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Development of cellular structure composites for energy efficient construction

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Abstract

The results of studies of cellular composites based on cement-free binding substances are presented. The effect of the composition of the liquid component of the molding mixtures on the porosity of the magnesial compositions was determined. Peculiarities of pore formation in alkali-silicate compositions of various compositions are identified. The possibility of additional porosity of cement-free foams is shown due to the gas-forming additive and hollow granules.

Keywords: magnesial compositions; soluble water glass; pores; cellular concrete

1. Introduction

Construction is a major consumer of material and energy resources. Thermal conductivity of magnesial and alkaline porous composites with various densities vary in range 0.056–0.074 W / (m · °C). Thermotechnical calculation and results from the experiments have shown that in order to provide a defined thermal resistance of wall fencing, the consumption of developed composites is reduced by 11 %–32 % in comparison with to cement cellular concrete [1–17].

Improving the energy efficiency of construction is an important task for preserving the environment, reducing energy consumption. At present, there is a growing trend towards early optimization of energy costs in the design and construction of buildings. The energy efficient construction is aimed at resource saving while maintaining or improving the quality of construction and comfort of the internal environment of buildings. In energy-efficient buildings, the level of heat consumption for heating is 2.5–3.0 times lower compared to standard facilities [3].

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Energy-efficient building includes a set of technical solutions: the choice of structures in the design stage [18–21], the energy supply system during operation [1–5]. Energy saving is achieved only under condition of reliable thermal insulation, which ensures a reduction in losses during the transportation of heat and an increase in the energy-efficiency buildings. Modern construction uses widely effective materials which are characterized by the availability of raw materials and the simplicity of manufacturing technology, sustainable and economy in operation [5–17].

A necessary condition for energy saving is reliable thermal insulation, which is guaranteed by durable thermal insulation materials. Cellular concrete is a material of modern construction. To increase the efficiency of heat-insulating products, the strength of cellular concretes must be increased. The results of the studies [3, 15–17] had determined two directions of strengthening of materials with preservation of thermal insulation capacity: the first is the strength of the framework of interpore partitions; the second is the improvement of the pore structure.

The development of modern technology of cellular concrete is associated with the expansion of varieties of binding substances. In recent years, the interest in binding compositions based on technogenic raw materials has been increased [22–28]. Among cement-free materials, binding substances have a special place, for the activation of which solutions of salts are used. The change in the composition of the liquid component can affect the properties of the molding masses.

The porosity is the determining stage in the production of cellular materials. The influence of technological factors on the formation of the pore structure of multicomponent molding mixtures is of interest.

The purpose of this paper is to study the effect of the material composition on the porosity of magnesial and alkali-silicate compositions containing the technogenic filler.

2. Research methods

The object of investigation is cement-free cellular composites based on magnesial and alkali-silicate binding substances. Composite binding substances were obtained by adding technogenic material to the caustic magnesite (magnesial binding substances) and soluble water glass (alkali-silicate binding substances).

Magnesian compositions were closed with solutions of $MgCl_2$ and $MgSO_4$ of different densities. For the preparation of alkali-silicate compositions, aqueous solutions of NaOH, Na_2CO_3 and $Na_2O\ (SiO_2)_n$ (soluble water glass) were used.

To produce cellular molding mixtures the foaming agents of various origins were added: the “Unipore” protein foam concentrate, “"Fairy” and “Zelle – 1” synthetic foam concentrates.

The foams were prepared in a one-stage method: the suspension obtained by mixing the components was foamed in a mixer. The properties of the foam were evaluated by expansion ratio and density. Foam stability was determined by syneresis – separation of the liquid phase from the foam. To test the physical and mechanical properties of composites, samples with dimensions of 40 x 40 x 40 mm were moulded. The microstructure of the composites was studied by the electron microscopy.

3. Cellular structure magnesial compositions

Magnesial compositions are closed by solutions of salts exceeding the density of water. Information on the nature of the formation of foam in salt solutions for cellular concretes is not numerous.

For the study of foaming, solutions of $MgCl_2$ and $MgSO_4$, which provide the highest intensity of hardening of magnesial binding substances, have been chosen.

The surface tension of the liquid was determined by the stagometric method. The viscosity of the salt solutions was evaluated on a VPZh-2 viscometer. The foam was obtained from aqueous solutions of $MgCl_2$ and $MgSO_4$ with a density of 1100, 1150, 1200, 1250 and 1300 kg/m^3. The “Unipore” and “Fairy” foam concentrates were added to the salt solution in an amount of 3 %. The ability of solutions to form a foam was characterized by: viscosity, surface tension of the liquid; expansion ratio and stability of the foam.

The adding of foam concentrates affects the viscosity of liquids: “Unipore” increases, “Fairy” reduces this indicator (Table 1). The ambiguous behavior of aqueous solutions of foam concentrates is caused by different density of liquids (“Unipore” – 1130 kg/m^3, “Fairy” – 980 kg/m^3). Surface tension in solutions with foam concentrates is decreased, taking values twice as small for “Unipore” and almost four times smaller for “Fairy”.

Solutions based on $MgCl_2$ are distinguished by an increased viscosity, which is increased with increasing the density. The type of foam concentrate practically does not affect the viscosity of $MgCl_2$ solutions. A surface tension shows increased sensitivity to the addition of foam concentrate. For solutions with “Unipore” the surface tension is decreased with increasing the salt concentration. For solutions with “Fairy” the surface tension is increased with increasing the salt concentration.