INTERNATIONAL JOURNAL OF BUILT ENVIRONMENT AND SUSTAINABILITY
Published by Faculty of Built Environment, Universiti Teknologi Malaysia
Website: http://www.ijbes.utm.my
IJBES 5(1)/2018, 1-11

The use of amorphous silica-alumina-based additive in the adhesive dry mixes of building materials

Loganina V. I.
Department of Quality Management and Construction Technologies, Penza State University of Architecture and Construction
Email: loganin@mail.ru

Zhegera Ch. V.
Department of Quality Management and Construction Technologies, Penza State University of Architecture and Construction
Email: jegera@yandex.ru

History:

Received: 30 August 2017
Accepted: 18 October 2017
Available Online: 30 January 2018

Keywords:

Dry mixes, Amorphous silica-alumina, Plastic strength; Tile adhesive, Cement.

DOI:

10.11113/ijbes.v5.n1.241

ABSTRACT

Proved the possibility of using amorphous aluminosilicate as a modifying agent for the adhesive dry mixes. Are given the data on the microstructure and chemical composition of the amorphous aluminosilicates. Installed , that the microstructure of the synthetic additives is characterized by particles of round shape, dimensions 5,208-5,704 μm, Also there are particles of elongated shape in size 7.13-8.56 μm. Predominate chemical elements O, Si, Na, S, and Al in quantity 60.69%, 31.26%, 24.23%, 18.69% and 8.29% respectively. Described the character changes in the rheological properties of cement-sand mortar, depending on the percentage of additives. Determined, that the introduction in the cement-sand mortar the additive based on amorphous aluminosilicate leads to higher values of plastic strength. Are given the model of cement stone strength using synthetic additives in the formulation. The results of the evaluation of the frost resistance of cement-based tile adhesives with the use of amorphous aluminosilicates as a modifying additive are presented. In the article is determined the mark on frost resistance of tile glue and frost resistance of the contact zone of tile glue. The evaluation of the performance properties of the layer of tile adhesive on the basis of cement, dry mixes. The calculation of the value of displacement of the adhesive layer made on the basis of the developed recipes cement dry mixes applied to a vertical surface. Experimental data obtained values of displacement tiles relative to the substrate. Described the results of physical and mechanical properties of tile adhesive made on the basis of the developed adhesive dry mix formulations.

1. Introduction

One of the priorities of modern building materials science is the development of effective building materials. To regulate the technical and operating characteristics of dry mortar formulation is administered in their structure various modifying agents (Loganina V.I., 2013; Loganina V.I., 2009; Jenni A., 2005; Stark U., 2003; Taramasso M., 1980; Mirsky Y.V., 1964; Doroshenko Y.M., 1989; Yiqing F., 1991).

Most of the modifiers used in the formulation of domestic dry construction mixtures are coming from abroad, which significantly increases the cost of dry mixes and makes production dependent on imported supplies. In this regard, need to the development of domestic of production the modifiers. As the modifying agent of domestic production is proposed to use synthetic zeolites as structure-forming and water-retaining additive for dry construction mixtures.

Previous studies have confirmed the efficacy of synthetic zeolites as a modifying agent for cement and lime dry mixes (Loganina V.I., Zhegera K.V, 2014; Loganina V.I., Zhegera K.V, 2015; Loganina V.I., Makarova L.V., 2014; Loganina V.I., Makarova L.V., Tarasov R.V., Zhegera K.V., 2014; Loganina V.I., Makarova L.V., Tarasov R.V., Ryzhov A.D., 2014; Loganina V.I., Ryzhov A.D., 2015; Mumpton F. A., 1999; Andrejkovicova S., 2012; Aiello R., 1971; R Barrer.M., 1968; Broussard L., 1960). A recipe for dry building mix (DBM) is developed, which includes Portland cement M400, mineral aggregate in the ratio of fractions of 0.63-0.315: 0.315-0.14, respectively, 80:20 (%) and bulk density of 1538.2 kg/m^3, plasticizer Kratasol, redispersiblepowder NeolithP4400 and as a mineral additive - amorphous aluminosilicates.

2. Methodology

For this research Wolski Portland Cement M400 was used, and sand deposits of Ukhta in the ratio 1:2. Samples with water-cement ratio equal to W/C =0.5 were made. The samples hardened in air-dry conditions at a temperature of 18-20 ° C and relative humidity of 60-70%. After 28 days of hardening period, the compressive strength of morta was determined.

The additives based on amorphous aluminosilicates was obtained by precipitating aluminosilicates from liquid sodium glass with a silicate module 2.8 by introducing a 15% solution of technical aluminum sulfate $Al_2(SO_4)_3$ followed by washing of the obtained Sediment with distilled water and its drying in a drying oven at a temperature t = (105 ± 5) ^{0}C to constant mass and grinding.

