Biostability of Facade Systems

T F Elchishcheva¹, V V Afonin², I V Erofeeva², E A Zaharova³ and A B Atmanzin³

¹Tambov state technical university, 106 Sovetskaya Street, Tambov, 392000, Russian Federation
²National Research Ogarev Mordovia State University, 68 Bolshevistskaya Street, Saransk, 430005, Republic of Mordovia, Russian Federation
³National Research Nizhny Novgorod State University named after N.I. Lobachevsky, 23 Gagarina Avenue, Nizhny Novgorod, 603950, Russian Federation

E-mail: aelschevat@mail.ru (corresponding author), vvafonin53@yandex.ru, ira.erofeeva.90@mail.ru

Abstract. Protection of buildings and structures made of stone materials from biological corrosion is relevant for all groups of buildings, especially in wet and wet modes of operation of external enclosing structures and in conditions of pollution from industrial emissions. The presence of salts in raw materials, mixing water and technological additives to improve the properties of the mixture in the manufacture of building materials, masonry and plaster mortars causes the transfer of salts to the facades of buildings. Due to the hygroscopic effect, salts attract atmospheric moisture, and waterlogged material is a favorable environment for the development of spores of various types of filamentous fungi. The combined effect of salt and biological corrosion reduces the strength properties of materials. Destruction of paint and plaster layers disrupts the appearance of building facades. The study investigated the biological resistance of samples of facade plastering systems to the action of test cultures of filamentous fungi. The fungicidal and fungicidal properties of facade plastering systems of various compositions have been studied. The influence of different types of primer, filler and color on fungal resistance, fungicide and physical and mechanical properties of facade coatings was revealed. It was revealed that multilayer facade systems, consisting of materials with high vapor permeability, water-repellent properties and biostability, provide joint protection against salt exposure and the influence of biological pollution. The aesthetic qualities of the facade surface are ensured by decorative plastering or painting.

1. Introduction

Solving the problems associated with the biological destruction of building materials and structures, as well as those devoted to the protection of buildings and structures from biological corrosion is an extremely important task. The activity of microorganisms, especially filamentous fungi and bacteria, causes biodegradation of materials. The share of damage from their influence accounts for more than 40% of the total volume of biological damage. The greatest danger is posed by biological destruction and pollution for various types of buildings and structures, which are located in settlements, in the immediate vicinity of which are large industrial enterprises with an aggressive production
environment. In this case, the intensity of biological damage to buildings and structures is steadily increasing [1–8].

Microorganisms on the surfaces of buildings and structures degrade the quality of the urban environment. As a result of the movement of air flows, they enter the lungs of a person and settle on his skin, causing various diseases [5, 10–13].

Field studies of external building envelopes and an experimental study of the properties of building materials and coatings under the influence of microorganisms indicate a decrease in the strength of structures, destruction of brick and concrete products, peeling of plaster layers, swelling of putties, etc. [9, 14–17].

Filamentous fungi impair the appearance of structural materials by discoloring their surface or forming spots of uneven shape on them. Growing on the surface of natural and artificial materials, mushrooms form velvety, felt and cotton-like deposits of various colors, which cause functional degradation of surfaces. In those cases when the mycelium penetrates deep into the material, forming cavities of various sizes in it, the mechanical strength of the materials decreases. Painted surfaces affected by filamentous fungi lose their original structure – they swell, peel off, crumble, become covered with brown and gray-green spots, lose aesthetic and operational properties. Recoating such affected areas often does not give positive results, as fungi germinate through the fresh paint layer.

Damage by microorganisms is observed in both old and new buildings. Almost all buildings and engineering structures can be exposed to them [4, 8, 12, 13, 17–19].

First, it is determined by the composition of the air in which they are operated.

Secondly, the smallest particles of organic matter of plants, animals, birds are a nutrient substrate for fungi and microbes, which is almost always present in the air, or has already settled on the surface of structures and structures.

