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COMPARISON OF PROPERTIES OF LIQUID GLASS-BASED THERMAL INSULATION MATERIALS PREPARED BY VOLUME AND CONTACT GROUTING

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The article reports two methods of preparation of block thermal insulation materials based on liquid glass; a comparative assessment of them is performed. These methods are implemented via volume and contact grouting of the liquid glass granules by the microwave-assisted swelling of a binder. In order to determine the effectiveness of a certain grouting method, the samples were swollen at different power capacities of a microwave oven and the basic operational characteristics of blocks were determined. The obtained results showed that the materials fabricated by volume grouting are characterized by higher strength and lower moisture sorption and water absorption properties than that prepared by contact grouting due to a closer packing of granules and more uniform distribution of the binder in the intergranular space. This is achieved through the use of microwave irradiation in the production of block materials, which ensures uniform heating of all layers of the material and simultaneously allows swelling both the granules and the binder. Therefore, a strongly grouted material is obtained, which can be used as a structural thermal insulation.

Keywords: block thermal insulation material, liquid glass, swelling, microwave irradiation, volume grouting, contact grouting.

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Introduction

The use of effective thermal insulation materials (TIMs) reduces heat loss into the atmosphere and solves the problem of energy efficiency to some extent. The development of the energy-efficient technologies for the production of thermal insulation foamed materials by means of microwave irradiation, such as granules based on liquid glass, and materials made of them (blocks, slabs, etc.) used in civil engineering to provide thermal insulation of buildings is a topical issue.

Currently, there are four main ways to manufacture porous materials: (i) the production of artificial porous granular materials to fabricate highly porous products [1]; (ii) the use of natural porous materials to make products by additional porization during the production process [2]; (iii) the production of highly porous products from dense artificial and natural fibrous and powdery materials [3]; and (iv) the production of layers of loose and bulk materials [4].

There are six basic ways of porization: removal of the pore-forming agent, non-close packing, contact grouting, volume grouting, creation of combined structures and bloating.

Contact grouting is based on grouting of granular and fibrous elements of the structure in the places of their mutual contact with the help of thin adhesive layers of the binder. Volume grouting differs from the contact one as the binder fills all the voids in the frame-forming material. Creation of combined structures enables to receive highly porous products with two and more types of porosity: fibrous-cellular, granular-cellular, fibrous-cellular-capillary, etc. [5].

The aim of this work was to prepare block thermal insulation materials with a monolithic high-porous structure and satisfactory strength properties. In this paper, we compared the properties of the TIMs obtained through the volume and contact grouting of the granular filler by the liquid glass binder and selected the most appropriate grouting method.

Experimental

Contact and volume grouting of the TIMs were investigated. During contact grouting, the bloated granular filler based on liquid glass and a mineral additive were used. The voids between them were subsequently filled with the bloated liquid glass binder hardened under the influence of microwave irradiation. During volume grouting, crude (not bloated) granules were used. They were mixed with the liquid glass binder. Under the influence of microwave irradiation in the microwave oven, there was simultaneous bloating of both granules and the binder.

In order to determine the effectiveness of a specific grouting method, the effect of power capacities of a microwave oven on the bloating samples was investigated. We determined the bloating coefficient, density, water absorption and moisture sorption and durability, which are important characteristics of the thermal insulation materials.

The bloating coefficient shows an increase in the volume of the bloated composition with respect to its primary volume and is calculated by the following formula:

$$K = \frac{V_2}{V_1}, \qquad (1)$$

where V_1 is the composition volume before bloating and V_2 is the bloated sample volume.

The density of the TIMs shows the ratio of the sample mass to the volume occupied by it, including the volume of the gas phase, and is calculated by the following equation:

$$\rho = \frac{m}{V}, \qquad (2)$$

where m is the sample mass and V is the sample volume.

Moisture sorption and water absorption were determined according to the Ukrainian state standard DSTU B V.2.7-38-95 using samples of rectangular shape with the dimensions of 100×100×35 mm. The samples were dried to achieve a constant mass at the temperature of 50–60^{0}C, then weighed with the accuracy up to ±0.01 g. When determining moisture sorption, the samples were placed over water poured into a desiccator placed in a thermostat with a temperature of 20±3^{0}C. After 72 h, the sample was removed from the desiccator and weighed. The moisture sorption was calculated by the following formula:

$$W_m = \frac{m_2 - m_1}{m_2} \cdot 100\%, \qquad (3)$$

where m_1 is the sample mass dried to constant mass and m_2 is the sample mass after water vapor saturation.

