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Efficient concrete increased water resistance modified with mineral and polymeric additives

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Abstract. The article deals with issues of optimizing the composition of efficient concrete increased water resistance, reducing its cost without losing or increasing its basic properties. In recent years, the most effective method of tightness to water in the construction of buried and underground structures, as opposed to the use of bituminous and other traditional materials, is a method based on the use of concrete with increased water resistance. This type of tightness to water is called "White bath" in Europe. The essence of the technology is that the role of the impervious layer is performed directly by the concrete itself. The subject of the study is the composition of self-stressing concrete, which has a high density and fastness to water, but a high price compared to the concrete on Portland cement, which limits its wide application. The aim of the study is the development and optimization of the composition or stressing concrete with desired properties using a variety of mineral and polymeric additives to reduce the cost of the finished product while maintaining or improving the significant operational indicators.

1. Introduction

Process engineers face a number of tasks related to the properties and quality of concrete in modern capital construction. With the traditional device of waterproofing the contour of a building or structure below the ground level, important problems are the low tightness to water and crack resistance of the concrete itself and, as a result, the need to apply various waterproofing compositions based on oil products on its surface. As a result, there is an additional increase in the cost of construction. In contrast to the traditional method of waterproofing, one is used in which waterproofing is carried out by the concrete itself, without applying additional coating materials on it. In Western countries, this method of constructing an underground part of a structure is called the “White Bath”. In the technology of this method are generally used self-stressing concrete and concretes with compensated shrinkage. Self-stressing concrete and concretes with compensated shrinkage differ primarily in self-stress energy. The use of such concretes allows to build seamless structures of great length (up to 500 m) with increased crack resistance and tightness to water due to the developed special technology. The mechanism of hardening of self-stressing concrete is based on the creation of directional crystal formation in hardening

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cement stone and thereby providing an adjustable amount of expansion that occurs in the plastic structure of the material, while under conditions of limited expansion, self-stress is developed to compensate for tensile stress [3]. The problem of such concrete is its cost, because the expanding additive (EA) based on ciment fondu has a high price. The objective of this study is to optimize the composition of self-stressing concrete with desired properties, reducing the quantity of EAs, through the use of various modifying additives, including secondary raw materials obtained from certain types of wastes from the production of metallurgy and the construction industry. It should be noted that the problems of optimizing the composition of the straining concrete, reducing its cost were partially considered by Gridchina, A.A. Titova L.A. [3,6,8]. Development of scientific ideas and recommendations obtaining of concrete with shrinkage compensated on the basis of different expanding agents instead of using a ready-expanding cements were engaged in Zvezdov A.I., Titov M.Yu. [4,5,9]. Issues of composition, structure and properties of self-stressing cements studied by Kuznetsova T. V. [10,12,13,14,15,16], Royak S. M. and G. S. Royak [17].

2. Methods

The object of the study is straining concrete, in which finely ground expanded blastfurnace slag and a polycarboxylate-based superplasticizer were taken as an additive. The following materials were used in experimental studies: standard polyfractional sand (GOST 6139-91), self-stressing cement with medium self-stress energy (GOST R 56727-2015), ballast of broken stone with the largest nominal grain size of 10 mm (GOST 8269.0-97), fine expanded blastfurnace slag. Grinding of expanded blastfurnace slag was carried out in a ball mill under three different modes in order to obtain different particle sizes in order to analyze the dependence of the packing density on their dispersity and, accordingly, select the optimal variant in the selection of parameters of the binder components. For the accuracy of the experiment, it was necessary to determine the size of the particles of cement and expanded blastfurnace slag in three different grinding modes on a laser particle size analyzer FRITSCH ANALYSETTE 22 NanoTec (measurement range from 0.01 to 2100 mkm). Measurement of the density of cement and expanded blastfurnace slag was carried out using a Le Chatelier device according to the method according to GOST 30744-2001. The air permeability method on PSC was used to determine the Blaine specific surface area of the expanded blastfurnace slag. To study the properties of tensile concrete, 4 series of specimens with a size of 10x10x10 cm were manufactured, 4 pieces each. in each sample, with expanded blastfurnace slag content of 15, 20, 25%, respectively, in samples 2,3,4 (Table 1).

Table 1. Concrete composition, kg/m3.

