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High-Strength Fine-Grained Fiber Concrete with Combined Reinforcement by Fiber

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Abstract: There are reviewed in the study the questions of combined disperse reinforcement of fine-grained concretes with steel wave fiber and polypropylene fiber. There is a possibility to increase the effectiveness of composition astringent which is made by recrushing of portland cement with plasticizing additive “Polyplast premium” in the vibrating mill to the specific surface area 600 m/kg at the expense of control 2 of structure formation processes during the synthesis of cement matrix by use of nanodispersed powder with the specific surface area up to 160 m/kg which is extracted from hydrothermal sources of volcanic 2 regions. The injection of NDP in number of 0.01% of astringent mass precipitates the process of synthesis of new formations by binding of emissive CaO into the hydrosilicates calcion of different basicity during the alite aquation. Such optimization of the cement stone microstructure allows to get an astringent with the activity of 120 MPa. There are proposed the principles of optimization of fine-grained concretes structure: at nanolevel at the expense of use of composition astringent and nanodispersed powder, at microlevel, at the expense of high-density packaging of aggregate at macrolevel-at the expense of the injection of steel and polypropylene fiber. It allowed to develop a wide range of use of fine-grained fiber-reinforced concrete for the monolithic construction with breaking point up to 169.6 MPa by compression, frost-resistance F700 and high deformative characteristics.

Key words: Fine-grained concrete technology sand fiber-reinforced concrete, macrolevel, polypropylene fiber, monolithic construction, deformative characteristics, structure formation

INTRODUCTION

In view of active plan of expansion of house-building in Russian Federation including Belgorod Region, there appeared a wide variety of the materials which are used for the monolithic construction in the market of individual house-building. It is known that for the monolithic construction the concretes must have the high crack resistance compressive, tensile and flexural strength low shrinkage sufficient water tightness and frost resistance. For the securing of these properties it is necessary to develop the effective high-strength concretes.

The reinforced concrete is a classical combination of fine-grained concretes with the addition of different reinforcing agents-of steel, glass or synthetic. This type of concrete is the fiber-reinforced concrete it is meant for development of highly durable constructions. The fiber-reinforced concrete which is used by monolithic construction allows to develop the construction of any complexity and configuration and the fiber-reinforced concrete composites significantly improve the quality and longevity of buildings and constructions (Worner, 1990; Alfes and Wiens, 2010; Alfes, 2006; Grubl *et al*., 2002; Kustermann *et al*., 2005).

MATERIALS AND METHODS

The main part: The properties of high quality fine-grained concrete in many respects depend on the properties of astringent. For the development of fine-grained concrete it is necessary to apply highly active composition astringents (Table 1).

As a base for development of such astringents it was chosen Cem I 42.5 H of production of joint-stock company “Belgorodskiy cement” (Belgorod). The composition astringent was made by recrushing of portland cement with plasticizing additive “Polyplast premium” in the vibrating mill to the specific surface area 600 m/kg. For the purpose of determination of most appropriate plasticizing additive with optimal dosage it was explored its influence upon fine-ground cement (Table 1).

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From the results it is clear that content of “Polyplast premium” in volume of 0.3% of astringent mass gives an optimal minicone spread-D = 164 mm while the other additives demand the injection of higher dosage of additives for gaining an identical plasticizing effect (Fig. 1). It proves the fact that the most effective additive of the tried is the additive “Polyplast premium” which was accepted for further research (Craig *et al*., 1986; Gopalaratnam and Shah, 1986; Klyuev *et al*., 2017; Klyuyev *et al*., 2013; Klyuyev and Guryanov, 2013; Perfilov, 2013; Perfilov *et al*., 2009; Morozov *et al*., 2017).

The structure of cement stone on composition astringent is denser compared to the portland cement, it is a very dense package of grains in the lump of new formations (Fig. 2).

