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Effect of soapstock in the composition of modified additive for improving strength characteristics of concrete structures

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ABSTRACT
The article presents the results of research on the influence of soapstock used in the composition of two-component modified additive. Standard tests of beam samples for flexural and compressive strength, and standard cubic samples for water absorption and frost resistance were performed. Tests were performed for samples with different contents of soapstock (Sp): 5, 7.5, 10 and 12.5 % by weight of cement, microsilica and phosphogypsum. The strength measurements of the beam samples showed that the maximum effect concerning the increase in material strength was achieved at 5% of the soapstock content. However, it should be noted that the subsequent decrease in strength with increasing concentration of soapstock is not significant, up to Sp=10% does not exceed 1%. Thus, the optimal concentration of soapstock, at which the maximum effect on the strength of the material will be achieved, is 5-10%. The obtained curve of dependence of water absorption change on the soapstock concentration showed the optimal gradient of water absorption, which corresponds to Sp=10%. With further increase of soapstock, the decrease of water absorption index is not significant. Tests on frost resistance showed that the maximum resistance to cyclic freezing is observed in samples with Sp=10%, further increase reduces frost resistance. The regularity in the increase of frost resistance with increasing concentration of soapstock is logical because with each increase in concentration, the hydrophobization of the material increases. However, if the hydrophobicity of samples with Sp=12.5%, although not significantly, still increases about Sp=10%, the frost resistance decreases.

Keywords: foam concrete, two-component modified additive, technological scheme, soapstock, strength properties, water absorption, frost resistance.

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Introduction

The application of new materials and technologies in production is a key factor in the development of the construction industry, bringing innovation and rethinking the way materials are created and used. Special attention is paid to concrete construction, where innovative approaches contribute to the formation of more efficient, durable and sustainable structures. The production of construction materials plays an important role in the economy, providing raw materials for the industry and significantly influencing the overall output. New materials and production methods are being actively researched in this area, including the development of more environmentally friendly processes. One example of such innovation is the recycling of anthropogenic waste into construction composites, which helps to reduce environmental impact and increase the sustainability of building materials [[1], [2], [3], [4]].

In modern construction, guaranteeing the strength and durability of materials is an integral part of creating reliable and sustainable structures. In this context, foam concrete occupies a special place among a variety of building materials used in various industries. Due to its lightness, excellent thermal insulation properties and high degree of resistance to destruction, foam concrete is widely used for the construction of various building structures and products. However, despite its many advantages, there is considerable potential for further improvement of the properties and characteristics of this material through the use of various additives and innovative technologies [[5], [6], [7]].

Cellular materials such as foamed concrete play a key role in modern construction due to their high thermal insulation and applicability in building construction. It not only contributes to environmental improvement, but also saves resources as improved thermal insulation helps to reduce the consumption of fuel, energy and natural materials. However, the foam concrete production process faces the problem of the short life of the foam. Various stabilization methods are used to increase the durability of foam concrete, among which modified additives are particularly promising. These additives help to increase the stability of the foam and extend its service life [[8], [9], [10], [11]].

A wide range of modified additives and their application methods provide an opportunity to optimize foam strengthening, which ultimately leads to improved quality and reliability of foam concrete structures. Rapid development in this area of research pushes the construction industry towards innovative solutions that contribute not only to reducing the negative environmental impact but also to improving energy efficiency, which is an important aspect in today's environmentally oriented construction practice [[12], [13]].

A large part of the transformation of concrete as an important building material is determined by the use of various additives that can improve its physical and mechanical properties [[14], [15]]. These additives can be carefully selected according to the specific needs and technological application of concrete. For example, some additives are aimed at increasing the setting or curing rate of concrete, while others are designed to increase its strength, reduce water absorption, improve frost resistance and provide other desired characteristics [[16], [17], [18], [19]]. The use of properly selected additives plays a key role in creating concrete structures that meet high requirements for strength, durability and resistance. The results obtained correlate well with similar studies conducted in the field of foam concrete [[20], [21], [22], [23]]. In these works, comprehensive studies of the physical and mechanical properties of foam concrete were carried out, including comparative analysis of different variants of compositions. These studies not only confirm the obtained results, but also provide valuable data on the technical characteristics of foam concrete under different conditions and with different compositions.

This article details the process of development and application of a modified additive, which has a plasticizing effect to significantly improve the characteristics and functionality of foam concrete as a building material. The additive is developed taking into account the peculiarities and requirements of foam concrete production, which allows to achieve a higher level of quality and efficiency of its application.

In the composition of the additive it is supposed to use industrial wastes, exactly the following components: microsilica (Ms further), phosphogypsum (PhG further) soapstock (Sp further), post-alcohol bard (PaB further), as well as caustic soda.

Microsilica - waste from metallurgical production, delivered from TNK Kazchrome JSC. The chemical composition is as follows: SiO_2: 90-92%; Al_2O_3: 0.6-0.8%; Fe_2O_3: 0.4-0.7%; CaO: 0.4-0.9%; MgO: 0.8-1.0%; Na_2O: 0.6-0.8%; K_2O: 1.2-1.4%; C: 0.9-1.2%; S: 0.2-0.3%. To increase the strength properties of concrete, microsilica, which is a finely dispersed medium of active minerals, is introduced into its composition.

Post-alcohol bard - waste from alcohol production, delivered from Aydabul distillery JSC. PaB has the following composition: crude protein - 2.0%, non-fatty substances - 3.0%, fat - 0.5%, cellulose - 0.5%. For its better mixing and plasticization, post-alcohol bard, which is essentially a surface active additive, is introduced into the composition.

Phosphogypsum - waste from phosphoric acid production, delivered from Kazphosphate LLP. The composition includes: - calcium sulfate dihydrate ($CaSO_4*2H_2O$) not less than 70 %; - water-soluble phosphates not more than 0.3 %; - fluoride compounds (in terms of fluorine) not more than 0.25 %; - water (H_2O) not more than 26 %. For mineralogical balance, phosphogypsum is introduced into the concrete mix as a result of the addition of microsilica, which includes up to 95% silicon oxide.

Soapstock - waste from refined oil production, delivered from Altec Ltd. The use of soapstock in the composition of concrete contributes to its volumetric hydrophobization due to the fact that it is represented by a fatty acid composition.

Caustic soda (NaOH) – stabilizer, delivered from Kaustik JSC. The additive also contains a small amount of caustic soda, which is necessary for leaching of soapstock and slowing down the process of its oxidation.

