The effect of aluminosilicate modifying additive on the deformation properties of adhesive dry building mixtures

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Abstract. The article provides information about the possibility of using amorphous aluminosilicates as a modifying additive for dry building mixtures. The data on the synthesis of the additive, its chemical and physical properties are given. A recipe for adhesive dry building mixtures with the use of amorphous aluminosilicates is proposed synthesized by the proposed method. The technical and physical properties of tile adhesives made using amorphous aluminosilicates as a modifying additive are considered. The deformative properties of tile adhesive made on the basis of the proposed recipe are considered. The elastic modulus of the coating, shrinkage deformation, ultimate tensile strength, axial tensile strength and crack resistance coefficient are calculated. According to the results obtained, appropriate conclusions were made.

1. Introduction

In the modern world, more and more attention is paid to the development of efficient building materials with high physical and technical properties. To achieve this goal, they study the structure of the material and purposefully form it in the form of a heterogeneous, multiphase system with a complex hierarchy. One type of control over the properties of such a system is the modification of their structure by nanoscale particles [1-8].

For example, for the formation of enhanced performance characteristics of dry building mixtures (DBM), various modifying additives are introduced into their formulation [9-14].

Dry mixes are a modified fine-grained building material, which includes mineral binders (cement, lime, gypsum, polymer compositions), fillers with optimal granulometry and a certain fractional composition, as well as the necessary chemical modifying additives [15-17] change the technical characteristics of dry building mixtures, plasticizing, water-retaining, anti-frost, sealing and other chemical additives are introduced into their formulation.

Analyzing the world and domestic experience in the use of dry mixes, we can note their high efficiency and some advantages over traditional methods of work. These advantages include:

- reduction of material consumption in comparison with traditional types of work in 4–12 times;
- increase shelf life without loss of properties and spending as needed;
- possibility of storage and transportation at low temperatures;
- invariability of the formulation of compositions and, consequently, improving the quality and durability of the work;
- increase in labor productivity by 2 – 5.5 times depending on the type of work carried out, their mechanization, etc. [18-19].

In addition, dry mixes are easy to use and have high technological and operational indicators, giving an undoubted advantage in the application of this type of product, in this regard, they are in consumer demand.

At the moment, the majority of modifying additives for the DBM are produced abroad, which has a significant impact on the cost of the finished product.

To expand the range of modifying additives for dry construction mixtures, a possible reduction in the cost of the finished product and control the structure formation of cement dry mixes, it was proposed to introduce synthesized aluminosilicates into their formulation [20 -21].

Synthesis consists in the precipitation of aluminosilicates from a 15% solution of technical aluminum sulfate $\text{Al}_2(\text{SO}_4)_3$ with the addition of sodium silicate and then washing the obtained precipitate with distilled water. The additive is a white powder with a specific surface, determined by the BET method, equal to $S_{sp} = (68.6 \pm 3.5) \text{ m}^2/\text{g}$. After drying at a temperature of $(105 \pm 5)^\circ\text{C}$, the true density of the additive is $2140 \text{ kg/m}^3$, the bulk density is $568.2 \text{ kg/m}^3$ [22].

It was established that the structure of the additive is represented mainly by round-shaped particles of size $5.208 \mu\text{m} - 5.704 \mu\text{m}$, but there are found flaky particles with a size of $7.13 \mu\text{m} - 8.56 \mu\text{m}$ (Figure 1).

![Figure 1. Microstructure of the additive.](image)

The chemical composition of the additive is represented by chemical elements such as – O, Si, Na, S, and Al – with a content of $48.71\%$, $19.59\%$, $16.42\%$, $9.67\%$, and $4.7\%$, respectively.
According to XRD data, the mineralogical composition of the additive is represented by tenardite - rhombic modification of sodium sulfate Na₂SO₄, gibbsite Al(OH)₃, aluminum silicate sodium hydrate Na[AlSi₂O₆]*H₂O. The concentration of the amorphous phase of the synthetic additive is 77.5%.

One of the indicators of the quality of the coating based on adhesive dry construction mixture is crack resistance.

To assess the crack resistance of tile adhesives made with the use of an amorphous aluminosilicate based additive in the formulation, shrinkage deformations of the coating were measured during its curing.

As a result of the research, a recipe of adhesive dry construction mixture containing portland cement, sand of certain fractions, plasticizing agent Kratasol PFM, redispersible powder Neolith P 4400 and an additive based on amorphous aluminosilicates (table 1).

