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STUDY OF THE HYDROPHYSICAL PROPERTIES OF HEAVY CONCRETE MODIFIED WITH COMPLEX ORGANO-MINERAL ADDITIVES

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ABSTRACT: The main task of implementing environmental policy is to create a resource-efficient system for the placement and disposal of industrial waste and secondary raw materials, in particular, in the production of building materials and products of specified properties. Within the framework of these studies, issues related to the activation of microsilica, which is a waste of ferroalloy production, and methods of its use for modifying the structure of cement stone, particularly for heavy concrete, are considered. The study aims to establish the positive effect of the activation process of silica fume and a micro-reinforcing component on the modification of the structure of heavy concrete to increase the hydrophysical properties. The object of research is a modified heavy concrete based on activated microsilica with a micro-reinforcing component. In this work, the following research methods were used: physicochemical activation of microsilica with water, treated by electrolysis with the Melesta device; determination of the frost resistance grade in the WK3 180/40 climatic chamber; water tightness was determined in the UVB-MG4.01 installation; water absorption was determined using a SNOL electric digital oven. Research results: a positive effect on the hydrophysical properties of heavy concrete was established by reducing the content of the binder (cement) and replacing it with a microdispersed filler previously activated with an alkaline medium with pH = 10.2. It has been experimentally proven that the modified concrete composition exhibits improved hydrophysical properties compared to the control: water absorption – 2%; water impermeability grade – W14; frost resistance – F600 with a mass loss of up to 1.9% and a strength loss of 8%, which is due to the formation of a microporous structure in the cement stone with pore sizes up to 0.1 μm.

Keywords: Frost Resistance, Water Resistance, Water Absorption, Silica, Basalt Fiber, Hydrophysical Properties

1. INTRODUCTION

Heavy concretes are used as structural materials operating under harsh conditions for the construction of buildings and structures for civil, industrial, and special purposes [1,2]. This is due to their high strength (up to 150 MPa and above), frost resistance (F1 = 1000), density (up to 2500 kg/m³), water impermeability (W20), and corrosion resistance in aggressive environments [3]. Currently, research is actively being conducted on modifying concrete through the use of chemical additives-modifiers, as well as micro- and nano-dispersed additives (carbon nanotubes, silicate microspheres, metal oxide nanoparticles, etc.) [4,5].

The advantages of such concrete compared to traditional ones include enhanced quality indicators: physical and mechanical characteristics (compressive strength, tensile strength during bending, crack resistance), which are associated with increased density and modification of the cement stone structure [6]. However, in terms of several physical and mechanical characteristics, heavy concretes do not meet modern requirements for contemporary building materials and products based on them [7,8]. To improve their operational characteristics, recent research has focused on modifying cement concretes by introducing effective complex additives containing active quartz particles [9] and micro-reinforcing components [10], which is a promising and resource-saving direction in materials science. Existing literature on this problem does not provide a comprehensive understanding of the influence of the concrete mix composition, the transformation of amorphous silica particles into an active form in an alkaline environment combined with micro-reinforcing components like polypropylene fiber or basalt fiber on the physical and mechanical properties. Therefore, studying the synergistic effect of micro-reinforcing fiber and activated silica on the operational characteristics of heavy concrete is relevant from both fundamental and applied perspectives [12].

One way to address the issue of improving the characteristics of heavy concretes is by introducing active mineral additives into the concrete mixtures, such as fly ash, silica fume, and rice husk ash. The most promising results in this direction have been obtained in studies [13].

