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STRENGTH AND DURABILITY EFFECT OF SELF-COMPACTING CONCRETE REINFORCEMENT WITH MICRO-SILICA AND VOLUME FIBER

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ABSTRACT: This paper describes the research on micro-silica, popular in Kazakhstan ferrosilicon production technogenic waste, its impact on self-compacting concrete rheological and physical-engineering properties, and performance and durability improvement of building structures made of this concrete type utilizing volumetric fiber reinforcement. The paper includes the results of laboratory and industrial tests of self-compacting concrete mixtures (SCC) strength and operational properties. The most effective ratio of micro-silica as a filler in the binder and the optimal amount of low-modulus polypropylene fiber was selected to manufacture high-quality self-compacting concrete of C25/30, C30/35, C35/40, C40/45 classes produced using local raw materials. Examples of compositions using micro-silica confirm the possibility of up to 20% cement consumption reduction and increase the concrete frost resistance to F340, reduction of self-compacting concrete volumetric water absorption by up to 30%, increase bending strength by up to 35% with the combined use of silica and polypropylene fiber in a right proportion are described here. The research results provide practical value for self-compacting and cast concrete Kazakhstani manufacturers.

Keywords: Self-compacting concrete, Concrete strength, Micro-silica, Polypropylene fiber, Frost resistance, Water absorption.

1. INTRODUCTION

Worldwide construction practice shows that self-compacting concrete development is necessary to meet the growing construction industry's needs. The emergence of new breakthrough projects in the construction sphere (such as innovative suspension bridges in Japan and China, large hydraulic engineering complexes and transport structures in the Netherlands, and several others) has increased the requirements for high-strength concrete. It was necessary to use a high volume of cast concrete mixtures in such project construction. [1] Quite often, concreting construction sites are located at a great distance from the concrete production location and even at a considerable distance from the coast (on the water). Same tendency we can observe in Kazakhstan as well. Today, the builders and designers are not just modeling the future structure but also selecting building materials to implement the project and to ensure the necessary operational properties throughout the entire service life of the structure. Here, we can meet up with difficulties, as the engineering idea might be limited by the complexity of laying concrete in structures of complex geometric shapes, densely reinforced large-sized structures. These tasks and problems can be resolved by using self-compacting concrete (SCC). Also, there is another task that requires a quick solution - time and labor costs reduction while laying concrete mix, as well as operational characteristics improvement. The use of self-compacting concrete in monolithic construction and in the reinforced concrete products manufactured directly at the plants eliminates the vibration stage, thereby reducing the noise load on the environment and the production environment. [2]. At the moment, we have studies proving the possibility of SCC formation with high physical and technical characteristics and the successful opportunity of fiber reinforcement usage [20]. However, the difference between SCC and traditional classical heavy concretes with specified physical and technical properties gives a number of serious tasks for concrete science researchers that require a systematic and step-by-step approach to predicting SCC physical, technical, and operational properties, studying rheological models of cast concrete mixtures, optimal aggregates distribution in the concrete matrix, as well as dependencies assessing the fine fillers and dispersed fiber reinforcement impact on self-compacting mixtures characteristics [4]. According to other researchers' previously published works, fine fillers facilitate the increase in concrete mixture workability, resistance to delamination, an increase in structural concrete uniformity, and early age strength [5]. Also, according to the researchers, when designing SCC compositions, one of the ways to solve the above tasks is to ensure high expansion of coarse aggregate grains. It is not possible to solve this problem by adding chemical additives alone since this will lead to the stratification of the concrete mixture, and fine filler usage gives a certain positive result without loss of strength characteristics. The novelty of the research topic is justified by SCC's limited use at Kazakhstani construction sites; the reason for this is the insufficient amount of composition research and the fact that there are not so many concrete and reinforced concrete products manufacturers who can utilize this type of concrete production technology. Concrete manufacturing plants have limited opportunities for SCC production and need foreign specialists' involvement [1]. The new aspect of this study is that almost 100% of the use of local raw materials is in SCC composition proportioning. In the research, we have systematized the theoretical and methodological arguments of SCC production and have developed self-compacting concrete mixture compositions using modifiers produced from industrial waste and volumetric fiber reinforcement [20].

