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Approach on Improving the Performance of Thermal Insulating and Acoustic Glass Composites

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Abstract. This paper presents an approach on creating new high performance thermal insulating and acoustic glass aerated concrete composites. It consists in design of artificial building conglomerates on nano-, micro- and macro levels with correspondence of natural rocks. Heat-insulating glass composites have low thermal conductivity, high durability, ecological safety and durability, simplicity of installation. The obtained heat-insulating glass composite has compressive strength from 6 up to 8 MPa due to its cellular structure and glass properties. In addition, the material has easy abrasive treatment that allows to create products of any shape. The developed aerated concrete blocks have 42% less thermal conductivity with thickness of the block of 200 mm to ensure the necessary resistance of heat transfer. Adhesive shear strength of the mortar is in the range of 2.35 MPa. It is stated the decrease of the bond strength with the base of heat-insulating structural glass composite is less than 10.6% during the test of frost resistance, which does not exceed the standard value.

1. Introduction

The implementation of the interconnected system “human-material-living environment” requires the use of effective materials, energy saving technologies and thoughtful building design schemes. It guarantees safety and comfort of residence.

The theoretical approach to the creation of new high performance materials is based on geodaetica as a new field in materials science [1, 2]. It allows to design new materials with specified structure and properties, receive materials with unique properties by controlling the morphology of technogenic products [3, 4].

It is necessary to create an amorphous-crystalline structure of the of glass composites with crystalline inclusions. It would allow to increase the strength, maintain high heat and sound insulation

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characteristics and at the same time prevent the formation of a solid crystal frame, increase heat and sound transmission in the material [5, 6, 7].

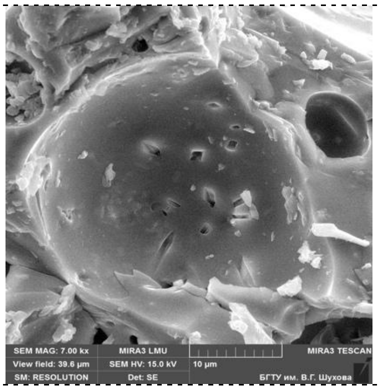

Figure 1. Microscopic image of volcanic tuff and pumice samples with magnification of 7000 times.

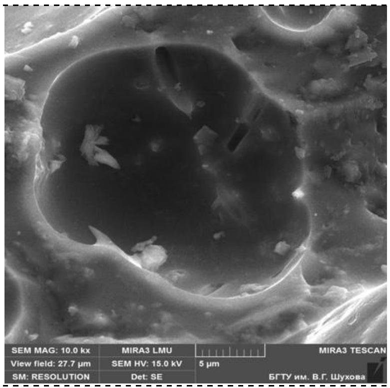

Figure 2. Microscopic image of the volcanic tuff and pumice samples with magnification of 10000 times.

The microstructure of amorphous-crystalline composite was studied by electron microscopy method. The images are presented on Figure 1 and 2. The picture clearly show the amorphous-crystalline structure of material. The structure of pumice and tuff can be represented as an amorphous matrix reinforced with crystalline inclusions. These inclusions belong to the layered minerals of trigonal and tetragonal prismatic shape, the crystal size of the cross section of 0.7-2 μm, a length of 10-30 μm.

There are two options for creating an amorphous reinforced matrix:

- physical method which means the introduction into amorphous matrix the filler with crystal structure;
- chemical method which means the introduction of components into the composite. This process will allow during the temperature treatment to select the crystal phases in the amorphous matrix.

The creation of an amorphous crystalline matrix with the size of 0.7-30 μm by the first method is quite technologically difficult. It requires fine grinding of the initial components.

The second method is preferable, but requires the selection of a special temperature-time treatment of foaming.

In this study the created glass matrix was consisted of silica obtained by foaming of diatomite with functional additives at a temperature of 650 °C.

The material was modified to control its structure at the nano -, micro - and macrolevel and to obtain the new properties.

The special nanomodified additives increase the strength characteristics of foamed silica at micro level, when the glass matrix reinforced with crystalline phase with size of 0.6 - 7 μm and fine-porous structure (100 - 500 μm), which does not reduce the thermal and acoustic characteristics of the new composite material.

