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Additive for improving the quality of foam concrete made on the basis of micro silica and quicklime

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ABSTRACT

The article presents studies of the use of plasticizing additives in combination with fine aggregate (microsilica) and CaOH quicklime for the production of foam concrete. The research will determine the effect of plasticizing additives and active fillers on the properties of foam concrete during their production. The main issue in the production of foam concrete is the time of setting, as their increase leads to shrinkage of foam concrete mixture and as a consequence of the uneven structure of the material. Therefore, the use of plasticizer additives in the production of foam concrete is not recommended. Plasticizer, as a surface-active substance, increases the setting time of the cement binder. However, examining the features of micro silica in combination with caustic lime and plasticizer was found to reduce the time setting. Laboratory studies have shown that the use of these components will produce foam concrete with the projected density, with a uniformly distributed pore structure, high strength, and frost resistance. According to the results of the study, the influence of the number of additives components on the qualitative characteristics of foam concrete was determined, and the optimal composition of the components, plasticizer additives, micro silica, and caustic lime was selected.

Keywords: Concrete maturity, surface strength, shock-pulse method, operational control, sensor.

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Introduction

Construction refers to one of the important areas of industry, so the solution of the issues related to the creation of new or upgraded effective building materials becomes a fundamental factor in its development [1]. In this regard, the most important task is to develop new building materials with improved performance properties [2].

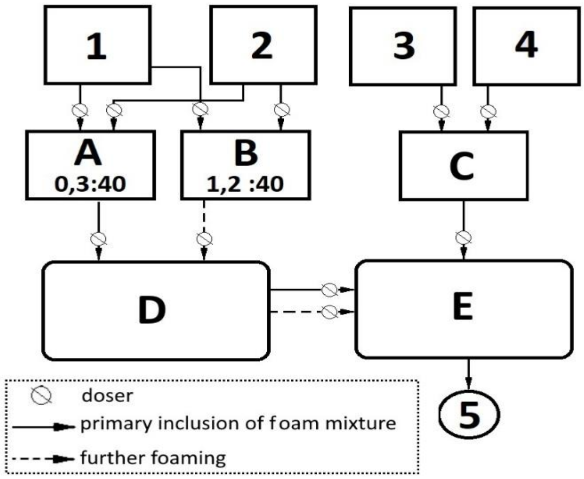
One of the directions for obtaining effective building materials is the use of additives modifiers, which significantly improve the properties of the material, allowing the expansion of the field of their application. The use of additives to improve the physical and mechanical properties of building materials is common practice in modern urban planning [3]. To develop modifier additives both quality raw materials and industrial wastes are used, which is also quite effective. Today, specialized concrete additives used both in industrial-scale production of concrete mixture and in the order of individual construction are in great demand in the market [4]. The use of additives modifiers in concrete is a standard measure, but their use in cellular concrete is not always justified, because with the receipt of certain qualitative characteristics are often lost other, not insignificant indicators. For example, the use of plasticizers and hydrophobic additives increases strength and reduces water absorption, but has a negative effect on increasing the setting time of the mortar, which leads to shrinkage and the development of uneven density [5].

When studying cellular concrete, they should be divided into two types foam concrete and aerated concrete. The main distinguishing characteristic of foam concrete and aerated concrete is the technology of obtaining the pore structure. Gas concrete is obtained through the use of gas-forming additives, such as aluminum powder and hydrogen peroxide technical [6]. In the process of chemical reaction, gas is released, which contributes to the swelling of the gas concrete solution, due to which a communicating pore structure of gas concrete is formed. The use of modifier additives increases the time of setting, which negatively affects the structure formation of aerated concrete mortar. Foamed by gas-forming additives solution should hold the structure until the end of the process of setting, otherwise, if the solution does not have time to set (as a consequence of this may serve plasticizers and hydrophobizing additives, containing in their composition surfactants), shrinkage of the material and violation of geometric parameters and structural characteristics occur [7]. Foam concrete is also a cellular concrete, the distinguishing feature from aerated concrete is the process of formation of the pore structure. To obtain the pore structure of foam concrete, a blowing agent is used, from which quality foam of the required multiplicity is obtained [8]. The foam is then injected into the mortar and swells it. The foamed mortar acquires a cellular structure with closed pores [9]. As with aerated concrete, the main problem is to increase the setting time, so the use of plasticizers and hydrophobic additives becomes impossible [10].

