Strength and deformation characteristics of fiber concrete modified with a peat additive

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Abstract. Dry mixtures are widely used in modern construction. Development of new modifying agents for improving of dry mixtures performance characteristics and increasing its economic efficiency is an important problem. The paper presents study results of the effect of additives based on thermo modified peat on properties of cement mortars. It is established that introduction of additives in the mortars compositions provides improving of their strength and deformation properties.

1. Introduction

The applying of dry construction mixtures in the implementation of masonry and installation kinds of work is able to significantly improve the quality and productivity of labor, to reduce of transporting materials expenses, to provide the presence of the necessary grade and destination mixture in the required amount on the construction site. This way contributes to achieve a more rational organization of production.

Modern technologies of dry building mixtures production allow to obtain compositions with determined rheological and operational characteristics and to regulate their basic properties by introducing modifying additives for various purposes [1].

Plasticizers, stabilizers, water-retaining and water-reducing additives are most often used for regulating dry building mixtures properties, in addition, additives regulating the setting time, antifreezing, hydrophobizing and air-entraining modifiers are applying if necessary [2, 3]. Using of additives of foreign manufacture in the dry building mixtures composition provides a significant increase in the cost of the final product.

One of the methods of solving this problem is to organize the production of modifying additives based on local raw materials. The raw material base of the Siberian region allows the creation of modifying additives based on peat for regulating the properties of dry building mixtures. The material composition of peat is represented by a variety of organic and mineral compounds. The presence of chemically active organomineral functional groups in the raw material provides the opportunity to use various methods of peat modifying: thermal, chemical, mechanical and a combination of several types.
of impact for the production of various purposes products, including effective modificators for dry building mixes.

The study results of the peat additives effect on the hardened cement paste properties are presented in the scientific works [7, 8]. It has been established that the introduction of the MT-600 additive, obtained at a temperature of 600 °C under conditions of limited air access, leads to significantly increasing of the hardened cement paste compressive strength by 43 % and to reducing the water absorption by 32.5 %. Therefore, the obtained additive can be recommended for using in the composition of mortars with improved strength and hydrophysical characteristics.

2. Methods and materials

Investigations of the mortars strength characteristics of were carried out in accordance with requirements of All Union State Standard (GOST) 5802-86. Cubic samples of cement-sand mortars of size 70x70x70 mm were used for measuring the compressive strength. Flexural strength investigation were carried out on prisms 40x40x160 mm.

In order to study the deformation properties of material, compressive strenght of cement-sand mortar samples with a size of 40x40x40 mm were determined by the testing machine “Instron 3382” at a loading rate of 2 mm per min. The influence evaluation of modifying additive on the nature of deformation fields formation of a cement-sand mortar samples was carried out using a digital optical measurement system “Vic 3D”. The system allows to obtain information on the displacement of microvolumes on the sample surface along three orthogonal axes during its deformation [7, 8].

The degree of modifying additives effect on the strength and character of the formation of the deformation of the mortars samples was determined by comparing stereoscopic images of the deformed surface of basic and modified samples.

For testing basic and modified cement-sand mortars were prepared, the binder: sand ratio was 1:3. The MT-600 additive content was 0.5 % by cement mass in the modified mortar. A mixture of sand fractions 1.25–2.5 and 0.16-0.31 in the ratio 70:30 was used as an aggregate for masonry mortar. The using of two or more aggregate fractions in the cement-sand mortar allows to reduce cement consumption due to the reduction in the voidness of the aggregate without impairing the construction and technical characteristics of the material. The flowability of the compositions was the same and was 6-8 cm. As a base sample, a mixture of binder and aggregate was prepared in a ratio of 1:3.

For the study of cement mortar portland cement CEM I 42.5N from “Topkinsky Cement” plant was used as a binder. Cement complies with requirements of All Union State Standard (GOST) 30515-2013 “Cements. General specifications”

The silica sand from Kudrovskoe field of the Tomsk region was used sa an aggregate. The applying sand satisfies the requirements of All Union State Standard (GOST) 8736-2014 “Sand for construction works. Specifications”

In the modified samples, the MT-600 additive based on the low peat of the Gusevskoe field was used. The modifying agent was obtained by pyrolysis of peat at a temperature of 600 °C in a laboratory installation. The elemental composition of the additive represents predominantly silicon, aluminum, carbon, and calcium. The phase composition of the peat additive is presented in Table 1.

| Phase       | Size, [nm] | Content, [%] |
|-------------|------------|--------------|
| SiO₂        | >400       | 43.81        |
| CaCO₃       | 180        | 47.99        |
| C (graphite) | 15         | 7.77         |
| CaAl₂Si₂O₈  | 100        | 0.31         |
| C60         | 10-20      | 0.12         |

The powder of pyrolysed peat has a high dispersion: the average particle size is (42 ± 3) μm, and the specific surface area is 600 m²/kg.
Electron microscopy analysis allowed to establish that the additive contains nano-sized elements as various forms of nanocarbon, such as fullerenes, ranging in size from 5 nanometers, nanotubes and nanofibers, whose dimensions reach 200 nanometers or more, with a transverse dimension of 20 nanometers or less.