When determining water absorption, the sample was immersed in water. During the first 3 hours, the samples were immersed in water up to half, and they were fully immersed in water during the rest of the test. After 24 h, the sample was removed from water; the excess of water was removed from its surface and they were weighed. The mass of water poured onto the weighing cup from the sample voids during weighing was included in the mass of the water-saturated sample. Water absorption was calculated by the following formula:

$$W_w = \frac{m_3 - m_1}{m_1} \cdot 100\%, \qquad (4)$$

where m_3 is the sample mass after saturation with water.

The strength characteristics of the materials were determined in accordance with the Ukrainian state standard DSTU B V.2.7-38-95 using P-5 test machine which allows determining the breaking load with an accuracy of not less than 0.5 kgf. For materials that do not demonstrate brittle fracture, the tensile strength is determined at 10% compression deformation. In order to determine it, the sample must have the shape of a cube with an edge length equal to the product thickness. The sample was placed on the press base plate so that the compression force was directed parallel to the vertical axis of the sample, and the axis of the sample passed through the center of the base plate press. The load on the sample should increase evenly without shocks at a speed of 10 mm/min. The sensors on the press measure the sample strength characteristics during the test. The tensile strength at 10% compression deformation was calculated by the following expression:

$$\sigma_{10} = \frac{P}{lb}, \quad kgf/cm^2, \qquad (5)$$

where P is the load at 10% linear deformation; l is the sample length and b is the sample width.

When determining the flexural strength, the sample should be in the form of a parallelepiped with the dimensions of 250×10×10 mm. The sample was placed on two pillars with rounding points in the joints. The distance between the axes of the pillars should be 200 mm. The load on the sample was transmitted through a roller with a diameter of 10 mm, laid across the width of the sample at an equal distance from the pillars. Destructive load was considered as the load at which the sample was destroyed. The flexural strength was calculated by the following formula:

$$\sigma_i = \frac{3Pl}{2bh^2}, \quad kgf/cm^2 \qquad (6)$$

where P is the destructive load at flexion; l is the distance between the axes of the pillars; b is the sample width and h is the sample thickness.

Results and discussion

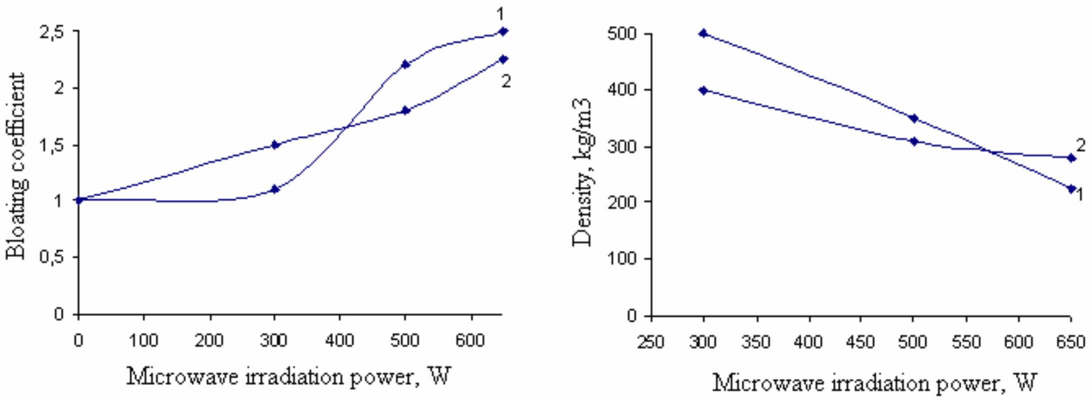
Figure 1 shows the dependence of the bloating coefficient and density on the microwave oven irradiation power for contact (granular filler to binder ratio is 1:1.5) and volume grouting (granular filler to binder ratio is 1:1). The ratios of the mixture components were selected based on the previously obtained data for the lowest density.

As can be seen from Fig. 1,a, the highest bloating coefficient (2.5) is archived at the maximum microwave irradiation power in the case of volume grouting of the block material as compared with contact grouting where the highest bloating coefficient is only 2.26. During simultaneous bloating of the granular filler and the binder, a uniform porous structure is formed, the granules are sintered with each other during porization and the intergranular space is uniformly filled with the porous binder.

During contact grouting, a uniform filling of the intergranular space is complicated by the spherical shape of granules and their practically smooth surface, which results in low adhesion of the binder to the granular filler, disordered distribution of granules in the binder layer and collapse of the bloated foam.

