Heat insulators based on silica clay raw materials

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Abstract. The paper presents the results of laboratory studies and pilot tests of the production of foamed glass based on the silica clay from Shipovo field (Republic of Kazakhstan). It is shown that the granulated foamed glass can be commercially produced from widespread siliceous raw material, using home equipment.

Development and production of durable, environmentally-friendly and effective heat insulators for Ural, Siberia and Far East regions is still a topical challenge. Experience has proven that as time goes on mineral products on synthetic binders, polystyrene and other artificial organic materials lose their thermal-insulating properties [1]. For this reason science and industry seek for new materials which routinely turn out to be undeservingly dust-down and forgotten. Among these materials there are foamed glass, foamed silicates and foamed-crystal materials, which differ in types of raw material and manufacturing techniques [2]. This light ($\rho_{\text{pour}} = 140-650$ kg/m$^3$), resisting ($R_{\text{compr}} = 0.5-5$ MPa), durable and inflammable material with low thermal conductivity (0.045-0.1 W/m$\times$K) can be produced in the form of either granules or blocks and plates [3]. Today the technology of foamed glass production, developed in Russia by Academician I. Kitajgorodsky, is implemented in the equipment of the German companies «Foamglas» and «Poraver».

Despite the high quality of the foamed glass from glass scrap or specially prepared glass, this production process has not been commonly implemented yet. Main restrictions here are high energy consumptions for glass melting, limitedness of such material source as glass scrap, which is characterized by a wide variety of chemical compound, and also a high price of German equipment.

In Russia there are not only theoretical but also commercialized projects for the production of foamed materials, involving silica-containing rocks not pre-melted into glass [2].

Main types of silica rocks (tripolit, diatomite, silica clay, etc.) do not contain an inherent source of pore-forming gases and feature quite a high melting point (above 1,100°C). Nevertheless there is a serious motivation to use them as a raw material for the foamed glass production. Silica rocks belong to the opal-crystobalite varieties with a high content of chemically active amorphous silica, which define the main direction of the production process of porous construction materials. The process is based on the interaction between the amorphous silica and NaOH solution resulting in the formation of hydrated polymer sodium silicates, i.e. liquid glass ($\text{Na}_2\text{O} \cdot m\text{SiO}_2 \cdot n\text{H}_2\text{O}$). Application of sodium hydroxide in foamed materials production from silica rocks solves two problems: melting point decrease and formation of a bloating gas source.
Though the works for foamed substances production from natural raw materials have been performed within more than 10 years, there is still no special operating factory in Russia except for small experimental plants. It results from insufficient academic elaboration of the problems of glass formation and gas elimination in such compositions and also from the conversion complexity of some processes to the industrial level.

The present paper shows the results of the lab-scale technological optimization of the compositions and thermal modes for the production of granulated foamed glass (GFG), followed by pilot tests of the production of this glass from the silica clay from Shipovo field (Republic of Kazakhstan, South Ural).

Complex analysis of the silica clay was performed in the Institute of Geology and Mineralogy, SB RAS, by the X-ray-fluorescence (VRA-20R), X-ray diffractometry (Thermo Scientific ARL-X’tra), thermogravimetry (Mettler TC-10A) and electronic microscopy (Philips XL30-FEG) methods [4]. Chemical compound of the silica clay is presented in Table 1.

### Table 1. Chemical compound of the silica clay from Shipovo field

| Oxide percentage % per dry substance, % | SiO₂ | Al₂O₃ | TiO₂ | Fe₂O₃ | MnO | MgO | CaO | Na₂O | K₂O | P₂O₅ | n.n.n. |
|--------------------------------------|------|-------|------|-------|-----|-----|-----|------|-----|------|-------|
|                                      | 81.07 | 7.63  | 0.43 | 3.87  | 0.036 | 1.08 | 0.69 | 0.23  | 1.66 | 0.08  | 3.59  |

The main component of the silica clay is chemogenic opal; crystal phases are presented by quartz and crystobalite. There are also minor quantities of plagioclase and clay minerals. The rock is a porous conglomerate (porosity rate reaches 85%), which promotes formation of hydrated sodium polysilicates, not only on a particle surface but also inside them.

**Results of the lab-scale technological analysis.** Optimal compositions and methods of granules preparation were developed under laboratory conditions in order to manufacture the GFG and block-structured foamed glass from silica-clay raw material, as the sodium hydroxide concentration in the compositions (per dry components of the furnish) varied from 17 to 22 mass per cent. With the maximum concentration of NaOH the obtained GFG had the poured density of 80 kg/m³, block-structured foamed glass density was of 120 kg/m³. With the same sodium hydroxide concentration in the furnish (17 mass per cent), regarding the peculiarities of granulate preparation technique, we produced the GFG of size -12 +10 mm with the poured density within the range from 135 to 200 kg/m³.

**Results of pilot tests.** Laboratory results were tested on the pilot equipment for simulation and tuning of the technological modes of foamed silicates production from silica rocks, company «Baskey Ceramics».

The representative technological samples of the silica clay from Shipovo field had the humidity of 32 – 35%, the size -40+0 mm. It was simultaneously dried up to 6 – 8% humidity and crushed to the size -140+0 µm in the crushing-drying machine USP-S-04.55M with the capacity of 2 tones per hour. The average size range of the crushed silica clay from three tanks of the machine aspiration system approached to the grain range of the silica clay powder used for GFG production in the laboratory conditions.

The produced powder was granulated in the industrial periodical turbo-bladed mixer-granulator TL-100 made by «Dzerzhinskstekhnomasb». In order to provide the processes of silicate-forming and granulation the technological parameters such as granulation time, humidity and size range of the granulate were practiced. The granulate of poly-fraction composition with the humidity of 22% was produced in the turbo-bladed granulator.

The granulated silica clay was dried in the industrial heating drum. Before the calcination in an electrical furnace the dry granulate was mixed with a kaolin powder (5 – 10 mass %) in order to prevent granules adhesion during the bloating. The modes of GFG drying and calcination during the pilot tests correlated to the laboratory recipe.

Physical and mechanical properties of the representative sample of the produced foamed glass are presented in Table 2.
Table 2. Physical and mechanical properties of the representative sample of the produced foamed glass

| Parameter                                      | Unit         | Test result value/size |
|------------------------------------------------|--------------|------------------------|
| Poured-bulk density of fraction 2.5 – 5 mm    | kg/m³        | 220, D250              |
| Ultimate compressive resistance in the cylinder| MPa          | 1.54, П100             |
| Resistance to silicate disintegration          | %            | 1.4, –                 |
| Frost resistance 15 cycles                    | %            | 1.8, –                 |
| Humidity absorption, vol.                      | %            | 4.2, –                 |
| Loss of mass during boiling                    | %            | 0.55, –                |
| Content of water-soluble sulphides and sulphites in SO₃ equivalent | % | 0.22, – |

Fig. 1 shows the porous structure of the GFG based on the silica clay from Shipov field. It features uniformity and satisfactory vitrification. Smaller pores form in the vitrified walls of pores (Fig. 2). This vindicates the uniform formation of hydrated polymer sodium silicates over the whole volume of the granulated material.

**Figure 1.** General view of a porous macrostructure of the GFG. Scale rule corresponds to 5 mm.

**Figure 2.** A porous microstructure of the GFG. Scale rule corresponds to 50 μm.

The results of pilot tests show that it is possible to organize the industrial-scale production of granulated foamed glass which would satisfy all reference standards, using widely spread silica rocks and home equipment.

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