The research purpose was to obtain self-compacting concretes produced from Kazakhstani industrial waste as modifiers and volumetric fiber reinforcement with low-modulus polypropylene fiber to improve performance indicators. Here, the research object was self-compacting concrete for C25/30, C30/35, C35/40, and C40/45 classes. The research subject is concrete and concrete mixture physical and technical characteristics obtained by the above concrete class compositions proportioning.

This research resolves the following tasks in accordance with the established purposes:

- analysis of SCC researches international and domestic experience.
- study of theoretical and experimental approaches for SCC production.
- Obtain a self-compacting concrete mixture that meets regulatory document requirements and has the necessary physical and technical characteristics and high durability indicators.
- getting the results of SCC compositions production approbation.

2. RESEARCH SIGNIFICANCE

This paper investigated the impact of micro-silica on self-compacting concrete rheological and physical-engineering properties and performance and durability improvement of building structures made of this concrete type utilizing volumetric fiber reinforcement. The research purpose was to obtain a self-compacting concrete mixture that meets regulatory document requirements and has the necessary physical and technical characteristics and high durability indicators. The new in this study is almost 100% use of local raw materials in SCC composition proportioning.

3. MATERIALS AND METHODS

Here in this work, we have used theoretical and practical research methods. The theoretical research aimed to study the composition of the existing production cast concrete mixtures and determine the work aspects, focusing on industrial waste use.

Practical research was aimed at experimental confirmation of the theoretically developed compositions and SCC production methods.

This research was conducted in 5 stages, each of which was aimed at solving specific tasks (Fig. 1).

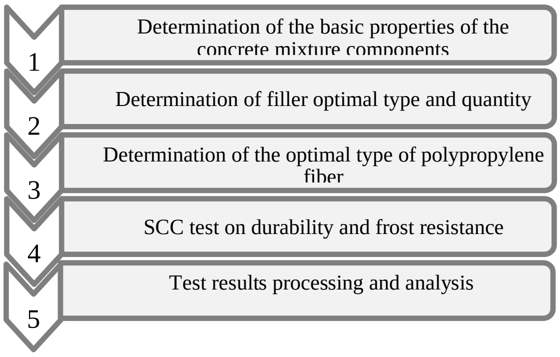

Fig.1 Work stages

Here, we have used local raw materials and fine aggregates made of Kazakhstani industrial wastes and low-modulus polypropylene fiber.

The research methodology is targeted on comparing experimentally obtained self-compacting concrete rheological and physic-technical characteristics by varying the new components added to SCC composition. All researches and tests were executed in accordance with the EN regulatory documentation valid on the Republic of Kazakhstan territory.

2.1 Determination of the concrete mixture component's basic properties.

M400D20 cement produced by "Standard Cement" LLP (Shymkent, Kazakhstan) was accepted as a binder for the being studied concrete mixtures. We have conducted a number of tests to confirm the selected binder's compliance with the norms and requirements [16]. The specified methodology in the standard allows to determine the following parameters:

1) Fineness of grinding:

The binder showed 93.9% grinding fineness.

2) Normal density and setting time of cement dough:

The binder test results showed a normal density of 26.80%. The setting began after 2 hours 04 minutes, and the setting ended after 4 hours 05 minutes from the water addition moment. The obtained indicators meet the norms.

3) Compressive and bending strength (at the age of 28 days):

When determining the strength characteristics of the researched binder, it showed the following 28 days age result: bending – 5.5 MPa; compression –

41.7 MPa. The obtained indicators meet the norms.

In our tests, we have used sand from "Giyada" LLP manufacturer (Almaty region, Kazakhstan); it meets the standard [7]. According to this standard, sands with the maximum amount of pulverized and clay inclusions for groups of increased size, large and medium in the amount of 3%, can be used as a fine aggregate for heavy concretes, and SCC comes to this definition as well. However, according to the laboratory and production test results, in order to obtain satisfactory characteristics of the concrete mixture and the final conglomerate, it is necessary to use sand with an amount of dust-like inclusions that does not exceed 1.4%. The test to determine the amount of pulverized and clay inclusions of the sand in question was executed by sedimentation method [7]. According to the test results, the content of pulverized and clay inclusions in the sand under study was 1.07%. Also, according to standard [7], by sieving and determining the aggregate grain composition, the sand size modulus was determined as 2.5. These indicators are acceptable for use both in heavy concretes and in SCC in particular.