The result is a hydrophobic concrete with increased strength. The main purpose of this additive is to improve the hydrophilicity of the cement, which promotes more efficient moisture penetration and reduces the need for water to mix the foam concrete mass. This will lead to a more homogeneous structure of the foam concrete, which is an important factor in its quality and strength. In addition, the additive will help reduce the number of micropores in the cell walls of the foam concrete, which will provide a better porous structure for the material, improving its properties.

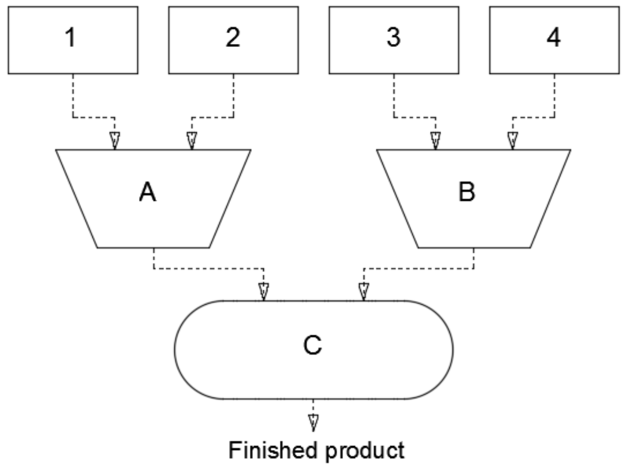
The study aims to evaluate the effect of each of the above-mentioned component of the additive. However, this paper will present the results of the third stage of the study, namely the effect of soapstock on the transformation processes of concrete, exactly on its strength, water absorption and frost resistance. Cement-sand mixture with 20% inclusion of microsilica and 15% content of phosphogypsum by weight of cement was presented as a reference sample. The technological composition of the reference sample was obtained from the results of the first and second stages of the study, the effect of microsilica and phosphogypsum on the quality of concrete.

Experimental technique

The proposed additive is a composite mixture of industrial waste consisting of a liquid and a solid phase. The solid phase (component 1, K1), in turn, is represented by a dry mixture of microsilica, phosphogypsum and neutralized soapstock, and the liquid phase (component 2, K2) - by post-alcohol bard.

To increase the strength properties of concrete, microsilica, which is a finely dispersed medium of active minerals, is introduced into its composition. For its better mixing and plasticization, post-alcoholic bard, which is essentially a surface active additive, is introduced into the composition. For mineralogical balance, phosphogypsum is introduced into the concrete mix as a result of the addition of microsilica, which includes up to 95% silicon oxide. The use of soapstock in the composition of concrete contributes to its volumetric hydrophobization due to the fact that it is represented by a fatty acid composition. The additive also contains a small amount of caustic soda, which is necessary for leaching of soapstock and slowing down the process of its oxidation. Ultimately, we obtain hydrophobic concrete with increased strength.

Figure 1 shows the technological scheme of production of the modified additive. The technological process of production includes two subsequent stages of production. At the first stage preparation of the dry component of the additive is carried out in the process of grinding, drying and mixing of microsilica and phosphogypsum. Grinding of components is necessary to obtain a homogeneous fine-dispersed medium, to obtain their maximum activity in the process of hydration of concrete. Drying is necessary for the qualitative selection of components by weight and exclusion of unaccounted water in the composition of the additive. In the second stage, the liquid component of the additive is prepared, exactly mixing of soapstock with post-alcohol bard and their subsequent neutralization by acidity.



1 – Microsilica
2 – Phosphogypsum
3 – Soapstock and caustic soda
4 – Post-alcohol bard
A, B – Mixer
C – Rotary Dispergator

Stage 1: (preparation of dry component): mixing of microsilica with phosphogypsum in mixer A.
Stage 2: (preparation of the liquid component): mixing in mixer B of soapstock, caustic soda and post-alcohol bard.

Figure 1 - Technological stage of additive production

Table 1 - Variable compositions of mixtures

Stages	Content of components by weight, g							
	Sand	Cement	Ms	PhG	Sp	NaOH	PaB	Water
Reference	1500	500	0	-	-	-	-	200
Stage 1	1500	450	50	-	-	-	-	200
	1500	425	75	-	-	-	-	200
	1500	400	100	-	-	-	-	200
	1500	375	125	-	-	-	-	200
Stage 2	1500	450		50	-	-	-	200
	1500	425		75	-	-	-	200
	1500	400		100	-	-	-	200
	1500	375		125	-	-	-	200
Stage 3	1500	475.0			24.750	0.250	-	200
	1500	462.5			37.125	0.375	-	200
	1500	450.0			49.500	0.500	-	200
	1500	437.5			61.875	0.625	-	200
Stage 4	1500	500					5	195
	1500	500					10	190
	1500	500					15	185
	1500	500					20	180

Table 2 – Variable compositions of the studied mixtures

Sample	Content of components by weight, g							
	Sand	Cement	Ms	PhG	Sp	NaOH	PaB	Water
Reference	1500	340	85	75	-	-	-	200
Sp=5%	1500	323	81	71	25	0.25	-	200
Sp=7.5%	1500	315	79	69	37	0.38	-	200
Sp=10%	1500	306	77	68	50	0.50	-	200
Sp=12.5%	1500	298	74	66	62	0.63	-	200

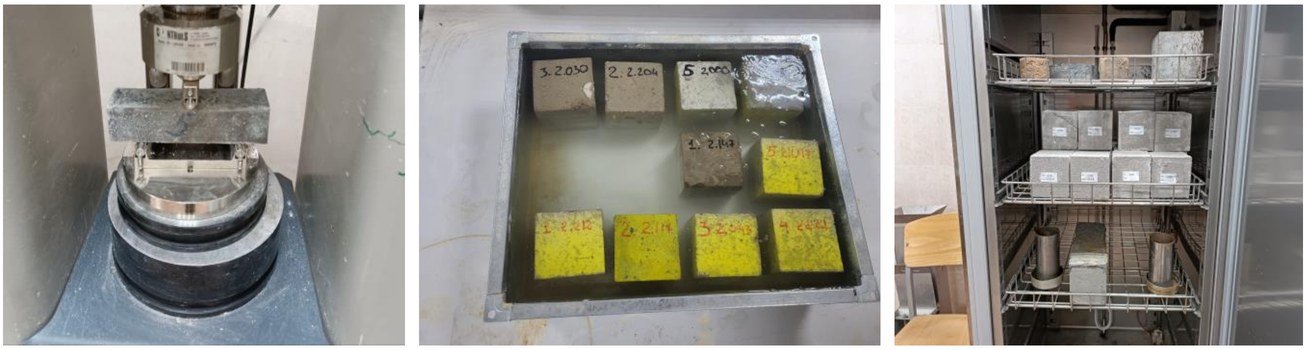


Figure 2 - Conducting laboratory tests

Table 1 shows the variation compositions of the mixtures of each stage of the study. Table 2 shows the variation compositions of the mixtures of the third stage of the study, exactly the compositions with different contents of soapstock (hereinafter - Sp).