Inozemtseva A.S. et al. present research results on a concrete mix with a complex modifier comprising rice husk ash, fly ash (inorganic component), and superplasticizer C-3 or Sika ViscoCrete 5-New (organic component) [14]. A dual mechanism of modifier action in cement systems was identified: the "chemical" factor—the presence of silicon dioxide in an amorphous modification and highly dispersed rice husk ash; the "physical" factor—filling the space between crystal hydrates and reducing the volume of free water, leading to decreased capillary porosity of the cement stone and increased gel pore volume. Introducing rice husk ash and fly ash into the concrete mix, with each additive amounting to 10%, along with the superplasticizer Sika ViscoCrete 5-New at a dosage of 1.5% of the binder's weight, increases the 28-day tensile strength during bending by 10%, prism strength by 19.5%, and cube compressive strength by 18.2% compared to the control sample. The results of using this additive to produce high-strength concrete are also presented in studies, which do not entirely correspond to the data [15]. The discrepancies can be explained by the quartz content in the active mineral additives and the recommended dosage of the complex additive [16,17]. Other types of additives that enhance the crack resistance characteristics of concretes are studied in works [18]. In their work Stanevich, V.T. et al. The main attention was paid to the effect of dispersed reinforcement with polypropylene fiber on concrete elements [19]. It is shown that introducing polypropylene fiber with a consumption of 4 kg/m³ and an elementary fiber length of 6 mm into the fine-grained concrete mixture increases the compressive strength by 25.4% and the flexural strength by 51.2% compared to the control composition. However, an effect of "over-reinforcement" is noted when the recommended fiber dosage is exceeded, negatively impacting the physical and mechanical characteristics of the studied concrete samples. Further increasing the polypropylene fiber content reduces the thickness of the cement stone between them, leading to delamination and loss of continuity in the sample. Similar changes in the above indicators compared to control samples were observed in works [20].

A more promising approach in terms of resource efficiency is the use of modifiers containing amorphous silica, which is a more accessible and environmentally friendly waste product of the ferroalloy industry. Its advantage lies in its ability to positively affect the main operational properties of heavy concrete: water impermeability, strength, frost resistance, wear resistance, durability, resistance to chloride and sulfate corrosion, resistance to seawater, and weak acids. Several modifiers have been studied in works by foreign authors [20,21]. A study by Riza Suwondo et al. it shows that the introduction of a complex additive, superplasticizer GleniumACE 430 along with silica fume into a concrete mix based on the hydraulic binder, increases frost resistance up to 400 cycles and above, which is associated with the amorphization of the cement stone structure [21].

The discrepancies can be explained by the different methods of introducing and dosing the modifier. The analysis of the composition and characteristics of concrete, the influence of complex modifiers on strength and operational characteristics, shows that the issues of reducing silica fume consumption by converting particles into an active form and the combined influence of dispersed reinforcement on the specified characteristics of the studied material remain unresolved [22,23,24]. Therefore, this work aimed to develop an organo-mineral composition with optimal consumption of activated silica fume and micro-reinforcing fiber to enhance the strength, deformability, and hydrophysical characteristics of heavy concrete.

The authors put forward the following hypothesis: The introduction of a stabilized suspension of activated silica with a plasticizing additive and basalt fiber into the concrete mixture will make it possible to obtain modified heavy concrete with increased physico-mechanical and hydrophysical properties due to the formation of an additional amount of low-base calcium hydrosilicates, compaction, and strengthening of the cement matrix structure, fiber work in the formation system of a spatially reinforced cement stone structure.

2. RESEARCH SIGNIFICANCE

The primary objective of implementing environmental policy is to create a resource-efficient system for the disposal and utilization of industrial waste and secondary raw materials, particularly in the production of building materials and products with specified properties. The research aims to establish the positive effect of the activation process of microsilica combined with a micro-reinforcing component on modifying the structure of heavy concrete to improve hydrophysical properties. The object of the study is modified heavy concrete based on activated microsilica combined with a micro-reinforcing component. The following research methods were used in this work: physicochemical activation of microsilica with water treated by the electrolysis method using the "Melesta" device; determination of frost resistance grade in a WK3 180/40 climate chamber; determination of water impermeability using the UVB-MG4.01 setup; water absorption was determined using the electric digital furnace SNOL.

3. RESEARCH MATERIALS AND METHODS

The study used initial water-cement materials with the following characteristics. The binder was Portland cement grade CEM I 42.5N, produced by Holcim (Russia) LLC (Kaluga). The chemical and mineral composition of the cement was determined using X-ray phase and X-ray fluorescence analyses, the results of which are presented in Table 1 and Table 2.

The dispersive composition, technological and strength characteristics of the cement and the cement stone obtained from it were determined using sieve analysis (controlling the fineness of grinding with at least 85% of the mass of the sieved sample passing through sieve No. 008 with cell size 80 μm), pycnometric method (the true density of the cement was 3156 kg/m³), determination of flexural and compressive strength (universal testing block UPB 86/200, Form+Test, Germany) following standard methods. To determine mechanical strength, sample beams of size 4×4×16 cm were prepared from a cement-sand mortar with a water-cement ratio of W/C = 0.4. After manufacturing, the samples were kept in molds for 1 day in a bath with a hydraulic seal, maintaining conditions of at least 90% relative humidity and an ambient temperature of (20±2)°C.

