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ON THE IMPACT STRENGTH OF SELF-COMPENSATING BASOLTOFIBROBECRETE

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Abstract: This article presents the results of experimental studies to investigate and evaluate, in accordance with standard requirements, the impact strength of developed self-compacting basalt fiber concrete compositions. The research demonstrated that replacing the cement binder with a composite consisting of Portland cement, zeolite-containing rock, and quartz sand can produce highly effective self-compacting basalt fiber concrete mixtures. Experimental studies have shown that even after initial cracks have formed, basalt fiber concrete samples are capable of withstanding increased impact loads. This indicates that the developed self-compacting basalt fiber concrete, as a composite material with very high impact strength, can be recommended for the construction of highly critical protective structures.

Keywords: Basalt fiber concrete, Portland cement, zeolite rock, quartz sand, basalt fiber, composite binder.

INTRODUCTION

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Recent years , great attention has been paid to the introduction of energy- and resource-efficient materials and technologies into the production of construction. This is explained by the need to reduce costs in construction, improve product quality, and dramatically reduce harmful effects on the environment. However, among these, the decisive factor is the desire of investors to achieve greater economic benefits by reducing the consumption of raw materials, energy, and time. In particular, concrete mixtures, which are distinguished by their high technological characteristics, are increasingly used in the modern construction of prefabricated buildings and structures. Such concrete mixtures, while maintaining their viscosity and uniformity, are able to independently fill the formwork, even those with dense reinforcement or complex geometric shapes, without any external mechanical influence. Perhaps that is why they are called self-compacting concrete (SCC) in modern construction practice [1-3, 13].

LITERATURE ANALYSIS AND METHODS

Due to their properties and structural features, lightweight concretes solve two problems at once: they have higher strength than heavy concretes, and they also reduce construction time and labor intensity. In addition, such concretes have high workability and high rates of strength gain. Therefore, lightweight concretes are considered to belong to the class of "high-performance concretes". The formation of such properties in lightweight concretes is achieved through the use of a complex of modifiers, including effective superplasticizers, viscosity modifiers, active mineral additives, and hardening accelerators [5-7,15-20].

The use of UZBs in the construction sector in the Republic of Uzbekistan still poses difficulties. This is due, on the one hand, to the difficulties in organizing the production of such concretes, and, on the other hand, to the lack of relevant regulatory documents. Currently, the solution to these problems also requires the intensification of scientific research on the development of UZB technology, which is largely dependent on local resources and conditions.

Currently, scientists from the leading higher educational institutions of our republic, Tashkent University of Architecture and Construction (TACU) and Tashkent State Transport University (TSTU), are conducting scientific research to study the technology of self-compacting concrete and improve it taking into account local conditions [8,9]. In particular, research conducted at TSTU has shown that the production of self-compacting concrete based on a composite cement binder can be highly effective. When solving the issue of optimizing the composition of the composite binder that forms the basis of self-compacting concrete in terms of the strength factor based on mathematical models [4,12], the following optimal amounts of its components were determined: zeolite rock - 28.5%, quartz sand - 10.6% and the amount of Master Glenium 27 Master Glenium 27 - 0.95%. In this case, the introduction of the Master Glenium 27

As is known, the requirements for self-compacting fiber-reinforced concretes, in particular basalt fiber-reinforced concretes, are also formed depending on the field of application. In particular, the modern concept of designing special and protective structures requires careful analysis in order to understand and predict the state and deformation of the building structure under impact loads, since the amount of these states and deformations directly depends on the type of structure under consideration, the properties of structural materials, and the rate of deformation.

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Understanding the mechanism of deformation in terms of crack formation, brittle fracture and surface damage, as well as relevant characteristics of impact impact when designing self-compacting fiber reinforced concrete structures
is a very important process. The physical properties of the impacting body and structure under each impact are factors that determine the overall result of deformation and fracture. Other factors that are related to this result are the speed and angle of impact. If the deformed shape during the impact of two arbitrary bodies can be accurately predicted, then probabilistic methods for obtaining the mode of destruction from the impact load of dynamic calculations can be used with great confidence.

It is known that self-compacting basalto-fibro concrete is considered a typical composite material and is divided into micro- and macrostructures in research based on polystructural theory. The important structural parameters of such composites are technological cracks and residual deformations that occur during construction production. Later, the collapse of the structure occurs due to the growth of these cracks into main cracks and their development.

To study the impact toughness of the newly developed self-compacting basalt fiber concrete, a stand consisting of 5 functional blocks was used (Fig. 1) [13]. The functional blocks were: 1) a force block; 2) a piston hammer with an adjustable mass; 3) a block for recording the speed of the object before impact; 4) a block for installing interchangeable impactors with different configurations and rotations; 5) a block for clamping test specimens subjected to impact at different angles.

The principle of operation of this device (stand) is as follows: with a preliminary knowledge of the strength properties of the building material under study, the estimated weight is selected and the cartridges are selected accordingly. The sample under study is installed in the clamping block - 10. After that, the correctness of the installation of the electronic stopwatch sensors is checked. The hammer is returned to its final position, the cartridge is installed in the magazine and brought into combat mode. After making sure that there are no people within the safety zone, the trigger of the trigger mechanism is pressed and a shot is fired from the piston-hammer. The time - t is recorded according to the stopwatch readings and the speed of the piston movement before the impact is determined. To repeat the impact, the handle is returned to its original position. After that, the working cycle is repeated the required number of times.

