V.T. EROFEEV[1], A.D. BOGATOV[1], V.F. SMIRNOV[2], S.N. BOGATOVA[1], S.V. KAZNACHEEV[1]
[1] Mordovian N.P. Ogarev's State University Saransk, Russia
[2] Nizhegorodskiy N.I. Lobachevskiy State University
fac-build@adm.mrsu.ru

BIORESISTANT BUILDING COMPOSITES ON THE BASIS OF GLASS WASTES

Key words

Broken glass, binding mortars, concretes, bioresistance.

Summary

The article presents the production technology of binding and building composite materials on the basis of glass wastes. Compositions of mortar mixes, heavy and light concretes are developed and optimized. It is proved that given materials are bioresistant in conditions, influenced by microscopic organisms.

Broken glass makes a considerable part of all the techogenic wastes that are thrown away as useless.

In Russia alone, the volume of glass wastes amounts to 4 million tons per year. A greater part of such wastes, while accumulating, contaminates the environmental medium. Meanwhile, broken glass is a productive secondary resource that can be used in the building industry for producing binding materials, mortars, concretes, and constructions on their basis.

At present, the existing processes of making building materials with the application of broken glass are based on technologies that envisage the sintering of raw materials at high temperatures or relevant treatment in autoclaves [1-4]. If high energy consumption and cost of such processes are taken into account, then the most perspective way to solve the problem of broken glass utilization is, in our opinion, the production of binding materials, composites and other products that can solidify and harden at temperatures lower 90°C or in normal humid-temperature conditions.

Theoretical propositions for the production of building materials on the basis of industrial glass wastes have been suggested works by domestic and foreign authors [3–5, 7, 8]. In these works, it has been shown that the hardening of systems involving natural or artificial glasses is based on the interactive reaction between the silica and alkaline water solutions. Because of the interaction, the compounds are being synthesized and their chemical composition approaches the chemistry of sedimentary and metamorphic rocks of the nature of natrolite, mordenite, etc. However, this process takes place at high temperatures and pressures. The economic efficacy of using such materials may be attained if the technology of their production is simplified. We have experimentally proved that the formation of the above-mentioned compounds can take place without autoclave treatment. This is attainable if certain corrective additives are introduced. Clay and carbonate rocks, as well as industrial wastes of the building industry producing ceramic materials are found to be effective as such additives.

Researches on durability dependence on the quantitative content in the composition of the water solution of caustic natron and mineral additive and of a latter type were conducted. It is established that the best properties have been obtained with mixtures that use fine powders of chalk and haydite as a mineral component.

Based on developed binding, the compositions of mortars and concrete with an optimum ratio are obtained, and their physical and technical properties are studied. The main characteristics of materials are presented in Table 1.

The developed binding compositions of mortars and concrete meet the physical, mechanical, thermo technical and technological requirements demanded of walling, and they can be used for constructing superstructure of low buildings. One of distinguishing features of new materials is the use of sand with clay impurities as filling materials. When mortars and concrete harden on such sands in the conditions of high alkalinity of a liquid phase there is a hydration of clay minerals, resulting in alkaline **hydro-**alumino-silicate, promoting their consolidation of structures. Therefore, based on experimental research, it is established that when using mixture of sand with a 7% of clay to prepare mortar its durability after thermo humidity processing proved to be 18% higher than a similar mixture with pure quartz sand as a filler.

Table 1. Physical and technical properties of building materials based on glass alkaline binding

Index	Mortar	High-density concrete	Low density concrete	Cellular concrete	Concrete with aggregates from microspheres
Pressure strength, MPa	18	25	16	0.5–0.9	20
Average density, kg/m ^{3}	2000	2400	1400	500	650
Thermal conductivity, W/m ºC	–	–	0.43	0.13	0.19
Coefficient of elasticity, MPa	6000	9750	4600	400	6500
Coefficient of temperature equilibrium	$0.897x10^{-2}$	$1.558x10^{-5}$	$0.427x10^{-5}$	–	–
Linear shrinkage, %	0.13	0.12	0.24	–	–
Water absorption during 24 h, % by mass	0.3–0.6	0.2–0.3	1.5–4.5	30–50	0.2

Thus, the application of binding based on broken glass makes it possible to use sand with high clay impurities to produce concretes, but for cement concrete, it is not recommended. It is necessary to note that sand resources of that kind in Russia are common enough; whereas, in many regions, expensive operations on the enrichment of local sands are performed.

