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The Composition and Properties of Autoclaved Gas Concrete with Amorphized Raw Modifiers

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Abstract. The article presents the research devoted to the effect of mineral modifiers obtained by mechanical activation of amorphized raw materials in water environment with obtaining a stable suspension on the gas concrete properties of autoclaved hardening. It was shown that the introduction of a mineral additive provides the intensification of the processes of porization of the gas concrete mixture, which ensures the formation of a heteropore structure of the finished composite. It was justified that the mineral modifier from amorphized rocks, regardless of the composition in the pre-autoclave period, acts as a structure-forming component causing the reduction of porous processes with the formation of a system with an improved micro- and macrostructure. The structural features of cellular products of autoclaved hardening, reasoned by the presence of a mineral modifier from amorphized rocks, were shown. With the introduction of the active additive, the increase in the pore size occurs during the process of condensation of the interpore partition. It provides the increase in the strength of products with the improvement of their heat-insulating characteristics.

Introduction

Silicate products of autoclaved hardening are the leaders among piece goods used for the construction of residential civic buildings. At the same time, the high efficiency of autoclaved gas concrete is reasoned by the combination of optimal strength and heat insulation properties that ensure the durability of structures and a comfortable living environment, including the regions with severe climate.

However, high growth rates of individual residential construction, as well as the increase in quality requirements for produced building materials, necessitates the search for alternative types of technological solutions and raw materials which can give the finished product the necessary technical and operational characteristics with substantial savings on the cost of production. At different times, the use of technogenic raw materials of different composition, components of the nano-sized level (primary nanomaterials), etc. was proposed in order to solve this problem [1–9]. However, the development of technologies for the production of autoclaved gas concrete using highly active dispersed additives, providing not only savings of basic material resources, but also capable of directing the regulation of structure-forming processes, which will provide products with the specified high performance properties, is more relevant and more reasonable.

Earlier performed studies have proved the efficiency of using nano-structured binder based on full crystalline raw materials as a modifying component in the preparation of autoclaved hardening products [10–12]. Obviously, having a high activity, the modifier will affect the processes of pre-autoclaving structure formation, as well as participate in the phase formation in hydrothermal conditions during the process of autoclaving of products. The purpose of this research is the estimation of the effect of the modifying structure-determining component (mineral modifier (MM)), obtained by mechanical activation in water environment of amorphized rocks of different composition on the properties of autoclaved gas concrete.

Materials and Methods

In this research CEM I 42.5N cement produced by “Belgorod Cement enterprise”, quicklime lime, quartz sand from the Korochanskoye deposit (Belgorod region), G-5 gypsum, and Stapa Alupor aluminum paste were used as raw materials. All the raw materials meet regulatory requirements.

As raw materials for the production of modifiers, the perlite of the Mukhor-Tala deposit (Buryatiya) and the silica clay of the Alekseevskoye deposit (Mordovia) were used.

The modifiers were obtained using the suspension method: at the first stage, the dry raw materials are milled in a ball mill until the limit of milling capacity is reached, which is identified visually by the aggregation of particles. Next, the milling of the raw material in the water takes place with obtaining a sedimentation-stable suspension with a the concentration of solids of at least 0.7, humidity up to 20% and high dispersion, determined by passing through a sieve with the mesh size of 0.063 mkm with a residue of not more than 1%.

The resulting modifiers are characterized by high activity, which is confirmed by the specific surface of the solid phase and activity against calcium hydroxide (refer with Table 1) [13].

Table 1. The properties of mineral modifiers of different composition [13]

Item	Active specific surface, [m^2/kg]	Number of active Broensted acidic sites, [mg·ecv/g]	The amount of absorbed CaO by the method of Zaporozhets, [mg/g]
Perlite MM	7 800	45.2	118
Silica clay MM	5 900	25.8	112

Since the main components that perform the structure-forming function in the pre-autoclave period are cement in the total volume of the mixture, the research work proposed the introduction of an active dispersed component (MM) to replace part of the cement in the range from 10 to 50 % with a gradation of 10% and 100 (complete exclusion of cement from the mixture). It will also save and reduce the cost of the composites.

The calculation of the composition of the mixture was made based on the factory data. Autoclave treatment of samples of gas concrete was carried out at “Aerobel” enterprise in Belgorod according to the mode of temperature rise for 2 hours, isothermal aging for 10 hours, and pressure drop for 3 hours; pressure of saturated steam of 1.2 MPa.