The research of the influence of different riddling fractions upon water and cement requirement allowed to determine that the fraction of <0.315 mm exerts the most negative influence upon these characteristics it is concerned with the fact that the micas containing in quartzite sandstone are destroyed during the crushing and go to the pulverulent fraction. In what follows it was used the carbureted riddling without this fraction (Morozov *et al*., 2017; Pukharenko 2006; Karpenko *et al*., 2013; Rabinovich and Baev, 2009; Lesovik *et al*., 2014; Lesovik *et al*., 2015a, b; Demyanova *et al*., 2006; Kalashnikov *et al*., 2011; Khezhev *et al*., 2018).

The characteristic feature of crush riddlings is the angular form of the grains with highly-developed surface, what promotes the higher adhesion of the cement stone to them (Fig. 3). The research of physico-mechanical characteristics of carbureted crush riddling of quartzite sand stone of Lebedinskoe field allowed to determine the physicomechanical characteristics (Table 2).

Table 1: The results of determination of optimal content of additive for composition astringent

Content of additive, percentage of mass	Material consumption on minicone (g)		Diameter of minicone spread, D (mm)		
	Inventory holdings	Water	Polyplast premium	Polyplast SP-1	SB-3
0.1	100	35	119	60	61
0.2	100	35	137	82	68
0.3	100	35	164	94	77
0.4	100	35	169	120	100
0.5	100	35	170	158	113
0.6	100	35	170	167	134
0.7	100	35	171	170	153
0.8	100	35	-	171	166
0.9	100	35	-	-	171

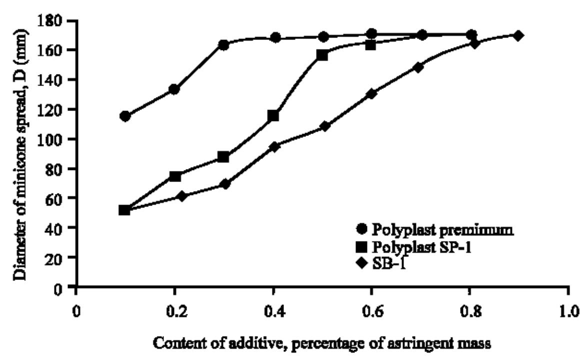

Fig. 1: Dependence of minicone spread on additive content

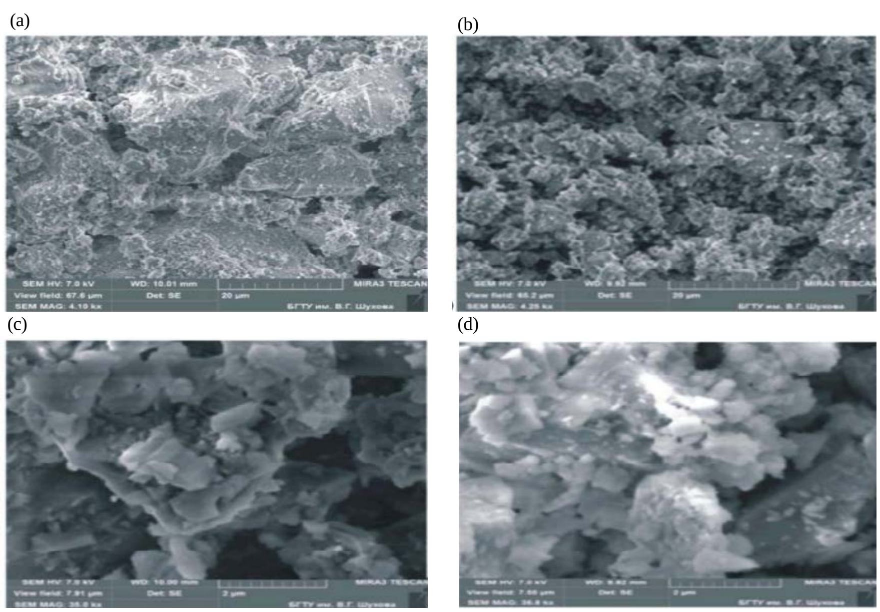

Fig. 2: Microstructure according to properties of astringents: a, c) Morphology of new formations of cement stone Cem I 42.5H and b, d) Morphology of new formations of cement stone of composition astringent

