Thermal insulation and acoustic building composite materials based on expanded obsidian

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Abstract. In modern conditions, one of the ways allowing the construction company to be competitive in the market is the use of modern high-quality and, at the same time, cheaper building materials. Many technogenic formations, in particular solid waste, are valuable technological raw materials and can be involved in technological redistribution in order to obtain composite building materials. In the production of crushed stone, sands from lithoid pumice and perlite, it is advisable to produce separation and separate obsidian. In this case, the separated obsidian turns into production waste. The expansion of obsidian will allow to obtain a large porous ultralight material and thereby solve environmental issues – recycle production waste. On the base of expanded obsidian, it is possible to obtain new types of effective composite thermal insulation and acoustic materials (cellular concretes and acoustic plasters), which have high performance properties and expand the range of effective building composite materials.

Introduction

It is known that in the construction of buildings and structures, developers are faced with a number of problems relating to both architectural solutions (external and internal layout, appearance of the building, its colors) and the creation of a sound and durable structure. Thus, a natural question arises: how to achieve comfortable conditions inside the premises and maximum comfort at minimum cost of construction (thermal insulation and acoustic comfort accounts for 1 to 3% of the total cost of construction and installation works) to minimize operating costs, primarily energy costs.

It is possible to solve this problem only by using those construction materials which guarantee high efficiency when using in concrete parts of the given building or a construction. And here it should be born in mind that composite thermal insulation and acoustic materials are exactly those types of materials that give the largest economic benefit during the operation and provide comfortable living [1...8].

The characteristics of a satisfactory indoor climate of the room vary within fairly narrow limits: the temperature fluctuation is only ±3°C, the permissible humidity is from 20 to 60%, the air velocity is not more than 0.2 m/sec. Therefore, it is very important to make such design solutions that could significantly reduce the load on the heating and air conditioning equipment.

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Many technogenic formations, in particular solid waste, are valuable technological raw materials and can be involved in technological redistribution in order to obtain composite building materials [1...8].
In the production of crushed stone, sands from lithoid pumice and perlite, it is advisable to separate and separate obsidian. In this case, the separated obsidian turns into production waste. The expansion of obsidian will allow to obtain a large porous ultralight material and thereby solve environmental issues - recycle production waste. Expanding of volcanic glass (obsidian) occurs due to gases, primary (magmatic) and secondary (hydraulic) water located in the pores. During the expanding process, the gases in the pores expand about 4.5 times when heated, which contributes to expansion.

Methodology
The technology of expansion of obsidians containing hard-to-remove cohesive moisture is based on the combination of the processes of evaporation of moisture and expansion of various gases in the pores with the process of transition of the rock substance from solid to pyroplastic state. Theoretically, the volume of moisture vapor at 900-950°C is 4000 times greater than the volume of moisture from which they are obtained, it is enough that obsidian contains only 0.045% water to expand it more than 13 times. In the process of expansion, the limiting shear stress of the vitreous substance in the elastoplastic state is initially overcome by expanding in the pores when heated by moisture vapor. After that, the vapor release from the expanding pores is regulated by the viscosity of the vitreous substance, the value of which should be slightly greater than the value of the viscosity available during the transition from the elastoplastic to the fluid state. When cooled, a vacuum is created inside the closed pores.

Considering the model of expanded obsidian, the mechanism of this process can be represented as follows: under the action of a heat flux having a temperature of the beginning of the rock transition to the elastoplastic state, the peripheral and then the deep layers are heated with the gradual evaporation of the moisture contained in it. In addition to moisture vapors, various gases are also released [9...12].