Plastic strength or yield stress of the mixture was determined by tapered plastometer KP-3. The basis of this method is the immersion cone into the test composition and the effect on the cone of a constant load (P), whereby the measured depth of his immersion in the composition equal it τ. After reaching equilibrium shear stress cone becomes equal to the yield point τo and is determined by the formula:

$$\eta = \tau = \tau_0 = k * \frac{P}{h^2}$$

where η - plastic strength.

τ - shear stress.

τo - yield stress.

k - coefficient depending on the value of the vertex angle of the cone; for the metal cone with an apex angle of 30° - k = 1,116.

R - the weight of the movable part of the device (load).

h - depth of immersion of the cone in the mortar mixture.

Compressive strength was determined on specimens measuring 7.07×7.07×7.07 cm. The sample was mounted in the center of the press plate, combining the sample and the geometrical axis of the plate, and presses the upper plate of the press. The load on the sample increased uniformly and continuously at a rate to its destruction after 20-60 second after the start of the test.

Compressive strength R_c, MPa (kg/cm^2) was calculated by the formula sample of

$$R_c = \frac{P}{F}$$

where P - the highest load installed in the test sample, MN (kgf);

F - sectional area of sample calculated as the arithmetic mean of the areas of the upper and lower surfaces thereof, in m^2 or cm^2.

The resistance to slipping of the solution was evaluated. The method was as the followings: Ceramic tile with a mixture was applied to a concrete surface of 10×20 cm with the layer thickness from 5 to 20 mm and maintained in a vertical position for some time, after that the creeping flow resistance was estimated, mm.

Adhesive strength was determined by the method of tearing off the stamp. The method is based on the determination of the peel strength of the stamp from the surface The used dies had a cylindrical shape with a diameter of 18 mm, pasted with epoxy glue (EDP-TU 0751-018-48284381-00) on finished surface. Set the sample horizontally, attaching a dynamometer to the die, and fixing the force necessary for tearing off the stamp from the test sample. The strength of adhesion of the finishing composition to the substrate was determined by the formula:

$$R_a = \frac{P}{F}$$

where P is the detachment force

F - contact area of the stamp with coating in m^2.

Water retention was determined by testing the mortar layer 12 mm thick, laid on blotting paper (sheets of blotting paper size of 150×150 mm, TU 13-7308001-758-88).

Before the test, 10 sheets of blotter paper were weighed with an accuracy of up to ±0.1g. The sheets of blotting paper were placed on a glass plate, stacked on top of a pad of gauze fabric, installed a metal ring and once again weighed. Carefully blended mortar mix laid flush with the edges of the metal rings, aligned, weighed and left for 10 min. Metal ring with a solution was carefully removed together with gauze. Blotting paper was weighed with an accuracy of up to ± 0.1g.

Water-the holding capacity of mortar was measured expressed as a percentage of water content in the sample before and after the experiment using the equation below.

$$V = \left[100 - \left(\frac{m_2 - m_1}{m_4 - m_3}\right) \times 100\right]$$

where m_1 - mass of blotting paper before test in gram

m_2 - mass of blotting paper after the test in gram

m_3 - mass installation without mortar in gram

m_4 - mass installations with mortar mixture in gram.

Water-holding capacity of the mortar was determined twice for each solution mixture sample, and the arithmetic mean of the two determinations was calculated, differing by no more than 20% of the lower value.

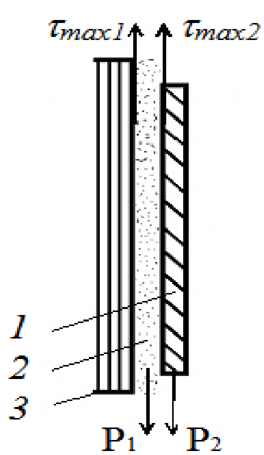


Figure 1: *Design scheme: (1) Wall tile (2) Adhesive layer (3) Vertical backerboard.*

The creep resistance of the layer of tile adhesive was calculated. The essence of the calculation is as follows: A layer of tile adhesive of thickness 'd' and height 'h' is attached to the wall material (backerboard) and holds a tile with weight P2. The layer is loaded with volume forces P1. In the adhesive layer at the interface with the backerboard and the tile there are shear stresses, t_{max1} and t_{max2} respectively, which keep in balance the adhesive layer (Figure 1).

$$\begin{cases} \tau_{\max 1} \times S = P_1 + P_2 \\ \tau_{\max 2} \times S = P_2 \end{cases}$$

To evaluate the conditions when a layer of tile adhesive is in equilibrium (the absence of creep), it is possible to use a system of equations:

where P_1 and P_2 are the weight of tile adhesive and the weight of the tile respectively.

S - area of the adhesive layer, which is equal to the tile area.

