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Cellular Concretes Based On Nanostructured Perlite Binder

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Abstract.

The article is devoted to the characteristics of foam concrete with the application of nanostructured binder (NB) on the basis is amorphous aluminosilicate rocks. The optimal technological parameters of the production of nanostructured perlite binder (NPB) were stated. The selection of foam generating agents was accomplished and mechanisms of formation of cellular composites on the basis of NPB were studied. Physical and mechanical characteristics of the obtained material were determined.

Introduction.

Currently, reduction of energy consumption in the production of building materials requires the introduction of new technologies of production of binders and composites based on them. The priority is the implementation of eco-friendly, economically viable in terms of production technology of building materials, the use of which will improve the efficiency and competitiveness of construction products in the global market.

The most common type of binder is cement, which serves as a main component in the production of a wide range of construction materials. However, due to the constant rise in prices for this type of binder and the negative impact of its production on the environmental situation, it becomes necessary to shift to the use of zero-cement binders of nonhydration hardening type on the basis of the available raw materials .

In previously performed researches possibility of manufacturing of foam concrete using a new type of zero-cement binders of nonhydration hardening type - nanostructured binder (NB) on the basis of silicate rocks.

Russia has a unique resource base, great resources of rocks of different aggregative state, genetic type, which may be of value as a single component raw material for the production of NB [1]. From the point of view of reducing the energy intensity of NB's production siliceous volcanic rocks of significantly acid composition, which includes perlite, are of interest. These glassy rocks are the most energy-saturated formations and have no analogues in previously approved raw materials for production of NB [2]. On the basis of conducted studies the efficacy of NPB for production of cellular concretes by foaming was established.

Experimental program.

For the preparation of nanostructured perlite binder (NPB) perlite of Mukhor-Tala deposit (Buryatia) was used, as a model system - NB on the basis of silica-based materials was used.

The structure of the rocks due to their genetic features, is characterized by an amorphous state of mineral components. For the quantitative determination of parameters of phase-dimensional nanoheterogeneity full-profile X-ray phase analysis was employed (Table 1, Fig. 1).

Features of extraction and processing of raw materials require mandatory preliminary preparation, including crushing and subsequent classification with the release of useful fractions. For the purpose of optimal use of a dust fraction (crushing waste) and reduction of energy costs,

NPB was obtained by two ways: by suspending (NPVs) and wet grinding (NPVm) . The principal difference between these methods is the level of dispersion of the initial product. Upon receipt by the wet method perlite materials should consist of fractions from 0.315 to 2 mm, while the method of obtaining of binder by suspension - less than 0.315 mm.

Table 1. Quantitative concentration and dimensional parameters of nanostructured Si_2O raw materials

Substance	Mineral components	Mass, %	ACD[1], nm
Perlit	cristobalite	23	2
	α- quartz	77	1,2
Quartz sand	α- quartz	90	450
	β- quartz	10	24

[1] ACD – areas of coherent dispersion (crystalline particles)

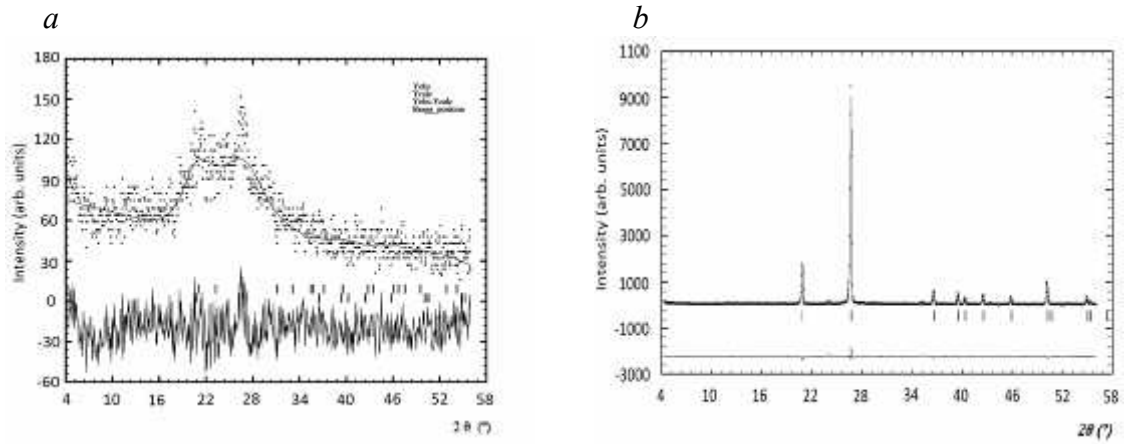


Fig. 1. Rietveld diagrams for calculation of perlite (a) and quartz sand (b)

Analysis of rheological characteristics of NPB, obtained by various methods (Fig. 2) indicates that the binder synthesized by suspending differs in significantly higher viscosity of the system and correspondingly higher thixotropy .