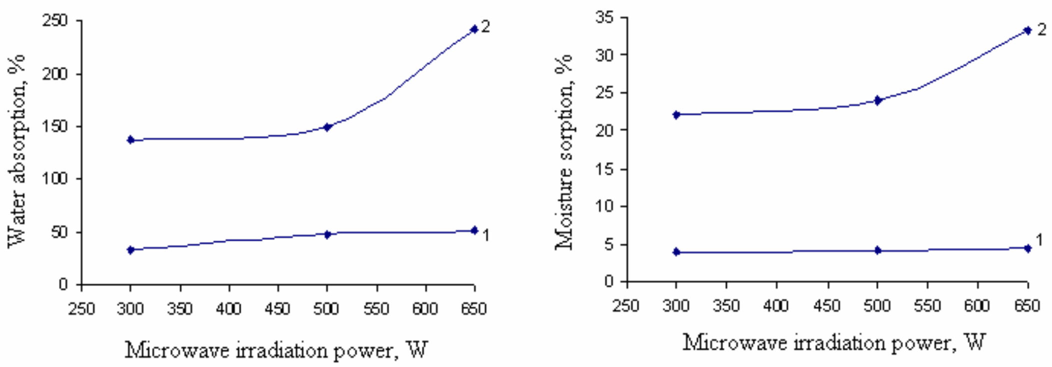
The data in Fig. 1,b indicate that it is possible to achieve lower density (230 kg/m^3 at the microwave irradiation power of 650 W) when block materials are bloated by volume grouting due to the uniform release of molecularly bound water from the structure and granules and the binder during bloating. Consequently, a finely porous structure of the predominantly closed type was obtained.

Contact grouting results in poor adhesion between the binder and the expanded granular material, which leads not only to foam collapse and increased density, but also to the sample brittleness



a **b**

Fig. 1. Dependence of the bloating coefficient (a) and density (b) of the thermal insulation material on the microwave irradiation power: 1 – volume grouting; 2 – contact grouting



a **b**

Fig. 2. Dependence of water absorption (a) and moisture sorption (b) of the thermal insulation material on the microwave irradiation power: 1 – volume grouting; 2 – contact grouting

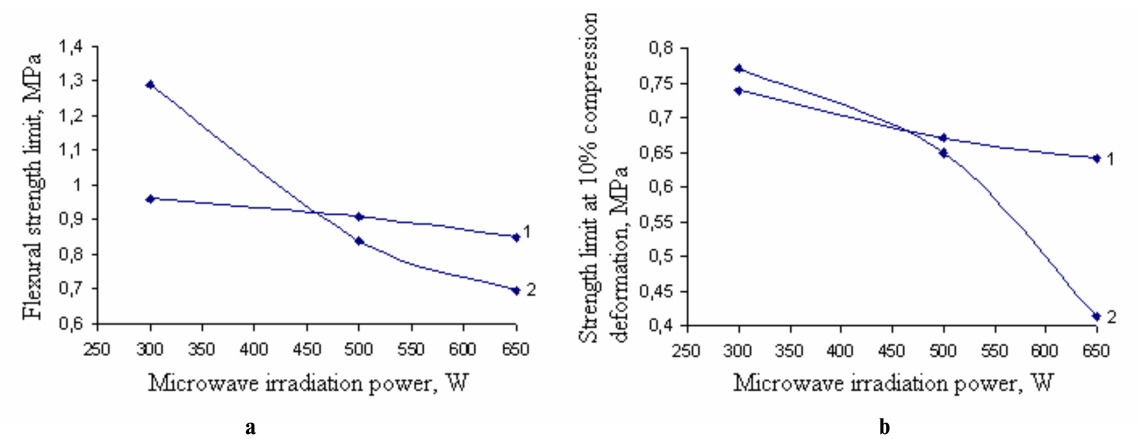
and its lower strength. In addition, it is necessary to use a greater amount of the binder than during volume grouting to get the monolithic structure leading to block overloading. At the microwave irradiation power of 650 W, the density of the contact grouted material is 280 kg/m^3.

Fig. 2 shows the characteristics of water absorption and moisture sorption when producing block materials at different microwave irradiation capacities. The ability of the liquid glass composition to porosity during bloating increases with increasing the microwave irradiation power. Therefore, water absorption and moisture sorption values also increase both for volume and contact methods of grouting. When the microwave irradiation power changes from 300 W to 650 W, water absorption increases from 137% to 241%, and hygroscopicity increases from 22.2% to 33.3% for materials manufactured via contact grouting. During simultaneous bloating of granules and the binder (i.e., volume grouting), the growth of the microwave irradiation power from 300 W to 650 W leads to an increase in water absorption from 33.5% to 51.2% and an increase in moisture sorption from 3.98% to 4.51%. These values are by an order less than in the case of contact grouting. An uneven distribution of granules in the binder layer and the formation of large imploding voids and pores during contact grouting result in a low resistance of the material towards liquid water and its vapor, which negatively affects the thermal insulation properties. Therefore, it would be better to fabricate block materials by means of volume grouting to maintain high performance characteristics.

