Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

EFFECT OF MODIFIER MB10-01 ON THE PHYSICAL AND MECHANICAL PROPERTIES OF HIGH-STRENGTH COARSE-AGGREGATE CONCRETE

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Published online: 24 November 2017

ABSTRACT

In our study we used concrete modifier MB10-01, an admixture on an organic-mineral basis contained of micro-silica, fly ash, hardening regulator, and superplasticizer, to produce the high-strength coarse-aggregate concrete (HSCAC)with compressive strength of more than 100 MPa. We produced samples of HSCAC with dimensions of 100x100x100 mm and 100x100x450 mm. The physical and mechanical properties of HSCAC, such as: compressive strength, tensile strength at bending, strength at axial tension, cracking moment and HSCAC grade, 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.

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doi: http://dx.doi.org/10.4314/jfas.v9i7s.37

1. INTRODUCTION

Infrastructure development requires high-performance material, and it also requires many studies. High-strength concrete is a durable material, and it has superior physical and mechanical properties compared to normal-strength concrete because of the hardness of the breakdown [1]. Analyzing the development trends of modern construction, we may notice that they are increasingly linked to the development of concretes on the basis of new technologies (unconventional concretes)[2-5].

Scientific researchers identify the factor of long-term economic effect from the use of unconventional concretes in structures, which is caused not only by their increased strength, but also by high performance properties, such as: frost resistance, corrosion resistance, high water resistance grade etc. [6-8].

In addition, such concretes have an increased workability of the concrete mixture [9-11]. For such concrete, the special term "High-Performance Concrete" or "High-Strength Concrete" is introduced. Some new technologies for the production of high-strength concrete have been worked out in Russia. Among them – theproduction of concrete with using of multifunctional modifiers of MB series on the organic-mineral basis [12-15]. Studies in the field of concrete were limited to the concrete of conventional strength and practically did not touch on the concrete of high strength.Current design codes limit on the concrete strengths due to the limited test data and experience on the behavior of the high strength concrete.

Many researchers studied the compressive behaviors of high-strength concrete [7, 16-20], however, behaviors of high-strength concrete under the tensile were not studied enough.

High-strength and ultra-high-strength concretes are relatively new materials 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 [1, 14]. 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 [2, 3, 11, 13, 21-23], however the total physical and mechanical properties of high-strength concrete with modifiers 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 and cracking moment, of modified high-strength coarse-aggregate concrete (HSCAC) with organic-mineral based admixture MB10-01.

2. MATERIALS AND METHODS OF RESEARCH

Within this study the modified high-strength concrete with coarse-aggregate, with the compressive strength of more than 100 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 HSCAC was carried out with the following composition: Portland cement of type I = 490 kg/m^3 as the binder; concrete modifier MB10-01 (an admixture on an organic-mineral basis contained of micro-silica, fly ash, hardening regulator, superplasticizer) = 110 kg/m^3; sand with fineness modulus of 2.7 = 880 kg/m^3 as the fine aggregate; crushed granite with fraction of 5-15 mm = 730 kg/m^3 as the coarse aggregate; water = 140 l/m^3.

All HSCAC samples were made from a single concrete mixture. Concreting of the HSCAC 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" [24, 25].

Laboratory experiment was carried out in accordance with the CIS Interstate Standard "GOST" (GOST 10180-2012, 2013; GOST 53231-2008, 2009).

Within this study we produced total eight series of test samples of HSCAC from the stated composition with dimensions of 100x100x100 mm – four series; 100x100x450 mm – four series. In accordance with the plan of experiment, each series consists of three samples, twelve in every type, total 24 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 bending test.

Compressive strength was identified by the following formula [25]:

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

where α is the scale factor on compression test, α = 0.95 for cubes of 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 [24]:

$$C_f = 0.8\ R_t$$

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 [25]:

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

where δ is the scale factor for tensile test, δ = 0.92 for prisms of the dimensions of 100x100x450 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 [26]:

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

Cracking moment was identified by the following formula [26]:

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

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

3. RESULTS AND DISCUSSION

The most important physical and mechanical properties of concrete are the compressive strength, tensile strength at bending, strength at axial tension, cracking moment and concrete grade. Applicability of HSCAC 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 and concrete grade at axial compression of HSCAC prepared with modifier MB10-01.

