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EFFECT OF MODIFIER MB10-50C ON THE PHYSICAL AND MECHANICAL PROPERTIES OF HIGH-STRENGTH FINE-AGGREGATE "POWDERY" CONCRETE

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ABSTRACT

In this study we used concrete modifier MB10-50C, an admixture on an organic-mineral basis contained of micro-silica, fly ash, hardening regulator, superplasticizer, to produce the high-strength fine-aggregate "powdery" concrete (HSFPC). We produced samples of HSFPC with dimensions of 100x100x100 mm and 100x100x400 mm. The physical and mechanical characteristics of HSFPC, such as: compressive strength, tensile strength at bending, strength at axial tension, cracking moment, HSFPC grade, and elastic modulus, at the curing periods of 7, 14, 28, 60 days, have been determined. The research results have been implemented in the construction of high-rise buildings of the Moscow International Business Center "Moscow City", and in reconstruction of the Engineering Faculty building of the RUDN University.

Keywords: compressive strength, tensile strength at bending, strength at axial tension, cracking moment, elastic modulus.

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1. INTRODUCTION

Currently, the design and construction of high-rise buildings are being intensively carried out all over the world. Every year the construction projects are becoming more and more challenging. And the built projects clearly prove that what decades ago seemed impossible, today is a real operating building that has changed the usual image of the city. Construction of high-rise buildings requires the use of high-performance materials, which provide the very possibility of erecting the objects, and also allow the use of optimal architectural and structural solutions.

To date, the high-strength concretes with compressive strength of more than 100 MPa have been developed and are actively introduced, and is producing on an industrial scale [1, 2]. Over the past decade, the studies have been carried out on the basic physical and mechanical properties of coarse-aggregate high-strength concretes [2, 3].

Many researchers studied the compressive behaviors of high-strength concrete [4-9], however, behaviors of high-strength concrete under the tensile were not studied enough.

The properties of fine-aggregate high-strength concretes are studied by many researcher [4,10-15], and for them all basic physical and mechanical characteristics are not identified yet. At the same time, the high-strength and ultra-high-strength concretes are much more brittle [2], and this feature of the failure of high-strength and ultra-high-strength concretes is also very substantial, but very little researchers have been studied these matters.

Some researchers studied the effect of different admixtures on the high-strength concrete [13, 16-21], however the total physical and mechanical properties of high-strength concrete with modifiers (admixtures) are not studied enough.

The aim of the study is to determine the physical and mechanical properties, such as compressive strength, tensile strength at bending, strength at axial tension, cracking moment and elastic modulus, of modified high-strength fine-aggregate "powdery" concrete (HSFPC) with organic-mineral based admixture MB10-50C.

2. MATERIALS AND METHODS OF RESEARCH

Within this study the high-strength concrete with fine-aggregate, with the compressive strength of more than 120 MPa, is selected as the basic research material, which finds the increasing application in the contemporary construction, especially in high-rise buildings.

The study of HSFPC was carried out with the following composition: Portland cement of type I = 930 kg/m^3 as the binder; concrete modifier MB10-50C (an admixture on an organic-mineral basis containing micro-silica, fly ash, hardening regulator, superplasticizer) = 370 kg/m^3; river sand with a fineness modulus of 2.7 = 870 kg/m^3 as the fine aggregate; water = 205 l/m^3.

All HSFPC samples were made from a single concrete mixture. Concreting of the HSFPC samples took place in the construction site laboratory during construction of the Moscow International Business Center "Moscow City".

Laboratory experiment was carried out in accordance with the CIS Interstate Standard "GOST" [22-24].

Within this study we produced total eight series of test samples of HSFPC from the stated composition with dimensions of 100x100x100 mm – four series and 100x100x400 mm – eight series. In accordance with the plan of experiment, each series consists of three samples, twelve in each type, total 36 samples.

All samples were cured in air-humid condition in wet sawdust at the room temperature of 19-22 °C.

Laboratory tests were carried out at the curing periods of 7, 14, 28, 60 days on a hydraulic press of up to 5000 kN at the compression test, and up to 200 kN at the tensile test.

Compressive strength was identified by the following formula [24]:

$$R_c = \alpha \cdot \frac{F_c}{A}$$

where α is the scale factor on compression test, α = 0.95 for cubes with the dimensions of 100x100x100 mm; F_c is the failure load on compression; A is the surface area of the sample.