The study of the process of array blow-out was performed using the gas volumetric method. For this purpose, a cellular concrete mixture was prepared, which was placed in a vessel, hermetically closed with a lid. In the process of polishing the mixture, the increase in the volume of the mixture was measured according to the grading scale of the glass bulb. The measurements were stopped when a constant volume of the mixture in the flask was reached.

The investigation of the structure of gas concrete at the macro level was carried out using a HiroxKH-7700 digital video microscope.

The study of the micro-structural features of the materials was carried out using a high-resolution scanning electron microscope TESCAN MIRA 3 LMU with the Schottky field-emission cathode.

The studies of the physic and mechanical properties of the finished gas concrete (strength, density, thermal conductivity) were carried out according to the requirements of National State Standard № 3135972007 “Cellular concrete of autoclaved hardening. Technical conditions”.

Results and Discussions

According to the data obtained, with the increase in the concentration of modifiers in the system, the increase in the volume of arrays was observed as compared with the initial control composition without an additive (refer with Table 2): up to 60% for a modifier made from perlite and up to 55% for an additive from silica clay.

The introduction of modifying additives to some extent intensifies the processes of expansion of the gas concrete mix and provides a reduction in their duration while reducing the proportion of cement in the composition of the mixtures from 8 to 35%, depending on the composition of the mixture. The complete elimination of cement from mixtures with the replacement of active modifying components reduces the reaction time by almost two times.

Table 2. Kinetics indicators of arrays blow-out

Compound №	Content of MM, [%]	Mixture volumetric gain			
		[sm^3]		[%]	
1	0 (control)	74		56.9	
		Perlite	Silica clay	Perlite	Silica clay
2	10	76	75	58.5	57.7
3	20	78	78	60.0	60.0
4	30	85	83	65.4	63.8
5	40	94	89	72.3	68.5
6	50	102	100	78.5	76.9
7	100	119	116	91.5	89.2

Complex optimization of the pre-autoclave structure formation processes ensures the production of goods with the required operational characteristics (refer with fig. 1). The introduction of modifiers into the mixture in the range of 10–30% leads to the increase in the strength properties of composites while maintaining their grade in density.

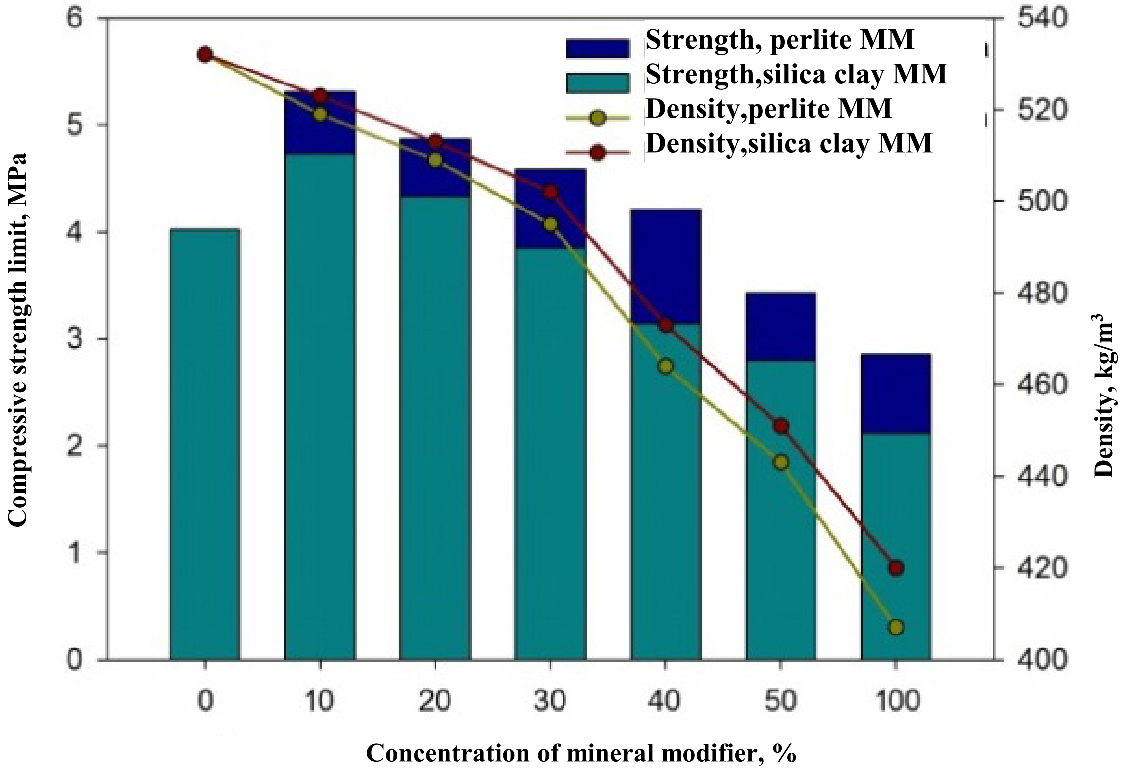

Fig. 1. Physical and mechanical properties of autoclaved gas concrete depending on the composition