Crushed stones of 5-10 mm and 10-20 mm fractions produced by “Arna” LLP (Almaty region, Kazakhstan) were accepted as a large aggregate. This aggregate complies with the requirements of the regulatory document [8], which defines the basic requirements for crushed stone from dense rocks used as a filler for heavy concrete, including SCC.

In this research, we have studied the following as a fine filler:

- Micro-silica by “Tau-Ken Temir” LLP (Karaganda, Kazakhstan);
- Refined ferrochrome slag (hereinafter referred to as RFC slag) by “Aktyubinsk Ferroalloy Plant” JSC (Aktobe, Kazakhstan).
- Fly ash by “Almaty TPP-1” (Almaty, Kazakhstan). [17]

We have used a chemical additive based on 2nd generation AR Premium polycarboxylate esters as a hyper plasticizer; it is produced by “Arirang group” LLP, Astana, and has the following characteristics (Table 1):

Table 1. Technical characteristics of AR Premium AH hyper plasticizer

Indicator	Indicator value
Exterior	Homogeneous liquid of light yellow color
Density at 25º C, kg/m^3	1030 - 1070
pH factor, pH	4
Cl-ion content, not more than	0.1

For volumetric reinforcement purposes, we have used low-modulus polypropylene fiber produced by “PolyTech”, Astana, with the following characteristics (Table 2):

Table 2. Polypropylene fiber technical characteristics.

Indicator	Normative value	Actual value
Chemical formula	Polypropylene	Polypropylene
Type	Monofiber	Monofiber
Fiber length	16-25 mm	Meets the norms
Fiber diameter	17 - 23 mkm	19 mkm
Shape	Round	Round
Surface	Was treated with a special solution that facilitates dispersion and adhesion to cement mortar	
Density	0.88 g/sm³	0.88 g/sm³
Fiber frequency	17.9 mln./kg	Meets the norms
Tension breaking strength (average)	320-500 MPa	Meets the norms
Young's modulus	3400-3800	Meets the norms
Colour	White	White

2.1 Determination of Mineral Additive Optimal Type and Consumption

To determine the efficiency of fine mineral additives made of industrial waste, we have conducted tests aimed at obtaining concrete mixtures with the same cone spray (75 cm) and determining the concrete strength characteristics at different hardening times (3, 7, and 28 days). As part of this test, the control plant composition of C30/35 class self-compacting concrete with no fiber reinforcement was accepted as a control composition [20].

Table 3. SCC composition (control)

W/C	Cement, kg/m³	Sand, kg/m³	Crushed stone, 5-10 mm, kg/m^3	Crushed stone, 10-20 mm, kg/m^3	Additive, kg/m³	Microsilica, kg/m³
0.37	40	900	625	50	6.5	5

A Standard Abrams cone was used to determine the cone flow. The cone and the metal sheet were wetted, and then the cone was mounted on the metal sheet with a smaller base on the surface of the sheet. The concrete mixture was poured until the cone was completely filled in one step. The cone was lifted for 5-7 seconds, and after the mixture stopped completely, the two largest diameters of the spread were measured. The arithmetic mean of the two largest spreading diameters became the test result. According to [10], SCC is classified into three workability classes.

Table 4. SCC classification by workability indicator

Class	Cone flow, mm
SF 1	550-650
SF 2	660-750
SF 3	760-850

Further on, it was necessary to review the effect of the mineral additive (made of industrial waste) type and amount on the workability of the SCC concrete mixture [9].

To analyze the mineral additives based on industrial waste efficiency, we have developed mix compositions to obtain a 75 cm cone. The obtained compositions are presented in Table 5 below.