The concrete grade was identified by the formula (GOST 53231-2008, 2009):

$$C_f = 0.8\, R_t$$

where R_t is the actual concrete strength according to the test data, $R_t = R_c \cdot \alpha$.

Tensile strength at bending was identified by the following formula [24]:

$$R_{ct} = \delta \cdot \frac{F_t \cdot l}{a \cdot b^2}$$

where δ is the scale factor for tensile test, δ = 0.92 for prisms with the dimensions of 100x100x400 mm; F_t is the failure load on tensile; l is the distance between supports during sample testing; a and b are the width and the height of the cross section of the sample accordingly.

Strength at axial tension was identified by the formula [25]:

$$R_{ctf} = \frac{R_{ct}}{1.75}$$

Cracking moment was identified by the following formula [25]:

$$M_{crc} = R_{ct} \cdot \frac{bh^2}{3.5}$$

where b and h are the width and the height of the cross section of the sample accordingly.

Elastic modulus was identified by the formula [22]:

$$E_b = \frac{\sigma_1}{\varepsilon_y}$$

σ_1 is the compression stress increment from the zero load up to the load of 30% of the failure, determined by the formula [22]:

$$\sigma_1 = \frac{P_1}{F}$$

P_1 is the load equal to 30% of the failure load; F is the cross-sectional area of the prism;

ε_y is the total relative elastic-instantaneous longitudinal deformation at the loading stages from the zero load up to the load of 30% of the failure, determined by the formula [22]:

$$\varepsilon_y = \frac{\Delta_y}{l}$$

Δ_y is the total absolute elastic-instantaneous longitudinal deformation at the loading stages from the zero load up to a load of 30% of the failure; l is the deformation measurement base.

3. RESULTS AND DISCUSSION

The most important physical and mechanical characteristics of concrete are the compressive strength, tensile strength at bending, strength at axial tension, cracking moment, concrete grade and elastic modulus. Applicability of HSFPC in the construction depends on these characteristics.In the framework of this study we carried out the experimental determination of compressive strength, tensile strength at bending, strength at axial tension, cracking moment, concrete grade and elastic modulus at axial compression of HSFPC prepared with modifier MB10-50C.

To determine the physical and mechanical properties of HSFPC, the following types of test samples were examined:

1. Four series of the HSFPC samples of 100x100x100 mm of cube shape were tested to determine the compressive strength (cubic strength) and HSFPC grade. The results of experimental study of compressive strength and HSFPC grade are shown in the Table 1.
2. Four series of the HSFPC samples of 100x100x400 mm of prism shape were tested to determine the tensile strength at bending, the strength at axial tension and the cracking moment. The results of experimental study of tensile strength at bending, strength at axial tension, and cracking moment are shown in the Table 2.
3. The last four series of the HSFPC samples of 100x100x400 mm of prism shape were tested to determine the elastic modulus (shown in the Fig. 5).

Table 1. Result of the laboratory tests of HSFPC samples of 100x100x100 mm, prepared with modifier MB10-50C, on compressive behavior

Curing Period, Days	Samples	F_c,kN	R_c, MPa	α	R_t,MPa	Average R_t,MPa	HSFPCGrade
7	F1	1345	134.5	0.95	127.8	126.79	C101
	F2	1345	134.5	0.95	127.8		
	F3	1313	131.3	0.95	124.7		
14	F4	1393	139.3	0.95	132.3	135.28	C108
	F5	1440	144.0	0.95	136.8		
	F6	1439	143.9	0.95	136.7		
28	F7	1446	144.6	0.95	137.4	139.39	C111
	F8	1479	147.9	0.95	140.5		
	F9	1477	147.7	0.95	140.3		
60	F10	1568	156.8	0.95	149.0	145.50	C116
	F11	1509	150.9	0.95	143.4		
	F12	1518	151.8	0.95	144.2		

Table 2. Results of the laboratory tests of HSFPC samples of 100x100x400 mm, prepared with modifier MB10-50C, on tensile behavior

Curing Period, Days	Samples	F_t,kN	R_{ct}, MPa	R_{ctf}, MPa	M_{crc}, N.m	Average R_{ct}, MPa	Average R_{ctf}, MPa	Average M_{crc}, N.m
7	P1	24.1	7.23	4.13	1105.71	7.23	4.13	1106.59
	P2	24.4	7.32	4.18	1119.26			
	P3	23.9	7.16	4.09	1094.80			
14	P4	28.3	8.49	4.85	1298.16	8.01	4.57	1212.76
	P5	27.0	8.11	4.63	1204.04			
	P6	24.8	7.43	4.25	1136.08			
28	P7	35.7	10.72	6.13	1639.14	10.73	6.13	1640.67
	P8	35.4	10.62	6.07	1623.85			
	P9	36.2	10.85	6.20	1659.02			
60	P10	41.5	12.44	7.11	1902.14	12.12	6.93	1853.71
	P11	42.7	12.82	7.33	1960.24			
	P12	37.0	11.11	6.35	1698.77			

Fig. 1 shows the diagram of changes in compressive strength (cubic strength) of HSFPC depending on the curing period.