First of all, it is necessary to note that the increase in the content of the modifier in the system contributes to the decrease in the density of the obtained products (Figure 1). The decrease in the density grade was observed from D500 (control composition) to D400. In this case, the total density drop in the case of samples with MM on the basis of the perlite was 29%, and for products with

MM on the basis of the silica clay was 24%. The samples that contain perlite-based MM were characterized by lower densities compared with products with the addition of a silica clay modifier with a similar percentage, which confirms the previously obtained results of the coefficient of expansion of mixtures and volume increase.

The effect of the decrease of the grade in terms of density is reasoned by the high initial activity of the mineral modifier with respect to lime, leading to the intensification of the processes of blowing out and gas formation in the mixture, as well as decreased density of the raw components of the modifier compared to cement.

Nowadays, the gas concrete producers have implemented technologies for the production of goods with grades in density up to D100, however, as a rule, the materials with a density below D400 are not practical due to insufficient strength of such products, which places special conditions for transporting and direct processing of such products in building process. According to the data obtained (refer with figure 1), the introduction of MM on the basis of perlite in the range of 10–50%, while reducing the density of composites, contributes to the increase in strength up to 30%, and the use of MM on the basis of the silica clay in the composition of the raw mix - up to 20%. A further increase in the percentage of modifier content leads to a slight decrease in the strength properties of gas concrete samples. However, from the point of view of obtaining heat-insulating gas concrete, the materials with modifying component, regardless of its composition, are characterized by a substantial deposit of strength, which will allow expanding the range of products produced at manufacturing enterprises while saving material costs.

Table 3. Heat conductivity coefficient of gas concrete depending on the composition

Compound №	Modifier	
	Perlite based	Silica clay based
0	0.120	
10	0.111	0.113
20	0.108	0.109
30	0.105	0.106
40	0.100	0.102
50	0.095	0.097
100	0.078	0.080

The increase in the number of modifier in the system leads to the decrease in the coefficient of heat conductivity (refer with Table 3). It is worth noting a slight difference in heat conductivity of materials depending on the composition of amorphized raw materials for the modifier. This is reasoned by the similar nature of the influence of both modifiers on the system: the decrease in the density of the mixture with increasing degree of expansion is noted. The insignificant deviations of heat conductivity indicators for the additives of different composition can be explained by the mechanism of their influence: in the case of silica clay, a “mechanical” effect occurs to a greater extent in terms of condensation of the mixture and sorption of the active component; in the case of aluminosilicate perlite, the chemical bonding of the components of the mixture with the formation of a dense closed structure is observed.

The macrostructure of gas concrete products confirms the findings (refer with figure 2).

The samples of gas concrete of control composition are characterized by uneven distribution of pores, mostly of irregular shape (refer with figure 2, a). Interpore partitions have a loose structure and are distinguished by substantial thickness.

The structure of samples with 10% MM content is characterized by the polydisperse character of pores evenly distributed in a volume with partitions of an insignificant thickness (refer with figure 2, b, d). The increase in the content of the modifier in the mixtures leads to the decrease in the diameter of the pores.

The skeleton of materials with complete replacement of cement by MM is penetrated by a large number of pores isolated from each other with partitions of small thickness (refer with figure 2, c, e). The pores are predominantly smaller in comparison with all other samples. It is explained by the higher viscosity of the molding mixture. Due to its high activity, the modifier accelerates the process of accumulating an array of plastic strength, thereby preventing gas bubbles from escaping from the material, as well as breaking the walls of the membranes of the pores themselves. Consequently, it has become possible to obtain autoclaved gas concrete of reduced density with improved heat insulation properties.

