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Innovative production technology of binding and building composite materials on the basis of glass wastes

A. Bulgakov
Southwest State University, Kursk, Russia

V. Erofeev & A. Bogatov
Mordovia N.P., Ogarev State University, Saransk, Russia

V. Smirnov
Nizhegorodskiy N.I., Lobachevsky State University, Nizhny Novgorod, Russia

R. Schach
Technical University Dresden, Dresden, Germany

ABSTRACT: The production technology of binding and building composite materials on the basis of glass wastes is presented. 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.

1 INTRODUCTION

The durability and reliability of building materials and constructions used in cattle-breeding premises, poultry, milk-and-meat complexes, as well as in enterprises of microbiological industries processing organic materials that can be a nutritious medium for various micro-organisms, greatly depend on the protection of these materials from biological damages. By biological damages one may understand any undesirable changes in the properties of these materials and the infringement of their service-ability as a result of the influence of biologically active environments such as bacteria, fungus, actinomycets, etc [6–10]. In this respect, most active micro-organisms are mycelious fungus causing the material degradation by a direct consumption of the material as a whole or its separate components, as well as by the chemical influence exercised by such micro-organism products as acids, ferments and aminoacids. The detriment inflicted onto buildings and constructions by biological damages has been estimated to be billion dollars annually [8–12].

When dwelling on the surface of building structures, the micro-organisms alongside with the degradation cause the deterioration of ecological environments in the premises of buildings and constructions resulting in mould smell and toxic allergenic products that can be a reason for various diseases, since some kinds of micro-organisms are pathogenic for a human being and animals.

For example, the journal of the European Society experts reports that the smallest doses of fungous poison may, in some years, cause cancerous tumors. As reported by experts from Finland, the treatment of one patient with allergic diseases costs annually about 3400 dollars. From the abovementioned it follows that the risk of the occurrence and development of biological damages should be excluded at the earliest stage, i.e. as early as the stage of designing constructions and buildings. Thus, the production of building materials and structures with an improved biological stability is an important task in the field of building material production.

2 THEORETICAL BASIS FOR MAKING COMPOSITE MATERIALS WITH IMPROVED BIOLOGICAL RESISTANCE

The mechanism of biological degradation in building materials comprises a number of stages such as: micro-organism dwelling and adsorption on the surface of products, formation of micro-organism colonies and accumulation of metabolism products. The intensity of the given processes is determined, in many respects, by the structure and chemical composition of the material and its components. Taking into account all this, and the fact that the micro-organisms perish in strongly sour and alkaline media (media with pH = 3–7.5 are most optimal), we have carried out the research into the production of building materials with pH media ill-disposed to micro-organism settling and reduplication. Numerous studies have shown that such composite materials, alongside with many others, can be made on the basis of broken glass which is used as a binding element.

As is known, the glass in its chemical composition approximates such precipitous and metamorphic rocks as natrolyte, mordenyte, etc. In mineralogy their formation is explained, by the hydratation of waterless alkaline minerals, by the decrease in the contents of hydrate alkaline new formations and their replacement by hydrogen ions, or hydroxonia, as well as by the transition of aluminum from the 4th to the 6th coordination, i.e. by the phenomena occurring at the hydratation and solidification of building cements [1–4]. 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]. All this has been taken into consideration in our study with the aim of optimizing chemical compositions of glass used in electric bulb production for the purpose of providing the process of structure formation.

The experiments carried out have shown that building industry alumosilicate wastes can be used as adjusting additives. The optimal ratio between the contents of broken glass and the binding additives has been experimentally determined. With the optimal contents of powder components and liquid activator of the alkaline type we have obtained solidifying systems having an increased biological resistance and strength limits of 20–40 MPa at burning.

On the basis of developed binding, the compositions of mortars and concrete with optimum ratio are obtained and their physical and technical properties are studied. Main characteristics of materials are presented in Table 1.

The developed binding compositions of mortars and concrete meet the physical, mechanical, thermotechnical, 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 impurity 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 hydroaluminosilicate promoting their structures consolidation. So, on the basis of experimental researches 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.

Thus, the application of binding on the basis of broken glass makes it possible to use sand with high clay impurity 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 great enough in Russia, whereas in many regions expensive operations on enrichment of local sand are performed.

3 EXPERIMENTAL STUDY OF BIOLOGICAL STABILITY

The experiments were carried out by two methods (1 and 3), the essence of which consisted in holding the materials infected by fungous mould in the conditions optimal for fungus development. Then, the estimations were made for the presence of fungus and fungus resistivity in the samples of the material studied. Method 1 (with no additional sources of carbon and mineral nutrition) was used to establish the fact whether the material was a nutritious medium for micromycets. Method 3 (the Chapek-Dokes nutrition medium) helped to determine fungous properties of the material and the influence

