AN INNOVATIVE COMPOSITE MATERIAL BASED ON SINTERED GLASS FOAM GRANULES

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ABSTRACT

An innovative composite material is developed in correspondence with the current trends of ecological technologies development through the utilization of waste materials and the studies referring to existing sound insulation products applicable in the construction. The product is made on the basis of granules made of glass (produced by glass domestic waste), hydraulic inorganic binder (Portland cement) and additives. It is non-flammable, non-combustible, water-tight, weather-resistant, and long-lasting. It is characterized by appropriate sound and heat-insulating characteristics. The acoustic and mechanical indicators of standard experimental samples of the developed composite are studied. It is concluded that the material is potentially applicable in the production of sound and heat insulating panels for construction of non-bearing partition walls and installation of exterior insulation of buildings frontage walls.

Keywords: composites, sintered glass foams granules, soundproofing materials, heat insulating materials.

INTRODUCTION

The achievement of appropriate energy efficiency and substantial sound insulation of residential buildings and production premises is one of the goals in the design and construction of buildings. New soundproofing products are required due to the significant noise levels observed in the modern cities, the large industrial areas, the highways, the industrial, administrative and multifamily buildings. A significant reduction of the noise impact is achieved both in the external urban environment and in different parts of the building by installing an effective soundproofing system for buildings [1 - 4].

The design and construction of an efficient thermal insulation system with the use of modern thermal insulation materials ensures a suitable microclimate and significantly reduces the necessary energy consumption to achieve and maintain favorable temperatures [5 - 8] in winter and summer seasons. The major trend in modern new construction [5] and the gradual reconstruction of the existing aging buildings (built on the ground of different construction systems) [9] refer to the construction of the so-called „energy-saving buildings“ with increased thermal insulation capacity of their surrounding structures (walls, roofs, floors, etc.).

There are various insulating materials: expanded polystyrene (EPS) [10, 11], extruded polystyrene (XPS) [11], mineral wool, aerated concrete, foam concrete, etc. EPS is widely used in the construction practice. It has good sound and thermal insulation properties and adequate vapor permeability, but is unreliable when a fire occurs. The standard EPS boards that are available on the
market find use in the construction of external thermal insulation and sound insulation of various architectural sites \[1, 5, 9\]. XPS insulation products are characterized by a low vapor permeability coefficient and a good mechanical resistance. They are mainly used for buildings internal insulation \[1, 5\]. Other insulation products like polyurethane, cork slabs, wood-fiber insulating sheets, rubber sheets, foam glass, flax, hemp, etc. are also used.

The mineral wool used in modern construction (stone, glass, slag) has a specific fiber structure, combustibility class A1, vapor permeability, capillary water absorption and good heat and sound insulation characteristics \[1\]. Cellular concrete, characterized by pores in the bulk of the articles, is obtained from a binder, water, a pore-forming agent (gas-foaming or foaming additives) and the like. It is widely used in practice. The non-slim concrete produced with the participation of a limited amount of binder and large additive material refers to another type of alternative products. An adequate model of the structure of its pore space in the presence of light fillers is presented in ref. \[12\].

The development as well as the use of new insulation materials applicable in modern construction \[13, 14\] presents a definite interest.

The technology for the production of foam glass \[15, 16\] is refined. A horizontal model of a system for the production of thermal insulating materials from a foam glass using waste materials (glass household waste) \[17\] is designed. A pilot production line for the production of foam glass granules by an energy efficient technology \[15\] is developed. Experimental batches of glass foam granules are obtained according to an innovative technology. They are patented upon improvement \[16\]. The technology for obtaining glass foams products is simpler and more cost-effective than that of the production of solid foam glassware. It provides the production of various composite products \[18\]. The foamability of deep-water organogenic-mineral sediments and their use as glass foaming agents for the preparation of foam-like samples are studied \[19\]. Glass foam granules are experimentally obtained upon heat treatment \(850°C - 900°C\) of a mixture containing a powder foam and deepwater organogenic mineral sludge (DOMS).

A composite thermal insulation material based on DOMS and glass foam granules from household waste is obtained \[20\]. The samples are prepared by heat treatment of semi-finished products made of mixtures of foam glass granules and fictile mass obtained from the extracted sludges originating in the Black Sea.

Innovative sound and heat-insulation composite materials on silicate basis are developed \[21 - 23\] by a team with the participation of experts from IMSETCH-BAS. This paper describes the laboratory conditions for the experimental specimens’ preparation and their acoustic and mechanical characteristics.

**EXPERIMENTAL**

The applied technology for making composites of glass foam granules included several basic stages: raw material preparation using household glass waste, foaming granules addition, and composite test bodies’ formation. For the purpose of the study, laboratory formwork matrices were designed and manufactured to form standard test bodies (Fig. 1). The presence of a perforated bottom and the application of vibration provide separation of the excess liquid phase from the system \[22\]. The laboratory specimens are obtained from glass foam granules, hydraulic inorganic binders and supplements. The optimal quantitative ratio of the components was determined experimentally. A recipe composition containing 95 mass % of Portland cement content (CEM I 42.5N) and 5 mass % of zeolite (a clinoptilolite fraction below 63 μm) was developed. The amount of water introduced was 50 % of Portland cement and zeolite weight. A fraction of 5 mm to 20 mm (made from household glass waste) glass foam granules were added to the resulting cement solution under continuous agitation aiming their contact surface

![Fig. 1. Photograph of a laboratory form matrix for molding experimental specimens.](image)
impregnation. The homogenised mixture was placed in preformed formwork matrices (Fig. 2). Depending on the vibration time and granularity, the bulk density of the product varied between 240 kg/m$^3$ to 380 kg/m$^3$. The bulk density of the composite product in a raw and a dry state was increased by increasing the amount of granules of a smaller diameter in the feed mixture. The resulting blanks were decrypted after 24 h and a 10-day technological stay (at a temperature of 15°C to 28°C). Then they were subjected to mechanical finishing to the required size and shape. A waterproofing mortar was deposited to form a sandwich panel (outer layers - intermediate layer) on the external surfaces (front and back) of the composite panels obtained (Figs. 3 - 5).

