Biodestruction of Buildings and Constructions and Improvement of Their Longevity and Environmental Friendliness at the Basis of Application of Bio-Resistant Materials

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Abstract. The article discusses the problem of negative biological effects in buildings and structures. The analysis of microflora released from damaged objects is given. Risk groups for the development of diseases caused by microbial biodestructors that are potentially dangerous to humans are given. The biodegradation of residential and public buildings causes a decrease in the level of people's health, and their disability occurs due to the deterioration of the urban environment. Microbes contained in building structures, in finishing and protective materials, can settle on the skin, enter the bloodstream through the lungs, and also with food into the human body. A number of pathologies that are difficult to cure and life-threatening have arisen recently due to a sharp drop in human immune reactivity.

The object of the study was cement composites, which include port-lance cement, a mixing fluid, a filler, a fine aggregate, and additionally silicon organic compounds. The hypothesis is that the latter in the form of aryl-(aryloxy) silanes, due to their hydrolysis in a humid environment, can become potent biocidal components.

During the research, generally accepted physical-mechanical and biological methods were used. To assess biostability, samples of cement composites were infected with a test by mycelial fungi: Aspergillus niger van Tieghem, Aspergillus terreus Thom, Aspergillus oryzae (Ahlburg) Cohn, Chaetomium globosum Kunze, Paecilomyces varioti Bainierulicollimumium Penicillium peniciumium Penicomium Thiumllium Penicillium peniciumium, Trichoderma viride Pers. ex Fr.

Tests have shown that silicon organic additives contribute to a significant increase in the biostability and strength of cement composites. Studies have revealed the presence of a correlation of the fungus resistance of building composites with the addition of silanes and their hydraulic activity.
1. Introduction

Analysis and assessment of the relationship of architecture, construction and ecology provide for the definition of their role in the development and solution of the problems of preserving and restoring the environment surrounding a person, including its recovery [1, 2, 3, 4, 5].

Various unfavorable factors affect building structures, buildings and structures [6, 7, 8, 9], as a result of which corrosion processes develop. The complexity of their study is due to the fact that the mechanisms of chemical, physical, including mechanical, and biological destruction, firstly, can be initiated in all environments (in air, water, soil, bottom sedimentary, stone); secondly, they are able to spread from one medium to another; thirdly, they can occur both sequentially and simultaneously in any combination, and corrosion of one category, changing the properties and characteristics of the material, contributes to the development of corrosion of another category [8, 10, 11, 12, 13].

Chemical, physical and biological corrosion and their combinations are the reason not only for the deterioration of the condition, destruction of buildings, structures and utilities, but also a potential cause of the incidence and complication of heterotic manifestations in humans. Among the corrosion processes, biological ones are the most undesirable, the damage from which makes up more than 5% of the gross world output [10, 14, 15].

Microorganisms constantly live in the human environment, using organic and inorganic compounds that are part of everything created by him as a nutrient substrate and habitat [1, 7, 10]. Accordingly, biocorrosion - the destruction of building, decoration and any other natural and artificially created materials by micro- and macroorganisms by representatives of various systematic groups, can be affected by buildings, structures and utilities for various purposes [1, 16, 17].

Many microorganisms multiply rapidly under suitable conditions and are therefore able to massively contaminate living or nonliving medium [18, 4]. In the first case, these are pathogenic or conditionally pathogenic species; in the second, they are saprotrophic species, or saprobes. Literature data indicate that more than 40% of the total volume of biodeterioration is associated with the activity of microorganisms - bacteria and fungi [6].

An analysis of the microflora isolated from damaged objects allows one to determine the types of mycelial fungi that are dominant in the process of biodeterioration and belong to the class of upright fungi: Aspergillusniger, A. flavus, A. terreus, Chaeloheimglobosum, Paecilomycesvariotii, Penicilliumfuniculosumosum, Penicilliumfuniculosumosumosumosumii P. cyclopium, Trichodermaviride, etc., as well as bacteria - sulfate-reducing, thionic, sulfur-oxidizing, ammonifying, nitrifying, denitrifying, hydrogen-oxidizing, iron-bacteria, cellulose-degrading, hydrocarbon-oxidizing [1, 6]: Thirobomods bacteria ropeal, Nitrosocystisgen, Micrococcusvarians, Pseudoraonasfluorescens, Mycobacteriumsp. Serpulalacrimans, etc.

As you know, spores of molds with air flows spread over considerable distances or are in a suspended, liberally sedimented state in indoor air. Conidia smaller than 5 μm in size can enter the respiratory system with air and cause infectious diseases or sensitization with the subsequent development of allergies [19, 20, 11].

