Additive based on aluminosilicates for lime dry mortar mixes

Loganina V.I.\textsuperscript{1a}, Skachkov Yu.P\textsuperscript{2b}, Ryzhov A. D.\textsuperscript{3c}

\textsuperscript{1} Department "Quality management and technology of construction production" Penza State University of Architecture and Construction, Russia, 440028, Penza, street Germana Titova, 28
\textsuperscript{2} Rectorate Penza State University of Architecture and Construction, Russia, 440028, Penza, street Germana Titova, 28
\textsuperscript{3} Department "Quality management and technology of construction production" Penza State University of Architecture and Construction, Russia, 440028, Penza, street Germana Titova, 28
\textsuperscript{a}email: loganin@mail.ru. \textsuperscript{b}email: rector@pguas.ru \textsuperscript{c}email: penza48@yandex.ru

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Abstract. Information on the properties of the additive based on amorphous aluminosilicates is given. The technology of synthesis of the additive is described. The influence of the additive on the process of the formation of a calcareous mixture is shown. The information on the properties of the developed dry construction mix are given.

Introduction

In the process of operation, protective and decorative coatings of the outer enclosing structures of buildings are exposed to moisture due to the action of rain, high relative humidity of the air, and also due to the diffusion of water vapor through the enclosing structure from the inner surface to the outer one during the cold period of the year [1, 2]. In the conditions of external influences on the coating, in some cases there is a partial destruction of the plaster coating, which manifests itself in the form of detachments or a grid of small hair cracks. One of the possible causes of these defects may be the condensation of moisture at the interface between the enclosing structure and the plaster coating and the subsequent destruction of the coating due to the increase in the volume of water in the pores of the material, when the water freezes. In practice, such cases occur more often when using plaster coatings with low values of vapor permeability (Figure 1, 2).
Figure 1. Photo of the facade of the building

a - on Tsiolkovsky Street after three years of operation (plaster on cement basis), Penza, Russia

b - on Kalinina Street after three years of operation, (plaster on cement basis) Penza, Russia

Figure 2. Photo of the facade of the building on Mozhaisky Street after six years of operation, (plaster on cement basis). Penza, Russia

It is established, that the main operational defects are cracks in the coating at the end of the building, as well as peeling of the coating.

As a rule, dry mixtures for outdoor work are made on a cement binder. Calcareous building mixtures are used less often because of the low resistance of coatings based on them. However, coatings based on lime compositions are characterized by greater crack resistance, better perceive tensile forces, have good vapor permeability and resistance to biodestruction [3,4]. Disadvantages of such compositions are low strength and water resistance. As is known, calcareous binder very slowly hardens, which complicates the production of finishing works. To accelerate the curing of lime and increase the durability of lime coatings, various additives are introduced [5,6,7]. There are additives based on amorphous aluminum oxides (γAl₂O₃) and aluminum hydroxide
Al(OH)$_3$, (Axilat SA 502 (Rhodia, France) and Amga (OJSC RUSAL Boksitogorsky alumina), Alumina CTC-20 (Germany). Additives are characterized by high dispersity and activity with respect to alkalis [8].

It is proposed in [9] to introduce additives based on synthesized calcium hydrosilicates (CHS) into the formulation of calcareous finishing compositions. Introduction to the lime additives based on CHS leads to an acceleration of the hardening process and increase the strength of calcareous samples.

It is of interest to investigate the possibility of using in calcareous mixtures of additives, containing amorphous aluminosilicates. The interaction of the calcareous binder with amorphous aluminosilicates will promote the acceleration of curing and increase the water resistance, as well as the mechanical strength of the coating.

At present, materials containing amorphous aluminosilicates are used as ion exchangers (for example, for water purification), as adsorbents in chromatography, during purification, drying and separation of gases, as well as catalytic cracking of petroleum products [10,11].

The analysis of patent and scientific and technical literature shows that the questions of their use in the formulations of calcareous mortar require careful consideration. The mechanism of interaction of synthetic adsorbents with astringent is not revealed, the patterns of structure formation of the composite have not been established. This indicates the expediency of investigating the possibility of using additives based on amorphous aluminosilicates in calcareous dry mixtures.

Results and Discussion

The following synthesis technology of the aluminosilicate additive was used in the work. Microdispersed aluminum powders ПАП -1 were added to sodium liquid glass at a temperature of 60-90 °C for 30-120 minutes.