Table 5. SCC concrete mix compositions

Component	unit	Composition number			
		1	2	3	4
Cement	kg/m³	540	440	440	440
Microsilica		55	0	0	155
Ashes		0	0	155	0
RFC slag		0	155	0	0
Water		220	230	250	215
Sand		900	960	800	1000
Crushed stone 5-10		625	440	550	470
Crushed stone 10-15		150	290	315	250
PCE additive		16,5	18,0	19,5	15,5
Cone flow	mm	700	720	680	750
W/C ratio		0,37	0,39	0,42	0,36

After analyzing the compositions for workability and water-cement ratio, we have determined the most promising mineral additive in terms of rheological parameters. The further research structure was targeted at comparing indicators of popular classes of self-compacting modified concrete physical, technical, and operational characteristics by using the most efficient mineral additive obtained as a result of mathematical calculation using a system of equations and experimentally confirmed by laboratory kneading and research of physical, operational and 3/28 days technical and characteristics. All studies and tests were executed according to the currently valid standards [10,19].

3.2 Popular Classes Concrete Composition Estimation

The estimation includes 4 stages:

• Technical specification, which must contain the minimum permissible value of the ultimate strength based on the molding conditions, along with usual requirements towards concrete strength and concrete mixture workability,

• Raw materials selection and collection of the necessary data characterizing their properties;

• Concrete mixture composition estimation is used to determine the main components' consumption in kg per 1 m^3.

• Experimental verification of the obtained composition and its adjustment (if necessary).

First, we determine the specified concrete compressive strength Rb by the dependence of concrete strength on the cement activity Rc and the water-cement ratio

$$R_b = \frac{R_c}{k\left(\frac{W}{C}\right)^n} \tag{1}$$

Where k and n are coefficients depending on concrete type of and aggregates quality f. According to N.M. Belyaev, for heavy concrete n = 3/2, when using crushed stone k = 3.5, gravel k = 4. The formula is valid for the estimation of the strength of concrete that has hardened under normal temperature and humidity conditions and was tested according to the standard method at 28 days of age. [11]

Further composition calculation is based on solving a system of equations of self-compacting concrete, which include mathematical expressions already known and widely used in practice, such as basic concrete strength law, equation of absolute volumes, which together makes it possible to ensure the relationship between main components consumption and properties with concrete strength and concrete mixture workability.

$$\begin{cases} R_{\text{Б}} = R_{\text{c}} * \text{A} * \left(\frac{\text{C}}{\text{W}} \pm 0{,}3\right) \\ \frac{\text{W}}{\rho_{\text{w}}} + \frac{\text{C}}{\rho_{\text{c}}} + \frac{\text{S}}{\rho_{\text{s}}} + \frac{Cs}{\rho_{\text{c}}} + \frac{\text{M}}{\rho_{\text{m}}} + \text{F} = 1 \end{cases} \tag{2}$$

where: Rб is specified concrete strength, MPa; Rc – cement activity, MPa; A – coefficient, assuming aggregate quality; C, W, S, Cs, M, F – use of cement, sand, crushed stone, fillers and aggregates, fiber per 1 m^3 of concrete, kg; fiber consumption is determined by workability indicators by trial kneading ρц, ρп, ρщ, ρв, ρн –cement, sand, crushed stone, water, filler grains density in kg/m^3;

Based on self-compacting concrete control compositions obtained by estimations, 4 main classes of modified self-compacting concrete composition were selected separately with a micro-filler-silica and separately with a micro-filler and fiber, the summary data for which are shown in Table 6.

From Table 6 summary describing popular classes of self-compacting concrete compositions, it can be seen that the replacement of a part of cement up to 30% by MKU micro-silica in #2 concrete compositions allows to reduce cement consumption by up to 20% without losing concrete mixture workability characteristics. Next research stage was laboratory test of selected compositions to determine their physical, technical and operational properties.

2.3 Determination of Main Strength Characteristics - Compression and Bending Tension

As part of the compression and tensile bending tests, we have formed samples in 2FK 100 and FP 100 forms according to [9] from the control composition mixture and further, from each subsequent test composition from Table 6. Later, after the samples reached the 28-days age, tests were carried out according to [21].