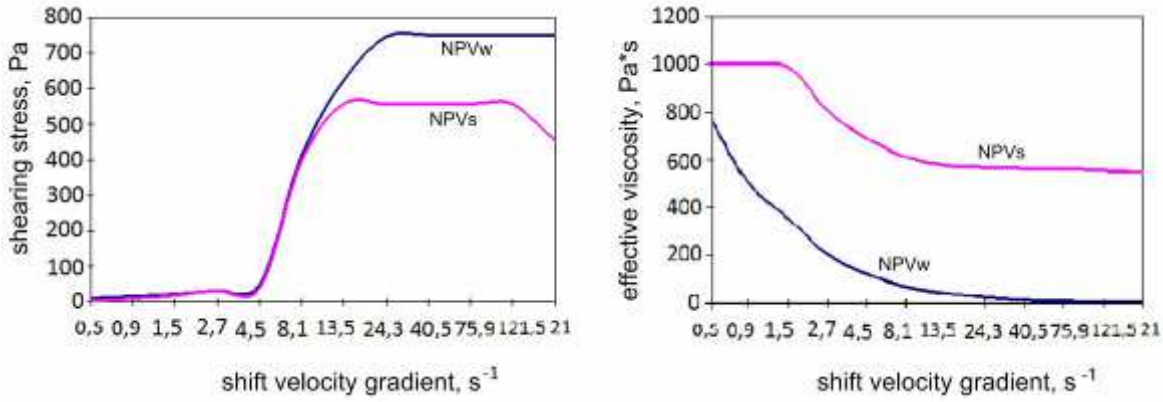


Fig. 2. The rheological characteristics of the system, depending on the method of obtaining

The distinctive feature of received NPB is thixotropic, transferring into the newtonian type of flow. The density reaches 1,880 kg/m^3. The difference is that these characteristics are obtained without application of modifying components.

Developed binder can be recommended for production of various types of construction materials, not only with a complete replacement of cement but also it can be used as a modifier [3].

When producing heat insulating foam concrete on the basis of the NPB as foaming agents we used synthetic, protein and developed complex foaming agents. The latter includes protein (Green Froth) and synthetic (Arecom–4) foaming agents.

Varying concentrations of components of complex foaming agent helps to stabilize the surface of a air void, to obtain materials with low density and lower cost [4].

To improve manufacturability of forming of foammass with the lowest density NPBw can be used in natural form and NPBs – with application of modifying additive because of originally high viscosity. The low mobility of the system affects the processability of the foam mineralization and degree of aeration of foammass (Fig. 3).

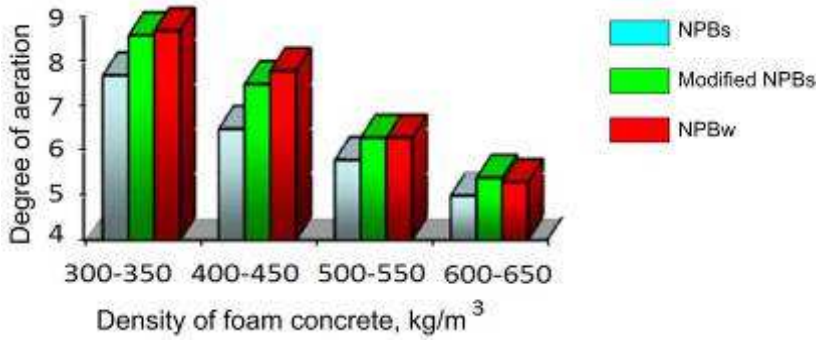


Fig. 3. Characteristics of foam concrete depending on the type of used perlite binder

Designed rational compositions of foam concrete on the basis of NPB and complex foaming agent without additional hardening helps to produce products with strength of 1–2.5 MPa and density of 300–550 kg/m^3 (Table 2).

