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ON THE RHEOLOGICAL PROPERTIES OF SELF-COMPACTING BASALT FIBER CONCRETE

***Abstract**: This article presents the results of experimental studies conducted to determine the rheological properties of self-compacting basalt fiber reinforced concrete and evaluate it according to international standards. In the conducted scientific research, a composite binder consisting of Portland cement, zeolite rock, and quartz sand was used as a binding agent for self-compacting basalt fiber reinforced concrete. The rheological characteristics of the developed basalt fiber concrete mixtures were determined and evaluated based on the requirements of international standards. This assessment demonstrated that they can be classified as self-compacting concrete mixtures (corresponding to the SF2 grade). It was established that all compositions of self-compacting concrete* *mixtures obtained on the basis of the developed composite binder comply with the requirements of international standards - EFNARC (2002) in terms of flowability and resistance to segregation.*

Key words*: international standards, basalt, segregation.*

Language*: English*

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Introduction

In recent years, significant attention has been given to implementing energy- and resource-efficient materials and technologies in the construction industry. This trend is driven by the need to reduce construction costs, improve product quality, and dramatically decrease harmful environmental impacts. However, the decisive factor among these is investors' pursuit of greater economic benefits by reducing raw material, energy, and time consumption. Specifically, concrete mixtures with superior technological properties are being increasingly used in the modern construction of monolithic buildings and structures. These concrete mixtures possess the ability to independently fill formwork, even those with dense reinforcement or complex geometric shapes, without any external mechanical influence while maintaining their viscosity and uniformity. Perhaps for this reason, they have been termed self-compacting concretes (SCC) in modern construction practice [1-3, 13].

Due to their unique properties and structure, SCCs simultaneously address two issues: they possess higher strength compared to heavy concrete, and they reduce construction time and labor intensity. Furthermore, such concretes have superior workability and faster rates of strength gain. Therefore, SCCs are considered to belong to the class of "high-performance concretes." The formation of such properties in SCCs is achieved through the use of a complex of modifiers, including effective superplasticizers, viscosity modifiers, active mineral additives, and hardening accelerators [5-7,13-18].

The application of Self-Compacting Concrete (SCC) in the construction sector of the Republic of Uzbekistan still poses challenges. This is due, on the one hand, to the complexities involved in organizing the production of such concrete, and on the other hand, to the absence of relevant regulatory documents. Currently, addressing these issues largely necessitates the acceleration of scientific research on developing SCC technology tailored to local resources and conditions.

Currently, scientists from leading higher education institutions of our republic, such as Tashkent Architecture and Construction University and Tashkent State Transport University, are conducting scientific research on the study of self-compacting concrete technology and its improvement, taking into account local conditions [8,9]. In particular, research conducted at the Tashkent State Transport University has demonstrated that the production of self-compacting concrete based on composite cement binders can be highly effective. When solving the problem of optimizing the composition of the composite binder, which forms the basis of self-compacting concrete, using mathematical models [4,12], the following optimal amounts of its components were determined: zeolite rock - 28.5%, quartz sand - 10.6%, and SP Master Glenium 27 - 0.95%. In this case, the incorporation of the superplasticizer (SP) is carried out not within the composition of the composite binder (CB), but in the water that is added to it.

It is known that the main characteristics of SCCs, which determine the quality indicators of structures made from them, include the following technological and rheological parameters: workability (flowability of the mixture), the ability to adjust setting times within specified limits, and, additionally, the capacity to maintain certain rheological properties throughout the entire SCC production process [19,20]. The use of highly flowable concrete mixtures with excellent cohesion, uniformity, and resistance to segregation allows for reducing the duration of cast-in-place concrete work in construction and optimizing the quality indicators of structures. Therefore, a series of experimental studies were conducted to examine the rheological properties of SCC compositions (Table 1) developed under laboratory conditions.