Table 6. Materials consumption per 1 m^3 of concrete mix

№	Concrete class, V	Cement CEM I 52,5H, kg	Fiber (12 мм), kg	Microsilica MKU, kg	Hyperplasticizer PCE, kg
1	C 25/30	500	-	50	16,0
	C 30/35	540	-	55	16,5
	C 35/40	560	-	65	17,0
	C 40/45	585	-	80	17,5
2	C 25/30	410	-	130	14,1
	C 30/35	440	-	155	15,5
	C 35/40	450	-	165	16,8
	C 40/45	465	-	180	17,0
3	C 25/30	410	6	125	14,5
	C 30/35	440	6	150	15,8
	C 35/40	450	6	160	17,2
	C 40/45	465	6	170	17,7

№	Concrete class, V	Crushed stone 5-10 мм, kg	Crushed stone 10-15 мм, kg	Sand, kg	Water, l	Total consumption, kg
1	C 25/30	635	175	900	200	2460
	C 30/35	625	150	900	220	2490
	C 35/40	600	150	900	225	2500
	C 40/45	585	145	880	230	2505
2	C 25/30	650	200	870	220	2480
	C 30/35	635	180	860	215	2485
	C 35/40	635	170	850	220	2490
	C 40/45	630	160	835	225	2495
3	C 25/30	650	190	860	230	2471
	C 30/35	635	170	840	240	2481
	C 35/40	635	160	830	245	2486
	C 40/45	625	155	820	250	2491

Note: Concrete mix flow rate grade is SF 2

Concrete bending tension strength was calculated with an accuracy of 0.01 MPa according to the formula:

$$R_{bt} = \delta \frac{Fl}{ab^2} K_W \qquad (3)$$

where F – destructive load, H;

a, b, l, - the width, height of prism cross-section and the distance between the supports, respectively, when testing samples for tensile bending, mm;

δ – scale coefficients for bringing the concrete strength to the concrete strength in basic size and shape samples;

After obtaining compressive strength data and samples bending tension strength calculations (Table 6), we have determined microsilica and bulk fiber reinforcement dependence on the bending tension strength.

2.4 Concrete Frost Resistance Determination

The frost resistance test was executed according to the second accelerated method according to [15], by freezing samples saturated with sodium chloride in air and then thawing them.

After obtaining frost resistance data, we determined the dependence of modifiers and volumetric fiber reinforcement effect on concrete frost resistance (Fig 3).

2.5 Concrete Water Absorption Determination

Tests to determine concrete water absorption were conducted according to [14], where concrete samples were placed in a container filled with water so that the water level in the container was about 50 mm above the upper level of placed samples. The samples were placed on gaskets in such a way that the height of the sample was minimal (prisms and cylinders were placed on their side). The water temperature in the tank should be (20 ± 2) ° C. Samples were weighed every 24 hours of water absorption on conventional or hydrostatic scales with an error of no more than 0.1%. When weighing on conventional scales, samples taken out of the water were pre-wiped with a wrung-out damp cloth. The test was carried out until the results of two consecutive weightings differed by no more than 0.1%.

The concrete water absorption of each sample Hm, % wt., was calculated with an error of up to 0.1% according to the formula:

$$W\text{м} = \text{Mв} - \text{Mc}/\text{Mc} * 100\% \qquad (4)$$

Where: Mв - mass of the water-saturated sample, g; Mc – mass of dry sample, g.

After getting water absorption data (Table 7), we determined the dependence of modifiers and volumetric fiber reinforcement impact on concrete water absorption (Fig.2).

3. RESULTS AND DISCUSSIONS

According to the tests results of the self-compacting concrete compositions with fillers made of industrial waste, reflected in Table 5, we can assume the following:

- #3 mixture with the addition of fly ash as a filler has the highest water demand (the smallest cone flow along with the highest consumption of PCE plasticizer, with the highest water-cement ratio W/C), which of course will affect the strength characteristics of the final conglomerate;
- the highest cone flow indicator with the lowest PCE plasticizer consumption indicators and the lowest water-cement ratio W/C shows #4 composition with microsilica addition to replace up to 30% of cement [22].

Based on this, it is microsilica that should be considered acceptable for utilization, and which is consistent with the authors' opinion [12].

Next popular classes of self-compacting concretes estimations and tests reflected in Tables 6 and 7 confirmed the hypothesis that in order to obtain SCC high strength characteristics, it is microsilica that should be used as a fine filler [13].