The ratio of microsilica to cement is 10, 15, 20 and 25% by weight. The ratio of phosphogypsum to microsilica to cement is 10, 15, 20 and 25% by weight. The ratio of soapstock to caustic soda with respect to microsilica with phosphogypsum and cement is 5.0, 7.5, 10.0, and 12.5% by weight. The ratio of post-alcohol bard to water is 2.5, 5.0, 7.5, and 10% by weight. Variable substitution of soapstock with caustic soda (for stabilization) from 5.0 to 12.5 % (2.5 % multiplicity) by weight of cement, microsilica and phosphogypsum. The ratio of the latter is fixed, is 20 % of microsilica by weight of cement and 15 % of phosphogypsum by weight of microsilica with cement (according to previously conducted studies).

Evaluation of strength parameters of samples in compression and bending of sample beams was carried out according to the standard method of GOST 30744-2001 [24] (Figure 2). Comparison of strength of samples of variable composition was performed to evaluate the optimal composition of the modified additive and to assess its performance. Comparison of strength values of samples with and without the additive will allow to evaluate the influence of the additive components on concrete modification and its transformation in terms of strength improvement. Evaluation of the samples for water absorption capacity of the compared concrete samples was performed according to GOST 12730.3-2020 [25] (Figure 2). Comparison of water absorption of concrete will allow to give an assessment of the serviceability of concrete with the use of modified additive, primarily related to the service life of the material. The hydrophobicity of the material will characterize its resistance to the damaging effects of water during service life, as well as its improvement in frost resistance (taking into account the mechanics of frost resistance testing). Evaluation of samples for frost resistance of concrete samples was carried out according to GOST 10060-2012 [26] (Figure 2). Comparison of frost resistance indices of variation types of concrete is also related to the assessment of the serviceability of the material, evaluation of its durability. The sequence of cyclic freezing and thawing of the samples was performed under the condition of reducing the number of cycles, i.e. as the cycles increase, the terms of control measurements were reduced (from 50 to 25 cycles). Control measurements of strength and mass were performed: at 50, 100, 150, 175, 175, 200, 225 and 250 cycles.

Results and Discussion

Figure 3 shows the results of strength measurements at 28 days of the bar samples. Figure 3A shows the results of partial and average strength values at different concentrations of soapstock, and Figure 3B shows the statistical values of coefficients of variation and comparison as a percentage of reference sample.

According to the measurement results (Figure 3A), the partial strength values of reference samples range from 55.56 to 58.39MPa, the average is 56.53MPa. The partial strength values of samples with Sp=5% content range from 55.65 to 58.19MPa, the average is 56.91MPa. For samples with Sp=7.5% content, the strength ranges from 55.28 to 59.11MPa, with an average of 56.88MPa. The same values for samples with Sp=10% content range from 54.79 to 57.35PMa, with an average of 56.37MPa. In samples with Sp=12.5% content, the strength from 51.63 to 56.49PMa, with an average of 56.61MPa. The samples with soaptock content of 5, 7.5 and 10% have similar strength values to the reference sample, according to the curves of Figure 1B, the difference being 0.69, 0.61 and -0.30%, respectively. The samples with 12.5% soapstock content have strength values different from the reference sample, the difference is -5.45%. The latter indicates the negative influence of soapstock at its high content in the concrete mixture. Further strength reduction from increasing the amount of soapstock and caustic soda $Na(OH)_2$ leads to an increase in the composition of alkali and fatty acids, which after the release of fatty acids reduce the activity of the cement hydration process, and alkali subsequently interacting with portlandites increase the process of internal corrosion of concrete. The evaluation of the coefficients of variation suggests that the high concentration of soapstock reduces the stability of concrete structures, as evidenced by the increase in the variation of these partial strength values. Thus, the influence of soapstock on the strength of concrete was not revealed, moreover, its high concentration negatively affects the strength of concrete.

To obtain the most accurate statistical value of reference sample strength, 21 partial values of cubic (not beam samples) strength (cumulative from the entire set of tests) were used. The large number of samples allowed to determine as accurately as possible the mathematical expectation of strength values, relative to which the loss of strength will be made. The latter becomes permissible because the influence of soapstock on strength increase is not observed, and the strength reduction at a high concentration of soapstock (more than 10%), in the context of frost resistance tests, does not affect the analysis of the results. Figure 4 shows the distributions of the partial strength values concerning the Gaussian diagram constructed from the results of the obtained partial strength values. For the convenience of comparing the data with the private values (auxiliary axis on the diagram), the probability density was corrected relative to unity. This correction does not change the quality of the curve but calibrates the scale of the Gaussian diagram to the private strength values. For information, the partial strength values are shown in the diagram of Figure 4 on the right: for ease of perception, all partial strength values have been sorted from smaller to larger.

The average strength of the 21 measurements was 66.38 MPa, the squared deviation was 0.97 and the coefficient of variation was 1.45%. The coefficient of variation, with a large number of tests, allows subsequent adjustments to be made for strength losses. Given a coefficient of variation of 1.45%, strength losses up to ±1.45% can be attributed to statistical error. Therefore, loss of strength was assumed to be effective when the values of the percentage of strength change (loss of strength) exceeded the values of the coefficient of variation reference sample.