The research is aimed at the development of new additives that do not affect the time of setting, but on the contrary, contribute to their reduction. The research aims to determine the complex influence of plasticizing additives of micro silica and caustic lime on structural and qualitative characteristics of foam concrete made by the two-stage introduction of foam.

Experimental technique

An important condition was to maintain the same composition of components and ingredients (additives) of prototypes for each method, as well as their dimensionality. The technological process of specimen preparation by two-stage foam injection is shown in Figure 1.



1 - water; 2 - foam concentrate; 3 - cement; 4 - sand; 5 - finished product; A - the container for the low-concentrated solution of plasticizing additive of a foam concentrate in water 0,3:40 l, B - the container for a solution of the modified foam concentrate in water 1.2:40 l, C - the cement-sand mixer, D - the foam generator, E - the mortar mixer

Figure 1 – Technology of foam concrete preparation by the method of two-stage foam injection

The technological process consists of three stages. During production, a strict sequence of components must be followed (Figure 1):

Stage 1: in a container (A) the foam concentrate (1) is thoroughly mixed with water (2), in ratio to water - 0.3:40 l; in parallel (independently) in a container (B) the foam concentrate (1) is thoroughly mixed with water (2), in ratio to water - 1.2:40 l; in parallel in a container (C) the cement (3) is mixed with sand (4), in the ratio of cement to sand (1:3).

Stage 2: obtained in a container (A) mortar through the foam generator (C) is converted to foam and combined with cement and sand mixture from the container (D), in a mortar mixer (E).

Stage 3: The mortar obtained in a container (B) is converted to foam by means of the foam generator (C) and introduced into the mortar mixer (E).

Table 1 - Compositions of the compared samples

Type of sample	Cement, kg	Sand, kg	Foamer, l	Plasticizer C-3, kg	Quicklime, kg	Microsilica (MC), kg	Water, l
Type 1 Reference sample	300	300	1.5				150
Type 2	300	300	1.5	5			120
Type 3	267	267	1.5	5	6	60	99
Type 4	270	270	1.5	5		60	94
Type 5	300	300	1.5	5	6		99
Type 6	267	267	1.5		6	60	140

After careful mixing in a mortar mixer, the resulting mortar (5) is poured into forms.

To study the effect of the complex of additives on the qualitative characteristics of foam concrete there was taken as a control comparative sample - foam concrete grade D600 without using any additives. The composition of the compared samples is presented in Table 1.

To determine the qualitative indicators of foam, concrete the following laboratory tests and methods were used:

- Determining the density of the samples was performed according to the GOST 12730.1-78 "Concretes. Methods for determination of density.

- Determination of water absorption is performed according to the procedure of GOST 12730.378 "Concretes. Method for determination of water absorption.

- Determination of thermal conductivity and thermal resistance of the material was carried out according to the method of GOST 7076 "Method for determining the thermal conductivity and thermal resistance under steady-state thermal conditions". The measurements were carried out on the device ITP MG-4 on the principle of generation of heat flow stationary, passing through a flat sample and directed perpendicularly to the front faces of the sample.

- Determination of the strength of foam concrete is performed according to the method of GOST 10180-2012 "Concretes. Methods for Determining Strength by Reference Samples". Testing in compression was carried out on an automatic press CONTROLS (Pilot) 500 kN.

All tests were performed on cube-shaped specimens of 10x10x10 cm.

Results and Discussion

The density. The density study allowed us to objectively assess the uniformity of the pore structure of foam concrete. Figure 2 shows the results of the average values of the densities of the different parts of the foam concrete samples: the upper, middle, and lower parts.