According to the law of structure affinity the monolith modifying additives and matrix must have a similar structure and texture to reduce internal stresses [8].

The modification of foamed silica by the fine additives based on technogenic crystalline quartz raw materials enables to create the structural material with high thermal and acoustic characteristics, low volume mass as pumice [9].

Verification of theoretical theses on the design of thermal insulation materials was carried out on foamed glass composite reinforced with crystalline material [10, 11, 12].

2. Materials and Methods

In this study were used:

- glass cullet with chemical composition presented in Table 1 in accordance with [13];
- carbon black in in accordance with [14];
- wastes of wet magnetic separation as a modifying component of foaming mixture with following chemical composition presented in Table 2;
- water.

The evaluation of physical and chemical properties were used following methods:

- porosity and water absorption of foamed glass samples were determined by saturation in accordance with [15];
- linear Thermal Expansion Coefficient was determined by a vertical quartz dilatometer DKV-5A;
- frost resistance was evaluated by freezing and thawing in climate chamber “FAETON”;
- phase composition was determined on the x-ray diffractometer “DRON-3.0”;
- specific surface area was determined by the analyzer “Microsizer -201”;
- thermal conductivity was determined by “ITP-MG4” in accordance with [16].

Table 1. Chemical composition of glass cullet

SiO_2	Al_2O_3	CaO+MgO	Na_2O	Fe_2O_3
71.8-73.0	0.9-2.0	11.5-12.8	13.2-13.4	≤0.1

Table 2. Wastes of wet magnetic separation.

SiO_2	Al_2O_3	FeO	CaO	MgO	Na_2O+K_2O	S	ignition losses
65.02	2.21	7.90	2.70	4.97	1.5	0.192	5.98

3. Results

The material was obtained by the traditional powder technology using wet magnetic separation wastes that served as a reinforcing frame to the foamed glass.

The Fig. 2 shows the image of the glass composite with crystal inclusions in the interporous partition that reinforces the matrix. The structure and texture of the obtained glass composites at the nano-, micro - and macro levels is identical to the structure of natural materials such as pumice and tuff.

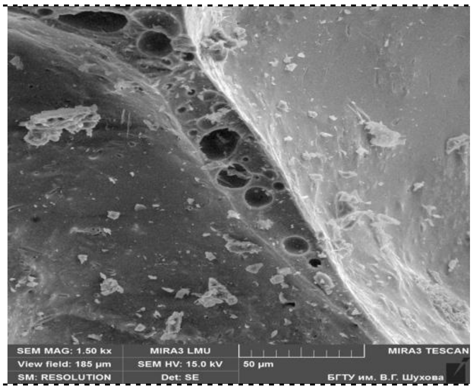

Figure 3. Microscopic image of insulating glass composite with magnification of 1000 times.

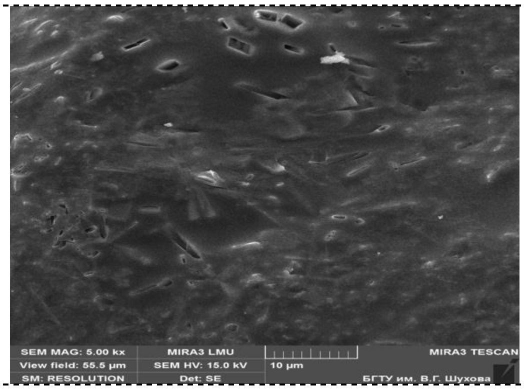

Figure 4. Microscopic image of insulating glass composite with magnification of 5000 times..

Glass composites have more extensive range of use in construction than foamed silica (fig. 5). The adhesion strength of tested samples with coating of mortar applied to glass fiber material was 2.35 MPa. The fiber glass composite model was tested on frost resistance of the contact zone to simulate service conditions. The pull strength of the glass fiber composite was close to the foam concrete blocks and ceramic bricks. The created material has low thermal conductivity that is 42% less than unmodified. The blocks with thickness of 200 mm can provide the necessary thermal protection properties of the enclosing structure.