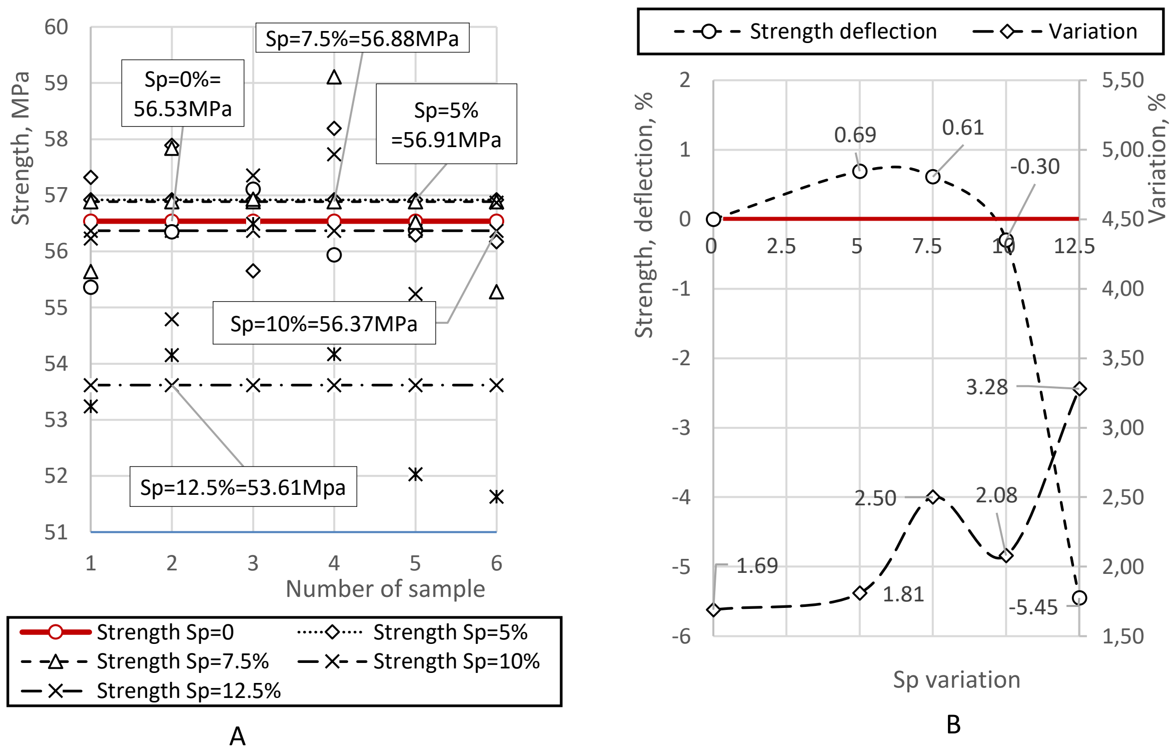


Figure 3 - Strength graphs of samples at 28 days of age

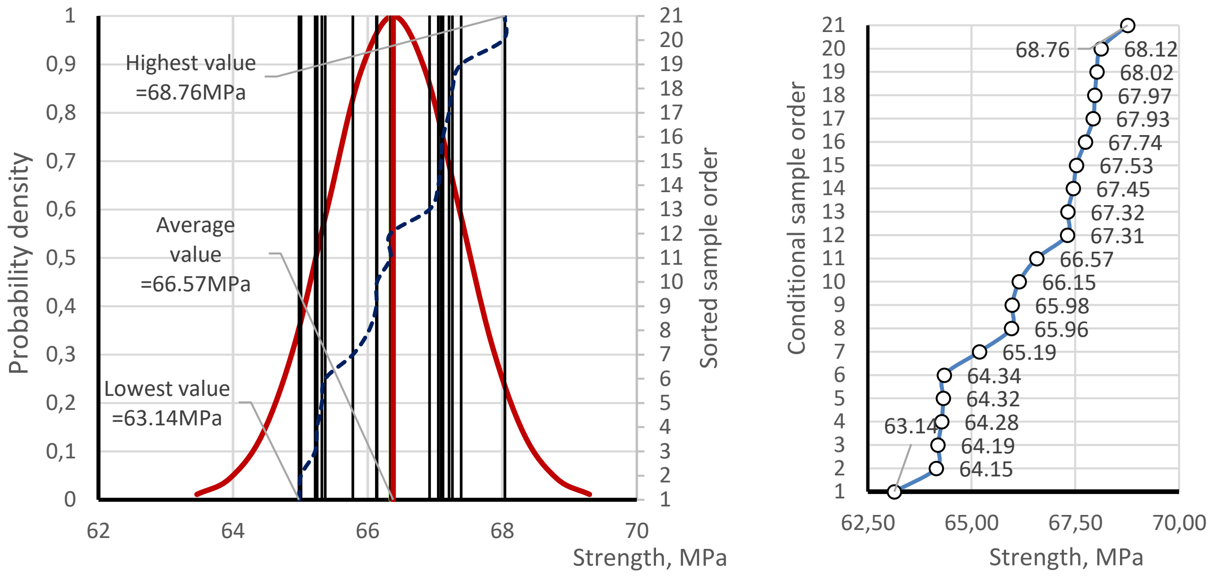


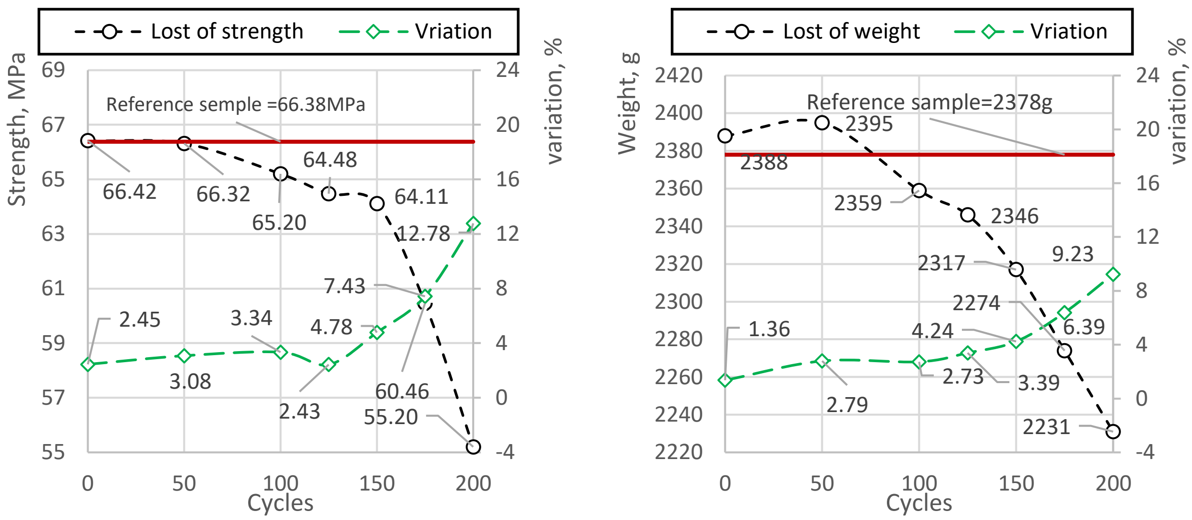
Figure 4 - Distribution of individual strength values

Figures 5-9 show plots of strength loss and mass loss as a result of cyclic freezing and thawing of cubic samples with variation inclusion of soapstock (Sp). Figure 5-9A shows absolute partial values of strength loss, and Figure 5-9B shows mass loss and their corresponding coefficients of variation.