According to the statistical data all partial values have a close relationship and high convergence within the control measurements: for type 1 the maximum quadratic deviation is 20.42 (lower segment) and the coefficient of variation is 3.42%; for type 2 the same values are - the maximum quadratic deviation (QD) is 25.72 (middle segment), the coefficient of variation (CV) is 4. 21%; for type 3, the QD is 14.11 (lower segment) and the CV is 2.32%; for type 4, the QD is 32.73 (upper segment) and the CV is 5.34%; for type 5, the QD is 20.31 (upper segment) and the CV is 3.33%; for type 6, the QD is 23.32 (middle segment) and the CV is 3.78%.

The results of the study showed that in all cases, the density in different areas has different values. The control sample showed an increase in density of the lower sample by 4.0% as opposed to the upper sample, indicating that during the setting process, part of the pore structure breaks down and settles, thereby compacting the structure of the lower layer of the material. The sample with plasticizer has the highest difference in density: the lower sample showed an increase in density of 4.6% compared to the upper sample. The samples where a complex combination of plasticizer, caustic lime, and micro-silica was used in the mixture showed a relatively equal density of the lower and upper sections.

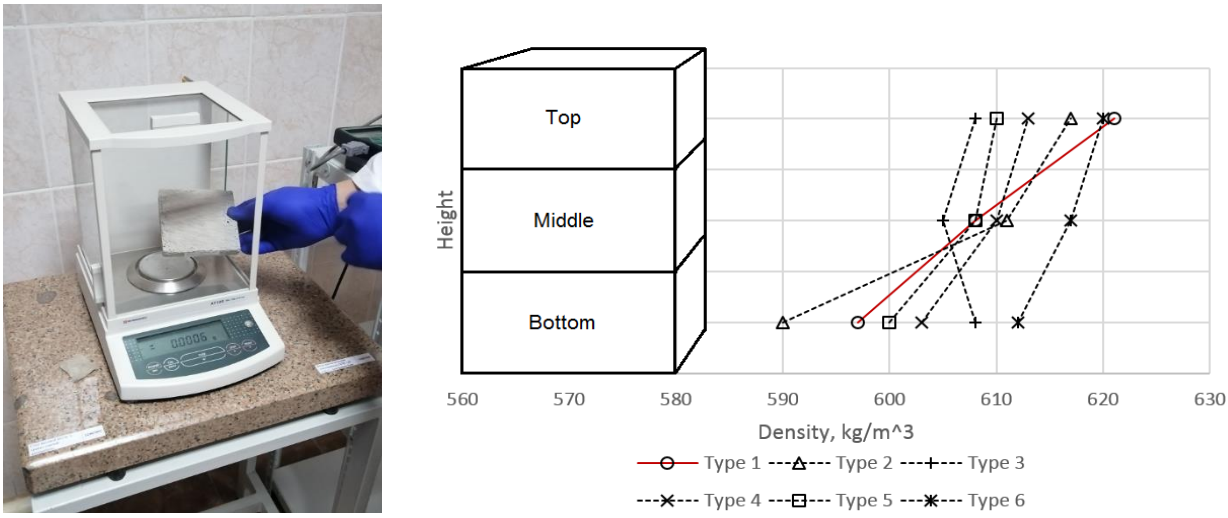


Figure 2 – Results of determining the density of foam block

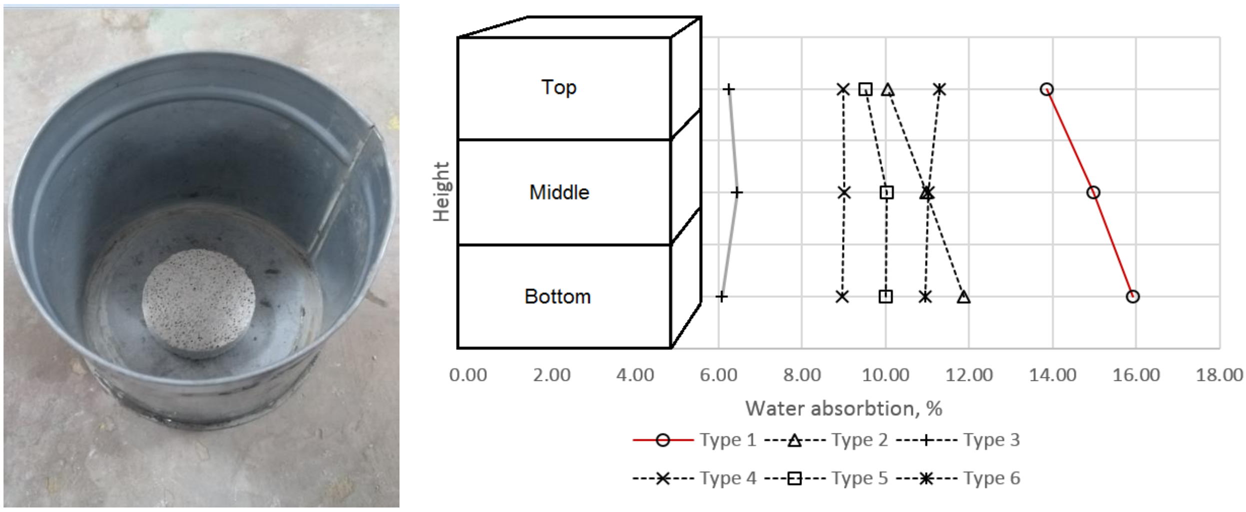


Figure 3 – Results of water absorption measurements