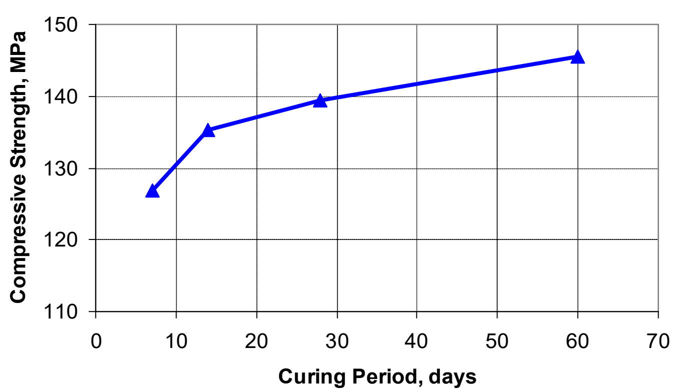

Fig.1. Compressive strength depending on the curing period of HSFPC samples of 100x100x100 mm

Analysis of the diagram in Fig. 1 shows that the strength growth inHSFPC samples is going on very fast up to 7 days, then after 7 days the rate is going down, but smooth and uniform until 60 days.

Study of our HSFPC samples (Table 1 and Fig. 1) prepared with modifier MB10-50C showed that the compressive strength in 7 days of curing can reach up to 125-127 MPa, which is about 90% of the compressive strength of 28 days curing period. It gives the possibility to load structures, such as high strength concrete columns and walls, at an early age.

The average compressive strength after 28 days of curing was 139.4 MPa, and after 60 days of curing was 145.5 MPa – strength increase was only slightly higher than 4% compared to 28 days curing period.

Fig. 2 shows the dependency of the cracking moment on the curing period of HSFPC samples of 100x100x400 mm.

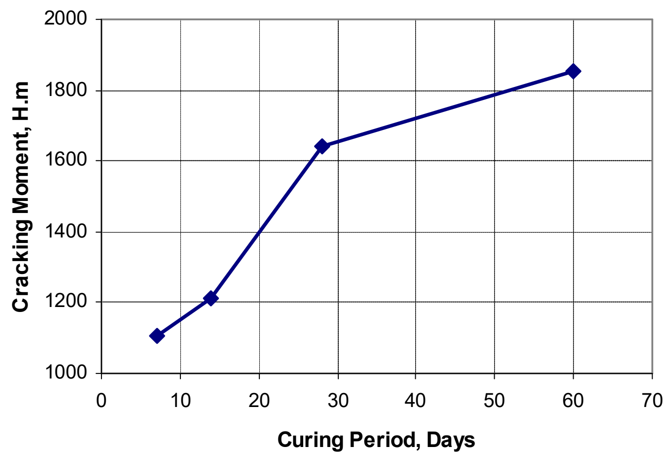

Fig.2. Dependency of the cracking moment on the curing period of HSFPC samples of 100x100x400 mm

An important feature of high-strength concrete is the early strength development. The diagrams in Fig. 3 and Fig. 4 show the kinetics of the tensile strength of HSFPC samples of 100x100x400 mm under the tests at bending and axial tension.

