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CONCRETE MODIFICATION WITH MODERN POLYCARBOXYLATE ADDITIVES

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Abstract

The intensive development of civil engineering involving constructions of complex architectural configuration; the construction of special buildings of unorthodox design, which in addition endure high loads; the manufacture of process tanks designed to store corrosive liquids and gases; the production of pavements and airfield coatings, etc. – they all require the development of high-quality multifunctional concrete composites that combine enhanced properties and provide operational serviceability. Therefore, obtaining composites with broad functionality will improve the concrete technology and monolithic construction. The paper presents the results of effectiveness analysis of a new generation polycarboxylate superplasticizer with account taken of the peculiarities of its molecular structure and mechanism. The results of the development of high-quality concretes of grades varying from B7.5 to B30 using local raw materials and a superplasticizer based on polycarboxylate ethers are presented. With the use of MasterPozzolith 3150W additive, studies were carried out to study the dynamics of strength gain, longevity, placeability and sedimentation tendency of concrete mix, which will have a beneficial effect on moulding and forming processes of concrete constructions parts.

Keywords: Concrete, concrete mix, molecular structure, polycarboxylate superplasticizer, sedimentation tendency, strength gain

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1. Introduction

The intensive development of civil engineering involving constructions of complex architectural configuration; the construction of special buildings of unorthodox design, which in addition endure high loads; the manufacture of process tanks designed to store corrosive liquids and gases; the production of pavements and airfield coatings, etc. – they all require the development of high-quality multifunctional concrete composites that combine enhanced properties and provide operational serviceability. Therefore, obtaining composites with broad functionality will improve the concrete technology and monolithic construction (Gusev et al., 2012; Liu et al., 2012; Tarasov & Lebedev, 2015; Vovk, 2012).

Various technological approaches are used in the development of enhanced, multi-purpose concretes, which include measures to accelerate the process of hydration of the applied binder which in turn is directly responsible for (Lipich & Balahura, 2024; Regnerová et al., 2024; Shumilina & Antsiferova, 2024):

i. the formation of material and phase compositions,
ii. modification of the structural components of cement stone,
iii. increasing constructibility and technological effectiveness as well as reduced capital costs for the production of concrete and reinforced concrete composites.

2. Problem Statement

The highest priority in terms of modifying the structural components of the cement stone can be put on the use of superplasticizers, given that the main rheological parameter of the commercial concrete mixture is its placeability, while the consistency of the mix (P3 and P4) with a sufficiently low water-cement ratio of up to 0.4 is possible only with chemical plasticization of the system (Berg et al., 2012; Nesvetaev et al., 2003; Plank & Sachsenhauser, 2006; Patil et al., 2016; Salamanova et al., 2015).

The use of superplasticizers in combination with mineral powders will theoretically provide invariably high indexes of concrete strength, its impermeability, resistance to aggressive reagents and, at the same time, should facilitate the simplification of its production technology (Salamanova et al., 2016).

Currently, the construction market is filled with a variety of chemical additives, which differ in composition and mechanisms of their impact on the binder (Figure 1).

It should be noted that sulfinated complex compounds are characterized by a linear structure of the polymer chain and the modification of the binder is accompanied by electrostatic repulsion of particles of clinker minerals, due to the adsorption of their surface by superplasticizer molecules and, as a result, an increase in the negatively charged value of the ʒ-potential (Liu et al., 2012; Tarasov & Lebedev, 2015).

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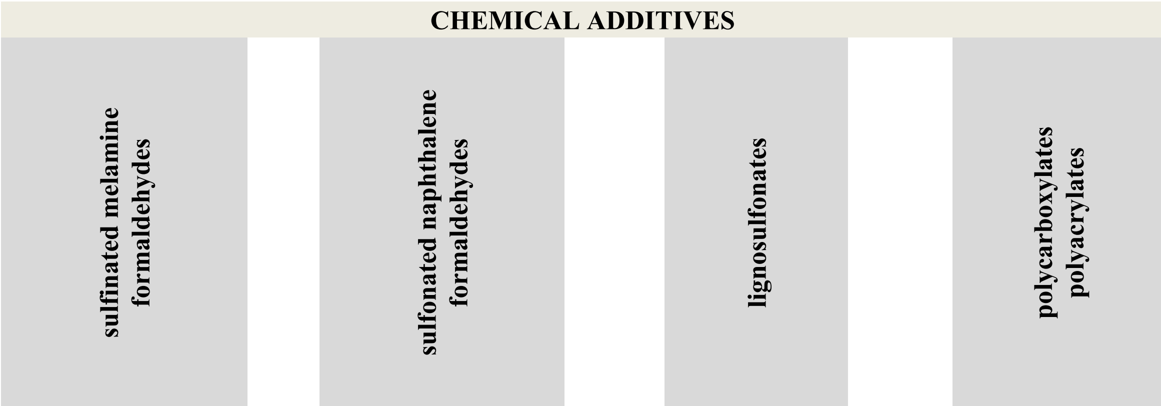