The water absorption. Water absorption of foam concrete was carried out by measuring the density, the results of the study are presented in Figure 3. Assessment of water absorption was also determined for different sections of the samples.

The obtained private values have from the average then a close relationship: for type 1 the maximum quadratic deviation is 1.60 (middle segment), and the coefficient of variation is 10.7%; for type 2 the same values are - the maximum QD is 0.52 (upper segment), the CV is 5.2%; for type 3 - QD is 0. 24 (lower segment), the CV is 3.9%; for type 4 - QD is 0.19 (lower segment), the CV is 3.2%; for type 5 - QD is 0.37 (middle segment), the coefficient of variation is 3.7%; for type 6 - QD is 0.52 (middle segment), the CV is 4.7%.

According to the studies, high (less favorable) rates of water absorption were shown by the control samples of the traditional composition, without the use of additives.

According to the results of the control sample, we see a difference in water absorption between the upper and lower samples, which is 12%. In general, a certain pattern of changes in water absorption capacity according to the height of the sample was not revealed. Nevertheless, there is an obvious effect of plasticizers on the reduction of water absorption (by 21.4% of the control sample), due to the reduction of micropores in the walls of the cells. Samples with the addition of plasticizer, hydrated lime, and micro-silica showed the lowest water absorption, with an average of 6.3%. This figure is a high-quality result for foamed concretes, which is obtained by reducing the time of setting and reducing the formation of micropores in the walls of the cells. In samples of types 3,4,5, the most uniform distribution of water absorption over the