Table 1. Compositions and physical-mechanical properties of fine-grained concrete

Composition №	Material consumption rate, kg/m^3					Strength, MPa		Elastic modulus, GPa
	CB		SP	sand	water	cubic	prismatic	
	cement	add.						
1	702	452	11	1020	235	66,2	50,9	35,1
2	646	508	15	1020	223	68,6	51,0	36,0

3	582	572	18	1020	201	65,4	50,6	34,2
4	652	502	11	1020	253	64,8	49,8	33,4
5	606	548	15	1020	231	72,6	59,2	40,3
6	631	523	18	1020	203	63,0	48,9	32,2
7	601	553	11	1020	251	68,9	51,1	35,9
8	695	459	18	1020	196	70,3	52,3	36,3
9	631	523	15	1020	221	66,2	50,8	38,8
10*	545	-	-	1634	218	42,9	31,8	25,2
11	545	169	-	1465	241	41,2	30,3	29,0
12	545	-	15	1691	182	50,3	33,2	30,5
Note: CB - composite binder; SP - superplasticizer; * - composition is mechanochemically inactive compared to others								

In the experimental studies, the following initial materials were used: Portland cement SEM I 32.5 N from the Akhangaran cement plant as a cement binder; sand from the KDB "Pskent" deposit (GOST 8736-93) as a fine aggregate; crushed stone prepared from gravel from the KDB "Pskent" deposit (GOST 8269.0-97) as a coarse aggregate; zeolite rock from the Beltau deposit (Navoi region) as a mineral micro-filler included in the composite cement binder; quartz sand from the Maysky deposit (Tashkent region) as another mineral micro-filler included in the composite cement binder; Master Glenium 27 series polycarboxylate superplasticizer from the BASF company (Germany) as a chemical additive; and basalt fiber with a diameter of 13-17 μm and a length of 6-12 mm, produced by JV LLC "MEGA INVEST INDUSTRIAL" (Jizzakh region) as a dispersed fibrous micro-filler. The study of the properties of self-compacting concrete mixture was conducted in accordance with the requirements of GOST 10181-2000 and foreign regulatory documents.

In experimental studies, to determine the effect of the composite binder on the rheological properties of the fibroconcrete mixture, rheograms of water-binder systems with the following compositions were compared: a) water+PC; b) water+PC+SP; c) water+PC+AA; d) water+CB fibroconcrete mixtures (Figure 1).