Thirdly, the process of formation of efflorescence inside the structure of the material and on its surface causes various types of salt corrosion. The latter can reduce the durability and aesthetics of buildings. The presence of efflorescence is typical for almost all types of buildings and structures. For example, the facades of buildings, especially the facades of historical monuments of architecture with destroyed waterproofing, as well as buildings of industrial enterprises with an industrial environment containing salts and industrial gases [20–22]. In addition, efflorescence is characteristic of external walls, which are usually multi-layer systems, and consist of separate layers. In such systems, building materials have different properties (composition, density, porosity, moisture) and during the operation of the wall enclosing structure, they can influence each other (the emergence property) [22] and the operation of the system as a whole. In the presence of salts in the raw materials and mixing water for the manufacture of wall stone materials and plaster compositions, the use of technological additives to improve the properties of the concrete mixture, plaster or masonry mortar, the imbalance in the properties of materials in the system often leads to the transfer of salts to the outer surface of the facing layer of brickwork and plaster. In this case, the safety of the plaster layer may decrease due to the destruction of the material due to the crystallization pressure exerted by salt crystals on the walls of pores and capillaries in the thickness of the plaster composition. When the plane of precipitation of salts is located close to the outer surface of the plaster layer, its peeling occurs, which destroys the decorative paintwork of the facade. In cases where salting out also occurs on the surface of the facade, the formed efflorescence spots contribute to the constant attraction of new portions of moisture into the enclosing structure due to the high hygroscopic properties of salts, and also reduce the aesthetic qualities of building facades and interfere with the integral perception of the architectural object. The attractiveness of such a building for potential buyers is likely to decrease. The increased humidity of saline building material caused by the sorption of moisture from the ambient air due to the high hygroscopicity of inorganic salts [21, 22] is a favorable environment for the multiplication of various microorganisms on the surface and inside the wall structures.

Biological damage to building facades is usually caused by a malfunction of the drainage system, ventilation, destruction of vertical and horizontal waterproofing, dustiness of the facades, wetting due
to atmospheric precipitation at an angle to the facade of the building, as well as an increased content of ammonia, sulfur, carbon, nitrogen and other compounds in the atmosphere, pollutants [4, 6–9, 23–26].

The counteraction to biodegradation of materials of buildings and engineering structures includes a set of measures that unites various stages of the activity of specialists, technologists, operators [3–5, 13, 27].

To reduce waterlogging of facade systems, caused, among other things, by salt exposure, measures of primary and secondary protection are provided. Primary protection consists in preventing the excess of the salt content in raw materials for the manufacture of building materials according to the standardized indicators for the presence of oxides of sulfur (SO3), sodium (Na2O) and potassium (K2O). When choosing the type of binder for the manufacture of concrete and mortars, an advantage is given to a salt-resistant and biocorrosion-resistant binder, for example, a glass-alkali binder. If necessary, the introduction of technological additives (plasticizing, air-entraining, gas-forming, anti-freezing, hardening accelerators, setting retarders, structure sealers, corrosion inhibitors) into concrete, masonry and plaster solutions are used that guarantee the absence of efflorescence (according to GOST 24211-2008 "Additives for concrete and building mortars, General Specifications, with Amendment No. 1, with Amendment"). Protection against salt effects of plasters for finishing facades is provided by the introduction of hydrophobic additives during their manufacture.

In the absence or inadequacy of the primary protection of the facade plaster composition, secondary protection is designed to limit or exclude the effect of the saline environment on the plaster. It is carried out in accordance with GOST 31384-2017 "Protection of concrete and reinforced concrete structures from corrosion. General technical requirements". For this, impregnation with water repellent compounds is applied to the surface of the plaster layer.

Among the many measures aimed at counteracting the biocontamination of buildings and structures, the correct choice of materials and technologies is highlighted, providing for scientifically organized quality control of the input and output indicators of their properties and repairs.

The use of special protective facade plastering systems is very promising. Their durability is largely determined by the main plaster layer, which combines the putty, primer and paint layers.

The purpose of this work is to study the biological resistance of facade plastering systems of various types.

The research objectives are:

1. Study of fungal resistance and fungicidal properties of facade plastering systems of various types.
2. Revealing the influence of different types of primer, filler and color on the fungicidal and fungicidal properties of facade coatings.
3. Determination of the physical and mechanical properties of facade plastering systems before and after the biological effects of filamentous fungi.

2. Materials and methods

During the research, Russian and foreign building materials were used.