To evaluate the conditions when adhesive layer is in equilibrium (the absence of creep), it is possible to use the inequality:

$$|\tau_{\max}| \leq \tau_{c\partial}$$

where t_{cd} is limit stress of the shift t_o, rheological characteristics and adhesion strength of the tile adhesive t_{ad} summed up:

$$\tau_{c\partial} = \tau_0 + \tau_{a\partial}$$

Considering $P_1 = \rho_1 \times V_1$ that at the initial moment of application of tile adhesive layer the magnitude of t_{ad} is very small, the expression (6) can be written as:

$$\tau_{\max} \leq \tau_0$$

Volume forces (P_1), appearing in the adhesive layer, are calculated by the following formula.

$$P_2 = \rho_2 \times V_2$$

where ρ_1 stands for the density of the applied adhesive solution, kg/m^3

V_1 is amount of the applied adhesive, m^3.

Volume forces (P_2), appearing in wall tiles were calculated by the formula:

where ρ_2 is the density of facing tiles, kg/m^3

V_2 - the volume of facing tiles, m^3.

Evaluation of frost resistance of the adhesive on the basis of the developed cement-based cement-based DBM with the use of an additive based on amorphous aluminosilicates was performed by alternately freezing and thawing of samples of a glue solution measuring 70×70×70 mm after 28 days of air-dry hardening.

We have proposed an estimate of the shear strength of shear bonding with the help of the device GT 2.2.3 (Figure 2) (Zhegera K.V., 2015; Boldyrev G.G. Patent 2132545, 1996).

The mechanism of the GT 2.2.3 device is the creation of a horizontal shear load on the sample in the test installation on the basis of the test composition. The force created by the reduction gear is transmitted to the movable carriage of the shear box and measured by a force sensor (Figure 3).

The test sample is placed in the carriage of the device in such a way that the substrate is in a small shear ring, and the test composition is in a large shear ring. The technological gap of 1 mm forms the cut-off area. During the test, as the tangential load applied to the lower shear

Figure 2: *Appearance of the device GT 2.2.3: (1) Hairpin (2) Shearing mechanism (3) Shear box.*

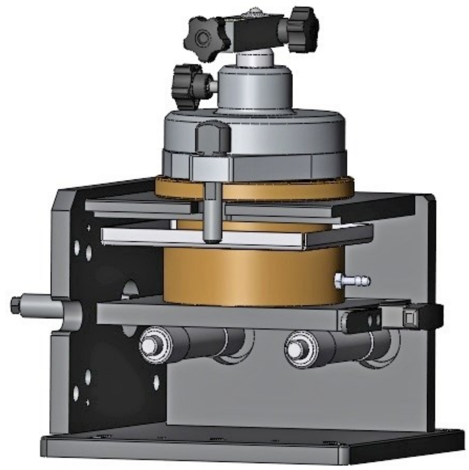


Figure 3: *Shear box - view without side wall*

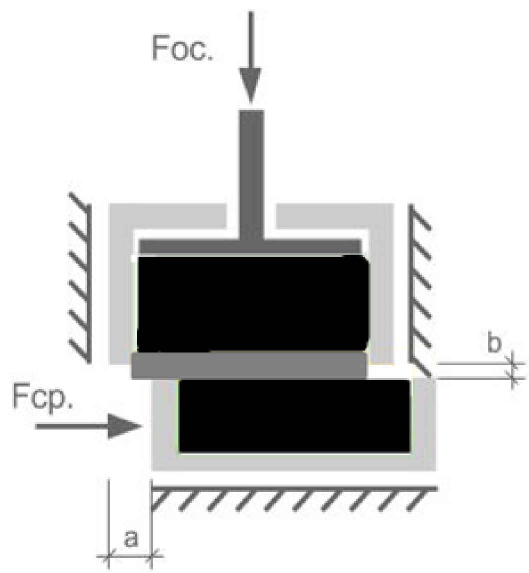


Figure 4: *Plan of test of specimens for shear analysis.*

ring increased, the value of the shear strains of the test composition relative to the substrate was recorded.

GT 2.2.3 instrument was used to determine the shear strength of the solvent adhesive layer relative to the substrate. A tile adhesive was used for the tests on the basis of the developed formulation of the dry glue mixture. The developed adhesive formulation contains Portland cement, mineral aggregate (sand), plasticizer, polymer and mineral additive (Loganina V.I., Zhegera K.V., 2015; Loganina V.I., Zhegera K.V., 2014).

For the tests, cement bases of cylindrical shape were used, the geometric dimensions of which are 71.4 × 15 mm. On the bases, the test composition of a tile adhesive with a thickness of 5 mm was applied (DIN EN 12004, 2012:09). The optimum shear rate of the solution adhesive layer is 0.2 mm/min. The samples were tested according to the scheme shown in Figure 3. For the testing purposes, the bases were prepared on a cement-sand base of cylindrical shape, the geometric dimensions of which were 71.4×15 mm. After hardening, the test composition 10 mm thick was applied to the bases.