The variation of strength sample from freezing cycles from 50 to 200 varies from 62.32 to 55.20 MPa. The maximum strength reduction corresponds to the maximum number of cycles, and the appreciable strength reduction occurs from 100 cycles. Thus, coefficients of variation increase with increasing number of cycles, varying in the range of 2.45-12.78%. The variation in strength values of samples with a minimum percentage of Sp=5.0% varies from 65.38 to 60.44 MPa, and a decrease in strength is also observed from 100 cycles. The coefficients of variation have a similar pattern as the reference samples, ranging from 3.03 to 8.75%. The variation of strength values of samples with Sp=7.5% varies from 66.45 to 62.17 MPa, while the strength reduction already occurs from 125 cycles, and the increment of variation coefficients is from 1.53 to 6.82%. In samples with a percentage of Sp=10.0%, a noticeable decrease in strength values occurs from 150 cycles, with a variation of strength values from 66.12 to 62.94%, and the coefficient of variation from 3.41 to 5.69. In samples with a maximum percentage of Sp=12.5%, the decrease in strength values occurs from 125 cycles, with variation in strength values from 63.33 to 58.13%, and coefficients of variation from 2.31 to 7.83%. However, the samples with maximum Sp content show an overall strength reduction relative to the reference sample, on average by 4.8%, indicating the negative effect of Sp on the strength performance of concrete, at their high concentration.

The mass reduction curves of the samples are generally similar to the strength curves. The reduction of reference samples varies from 2388 to 2231 grams, with an initial decrease in mass observed at 100 cycles. Similarly, as with strength, an increase in the coefficients of variation (for all Sp variations) from 1.36 to 9.23% is observed with an increasing number of cycles. For samples with Sp=5.0%, the variation in loss ranges from 2366 to 2264 grams, the initial decrease is also at 100 cycles, and the coefficients of variation increase from 1.36 to 7.12%. The samples with Sp=7.5% showed a loss in mass from 2375 to 2268 grams, but appreciable loss was observed at 125 cycles, and the coefficients of variation increased from 1.36 to 6.42%. For samples with Sp=10.0%, mass loss starts from 150 cycles, ranges from 2362 to 2309 grams, and coefficients of variation vary from 1.36 to 4.54%. The samples with maximum content with Sp=12.5 have losses ranging from 2397 to 2296 grams, with coefficients of variation varying from 1.36 to 6.39%. The onset of mass loss is observed at both 50 and 125 cycles, with mass loss at 100 cycles being negligible, quantitatively close to reference samples. The instability of the results indicates the negative effect of Sp in high concentration on the quality of concrete.

Analysis of the coefficients of variation in both cases indicates a decrease in the stability of the strength (and mass) results with increasing freezing cycles, but their quantitative index depends on the quantitative change in strength (and mass) relative to the initial one (corresponding to 0 cycles). The latter is confirmed by the lowest values of the coefficients of variation in samples with Sp=10.0%, which exhibit the least loss of strength. Quantitatively, the coefficient of variation of strength in samples with Sp=10.0% is 2.24 times less than in reference samples, and in relation to other variations of Sp, in 1.11-1.53 times. The coefficient of variation of masses in samples with Sp=10.0% is 2.14 times less than in reference sample, and in relation to other variations of Sp, in 1.17-1.67 times.



A B

Figure 5 - Strength and mass loss at Sp=0%

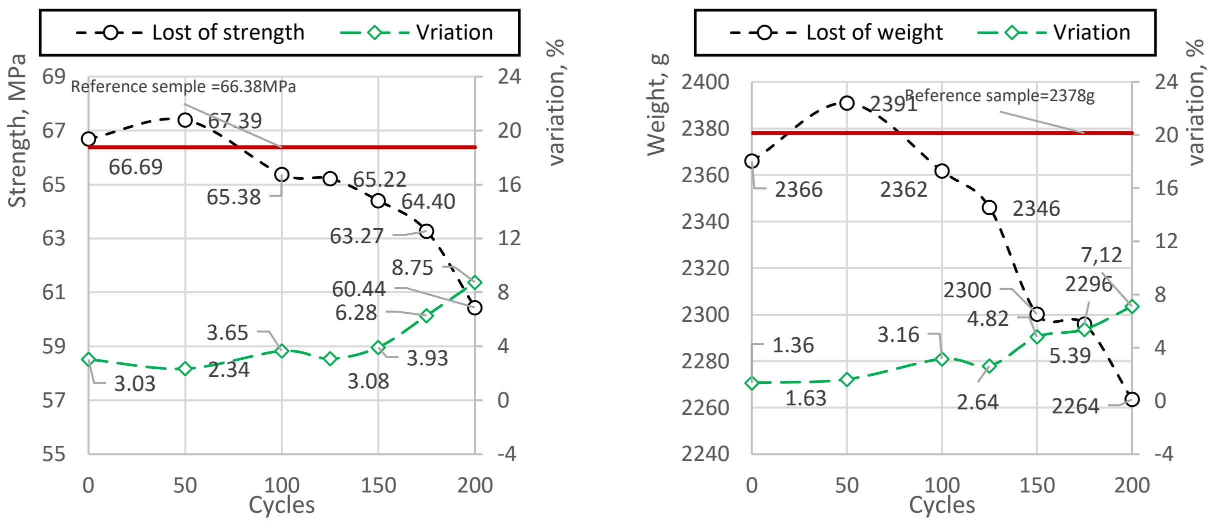


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Figure 6 - Strength and mass loss at Sp=5.0%