Table 1. Chemical Composition of Portland Cement

Grade	Chemical Composition, wt. %						
	Na_2O	SO_3	MgO	Fe_2O_3	CaO	Al_2O_3	SiO_2
CEM I 42.5N	0.57	0.3	0.69	3.75	65.3	4.89	24.4

Table 2. Mineral Composition of Portland Cement

Grade	Content of Crystalline Phases in Clinker, wt. %			
	C_4AF ($4CaO·Al_2O_3·Fe_2O_3$)	C_3A ($3CaO·Al_2O_3$)	C_2S ($2CaO·SiO_2$)	C_3S ($3CaO·SiO_2$)
CEM I 42.5N	11.46	7.84	12.62	68.08

After one day, the samples were demolded and then stored for 27 days in a water bath, with the temperature controlled within (20±2)°C.

Table 3. Results of Determining the Characteristics of Portland Cement Grade CEM I 42.5N

Indicator	Measurement Results	Standard Values According to GOST 31108-2016
Residue on 45 μm sieve, %	2.9	-
Residue on 80 μm sieve, %	0.3	-
Specific surface area, cm²/g	3545	-
True density, kg/m³	3156	-
Bulk density, kg/m³	1248	-
Normal consistency, %	27	-
Uniformity of volume change test (Le Chatelier ring)	Withstands	Withstands
Initial setting time, min	197	Not earlier than 60
Compressive strength at 2 days, MPa	24.7	At least 10
Compressive strength at 28 days, MPa	57.5	At least 42.5

At the end of the storage period, the sample beams were removed from the water bath and tested for strength characteristics no later than 30 minutes thereafter. The obtained results are presented in Table 3.

Granite crushed stone of fractions from 5 to 20 mm, produced by LLC "Sunsky Quarry", Petrozavodsk, was used as the coarse aggregate. It met the requirements for the content of plate and needle-shaped grains – 13.0%; dust, silt, and clay particles – 0.97%; crushability grade – 1400; frost resistance grade – 300; bulk density – 1350 kg/m³; specific effective activity of radionuclides (Aeff) – 92 Bq/kg; wear resistance grade I-1. The maximum distribution of the crushed stone by size was 20 mm. The studied aggregate belongs to the medium-grained type of crystalline structure.

Tap water with a sulfate content of 2500 mg/l (calculated as SO_4) and a total salt content of 3600 mg/l was used for mixing the concrete. To maintain the specified hardness grade (J1), the water-cement ratio remained unchanged (W/C = 0.35).

To increase the mobility of the concrete mixtures, the hyperplasticizer "MasterGlenium 115" based on polycarboxylate ether (produced by LLC "BASF Construction Systems", Krasnodar) was introduced, with a consumption of 1% of the binder's weight, as recommended by the manufacturer. The modifier was added to the concrete mixture simultaneously with the mixing water, at a rate of 4.2 kg per 1 m³ of the finished mixture.

Microsilica grade MKU-95 (produced by LLC "RUSAL Silicon Ural", Kamensk-Uralsky) was introduced into the concrete mixtures as an active mineral additive, with a variation range from 10% to 20% of the binder's weight. Its chemical composition is shown in Table 4. Microsilica of this grade is a byproduct of ferrosilicon production, containing dust particles ranging from 0.87 μm to 76.06 μm. Microsilica was added to the concrete mixtures during the mixing stage of coarse and fine aggregates with cement.

In several experiments, activated microsilica was used. Activation was carried out using the electrolysis method (device "Melesta", produced by LLC "MVP") with electrodes: a cathode made of stainless steel, and an anode made of titanium coated with ruthenium oxide. Tap water in a volume of 0.8 liters was poured into the device, and electrolysis was conducted according to the device's specifications until the water temperature reached 35°C.

For laboratory research, a device manufactured by LLC MVP “Melesta” was used as an electrolyzer.