Portland cement without additives PC 500-D0-N, manufactured in accordance with GOST 10178-85 “Portland cement and slag Portland cement, was used as a binder for the plaster mortar. Specifications (With Amendments No. 1, 2)”, production of the Ulyanovsk cement plant (Russian Federation).

Quartz sand with a fraction of 0.63–1.25 mm of the Khromtsovsky quarry, Ivanovo region (Russian Federation) was used as a fine aggregate in the mortar mixtures. The main characteristics of the sand are given in tables 1 and 2.

Drinking water was used as a mixing liquid, which meets the regulatory requirements of GOST 23732-2011 “Water for concrete and mortars. Technical conditions”.

For the formation of facade coatings on a cement plaster mortar, putties, primers and paints were used, produced by TERRACO (Sweden).
The following were used as penetrating primers: water-based acrylic copolymer P-Primer Clear (Penetrating primer cleared), which reduces the water absorption of the base and the transfer of efflorescence to the base surface; silicone based primer Silprime with high vapor permeability and water repellency.

The following materials were used as fillers: Handycoat EZ-Skim vapor-permeable polymer putty; decorative, sand-filled, matt acrylic-based coating – SARDINIA BRASH putty.

For the manufacture of a thin decorative layer of plaster on the main plaster, the following were used: made on the basis of an acrylic binder on a water basis, a vapor-permeable Supertex Exterior coating, which forms a decorative structure in the form of drops; textured plaster coating with water-repellent properties on an acrylic base with a grooved texture on the surface Terracoat XL 1.0 "Bark beetle" (grain size 1 mm).

For the formation of the finishing decorative layer, vapor-permeable facade paints were used: Maxishield water-based acrylic paint; Silshield silicone paint, cream color.

### Table 1. Sand characteristics of the Khromtsovsky quarry, Ivanovo region.

| Indicator name                        | Requirements GOST 8736-2014<sup>a</sup>, GOST 30108-94<sup>b</sup> | Actual indicator |
|---------------------------------------|-----------------------------------------------------------------|------------------|
| Size module <sup>a</sup>              | 2.5–3.0                                                         | 2.76             |
| Content of dusty and clay particles <sup>a</sup> (%) | no more than 2.0                                               | 1.0              |
| Clay content in lumps <sup>a</sup> (%) | no more than 0.25                                              | absent           |
| Bulk density <sup>a</sup> (kg/m³)     | 1580                                                           |                  |
| Content of harmful components and impurities <sup>a</sup>: sulphates in terms of (%) | no more than 1.0                                               | 0.37             |
| amorphous varieties of SiO₂ (mmol/l)  | no more than 50                                                 | 28.83            |
| Specific effective activity of natural sand up to 370 | 39                                                             |                  |
| Material class <sup>b</sup>           | I                                                              | I                |

<sup>a</sup> GOST 8736-2014 “Sand for construction work. Technical conditions”.

<sup>b</sup> GOST 30108-94 “Building materials and products. Determination of the specific effective activity of natural radionuclides (with Amendments No. 1, 2)”.

### Table 2. Characteristics of the grain size composition of quartz sand of the Khromtsovsky quarry Ivanovo region.

| Residues (%) | Sieve hole sizes (mm) | Pallet |
|--------------|-----------------------|--------|
|              | 2.5 | 1.25 | 0.63 | 0.315 | 0.16 |          |
| Private      | 0.28 | 1.11 | 6.44 | 32.16 | 47.34 | 12.67    |
| Full         | 0.28 | 1.39 | 7.83 | 39.99 | 87.33 | 100      |

Tests of materials for fungal resistance and fungicide were carried out in accordance with GOST 9.049.91 “Unified system of protection against corrosion and aging (ESZKS). Polymeric materials and their components. Laboratory Test Methods for Resistance to Mold Fungi”. The test procedure consisted of keeping the samples in an environment with microscopic organisms. The following types of fungi were used as test organisms for testing in accordance with
GOST 9.049.91 [13]: Aspergillus oryzae Cohn, Aspergillus niger van Tieghem, Aspergillus terreus Thom, Chaetomium globosum Kunze, Paecilomyces variotii Bainier, Penicillium funiculosum Thom, Penicillium chrysogenum Thom, Penicillium cyclopium Westling, Trichoderma viride Pers. ex Fr.

