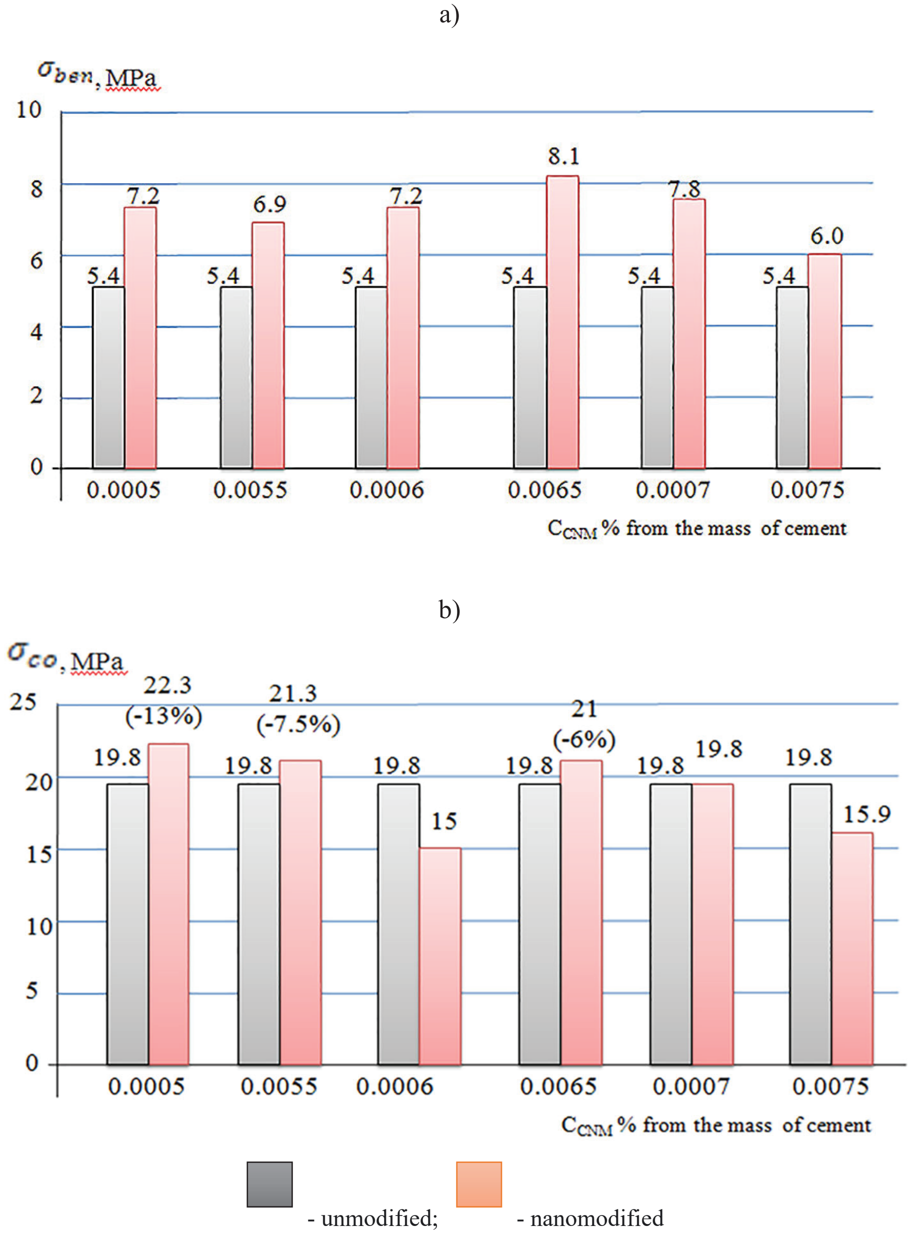

Fig. 1. Histograms of the influence of the content of a nanomodifying additive based on gel-like dispersions of CNM "Taunit" S_{UNM} on the strength characteristics of fine-grained concrete: a-bending resistance, σ_{ben} ; b- compressive strength, σ_{co}.

a) b)

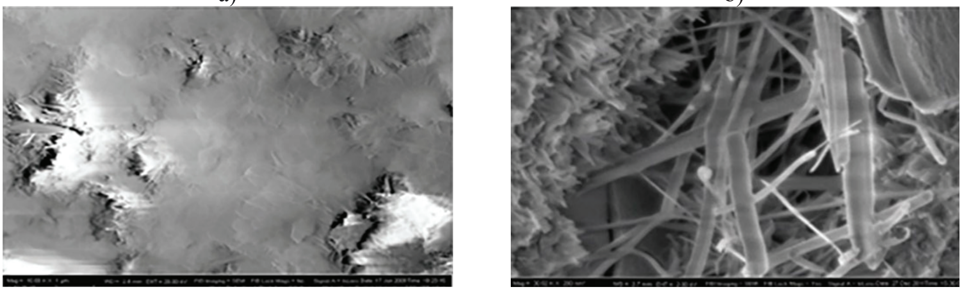

Fig. 2. Electron micrographs of the structure of unmodified (a) and nanomodified (b) concrete.