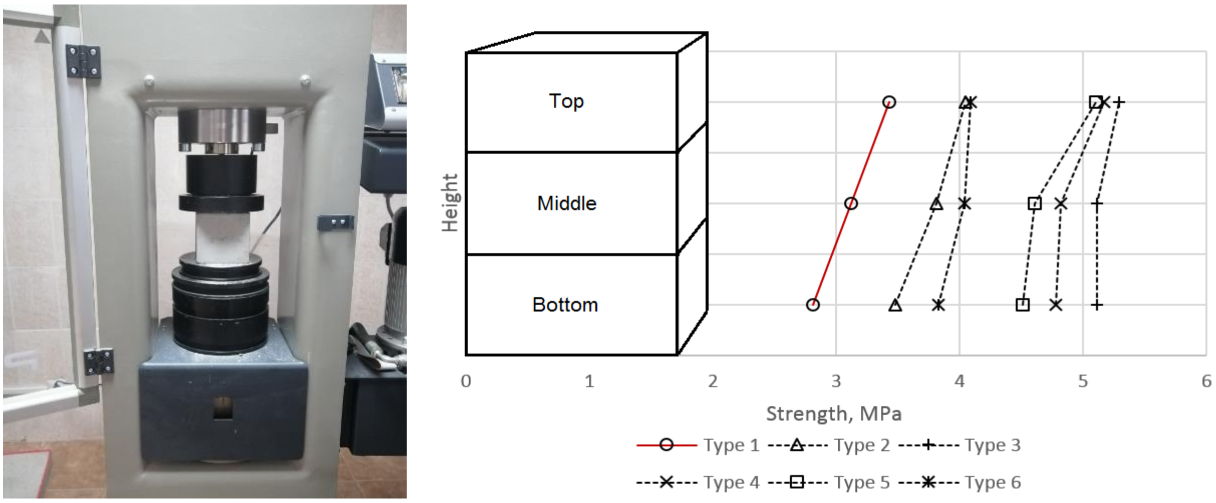


Figure 4 - Results of strength measurements

height of the sample is observed, which together with the results of densities indirectly indicates a relatively uniform porous structure.

The strength. The strength studies were also carried out on samples obtained from different sections of the foam concrete material (foam block). The results are presented in Figure 4.

The partial values obtained have a high degree of convergence: for type 1 the maximum QD is 0.107 (upper segment) and the CV is 3.42%; for type 2 the same values are - the maximum QD is 0.15 (lower segment), the CV is 4.21%; for type 3 the QD is 0. 12 (middle segment), the CV is 2.32%; for type 4 - QD 0.25 (middle segment), the CV is 5.34%; for type 5 - QD 0.17 (middle segment), the CV is 3.33%; for type 6 - QD 0.15 (middle segment), the CV is 3.78%.

The difference in the strength of the upper and lower sections of the foam concrete made by the traditional composition without the use of additives was high 22.1 %, and the coefficient of variation by height is 10%. The obtained result indicates the uneven distribution of strength characteristics along with the height of the sample. The difference between the same indices of samples with additives is from 3.5 to 16.4%, and the coefficient of variation by height is from 1.7 to 7.6%. Thus the use of additives gives a positive effect in increasing the strength characteristics of foam concrete.

Thermal conductivity. The results of the thermal conductivity study are presented in Table 2.

All partial values of all compared sample types have a very close relationship and convergence: the maximum coefficient of variation ranges from 1.18 to 2.08%, and quadratic deviations do not exceed 0.005.

According to the results of thermal conductivity of control samples, it is possible to see the difference in the values of the upper sample and the lower sample, which in percentage ratio is 13.4 %. The large variation in values within a single test sample indicates the conditional reliability of the thermal conductivity indicators, which must be taken into account in the design. Thermal conductivity of

Table 2 - The results of the thermal conductivity

Sample	**Thermal conductivity coefficient λ_0 W/m ×°C**		
	Top samples	***Middle samples***	***Bottom samples***
Type 1 Reference sample	0.15	0.17	0.17
Type 2	0.16	0.17	0.17
Type 3	0.16	0.16	0.16
Type 4	0.15	0.16	0.16
Type 5	0.17	0.17	0.17
Type 6	0.15	0.15	0.16

sample Type 3, where all complex additives was used showed the maximum quality result, thermal conductivity in all areas (both upper and lower) was the same value of 0.16 W/m × °C. The same uniform thermal conductivity in all sections is shown by the sample of Type 4 - 0.17 W/m × °C. Samples of Types 1, 3, and 5, showed practically the same result, which was a difference in values of 6.1-6.7%.

Conclusions

Presented composition of the additive intended for the production of foam concrete, which includes the following components: plasticizing additives in combination with fine filler (microsilica) and hydrated lime CaOH. The relative uniformity of the composition was confirmed by the results of the assessment of the density of the material, measured at different heights of the samples (top, middle, and bottom). The maximum density difference by height observed in specimens of type 2, was 4.5%, and the minimum in specimens of type 3 with the full complexity of the components of the proposed additive, was 0.5%. The most unfavorable rates of water absorption corresponding to the samples of traditional composition, the difference of data on the height of the samples, on average, was 12%. In general, for the samples with the use of plasticizers, there is an obvious decrease in water absorption up to 21.4 %. The results of comparisons of strength characteristics of samples showed minimum values for samples of traditional composition, and maximum for samples with the use of the additive. The maximum difference in strength by height was revealed in the samples of traditional composition, amounting to 22.1%. The samples with additives showed varying degrees, but a naturally smaller scatter, ranging from 3.5 to 16.4%. The results of thermal conductivity also showed less stability of the samples of traditional composition, the difference of private values on the height of which was 13.4%. Samples using the entire set of additives showed the most stable result, and samples with partial use of components showed high convergence with a scatter of data from 6.1 to 6.7% in height.