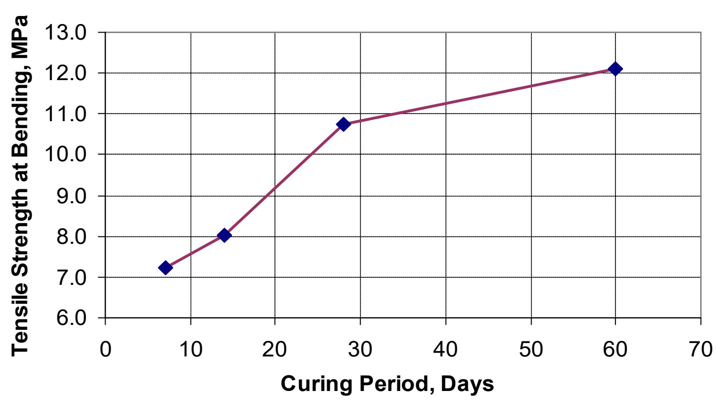

Fig.3. Dependency of the tensile strength at bending on the curing period of HSFPC samples of 100x100x400 mm

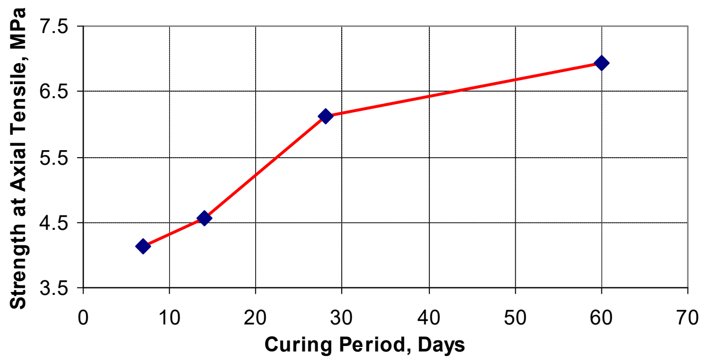

Fig.4. Dependency of the strength at axial tension on the curing period of HSFPC samples of 100x100x400 mm

Analysis of the diagrams (Fig. 2 – 4) show that after 14 days of curing there is an increase in characteristics under tensile load until 28 days, however the rate is going down after 28 days. Study of our HSFPC samples prepared with modifier MB10-50C (Table 2, Fig. 3 and Fig. 4) showed that HSFPC prepared with modifier MB10-50C under tensile load can reach about 7.7% of the compressive strength in 28 days of curing, such as the tensile strength at bending in 28 days of curing reached up to 10.7-10.8 MPa. This feature is very essential to know regarding the possibility to load structures, such as high strength concrete slabs.

Fig. 5 shows the dependency of elastic modulus on the curing period of HSFPC samples of 100x100x400 mm.

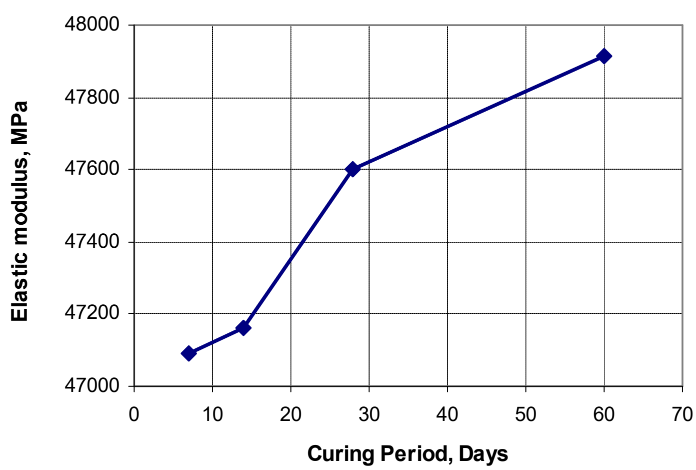

Fig.5. Dependency of the elastic modulus on the curing period of HSFPC samples of 100x100x400 mm

Diagram of Fig. 5 shows that the nature of changes in elastic modulus on the curing period of HSFPC prepared with modifier MB10-50C is same as under tensile load, however first 14 days the rate is low.

Our HSFPC samples prepared with modifier MB10-50C achieved a high abrasion resistance of the material surface, resistance to chipping, and also impact resistance due to the high compressive strength.

The research results have been implemented in the construction of high-rise buildings of the Moscow International Business Center "Moscow City".

For high-strength concrete the early strength development is typical, which allows to effectively use it during reconstruction of historic buildings, and earlier demolition of formworks in cast-in-situ structures. We have been implemented these facts in reconstruction of the Engineering Faculty building of the RUDN University.

4. CONCLUSION

On the basis of the experimental study, the physical and mechanical properties of high-strength fine-aggregate "powdery" concrete prepared with modifier MB10-50C, such as compressive strength, tensile strength at bending, strength at axial tension, cracking moment and elastic modulus were identified.

The obtained results can be considered as the basis for development of the theory of strength of the high-strength fine-aggregate "powdery" concrete prepared with modifier MB10-50C.

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