Anodic process

$$Ca(HCO_3)_{2p\text{-}p} \rightarrow CaCO_3\downarrow + H_2O \quad (1)$$

$$Mg(HCO_3)_{2p\text{-}p} \rightarrow Mg(OH)_2\downarrow + H_2O + CO_2\uparrow \quad (2)$$

Cathodic process

$$2H_2O + 2e^- = H_2\uparrow + 2OH^- \quad (3)$$

As a result of the electrolysis of tap water, its softening occurs (Eq. 1 and Eq. 2) due to the transition of soluble calcium and magnesium bicarbonates into insoluble compounds. This process takes place at the anode. An electrochemical release of hydrogen occurs at the cathode (equation 4.5), since calcium and magnesium metals have a redox potential much more negative than hydrogen and are at the beginning of this series in a series of voltages. The resulting hydroxide-ion OH- determines the alkaline medium of the solution. After measuring the pH of the water treated by electrolysis, the pH of the medium was 10.2.

Table 4. Chemical Composition of Microsilica MKU-95 According to Specification

Component	Content, wt. %, no more than
SiO_2	97.00
P_2O_5	0.49
MgO	0.48
Al_2O_3	0.12
Fe_2O_3	0.22
SO_3	0.20
CaO	0.26
$Na_2O + K_2O$	1.04
H_2O	0.19

It was found that microsilicon introduced into treated water, due to alkaline excitation and in the presence of Ca2+ ions, acquires increased chemical activity by the following reaction:

$$Ca^{2+} + 2OH^{-} + 2SiO_2 \rightarrow Ca(HSiO_3)_2 \quad (4)$$

At the same time, there is a decrease in the pH of the medium from 10.2 to 7.5.

When activated silica is introduced into cement, the processes of hydrolysis and hydration of cement grains proceed more intensively. In our opinion, this is due to the formation of active crystallization centers in the form of hydrolysis products of activated silica, which concentrate hydrate neoplasms around themselves. It was revealed that calcium silicate is formed in the active areas of silica in the presence of a plasticizer, followed by its hydrolysis, as evidenced by a change in the pH of the medium: after 3 hours, it increased from 6.8 to 7.4; after 24 hours, to 8.2.

At the next stage, the structure of microsilicon compounds converted to the active form was established using the "Varian 640-IR" infrared Fourier spectrometer. The obtained IR spectra, shown in Figure 4.3, of microsilicon (MCU-95): in a dry state and treated with an acidic and alkaline medium. At the same time, it should be noted that according to the scientist T. Akhmetzhanov, the oscillation frequency of the supposed activation products of microsilicon in the form of orthosilicic acid $Si(OH)_4$ coincides with the oscillation frequency of quartz glass, which lies in the region of 1025-1196 cm^{-1} [24].

The results of IR spectroscopy showed (Figure 1) the coincidence of the oscillation regions of the spectra of microsilicon treated with water by electrolysis in an acidic (pH=2.1...2.3) and alkaline medium (pH = 10.2), while fundamentally different from the IR spectrum of amorphous microsilicon, which confirms its increased chemical activity from the dispersion of microsilicon to the state of orthosilicon acid $Si(OH)_4$.

The IR spectrum of the repeated violation of the total internal reflection of the treated silica by an acidic and alkaline medium, shown in Figure 4.3, coincides with the orthosilicic acid sol in terms of the position of peaks and absorption bands in the transmission spectra in the range 500-4500 cm^{-1}. In the range of 500-600 cm^{-1}, the absorption band is associated with deformation fluctuations of bonds inside silicon-oxygen joints and their groupings. Due to symmetrical vibrations of Si–O–Si bonds (vibrations of silicon-oxygen tetrahedra relative to each other), an absorption band of 700-900 cm^{-1} occurs, which indicates their complete polymerization.