The test sample was placed in the carriage of the device in such a way that the bases was in a small shear ring 2 and the test composition in a large shear ring 3 (Figure 2). The remaining volume of the large shear ring was filled with a gypsum test to ensure better fixation of the sample and an even distribution of the load on it. The technological gap of 1 mm forms the cut-off area. During the test, as the tangential load applied to the lower shear ring increased, the value of the shear strains of the test composition relative to the base was recorded.

To measure the homogeneity of the data obtained during the experiment using the proposed technique, the coefficient of variation was determined. The shear strength values obtained during the series test were used for the calculation. The root-mean-square deviation when testing a series of samples is 3-6 kPa. The resulting coefficient of variation is equal to 1.5-2.6%, therefore, the variability of the variational series can be considered insignificant. The measurement error of the instrument itself is 0.5% of the measuring range.

3. Research results

Amorphous silica-alumina based additive is a powder of white color with a high specific surface component S_{sp} = 68.6 m^2/g. Microstructure and chemical composition of the amorphous aluminosilicate examined via analytical scanning electron microscopy (Figure 5 and Table 1). 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 represented by particles, the size of which is 2.25-8.1 μm. The X-ray diffraction analysis revealed that the amorphous phase content was 77.5%.

The presence of an additive based on amorphous aluminosilicates in the cement dough formulation affects the structure formation of the cement stone-a decrease in the amount of free water and an increase in the chemically bound water compared to the 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%.

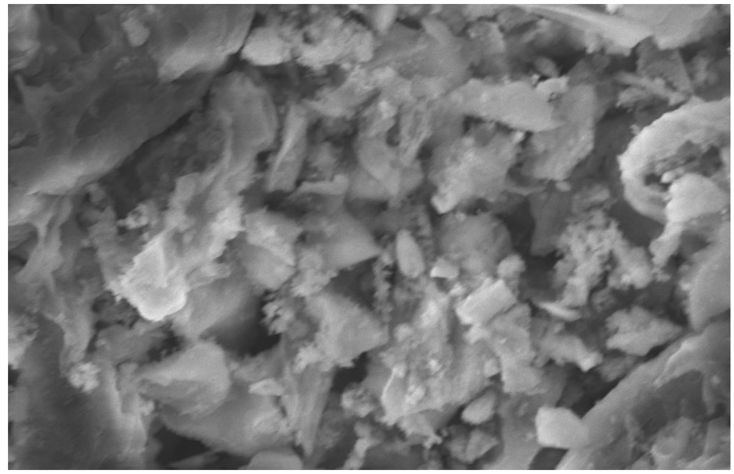


Figure 5: *Microstructure of amorphous aluminosilicate*

Table 1: *Chemical composition of the admixture*

Content	Chemical elements additives weight [%]				
	O	Na	Al	Si	S
Maximum	60.69	24.23	8.29	31.26	18.69
Minimum	36.73	8.61	1.10	7.92	0.68

It was found that the microstructure of the synthetic additives is characterized by particles of round shape, dimensions 5,208-5,704 μm, but the particles are present also oblong form, size 7,13-8,56 μm.

Analyzing the data in Table 1 revealed that predominate chemical elements O, Si, Na, S, and Al in chemical composition amorphous aluminosilicates - containing 60.69%, 31.26%, 24.23%, 18.69% and 8.29% respectively. The preponderance of this elements has a positive effect on the formation of cement stone structures with used synthetic additives. The effect of amorphous aluminosilicate to modify the rheological properties of cement-sand mortar was investigated. In the Fig. 6 given results of these studies are presented.

Analysis Fig. 6 showed, that the introduction in the cement -sand mortar the additive based on amorphous aluminosilicate leads to higher values of plastic strength

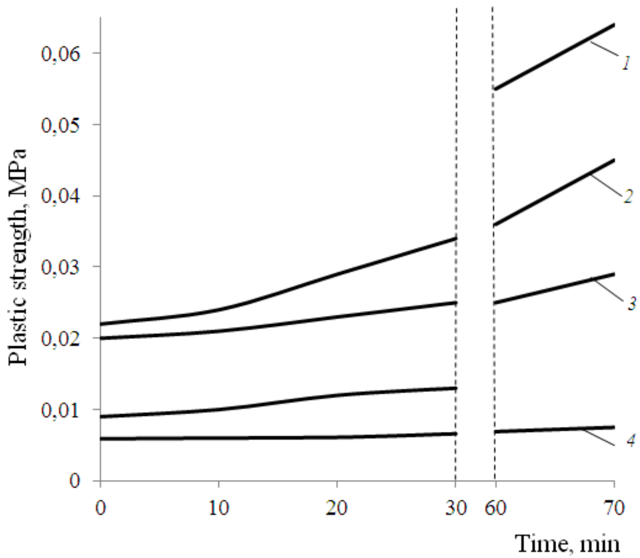


Figure 6: Kinetics set plastic strength cement-sand mortar: (1) with a synthetic additive (30% by weight of cement) (2) with a synthetic additive (20% by weight of cement) (3) with the use of synthetic additives (10% by weight cement) (4) a control sample (without the use of synthetic additives)

aged 20 min after curing compared to the control sample is 1.9 - 4.7 times (depending on the content the additives). Thus, the sample aged for 20 minutes from the beginning of solidification has strength of 0.0061 MPa, while the sample using of amorphous aluminosilicate (20% by weight of cement) was of 0.023 MPa.