The results of chemical analysis of gas pores of volcanic glasses showed that their 45.2...73.0% is water vapor, 5.9...56.23% is carbon dioxide, 1.1...2.4% is hydrogen and 1.6%...17.9% is nitrogen. When heated, the front of the heat flux does not pass inside immediately, so first the peripheral and then the deep layers are expanded. The prerequisite is that the expanded peripheral layers of obsidian until the end of the expansion of the deep layers remained in the original condition. The main factors influencing the expansion coefficient are: the expansion temperature and the expansion interval; the higher the transition temperature of the rock to the elastoplastic state, the more difficult it is to obtain a high value of the expansion coefficient; the higher the temperature of the medium, the less time it will take to heat the inner layers of the grain to and it is easier to combine the evaporation of moisture with the moment the substance reaches the viscosity interval; the duration of the thermal effect on the grain of the rock subjected to expansion; the maximum temperature of the medium in conjunction with the duration of its impact on the volcanic glass; the chemical composition of the rock expansion and the alkali content of it; with increasing content of Na₂O+K₂O from 4.81 to 6.41%, the values of the expansion coefficient are decreasing.

Results
It is experimentally proved that obsidian can be expanded at temperatures from 1000 to 1200°C. Above 1200°C there is a partial melting of the mass. We found that the expansion of obsidian fractions from 5 to 20 mm at temperature of 1050...1150°C for 3...10 minutes it is possible to get ultralight large aggregate with an average density of 200...350 kg / m³.

Table 1 and 2 show the chemical composition of obsidian and physical and mechanical properties of expanded obsidian. Figures 1 and 2 show photographs of not expanded, expanded and expanded obsidian fractions a) 10...20 mm b) 5...10 mm c) 2.5...5 mm d) porosity.
Table 1. Chemical composition of obsidian (mass, %)

|       | N  | SiO₂ | Al₂O₃ | Fe₂O₃ | FeO | CaO | MgO | MnO | Na₂O | P₂O₅ | R₂O | loss on ignition | PH of water behavior |
|-------|----|------|-------|-------|-----|-----|-----|-----|------|------|-----|-----------------|---------------------|
| On average | 73.11 | 14.02 | 0.67  | 0.91  | 1.1 | 0.4 | 0.09 | 0.06 | 0.9  | 8.67 | 0.8 | 7.1             |                     |

Table 2. Physical and mechanical properties of expanded obsidian

| Indicators                             | 2.5...5.0 mm grain size | 5.0...10.0 mm grain size | 10.0...20.0 mm grain size |
|----------------------------------------|-------------------------|--------------------------|---------------------------|
| Average density, kg/m³                 | 360                     | 390                      | 454                       |
| Porosity, %                            | 89.2                    | 88.4                     | 86.2                      |
| Compressive strength limit, MPa        | 8.8                     | 10.2                     | 15.1                      |

Figure 1. Obsidian a) not expanded, b) expanded

a)                                                                                                   b)
Figure 2. Expanded obsidian fractions a) 10 ... 20 mm b) 5 ... 10 mm c) 2.5 ... 5 mm g) porosity

On the base of expanded obsidian, thermal insulation and acoustic materials were developed and obtained: aerated concrete and plaster with cement and gypsum (compositions and physical and mechanical parameters are given in table 3).

Table 3. Compositions and physical and mechanical properties, thermal insulation and acoustic materials.

| Composition of 1 m³, kg/m³ | Expanded obsidian | Cement | Lime | Alumina powder | Gypsum | Water | Density, kg/m³ | Compressive strength, MPa | Bending strength, MPa | % sound insulation | Coefficient of thermal conductivity, W/mK |
|---------------------------|------------------|--------|------|----------------|--------|-------|---------------|--------------------------|----------------------|---------------------|-------------------------------|
| Aerated concrete          | 536,4            | 220,4  | 91,8 | 0,688          | --     | 481,1 | 835           | 12,9                     | --                   | 58,4                | 0,08                          |
| Gypsum plaster            | 404,3            | --     | --   | --             | 890,6  | 528,7 | 1311          | 19,79                    | 6,923                | 56,0                | 0,14                          |
| Cement plaster            | 532,0            | 781,3  | --   | --             | --     | 507,8 | 1563,3        | 28,87                    | 6,24                 | 55,1                | 0,12                          |

Summary

Many technogenic formations, in particular solid waste of enterprises are valuable technological raw materials and can be involved in technological redistribution in order to obtain composite materials. The advantages of materials based on expanded obsidian – a porous material, is a unique combination of thermal insulation and acoustic and structural properties.

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