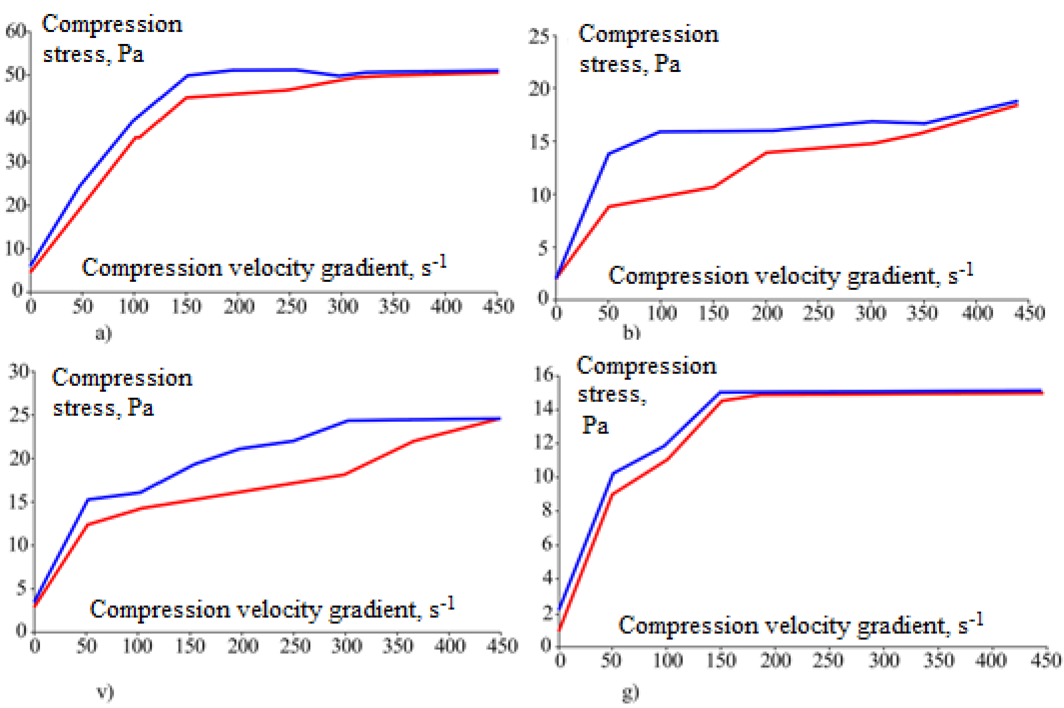

Figure 1. Rheograms of fiber-reinforced concrete mixtures

The study of rheological parameters of fiber-reinforced concrete mixtures was conducted using a viscometer, with measurements taken 5 minutes after water was added to the dry mixture. To ensure the reliability of the obtained results and enable their mutual comparison, mixtures of various compositions were prepared with uniform workability.

The results of the experimental studies (Figure 1) allowed us to draw the following conclusions: the highest initial viscosity value was characteristic of the "water+PC" system, while the lowest (almost zero) was observed in the "water+CB" system. The "water+PC+SP" and "water+PC+AA" systems occupied intermediate positions according to this controlled parameter. In this case, the fiber-reinforced concrete mixture based on CB demonstrated the lowest shear stress value, which fully aligns with the main objective of designing the SCC. Furthermore, the system containing CB is characterized by a minimal width of the hysteresis loop, indicating a relatively lower degree of structuring in the system. It is also noteworthy that the flow of fiber-reinforced concrete mixtures of all compositions exhibited thixotropic properties, namely the ability to reduce viscosity under mechanical influence and increase viscosity when at rest.

It is known that particles of the polymineral modifier, coated with adsorption layers of water, fill the interstitial spaces between cement particles. This creates a viscous-plastic medium with unique characteristics: significantly higher viscosity and plastic strength compared to the "cement-water" system. In finely ground particles, a chemically bound aqueous layer forms, which can equal the particle's volume. Correspondingly, the volume of chemically unbound water in the mixture, capable of providing the given rheological characteristics, decreases by an amount equal to the quantity of finely ground material. As a result, the viscosity of the system increases proportionally to the concentration of the finely ground microfiller.

From the perspective of easy moldability, the compositions of the studied fiber-reinforced concrete mixtures were designed based on the following condition: achieving a spread of a cone with an average diameter of 680±30 mm. This was accomplished by adjusting the water-to-solid ratio (Fig. 2).

Figure 2. Slump flow of SCC mixture

These values of cone spread correspond to the SF2 grade of SCC mixture. In the context of solving the problem of designing an SCC mixture, special attention was paid to the fact that an increase in the amount of activated additive in the binder leads to a decrease in the workability of the mixture. This is caused by an increase in the area of the activated surface of ultra-fine particles, which, in turn, leads to an increase in the water demand required for the particles to slide over each other. Despite the combined grinding of the composite binder components, it contains a certain amount of activated additive particles that have not undergone complete grinding. The material composition of the activated additive is relatively simple and consists of agglomerated particles, which is especially noticeable when compared to cement particles. With an increase in the water content of the mixture, the porosity also increases, including due to a further increase in crack formation, which, in turn, negatively affects the hardening concrete. The influence of the amount of micro-filler and superplasticizer added to the mixture on cone spread is shown in Figure 3.