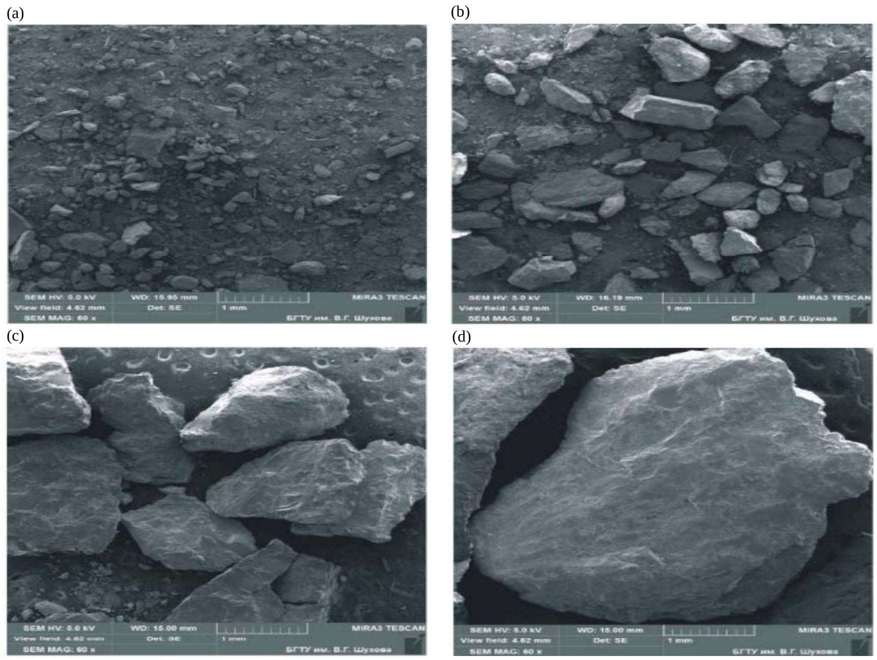

Fig. 3: Photomicrographs of crush riddling of QSS: a) fr. 0.16; b) fr. 0.315); c) fr. 1.25 and d) fr. 2.5

Table 2: Physico-mechanical characteristics of aggregate

Name of index	Unit	Crush riddling
Module of coarseness	Mcoa	4.72
Bulk density in noncompacted state (kg/m^3)	C_{bulk}	1520
Bulk density in compacted state (kg/m^3)	$C_{bulk\ compact}$	1590
Real density (kg/m^3)	C_{real}	2680
Voidness (%)	V	47.8
Water requirement (%)	W	6.5
Cement requirement	C	0.520

Table 3: The results of determination of compression resistance (MPa) of the assays on composition astringent

Age of assay (days)	Content of NDP in developed composition astringent (%)		
	0.1	0.01	0.001
3	91.50	89.100	77.1000
7	103.6	101.20	95.4000
28	124.0	120.80	118.300

RESULTS AND DISCUSSION

As a result of the research and analysis of findings it is determined that the assays on base of composition astringent have the best physico-mechanical indexes with the activity up to 98 MPa. It can be explained with the low index of water requirement of the composite as well as with better spatial packaging of grains in the derived composite. We can draw a conclusion that the application of fine ground astringent with the addition of super-plasticizer allows to increase strength properties of the concrete.

Further optimization of structure of cement matrix was carried out by injection of nanodispersed powder, developed from hydrothermal sources of volcanic regions, to composition astringent (Table 3).

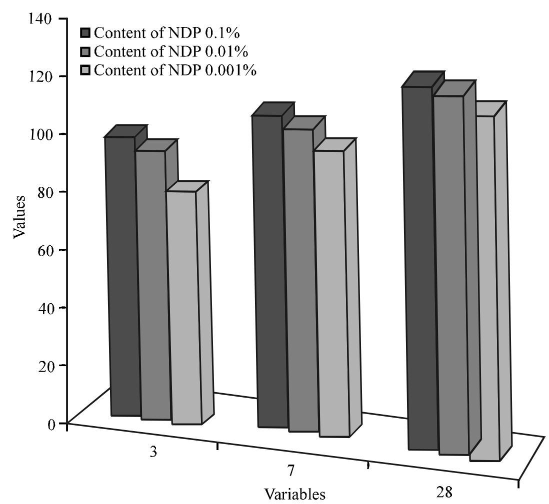

Fig. 4: The dependence of compression resistance of the assays on the content of addirive

The experiments showed that the injection of nanodispersed powder in volume of 0.01% optimizes the structure of cement stone of composition astringent what results in significant increasing of astringent activity up to 120.8 MPa (Fig. 4).