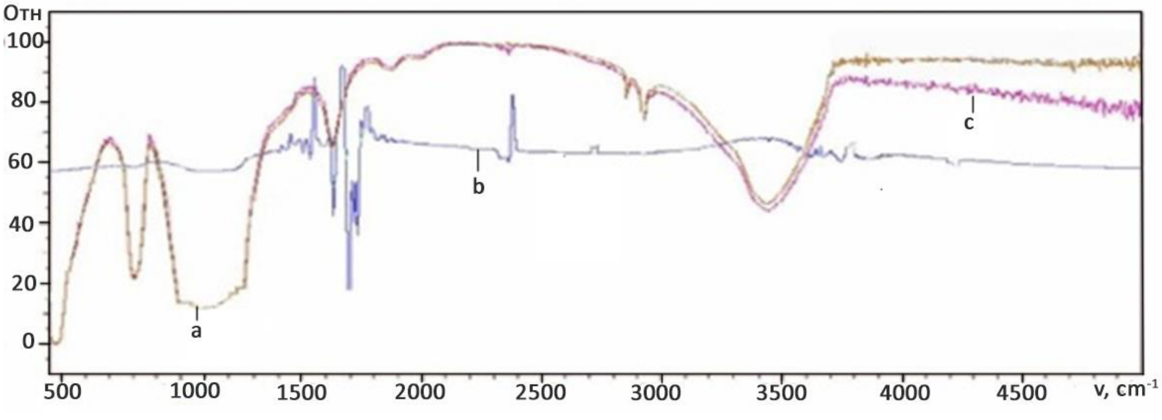

Fig. 1 – IR spectra of samples: a – microsilicon MCU-95 treated with an alkaline medium; b – microsilicon MCU-95 (amorphous); c – microsilicon MCU-95 treated with an acidic medium

In the spectral region of 1000-1290 cm-1, there is a deep absorption band associated with transverse, mixed, and longitudinal vibrations of Si-O-Si bonds, with a minimum transmission at 1080 cm^{-1}.

For further research, taking into account the peculiarities of the influence of an acidic environment on the corrosion of reinforcement in reinforced concrete products, it was decided to treat microsilicon only with water obtained by electrolysis with pH = 10.2. Thus, it can be concluded that when processing silica with various media, spectra were obtained that are fundamentally different from the IR spectrum of amorphous silica, which confirms the increased chemical activity of activated silica and its dispersion to the state of orthosilicic acid $Si(OH)_4$.

It has been established that the process of dispersing microsilicon to the state of orthosilicic acid $Si(OH)_4$ and its dimers is influenced in an acidic medium by oxonium H_3O^+ ions, and in an alkaline medium by hydroxyl ions OH^-.

Further, the effectiveness of the use of chemical activation of microsilicon was evaluated by experimentally established values of the mechanical and physicochemical properties of the modified concrete compositions.

To enhance the crack resistance of the concrete, micro-reinforcing components—polypropylene fiber or chopped basalt fiber (LLC "Europolis", Dubna, Moscow region)—were introduced into the concrete mixture during the dry mixing stage of the binder (Portland cement) together with fine and coarse aggregates. The characteristics of the micro-reinforcing components are shown in Table 5.

Table 5. Characteristics of Micro-Reinforcing Components

No.	Characteristic	Polypropylene Fiber	Chopped Basalt Fiber
1	Fiber length, mm	13…14	12
2	Diameter of single fiber, µm	63	17
3	Density, g/cm³	0.89	2.65
3	Melting temperature, °C	165	1450
4	Elongation at break, %	25…40	1.2…3.5
5	Alkali and corrosion resistance	Low	High
6	Tensile strength, R, MPa·10³	0.55	3.1…3.6
8	Elastic modulus, F_f, MPa·10³	3.2	100…124

4. RESEARCH METHODOLOGY

The processes of physicochemical activation of microsilica with water, treated by the electrolysis method, are based on its treatment to obtain catholyte and anolyte. The following methods and equipment were used to test hydrophysical characteristics: determination of frost resistance grade in the WK3 180/40 climate chamber, determination of water impermeability in the UVB-MG4.01 setup, and water absorption using the SNOL electric digital furnace.

The electrolysis method leads to the activation of microsilicon. This in turn leads to an accelerated reaction and improved properties of the modified concrete.

To increase the durability of building products and structures under harsh operating conditions, it is also necessary to improve the hydrophysical properties of concrete, such as water impermeability, water absorption, and frost resistance, which significantly enhance the longevity and reliability of structures.

Water absorption and water resistance tests were carried out according to the standard procedure. For this purpose, cylindrical samples with a diameter of 150 mm and a height of 100 mm were prepared from the studied concrete mixtures, considering that the maximum aggregate grain size was 20 mm. Water absorption was determined by weighing pre-saturated water samples every 24 hours until two consecutive weighing results differed by no more than 0.1%. Water impermeability was determined by the "wet spot" method. For each studied composition, 6 samples were prepared and stored on a rack above water (in a normal hardening chamber) at a temperature of 20 ± 2°C, relative air humidity of 95 ± 5%, and then pre-conditioned for 1 day in the air at a temperature of 20 ± 2°C before testing. The testing process involved increasing water pressure in steps of 0.2 MPa for 1-5 minutes, with a loading duration of 12 hours at each step. The water impermeability of each cylinder sample was assessed by recording the maximum water pressure at which no water seepage was observed through the sample body, in the form of a wet spot or signs of water filtration as drops on the end surface opposite to where the water was applied under pressure. Water impermeability of the concrete series was determined by the maximum water pressure at which no filtration was observed in at least four out of six samples.

