Improving the adhesive properties of painting thermal insulation with cement-containing surfaces

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Abstract. The article describes the main methods of increasing adhesion, analyzes the cement-containing component that was added to the heat-insulating material based on the experiment, draws the appropriate conclusions about the change in the adhesive properties of the resulting composition.

Introduction
In construction, much attention is paid to increasing the thermal resistance of building envelopes. At the same time, the customer, together with the contractor, makes every effort to reduce the total cost of the work performed. In the low-rise buildings’ construction, the percentage of which in the residential buildings’ general construction is growing steadily, the outer walls are often built with the expanded clay concrete blocks [1,2,3], as well as with other block building materials [4,5,6]. One of the huge drawbacks of these buildings is the impressive cost of heat and energy resources, the heat supply of buildings due to the errors during the heating systems’ operation, significant thermal conductivity of building envelopes, lack of supply air entering the building through the controlled ventilation and poorly executed insulation of heating systems. Actual tasks to reduce energy consumption have led to the energy-saving technologies’ development. The percentage of energy consumption of the total heat energy used in Russia is in the range from 43 to 45%. The introduction of BC 50.13330.2012 “Thermal protection of buildings” has led to the increased energy efficiency in new buildings, but unscrupulous companies, with the aim of saving money by reducing the energy-efficient construction costs, invest in the construction of buildings with a low energy saving indicator.

It should also be noted in 2009 that the State Duma of the Russian Federation adopted the federal law “On Energy Saving and Improving Energy Efficiency”, the essence of which is mandatory compliance with energy efficiency requirements, one of which is the availability of energy meters, all buildings put into operation, the same applies to the buildings during operation. The law has formed the organizational measures to achieve savings through energy-efficient materials.

Modern highly effective heat-insulating materials fulfill these tasks in solving the problem of energy conservation in construction. An example is liquid thermal insulation. We have insulated Magniterm with paint thermal insulation of the low-rise buildings’ external walls for 5 years and have confirmed the effectiveness of using this insulation. However, in some cases, we have encountered insufficient...
adhesion. Over the next 2-3 years, the material exfoliated in the places from the surface of the walls. Therefore, our practical and scientific task has become increasing the adhesive properties of the material.

Adhesion

According to the conducted consulting studies, the basis for the correct connection of materials of various textures and types is a lot of physical phenomena and properties in construction. It is adhesion that most strongly affects bonding of different substances to each other. Depending on the nature of the molecular networks of various substances and materials with each other, adhesion can have different values, which can change due to the processes that last during drying. Adhesion decreases markedly when shrinkage occurs, in which there is a weakening of the materials adhesion to each other on the surface. This is noticeable when combining old concrete with a new masonry mortar. The decrease in adhesion is also influenced by the temperature and humidity of the environment at the application time of the decorative or protective materials, various contaminants, for example, dust on the substrate surface.

Analysis of the adhesion enhancement methods

Modern methods for increasing adhesion were analyzed and systematized. The following are determining and allowing significant adhesion increase.

Chemical. When using it, special plasticizers, impurities or additives are added into the building materials to achieve the desired result.

The application of special compositions to the surface refers to the physical and chemical method. Examples of this method are special primers, plasters and putties.

In the mechanical method, to increase adhesion, notches are applied to the surface, abrasive is applied, and dust removal or cleaning of various contaminants is used.

Adhesion is one of the main indicators of the work quality and the structures’ reliability; therefore, new methods are being developed to increase it. Their use will increase the service life of the building structures and finishing materials, which ultimately leads to significant savings.

Object of study

In this work, the object of study is the liquid thermal insulation Magniterm, the basis of which is vacuum ceramic and silicone micro granules in an acrylic binder, characterized by a low coefficient of thermal conductivity. By consistency, it can be compared to the water-based paints.

According to the manufacturer, the insulation Magniterm has a high adhesion of 1.04 MPa, which makes it possible to apply coatings on the surfaces of any form and composition.

Purpose of research

The aim of the research work is to increase the adhesive properties of paint thermal insulation.

