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IMPROVEMENT OF CONSTRUCTION-MECHANICAL PROPERTIES OF HIGH-STRENGTH SELF-COMPACTING CONCRETES

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Abstract. The flowability of a concrete mixture depends mainly on the volume of cement-sand mortar in its composition and the ratio of the active part to coarse aggregates. When the volume of cement-sand mortar increases, the flowability increases, but when the ratio of the active part (binder and water) to coarse aggregates exceeds a certain limit (r=0.52), the flowability begins to decrease. This is explained by the fact that as the amount of sand increases, the volume of the mortar part increases and, as a result, the water demand increases. If the water/solids ratio does not change, an increase in the amount of sand causes a decrease in the average density of the mixture.

Keywords: concrete mix, flowability, cement-sand mortar, water requirement, average density

1. INTRODUCTION

The demand for high-strength and long-lasting concrete materials in the modern construction industry is constantly increasing. Especially in the construction of complex structures, densely reinforced elements and projects requiring high quality, the application of traditional concrete is sometimes not enough. For this reason, high-strength self-compacting concrete (SCC) has become a wide field of research and application in recent years.

Self-compacting concrete is a special type of concrete that can flow inside the mold under its own weight and fill the voids without the application of vibration. This feature increases their workability, speeds up the construction process and reduces labor costs. At the same time, when properly designed, these concretes demonstrate high density and homogeneity, which has a positive effect on their mechanical performance. High-strength self-compacting concrete is distinguished by both high fluidity and high compressive and tensile strength.

Improving the construction and mechanical properties of SCC is an important scientific and technical problem. The quality of these concretes depends mainly on the correct selection of their composition, water-cement ratio, mineral and chemical additives used, as well as the rheological properties of the mixture. Mineral additives such as silica fume, fly ash, slag increase the microstructure of concrete by densifying its strength. The use of superplasticizers allows for high fluidity and at the same time creates conditions for increasing strength by reducing the amount of water.

In addition, the long-term operational properties of SCC - for example, crack resistance, water resistance, resistance to freeze-thaw cycles and corrosion resistance - are also of particular importance. To improve these indicators, fibrous reinforcement, the application of nanomaterials such as nanosilica, and optimization of hardening conditions are widely used.

Thus, the development of high-strength self-compacting concretes is one of the important directions of modern construction technologies, and improving their construction and mechanical properties is of great importance both from an economic and technical point of view.

2. LITERATURE REVIEW AND PROBLEM STATEMENT

In this work, Fix 1211 addition has been used in different amount in the iron mix. The samples prepared have been used thermically in the temperature 77°C in normal atmosphere condition. The samples thermically developed have been thermically analyzed with the constant 5°C/min of 20 ml/min argon gas from 30°C up to 900°C. Thermo-physical mechanisms have been researched in the cement, sand and road metal with the thermogravimetric (TG) and Differential Scanning Calorimetry (DSC) analysis. Mass kinetics, activation energy and special heat capacity have been researched for different temperature intervals. The decomposition mechanism of the mass in stages and the speed of decomposition is equal to the cost of the heat flow. The mass loss has been determined in 6.99 mg under the first code, 5.82 mg under the second code, 5.63 mg under the third code, 4.65 mg under the fourth code in $30 \leq T \leq 900$°C temperature interval. In addition, it has been researched that the activation energy has been changed between 0.56-0.80 eV and 0.23-0.36 eV under each code and phase passage [1].

Applications have been identified for self-compacting concrete, which can be placed without vibration compaction and easily molded into dense areas of reinforced concrete structures without segregation. This type of concrete is suitable for use in industrial building construction [2].

The studies revealed that the strength of concrete made with crushed stone from the Velvele River was 76.3 MPa, while the strength of concrete made with Shamkir granodiorite was 82.7 MPa. SF 18 superplasticizer was used to ensure high flowability of the self-compacting concrete, and Silicacem microsilica was used as a garnet dispersion filler to improve segregation resistance. The resulting self-compacting concrete was found to be successfully used in densely reinforced complex structures [3].

3. RESEARCH MATERIALS AND METHODS

In this study, NORM CEM II/A-P 42.5R cement was used as the binding material. As coarse aggregates, Shamkir granodiorite and 5–10 mm fraction river gravel, sourced from the territory of the Republic of Azerbaijan, were applied. Fine aggregates included river sand with a specific density of 2.61 g/cm^3, a water absorption of 1.1%, and a fineness modulus of 2.0–2.5, as well as crushed stone with a fineness modulus of 3.0–3.5.

To reduce segregation and enhance the strength characteristics of self-compacting concrete mixtures, microsilica was incorporated into the composition. Superplasticizers and hyperplasticizers were used to lower the water demand and improve the rheological properties of the concrete mix.

4. WORK CONDUCT

Microsilica and high-strength fillers have been used as mineral additives to improve the construction and technical properties of high-strength self-compacting concrete. Microsilica affects the rheological properties of cement systems in the initial stages of structure formation, and in the final stages of hardening, it changes the phase structures of cement stone, creating high strength. Silicacem microsilica powder increases the durability and strength of concrete in various conditions. Microsilica, which is quite active from a chemical point of view, is widely used as a putty and reacts with the hydration products of cement to form hydrosilicates.

Studies have shown that the corrosion resistance of concrete with the addition of 7-8% microsilica is 13 times higher than that of ordinary concrete. Also, the electrical resistance of concrete with the addition of microsilica increases, which is due to the intensity of the hydration reaction and a decrease in the number of pores with free ions.