This stand allows you to very accurately determine the force of the impact, change the angle of impact in any direction, and determine the characteristics of the destruction both qualitatively and quantitatively.

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Fig. 1. General view of the experimental stand

In this stand, the performance of fine-grained concrete under single and repeated dynamic impacts with widely varying impact characteristics was investigated.

RESULTS

Impact strength of concrete was determined according to the method presented in [13]. According to this method, the index of impact resistance of the composite is calculated as the arithmetic mean value of three samples according to the following formula:

$$R_{y\partial} = \frac{A}{V} = \frac{[1+2+3+\ldots+(n-1)]m\cdot 9{,}81}{V}$$

where: n is the serial number of the impact that caused the sample to break; (n -1) – the serial number of the impact preceding the impact that led to its destruction, i.e. the height of the load, cm ; A – the amount of work spent on the destruction of the standard sample , J; m – the mass of the steel , kg; V – the volume of the sample , cm ^{3} .

The following starting materials were used in the experimental studies: Portland cement of the brand CEM I 32.5 N of the Akhangaron cement plant as a cement binder; sand from the KDB "Pskent" deposit as a fine filler (GOST 8736-93); crushed stone made from gravel from the KDB "Pskent" deposit as a coarse filler (GOST 8269.0-97); zeolite rock from the Beltau deposit (Navoi region) as a mineral microfiller included in the composition of the composite cement binder ; quartz sand from the Maisky deposit (Tashkent region) as another mineral microfiller included in the composition of the composite cement binder ; as a chemical additive - Master Glenium 27 series polycarboxylate superplasticizer from BASF (Germany) , As a dispersed-fibrous microfiller, basalt fiber with a diameter of 13-17 microns and a length of 6-12 mm is produced at the enterprise of JV LLC "MEGA INVEST INDUSTRIAL" (Jizzakh region) .

the conducted experimental studies are presented in Figure 2.

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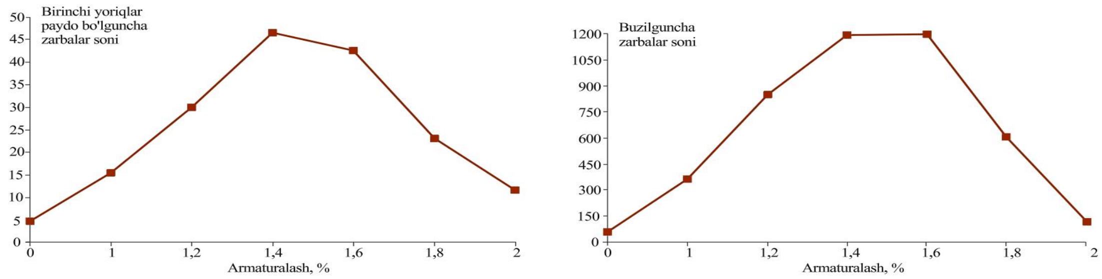

Figure 2. Dependence of characteristics of impact viscosity of basaltofibrobeton on the amount of fiber in the composition

The analysis of the results of the obtained experimental studies shows that the inclusion of basalt fiber in the composition improves the impact viscosity characteristics of the composite, only when its content in the composition increases to a certain value. In particular, the crack resistance of self-compacting basalto-fibro concrete can increase up to 9 times compared to concrete blocks without fibratola. Such a result is achieved when the volume concentration of basalt fibrofibers in UZB is equal to 1.4%. If the volume concentration of basalt fibrofiber in the composition is more than 1.6%, then the characteristics of impact viscosity of self-compacting basaltofibroconcrete are sharply reduced.

The use of fiber in composite materials is very important. In particular, fibers, when added to concrete, provide it with the required plasticity, thereby helping the composite to absorb a large part of the energy before failure. The composite matrix provides preferential crack propagation, residual strength after crack initiation, high impact toughness, and resistance to large deformations and elongation (bending).

As is known, dynamic (impact) effects are characterized by a continuous change in parameters, high intensity and short duration. Dynamic strength, which differs from static strength, is more likely due to the presence of initial defects in the structure of concrete. This phenomenon can be explained by a decrease in the possibility of stress redistribution due to a delay in the development of microplastic deformations. Fibers, as “bridges”, reduce the internal stresses of the composite, and accordingly, prevent the further development of defects and reduce the number (size) of centers of development of internal defects formed in it. This indicates that fiber fibers actively participate in the formation of the composite microstructure and have a positive effect on this process.

The graphical relationship between strains and stresses in tension for basalt fiber concrete can be described as consisting of two zones (Figure 3).