Recently, increasing attention is given to research on the operational reliability of building materials and, in particular, their stability in the conditions of environments that are biologically active. Bacteria, fungi, and actinomycete belong to those environments [6–10].

Biological corrosion of materials takes place at the enterprises of the food, chemical, medical, and microbiological industry, and in agricultural, transport, and hydraulic engineering buildings and constructions. Public and residential constructions are exposed to microorganisms' affection, since the smallest particles of the organic substance of soil, plants, and animals serve as a nutritious substratum for fungi that are practically always presented in the air, and they are accumulating on construction surfaces.

The most active destroyers among microorganisms are mycelium fungi that cause degradation by direct consumption of a material or its separate components as a foodstuff, and they have a chemical influence on a material through their vital activity products to which include organic acids, enzymes, and amino acids. Damage caused to buildings and constructions because of biodamage cost many ten milliard of dollars annually [8–12]. Additionally, microorganisms can cause serious diseases, because some are pathogenic in relation to human beings and animals.

Research of biological resistance of bindings based on glass breakage was carried out according to GOST 9.049-91.

The research results of fungi fouling of the components forming bindings and hardened compositions themselves are given in Tables 2 and 3.

Table 2. The research results of fungi resistance of binding ingredients

Name of material	Degree of fungi fouling in numbers according to GOST 9.049-91		Estimation of fungi resistance
	Method 1	Method 3	
Limestone	2	5	fungi resistant
Brick dust	4	5	not fungi resistant
Glass powder	2	5	fungi resistant
Haydite powder	2	5	fungi resistant
Clay	3	5	not fungi resistant
Slag	2	5	fungi resistant
Gypsum	1	5	fungi resistant

Table 3. Research results of the fungi resistance of bindings based on broken glass

Name of material	Degree of fungi fouling in numbers according to GOST 9.049-91		Estimation of fungi resistance
	Method 1	Method 3	
Glass alkali binding			
1) with ground brick	0	0	fungicidal
2) with ground clay	0	3	fungi resistant
3) with ground c haydite			
without additive	0	0	fungicidal
with additive			
a) six water chloride aluminium	0	3	fungi resistant
б) sodium aluminate	0	0	fungicidal
в) acetone	0	0	fungicidal

As the research results show, binding components do not possess fungicidal properties; however, limestone, ground glass, ground haydite, and semi-water plaster are fungi resistant. Composition tempering is done by an alkaline solution, so that the hydrogen indicator of the environment increases to values adverse to growth and reproduction of microorganisms and that raises their biological resistance considerably. As it shown in Table 2, the majority of examined structures possess fungicidal properties.

Test results of samples' bioresistance on the developed bindings and the traditional ones based on Portland cement, building plaster, technical sulphur, and epoxide resin are presented in Table 4.

As it can be seen from the table, the developed glass alkaline bindings and materials, in contrast to widely used cement, plaster, polymeric and sulphuric bindings, possess fungicidal properties and that proves the practicability of their use when manufacturing goods are maintained in the conditions influenced by biologically active environments.

Table 4. Research results of bioresistance

Name of material	Degree of fungi fouling in numbers according to GOST 9.049-91		Estimation of fungi resistance
	Method 1	Method 3	
Portland cement rock	0	3	fungi resistant
gypsum rock	0	3	fungi resistant
hardened epoxy resin	0	3	fungi resistant
engineering sulphur	0	3	fungi resistant
hardened binding on the basis of glass	0	0	fungicidal (R = 45 mm)
cellular concrete on the basis of glass alkali binding	0	0	fungicidal (R = 24 mm.

Note: R – zone radius of fungi growth inhibition.

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Odporne biologicznie kompozyty budowlane na bazie odpadów szklanych

Słowa kluczowe

Stłuczka szklana, betony, bioodporność, zaprawy wiążące.

Streszczenie

W artykule zaprezentowano technologię produkcji budowlanych materiałów kompozytowych wytwarzanych z wykorzystaniem odpadów szklanych. Kompozycja zapraw, ciężkich i lekkich betonów została opracowana i zoptymalizowana. Wykazano, że uzyskiwane materiały są bioodporne w warunkach oddziaływania mikroorganizmów.