It is obvious that, when introduced into the formulation of cement-sand mortar additives based on amorphous aluminosilicate period of hardening cement-sand mortar reduced, that is, the admixture has a water-holding capacity.

We have developed a composition of tile glue for the facing of external facades and internal walls of buildings ceramic tiles, which includes Portland Cement, mineral filler, plasticizer, polymer and mineral additive. As a mineral filler sand quartz fractions of 0.630-0.315 mm and 0.315-0.14 mm in a ratio of 4:1 are used, as a polymeric additive - a redispersible powder - Neolith P 4400, as a plasticizer additive Kratasol PFM, as a mineral additive - synthesized aluminosilicates.

The samples of cement composites using amorphous aluminosilicate based additive have a higher compressive strength on hardening in air-dry conditions as compared to control samples (no additives). Thus, the compressive strength of cement composite with additives on the basis of synthetic zeolites after 90 days air-dry hardening was 38.2

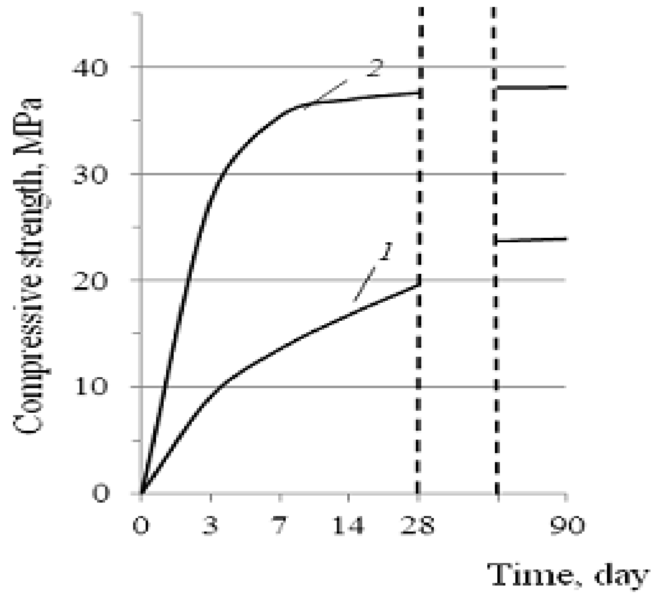


***Figure 7:** Kinetics of the curing cement samples in an air-dry conditions: 1 - reference sample (no additives); 2 - a sample with the addition of 20% additive by weight of cement.*

MPa, and the strength of the control sample (no additive) was 24.6 MPa (Figure 8).

The increase in strength of samples cement paste occurs due to more favorable humidity conditions (Figure 8). There is a lower rate of removal (evaporation) of water samples in the process of hardening.

The addition of synthetic zeolite has a significant effect on

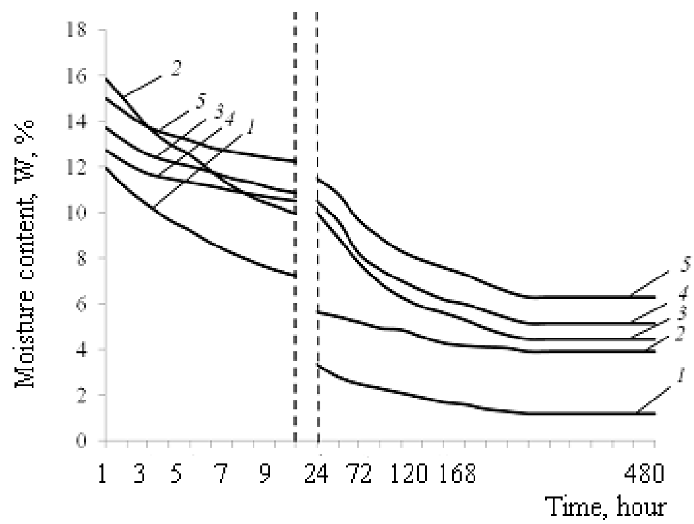


***Figure 8:** Kinetics of drying cement samples: (1) reference sample (no additives) (2) of the content 1% additive by weight of cement (3) of the content 10% of the additive by weight of cement (4) of the content 20% of the additive by weight of cement (5) of the content 30% of the additive by weight of cement.*

the water retention. Thus, in cement paste without added moisture for 20 days (480 hours) in an air-curing dry conditions was 1.2% (Figure 8, Curve 1), While the cement paste with additive in quantity 1% - 30% respectively, 3.89%-6.3% (Figure 8, Curve 2-5). It revealed that the moisture content of cement paste (without additives) on the 20th day of air-dry hardening less than cement paste with additive content of 1% - 30% by weight of cement 3.24 - 5.25 times, depending on content of the additive.

