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# Estimation of Frost Resistance of the Tile Adhesive on a Cement Based with Application of Amorphous Aluminosilicates as a Modifying Additive

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**Abstract**. In the article given information on the possibility of using amorphous aluminosilicates as a modifying additive in the offered tile cement adhesive. In the article, the data on the preparation of an additive based on amorphous aluminosilicates, on its microstructure and chemical composition. Presented information on the change in the porosity of cement stone when introduced of amorphous aluminosilicates in the his composition. The formulation of a dry building mix on a cement base is proposed with use of an additive based on amorphous aluminosilicates as a modifying additive. Recipe of dry adhesive mixes include Portland cement M400, mineral aggregate in proportion fraction 0.63-0.315:0.315-0.14 respectively 80:20 (%) and filling density of 1538.2 kg/m$^3$, a plasticizer Kratasol, redispersible powder Neolith P4400 and amorphous aluminosilicates. The developed formulation can be used as a tile adhesive for finishing walls of buildings and structure with tiles. Presented results of the evaluation of frost resistance of adhesives based on cement with using of amorphous aluminosilicates as a modifying additive. Installed the mark on the frost resistance of tile glue and frost resistance of the contact zone of adhesive. Established, that the adhesive layer based on developed formulation dry mixture is crack-resistant and frost-resistant for conditions city Penza and dry humidity zone - zone 3 and climatic subarea IIB (accordance with Building codes and regulations 23-01-99*) cities Russia's.

## 1. Introduction

For finishing exterior and interior walls of buildings and structures the developed a recipe of the tile adhesive, made on the basis of a dry building mix. To improve the technological and maintenance properties of the tile adhesive in composition of the dry building mix impose special additives to accelerate curing and increase resistance to sliding [1-3].

Earlier conducted research [4-6] made it possible to establish the effectiveness of amorphous aluminosilicates as a modifying additive in a dry construction mixture. A recipe for dry building mix is developed, which includes Portland cement M400, mineral aggregate in proportion fraction of 0.63-0.315: 0.315-0.14, respectively, 80:20 (%) and bulk density of 1538.2 kg/m$^3$, plasticizer Kratasol, redispersible powder NeolithP4400 and as a mineral additive - amorphous aluminosilicates.

The supplement based on amorphous aluminosilicates was obtained deposition aluminosilicates with the help of liquid sodium glass with a silicate module 2.8 by introducing a 15% solution of technical aluminum sulfate $Al_2(SO_4)_3$ [7] with subsequent washing of the obtained sediment with distilled water and its drying-out in a drying oven at a temperature t = (105 ± 5) $^0$C to constant mass and milling [8].

The composition of the additive based on amorphous aluminosilicates is mainly dominated by a high content of chemical elements such as - O, Si, Na, S and Al - with content of 48.71%, 19.59%, 16.42%, 9.67% And 4.7%.

The structure of the additive is mainly presented by particles, the amount of which is 2.25-8.1 μm. X-ray phase analysis found that the amorphous phase content was 77.5%.

Installed that presence of an additive based on amorphous aluminosilicates in the cement paste formulation affects the structure formation of the cement stone: in the samples there is no free water and is established increase in the chemically bound water against to control sample. Thus, in the control composition (without additive), the content of free and chemically bound water is 7.3% and 14.5%, respectively, while in the sample with a 20% content in the formulation, amorphous aluminosilicate based additives are 6.1% and 17.0%.

## 2. Formulation of the problem

In order to confirm the possibility of aping a tile adhesive on the basis of developed by dry mixture, in external works was investigated the frost resistance of the adhesive layer on the basis of the developed dry building mix.

The ability of the adhesive layer is not affected for a long time with repeated freezing and defrosting in a saturated water state is determined by the presence in its structure of reserve pores that are unfilled with water. Under influence of the pressure of growing ice crystals, when frozen into the reserve pores, part of the water is squeezed, which helps to reduce the destructive effect of ice on the structural strength material. The destruction of the material in a water-saturated state with repeated freezing and defrosting occurs only when all the reserve pores are filled with formed ice. The higher the conditionally closed porosity of the sample, more cycles of alternating freezing and defrosting are necessary to cause the sample to break down. Therefore, in order to talk about the frost resistance of tile glue, it is also necessary to determine its porosity.

## 3. Results and discussions

In the Table 1 presents results of a study of the porosity of cement stone with addition of an additive based on amorphous aluminosilicates.

**Table 1.**Change value of porosity cement samples depending on the content of the additive

| Compositions | Porosity,% | | | |
|---|---|---|---|---|
| | The total | Capillary | Gel | Contractional |
| **Control** | 41.2 | 18.7 | 15.5 | 7.0 |
| **10% Additives** | 40.3 | 16.7 | 16.3 | 7.3 |
| **20% Additives** | 38.3 | 12.0 | 18.1 | 8.2 |
| **30% Additives** | 37.3 | 9.0 | 19.5 | 8.8 |

The total and capillary porosity of the control samples is 1.1 and 1.6 times higher than the porosity of the sample with the additive (the amount of the additive is 20% of the cement mass), and the contractile and gel porosity is 1.2 times lower.

Evaluation of frost resistance of the adhesive on the basis of the developed cement-based dry building mix with use of an additive based on amorphous aluminosilicates in the formulation was carried out by alternately freezing and defrosting on the samples with size 70 ×70 ×70 mm, which were hardened 28 days on the air [9]. In the Table 2 presents the results of testing on frost-resistance of tile adhesives. Figures 1 and 2 show samples of tile adhesive prior to the test and after the test, respectively.