Constituents of concrete	Sample number			
	1	2	3	4
Cement	404	344	324	303
Water	150	150	150	150
Ballast of broken stone	1266	1266	1266	1266
Sand	639	639	639	639
Expanded blastfurnace slag	-	60	80	101
PCE (polycarboxylate)	2,83	2,83	2,83	2,83

At the age of 28 days, cubes were tested for compressive strength according to GOST 10180-2012. Then samples of 4 compositions were made (Table 1), 3 samples in each series, dimensions 50x50x200 mm to determine self-stress according to the method GOST 32803-2014. Maturing of the samples was carried out in special dynamometric conductors, which in the process of expansion of the concrete created an elastic restriction of deformation, equivalent to the longitudinal reinforcement of the prism samples, equal to 1%. Measurements of conductors were carried out daily at the age of 1-7 days and then at the age of 10, 14 and 28 days each time with the calibration of the measuring device with the help of the standard. Then, by calculation, the self-stress value of the sample-prism Sp was determined.

Samples of cylindrical samples with a diameter of 150 mm and a height of 30 mm were also prepared with compositions similar to those used in previous tests (Table 1). According to the method of GOST 12730.5-84, the tightness to water of concrete was determined.

3. Results

As a result of laser analysis of the sizes of particles of cement and expanded blastfurnace slag in three different modes of grinding, the following data are presented in Table 2.

Table 2. Granulometric composition of the studied samples (sample 10 g).

Specimen designation	Average particle size (d50), mkm	Maximum particle size (d98), mkm	Particle content less 2 mkm, %
Self-stressing concrete	14,685	62,456	12,31
Expanded blastfurnace slag initial	11,073	45,022	14,97
Expanded blastfurnace slag (grinding 15 min)	10,882	40,878	14,97
Expanded blastfurnace slag (grinding 30 min)	9,919	37,119	16,65

Also, integral and differential particle size distributions in material samples were obtained. (Figure 1,2,3,4)

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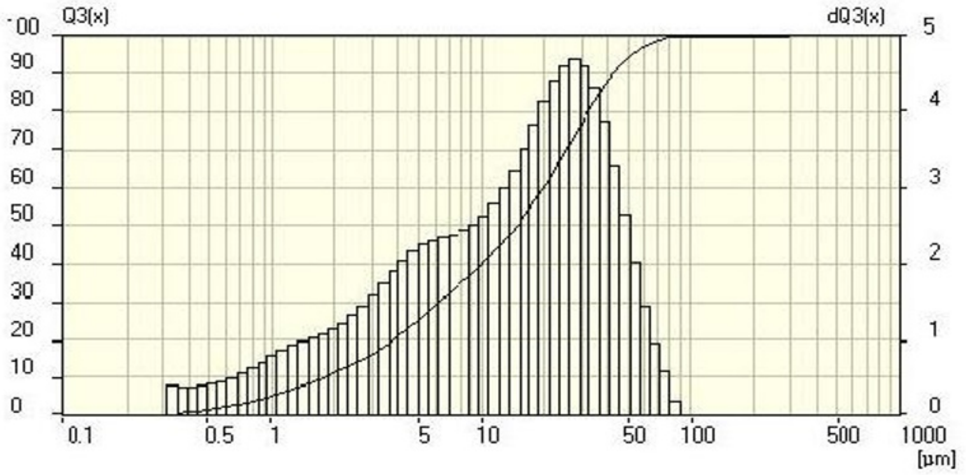

Fig. 1. Integral and differential particle size distribution of the self-stressing concrete sample.