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

1. Four series of the HSCAC samples of 100x100x100 mm of cube shape were tested to

determine the compressive strength (cubic strength) and the concrete grade. This series was numbered as C1, C2, C3, …, C12. The results of experimental study of compressive strength and HSCAC grade are shown in the tables 1.

2. Four series of the HSCAC samples of 100x100x450 mm of prism shape were tested to determine the tensile strength at bending, the strength at axial tension, and the cracking moment. This series was numbered as P1, P2, P3, …, P12. The results of study are shown in the table 2.

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

Analysis of the diagram in Fig. 1 shows that the strength growth inHSCAC samples is smooth and uniform, no jumps or changes are observed.

Table 1. Result of the laboratory tests of HSCAC samples of 100x100x100 mm on compressive behaviour

Curing Period, Days	Samples	F_c, kN	R_c, MPa	α	R_t, MPa	Average R_t, MPa	HSCAC Grade
7	C1	781	78.1	0.95	74.2	71.53	C57
	C2	784	78.4	0.95	74.5		
	C3	694	69.4	0.95	65.9		
14	C4	900	90.0	0.95	85.5	89.13	C71
	C5	941	94.1	0.95	89.4		
	C6	974	97.4	0.95	92.5		
28	C7	1098	109.8	0.95	104.3	103.33	C82
	C8	1084	108.4	0.95	103.0		
	C9	1081	108.1	0.95	102.7		
60	C10	1153	115.3	0.95	109.5	105.66	C84
	C11	1071	107.1	0.95	101.7		
	C12	1114	111.4	0.95	105.8		

Study of our HSCAC samples (Table 1 and Fig. 1) prepared with modifier MB10-01 showed that the compressive strength in 7 days of curing can reach up to 66-74 MPa, which is about 70% 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.

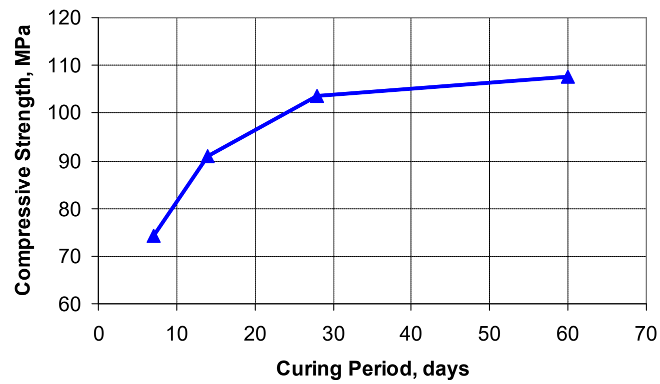

Fig.1. Compressive strength (cubic strength) of HSCAC depending on the curing period of HSCAC samples of 100x100x100 mm

The average compressive strength after 28 days of curing was 103.33 MPa, and after 60 days of curing was 105.66 MPa – strength increase was only slightly higher than 2% compared to 28 days of curing period.

Table 2. Result of the laboratory tests of HSCAC samples of 100x100x450 mm on tensile behaviour

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	22.6	6.78	3.87	1105.7	6.87	3.92	1121.9
	P2	21.5	6.45	3.69	1054.3			
	P3	24.6	7.38	4.22	1205.7			
14	P4	25.5	7.65	4.37	1248.6	7.54	4.31	1231.43
	P5	24.6	7.38	4.22	1205.7			
	P6	25.3	7.59	4.34	1240.0			
28	P7	27	8.1	4.63	1322.9	7.73	4.41	1261.93
	P8	26.3	7.9	4.51	1288.6			
	P9	23.9	7.2	4.11	1174.3			
60	P10	28	8.4	4.8	1371.4	8.33	4.76	1360
	P11	28.8	8.6	4.91	1402.9			
	P12	26.8	8	4.57	1305.7			

Fig. 2 shows the dependency of the cracking moment on the curing period of HSCAC samples of 100x100x450 mm.

