Formation of optimal structure of cellular concrete

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Abstract. The paper presents the results of experimental studies on the effect of silica-containing components on the structure and properties of cellular concrete. It is shown that the creation of the optimal pore structure of concrete and the structure of the interporous frame, the intensification of hydration and crystallization processes in hydrothermal treatment can improve the physical and mechanical characteristics of cellular concrete. At the level of modern knowledge about the structure and properties of cellular concrete, the potential for increasing its strength characteristics has been studied. Through the effective use of the energy potentials of the multicomponent binder, including Portland cement, calcium lime and activated silica components, the nanopore structure of the matrix stone is formed.

1. Introduction
The modern development of building materials science is focused on obtaining efficient materials with advanced thermal insulation characteristics. The leading position in the segment of external structures of frame buildings is occupied by products made of cellular concrete. This is explained by the numerous advantages of this material: low thermal conductivity, non-flammable, light and durable [1,2]. Its use makes it possible to apply single-layer wall structures, reduce the load on the foundation and load-bearing elements of buildings when they are floored.

The scientific and practical experience of production and application of cellular concrete products indicates the need for solving a number of problems in terms of improving physical and mechanical characteristics [3,4].

The development of scientific and technological foundations for increasing the strength of cellular concrete due to changes in the structure and phase composition of products of hydrosilicate hardening, intensification of hydration and crystallization processes in autoclave processing is a promising direction [5-7]. The potential for increasing the strength characteristics of this material due to its chemicalization is quite high [8,9].

The topical issue of technical regulation of the properties of cellular concrete is proposed to be solved by efficient management of the processes of structure formation of a multicomponent system with the aim of forming an ultra-microporous structure of the cement matrix. The porous structure of cellular concrete is formed due to a number of factors: the type and ratio of the raw components of the mixture, the degree of their dispersion; water-solid ratio and rheological characteristics of the mixture; temperature conditions and the speed of the process of effective mass porosity; modes of hydrothermal treatment, etc [3,10].
2. Materials and methods
To study hydration, crystallization processes and structure research, spectral analysis, electron microscopy and a number of other standard analyses and techniques are used.

In order to improve the crystal-chemical characteristics of the new growths and the structure of the matrix material of cellular concrete, quartz sand was milled in a laboratory ball mill LB M-7 with triethanolamine (TEA) and lime added [11].

At the next stage of the experiment, the feedstock components were ground with the addition of fly ash in proportion to quartz sand 1: 0.22 also in the presence of TEA. The fly ash is characterized by the following chemical composition: SiO$_2$ – 60.0 ÷ 62.0%, Al$_2$O$_3$ – 29.0 ÷ 31.0%, Fe$_2$O$_3$ – 4.0 ÷ 5.0%, CaO + MgO – 1.5 ÷ 2.5% [12].

3. Results
TEA is referred to one of the most effective surfactant polar chemical compounds that intensify the grinding process [13-15]. The mechanism of TEA action is conditioned by the Rehbinder effects and the removal of electrostatic charges due to polarization.

Other conditions being equal, there are changes recorded in the structure of the cellular concrete with an activated silica component. The changes are observed in the contact zone with calcium hydrosilicates (figure 1). Due to the occurrence of solid-phase mechanochemical reactions on quartz grains, localized sections of quasi-morphic surface layers are formed [16].

![Figure 1. Zone of contact of natural quartz grain with hydrosilicates of calcium: a) cellular concrete stone with siliceous component subjected to "ordinary" milling; b) cellular concrete stone with mechanochemically activated siliceous component.](image1)

![Figure 2. Structured cellular concrete conglomerate: a) monodisperse polyhedral structure; b) crystals of ettringite-like compounds.](image2)
Figure 1b shows the process of oriented crystal growth on the surface of quartz activated grain. The dominant mechanism for the participation of silica component in the processes of structure formation during hydrothermal processing of the mixture is the crystallization of hydrosilicate compounds on the surface of mechanically activated grain as a result of epitaxial and chemo-epitaxial interaction. The defects formed during mechanoactivation are an energetically favorable place for the beginning and growth of a stable epitaxial layer of hydrated neoplasms.

Cellular concrete obtained on the basis of Portland cement, silica, lime, ash and milling intensifier - TEA has a branched pore structure with pore sizes of 1.5-4 μm. A monodisperse polyhedral structure is formed, stacked in a hexagonal model (figure 2).

After autoclave treatment the homogeneous growth of crystalline neoplasms of low-basic calcium hydrosilicates of tobermorite-xonotlitic series [17] is observed in microstructures of samples of cellular concrete. These neoplasms are in the form of oriented tetrahedral structures combined into a continuous high-strength structure. The crystals cross the pores and coalesce with the formations of the opposite surface (figure 3), which allows to consider the resulting structure, nanoreinforced with its own hydrated phases of prismatic and acicular structure. At the same time, their growth is not accompanied by deformation of the cement-lime matrix phase [18,19].

![Figure 3. Formation of calcium hydroaluminosilicates in pore space.](image)

The change in the porosity character is clearly diagnosed on the obtained images (figure 2,3). The pores become nominally closed due to the formation of hydrate phases in large pores oriented and crossing free space with a decrease in their size from 400-500 μm to 10-20 μm, which is the most effective in controlling the properties of cellular concrete.

4. Conclusion
Summarizing the given data, it should be noted that as the pore radius decreases, the total pore volume at the nanoscale increases, that is, the pores of a small size occupy a larger space in the concrete than big pores.

A cumulative analysis of the experimental data makes it possible to conclude that the production of cellular concrete of class B3.5 is promising in terms of strength at a density of 350 kg / m3 due to mechanochemical activation of the calc-siliceous binder in the presence of TEA with the replacement of part of quartz sand with fine ground ash.

Thus, the production of cellular concrete, which in terms of density corresponds to heat-insulating, and in strength – to structural and heat-insulating, is a real fact and a promising direction in modern production of building materials [20].

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