For frost resistance testing, the first basic method of multiple freezing and thawing in a water-saturated state was used according to the methodology, with the testing conditions set as follows: water for saturation and thawing at a temperature of 20 ± 2°C and freezing at minus 18 ± 2°C. Frost resistance grade determination was conducted on samples with edges of 100×100×100 mm at the age of 28 days. The number of control samples is 6 pieces and the main ones are 12 pieces for each composition. The main samples before freezing, and the control ones before strength tests, were saturated with water by immersion for 24 hours at 1/3 of the height of the cube samples. The next step was to raise the level to 2/3 of the height and continue exposure for 24 hours, after which we raised the water level so that the distance from the upper face of the samples to the liquid level was more than 20 mm and continued exposure for the next 48 hours. The testing regime was strictly followed—freezing time of at least 2.5 hours and thawing for 2 ± 0.5 hours. If chips, cracks, and spalling of the edges occurred during testing, the study was terminated.

5. RESULTS

The results of water absorption and water impermeability tests of concrete are presented in Table 6.

Table 6. Results of Water Absorption and Water Impermeability Tests of Concrete

Composition No.	Modifier, % of Cement Weight for Microsilica and % of Volume for Fiber	Water Absorption, %	Water Impermeability of Samples, MPa	Concrete Water Impermeability Grade
1	Control, without modifiers	3.5	0.8	W8
2	MKU-95, 15%	2.3	1.0	W10
3	Activated MKU-95, 15%	2.15	1.0	W10
4	Activated MKU-95, 15%; Polypropylene Fiber, 0.75%	2.1	1.2	W12
5	Activated MKU-95, 15%; Basalt Fiber, 0.75%	2.0	1.2	W14

Analysis of the data in Table 6 shows that concrete containing activated microsilica combined with basalt fiber (composition 5) has reduced water absorption compared to the control (composition 1) by 57%. The water impermeability of modified concrete (composition 5) increased by 6 grades (loading steps) compared to the control concrete (without modifiers, composition 1), by 4 grades compared to compositions without fiber (compositions 2, 3), and by 2 grades compared to the composition with polypropylene fiber (composition 4).

The improvement in hydrophysical properties is explained by the enhancement of the structure quality of the modified cement stone and concrete based on it in the presence of a complex modifier (high water-reducing additive "MasterGlenium 115" plus reactive chemical additive microsilica grade MKU-95) together with basalt fiber. The surfactant "MasterGlenium 115" reduces the development of capillary cracks, developing microporosity with pore sizes of 0.1 μm, which is close to contraction porosity, consistent with the conclusions of studies [1-3,21-22].

The results of frost resistance tests of the studied concrete are presented in Table 7 and Figure 1.

Analysis of frost resistance data led to the following conclusions:

- The results of control concrete (composition 1) testing showed that starting from 350-400 cycles, the samples exhibited a mass decrease of up to 4% and cubic compressive strength reduction of 10%.
- At cycles equal to 550-600, the depth of damage in samples with polypropylene fiber and activated microsilica (composition 4) became critical, reducing strength characteristics by more than 13%, with a mass loss reaching 3.3%.
- High frost resistance (composition 5) with optimal consumption of activated microsilica grade MKU-95 at 15% and basalt fiber at 0.75% is characterized by a mass loss of up to 1.9% and a strength reduction of 8% after 600 cycles of testing. This is due to the formation of a closed microporous structure of the cement stone and its high water impermeability [22-24].

Table 7. Results of Concrete Frost Resistance Testing

No.	Modifier, % of Cement Weight for Microsilica and % of Volume for Fiber	Mass Loss of Sample, %, after Cycles						$^{*}K_{\text{mpз}}$ after Cycles					
		200	300	400	500	550	600	200	300	400	500	550	600
1	Control, without modifiers	0.9	1.7	3.2	-	-	-	1.02	0.98	0.91	-	-	-
2	MKU-95, 15%	0.5	1.1	2.0	3.4	5.3	-	1.05	1.01	0.97	0.90	0.71	-
3	Activated MKU-95, 15%	0.4	0.9	1.6	2.8	4.9	-	1.06	1.02	0.99	0.93	0.78	-
4	Activated MKU-95, 15%; Polypropylene Fiber, 0.75%	0.2	0.5	1.1	1.9	2.5	3.3	1.09	1.06	1.01	0.97	0.91	0.87
5	Activated MKU-95, 15%; Basalt Fiber, 0.75%	0.1	0.3	0.5	1.2	1.6	1.9	1.11	1.08	1.04	1.0	0.96	0.92

$^{*}K_{\text{mpз}}$ - is the ratio of the sample strength after frost resistance testing to the strength of the material sample in a water-saturated state before frost resistance determination.