Figure 1. Classification of chemical additives

3. Research Questions

Molecules of polycarboxylates and polyacrylates are represented by spatial networks with transverse links, which create a volumetric protective shell on the surfaces of solid phases; the value of the ʒ-potential is less, but the negatively charged potential leads to steric and electrostatic repulsion of particles. The thickness of the adsorption layer is higher; therefore, the proportion of the adsorbed-bound liquid increases comparatively (Berg et al., 2012). The above arguments confirm the plasticizing and setting effect of chemical modifiers, regardless of the mechanism and structure of the additives.

4. Purpose of the Study

To develop high-quality concrete compositions of B7.5 – B30 grades using local raw materials, a modern chemical additive from the manufacturer BASF – The Chemical Company – Master Pozzolith 3150W was studied.

5. Research Methods

Experimental studies were carried out using the materials most available and in demand for the region. Sampling was carried out in accordance with the requirements of GOST (All Union State standard) 30515-13, GOST 8269.0-97 and GOST 8735-88. Experimental mixtures were prepared in the laboratory using the following components:

i. Portland cement CEM I 42.5N State Unitary Enterprise "Chechencement" – GOST 10178, activity 52.2 MPa, specific surface area 330 m2/g;
ii. Quartz sand of the Chervlensky deposit Ms = 2.8 – GOST 8736;
iii. Crushed stone of fraction 5 20 mm of sedimentary origin of the Argun deposit – GOST 8267
iv. Superplasticizer – Master Pozzolith 3150W based on polycarboxylate esters in liquid form.

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6. Findings

To determine the optimal dosage of the investigated superplasticizer, the additive was introduced with mixing water into the concrete mixture in an amount from 0.5 to 1.2% of the mass of Portland cement. The results of the research are shown in Figure 02 (Ahmad et al., 2024; Singh et al., 2024; Waite, 2024).

The results of the studies showed that with an increase in the dosage of the superplasticizer, the grade in consistency increases, so at a consumption of MasterPozzolith 3150W – 0.8%, a concrete mixture P4 was obtained with a cone slump of 16 cm, with an increase in the introduced modifier to 1.0-1.2% of the mass of Portland cement applied, the grade of consistency reaches P5 with a cone slump of 23 cm. It should be noted that when the dosage of the superplasticizer is 1–1.2%, the start of concrete mixture hardening slows down while the final hardening stage occurs only on the second day under natural hardening conditions.

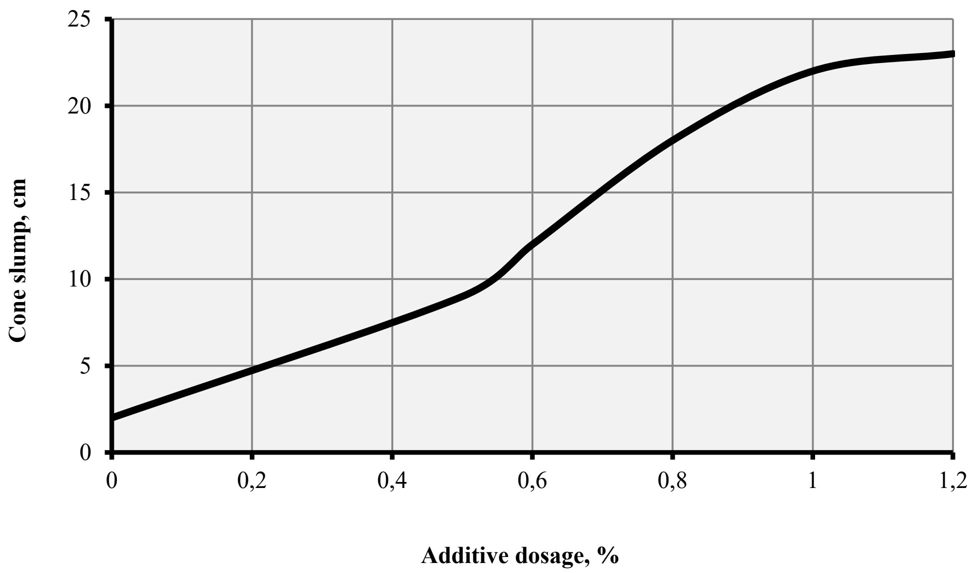

Figure 2. Dependence of the Master Pozzolith 3150W additive dosage on the consistency of mix