Two methods were applied to study of acoustic properties of materials. The first method was the standing wave method. It used an impedance tube to determine the sound absorption and the reflection coefficients in the frequency range from 100 Hz to 2000 Hz [23, 24]. The second one was two chambers method. The sound insulation coefficient R was used [24 - 26] in determination of insulating capability of the test specimens. The acoustic tests performed were carried out by the two chambers, between which the experimental specimens were fixed. The cameras were made with thick walls and lined with suitable sound absorbing materials. The sound pressure of the falling sound wave was recorded by a microphone. Another microphone, placed in the receiving camera, detected the pressure of the wave passing through the object. The sound pressure measurements
in the two chambers were performed at frequencies in octave frequencies. The measurement of the sound level in the chambers was done with the RFT 00024 noise meter device. The thermal conductivity measurements were carried applying the comparative-axial-heat-flow (cut-bar) technique. The steady-state method was used. The experiments were carried out in accordance with ASTM E1225. The principle of the measurement was connected with passing the heat flux through a known reference sample and an unknown sample and a comparison of the respective thermal gradients, which were inversely proportional to their thermal conductivities.

A standard tensile and compression test machine was used to perform the prescribed mechanical tests. Tensile and compressive ZD 10/90 stresses were used. The experimental specimens were prepared in the form of a prism of a size 4 cm ×4 cm ×16 cm. The samples were tested for bending and compressive strength. The load was evenly increased until the test specimen was destroyed.

RESULTS AND DISCUSSION

An innovative non-combustible, non-flammable, long-lasting, ecological, composite material is developed [21, 22] on the ground of glass foam granules, hydraulic binder and zeolite. The resulting product is resistant to climatic fluctuations and has a heat transfer coefficient of up to 0.055 W/m K. The material is described in a patent application [21], while its innovation has been proven through a novelty study. The applied technology approach allows the production of standard monolithic products for direct use or for the production of various profiles by cutting out. The material is suitable for obtaining products of different functional use: plates, pipe segments, trough blocks, silencers, etc. The composite complies with the building and technical regulations and fire safety standards described in the Fire Safety Regulation [27] and the modifications made and consistent with European requirements [28]. The product is suitable for insulating the spaces around the windows and the doors of the buildings with a material complying with the stated normative requirements. The plate composite boards are potentially applicable in the implementation of a standard external integrated thermal insulation system including an installation of an insulating material by means of a suitable adhesive composition and dowelling to the external façade walls, an application of a protective polymer-cement coating with reinforcement mesh and a finishing coating. The product would provide the necessary degree of thermal insulation and more significant safety in case of fires when used for tiling facade brick and concrete walls, unpainted flat roofs of civil and industrial buildings and other sites.

The experimental samples studied are superior in respect to their complex characteristics to some of the popular alternative products available in the building materials market. The applied composite making technology is consistent with the existing environmental trends for the use of waste product industries. Based on the experimental results obtained, the main guidelines for further optimization of product performance are defined. A sandwich type panel [23] consisting of an inner layer of the developed composite [21, 22] and external surfaces (frontal and chill) with a suitable waterproof mortar is prepared for a more rational application of the material. The use of various overlay indicators that conform to the specific operating conditions of the panels increases their efficiency. The change of the sound-reflection and sound-insulation coefficients is tracked in different sample bodies (Fig. 6). The preliminary acoustic tests

Fig. 6. Change of sound-reflection (1) and sound insulation coefficients (2) of two types of experimental composite specimens.
are performed under laboratory conditions. In a series of experimental specimens the experiments are found to correlate with the sound insulation coefficients in the studied frequency range (up to 8000 Hz). Average sound insulation R values up to 36 dB are found.

The prepared samples (like sandwich panels) are characterized by a coefficient of thermal conductivity $\lambda = 0.050 - 0.053$ W/mK and an average compressive strength of 5.4 MPa.

A technological scheme of a production section for the production of composite products is developed by applying specialized molding equipment and making sandwich type sound and thermal insulation panels. The product is potentially applicable for building non-load-bearing internal partition walls and for exterior insulation of buildings.

The material is considered to be potentially applicable for the production of sound and heat insulating panels for the construction of non-supporting partition walls and for the installation of exterior insulation of facade walls of buildings.

Based on the experience of the team and the experimental data obtained from the present and previous studies [21 - 23] it is possible to develop constructive pilot project documentation for the production of innovative composites of glass foamed material (GFM). The selection of the type, the minimum technical and functional characteristics of the main facilities necessary for the production process are performed: hammer crusher, vibro sieve, ball mill, granulating aggregate, horizontal or tunnel furnace and specialized molding equipment.

**CONCLUSIONS**

An innovative sound and heat-insulating composite material made of granules made of glass foam granules (derived from glass household waste) and a hydraulic inorganic binder in the form of a Portland cement solution and additives is developed. The resulting product is non-flammable, long-lasting, ecological, waterproof and resistant to climatic temperature changes. Based on the material, a sandwich type panel is designed made of an inner layer of the composite and external surfaces with a waterproof paste. Applying appropriate overlay to the specific operating environment of the articles increases their effectiveness. The experimental results warrant the product to be considered as promising and potentially applicable for the production of sound and heat insulating panels for building non-bearing walls and external insulation of facades.

**REFERENCES**

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