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Physico-Mechanical Properties of Foam Concrete with a Keratin-Based Foaming Agent

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Abstract*: The work shows that the technology for producing keratin-based foaming agent, in terms of its physicochemical characteristics, is highly competitive with other foam concrete with another foaming agent. The study describes the compositions of foam concrete on the basis of a keratin-based foaming agent and its basic physicomechanical properties. The effect of the keratin-based foaming agent in terms of increasing the timing of the beginning and end of the cement setting in cement systems is less than in traditional foam concrete. This is explained by the presence of the complex additive MB-01 and Aquatron-6, which seal the Plato channels and contribute to retaining more water in the foaming agent films. A complex of technological methods for the use of keratin raw materials and calcium hydroxide for its hydrolysis, as well as the mineral-chemical additives MB-01 and Aquatron-6, made it possible to produce foam concrete with given properties of strength and density.

***Index Terms:* keratin raw material, hydrolysis mode, hydrolyzate neutralization, surface tension, sublimation, foam concentrate.**

I. INTRODUCTION

These days, there are high rates of urban construction. Therefore, there is a need to increase the number of products from cellular concrete. Scientists from India studied the compatibility of a foaming agent with chemical additives in foam concrete. Coarse aggregate and reinforcement including light fibers were used in the foam concrete [1]. There is a study of foam concrete on the basis of three mixtures and their structure, and foams in the hardened state. The scientists obtained foam concrete for compressive strength of 0.74 MPa and thermal conductivity of 0.054 W/m [2]. In [3], it was established that the use of foam concrete reduces the load on the foundation, contributes to energy saving and reduces costs during construction. Moreover, the use of foam concrete reduces the estimated cost due to low transportation costs in comparison with a concrete. The recommendations of O.V. Korotyshevsky can also be considered as a criticism of the work [4]. He formulated the recommendations during the development of resource-saving production technology for high-performance foam concrete. He unequivocally states that the preparation of foam concrete by the method of “dry mineralization of foam” is possible only with the use of low-expansion foams [5]. A.A. Akhundov, on the basis of the carried out scientific and practical work, unequivocally came to the conclusion that the manufacturing technology of foam concrete is rather simple in comparison with aerated concrete. Foam, obtained in a special unit – foam generator, is added in the prepared cement-sand mixture. After the ingredients of the concrete mix with the foam are combined, various building products can be formed [6, 7]. Promising methods include the one proposed by V.A. Martynenko – a two-stage heat-wet product development in cassette forms, where the first stage is the steaming of products, and the second is autoclave processing under reduced mode [8]. This technology also allows increasing the turnover of forms and reducing production areas by accelerating the hardening of cellular concrete. The work [9] gives strong arguments in favor of cellular concrete, used as insulating wall structures of residential and civic buildings. G.P. Sakharov proposes an original integrated approach to solve the problem of thermal protection of walls of heated buildings based on the use of foam concrete stones with technological voids or thermal inserts made of cellular plastics. The average density of stones with thermal inserts is 400-450 kg/m^3, and the thermal conductivity is 15-17% less than that of monolithic cellular concrete of the same density [10]. The works of S.A. Gusenkov, V.M. Smirnov, S.D. Galkina and V.S. Erofeev shows the ability to solve the problem of creating efficient cellular concrete technologies. They developed an advanced technology and a modern equipment that allows producing foam concrete with density from 400 to 1200 kg/m^3, which hardens under atmospheric pressure. The produced foam concrete products are effective building material, contributing to the improvement of thermal performance of buildings being constructed. The equipment created is characterized by low energy consumption and allows obtaining products with high physicomechanical and thermal performance [11]. A.I. Kharkhardin and L.S. Vesnin pay attention to the dependence of the technical and economic indicators of the production of foam concrete products on the type and properties of raw materials, foam-activating substances, and chemical additives; foam generator design and quality of the mold manufacturing costs for materials, heat, and electricity for the manufacture of 1 m^3 of foam concrete products are 161-362 rubles, depending on the brand of foam concrete [12].

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The recommended foam generating agents of Russian production – resin-saponin, rosin soap, aluminosulfonaphthene, hydrolized blood, PO-1, PO-6, PO-3a, SP-1, SP-2, Sampo, Penostrom, etc. – do not provide high foam concrete qualities with the given properties.

The reason is low foam stability in time, due to high syneresis. Considering the current situation, we have developed an environmentally friendly foaming agent based on keratin raw materials [13].