On the basis of mathematical research and experimental design (DIN EN 12004:2007) the model of cement stone strength was constituted. The factors affecting the change in strength of cement paste such as size of the specific surface additives (x_1), the percentage of synthetic additives (x_2) and the percentage of plasticizer Kratasol PFM (x_3) were investigated. After the analysis of the experimental data and the exclusion of insignificant coefficients of the regression equation, the model of cement stone strength

$$y = 24.477 + 2.6433x_1 - 1.0383x_2 - 1.3303x_3 - 4.5958x_1^2 - 3.3495x_2^2 - 2.0564x_3^2 + 0.6938x_1x_2 + 0.3688x_1x_3 + 0.3188x_2x_3$$

expressed by the formula:

According to DIN EN 1308 requirements, compositions based on DBM must be resistant to creep when applying them to vertical surfaces. In this regard, the article evaluates the sustainability of the developed composition to creep.

When calculating the shearing stresses it is assumed that the adhesive layer has thickness (d) of 0.005 m. The calculation results are shown in Table 2. The analysis of the data presented in the Table 2 shows that the values of shearing stresses t_{max1} t_{max2} are less than the limit stress of tile adhesive τ_0. As such, maximum shearing stress in the zone of contact with the backerboard (t_{max1}) is 0.00024 MPa, and maximum shearing stress in the contact zone with ceramic tiles of size 0.3 × 0.3 × 0.005 m (t_{max2}) is 0.00015 MPa. The limit stress of tile adhesive shift (τ_0) is 0.002 MPa. Thus, the condition of the absence of ceramic tile- and tile adhesive creep is met.

The analysis of the calculation results given in Table 2 shows that the condition of absence of creep is met when using other types of tiles as well. The results of these calculations are confirmed by experimental data. The experiment was to measure the maximum creep of a tile under its own weight with a caliper.

Maximum creep of a tile under its own weight was calculated as the difference between the two readings on calipers. The amount of creep of the adhesive layer based on the developed DBM formulation was 0.3 mm. The German standard DIN EN 1308 - 2007 sets 0.5 mm as the maximum tile creep (τ_{cn}).

Water-holding capacity of the mortar was determined twice for each sample solution mixture, and was calculated as the arithmetic mean of the two determinations, differing by no more than 20% of the lower value.

Data analysis (Table 3) shows that the water-retaining additive effect based on a synthetic zeolite in quantity 10% by weight of the binder effect of the introduction of identical 1% methylcellulose. However, addition of a synthetic zeolite has, as already mentioned, a significant structuring effect.

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

Table 2: *Resistance to creep of tile adhesive based on of the developed DBM*

Tile type	Tile size, m	Shearing stresses, MPa		Limit stress of tile adhesive shift τo (MPa)	Condition of creep absence
		t_{max1}	t_{max2}		
Ceramic	0.1×0.1×0.005	0.00022	0.00013	0.002	satisfied
	0.3×0.3×0.005	0.00024	0.00015	0.002	satisfied
Ceramic granite	0.6×0.6×0.01	0.00033	0.00024	0.002	satisfied
	1.2×1.8×0.02	0.00060	0.00052	0.002	satisfied
Granite	0.3×0.6×0.015	0.00069	0.00042	0.002	satisfied

Table 3: Influence of additives on the ability retain water

Additive	Addi-tive,%, by weight of the binder	The water retention of the mixture on the basis of a binder,%	
		cement	lime
-	-	93.3	94.7
Synthetic zeolites	10	95.7	96.3
	20	96.6	97.5
Methylcellu-lose	0.5	94.8	95.5
	1	95.9	96.4

The ability of the adhesive layer not to be destroyed for a long time with repeated freezing and thawing in a saturated water state is determined by the presence in its structure of reserve pores that are not filled with water. Under the 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 of the material. The destruction of the material in a water-saturated state with repeated freezing and thawing occurs only when all the reserve pores are filled with the formed ice. The higher the conditionally closed porosity of the sample, the more cycles of alternating freezing and thawing 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.

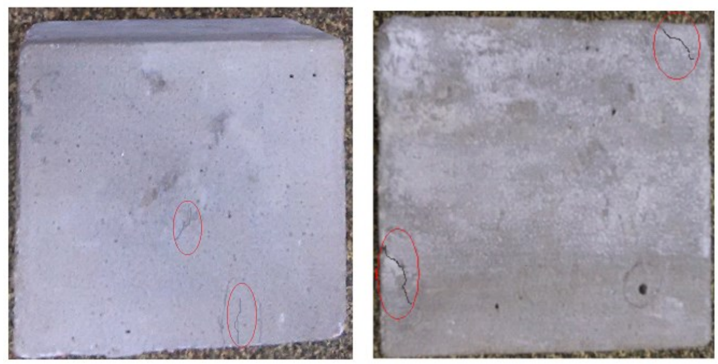
In the Table 4 presents the results of a study of the porosity of cement stone with the addition of an additive based on amorphous aluminosilicates.