In the research work, NORM company's CEM II/A-P 42.5R brand cement was used as the binder, and local Shamkir granodiorite and river gravel (5-10 mm crushed stone) were used as coarse fillers, river sand with a specific gravity of 2.61 g/cm³, water absorption capacity of 1.1%, a size modulus of 2-2.5, and stone chips with a size modulus of 3-3.5. Microsilica was added to reduce segregation resistance and increase strength in high-flow concretes. Superplasticizers and hyperplasticizers were used to reduce the amount of water in order to improve the rheological properties of the concrete mixture. In the research, a high-molecular surfactant such as Sika's SF20 superplasticizer was used to ensure the flowability of the mixture. The mineralogical composition of Portland cement is given in Figure 1.

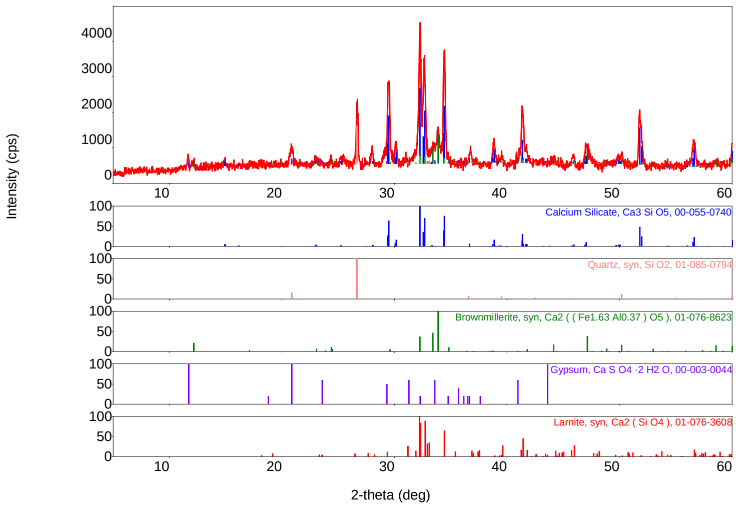


Figure 1. Diffractogram of CEM II/A-P 42.5R cement

A concrete mixture was prepared with the following composition: water/sem ratio 0.33; cement consumption 500 kg/m³; the amount of modifier used in 1 m³ of concrete mixture was 75 kg. The ratio of sand to crushed stone during the tests was taken in the following proportions: 0.47; 0.49; 0.50; 0.51; 0.52.

The ratio of 5-10 mm and 10-20 mm size fractions in the mixture was taken as 50:50. The ease of placing the concrete mixture in the mold and its strength prepared in a laboratory concrete mixer were determined experimentally. The ease of placing the concrete mixture in the mold was determined by the collapse (for plastic concrete mixtures) and spreading (for flowable concrete mixtures) of the Abrams cone.

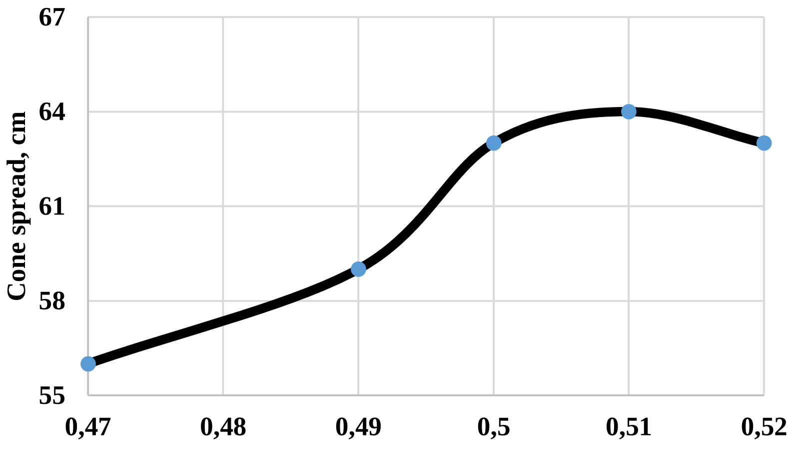
The compressive strength of concrete was determined after 28 days on 15×15×15 cm specimens stored under standard conditions (temperature 20±3°C, W=95±5%).

The results of the experiment are presented in Table 1, and as can be seen from the table, an increase in the amount of sand in the mixture (at a constant volume of cement paste) leads to an improvement in the ease of placement in the mold (Table 1, Graph 1).

Table 1.

Effect of sand/crushed stone ratio (r) on the properties of concrete and concrete mix

s/s	Concrete composition, kg/m^3								Properties of the mixture				R_{str}, MPa
	Cement	organic-mineral modifier	Sand	Crushed stone	Water	Chemical additive	Water/salid material	r, ratio	Average density, kg/m^3	Air volume, V_h,%	cone collapse, sm	Spreading diameter, cm	
1	503	76	762	859	178	6,95	0,31	0,48	2385	4,0	26	55	90
2	507	77	791	820	178	7,0	0,31	0,47	2380	4,5	26	58	88
3	502	74	807	807	178	6,91	0,31	0,49	2375	4,6	26	64	87
4	500	74	813	785	178	6,89	0,31	0,50	2357	5,0	26	63	83
5	497	76	823	759	178	6,87	0,31	0,51	2340	5,3	26	62	82



Result: The reason for the increase in the flowability of the concrete mixture is the increase in the volume of the cement-sand solution in the composition of the mixture. With an increase in the ratio of the active part (binder and water) to the large fillers called the inert component in the composition of the concrete mixture (r=0.52), the flowability begins to decrease. This dependence is explained by the fact that when the density of the cement paste remains constant (the volume remains unchanged), when the amount of sand increases, the volume of the solution part increases and, as a result, the water demand of the mixture increases. As can be seen from the table, when the water/solids ratio in the concrete mixture does not change, the amount of sand changes from 0.47 to 0.51, the average density of the mixture decreases from 2340 kg/m³ to 2385 kg/m³.

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