Today, there are several risk groups for the development of diseases caused by microbial biodestructors [5, 7, 13, 23]:
- builders involved in the demolition or repair of old buildings;
- specialists in the operation of ventilation or conditioning systems, in which giant colonies of molds can grow;
- residents of the first and last floors of buildings in violation of their waterproofing in the areas of the foundation or roof;
- municipal workers involved in garbage collection both indoors and outdoors;
- production employees associated with wood processing;
- patients in hospitals (newborn babies, especially premature babies, patients with malignant diseases and hemoblastoses, organ recipients in the state of arterial immunodeficiency, all persons receiving treatment with antibiotics, glucocorticosteroids and cytostatics; in these patients, sporadic and group severe mycosis with high mortality).
Lung diseases associated with the biodegradation of buildings - acute aspergillosis, bronchial asthma, allergic bronchopulmonary aspergillosis, mucorosis and other severe pneumomycoses cause serious anxiety [21, 22, 23].

According to experts of the World Health Organization, an urban resident is on premises for almost 80% of the time [28, 31]. These are residential, industrial, office premises, cultural institutions, spectacular constructions, hostels, for example, soldier's barracks, etc. If a person goes to hospital treatment, he spends 100% of the time in the room [7].

Therefore, depending on the options for interaction, several groups of the effects of structures on humans can be distinguished [7].

The first group is characterized by a combination of dampness with a periodic decrease in temperature, and when people are in such adverse conditions, the development of so-called catarhal diseases, including acute tonsillitis, pneumonia, viral infections, exacerbation of tuberculosis, rheumatism, chronic bronchitis, inflammation joint diseases of the joints. All of the above is especially undesirable for children, the elderly, and people suffering from chronic diseases accompanied by a decrease in immunity. Special studies have found that in rooms with signs of biodeterioration, the air is polluted not only by living cells of fungi that can cause diseases, but also by toxins released as a result of their death, some of which are carcinogenic. Accordingly, the direct result of their exposure may be fatigue, headaches, decreased performance.

The second group of adverse effects of biodeterioration on people consists in the properties of the microorganisms themselves - not just affecting the human body, but interacting with it. In particular, some types of fungi that grow in the thickness and on the surface of building materials, which are not pathogenic in nature, can acquire parasitic properties in the human body and cause infectious lesions - mycoses, and in people prone to allergic reactions - mycogenic allergies allergic rhinitis, asthmatic bronchitis, bronchial asthma, urticaria and others.

According to international experience, up to 60% of microbes - biodestructors are potentially dangerous for humans [6, 24, 25]. Of these, the first place belongs to ubiquitous micromycetes. Fungal diseases of the internal organs are still poorly understood, but at the same time they occupy an increasingly important place in the structure of human morbidity due to the influence of biodeterioration of buildings.

A large number of works have been devoted to the study of biodeterioration of various building materials, and especially concrete, used for the manufacture of many products and structures of buildings and structures [26, 27, 28, 29, 30, 31].

In these works, the types of available mycelial fungi of various types on concrete samples and the change in their physical and mechanical properties are shown. To increase the biological resistance of materials, it is effective to change various biocidal additives in the composition of composite building materials, which also contribute to improving the environmental situation in buildings and structures.

It is widely known that organosilicon compounds are used as additives in building materials to give them hydrophobic properties, plasticize concrete mixes, increase corrosion resistance, frost resistance of concrete and reinforced concrete structures, and also as components of durable paints and sealants. Additives with such a base can increase the biological resistance of concrete.

The purpose of the work is to establish the effect of preparations based on silicon-organic compounds on the biostability and physicotechnical properties of cement concrete.

2. Research objectives
1. To study the biostability of cement composites with additives of silicon-organic compounds — aryl-(aryloxy) silanes, which are aromatic esters of phytosilicic acid.
2. To evaluate the mechanisms of increasing the biological resistance of composites through the introduction of such additives.
3. To establish quantitative indicators of the strength and biostability of cement composites with additives.

Materials and methods:
Studies are given with the use of cement concrete. The compositions of the studied compositions contained Portland cement, quartz sand, wastes from the production of ferrosilicon and organosilicon compounds aryl-(aryloxy) silane. Physico-chemical properties of silicon organic compounds, which are aromatic esters of orthosilicic acid, are shown in table 1.

**Table 1.** Physico-chemical properties of the compounds.

| № | Compound                                      | Structural formula | Temperature boiling, °C | Pour point, °C | Temperature outbreaks, °C |
|---|-----------------------------------------------|--------------------|--------------------------|----------------|--------------------------|
| 1 | Phenyltricresoxysilane                        | ![Formula](#)      | 443                      | −27            | 156                      |
| 2 | Phenylphenoxy dicresoxysilane                 | ![Formula](#)      | 436                      | −27            | 126                      |
| 3 | Phenyldiffexicresoxysilane                    | ![Formula](#)      | 435                      | −30            | 120                      |
| 4 | Tetracresoxy silane                           | ![Formula](#)      | 435                      | −39            | 148                      |
| 5 | Phenoxytricresoxysilane                       | ![Formula](#)      | 446                      | −35            | 120                      |
| 6 | Diphenoxy dicresoxysilane                     | ![Formula](#)      | 436                      | −33            | 126                      |

The compositions of the studied compositions are shown in table 2.

