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Research Article

Effective Method of Improving the Performance Properties of Wall Products On the Basis of the Gypsum Binder

Yurii Gasan*, Olga Drozdova, Vitalii Tarasevych, Oleksandr Hryhorchuk

Department of Building Materials, Kyiv National University of Construction and Architecture, Kyiv, Ukraine

Abstract

The basis of the conducted research was the goal of modifying composite gypsum-containing binders for the manufacture of wall products with increased water resistance, strength, frost resistance, and durability by developing a hydrophobizing solution for processing products based on gypsum binder. The article presents the results of research on the modification of artificial gypsum stone with a developed hydrophobizing chemical solution based on calcium polysulfide and titanium dioxide. Comparative indicators of water absorption of original and solution-impregnated samples, which were exposed to the frontal influence of water, are given. The water absorption of the modified samples is within 9...21% and does not change after the frontal impact of rain. Indicators of chemical resistance of impregnated samples in solutions of magnesium sulfate, urea, acetic and oxalic acids, which are characteristic components for aggressive environments of livestock complexes, food and chemical industry, are presented. The test results of the samples showed that the developed chemical solution provides a chemical resistance factor of 0.7, that is, they are chemically stable in such environments. It is shown that, depending on the number of applied layers of the solution or the time of impregnation, hydrophobization gives high indicators of the softening coefficient of the products, which is in the range of 0.6...0.82. The research results showed that thanks to the developed hydrophobizing solution, the construction and technical characteristics of the artificial gypsum stone are significantly increased. Wall products made of this material have high operational characteristics, and it is advisable to use them both indoors and outdoors.

Keywords

Gypsum, Calcium Polysulfide, Water Resistance, Chemical Stability

1. Introduction

One of the most promising for the development of wall products is gypsum binder, due to the presence of a sufficient number of gypsum deposits and the ease of processing this raw material into binders. In addition, the production of gypsum binders is characterized by a relatively small specific consumption of fuel, electricity and raw materials. Thus, when burning gypsum, 35...45 kg of conventional fuel is used for 1 ton of products, while for burning lime and cement, respectively, 140...160 and 150...200 kg. Specific electricity consumption for the production of 1 ton of gypsum binder is 20...25 kWh, and 1 ton of cement is 90...130 kWh. 1.35...1.30 tons of raw materials are needed to produce 1 ton of gypsum binder, while 1.6...1.7 tons are needed to produce lime and cement.

Other positive qualities of gypsum, which determine its advantage in comparison with cement, are well known: speed

*Corresponding author: gasanyug@ukr.net (Yurii Gasan)

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of hardening, low thermal conductivity of products, low energy consumption and relative simplicity of production, increased aesthetic and sanitary-hygienic properties.

Insufficient water resistance of artificial stone based on gypsum binder is explained by researchers in different ways. According to P.P. Budnikova, V.N. Jung, the main reason for the low water resistance of gypsum products is the significant solubility of gypsum in water, which is 2.05 g/l $CaSO_4$ at 20 ℃. As a result, upon moistening, the connections between the crystals are broken, which causes a decrease in the strength of the gypsum stone and determines its low water resistance [1, 2].

O. N. Rebinder believes that the main reason for the decrease in the strength of gypsum stone when moistened is the adsorption of moisture by the inner surfaces of microcracks and the occurrence of the wedging effect of water films, as a result of which individual elements of the crystal structure are separated. At the same time, the adsorption effect is enhanced by the significant porosity of gypsum materials [3, 4].

Research conducted by various scientists over the past decades has allowed us to identify the most effective ways to increase water resistance: selection of the optimal composition of mixed binders, treatment of products based on gypsum binders with various water-repellent solutions, chemical and mineral additives, etc. [5-8]

One of the methods of obtaining waterproof materials is the impregnation of products based on gypsum binders with a developed chemical solution containing calcium polysulfide and titanium dioxide. The developed method of hydrophobization of products allows their use in buildings and structures for external and internal use.

In recent years, research has been conducted on the development of special solutions for processing lightweight concrete using nanosized elemental sulfur [9]. But the use of such solutions has certain disadvantages, such as the complexity of the technology, high cost and others. Studies of the toxicological safety of the production and operation of sulfur-gypsum composite products have shown that the use of sulfur in the production of construction products does not pose a potential threat to people and the environment [10, 11].

Currently, there are a large number of different protective coatings for building materials, but most of them retain their protective properties for a certain, rather short time (2-3 years). Everyone knows the need to re-apply protective materials to building facades due to the destruction of the previous protective layer.

The main thing in the development of gypsum products is to ensure the necessary water resistance in order to avoid the destruction of the products from atmospheric influences and aggressive environments.

2. The Purpose of the Work

The basis of the conducted research was the goal of developing a chemical solution for processing artificial gypsum stone for the manufacture of wall products with increased water resistance, strength, frost resistance and durability [12].

3. Materials and Research Methodology

G-5 gypsum binder was used to make the samples (DSTU B.V.2.7-82-2010. Construction materials. Gypsum binders. Technical conditions). To prepare the solution: titanium dioxide (GOST 9808 - 84. Pigment titanium dioxide. Technical conditions), calcium polysulfide (TU 2153-003-55841212-2003. Aqueous solution of calcium polysulfide. Technical conditions) manufactured by Svitlo LLC.

The compressive and bending strength was investigated according to the standard method described in DSTU B V.2.7-82:2010 (Construction materials. Binding gypsum. Technical conditions), water absorption and frost resistance were determined according to DSTU B V.2.7-42-97 (Construction materials. Methods of determining water absorption, density and frost resistance of building materials and products).