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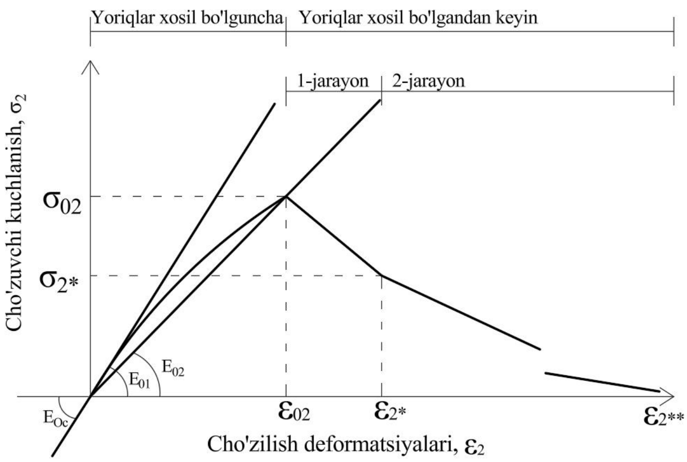

Figure 3. "Strain-strain" connection of basalto-fibro concrete in tension

The first zone is the zone before the formation of cracks, and the second is the zone after the formation of cracks. In this case, within the first zone, there are no cracks in the matrix consisting of fiber concrete. The stage after the formation of cracks is characteristic of the state of the beginning of cracking of the concrete matrix. It should be noted that we can observe that the curve characteristic of basalt fiber concrete has a relatively more plastic appearance compared to the curve characteristic of ordinary concrete. However, the part of this curve that has a fractured line appearance is clearly visible. This area is formed due to the action of basalt fibers that connect the cracks in the concrete matrix. The fractured line area can be considered as process 1 and process 2 and presented separately. During the first process, the stresses in the composite fiber-reinforced concrete matrix gradually increase, including the continuous stretching of the fibers. In the area corresponding to the second process, the residual stress is determined only by the contribution of the basalt fibers to the elongation. At the tensile limit deformation, when the tensile strength is zero, it is assumed that all basalt fibers have fully stretched, but the stretched fibers have not broken.

Further experimental studies were devoted to determining the impact viscosity of fiber concretes of different compositions (Table 1).

Table 1

Composition and physical-mechanical properties of fine-grained concrete

Composition No.	Consumption of materials, kg/m ^{3}					Strength, MPa		Modulus of elasticity, GPa
	KB		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

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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: KB-composite binder; SP-superplasticizer; * - content is not mechanochemically activated compared to others								

The results of the conducted studies are presented in Table 2.
Table 2
Characteristics of impact viscosity of fiber concretes

Method (According to Table 4.1)	1st crack how many beats	Percussion Energy (Crack 1), Dj	Sample email number of beats until	To the beat related energy (absorbing), Dj	Percussion coefficient of friction, μ	R_h / R_{tight}
2	30	1770	990	58410	33	0.15
5	45	2655	1210	71390	27	0.21
8	40	2360	960	56640	24	0.14
10*	5	295	25	1475	5	0.09
11	5	295	75	4425	15	0.11
12	5	295	85	5016	17	0.14
Note:* - the content is not mechanically activated; the amount of basalt fiber is 1.5% by volume						

The results show that the largest number of impacts is received by fiber-reinforced concrete samples prepared according to composition No. 5. Although the largest value of the impact viscosity coefficient - μ is characteristic of fiber-reinforced concrete samples prepared according to composition No. 2, it is incorrect to consider this indicator as a decisive indicator in the design of structures of responsible structures, since other indicators: the number of impacts to the first crack and the number of impacts to the sample failure gave relatively low results. The effect of the amounts of microfiller and superplasticizer included in the composition on the impact viscosity coefficient - μ is presented in Figure 4.

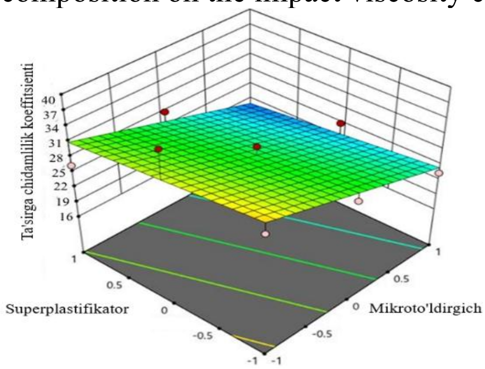

Figure 4. Effect of microfiller and superplasticizer amounts on impact viscosity coefficient - μ

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The fibrous "bridge" in the basalt fiber concrete structure determines the absorption of the impact energy after the formation of cracks and, therefore, the impact plasticity of the composite. The impact viscosity coefficient, μ, which is the ratio of the final and initial amounts of impact energy, is a good indicator of the plasticity of basalt fiber concrete under impact loading. Undoubtedly, the final impact energy (before decomposition) and the energy expended to form the initial crack are significantly different from each other, that is, the final one is significantly higher.

CONCLUSION

Experimental studies have shown that even after the initial cracks were formed, the specimens were able to withstand a large impact load before failure. Interestingly, the results obtained for self-compacting basalt fiber concrete are significantly higher than the final impact energy values reported for high-strength concretes in published studies [83,86] . This indicates that basalt fiber concretes have a very high potential for use as composite materials with high impact strength in critical structures of protective structures.

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