The study of materials was carried out by two methods – 1st and 3rd (according to GOST 9.049.91). In accordance with these methods, samples of building materials contaminated with mold spores are kept in conditions optimal for their development. Next, the material samples are assessed for fungal resistance and fungicide in points.

Method 1 assumes no additional carbon sources. It determines whether the material itself is a food source for micromycetes. Therefore, when tested according to method 1, the samples were placed in Petri dishes without culture medium.

Method 3 consists in infecting samples with mold spores on a complete nutrient medium Czapek-Doxa, which is a solution of mineral salts with added sugar. The culture medium consisted of the following components in the following amount – NaNO₃ (2.0 g), KC1 (0.5 g), MgSO₄ (0.5 g), K₂HPO₄ (0.7 g), K₂HPO₄ (0.3 g), FeSO₄ (0.01 g), sucrose (30 g), agar (20 g) and distilled water (1 L.). Method 3 establishes the presence of fungicidal properties in the material, as well as the degree of influence of external mineral contaminants on the fungal resistance of the material. When testing samples according to method 3, they were placed in Petri dishes on the surface of the Czapek-Dox culture medium.

One sample was placed in each Petri dish. The number of samples in each group was taken equal to five. The application of test fungi to the surface of the samples was carried out by uniform irrigation using a spray bottle in which there was an aqueous suspension of fungal spores. The merging of individual drops of the suspension was not allowed. Further, the infected samples in Petri dishes were placed in sealed bags operating in a temperature mode 29±2°C and relative humidity above 90%. The condition of the absence of moisture condensation inside the bags and the absence of exposure to direct natural or artificial lighting was observed.

As a characteristic for determining the microbiological resistance of materials, their overgrowth with microscopic fungi was considered, which was established on the 14th day from the start of the experiment.

Fungal resistance of products was assessed on a 6-point scale. A scale value of zero was taken when no mold growth was visible when viewed under a microscope. A value of 1 was taken when, when viewed under a microscope, germinated spores and slightly developed mycelium in the form of unbranched hyphae were visible. A value of 2 was taken when, when viewed under a microscope, mycelium in the form of branching hyphae was observed and sporulation was possible. A value equal on a scale of 3 was taken when, when examining the samples with the naked eye, the growth of fungi was weakly noticeable, but clearly visible under a microscope. A value of 4 on a scale was accepted if, when viewed with the naked eye, fungal growth was clearly visible and occupied up to 25% of the surface area of the test sample. A value of 5 on the scale was set when, when viewed with the naked eye, fungal growth was clearly visible and occupied more than 25% of the sample surface area.

A material is considered fungus-resistant when, according to method 1, its score on a 6-point scale is 0–2 points. When the degree of development of molds is equal to 0, the material is not a nutrient medium for fungal spores, it is neutral or fungistatic. When the degree of development of molds is equal to 1 and 2, the material contains nutrients that provide only a slight development of fungi.

When tested according to method 3, a material is considered to have fungicidal properties if a zone of no fungal growth is observed around the sample on a nutrient medium. At the same time, fungal growth can be observed on the surface and at the edges of the samples, estimated in points from 0 to 1. When the degree of development of molds on a nutrient medium is equal to 0, it is considered that the material has a strong fungistatic effect. When the value of the indicator is equal to 1, it is assumed that the material can be assessed as having a weak fungicide.

Along with biological research methods, an assessment of changes in the physical and mechanical properties of plaster systems was made. The index of hardness of the surface of the samples and the change in the mass of the samples before and after infection with fungi were considered as a control
parameter. Determination of physical and mechanical properties was carried out by introducing a cone-shaped indenter (CI) into the material using a Heppler consistometer.

Hardness $T$ (MPa) was calculated by the formula (1):

$$T_{15} = \frac{0.318F_M}{(\tan^2(\alpha/2) \cdot \Delta_{15}^2)},$$  \hspace{1cm} (1)

where $F_M$ – indenter load (MPa); $\Delta_{15}$ – indentation depth of KI 15 minutes after load application, mm; $\alpha$ – angle at the apex of the cone, degrees.