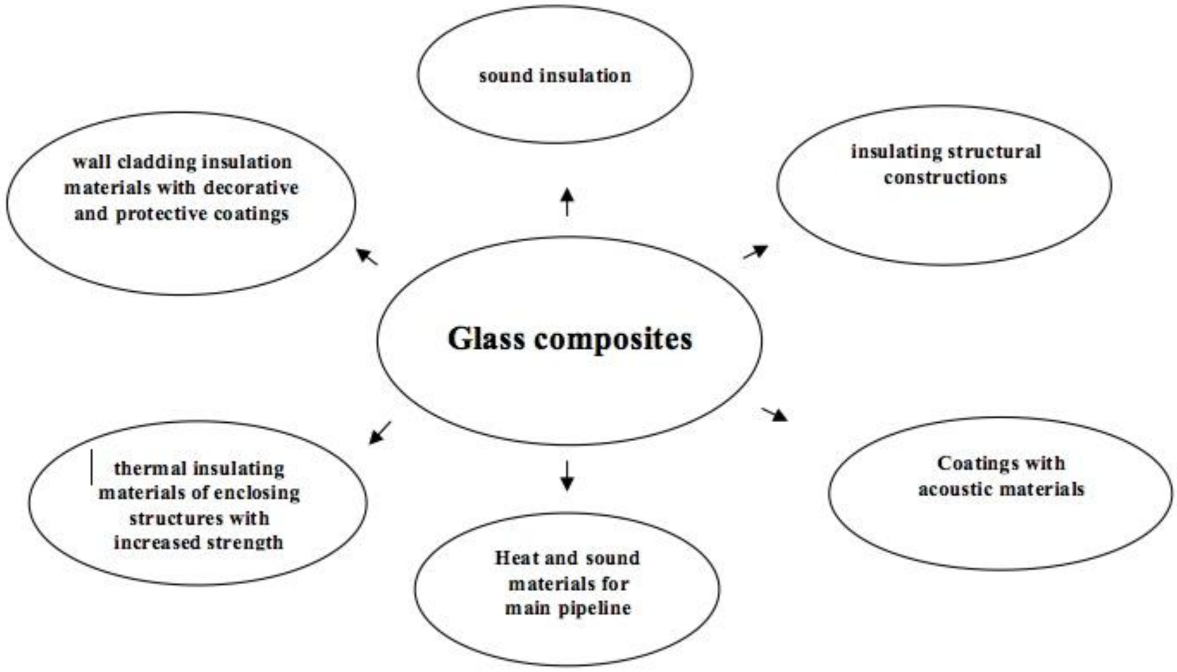

Figure 5. Application fields of glass composites.

In Table 3 are presented the main aesthetic, consumptive, technical and performance properties of the material. In Table 4 the properties of perlite and vermiculite compositions are presented.

Table 3. Performance properties of the glass composites.

Value	Parameters
Acid resistance	Class AA
Water resistance of coatings	III hydrolytic class
Compressive strength, MPa	6.5-8.6
Bending strength, MPa	2.0 – 2.2
Frost resistance, cycles	> 50
Thermal conductivity, W/m· K	0.07-0.09
Mean density, kg/m^3	280-360
Water absorption, %	5-8

Table 4. Properties of perlite and vermiculite compositions.

Material	Average density, kg / m^3	Thermal conductivity, W/ m·°C	Strength, MPa	
			Compressive strength	Tensile strength
Perlite cement	250-350	0.07-0.081	-	0.22-0.26
Glass composite heat insulating	180-300	0.064-0.093	0.3-1.2	0.2-0.7
Cement-vermiculite	400-500	0.08-0.1	0.5-1.0	-
Вермикулит на Vermiculite with liquid silica glass	250-300	0.07-0.09	0.4-0.6	0.2

4. Conclusions

The results of frost resistance test of the model consisted of 25 cycles of freezing-thawing showed the reduction of the adhesion strength to the base of thermal insulation and structural glass composite. It showed 10 percent reduction in strength 10.6%. It does not exceed standard value more than 20 %.

Thus, the use of insulating and constructional fiber glass materials in buildings allows to create energy efficient structures [17]. At the same time, all buildings and structures built with the use of glass composites will provide a significant reduction of technogenic waste impact. Modification of the composition and structure of foamed silica due to the introduction of nanomodified additives allows to synthesize insulating structural and acoustic composite. Glass composites exceed the strength characteristics from initial materials with maintaining thermal and acoustic parameters.

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