II. RAW MATERIALS

Horns and hooves of animals, carbamide, ferrous sulphate [$Fe_2(SO_4)_3$], tylose, cement 400 of the Shymkent cement plant and quartz-feldspar sand of the Ural deposit were used as raw materials.

III. RESEARCH METHODS

The technology of preparation of the foaming agent includes hydrolysis of keratin raw materials, which was conducted in hydrothermal bombs made of chromium-nickel steel. Hydrolysis was carried out at a temperature of 130±5°C with the additive of chemical reagents that contribute to the complete dissolution of the raw material. The value of syneresis was taken as an optimality criterion, i.e. time of flowing out of 50% of the liquid from the foaming agent solution after the formation of foam. The experiments showed that the syneresis time equals 50-60 minutes depending on the concentration of the protein surface active agent (SAA), the pH solution and the type of stabilizing additive.

IV. RESULTS AND DISCUSSION OF RESULTS

High stability of foams based on keratin foaming agent and stabilized with high molecular weight polymers is due to the joint adsorption of mother solution and a stabilizing additive that provides for the structure formation to a greater depth and preservation of a greater mass of liquid in the surfactant film. This circumstance allowed us to make an evolution in the technology of foam concrete, i.e. come close to obtaining foam concrete properties. At the same time, we set a goal to increase the raw and final strength of foam concrete. It is known that protein foaming agents greatly slow down the setting time of cement, which requires long exposure of foam concrete products in the forms (formwork). The introduction of a complex modifier consisting of MB-01 and Aquatron-6 in the amount of 2% by weight of the binder made it possible to reduce the setting time of foam concrete and increase the turnover of forms. At the same time, the multiplicity and stability of the foam did not change. The surface tension of foamed films with the addition of a complex modifier, determined by the method of William, was in the range of 39.5-41.3 mN/m. The obtained data are consistent with the data of A.A. Trapeznikov, where he shows that with the additive of microparticles to protein surfactants, they fall into the middle part of the film and form a structure that slows down the flow of fluid, i.e. Plato channels are clogged [14]. This circumstance (preservation of the multiplicity and stability of the foam) can apparently be explained by the fact that the Ca^{2+} cation, taken as a hydrolyzing reagent, blocks two charged centers (– COO^-) belonging either to one polypeptide chain or to two adjacent ones. There is a reduction in the structural elements of the protein in the longitudinal direction and a sharp increase in the chains in the transverse direction, i.e. the protein acquires a net-like structure, a “protein swelling” occurs [13]. At the same time, the charged centers of the protein intensively attract the polar molecules (dipoles) of water, and ion-dipole interaction occurs, which also causes high stability of protein foaming agents in cement systems. The absorption of salt ions from the solution in most cases occurs selectively, i.e. either a cation or anion binds with a protein, for example, from a solution of $Ca(OH)_2$ it is mainly absorbed by the Ca^{2+} ion. As a result, an imbalance of charges is created, i.e. a slight excess of positively or respectively negatively charged groups, which is the cause of protein swelling [15]. Using the foaming agent developed by us and the complex additive MB-01 plus Aquatron-6 in a 1:1 ratio, foam concrete was obtained. According to its physical and technical characteristics, it meets the requirements of GOST standard for non-autoclaved foam concrete. The compositions of foam concrete of various average density and their physicomechanical properties are shown in Table 1.

Table 1. Compositions and physicomechanical properties of foam concrete

An average density of foam concrete, kg/m^3	Material consumption per 1 m^3 of foam concrete				Compressive strength, MPa
	cement, kg	sand, kg	water, l	foam, l	
500	338	102	128	832	2.7
600	352	211	123	785	3.1
700	403	254	145	749	5.1
800	456	296	160	714	7.2

The results of the study show that the strength of samples of foam concrete, which was hardened under normal conditions and contains complex mineral-chemical additive is around, and even slightly higher than the strength of autoclaved cellular concrete (GOST 25485-89).

V. CONCLUSIONS

It has been established that keratin raw materials can be used as a raw material for the production of a foaming agent, where it requires less energy to grind. The effect of keratin foaming agent (in terms of increasing the time of the beginning and end of the setting of cement) in cement systems is less pronounced than in traditional foam concrete. This is explained by the presence of the complex additive MB-01 and Aquatron-6, which clog the Plato channels and contribute to retaining more water in the foaming agent films. As a result of a complex of technological methods for the use of keratin raw materials and calcium hydroxide for its hydrolysis, as well as the mineral-chemical additives MB-01 and Aquatron-6, it became possible to produce foam concrete with specified properties of strength and density.

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