The computer processing of the results of changes in physical and mechanical properties is based on an approach related to the methods of decision theory (ELECTRE method) based on three introduced criteria that are associated with the values of test results before and after infection of samples. The test results were reduced to relative dimensionless values – criteria. The first two criteria are associated with changes in property indicators at each point in the test time and adjacent points. The third criterion is equal to the sum of the first two criteria. Test results are expressed by the following statistical indicators: mean, standard deviation and coefficient of variation. They adjust the assigned criteria and form assessment matrices. Evaluation matrices make it possible to assess the resistance of materials to physical and mechanical stress.

3. Results and discussion

3.1. Study of biostability of facade systems with coatings

From the above review of the scientific literature on this issue, it follows that a large number of works are devoted to the development of biostable compositions of concretes and other cement composites by selecting special binders, fillers and additives.

In the present study, various plaster systems were considered in assessing biostability. The compositions of plastering systems and research results are shown in Table 3.

| Composition number | Composition of samples of plaster systems | Biostability of samples (points) according to method 1 side surface | Biostability of samples (points) according to method 3 side surface | Biostability of samples (points) according to method 3 top surface |
|-------------------|-----------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| 1                 | Cement-sand mortar (control composition) | 2                                               | 2                                               | 4                                               |
|                   | Coated: Penetrating primer cleared,      | 2                                               | 3                                               | 4                                               |
|                   | Supertex Exterior, Maxishield            |                                                 |                                                 |                                                 |
| 2                 | Coated: Penetrating primer cleared,      | 2                                               | 0–1                                             | 4                                               |
|                   | Maxishield                               |                                                 |                                                 | 3                                               |
| 3                 | Coated: Penetrating primer cleared,      | 1–3                                             | 0–2                                             | 4                                               |
|                   | Handycoat EZ-Skim putty, plaster         |                                                 |                                                 | 3–4                                             |
|                   | (Terracoat XL 1.0 Bark beetle)           |                                                 |                                                 |                                                 |
| 4                 | Coated: Penetrating primer cleared,      | 1                                               | 0                                               | 4                                               |
|                   | Handycoat EZ-Skim putty                 |                                                 |                                                 | 3                                               |
| 8                 | Coated: primer (Silprime), plaster       | 1                                               | 0                                               | 3                                               |
|                   | (Terracoat XL 1.0 "Bark beetle")        |                                                 |                                                 | 2                                               |
| 11                | Coated: primer (Silprime), paint         | 0                                               | 0                                               | 3                                               |
|                   | (Silshield)                              |                                                 |                                                 | 2                                               |

Table 3. Compositions of facade systems and their biostability.
15 Coated: primer (Silprime), putty (SARDINIA BRASH), plaster (Supertex Exterior) 2–3 0–1 3 3–4
16 Coated: primer (Silprime), putty (SARDINIA BRASH), paint (Maxishield) 0–2 0 3 2

Analysis of the studies performed indicates the following. Control samples based on a cement-sand mortar without the use of any coatings are overgrown with filamentous fungi over the entire surface in the same way. At the same time, without additional power sources, the degree of fouling of the samples is 2 points, and if they are present, it doubles and is 4 points.

The application of a protective layer contributes to a change in the biostability of plaster coatings. These changes occur not only along the top, but also along the lateral surface of the samples, which means the suppression of fungal growth by the components of the protective coating.

The protective coatings contributed to the production of fungus-resistant surfaces with fouling indicators when tested according to method 1, equal to from 0 to 2 points.

When tested according to method 3, the growth of fungi is increased by 2 points in comparison with the control samples. The best effects were obtained for facade systems of compositions numbered 11, 12 and 16. They were formed by applying the layers shown in table 3: by applying Silprime and fine-grained Terracoat XL 1.0 plaster (composition 11); by applying a primer (Silprime) and cream Silshield paint (composition 12); by applying a primer (Silprime), SARDINIA BRASH filler and Maxishield paint (composition 16).