We hypothesized that the addition of cement to a liquid thermal insulation should increase the adhesive properties of the material, since the basis is in most cases the cement-containing materials.

For this, adhesion of the Magniterm brand of control paint was examined in comparison with the same Magniterm paint, but with the addition of cement.

For the experiment, cement of the M500 D0 brand (CEM I 42.5N) was determined, since as a result of the cement sales’ analysis by the largest organizations in the region, this particular brand was the most common. Cement is characterized by the high strength characteristics, sufficiently fast setting time and the absence of undesirable impurities.

Experimental part

The experiment was conducted on the basis of a method for quantitative determination of the coatings’ adhesion by the separation strength in laboratory conditions.
The essence of the method is based on measuring the force corresponding to the separation of the coating from the protected concrete surface, directed perpendicular to the coating plane, using a glued metal disk and an adhesimeter [7].

The adhesion value of each coating system was determined by testing five twin samples.

**Prototyping**

Test samples consisted of a concrete substrate, a protective coating and a tear-off element - a disk glued to it. For testing, the samples of cubes 100 × 100 × 100 mm in size made of concrete mix, were used. As a substrate, concrete of the compressive strength class B30 (M400) was used.

Prototypes were made in metal collapsible forms. Before filling, the inner surfaces of the mold were lubricated with a thin layer of emulsion Emulsol - EX-A, providing the required formability. After that, the concrete mixture was additionally mixed by hand and fit into molds. The same actions were carried out with all prototypes made from one sample of concrete mix, which was compacted under the same conditions.

The concrete mixture in the molds was mechanically compacted on a vibrating table for 30 seconds. The mixture compaction quality was checked by stopping the settling of the concrete mixture, by leveling the concrete mixture on the surface, by the presence of a thin layer of cement paste on the concrete mixture surface. After laying and compacting the concrete mixture, the outer surface of the samples was aligned. Alignment was carried out with a metal spatula.

The samples were hardened for 28 days at a temperature (20+/−5) °C and relative humidity (65 +/- 5) %. After gaining strength, the samples were dismantled, their surface was cleaned of cement milk with a metal brush and sandpaper, and then dedusted with a flat paint brush.

The surface of the metal disks intended for gluing was flat, there were no traces of rust, oils, etc.

**Application of thermal insulation of ionic composition on prototypes**

The surfaces of the first five concrete samples numbered as K.1, K.2, K.3, K.4, K.5 were coated with Magniterm heat-insulating paint. The layer thickness of 1 mm was controlled by the electronic caliper. Before using Magniterm liquid thermal insulation, the composition was thoroughly mixed to a homogeneous mass. To obtain the required consistency, water was added with a calculation of not more than 10% of the paint volume. When mixing with an electric drill with a nozzle of the “mixer” type, the speed of revolutions did not exceed 200-300 rpm. Mixing time ranged from 3 to 5 minutes. Paint was applied with a brush in three passes. The layer thickness in one pass was in the range of 0.4-0.5 mm. If to apply the heat-insulating paint with a layer of more than 1 mm at a time, this will lead to the moisture-permeable film formation on its surface, which will interfere with the complete evaporation of the moisture contained, because of this, the coating is deformed, and its thermal properties are lost. Therefore, the application technology of the manufacturer was observed, according to which the polymerization time of each layer is 12-24 hours. For the experiment purity, each layer was left to dry completely for 24 hours at air temperature (19 +/- 4) °C and relative humidity (64 +/- 3) %. The thickness of the final coating layer was 1 mm.

**Application of fabricated cementitious composition to prototypes**

The surfaces of the second five concrete samples E.1, E.2, E.3, E.4, E.5 were painted with Magniterm thermal insulation with the addition of cement M500 D0 (CEM I 42.5N) with a thickness of 1 mm. The thickness of the coating composition was checked using an electronic caliper. The experimental composition was formed by adding cement M500 D0 to the liquid thermal insulation of Magniterm (CEM I 42.5N).