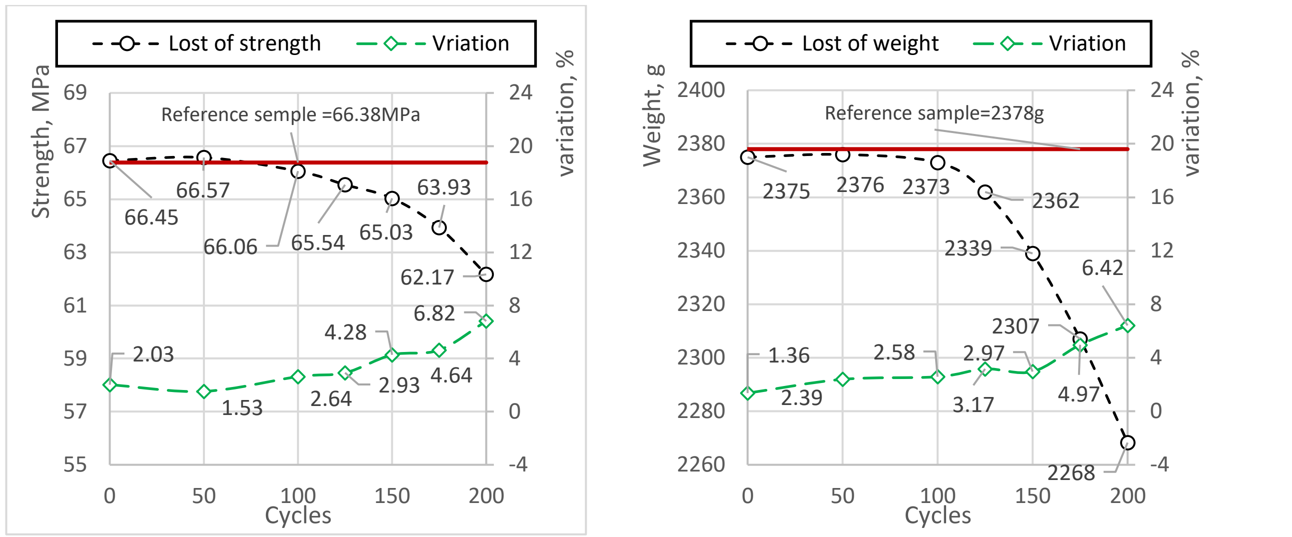

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Figure 7 - Strength and mass loss at Sp=7.5%

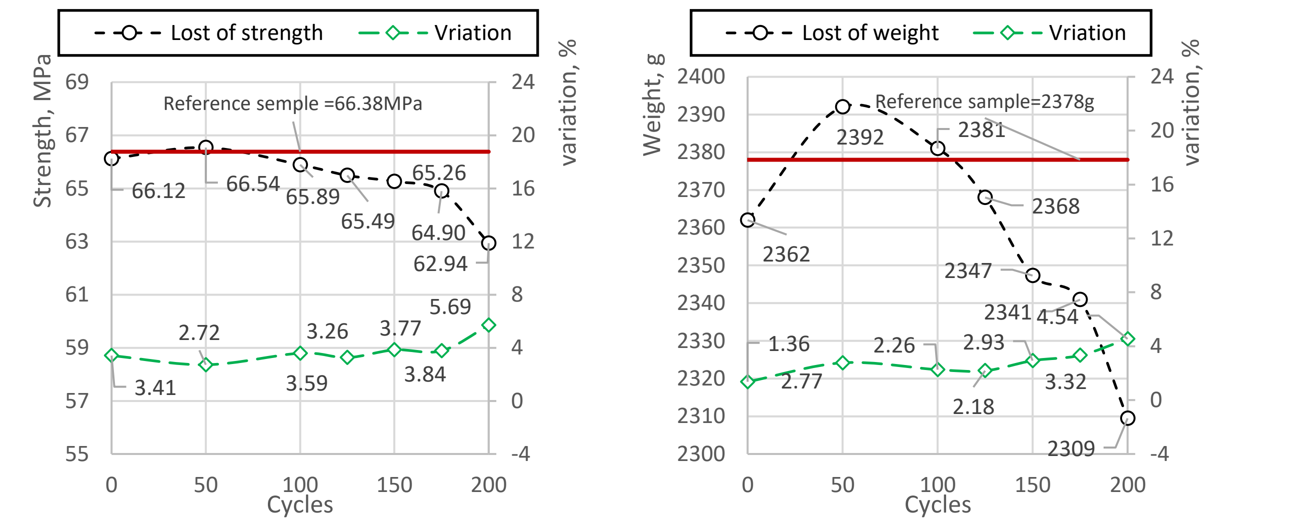

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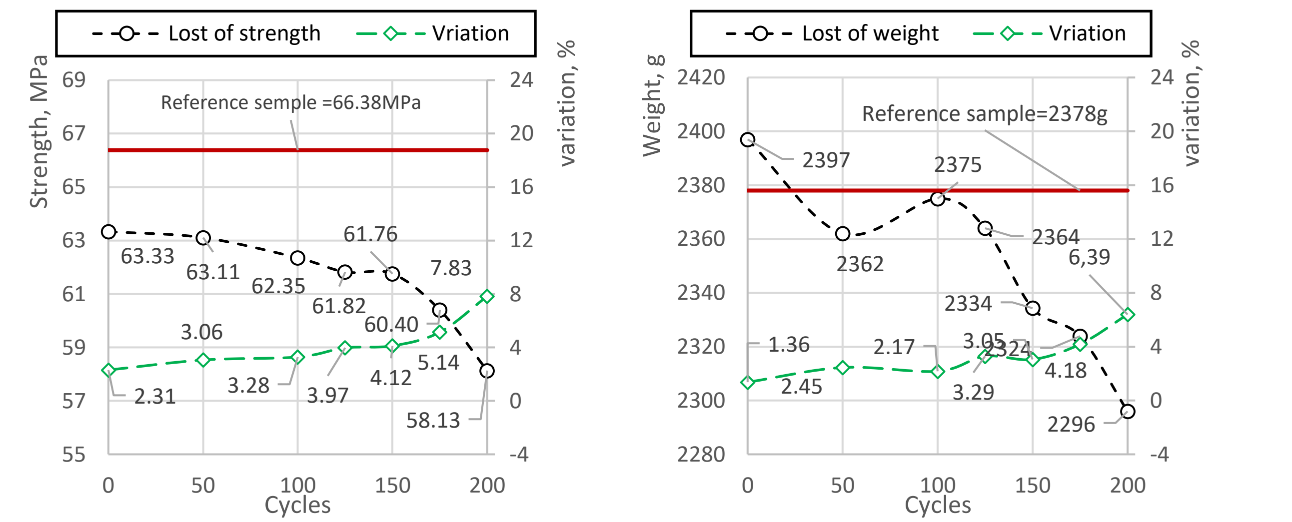
Figure 8 - Strength and mass loss at Sp=10.0%



A B

Figure 9 - Strength and mass loss at Sp=12.5%

Figure 10 shows comparisons of strength and mass losses in percentages as a function of soapstock content in the sample. (Figure 10A is a comparison of strength loss and Figure 10B is a comparison of mass loss). The comparison charts relative to the reference sample (red curve) show both qualitative and quantitative changes in mass and strength of the samples. The diagrams also show the numerical values of maximum losses corresponding to 200 cycles.