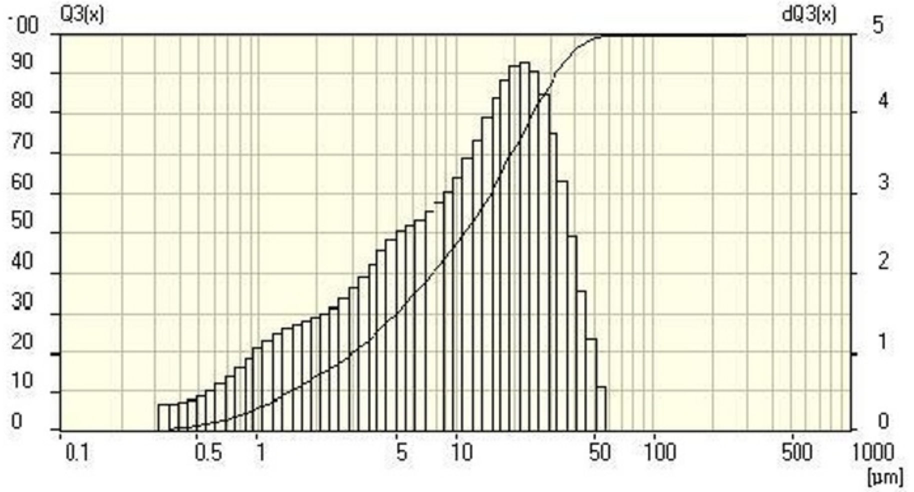

Fig. 2. Integral and differential particle size distribution of the expanded blastfurnace slag sample (initial).

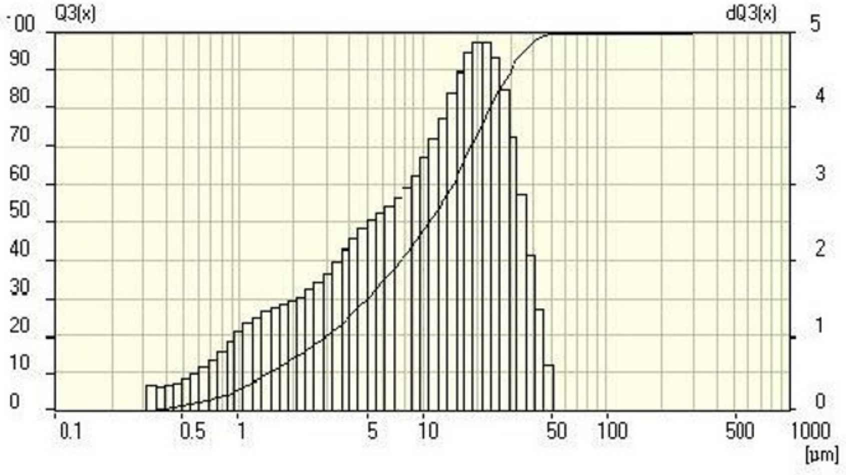

Fig. 3. Integral and differential particle size distribution of the expanded blastfurnace slag sample (grinding time 15 min).

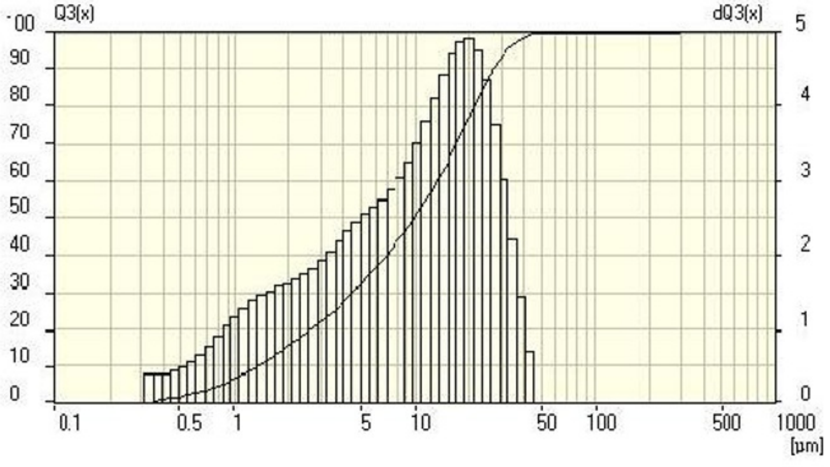

Fig. 4. Integral and differential particle size distribution of the expanded blastfurnace slag sample (grinding time 30 min).

For clarity, the figure below shows a graph superimposed particle distributions or stressing cement and expanded blastfurnace slag in the initial sample (the sample) for size comparison.