The nanodispersed powder reacts with calcium hydroxide, releasing by aquation of portland cement at the same time the hydrosilicate of second generation is synthesized. A very high specific surface

Table 4: Physical and mechanical properties of fine-grained concrete with high-density aggregate packaging

No. of series	Material consumption (kg/m^3)								
	Astringent		Riddling+sand (Fraction)						Compressive strength,
	C	SP	2.5	125	0.63	0.315	Water	B/B	rcompr (MPa)
1-1	710	-	1540				262	0.37	47.1
1-2	710	-	589	465	291	195	273	0.38	51.3
2-2	710	2.13	589	465	291	195	275	0.36	93.7

Table 5: The physico-mechanical characteristics of fine-grained concrete in dependence on compound of astringent

No. of series	Material consumption (kg/m^3)													
	Astringent (kg)			Crush riddling	Sand		Additive Muraplast	Fiber (kg)			Limit of compressive strength	Limit of flexural strength	Ptism strength	Coefficient of elasticity $E_b \cdot 10^{-3}$
	C	SP	NDP	CAP (kg)	(kg)	W (L)	FK68 (kg)	Steel	Polypropylene	B/B	series (MPa)	(MPa)	(MPa)	(MPa)
1-1	710	-	-	1540	-	262	-	-	-	0.37	47.10	5.30	36.2	31.4
1-2	710	-	-	1150	390	273	-	-	-	0.38	51.30	6.10	39.4	34.2
1-3	710	-	-	1150	390	240	5.76	-	-	0.34	59.00	7.90	45.4	39.3
1-4	710	-	-	1150	390	238	5.76	41.4	4.77	68.40	11.40	52.60	45.6	
2-1	710	2.13	-	1540	-	224	-	-	-	0.32	85.20	8.60	65.5	56.8
2-2	710	2.13	-	1150	390	257	-	-	-	0.36	93.70	10.40	72.0	62.5
2-3	710	2.13	-	1150	390	210	5.76	-	-	0.30	110.60	13.00	85.0	67.0
2-4	710	2.13	-	1150	390	205	5.76	41.4	4.77	126.00	15.60	96.90	84.0	
3-1	710	2.13	0.071	1540	-	180	-	-	-	0.25	120.80	11.00	92.3	80.5
3-2	710	2.13	0.071	1150	390	210	-	-	-	0.30	130.50	13.40	100.4	87.0
3-3	710	2.13	0.071	1150	390	166	5.76	-	-	0.23	150.10	16.90	115.5	100.0
3-4	710	2.13	0.071	1150	390	164	5.76	41.4	4.77	169.60	21.60	130.00	113.1	

area of NDP promote the more effective and faster reaction. Under the appropriate dispersion thousands of reactive spherical microparticles enclose every grain of the cement, compacting the cement stone, filling the hollow spaces with strong products of aquation and improving the adhesion with aggregates (Klyuev *et al*., 2017; Klyuyev *et al*., 2013; Klyuyev and Guryanov 2013).

The effect of filling of vesicles of calcium hydrosilicate of second generation promote the significant reduction of capillary cavity and the decreasing of penetrability of the concrete. Factually impenetrable concrete can be developed by tempered content of powder and relatively low content of portland cement.

For the development of more density packing of aggregate it was used the sand of Shebekino field with module of coarseness 1.2. As an astringent it was applied the portland cement Cem I 42.5 H and developed composition astringent with the use of NDP.

The calculation of high density polyfractional size of the aggregate for high quality concretes is the important factor of increasing of their physico-mechanical characteristics. The determination of grain size of a composite with high-density packing of particles is the practical problem of the research of the granular materials. Therefore, it is necessary to determine the influence of the aggregate upon concrete strength as well as the development of the effective concretes on base of high-density size of the aggregate. On base of high-density packing of crush riddling of quartzite sand stone there were got following results which are represented in Table 4.