3.2. Investigation of the mechanical properties of facade systems with coatings

Evaluation of changes in the mechanical properties of coatings was carried out before infection of samples of facade systems with filamentous fungi and after infection (Table 4).

| Table 4. Indicators of plaster systems before testing / after testing in biological environment. |
|---------------------------------------------------------------|
| Compos- | Loaded | Unloaded | Sample properties |
| tion number | Test time | | | | |
| | 1 sec. | 1 min. | 3 min. | 15 min. | 1 sec. | 3 min. | Weight (g) | Hardness (MPa) | \( \tau_{15} \) |
| 1 | 69 | 69 | 70 | 70 | 63 | 63 | 10.44 | 713.70 | 1542.86 |
| 2 | 95 | 106 | 108 | 110 | 102 | 102 | 9.34 | 282.02 | |
| 3 | 57 | 61 | 62 | 63 | 57 | 57 | 7.83 | 881.11 | |
| 7 | 95 | 110 | 113 | 115 | 107 | 107 | 10.24 | 264.43 | 1244.98 |
| 8 | 35 | 44 | 44 | 44 | 36 | 36 | 8.81 | 1806.38 | 472.84 |
| 11 | 78 | 95 | 99 | 101 | 93 | 93 | 12.00 | 342.82 | |
| 12 | 51 | 52 | 52 | 53 | 45 | 45 | 10.57 | 1244.98 | |

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To solve the problem of ranking the samples of facade systems according to the degree of resistance to the effects of an aggressive biological environment, special criteria were introduced. These criteria were compared to the alternatives – the studied samples of composite materials. 9×6 data matrices were constructed for each test time duration. The transformation of the matrices was carried out in order to change their dimension, taking into account the possible values of changing the properties. Each matrix was formed in the form of a coagulated column vector, which consisted of the data of the horizontal rows of Table 4. For example, for the composition number 1 from the first row of Table 4 for the samples before colonization with filamentous fungi we obtain: 69; 69; 70; 70; 63; 63. From the second line of table 4 for the samples tested after infection with fungi, we get: 14; 15; 15; 15; 6; 6. As a result, two coagulated column vectors are formed from the data before and after testing in a biological environment. Repeatability for each sample occurs after 6 conventional units of time. These repetitions took the form of a sequence of conditional time numbers {1, 2, 3, 4, 5, 6}. Accordingly, the working dataset had 54 rows and 3 columns. The first column displayed repetitions as a sequence of numbers – in this case, from 1 to 6. Each segment of the time repetition was reduced to relative dimensionless values relative to the first repetition interval.

The explanatory diagrams of criteria definition are shown in Figures 1 and 2.

The third criterion with the designation $J$ was taken in the form:

$$J_i = K_i + H_i, \ i = 1, 2, 3, 4, 5.$$  

![Figure 1. To the definition of the 1st criterion.](image1)

![Figure 2. To the definition of the 2nd criterion.](image2)

In accordance with the methods of decision-making theory, matrices of criteria and alternatives (numbers of compositions) were built, assessment scores were assigned taking into account the average values of the arrays of criteria, standard deviations and coefficients of variation. Further, the summation points were determined for each sample of the studied composites (alternatives). As a result, the samples were ranked according to the degree of resistance and the ones more resistant to the effects of the biological environment were determined. The actions performed are related to preliminary conversion to relative units relative to the first row of the matrix of changed properties of samples. This allows comparison of data regardless of their absolute values.

The final part of the experimental studies was associated with the determination of composites that are more resistant to aggressive biological influences that can occur in real industrial and unfavorable conditions. For this, a matrix of assessments was compiled with respect to alternatives (samples) and
the introduced three criteria. The first two criteria at the final stage were transformed by multiplying the relative values of the properties of the samples by the coefficients of variation. Table 5 provides a matrix of criteria for the examined facade plastering systems.

To create a score matrix, an array is formed with the number of rows equal to the number of criteria assigned points (from 1 to 72) and with the number of columns equal to the number of criteria (three). The array is filled with the data in Table 5 from the minimum to the maximum values of each of the criteria, which are determined with the addition of the half values of the maxima and minima to overlap the experimental data. The generated table is used to search for alternatives (samples) that most closely match the data of the generated auxiliary array. The calculated rating matrix is presented in Table 6, in the second column of which the ranked composite numbers are given, arranged from top to bottom in order of decreasing priority for use.

A more preferable composition is composition 11, which has an unchanged hardness index of 342.82 MPa and a weight change of 2.91%. Less preferred is composition 1, which had a hardness index of 713.70 MPa before testing and 1542.86 MPa after testing, and a weight change of 3.60%.