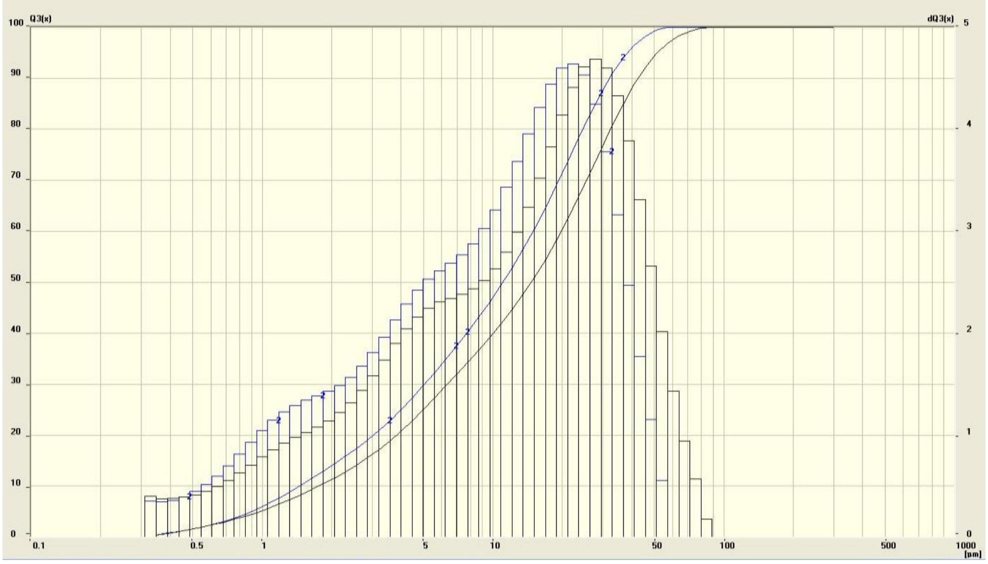

Fig. 5. The imposition of particle size distributions in NC samples (black) and expanded blastfurnace slag initial (blue).

Studies have shown that the true density of cement and expanded blastfurnace slag in the Le Chatelier flask was 2,85 и 2,66 g/cm^3 respectively, and the specific surface of the initial expanded blastfurnace slag was - 4685 cm^2/g according to Blaine. Compressive resistance of concrete at the age of 28 days of four different compositions is presented in Table 3.

Table 3. Compression capacity of self-stressing concrete with finely dispersed expanded blastfurnace slag.

Sample	№ sample	Sample size, cm	Compression resistance, MPa	
			of one sample	average value
«1»	1 2 3 4	9.9x10x9.9 10x10x9.9 10x10x10 9.8x10x10	50.33 51.91 52.08 50.17	51.44
«2»	1 2 3 4	9.7x10x9.9 10x9.8x9.9 10x10x9.9 9.8x10x10	51.11 49.94 52.85 51.32	51.76
«3»	1 2 3 4	9.9x10x9.9 10x10x9.9 10x9.9x10 9.8x10x10	51.55 52.47 51.33 50.56	51.78

«4»	1 2 3 4	10x10x10 10x9.9x10 10x10x9.9 9.9x10x9.7	53.98 52.91 52.20 51.36	53.03

As a result of processing the readings according to GOST 32803-2014 taken from dynamometric conductors, the following values of self-stress were obtained (Table 4)

Table 4. Values of self-stressing concrete with fine expanded blastfurnace slag.

Sample	«1»	«2»	«3»	«4»
Self-stress, MPa	9,95	12,01	13,93	16,40
Type of self-stress	Sp 1,2	Sp 1,5	Sp 1,5	Sp 2,0

Concrete watertightness grade of 1,2 samples is W18, and 3,4 samples – W20.

4. Discussion

Studies show that the physical, hydrophysical and mechanical properties of tensile concrete modified with finely ground slag with a dispersion exceeding the specific surface of the cement used in combination with a polycarboxylate-based liquid polymer superplasticizer composition. An insignificant (2.9%) increase in compression capacity was experimentally confirmed, and the self-stress of concrete with a certain dispersion of slag (samples 4) increased by 2 marks. Such an increase in self-stressing of concrete is due to the fact that expanded blastfurnace slag with a greater dispersion than that of cement is distributed mainly in interparticle voids, increasing the concentration of the solid phase per unit volume and, consequently, increasing the voltage of the entire system. At the same time there is an increase in tightness to water of concrete by 1 step.

5. Conclusions

It was established that with a decrease in certain limits of the content of the binder, which causes expansion or stress of the system and the replacement of its part with an active mineral additive, for example, blast-furnace slag, with greater dispersion, at which its particles are distributed mainly in interparticle voids, an increase in the concentration of the solid phase is achieved in a unit of volume and physico-mechanical properties of tensing concrete. The cost of 1 cubic meter of finished product decreases according to calculations by approximately 12%.

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