Table 7. Physical and mechanical properties of the being researched concrete compositions

№	Concrete project class	Compressive strength, MPa (R_c)		Bending strength, MPa (R_B)	
		After 3 days	28 days	After 3 days	28 days
1	C 25/30	22,2	33,5	4,37	5,21
	C 30/35	27,1	38,9	4,4	5,24
	C 35/40	30,1	45,1	4,42	5,26
	C 40/45	35,0	53,5	4,45	5,29
2	C 25/30	26,3	34,7	4,81	5,41
	C 30/35	29,5	39,6	5,17	5,53
	C 35/40	40,4	45,8	5,25	5,58
	C 40/45	48,3	54,7	5,36	5,71
3	C 25/30	27,3	34,8	5,8	6,87
	C 30/35	29,6	40,2	6,1	6,94
	C 35/40	40,4	50,1	6,17	7,01
	C 40/45	47,8	54,5	6,45	7,12

№	Concrete project class	Frost resistance, cycles (F)	Volumetric water absorption, %	Average concrete density, kg/m^3
1	C 25/30	220	7,1	2454
	C 30/35	220	6,8	2475
	C 35/40	220	6,5	2477
	C 40/45	220	6,0	2485
2	C 25/30	250	6,2	2451
	C 30/35	250	5,7	2467
	C 35/40	300	5,0	2496
	C 40/45	300	4,7	2504
3	C 25/30	340	5,1	2455
	C 30/35	340	4,4	2467
	C 35/40	340	4,0	2475
	C 40/45	340	3,6	2481

Based on obtained strength results, it follows that the calculated characteristics of all 3 compositions of C25/30, C30/35, C35/40, C40/45 classes self-compacting concretes comply with the norms, however, #2 concrete composition with up to 30% of cement replacement with microsilica show a noticeable increase in concrete compressive strength at 3-days early age to 35%, this early increase in strength with an increase in the amount of microsilica in the mixture corresponds to theoretical assumptions about the appearance of additional crystallization centers and a decrease in pore space in the concrete body during the use of reactive pozzolanic additives (active silica SiO_2), since the process of binding $Ca(OH)_2$ by an active mineral additive – SiO_2 into a poorly soluble compound – calcium hydrosilicate according to the equation: $Ca(OH)_2 + SiO_2 + mH_2O = CaO*SiO_2*nH_2O$. It also follows that #3 concrete composition with up to 30% of cement replacement with microsilica and volumetric 12 mm fiber reinforcement with low-modulus polypropylene fiber in an amount of up to 1.5% of the binder shows an increase in bending strength up to 35%, this clearly confirms the reliability of the theory of the need for self-compacting concretes volumetric fiber reinforcement with low-modulus polypropylene fiber in order to improve their crack resistance and increase concrete resistance to bending loads. [18]

Figures 2 and 3 show the dependence of concrete volumetric water absorption and frost resistance on the use of modifiers and volumetric fiber reinforcement.

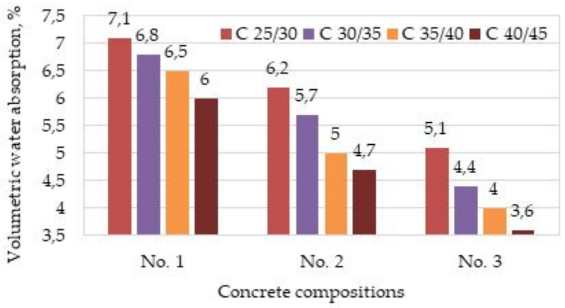

Fig.2 Dependence of concrete volumetric water absorption on the use of modifiers and volumetric fiber reinforcement: No.1 – with the addition of 10% MCU; No.2 – with the addition of 30% MCU; No.3 – with the addition of 30% MCU and fiber.

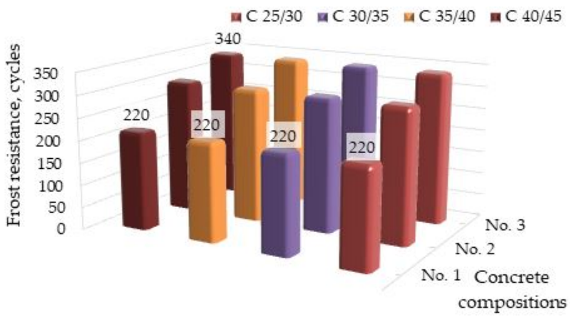

Fig.3 The dependence of the concrete frost resistance on the use of modifiers and volumetric fiber reinforcement: No.1 – with the addition of 10% MCU; No.2 – with the addition of 30% MCU; No.3 – with the addition of 30% MCU and fiber.