Conflict of interest. On behalf of all the authors, the correspondent author states that there is no conflict of interest.

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Көбік бетонының сапасын жақсартуға арналған микрокремнезем және сөндірілген әк негізінде жасалатын қоспа

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Қабылданды: *28 сәуір 2022*

ТҮЙІНДЕМЕ
Мақалада көбік бетонын өндіру үшін жұқа дисперсті толтырғышпен (микрокремнезем) және $Ca(OH)_2$ әкімен біріктірілген пластификациялық қоспаларды қолдану туралы зерттеулер келтірілген. Зерттеулер пластиктендіретін қоспалар мен белсенді толтырғыштардың көбік бетонының қасиеттеріне әсерін оларды өндіру процесінде анықтауға мүмкіндік береді. Көбік бетон өндірісіндегі негізгі мәселе – орнату уақыты, өйткені олардң артуы көбік бетон қоспасының шөгуіне әкеледі, соның әсерінен материалдың құрылымы біркелкі болмайды. Сондықтан көбік бетон өндірісінде пластиктендіретін қоспаларды қолдану ұсынылмайды. Пластификатор, беттік белсенді зат бола отырып, цемент байланыстырғышын орнату уақытын арттырады. Алайда, сөндірілген әк және пластификатормен бірге микрокремнеземнің ерекшеліктерін зерттей отырып, орнату уақытын қысқартуға мүмкіндік беретін ерекшелік табылды. Зертханалық зерттеулер көрсеткендей, бұл компоненттерді

қолдану біркелкі бөлінген құрылымы, жоғары беріктігі және аязға төзімділігі бар көбік бетонын алуға мүмкіндік береді. Зерттеу нәтижелері бойынша қоспалар компоненттері санының көбік бетонының сапалық сипаттамаларына әсері анықталды, компоненттердің оңтайлы құрамы, пластификатор, микрокремнезем және гидратталған әк қоспалары таңдалды.

Түйін сөздер: пенобетон, екі сатылы көбік енгізу, микрокремнезем, пластификатор, беріктік, аязға төзімділік.

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Добавка для улучшения качества пенобетона, изготавливаемая на основе микрокремнезема и гашеной извести

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АННОТАЦИЯ

В статье приведены исследования применения пластифицирующих добавок в комплексе с тонкодисперсным наполнителем (микрокремнеземом) и гашенной известью CaOH для производства пенобетона. Исследования позволят определить влияние пластифицирующих добавок и активных наполнителей на свойства пенобетона в процессе их производства. Основным вопросом при производстве пенобетона являются сроки схватывания, так как их увеличение приводит к усадке пенобетонной смеси и как следствие неравномерности структуры материала. Поэтому применение пластифицирующих добавок в производстве пенобетона не рекомендуется. Пластификатор, являясь поверхностно активным веществом, увеличивает сроки схватывания цементного вяжущего. Однако исследовав особенности микрокремнезема в комплексе с гашенной известью и пластификатором была обнаружена особенность, позволяющая сократить сроки схватывания. Лабораторные исследования показали, что применение данных компонентов позволят получить пенобетон с проектируемой плотностью, с равномерно распределенной поровой структурой, высокой прочностью, и морозостойкостью. По результатам исследования, определено влияние количества компонентов добавок на качественные характеристики пенобетона, выбран оптимальный состав компонентов, добавки пластификатора, микрокремнезема и гашенной извести.

Ключевые слова: пенобетон, двухстадийное введение пены, микрокремнезем, пластификатор, прочность, морозостойкость.

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