The curves in Figure 10 clearly show the effect of soapstock on the durability of concrete, relative to its resistance to cyclic freezing. The average value of maximum strength loss of reference samples in percentage terms is 16.84% and mass loss is 6.18% on average. For samples with Sp=5% content, the maximum strength loss is 8.95% and the maximum mass loss is 4.81%. For samples with Sp=7.5%, the same values are 6.34% in strength and 4.61% in mass. For samples with Sp=10.0%, the same values are 5.69% in strength and 2.88% in weight. For samples with maximum Sp=12.5%, the strength is 7.83% and weight is 3.45%. Thus, the maximum resistance to cyclic freezing was found in samples with Sp=10.0%. In case of loss of strength and mass, frost resistance in relation to reference samples increases by 50% (150/100), and in relation to other variations of Sp, by from 20 (125/100) to 50% (150/100).

Figure 11 shows the results of water absorption measurements of samples with different Sp contents.

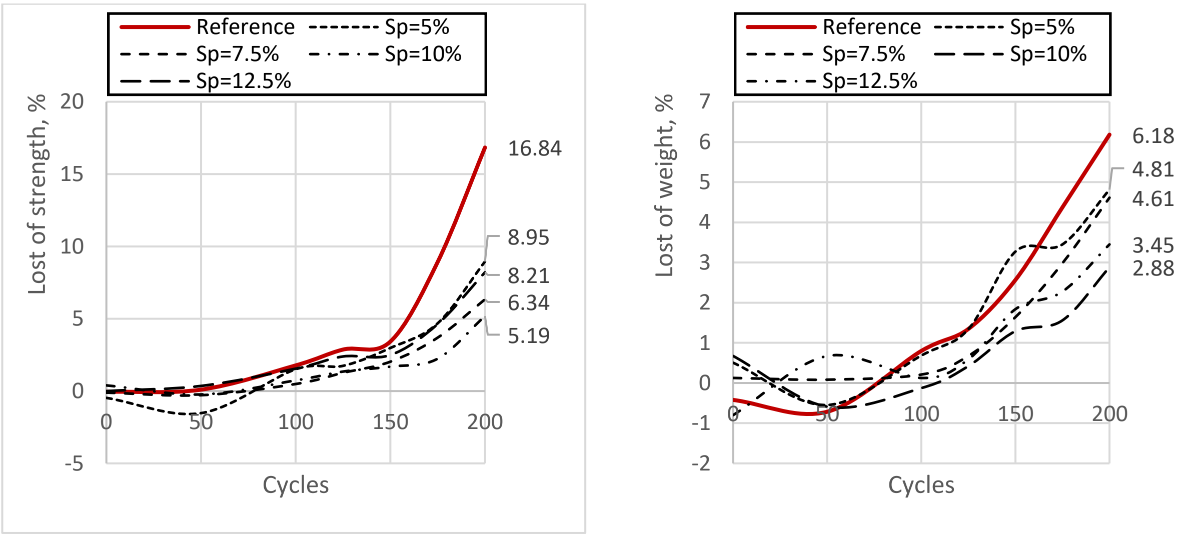


Figure 10 - Comparison of maximum strength and mass loss

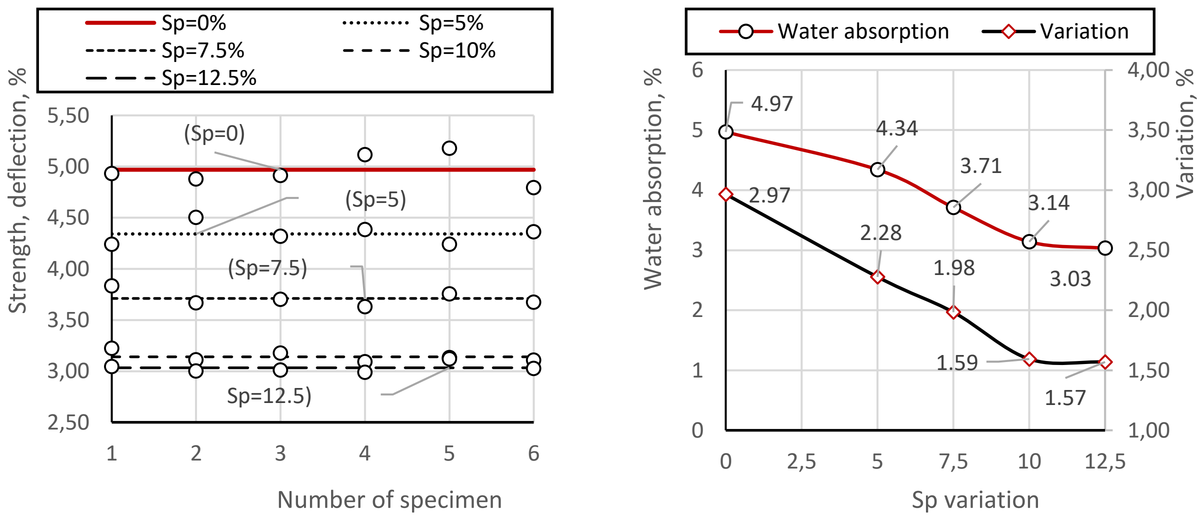


Figure 11 - Water absorption results

Figure 11A shows the private water absorption values and their corresponding averages. The straight lines in the diagram correspond to the average water absorption value of each type, in order to visualize the deviations of the private values from the average value. Figure 11B shows comparisons of the average water absorption values of samples with different Sp contents and their corresponding coefficients of variation.

According to the results, the average of the six water absorption measurements of the reference sample was 4.97%, with a variation from 4.79 to 5.18%. For samples with Sp=5%, water absorption varies from 4.24 to 4.51%, with an average of 4.34%. For samples with Sp=7.5% water absorption ranges from 3.63 to 3.83%, with an average of 3.71%. For Sp=10% from 3.09 to 3.22%, with an average of 3.14%. For Sp=12.5% from 2.99 to 3.12%, the mean is 3.03%. With each increase in the percentage of soapstock, there is a decrease in water absorption capacity. Relative to the reference samples, the decrease is: for Sp=5% samples, the decrease is 12.6%; for Sp=7.5% samples, the decrease is 25.3%; for Sp=10% samples, the decrease is 36.8%; for Sp=12.5% samples, the decrease is 39.0%. The decrease in water absorption relative to a linear increase in soapstock content (multiple of 2.5%), is not linear: up to 10% soapstock content there is a rapid decrease in water absorption, after - a sharp decline. Numerically, the increments are: 12.6, 14.5, 15.4, 3.4% from each subsequent addition of soapstock (2.5%). The sharp decline in water absorption indicates a decrease in the efficiency of hydrophobizing effect of soapstock on the material at its high concentration. Analysis of the coefficients of variation showed a high degree of convergence of private values of all variations, including reference samples: the coefficients of variation range from 1.57 to 2.97%. The variation of the results decreases with increasing concentration of soapstock, i.e. the maximum stability of the results logically corresponds to the maximum hydrophobization of the samples.