Application of NPB is promising for the production of low-density foam concrete. This phenomenon is explained by the peculiarities of formation of the material structure and real density of raw materials. Low density of main raw component of NPB – perlite contributes to the formation of light and durable interporous partitions during the process of structure formation of cellular composite [4]. Such regularity allows to recommend NPB for manufacturing of heat insulating materials. Developed compositions of foam concrete on the basis of nanostructured perlite zero-cement binder are classified according to the strength to the class B1.5–B2.5, with the brand of the density D 300–D 500, respectively.

Table 2. Compositions of foam concrete on the basis of nanostructured perlite binder

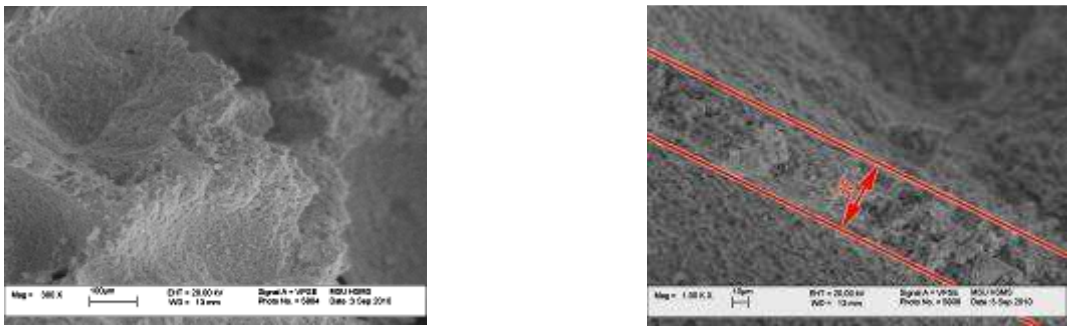
Composition of foam concrete				Density of foam concrete based on NPB, kg/m^3	Compression ultimate strength, MPa
Foaming agent, %		Water, %	NPB, %		
Green Froth	Arekom–4				
0,39	0,21	15,7	83,7	300–350	1–1,5
0,24	0,26	13	86,5	400–450	1,5–2
0,12	0,28	10,3	89,3	500–550	2–2,5

The nature of the microstructure of foam concrete based on nanostructured perlite binder is determined by the presence of uniformly distributed over the volume of isometric pores, that are not in contact with each other, with sufficiently smooth walls (Fig. 4). The presence of 8–10% of nanodispersed component and a high concentration of solid phase in the binder helps to create full-strength interporous walls (Fig. 4). That provides sufficient strength of the cellular composite with low density.

Results and discussions.

Manufacture and application of the developed material is advisable from an economic point of view. Cost of foam concrete on the basis of the NPB is by 40% lower than on the basis of a cement binder. Economy is conditioned by the application of available raw materials in the obtainment of the binder, the usage of complex foaming agent, which consists of inexpensive foaming additives. Using perlite as the main component in the production of NB allows reducing power consumption

by 20–30% in comparison with the cement production technology [5]. Technology of binder production and based on it materials is eco-friendly at all stages of production.



a b

Fig. 4. Microstructure of foam concrete on the basis of NPB:
a – general view of the porous structure, b – microstructure of interpore partitions

Conclusions

Possibility of obtainment of a zero-cement nanostructured binder on the basis of effusive silica-containing rocks of acid composition was theoretically substantiated and experimentally confirmed. Amorphized aluminosilicate material with a high content of water with minimum energy consumption allows synthesizing by wet mechanical activation binding systems with high sedimentation stability.

The possibility of obtainment of nanostructured binder based on perlite rock by wet mechanochemical synthesis or by suspending with rational use of dust fraction (waste crushing) was stated.

Composition of complex foaming agent, the components of which are protein (Green Froth – 0,12-0,39%) and synthetic (Arecom–4 – 0.21-0.28 %) foaming agents was developed. Concentration of components of complex foaming agent varies according to the desired characteristics of the foam concrete on the basis of NPB and the technology of production of the binder.

Compositions and technology of foam concrete on the basis of the developed binder, which allow production of heat insulating foam concrete with density of 300–500 kg/m^3, the compressive strength of 1–2.5 MPa, thermal conductivity of 0.08–0.1 W / (m×° C) were proposed.

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