### Table 1. Recipe adhesive dry building mix with the additive based on amorphous aluminosilicates.

| Components of dry mortar                        | The content of components in the dry mortar, % |
|-------------------------------------------------|-----------------------------------------------|
| 1 Portland cement                                | 31.05                                         |
| Ukhta Sand with the ratio of fractions:          |                                               |
| 0.63-0.315                                      | 49.68                                         |
| 0.315-0.16                                      | 12.42                                         |
| 2 Additive based on amorphous aluminosilicates  | 6.21                                          |
| 4 Supplement Cartasol PFM                       | 0.32                                          |
| 5 Dispersible powder Neolith P 4400              | 0.32                                          |

2. Methods

Shrinkage deformation of cement-based tile adhesive was determined by means of an optical comparator ISA-2 [23] and was calculated by the formula:

\[ \varepsilon = \frac{l_0 - l_i}{l_0} \cdot 100\% , \]  

(1)

where \( l_0 \) – sample length (distance between reference points) in the initial hardening period, mm; \( l_i \) – the length of the sample in the interim period of hardening, mm.

The modulus of elasticity [23] was calculated from the stress – strain diagram by the tangent of the angle of inclination to the abscissa axis of the tangent (Z) drawn to the initial straight section of the diagram.

The modulus of elasticity for each sample (\( E_{\text{el}} \)) in MPa was calculated by the formula:

\[ E_{\text{el}} = \frac{R_{\text{log}}}{\varepsilon'_i}, \]  

(2)

where \( R_{\text{log}} \) - tensile strength at the moment of separation of the tangent from the stress – strain diagram, MPa. \( \varepsilon'_i \) - elongation at break, %.

Crack resistance coefficient calculated by the formula [23]:

\[ K_{cr} = \frac{R_{\mu}}{R_{st}}, \]  

(3)

where \( R_{\mu} \) – the flexural strength; \( R_{st} \) – the compressive strength.

The samples were cured in air-dry conditions at a temperature of (20±2)°C and relative humidity φ = 50% – 55%.
3. Test results

Figure 2 shows a graph of changes in the shrinkage deformation of the coating on the basis of the control composition (without the use of additives based on amorphous aluminosilicates) and the composition made on the basis of the developed adhesive DBM.

![Figure 2](image)

**Figure 2.** The change of the shrinkage deformation in the process of hardening:

1 – control; 2 – the composition of the adhesive DBM

Data analysis (figure 2) shows that the most intensive growth of shrinkage deformations is observed within 5 days of air-dry hardening, after which stabilization of values is noticeable. So, the value of shrinkage deformations of the structure with the use of additive based on amorphous aluminosilicates on the 5th day of curing has a shrinkage strain equal $\varepsilon = 0.025 \%$, and after 90 days the value of shrinkage deformation amounted to $\varepsilon = 0.028 \%$ (figure 2, curve 2) the Control structure on day 5 of curing amounted to $\varepsilon = 0.031 \%$, and after 90 days the value of shrinkage deformation amounted to $\varepsilon = 0.034\%$. (figure 1, curve 1).

Cracking of DBM-based coatings occurs when internal tensile stresses reach the cohesive strength of the coating material. In this regard, the tensile strength of coatings on samples after 90 days of air-dry hardening was determined. The results of the experiments are shown in figure 3.

![Figure 3](image)

**Figure 3.** Changes in the relative tensile strain of tile adhesive samples: 1-control sample; 2-sample using additives based on amorphous aluminosilicates.
Analysis of the data presented in figure 3 revealed that the introduction of an additive based on amorphous aluminosilicates into the formulation of tile adhesive makes it possible to obtain a material characterized by an axial tensile strength of \( R_{kog} = 2.2 \) MPa. Ultimate elongation \( (\varepsilon_{lim}) \) is \( \varepsilon_{lim} = 0.018 \text{ mm/mm} \). Destruction of samples on the basis of the control composition occurs when the relative deformation \( (\varepsilon) \) equal \( \varepsilon = 0.011 \text{ mm/mm} \).

The deformative properties of tile adhesive made on the basis of the developed formulation of dry adhesive construction mixture are presented in table 2.

| Name of indicator                      | Value of indicator |
|----------------------------------------|--------------------|
| Modulus of elasticity of the coating,  | 128.6              |
| Shrinkage strain \( \varepsilon_{sh} \) | mm/mm 0.00028      |
| Ultimate extensibility \( \varepsilon_{lim} \)| mm/mm 0.018        |
| Crack resistance coefficient \( K_{cr} = \varepsilon_{sh}/\varepsilon_{lim} \)| - 0.015            |

The data obtained indicate sufficient shrinkage crack resistance of the adhesive layer on the basis of the developed recipe.

Additionally, the crack resistance was estimated by the conventional coefficient of crack resistance \( K_{cr} \), defined as the ratio of flexural strength to compressive strength by the formula 3.

The results of the calculation found that the samples of tile adhesives have sufficient crack resistance, since the value of the conventional coefficient of crack resistance \( K_{cr} \) is \( K_{cr} = 0.06 \).

4. Summary

Thus, the conducted studies have established that the tile adhesive based on the proposed dry construction mixture is crack resistant. Therefore, this type of adhesive dry construction mixture can be considered a durable composition.

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