Table 1. Physical and technical properties building materials on the basis of 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 °C	-	-	0,43	0,13	0,19
Coefficient of elasticity, MPa	6000	9750	4600	400	6500
Coefficient of temperature equilibrium	$0,897 \times 10^{-2}$	$1,558 \times 10 \times ^{-5}$	$0,427 \times 10^{-5}$	-	-
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

of external pollutions on fungous resistivity of the material. Samples of the size 1 × 1 × 3 cm were held in the sterile Petrie cups within 3 months. Each cup contained one sample, all the variants being investigated for 5 samples. The surface of the samples was infected with the fungus-test water suspension uniformly sprayed on the sample. Then, the samples were placed in Petrie cups and loaded into special chambers working within the temperature range 29 ± 2 C° and humidity over 90% for the period of 3 months. The following micromycets were used as test-organisms: Aspergillus oryzae (Ahlburg) Cohn; Aspergillus niger von Tieghem; Aspergillus terreus Thom; Chaetomium globosum Kunze; Paecilomyces varioti Bainier; Penicillium funiculosum Thom; Penicillium chrysogenum Thom; Penicillium cyclopium Westling; Trichoderma viride Pcis. The solid nutritious medium was prepared from $NaNO_3$ − 2.0 gr; KCl −0.5 gr.; $MgSO_4$ − 0.5 gr.; KH_2PO_4 - 0.7 gr.; $FeSO_4$ - 0.01 gr.; saccharose - 30 gr.; ogar - 20 gr.; distilled water - 1 liter. The estimation of fungous resistivity of the material was made at a 5-point scale. At zero, the fungous mould growth is not seen in the microscope; at point 1, grown spores and weakly developed mycelia are visible; at point 2, twig-shaped mycelia are seen in the microscope and spore growing is possible; at point 3, the growing of fungous is hardly seen by an unaided eye, but distinctly seen in the microscope; at point 4, the distinctly visible growth covers 25% of the tested sample; at point 5, it covers over 25% of the sample surface.

The material was estimated as fungous resistant if the grade varied from 0 up to 2 points by method 1. The material possessed fungicidal properties if one observes the absence of zone with fungus growth in the sample nutritious medium estimated from 0 to 1.

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

As the research results show binding components do not possess fungicidal properties, however limestone, ground glass, ground haydite, semi water plaster are fungi resistant. As compositions tempering is done by an alkaline solution so the hydrogen indicator of the environment increases to values adverse for 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.

The comparative results of the tests for the developed binding components and traditional materials based on portland cements, plaster, technical sulfur and apoxy rasin are given in tab. 4.

From Tab. 4, it is seen that the developed binding components, unlike cement, plaster, polymeric and sulfuric materials widely used in building industry, possess fungicidal properties. The strong alkaline medium of the binding components prevents micro-organisms from their settling on the surface of products. A considerable increase in biological resistivity of composite materials made on the basis of glass is reached by means of the introduction of various fungicidal additives into their structures. The greatest effect is reached if the acetone additive is introduced for the purpose. In this case, water resistance of the composite greatly increases, the radius of a fungous inhibition zone reaching more then 15 mm.

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 resistance
Brick dust	4	5	not fungi resistance
Glass powder	2	5	fungi resistance
Haydite powder	2	5	fungi resistance
Clay	3	5	not fungi resistance
Slag	2	5	fungi resistance
Gypsum	1	5	fungi resistance

Table 3. Research results of fungi resistance of bindings on the basis of 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
B) acetone	0	0	Fungicidal

Table 4. The results of the biological resistance test.

Material	Grade of fungous growth		Estimation of bioresistance
	Method 1	Method 3	
Portland stone	0	3	Non-fungicidal
Gypsum stone	0	3	Non-fungicidal
Solidified apoxy rasin	0	3	Non-fungicidal
Technical firm-stone (sulfur)	0	3	Non-fungicidal
Solidified binding component on the basis of broken glass	0	0	Fungicidal

4 PHYSICO-MECHANICAL PROPERTIES OF SOLUTIONS AND CONCRETES MADE ON THE BASIS THE DEVELOPED FINDING COMPONENTS AND THEIR MANUFACTURING

The technological process of manufacturing constructive products made on the basis of the developed components includes the preparation of raw materials and the stage of their manufacturing. The incandescent lamp glass is fed through an electromagnetic separator that extracts metal inclusions. The glass fraction is dried up in a drying drum. The crushed glass together with the adjusting additive that has undergone the above-mentioned operations, except for the electromagnetic fraction, is fed through dozators to a special mill and then to a bunker for the ready-made binding and, finally, to an amalgamator. The dosage of the components and mixing of solutions and concretes, as well as the formation of products on the basis of broken glass are made in analogy with the portland concrete technology.

The composition of the solutions and concrete obtained satisfy all requirements extended to wall materials and may be used for erecting 1–2 storey houses. With the use of antifire foam we have obtained foamed concretes with a density of 1100 kg/m^3 and a sufficient strength affording their application in protecting constructions. Composites having an average density of 500 kg/m^3 have been obtained with the help of gaseous additives.

5 CONCLUSIONS

The comparison of the experimental results shows that the materials obtained on the basis of broken glass as a binding component can be used in biologically active media with a greater advantage as compared to analogous parameters of traditional composites obtained on the basis of portland cement, building plaster, apoxy rasin and technical sulfur.

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