Table 4: Change in the porosity value of cement samples depending on the content of the additive

Compositions	Porosity,%			
	The total	Capillary	Gel	Contrac tional
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

1 2

Figure 9: Samples before testing.



1 2

Figure 10: Samples of tile adhesive after testing.

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 the use of an additive based on amorphous aluminosilicates in the formulation was carried out by alternately freezing and thawing on the samples with size 70×70×70 mm, which were hardened 28 days on the air. In the Table 5 presents the results of the tests for frost-resistance of tile adhesives. Figures 9 and 10 show samples of tile adhesive prior to testing and after testing, respectively.

As can be seen from Figures 9 and 10, samples of cement-based tile glue have subtle chalking, cracks on the surface visible to the naked eye make 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 5), i.e. can withstand 50 freeze-thaw cycles without changing the strength (within an acceptable error of 10%).

Table 5: *Frost resistance of tile adhesive*

Test result of samples (Cycles)								
	0	5	10	15	25	35	50	75
Average strength of the tile adhesive (MPa)	43.20	42.83	42.70	42.60	42.07	39.86	39.36	38.43
Change in the average strength of the tile adhesive (%)		0.16	0.47	0.70	1.94	7.78	8.24	10.42

Table 6: *The frost resistance of tile adhesive contact zone*

Test result of samples (Cycles)								
	0	5	10	15	25	35	50	75
Average adhesive strength of the tile adhesive (MPa)	1.20	1.18	1.17	1.12	1.03	1.00	0.97	Tile abrup-tion
Change in the average bond strength of the tile adhesive (%)		1.67	2.50	6.67	14.16	16.67	19.17	

When determining the brand for 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 thawing 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 6.

Figure 11: *Samples after the test: Left - thawing in the air; Right - thawing in a humid environment*

Analysis of the data presented in Table 6 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-thaw cycles. The test results are shown in Figure 11.

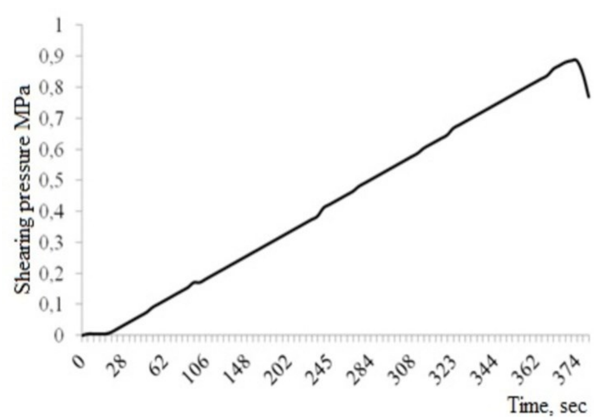


Figure 12: *Shear-based cement slip shear test*

Table 7: Physical and mechanical properties of tile adhesive

Indicator	Value of the indicator	
	Designed composition	The prototype (no additives)
Density of the mix [kg/ m^3]	1800	1670
The correction time [min]	20	30
Water retention [%]	97,8 – 99,3	95,0 – 97,0
Slipping tile no more than [mm]	0,3	0,5
Frost resistance of tile adhesive	*F*50	*F*50
Frost resistance of contact zone	$F_{кз}$50	$F_{кз}$50
Adhesion strength, R_{adg}, [MPa]	более 1.4	1.1
Cohesive strength, R_{kog}, [MPa]	2.2	1.6
Adhesion strength in shear, [MPa]	0.92	0.6

The analysis of the obtained results showed that the separation occurs on the ceramic tile and is R_{kog} = 0.97 MPa. The results of testing the glue layer on the basis of cement glue on a cement bases are shown in Figure 12.

Data analysis shows that the adhesive strength on the shear of the solution layer on the basis of the developed formulation of the tile adhesive is 0.92 MPa, which meets the requirements imposed on the adhesion strength of the adhesive layer (DIN EN 12004, 2007).

Physical and mechanical properties of tile adhesive with additive on the basis of amorphous aluminum silicates, which includes the M400 Portland cement, sand fractions 0,63-0,315: 0,315-0,16 in a ratio of 80%: 20%, amorphous aluminosilicates, plasticizer and PFM Kratasol redispersible powder Neolith P 4400 are given in the Table 7.