The frost resistance of concrete is primarily due to the structure of its pore space. To obtain frost-resistant concrete, the thickness of the layers between the air pores in its matrix should not exceed 0.025 cm. Therefore, for the proper effect, it is necessary to provide not only a certain volume of air entrainment, but also to obtain air pores as small as possible, which will reduce their total volume and will increase the frost resistance of concrete with the least decrease in its strength due to air entrainment [9-11].

They can be used not only as centers of crystallization, but also as objects that change the direction and regulate the rate of physical and chemical processes in hardening materials.

The frost resistance test was carried out on samples of fine-grained concrete grade M150 [12,13]. The test conditions for determining frost resistance were determined by the basic first method (for all types of concrete, except road and airfield pavement concrete), according to which samples were frozen in air at t = (–18 ± 2) °C, and thawed in fresh water at t = (+18 ± 2) °C. The frost resistance of concrete was evaluated by the number of freezing and thawing cycles n, at which relative deformations ε and mass loss ΔM did not exceed 5%. The results of tests for frost resistance of fine-grained concrete are presented in Figure 4.

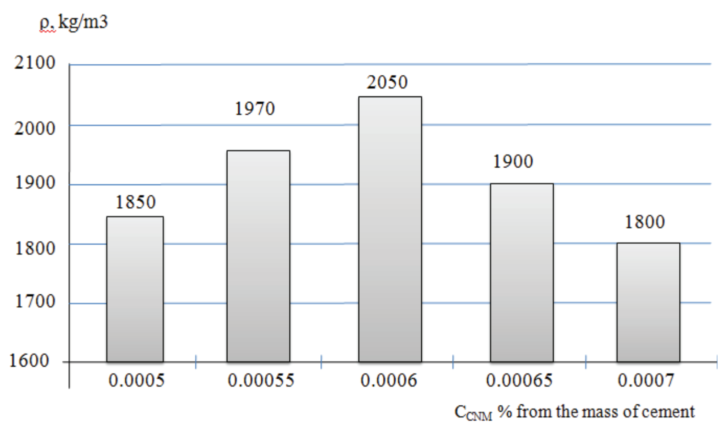

Fig. 3. Histogram of changes in the density of concrete ρ under the influence of a polyfunctional nanomodifier of various concentrations.

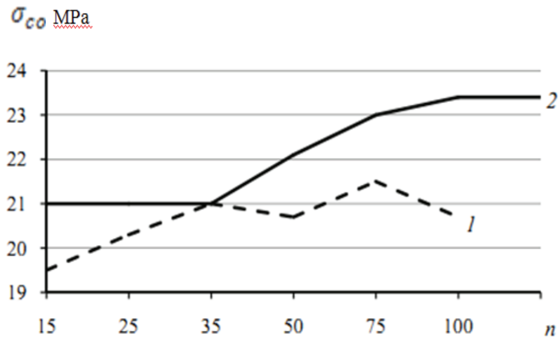

Fig. 4. Change in the strength of fine-grained concrete with alternate freezing and thawing:1 - unmodified; 2 – nanomodified.

Experimental studies on the frost resistance of fine-grained concrete samples showed that the concrete withstood 150 cycles of alternate freezing and thawing without loss of strength, weight loss and visible signs of destruction. An increase in the frost resistance of fine-grained concrete is observed due to a decrease in its porosity, which is achieved as a result of the nanomodification of concrete with a polyfunctional gel-like dispersion based on Taunit CNM and a change in the concrete structure.

Structural changes in concrete under the influence of a modifying additive based on UNM gel dispersions make it possible to create a reserve volume of air pores that are not filled with normal water saturation of concrete, but are available for water to penetrate under pressure that occurs when it freezes, increase density and frost resistance, and hence improve the brand concrete.

4 Conclusion

A feature of further work on the creation of technology transfer centers may be the development of partnership mechanisms between the state and business, which will ensure the transfer of the results of scientific and technical activities created with the participation of the business environment. It is necessary to develop a system of encouragement and motivation for participants in the innovation process, aimed at creating high-quality products, in order to introduce state budget funds into economic circulation through the creation and development of high-tech innovative construction enterprises.

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