The corrosion resistance of the modified samples was determined in laboratory conditions in organic acid solutions, for which the samples were kept for 6 months in a desiccator on a grid so that they were in contact with the solution from all sides, the acid solution was changed twice a month. Corrosion resistance was determined by the coefficient of chemical resistance (the ratio of the value of the average bending strength of samples after exposure to an aggressive solution to the value of the average bending strength of samples in natural conditions).

4. Research Results

As a result of the work, a chemical solution based on calcium polysulfide and titanium dioxide was developed [13]. Due to calcium polysulfide, this solution allows you to ensure water resistance and maintain the strength of artificial stone based on a gypsum binder, and since sulfur has a yellowish color, the addition of titanium dioxide ensures the white color of the product. To ensure the necessary physical and technical characteristics of the product, the solution is applied in several layers or by impregnation for a certain period of time.

In conditions of cyclic rain exposure, an important indicator is the accumulation of moisture in the material. For this purpose, tests on the kinetics of water absorption of non-impregnated and solution-impregnated gypsum stone samples were conducted. At the first stage, water absorption was measured for pre-dried samples, then the same samples were treated with a solution based on calcium polysulfide and titanium dioxide.

The samples were dried for three days, then subjected to frontal exposure to water for 2 hours, after that their water absorption was measured; the data are shown in Table 1.

Table 1. *Comparative indicators of water absorption of initial and solution-impregnated samples of artificial gypsum stone after frontal exposure to water.*

№	Sample based on G-5 gypsum binder	Water absorption, %	
		to the test	after the frontal impact of water
1	G-5	34	-
2	Impregnation 2 hours	21	21
3	Impregnation 4 hours	14	14
4	Impregnation 6 hours	8	8
5	6 layers of coating	9	9
6	GKZh-10	16	14
7	HGS-100	13	13

The data shown in Table 1 indicate the effectiveness of using the proposed method of protecting building materials when operating them in rainy conditions. That is, the solution is not washed out of the gypsum stone and retains its properties.

It is known that the chemical stability of the composite material depends on its permeability and the reactivity of the components to the influence of aggressive environments.

It was established that the impregnation of gypsum samples with the developed solution significantly reduces their overall porosity, which allows to significantly reduce the permeability of the gypsum matrix, and therefore it is possible to predict a decrease in the influence of an aggressive environment.

The chemical stability of impregnated samples was determined in solutions of magnesium sulfate, urea, acetic and oxalic acids, which are the most characteristic components of aggressive environments in animal husbandry and agricultural complex, transport construction. The results of tests of samples after six months of aging in the named environments are shown in Table 2.

Table 2. *Test results of impregnated samples for chemical resistance.*

№	Type of processing	W, %	Coefficient of chemical resistance			
			Acetic acid	Oxalic acid	Urea	$MgSO_4$
1	6 layers	92,0	0,73	0,73	0,72	0,72
2	Spraying	74,2	0,76	0,79	0,77	0,77
3	4 hours of impregnation	61,4	0,86	0,85	0,86	0,87
4	6 hours of impregnation	54,0	0,89	0,89	0,89	0,84

It was established that the gypsum samples impregnated with the developed solution have a chemical resistance coefficient of at least 0.7. This makes it possible to classify them as chemically stable in these environments.

Table 3 shows data for samples made on the basis of gypsum binder, which indicate a significant improvement in its main characteristics that determine the service life.

The experiment on hydrophobization with the developed chemical solution, depending on the number of applied layers or the time of impregnation, showed high values of the coefficient of softening of the products, which is in the range of 0.6...0.82.

Also, it was established that the depth of penetration of the solution into the structure of the sample depends on the number of coating layers. As a result of five applications, the solution penetrates to a depth of 10 mm.

Table 3. *Indicators of the sample made on the basis of gypsum binder after treatment with the control composition of the chemical solution.*

Physicomechanical indicators	Control sample	6 layers of solution applied. brush	Spraying	Diving, 2 hours	Diving, 4 hours	Diving, 6 hours
Compressive strength, MPa	10,1	11,6	11,5	10,8	11,1	12,2
Bending strength, MPa	4,5	4,8	4,9	4,8	4,9	4,9
Softening factor	0,5	0,81	0,81	0,63	0,82	0,83
Frost resistance	-	50	50	-	50	50

The developed solution makes it possible to achieve water resistance of products based on gypsum binders not only for relatively small sizes by immersing them, but also for brush or spray treatment of large structures and building elements. Also, the use of sulfur as a hydrophobizer allows you to obtain such properties as bactericidal, resistance to biological factors of destruction of products [14, 15].

5. Conclusions

1) As a result of the research, a chemical solution was developed for processing artificial gypsum stone for the manufacture of wall products.
2) It was found that thanks to the developed hydrophobic solution, it is possible to reduce the water absorption of gypsum stone to 8...16%, depending on the method of processing.
3) It is shown that the developed solution has a high ability to penetrate into the smallest pores, and the inorganic nature of the coating is the basis for effective and universal long-term protection.
4) The use of a chemical solution of this composition allows: to significantly increase the durability of building materials and products, as well as the service life of existing buildings and structures.
5) It was established that gypsum samples impregnated with the developed solution have a coefficient of chemical stability of at least 0.7. This makes it possible to classify them as chemically resistant in aggressive environments.
6) The proposed method is simple and therefore available for wide application.

Conflicts of Interest

The authors declare no conflicts of interest.

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