Analysis of the diagram (Fig. 2) shows that after 14 days of curing there is a decrease in the cracking moment feature.

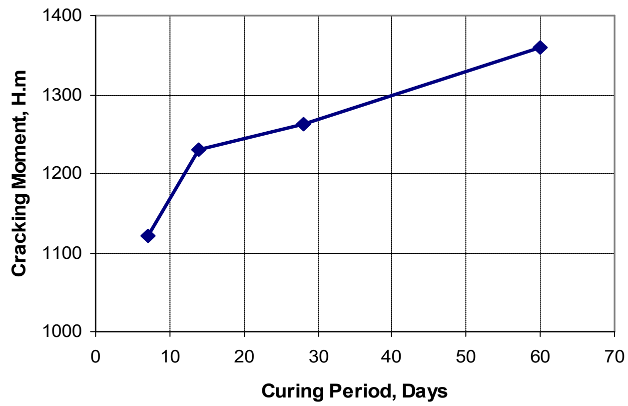

Fig.2. Dependency of the cracking moment on the curing period of HSCAC samples of 100x100x450 mm

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 HSCAC samples of 100x100x450 mm under the tests at bending and axial tension.

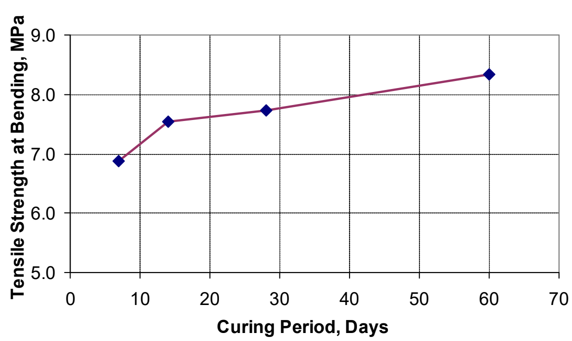

Fig.3. Dependency of the tensile strength at bending on the curing period of HSCAC samples of 100x100x450 mm

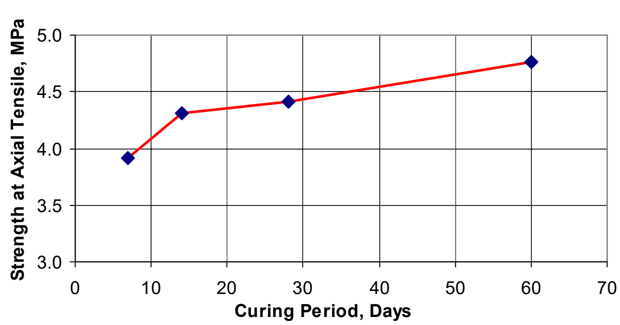

Fig.4. Dependency of the strength at axial tension on the curing period of HSCAC samples of 100x100x450 mm

Study of our HSCAC samples (Table 2, Fig. 3 and Fig. 4) showed that the high strength concrete with modifier MB10-01 under the tensile in 28 days of curing can reach about 7.5% of the compressive strength, such as the tensile strength at bending in 28 days of curing reached up to 7.2-8 MPa. This feature is very essential to know regarding the possibility to load structures, such as slabs.

Our HSCAC samples with modifier MB10-01 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 characteristics of high-strength coarse-aggregate concrete with modifier MB10-01, such as compressive strength, tensile strength at bending, strength at axial tension, cracking moment, were identified.

The obtained results can be considered as the basis for development of the theory of strength of the high-strength coarse-aggregate concrete with modifier MB10-01.

5. ACKNOWLEDGEMENTS

This research work was financially supported by the Ministry of Education & Science of the Russian Federation (Agreement No. 02.A03.21.0008).

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How to cite this article:
Okolnikova G E, Kharun M, Tiekolo D. Effect of modifier mb10-01 on the physical and mechanical properties of high-strength coarse-aggregate concrete. J. Fundam. Appl. Sci., 2017, *9(7S), 391-401*.