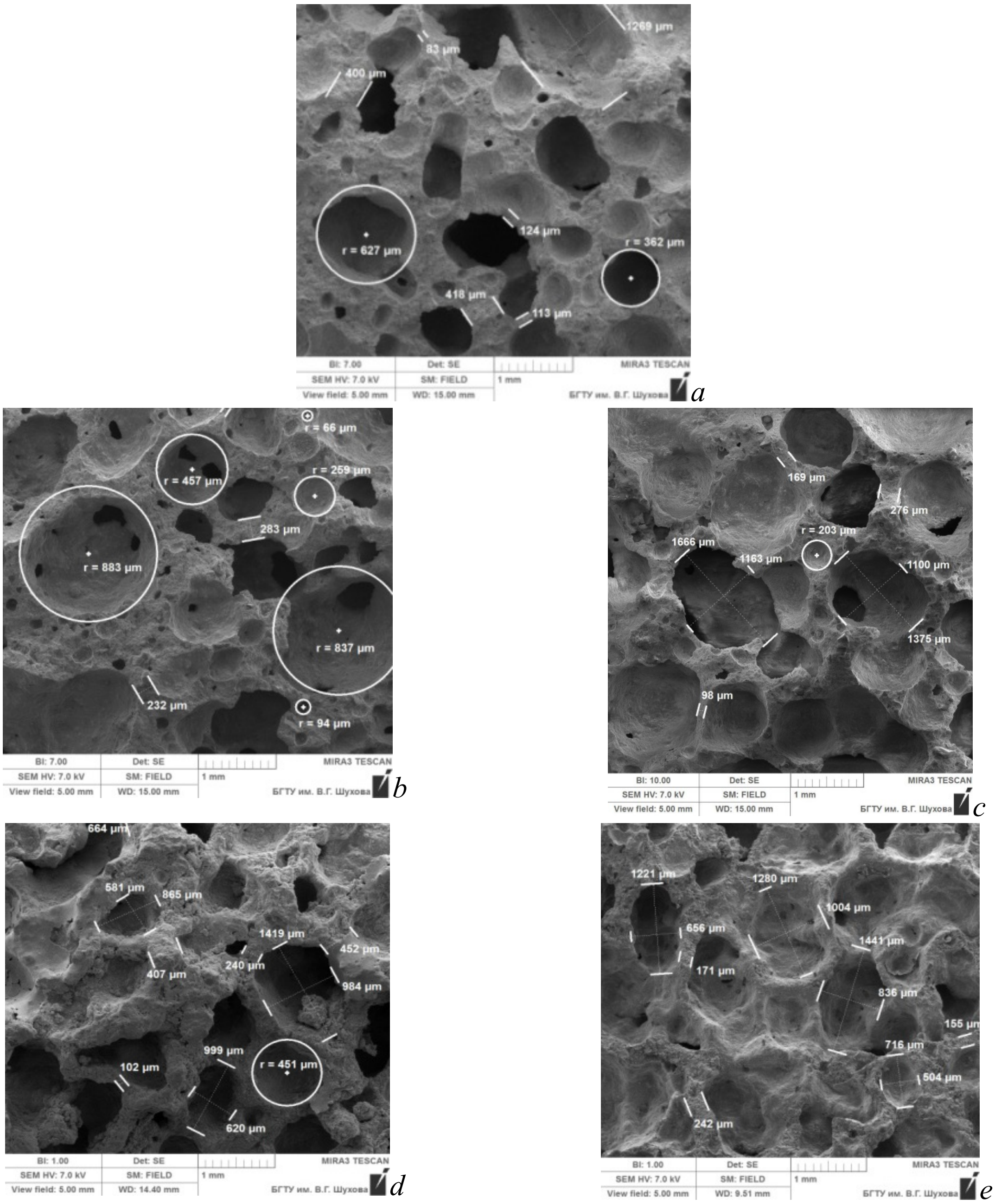

Fig. 2. Microstructural features of gas concrete depending on the composition:
a) control compound; *b)* with the use of silica clay MM (10 %);
c) with the use of silica clay MM (100 %); *d)* with the use of perlite MM (10 %);
e) with the use of perlite MM (100 %).

Summary

According to the performed research, it can be concluded that the mineral modifier from amorphized rocks, regardless of composition, acts as a structure-forming component, causing a reduction of porous processes with the formation of a system with an improved micro- and macrostructure, which provides material with the required physical and mechanical properties.

The introduction of an active mineral additive, regardless of its composition, leads to the improvement in the internal space of the composite in terms of enlarging pores and decreasing as a result of condensation of interpore partitions. At the same time, high strength indicators of autoclaved gas concrete samples with the addition of MM while reducing its density are explained by the optimization of the structure both at the macro and at the micro level.

All the above-mentioned aspects provide the production of cellular products with improved technical and operational characteristics with reduced material consumption of production.

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