**Figure 1.** Electron microscopic images of MT-600 modifying additive

To justify the increase in strength, electron microscopic studies of the microstructure of cement stone modified by the addition of TM 600 to the surface of the samples were carried out. Figures 2 and 3 show electron microscopic images of a control and modified cement stone with a magnification of 5,000 times.

**Figure 2.** Electron microscopic image of cement stone without additives, magnification x5000

**Figure 3.** Electron microscopic image of a cement stone with MT-600 modifying additive, magnification x5000.

In the micrographs (Figures 2, 3) it can be seen that the volume of neoplasms in comparison with the control cement stone increases, which is associated with a large number of crystallization centers. The size and number of micropores are also increased. In addition, needle-shaped or fibrous crystals
were found in the images of modified cement stone, which are more clearly visible at a lower magnification – 1800 and 1000 times.

![Electron microscopy images of a modified cement stone, magnification x1800 (1) and x1000 (2)](image)

Figure 4. Electron microscopy images of a modified cement stone, magnification x1800 (1) and x1000 (2)

3. Results

Mechanical strength is the main performance characteristic of hardened mortars.

Bending tensile strength and deformation characteristics do not relate to the main quality parameters of mortars, according to All Union State Standard (GOST) 4.233-86, however, the working conditions of the masonry and assembly hardened mortars suppose the possibility of tensile stresses occurrence during exploitation. In this connection, the paper compares the investigation results of the compressive strength, flexural strength characteristics and elastic modulus of solidified mortars.

The study results of the strength characteristics of cement-sand mortars, presented in Figure 5, show that in the early time of hardening (7 days), the introducing of the MT-600 additive increased the compressive strength by 44 % compared to the basic samples. And at 28 days of hardening the strength of samples modified by MT-600 is up to 20 % higher than basic ones strength.

At the same time, the average flexural strength of samples modified with additives MT-600 is 8.05 MPa, and the basic samples flexural strength is 6.996 MPa. Thus, the flexural strength of the modified hardened mortar by 15 % exceeds the same characteristic of the basic samples.

![Influence of additive based on thermally modified peat on the compressive strength of cement-sand mortars; 1 – control cement-sand mortar; 2 –modified cement-sand mortar](image)

Figure 5. Influence of additive based on thermally modified peat on the compressive strength of cement-sand mortars; 1 – control cement-sand mortar; 2 –modified cement-sand mortar

The deformation curves presented in Figures 6 and 7 show that the introduction of additives based on peat in cement compositions leads to increasing of the elasticity modulus of the modified mortar to 25 % comparing to the basic mortar.
The research results showed that the modified cement-sand mortar can work elastically in a wider range of loads, that ensures high crack resistance and deformability of mortar mixtures based on modified cement. The increase in the modulus of elasticity of cement stone with the introduction of additives based on peat can be associated with the formation of hardening structures that work under load, without the appearance of zones with plastic deformations. Let us consider the results of testing the specimens for compression. Four series of samples were tested, two of which are test samples, modified additive MT-600 and two series of control samples of cement-sand mortar, made without the use of additives.

Figure 5 shows the compression test results of the samples. The results are shown in Figure 8. Three images of the deformed surface correspond to each sample. The first picture was taken at loads equal to 1/2 from the destructive value, the second was made with destructive loads, the last photograph characterizes the stage of destruction of the samples.

In this case, the development of transverse deformations, which are the cause of the destruction of the samples, is considered. To the right of each image of the deformed surface, a scale of values of transverse strains is given in accordance with the color scale. The development of elastic deformations in samples with additives is characterized by the formation of a sealing zone in the middle part of the cube and gradual decompression of the medium in the vicinity of the free faces of the cubes. It is possible to note the linear dependence of the growth of transverse deformations from stresses to the level of average loads. The destruction of the investigated cubes began with the appearance of microcracks in the peripheral areas. At the same time, under loads preceding the destructive values, the rate of transverse deformations of the cubes decreased.
Comparison of patterns of deformations of samples with additives and deformation patterns of control samples showed their practical coincidence. Unlike control samples, the destruction of samples with additives occurred somewhat later, meanwhile, in time the destruction occurs faster and is characterized by a large decrease in the descending section of the strain diagram. This is confirmed by a comparison of the deformation diagrams.

4. Conclusion
Strength characteristics of solidified solutions were investigated. It was found that the introduction of a peat-based modifier into the composition of the solution mixture makes it possible to increase the compressive strength of the solution by 20% and the bending strength by 15%. The increase in compressive strength is explained by the presence in the additive of particles with a size of approximately 100 times smaller than the cement grains. In [5] Yu.M. Bazhenov calls such particles "seals", as they fill the voids between the particles of the binder, providing a more dense packing of particles. In addition, the effectiveness of sealing additives is due to the formation of additional crystallization centers and high surface energy, which contributes to the acceleration of hardening and increase the strength of cement stone. The higher bending strength is due to the presence of fibrous inclusions, which were found on micrographs of peat additives. It is assumed that such inclusions provide the effect of reinforcing neoplasms of cement stone at nano- and microlevels [1–4].
It is known that the modulus of elasticity of a material largely depends on its compressive strength. The conducted studies showed that for the compositions under study the directly proportional dependence of these quantities is preserved.

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