The results of physical and mechanical tests of block materials obtained by volume and contact grouting at different microwave irradiation capacities are shown in Fig. 3. The bloating of block materials by volume grouting results in their higher strength than by the contact one in case of almost similar densities at the microwave irradiation power of 650 W, the values of density being 230 kg/m^3 and 280 kg/m^3 for volume and contact grouting, respectively. After simultaneous bloating of crude granules and the binder, the flexural strength is 0.85 MPa. At the same time, the flexural strength of the finished sample is 0.7 MPa when producing materials by mixing the binder with the bloated granular filler. An uneven structure of the material, depressed properties, formation of large pores and collapse of the sample cause a decrease in the strength during contact grouting.

The strength limit at 10% compression deformation was also higher for the samples manufactured by volume grouting, it was 0.642 MPa at the microwave irradiation power of 650 W. Simultaneous bloating of granules with the binder allowed obtaining the material with a monolithic and uniformly porous structure showing improved physical and mechanical properties. After the contact grouting at the microwave irradiation power of 650 W, the material with the compression strength of 0.414 MPa was prepared. This means a decrease in the strength characteristics as compared with the material, for the production of which the pre-bloated granular filler was used.

Figure 4 gives photographs of the samples prepared by volume and contact grouting. As can be seen, the obtained samples are characterized by an uneven distribution of expanded granules in the binder layer in case of contact grouting. Thus, large voids and sections of the solid binder without granular filler are formed, that results in a reduced strength. On the contrary, the samples obtained by volume grouting are characterized by a closer packing of granules and uniform distribution of the binder in the intergranular space.



a b

Fig. 3. Dependence of flexural strength (a) and 10% compression deformation (b) of the thermal insulation material on the microwave irradiation power: 1 – volume grouting; 2 – contact grouting

a **b**

Fig. 4. Photos of the block thermal insulation materials obtained by volume (a) and contact (b) grouting

Conclusions

Preparation of block TIMs by contact grouting implies an increase in the binder to granular material ratio (1.5:1 respectively) as compared with volume grouting (1:1), because it is necessary to achieve a monolithic structure of the block and a uniform coating of the granular layer. An increased amount of the binder overloads the material. When comparing materials with the same density, those prepared via volume grouting are characterized by higher strength properties due to a closer packing of granules and a uniform distribution of the binder. The exposure to the microwave irradiation (the most optimal value of the power seems to be 650 W) in the production of block TIMs provides a uniform heating of all layers of the material, ensures bloating both granules and the binder, and results in the formation of a strong grouted material, which can be utilized as a structure thermal insulation.

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ПОРІВНЯННЯ ВЛАСТИВОСТЕЙ ТЕПЛОІЗОЛЯЦІЙНИХ МАТЕРІАЛІВ НА ОСНОВІ РІДКОГО СКЛА, ОДЕРЖАНИХ ШЛЯХОМ ОБ'ЄМНОГО І КОНТАКТНОГО ОМОНОЛІЧУВАННЯ

Т.Е. Римар, О.В. Суворін

У статті запропоновано два методи одержання блокових теплоізоляційних матеріалів на основі рідкого скла та здійснене порівняльне їх оцінювння. Ці методи реалізовані шляхом об'ємного і контактного омонолічування рідкоскляних гранул зв'язуючим, що спучується за допомогою НВЧ-випромінювання. Для визначення ефективності того чи іншого способу омонолічування блокового матеріалу були здійснені дослідження із спучування зразків при різних потужностях НВЧ-печі та визначені основні експлуатаційні характеристики блоків. У ході здійсненого дослідження показано, що матеріали, одержані об'ємним омонолічуванням, характеризуються більш високими показниками міцності та більш низькими показниками сорбційної вологості та водопоглинання завдяки щільній упаковці гранул і рівномірному розподілу зв'язуючого у міжгранульному просторі. Досягається це завдяки використанню НВЧ-випромінювання при виготовленні блокових матеріалів, що дозволяє здійснити рівномірний прогрів всіх шарів матеріалу та одночасно спучити і гранули, і зв'язуюче та отримати міцний омонолічений матеріал, який можна використовувати як конструкційну теплоізоляцію.

Ключові слова: блоковий теплоізоляційний матеріал, рідке скло, спучування, НВЧ-випромінювання, об'ємне омонолічування, контактне омонолічування.

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