Table 1. Recipes and properties of the concrete developed

Mix number	Concrete designation according to GOST 7473	Consumption of materials for 1 m3 of concrete, kg					W/C	Concrete mix density, kg/m^3	Required strength, MPa, equal to or greater
		Cement	Water	Crushed stone	Sand	Master Pozzolith 3150W			
	HCM B7.5 P4 F100 W4	220	200	1080	812	-	0.91	2312	9.8
		215	184	910	970	1.6	0.86	2318	
	HCM B10 P4 F100 W4	238	206	1085	805	-	0.87	2332	13.1
		235	195	915	965	1.7	0.83	2338	
	HCM B12.5 P4 F100 W4	267	210	1090	778	-	0.79	2344	16.4
		260	192	915	945	1.9	0.74	2349	

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HCM B15 P4	310	212	1100	745	-	0.68	2368	19.6
F100 W4	305	189	920	935	2.2	0.62	2371	
HCM B20 P4	358	214	1110	688	-	0.60	2370	26.2
F100 W4	353	194	920	870	2.5	0.55	2373	
HCM B22.5 P4	390	215	1110	658	-	0.55	2373	29.5
F100 W4	385	196	920	320	2.7	0.51	2374	
HCM B25 P4	410	216	1115	635	-	0.53	2376	32.7
F100 W4	405	194	920	838	2.8	0.48	2377	
HCM B27.5 P4	425	217	1125	615	-	0.51	2382	36.0
F100 W4	420	193	925	807	2.9	0.46	2384	
HCM B30 P4	465	219	1130	580	-	0.47	2394	39.2
F100 W4	460	202	925	783	3.2	0.44	2408	

The dosage of Master Pozzolith 3150W – 0.8% is considered optimal, since it has contributed to the production of high consistency concrete mixture, and does not inhibit the hardening process of the composition (Dokuchayeva et al., 2024; Tang & Yang, 2024).

At the next stage, the goal was to develop a line of concrete grading from B7.5 to B40 and to confirm the effectiveness of the polycarboxylate modifier Master Pozzolith 3150W at a dosage of 0.8%. The selection of the compositions of normal heavy concrete was carried out according to the methodology of GOST 27006-86 (2006) "Concretes. The rules for the selection of the composition ", the recipes obtained are shown in Table 1. From the developed compositions, samples were prepared, which were tested in accordance with GOST 10181-2014 Concrete mixtures. Test methods; GOST 18105-2010 Concrete. Rules for the control and assessment of strength; GOST 26633-2015 Heavy and fine-grained concretes. Technical conditions. The kinetics of the strength gain of all the proposed control samples of concrete at the age of 7 and 28 days was traced; Figure 03 shows the test results. It should be noted that the ultimate compressive strength of the control samples of the concretes under study at the age of 7 days showed numerical strength indicators of 71–81.3% of the required strength.