**Table 2.** Frost resistance of tile adhesive

| Test result of samples, cycles | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 5 | 10 | 15 | 25 | 35 | 50 | 75 |
| 43,2 | 42,83* / 0,16 | 42,70 / 0,47 | 42,60 / 0,70 | 42,07 / 1,94 | 39,86 / 7,78 | 39,36 / 8,24 | 38,43 / 10,42 |

*** Above the line is the average strength of the tile adhesive (MPa), below the line is the change in the average strength of the tile adhesive (%).**

1) 2)

**Figure 1.**Samples before testing

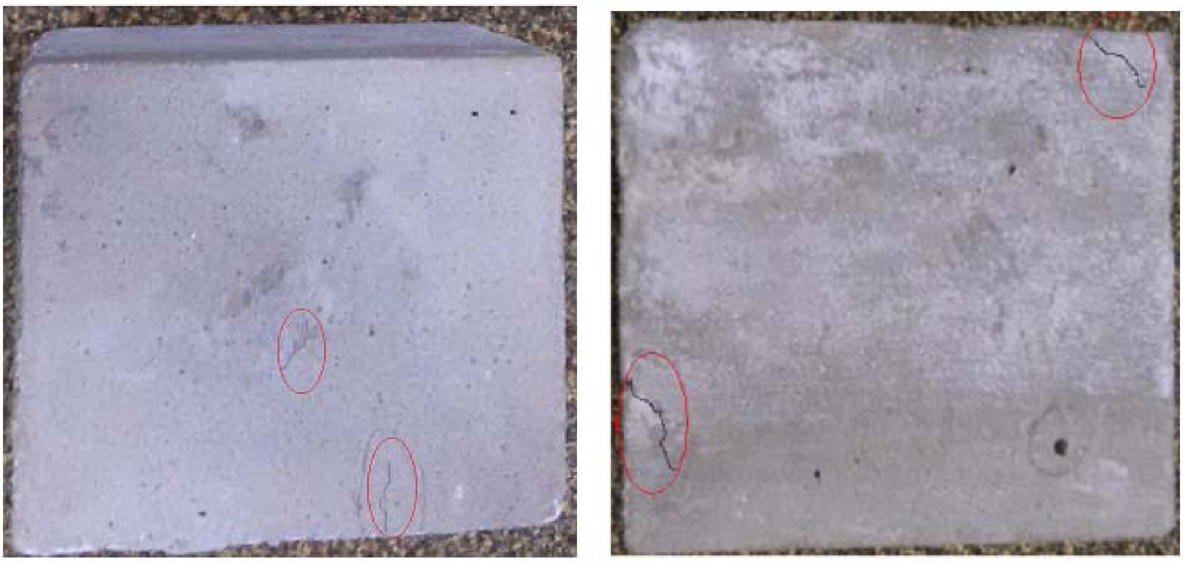

**Figure 2**.Samples of tile adhesive after testing

As can be seen from Figures 1 and 2, samples of cement-based tile glue have noticeable chalking, cracks on the surface visible to the naked eye, makes up to 5% of the surface, corrosion is absent. Thus, during testing of tile adhesive compositions based on the developed dry building mix formulation for frost resistance, it was established that the tile adhesive possesses a frost resistance

mark F50 (Table 2), i.e. Can withstand 50 freeze- defrost cycles without changing the strength (within an acceptable error of 10%).
In determining the brand to frost resistance (F) of tile glue, it is also necessary to take into account the frost resistance of the contact zone ($F_{cz}$). Determination of the brand frost resistance of the tile adhesive contact zone consisted in alternately freezing and defrosting a structure consisting of a layer of tile adhesive applied between a cement-sand substrate and a ceramic tile. After each cycle, a visual inspection of the surface was made to detect cracks, crumbling and peeling of the material, and a test was conducted to determine the adhesion strength. The results of the tests are shown in Table 3.

**Table 3.** The frost resistance of tile adhesive contact zone.

| Test result of samples, cycles | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 5 | 10 | 15 | 25 | 35 | 50 | 75 |
| 1,2 | 1,18* / 1,67 | 1,17 / 2,5 | 1,12 / 6,67 | 1,03 / 14,16 | 1,00 / 16,67 | 0,97 / 19,17 | The tile abruption |

* Above the line is the average adhesion strength of the tile adhesive (MPa), below the line is the change in the average bond strength of the tile adhesive (%).

An analysis of results in Table 3 showed that the contact area of the tile adhesive with a cement-sand substrate and a ceramic one has sufficient frost resistance. The mark on the frost resistance of the contact layer was $F_{cz}50$.
Evaluation of the adhesion strength to the cement-sand substrate was carried out after freeze- defrost cycles. The test results are shown in Figure 3.

a) b)
**Figure 3.** Samples after the test: a) - thawing in the air; b) - thawing in a humid environment

An analysis of results showed that the separation occurs on the ceramic tile and is $R_{kog}$ = 0.97 MPa.

## 4. Conclusions
Thus, the adhesion strength of the adhesive solution based on the developed adhesive dry building mix using an additive based on amorphous aluminosilicates after freezing- defrosting in the air and after freezing- defrosting in a humid environment is $R_{adg}$ = 0.97 MPa, which meets the requirements specified in the DINEN series standard 12004 - $R_{adg} \geq 0.5$ MPa [10].

It is established that the adhesive layer based on the developed formulation of the dry glue building mixture is crack-resistant, frost-resistant and resistant to peeling for the conditions of Penza and cities of Russia in the humidity zone-3 (dry) and climatic subareas IIB in accordance with SNiP 23-01 -99 *.

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