4. Conclusion

This study reveals that the use of a composite binder comprising of amorphous aluminosilicate leads to higher values in the plasticstrength early and late periods in hardening. A model of cement stone strength in the presence of synthetic additives and plasticizer Kratasol PFM has been given. The efficiency of the use of amorphous aluminosilicate as a modifying agent is proven. This agent improves the physical and mechanical properties of tile adhesive made on the basis of the developed recipes glue dry mixes. The adhesive strength of the solution based on the developed adhesive dry building mix using amorphous aluminosilicates based additive after freezing-thawing in the air and after freezing-thawing 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.

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 the cities of Russia in the moisture zone-3 (dry) and climatic subareas IIB in accordance with SNiP 23-01 -99* was established. The proposed technique for estimating the adhesive strength allows us to take into account not only the adhesive strength of the substrate, but also the shear bond strength.

References

Aiello R., Collela C., Sersale R. (1971). Molecular sieve zeolites, Advances Chem. Ser., 101 51.

Andrejkovicova S., Ferraz L., Velosa A.L., Silva A.S. and Air F.R. (2012). Lime mortars with incorporation of sepiolite and synthetic zeolite pellets, *ActaGeodyn. Geomater,* 9(1):79–91.

Boldyrev G.G., Hriyanina O.V., (1996) U.S. 1996 Patent #2132545

Broussard L., Shoemker D.P. (1960) Am. Chem. Soc. 82/5, 1041.

DIN EN 12004 (2012). Moscow. Publishing house: Standartinform

DIN EN 12004 (2007). Moscow. Publishing house: Standartinform

Doroshenko Y.M., Shanah J. I. (1989). Processes of structure and properties of cement stone with polymeric modifiers, 15 Szilikatip. esszilikattund. konf.: SILICONF R.l., Budapest, 273-276.

Jenni A., Holzer M., Zurbriggen M., Herwegh, M (2005). Influence of polymers on microstructure and adhesive strength of cementitious tile adhesive mortars, *Cement and Concrete Research,* 35(1):35-50.

Loganina V.I., Ariskin M.V., Karpova O.V., Zhegera K.V. (2015). Evaluation of crack resistance of the finishing layer based on adhesive dry mixture with synthetic aluminum silicates, Building materials. 1086.

Loganina V.I., Makarova L.V., Tarasov R.V., Ryzhov A.D. (2014) The limy composite binder with the use of the synthesized alumosilicates, *Applied Mechanics and Materials.* 662:11 -14.

Loganina V.I., Makarova L.V., Tarasov R.V., Sadovnikova M.A. (2014) Composition limy binder with the use of the synthesized alumiosilicates for dty construction blends, *Advanced Materials Research*. 977:34-37.

Loganina V.I., Makarova L.V., Tarasov R.V., Zhegera K.V. (2014) The composition cement binder with the use of the synthesized alumosilicates, *Advanced Materials Research.* 10223,6.

Loganina V.I., Petukhova N.A., Gorbunov V.N., Dmitrieva T.N. (2009) Prospects for the manufacture of organo-mineral supplements on the basis of domestic raw materials, Proceedings of the higher educational institutions, *Building*. 936-39.

Loganina V.I., Ryzhov A.D. (2015) Structure and properties of synthesized additive based onamorphous aluminosilicates, Case Studies in Construction Materials 3, 132-136.

Loganina V.I., Zhegera K.V. (2014) Bulletin of BSTU. V.G. Shukhov 5 p 36-41

Loganina V.I., Zhegera K.V. (2014) Evaluating the effectiveness of the use of synthetic aluminum silicates in cement systems, Academic Gazette UralNIIproekt RAASN. 384-87.

Loganina V.I., Zhegera K.V. (2015) Herald of South Ural State University. Series «Construction and architecture». 2(15) p 43-46

Loganina V.I., Zhernovsky V.I., Sadovnikova M.A., Zhegera K.V. (2013) The addition of aluminosilicate-based cement systems, *Eastern European Journal of advanced technologies.* 5:68-11.

Mirsky Y.V., Mitrofanov M.G., Dorogochinskiy A.Z. (1964) New adsorbents - molecular sieves, Grozny: Chechen-Ingush. 385.

Mumpton F. A. (1999) Larocamagica: Uses of natural zeolites in agriculture and industry, PNAS, 96/73463 – 3470

R Barrer.M., Cole J.F., Sticher H. (1968) Chem. Soc., Inorg. Phys. Theoret. 102475.

Stark U., Reinold M., Muller A. (2003) Neue Methoden zur Messung der Korngrobe und Kornform von Mikro bis Marko, Weimar, 11369 -1380.

Taramasso M., Perego G., Notari B. (1980) Proceedings of the 5th International Conference on Zeolites (Ed.L.V.C.Rees), Heyden, London, 2, 40.

Yiqing F., Lianzhang C. (1991) Effect of aqueous boric acid (H3B03) treatment on catalytic performance of HZSM-5 zeolite catalysts, Shiyou Jiagong, 7/2 44.

Zhegera K.V., Pyshkina I.S., Ryzhov A.D., Zhivaev A.A. (2015) *Regional architecture and construction* p 64-67.