At the same time, the following actions were taken organizationally. The liquid thermal insulation was mixed in a PVC container to a uniform mass. Cement was dissolved in water. The volume of added water was about 10% of the volume of paint. The mixture was constantly mixed with a low-speed electric drill with a mixer for 3 to 4 minutes. Next, the cement-containing composition was poured in a thin stream into a container with a basic composition, also with constant stirring for 3 to 4 minutes until
a homogeneous mass was obtained. After receiving the planned composition, it was applied with a flute brush and a metal spatula to the surface of the prototypes. The thickness of the applied layer was 1 mm. Prototypes were kept in the laboratory at air temperature (19 +/- 4) °C and relative humidity (64 +/- 3) % in 24 hours.

*Bonding the tear-off element to the prepared coating*

After the samples’ coating had been completely dry, a site with an approximate bonding area 0.5 m² the surface was selected, on which the epoxy adhesive was applied, on top of which metal disks were glued. The excess smudges of the adhesive were removed by the solvent before it had time to gain strength. Later, when the glue hardened, the coatings were cut to the base around the metal discs’ perimeter.

*Determination of adhesion*

To determine the adhesion (adhesion force) of paint coatings with a concrete base, the POS-50 MG4.OD device was used with the plates 50 × 50 mm, in which the specific separation force was at least 5 MPa. The samples were fixed through a metal disk pivotally connected to the gripping device of the POS-50 MG4.OD device. Loading was carried out uniformly with a speed of not more than 1 MPa / s. The test time before tearing off the metal disk is from 30 to 90 s. The magnitude of the force at which the detachment of the disk occurred was determined on the adhesimeter scale. A visual assessment and fixation of the zones and the nature of the metal disks’ separation from the base of the experimental sample was carried out with filling out the test report.

*Results Processing*

Adhesion value - R, MPa, was determined by the formula:

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R = \frac{F}{A},
\]

where \(F\) – is the value of the force at which the separation occurred, N;
\(A\) – is the separation area, mm².

After calculating the adhesion value of the first five control samples, their indications were summarized and divided by the number of samples, thus obtaining the arithmetic mean. The same has been done to all samples. The test results are shown in Table 1 and Figures 1, 2, 3.

**Table 1. Change in adhesion value depending on cement content.**

| No. | Sample  | Adhesion, MPa | Thermal conductivity, W/m°C | Cement content, % |
|-----|---------|---------------|-----------------------------|-------------------|
| 1   | 1 - control | 1.04         | 0.0012                      | 0                 |
| 2   | 2       | 1.08         | 0.00122                     | 2                 |
| 3   | 3       | 1.14         | 0.00123                     | 4                 |
| 4   | 4       | 1.17         | 0.00124                     | 5                 |
| 5   | 5       | 1.22         | 0.00126                     | 7                 |
| 6   | 6       | 1.301        | 0.00127                     | 9                 |
| 7   | 7       | 1.3013       | 0.00129                     | 11                |

Based on the experimental data presented in Table 1, it is seen that with the cement addition more than 7%, the samples 6, 7 show a significant increase in thermal conductivity and a slight increase in adhesion. Based on this, it does not make sense to increase the cement content further.
Figure 1. The dependence of the change in adhesion on the cement content.

Summary
Based on the conducted practical studies and laboratory experiments, a positive result was obtained: the samples with the cement addition of 5-7% are most optimal, while the thermal insulation Magniterm
adhesion with the addition of cement M500 D0 (CEM I 42.5N) is 13-15% higher than the adhesion of the Magniterm material. However, the thermal conductivity coefficient of the Magniterm thermal insulation with the addition of M500 D0 (CEM I 42.5N) cement was 4-4.67% higher than the thermal conductivity of the Magniterm material. This does not significantly affect the resistance of the external walls to heat transfer, therefore, in general, the resulting mixture is more effective than the control sample.

As a result of testing this composition on a real object, confirmation was obtained of the adhesion and thermal conductivity corresponding to the samples under study.

The full-scale experiments and testing of the coating used as decorative plaster were also carried out, on which any water-based paint or paint with the addition of wax can be applied, which performs not only a protective, but also an aesthetic function.

However, when performing work, it is necessary to strictly observe the technology of mixing the working mixture, applying and leveling.

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