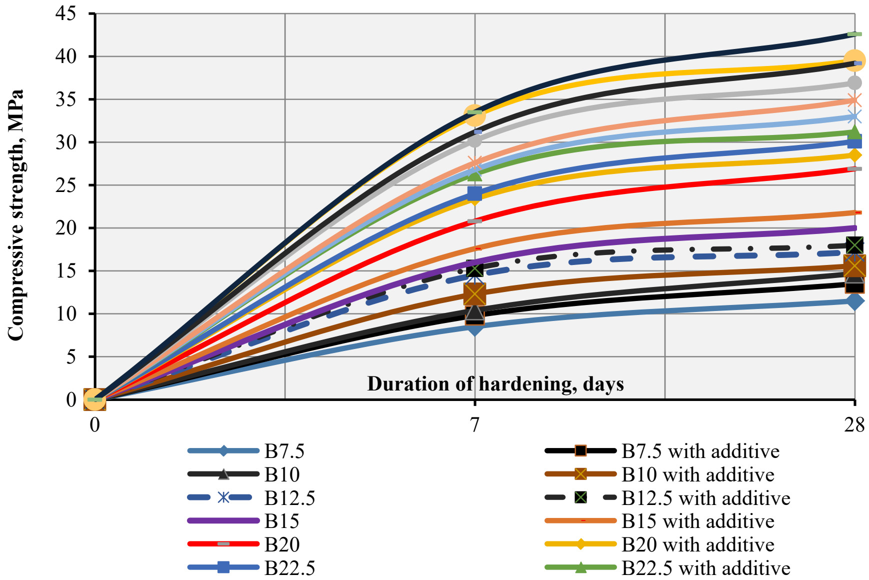

Figure 3. Kinetics of strength gain for concrete test sample of B7.5 – B30 grades

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Analyzing the results obtained, it can be stated that concrete mixes developed with the use of Master Pozzolith 3150W additive in a dosage of 0.8% of the mass of Portland cement showed ultimate compressive strength by 10–15% higher than the strength of samples without the additive. The strength of samples B30 and B27.5 with an additive is higher than B30 samples without additive, the numerical values of strength reached 43.7 MPa and 39.8 MPa and comparable to 39.6 MPa, which confirms the effectiveness of the investigated modifier.

The research made it possible to establish the relationship between the water-cement ratio and such indicators as the strength and density of concrete (Figure 04).

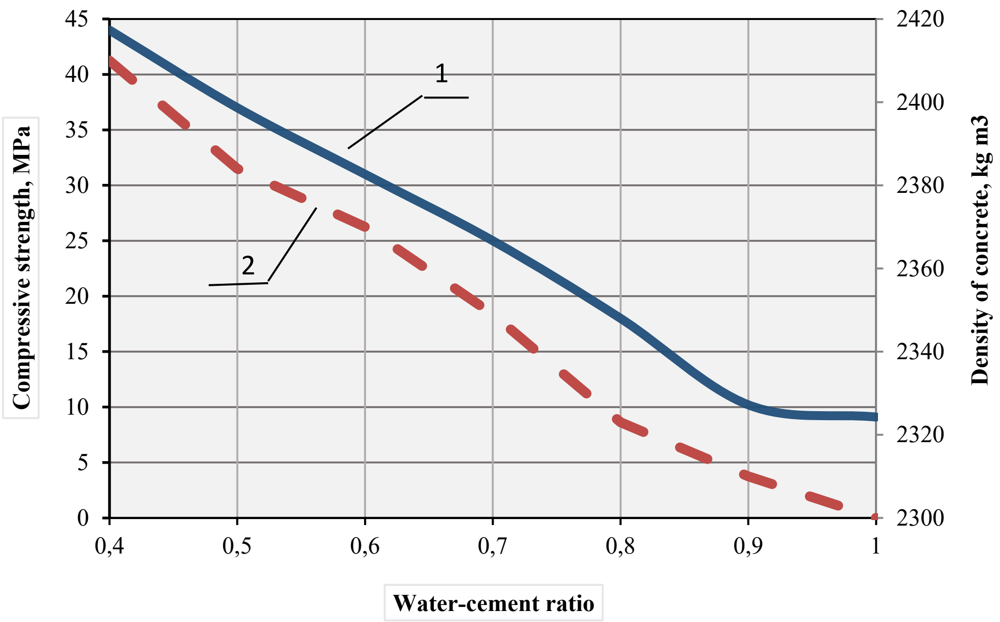

Figure 4. Dependence of the ultimate compressive strength (1) and density (2) of concrete on the water-cement ratio of the concrete mixture

7. Conclusion

The obtained dependences of the change in the physical and mechanical properties of concrete on the initial water-cement ratio confirm the known regularities showing a decrease in strength and density with an increase in water consumption. It has been proven that in order to obtain concrete with high strength indices, it is necessary to reduce water consumption, which is guaranteed to allow regulating the properties of the composites under study.

Thus, it was found that the studied additive MasterPozzolith 3150W contributes to the production of consistent mixtures of the P4 and P5 grades, the hardening of which is accompanied by a steady strength gain for 28 days. In addition, the use of an additive in an amount of more than 0.8% increases the longevity of the concrete mix, increases the resistance to sedimentation, preventing the processes of segregation and water separation of the freshly prepared concrete mixture, which ensures the widespread use of the proposed concretes in the practice of monolithic construction.

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