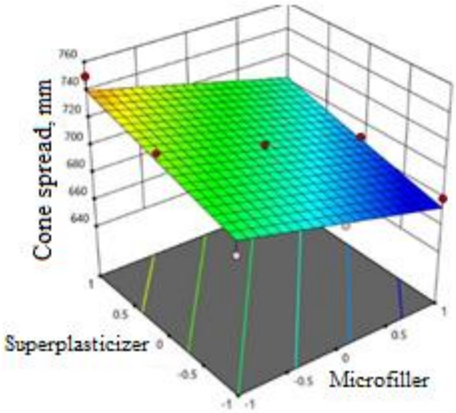

Figure 3. Slump flow for various SCC mixtures

The results of experimental studies indicate that the influence of microfiller and superplasticizer (SP) quantities on the rheology of the fiber-reinforced concrete mixture has a linear characteristic. It is understood that SP increases the workability of the mixture; however, the active silica additive (ASA) in the cement-concrete composition requires a higher amount of water compared to the control composition. Consequently, to ensure the same flowability of the mixture, the greater the amount of ASA, the more SP and water are required. At the same time, it was found that the inclusion of fiber in the composition somewhat reduces the workability of the mixture. The higher relative surface area of the fibers leads to greater absorption of the binder mixture around the fibers and, as a result, increases the viscosity of the concrete mixture, which in turn somewhat reduces the slump spread.

The results of the research conducted on the rheology of concrete mixtures are presented in Figure 4.

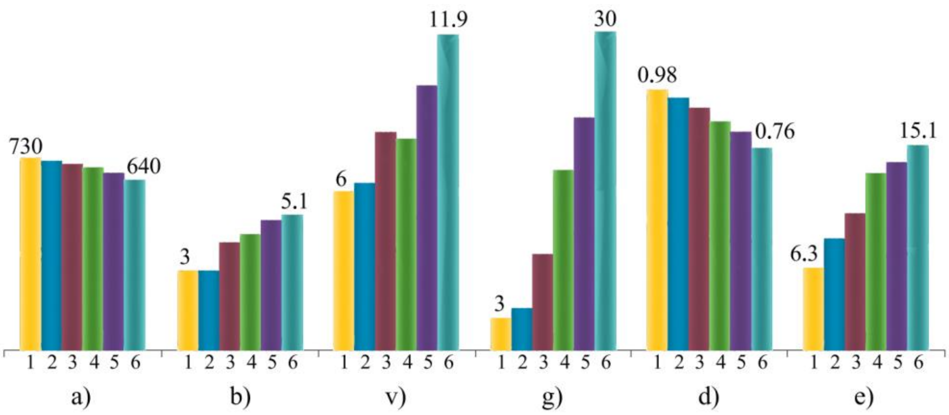

Figure 4. Rheological characteristics of self-compacting concrete mixtures
1,2,3,4,5,6 - correspond to compositions 2,4,5,6,8,9 given in Table 1; a-slump flow of the standard cone, mm; b-time to spread 50 cm, s; v-flow time through the V-funnel, s; g-passing ability through the U-box, H_2-H_1; d-ability to overcome reinforcement bar resistance in the L-box, H_2/H_1; e-segregation resistance, %.

Based on the analysis of these diagrams, it is worth emphasizing the following points. All compositions (1-5) of concrete mixtures obtained using the developed CB meet the requirements of international standards - EFNARC (2002) in terms of flowability and resistance to segregation. It should be noted that the use of colmatating microfillers (crushed zeolite rock and quartz sand) reduces the tendency for segregation and water separation in SCC mixtures. These conclusions are also fully consistent with the research results presented in scientific works [37,39]. In particular, according to the authors, the microfiller incorporated into the composition creates an additional "stability framework," which, in turn, further enhances the mixture's ability to resist segregation.

Conclusion.

It has been scientifically substantiated and experimentally confirmed that it is possible to obtain self-compacting concretes (SCCs) with high strength and performance characteristics, reinforced with dispersed basalt fibers, using local materials. The rheological properties of the developed basalt fiber

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concrete mixtures were determined, and based on these characteristics, it was demonstrated that they can be classified as self-compacting concrete mixtures (corresponding to the SF2 class). All compositions of self-compacting concrete mixtures obtained from the developed composite binder meet the requirements of international standards - EFNARC (2002) in terms of flowability and resistance to segregation.

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