To reveal the distribution and concentration of acid-base centers (active sites) on the surface of the additive particles, an indicator method for adsorption of indicators with different dissociation constant values $pK_a$ was used. The quantitive determination of adsorption sites $q_{pK_a}$, mg-kg / g or mg-eq / m$^2$ of a given acid strength was carried out by a photometric method. The solutions were photometricized in cuvettes relative to the solvent on a KFK-3KM photoelectrocolorimeter at the wavelength corresponding to the maximum absorption of each indicator ($\lambda_{max}$). The following indicators were used for the tests: diamond green ($pK_a = + 1.5$), fuchsin ($pK_a = + 2.1$), methyl orange ($pK_a = + 3.46$), bromfenol blue ($pK_a = + 4.1$), bromocresol purple ($pK_a = + 6.4$), bromothymol blue ($pK_a = + 7.3$), timol blue ($pK_a = + 8.8$), nil blue ($pK_a = + 10.5$) and ethylene glycol ($pK_a = + 14.2$).

Studies were carried out in the field of Brönsted acid centers ($pK_a$ from 0 to 7) and basic centers ($pK_a$ from 7 to 13), and Lewis acid centers ($pK_a > 13$). The value $pK_a = +7$ correspond neutral centers.

In the composition of the additive revealed a high content of oxides of Al$_2$O$_3$, SiO$_2$, Na$_2$O, constituting, respectively, 51.03%, 36.36%, 11.89%. The amorphous phase is represented by sodium aluminate. The content of the amorphous phase is 83%. Using a scanning electron microscope Tescan VEGA 3, it was found, that the structure of the synthesized additive is represented by particles of different shapes, (lamellar and acicular) in size from 0.11 to 10.49 μm.
It is established, that the surface of the sample of the additive is characterized by the predominance of the centers $pK_a^a = +4.7$, $pK_a^b = +6.4$. The total amount of acid centers is $\sum q_{pK_a} = 53.72$ mmol / g and the base centers is $\sum q_{pK_a} = 7.70$ mmol / g (Fig.3).

To study formation of structure of calcareous composites, samples were made on the basis of hydrated lime 1 grade with an activity of 84.4%. The maximum strength of calcareous samples is achieved by adding an aluminosilicate additive in an amount of 10% of the weight of the lime. The increase in the strength of calcareous composites when adding an additive based on amorphous aluminosilicates is due to the presence of additional chemical formations.

It was found, that the mineralogical composition of calcareous composites is represented by portlandite, calcite, calcium hydroxides, calcium hydroalumates. To confirm the results, a differential thermal analysis (DTA) was carried out with the help of the "Thermoscan-2" installation.

It was found, that in control samples in the age of 28 days of air-dry hardening, the amount of free lime is 47.67%, and in samples with using an additive based on amorphous aluminosilicates - 31.41%.

**Figure 3.** The distribution curve of acid-base centers on the surface of the particles of the additive

The introduction of an aluminosilicate additive into the calcareous system results in a slight decrease in the pH of the liquid phase. So, after one and a half hours from the moment of start-up, the pH of the control compounds (without additive) is 13.43, and at additive content of 10% - pH = 13.31.

It is found, that when the aluminosilicate additive is introduced in an amount of 10% of the weight of the lime, the maximum temperature of the structure formation is 24 °C and is reached after 60 min.

Additive based on amorphous aluminosilicates is expected to be used in the manufacture of heat-insulating dry construction mixtures.

Table 1. shows the main technological and operational properties of the thermal insulation composition based on the developed formulation using an additive based on amorphous aluminosilicates and coatings based on it.

| Indicator name | The value of the indicator for the composition |
|----------------|---------------------------------------------|
|                |                                             |
Design prototype 1 prototype 2 prototype 3

| Property                                | 700 | 300  | 550-600 | 1100 |
|-----------------------------------------|-----|------|---------|------|
| Average density DBM, [kg/m³]            |     |      |         |      |
| Consumption of the composition when applied with a layer thickness of 10 mm, [kg/m²] | 8.4 | 3.2  | 5.5     | 12   |
| Water retention ability, [%]            | 98.3| 96.0 | 97.0    | 98   |
| Coefficient of vapor permeability, [mg/(m·h·Pa)] | 0.18| 0.05 | 0.11    | 0.1  |
| Compressive strength, [MPa]             | 4.7 | >0.5 | 3.5     | 3.5  |
| Strength of adhesion to the base, [MPa] | 0.38| 0.5  | 0.3     | 0.4  |
| Frost resistance                        | F35 | F25  | F50     | F35  |
| Coefficient of thermal conductivity, [Watt/(m·°C)] | 0.18| 0.07 | 0.13    | 0.35 |
| Warranty period of storage, [month]     | 12  | 12   | 12      | 12   |

As a prototype 1, was chosen a dry cement-pearlite plaster mix "Perlutka SHT-4", as the prototype 2 - a heat-insulating plaster mixture UF-2 TM "UMKA" (produced by OOO "Ecotermogroup"), as a prototype 3 - plaster cement heat-insulating facade Knauf-Grünband (the firm "Knauf").

Conclusions

The developed DBM composition with an additive based on amorphous aluminosilicates possesses a number of advantages in comparison with analogs: fast setting time, high water retention ability, high adhesion strength to the surface under different operating conditions and low value of shrinkage deformations.

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