Conclusion

Based on the results of the tests performed, the following generalized conclusions can be drawn: Standard tests of beam samples for flexural and compressive strength, and standard cubic samples for water absorption and frost resistance were performed. Tests were performed for samples with different soapstock (Sp) contents: 5, 7.5, 10 and 12.5 % by weight of cement, microsilica and phosphogypsum.

Measurements of the strength of the beam samples showed that the maximum effect concerning the increase in the strength of the material is achieved at 5% of the soapstock content. However, it should be noted that the subsequent decrease in strength with increasing concentration of soapstock is not significant, up to Sp=10% does not exceed 1%. Thus, the optimal concentration of soapstock, at which the maximum effect on the strength of the material will be achieved, is 5-10%.

Tests on frost resistance showed that the maximum resistance to cyclic freezing is observed in samples with Sp=10%, further increase reduces frost resistance. The regularity in the increase of frost resistance with increasing concentration of soapstock is logical, because with each increase in concentration, the hydrophobization of the material increases. However, if the hydrophobicity of samples with Sp=12.5%, although not significantly, still increases about Sp=10%, the frost resistance decreases. The latter is because the high concentration of soapstock leads to a decrease in the structural strength of the material, since fatty acids in the composition of soapstock harm the strength set of concrete, as fatty acids in the water-soluble state (due to the use of caustic alkali NaOH) when getting into the cement mortar are evenly distributed, and after the setting of alkali pass into the active phase of cement binder, subsequently releasing fatty acids that form a hydrophobic structure. Large amounts of fatty acids reduce the adsorption of moisture and thus limit the hydration process.

The obtained curve of dependence of water absorption change on the concentration of soapstock showed the optimal gradient of water absorption, which corresponds to Sp=10%. With further increase of soapstock, the decrease of water absorption index is not significant.

Conflict of interest. The corresponding author declares that there is no conflict of interest.

CRediT author statement. All authors contributed to this study. **D. Dyussembinov**: Conceptualization, Methodology, Software. **R. Lukpanov**: Data curation, Writing draft preparation. **Zh. Zantlesova**: Visualization, Investigation. **R. Lukpanov**: Supervision. E. **Talal Awwad**: Software, Validation. **A. Altynbekova**: Reviewing and Editing.

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Бетон конструкцияларының беріктік сипаттамаларын жақсарту үшін модификацияланған қоспаның құрамындағы соапстоктың әсері

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ТҮЙІНДЕМЕ

Мақалада екі компонентті модификацияланған қоспаның бөлігі ретінде қолданылатын соапсток әсерін зерттеу нәтижелері берілген. Арқалық үлгілерге иілу және қысу беріктігі бойынша және суды сіңіру және аязға төзімділік бойынша стандартты кубтық үлгілерге стандартты сынақтар жүргізілді. Сынақтар соапстоктың әр түрлі мөлшерлеріне (Sp): цемент, микрокремний және фосфогипс салмағы бойынша 5, 7,5, 10 және 12,5% болатын үлгілер үшін жүргізілді. Арқалық үлгілердің беріктігін өлшеу материалдың беріктігін арттыру тұрғысынан максималды әсерге құрамында соапстоктың мөлшері 5% болғанда қол жеткізілетінін көрсетті. Алайда, соапстоктың концентрациясы жоғарылағанда беріктіктің кейінгі төмендеуі көп болмайтынын атап өткен жөн, Sp=10% дейін ол 1% аспайды. Осылайша, материалдың беріктігіне қатысты максималды әсерге қол жеткізілетін соапстоктың оңтайлы концентрациясы 5-10% құрайды. Суды сіңіру өзгерістерінің соапсток концентрациясына тәуелділігінің алынған қисығы Sp=10% сәйкес келетін су сіңірудің оптималды градиентін көрсетті. Соапстокты көбейткеннен суды сіңіру айтарлықтай төмендемейді. Аязға төзімділік сынақтары Sp=10% үлгілерде циклдік тоңазытуға максималды төзімділік байқалатынын көрсетті, ал кейінгі жоғарылау аязға төзімділікті төмендетеді. Соапсток концентрациясының жоғарылауымен аязға төзімділіктің жоғарылауының заңдылықтары қисынды, өйткені концентрация артқан сайын материалдың гидрофобизациясы артады. Дегенмен, Sp=12,5% үлгілердің гидрофобтылығы айтарлықтай болмаса да, Sp=10%-ға қатысты жоғарыласа, аязға төзімділік төмендейді.

Түйін сөздер: көбік бетон, пенобетон, екі компонентті модификацияланған қоспа, технологиялық схема, соапсток, беріктік қасиеттері, су сіңіргіштігі, аязға төзімділігі

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Влияние соапстока в составе модифицированной добавки для улучшения прочностных характеристик бетонных конструкций

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АННОТАЦИЯ

В статье представлены результаты исследования влияния соапстока, применяемая в составе двухкомпонентной модифицированной добавки. Были выполнены стандартные испытания образцов-балочек на прочность при изгибе и при сжатии, стандартных кубических образцов на водопоглощение и морозостойкость. Испытания выполнены для образцов с разным содержанием соапстока (Sp): 5, 7.5, 10 и 12.5 % по массе цемента, микрокремнезема и фосфогипса. Измерение прочности образцов-балочек показали, что максимальный эффект относительно увеличения прочности материала достигается при 5% содержании соапстока. Однако стоит отметить, что последующее снижение прочности при увеличении концентрации соапстока не значительно, до Sp=10% не превышает 1%. Таким образом оптимальная концентрация соапстока, при которой будет достигнут максимальный эффект относительно прочности материала, составляет 5-10%. Полученная кривая зависимости изменения водопоглощения от концентрации соапстока показала оптимальный градиент водопоглощения, которому соответствует Sp=10%. При последующем увеличении соапстока, снижение показателя водопоглощения не существенно. Испытания на морозостойкость показали, что максимальная стойкость к циклическому замораживанию наблюдается у образцов с Sp=10%, последующее увеличение снижает морозостойкость. Закономерность в увеличении морозостойкости при увеличении концентрации соапстока логична, поскольку с каждым увеличением концентрации растет гидрофобизация материала. Однако, если гидрофобность образцов с Sp=12.5% хоть и не существенно, но все же растет по отношению к Sp=10%, то морозостойкость снижается.

Ключевые слова: пенобетон, двухкомпонентная модифицированная добавка, технологическая схема, соапсток, прочностные показатели, водопоглощение, морозостойкость.

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