In comparison of concrete samples properties to high-density size of the aggregate it was determined the higher strength of the concrete in comparison to analogical composites on normal aggregate the concrete with high-density size of the aggregate has almost 1.5 as much higher strength, than normal fine-grained concrete, what is explained with better spatial packing of grains in the developed composite and features of structure formation (Klyuev *et al*., 2017; Klyuyev *et al*., 2013; Klyuyev and Guryanov 2013).

On the basis of complex researches there were developed composites of fine-grained fiber-reinforced concretes on composition astringent with the use of nanodispersed powder, derived from the hydrothermal sources of volcanic regions with the application of reinforcing fibers (Table 5 and Fig. 5).

The research of physico-mechanical characteristics showed that the properties of the concretes which were produced on composition astringents in all cases exceed the characteristis of the samples of analogical compound, produced on other astringent. We can conclude, the application of composition astringent with the addition of super-plasticizer allows to increase significantly the characteristics of the concrete. The important characteristics of the concrete, used in monolithic construction are water absorption and frost-resistance. These properties have a significant influence upon its longevity in concerning with what the given indexes were researched. The results of the researches prove the possibility of application of derived fiver-reinforced concrete it is determined that the concretes are characterized by low indexes of water absorption as well as high frost-resistance (Table 6).

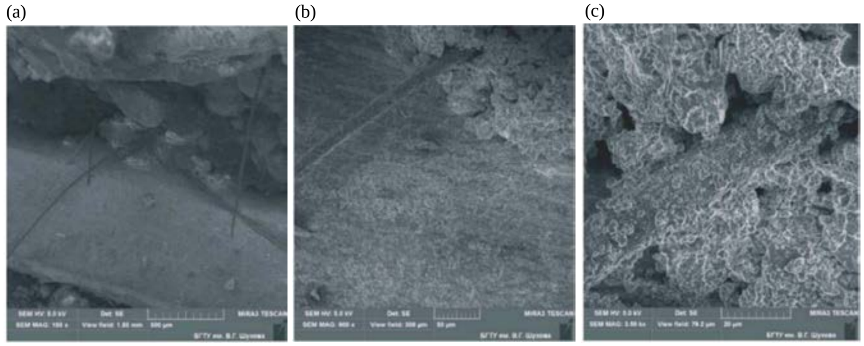

Fig. 5: Microstructure of contact zone of combined reinforcement with fibers and cement stone

Table 6: Water absorption and frost-resistance in dependence of astringent compound

No. of series	Material consumption for 1 m^3 Astringent (kg) C	SP	NDP	Crush riddling CAP (kg)	Sand (kg)	Water (L)	Additive Muraplast FK68 (kg)	Fibre (kg) Steel	Polypropylene	Water absorption	Frost resistance
1-4	710	-	-	1150	390	238	5.76	41.4	4.77	3.8	F300
2-4	710	2.13	-	1150	390	205	5.76	41.4	4.77	2.9	F500
3-4	710	2.13	0.071	1150	390	164	5.76	41.4	4.77	2.0	F700

CONCLUSION

There were developed the composites of high performance fine-grained concretes on the base of composition astringent with the nanodispersed powder, derived from hydrothermal sources and crush riddling of quartzite sand stone, enriched with Shebekino sand for production of high quality concrete. It is determined that the amount of sand for the increasing of density packing of grains of crush riddling of quartzite sand stone averages 25% of mass of technogenic sand. With the purpose of administration of processes of structure formation of the concrete, of technology of its production and regulation of the properties they used: composition astringent with NDP; Complex modifiers of structure and properties includind different chemical additives; mineral raw materials, providing the production of economical and long-lived concretes. There is proposed a compound of composition astringent with nanodispersed powder with providing of limit of compressive strength up to 120.8 MPa. There are developed the fine-grained concretes on composition astringent with NDP and sand for monolithic construction with the limir of compressive strength up to 169.6 MPa with the limit of flexural strength up to 21.6 MPa and with frost-resistance F700.

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