**Table 2.** Compositions of compositions.

| № | Ingredient                           | The content of the ingredient in the compositions, wt. h. |
|---|--------------------------------------|----------------------------------------------------------|
|   |                                      | I     | II    | III   | IV    | V     | VI    |
| 1 | Portland cement                      | 18    | 19    | 20    | 21    | 22    | 20    |
| 2 | Quartz sand                          | 17    | 48    | 51,5  | 55    | 60    | 51,5  |
| 3 | Waste production ferrosilicon        | 3,00  | 4,00  | 5,75  | 7,50  | 8,00  | −     |
| 4 | Aryl-(aryloxy) silane                | 0,5   | 1,0   | 1,5   | 2,0   | 2,5   | −     |
| 5 | Diatomite                            | −     | −     | −     | −     | −     | 5,75  |
| 6 | Water                                 | 31,50 | 28,00 | 21,25 | 14,00 | 79,50 | 22,75 |
To compare the performance of protected and unprotected materials, a sample (composition No. 1) was made using Portland cement of quartz sand and diatomite without fungicide according to the known method. Samples of each composition were prepared individually and formed in the form of cubes $2 \times 2 \times 2$ cm in size and prisms $1 \times 1 \times 3$ cm in size.

The samples were studied both after exposure to an aggressive biological environment, and before exposure. The first batch of samples was tested in a biological medium in Petri dishes, consisting of a set of mycelial fungi of the following species: Aspergillus niger van Tieghem, Aspergillus terreus Thom, Aspergillus oryzae (Ahlburg) Cohn, Chaetomium globosum Kunze, Paecilomyces variotii Thainomain Pener, Penicillium chrysogenum Thom, Penicillium cyclopium Westling, Trichoderma viride Pers. ex Fr. during three months. The samples were tested for bending and compression by standard methods.

3. Results and its discussion

The test results of the studied cement composites are shown in table 3.

**Table 3.** The quantitative value of the indicators for the groups of samples for each silane (No. 1–6 from table 1)

| Index | Sample Groups (table 2) | I   | II  | III  | IV  | V   | VI  |
|-------|-------------------------|-----|-----|------|-----|-----|-----|
|       | Cubic strength, MPa     | 30–32 | 42–47 | 49–52 | 41–44 | 27–31 | 24–26 |
| Mushroom resistance coefficient after 3 months of exposure of samples in Petri dishes on a nutrient medium | 0.69–0.71 | 0.80–0.86 | 0.89–0.92 | 0.89–0.90 | 0.88–0.92 | 0.68–0.69 |

From the results of the study it follows that compositions with organosilicon additives have sufficiently strong and stable fungicidal cement composites in relation to molds. It was also revealed that the mycocidal activity of the compounds of the proposed series is quite clearly correlated with their hydrolytic activity. Table 4 shows the values of the rate constant of hydrolysis of three types of silanes and the fungus resistance coefficient of samples with additives.

**Table 4.** Properties of compositions with the addition of silane.

| Derivatives silane | Structural formula | Constant speed Hydrolysis | Coefficient of mushroom resistance samples |
|--------------------|-------------------|---------------------------|-------------------------------------------|
| Tetracreso xisilane | $\text{CH}_3$ | 90.0 | 0.86 |
| Phenyltri phenoxysilane | $\text{Si} \equiv \left(\text{O} - \left(\text{CH}_3\right)\right)_4$ | 16.0 | 0.82 |
| Phenyltri cresoxysilane | $\text{Si} \equiv \left(\text{O} - \left(\text{CH}_3\right)\right)_3$ | 1.6 | 0.80 |
The mechanism for increasing the mushroom resistance of cement composites with additives is explained as follows. Under the influence of air moisture, spores of mycelial fungi activate the hydrolysis of aryl (aryloxy) silanes with the formation of potent fungicides, probably phenols or cresols, which inhibit the growth of mycelium. It is possible that the inhibitory effect of these silanes in relation to mold fungi occurs precisely at the moment of their entry into the fungal organism, where they are hydrolyzed under the influence of the corresponding excimes produced by microorganisms. Based on the research results, it can be concluded that there is a correlation of the fungus resistance of building materials with the addition of silanes and their hydrolytic activity.

4. Conclusions
1. The colossal damage caused by biologically active media causes close attention to the problem of biodegradation of buildings and structures. The biodegradation of residential and public buildings causes a decrease in the level of people's health, and their disability occurs due to the deterioration of the urban environment.
2. In the work, it is proposed to introduce silicon organic additives such as aryl - (aryloxy) silanes to increase the biostability of materials in their composition.
3. Studies have found that the introduction of organic additives such as aryl - (aryloxy) silanes in amounts of 0.2 - 2.5% can effectively suppress the growth of mycelial fungi under favorable conditions for their growth for a long time.
4. The mechanism of increasing biostability when introducing these additives is that under the influence of air moisture, spores of mycelial fungi activate the process of hydrolysis of aryl (aryloxy) silanes with the formation of potent fungicides, probably phenols or cresols, which inhibit the growth of mycelium.
5. Studies have revealed the presence of a correlation of the fungus resistance of building composites with the addition of silanes and their hydrolytic activity.

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