The results of modified concretes tests on water absorption and frost resistance show a general tendency to increase the frost resistance index from F220 for concretes without additives to F340 for modified concretes of the same classes. Also, volumetric water absorption rates are reduced by up to 30% [18]. This indicates that the obtained results correspond to theoretical assumptions about the creation of additional crystallization centers and coordinate reduction of pore space in the concrete body by using reactive pozzolanic additives (active SiO_2 microsilica) and the hypothesis that the surface of fibers is the basis for dense and durable layer forming cement neoplasms [3,4]. The microparticles binding inside the cement system allows us to judge them as independent elements of the concrete structure interacting with the dispersion medium through the interface of the phases, as a result, the contact zones of these surfaces, composed of neoplasm products, merge with each other, forming a fiber-cement framework, the density and strength of which is higher than at rest of the material [23,29].

Based on this subject literature analysis [24,25], it follows that little attention is paid to the issue of reducing cement proportion in the concrete composition. This important issue comes from not only economic but also environmental aspects, as huge emissions of carbon dioxide (CO_2) occur during the firing of carbonate raw materials at Portland cement production [6]. Also, little attention is paid to assessing the durability and serviceability of products made of heavy concrete. In practice, and not always, they use only the frost resistance determining method [26], which is used both when selecting the composition of concrete and in the process of quality control of concrete products and structures. The development of modified concretes, considering reducing their cost by decreasing the amount of Portland cement in concrete composition and improving their quality and durability in relation to operating conditions, is topical [24]. Complex studies to improve physical and technical characteristics in terms of frost resistance indicator assessment allow objective estimating of the service life of modified concrete. Similar characteristics also include the bending strength and indicators of operational durability and longevity. The latter includes an assessment by volumetric water absorption and an assessment of meteorological features of the region (transition through the zero-degree mark during the year and ambient humidity) [27,28]. These developments enable design and construction organizations to use modified concretes expediently in construction.

4. CONCLUSIONS

Based on micro-fillers test on the opportunity of their use in self-compacting concrete when using RFC slag as a micro-filler, it is possible to obtain SCC with a cone flow index of 720 mm at V / C = 0.39, with a satisfactory plasticizer consumption of 18.0 kg per 1 m^2 of concrete mixture.

The test results are comparatively worse when using TPP ashes – we faced decrease in the cone flow to 680 mm and the highest water-cement ratio of 0.42, also PCE plasticizer consumption is higher than at other being researched compositions.

When replacing a part of cement with microsilica in an amount of up to 30%, the concrete mixture gets the best characteristics, a cone flow of 750 mm and the lowest plasticizer PCE consumption of 15.5 kg per 1 m with the lowest water-cement ratio of 0.36.

Based on obtained compressive strength data, we can conclude that to get early age strength at (for example) 3 days; builders should utilize the following technological techniques, such as replacing part of the cement in the concrete with micro silica and also reducing the water-cement ratio. If it is necessary to reduce binder consumption, the addition of microsilica or similar mineral additives allows for the preservation of concrete physical and technical characteristics.

Based on the laboratory and industrial tests conducted, we can conclude that such approaches as volumetric fiber reinforcement and the use of concrete modifiers are justified both economically and practically. So, unlike standard concrete compositions, modified concretes can save up to 20% cement, keeping the best frost resistance indicators up to F340 and reducing the volume of water absorption by 30%, which will undoubtedly have a good effect on operational characteristics.

Re. important concrete strength and bending strength indicators. According to the research results, we can say that the use of polypropylene synthetic fiber in optimal amounts of 1-2% by weight of the binder should be justified to improve an important concrete characteristic – bending tension strength. The use of volumetric fiber reinforcement improves the physical, technical, and deformation characteristics of self-compacting concrete compositions, in particular, increases bending strength by up to 35%. Based on the experiments that were conducted, it can be summarized that it is possible to recommend the use of microsilica and volumetric reinforcement with polypropylene fiber in certain dosages to reduce cement consumption and improve the strength and performance properties of self-compacting concretes.

In general, we should note that the research purpose and tasks were successfully achieved, and we have received the necessary results for successful practical application.

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