The results obtained for the low physical and mechanical properties of the plaster system of composition No. 1 correlate with the result of increased overgrowth of composition 1 with fungi (Table 3), which allows us to conclude that the low physical and mechanical properties of facade systems, unprotected with special coatings, under the influence of filamentous fungi.

Table 5. Matrix of criteria.

| Composition number | Values of criteria before and after testing in a biological environment | | | | | |
|-------------------|-------------------------------------------------|---|---|---|---|---|
|                   | Before the test                                  | | | | | |
|                   | K       | H       | J       | K       | H       | J       |
| 1                 | 0.404864 | 0.138466 | 0.543330 | 0.986808 | 0.330839 | 1.317647 |
| 2                 | 1.006369 | 0.308899 | 1.315267 | 3.303285 | 0.504388 | 3.807673 |
| 3                 | 0.505437 | 0.284505 | 0.789941 | 4.014976 | 0.951277 | 4.966254 |
| 7                 | 1.164701 | 0.301879 | 1.466580 | 1.194105 | 0.705930 | 1.900035 |
| 8                 | 0.655253 | 0.321883 | 0.977137 | 1.280753 | 0.660642 | 1.941394 |
| 11                | 1.262903 | 0.303637 | 1.566540 | 3.125608 | 0.718933 | 3.844540 |
| 12                | 0.420324 | 0.166828 | 0.977137 | 1.280753 | 0.660642 | 1.941394 |
| 15                | 1.157579 | 0.280412 | 1.437992 | 2.097789 | 0.760736 | 2.858525 |
| 16                | 0.526497 | 0.282033 | 0.808530 | 1.247840 | 0.658648 | 1.906487 |

Table 6. Matrix of evaluations of the choice of compositions of composites that are more resistant to testing.

| Points total | Composition number | Reward points columns |
|--------------|--------------------|-----------------------|
|              | 1                  | 2         | 3                  | 4                  | 5                  | 6                  |
| 283          | 11                 | 53        | 41                 | 53                 | 41                 | 54                 | 41                 |
| 256          | 3                  | 22        | 52                 | 49                 | 54                 | 27                 | 52                 |
| 254          | 2                  | 43        | 43                 | 54                 | 29                 | 45                 | 40                 |
| 248          | 15                 | 49        | 27                 | 49                 | 43                 | 50                 | 30                 |
| 228          | 7                  | 49        | 16                 | 52                 | 40                 | 51                 | 20                 |
| 194          | 8                  | 28        | 17                 | 56                 | 38                 | 34                 | 21                 |
| 175          | 16                 | 23        | 17                 | 49                 | 38                 | 28                 | 20                 |
| 121          | 12                 | 18        | 15                 | 29                 | 22                 | 21                 | 16                 |
| 106          | 1                  | 17        | 13                 | 24                 | 19                 | 19                 | 14                 |
4. Conclusion

The results of studies of fungal resistance and fungicidal properties of facade systems without protective coatings and with protective coatings have been carried out. The need for a device for plastered facades of protective coatings to increase the fungal resistance and fungicidal properties of surfaces has been established. Some protective coatings provided fungus-resistant surfaces with fouling indicators when tested according to method 1 from 0 to 2 points.

A comparison of the biostability of facade systems with different types of primers, putties and paint layers is carried out. It has been established that facade systems of different compositions, for example, primer and decorative plaster, can be biostable; priming and painting; primer, putty and painting. It was revealed that different facade systems have different biostability, which is determined by the properties of individual layers of building materials that make up the facade systems.

The components of protective coatings are capable of inhibiting the growth of fungi, as evidenced by the increase in the biostability of plaster coatings on the lateral surfaces of the samples when tested according to method 3.

The greatest effect of biostability was obtained for facade systems, which include a silicone-based primer with high vapor permeability and water-repellent properties Silprime, acrylic-based plaster with water-repellent properties Terracoat XL "Bark beetle" with a grain size of 1.0 mm.

Special protective facade systems are capable of providing comprehensive protection against salt attack and biological corrosion. At the same time, a protective multilayer coating is formed, each of the layers of which provides water-repellent properties, high vapor permeability and biostability. The required decorative qualities of the facade surface (texture and color) are provided by water-based or silicone-based vapor-permeable facade paints.

5. References

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