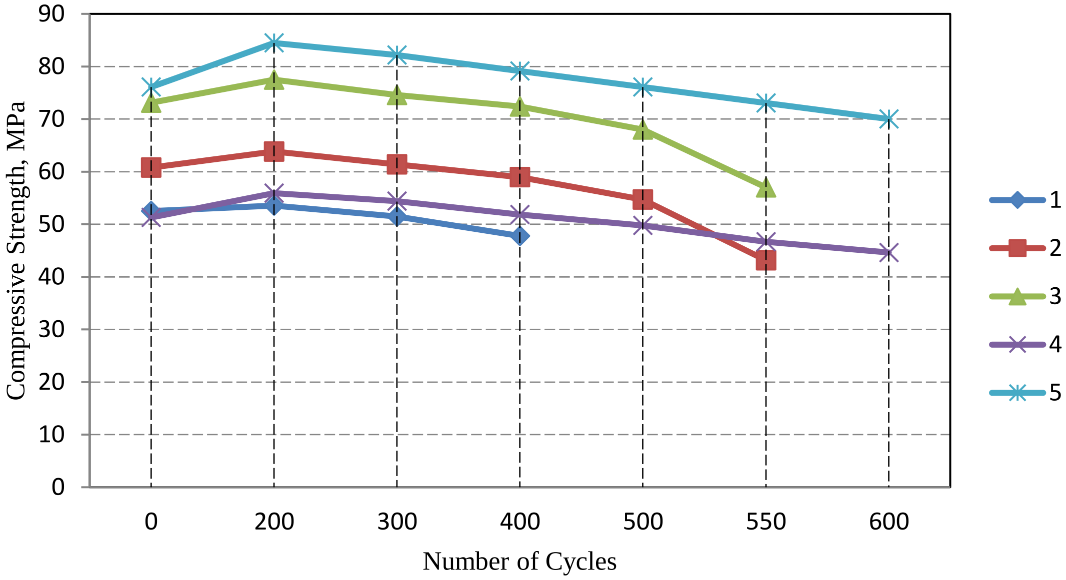

Fig. 2 - Graphical Interpretation of Frost Resistance Test Results of Heavy Concrete Samples: 1 – Control composition; 2 – MKU-95, consumption 15%; 3 – Activated MKU-95, consumption 15%; 4 – Activated MKU-95, consumption 15%, polypropylene fiber, consumption 0.75%; 5 – Activated MKU-95, consumption 15%, basalt fiber, consumption 0.75%

6. CONCLUSIONS AND DISCUSSIONS

Based on the presented research results, the following conclusions can be made:

1. The introduction of a complex modifier (high-water-reducing additive "MasterGlenium 115" plus the reaction chemical additive microsilicon of the MKU-95 brand) with the addition of basalt fiber leads to fragmentation of macropores and a decrease in the development of capillary cracks. Which in turn leads to microporosity (pore size 0.1 microns). The resulting closed fine-porous structure of cement stone leads to an improvement in the frost resistance of concrete.

2. The results of the concrete test show a 57% decrease in water absorption of the studied samples based on activated silica and basalt fiber (composition 5, Table 5) compared with the control sample.

For the same reason, the water resistance of the tested concrete (composition 5) increased by 6 grades compared to the control sample.

3. It has been experimentally proven that the modified concrete composition exhibits improved hydrophysical properties compared to the control: water absorption – 2%; water impermeability grade – W14; frost resistance – F600 with a mass loss of up to 1.9% and a strength loss of 8%, which is due to the formation of a microporous structure in the cement stone with pore sizes up to 0.1 µm.

4. It has been established that the proposed modification with a complex additive combined with basalt fiber allows the production of high-quality heavy concrete with improved hydrophysical properties: water absorption, water impermeability, and frost resistance. This makes it possible to recommend its use for the production of building products and structures that operate under harsh conditions.

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