Efficient reception of introducing basalt fiber in cement matrix of fiber concrete

Irkin Mukhamataliyev*, *Fazliddin* Ruzmetov, *Azamat* Khudoyorov, and *Sherbek* Uzakov

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. The article is devoted to solving the problem of the distribution of basalt fiber in the environment of the filled cement paste and the total volume of basalt fiber-reinforced concrete, which is one of the most important in the preparation of basalt fiber-reinforced concrete. This article presents the results of experimental studies to establish the most effective technological method of introducing basalt fiber into the cement matrix of the composite from the point of view of increasing the strength characteristics of fiber-reinforced concrete. In the experimental studies performed, standardized methods for the study of cement paste and stone were used. As a result of the research, graphical dependences of the strength and water demand of a dispersed-reinforced cement stone on introducing basalt fiber into the composite and the quantitative content of basalt fiber in the composite were obtained.

The analysis of the obtained results made it possible to establish that of the various methods for introducing basalt fiber into the cement matrix of basalt fiber-reinforced concrete, the most effective in terms of increasing the strength of the composite material, provided that the water demand of the fiber-reinforced concrete mixture remains unchanged, is preliminary dry mixing of cement with basalt fiber in a spring mill. The most favorable environment for the mechanical activation of basalt fiber in a spring mill has also been established, which makes it possible to achieve high rates in terms of the preservation of basalt fiber during joint grinding. The scientific novelty of the performed research lies in the fact that the issue of studying the distribution of basalt fiber was first studied at the level of the microstructure of basalt fiber-reinforced concrete.

1 Introduction

Modern construction is directly related to increasing the efficiency of construction production, reducing the cost and labor intensity of technological processes, economical use of material and energy resources, and using new progressive materials. One of the promising structural materials is dispersed-reinforced concrete, also called fiber-reinforced concrete.

Fiber-reinforced concrete is one of the varieties of an extensive class of composite materials, which today are increasingly used in industrial, civil, and transport construction. Dispersed concrete reinforcement is carried out by fibers - fibers evenly distributed in the

* Corresponding author: erkinmah@mail.ru

volume of the concrete matrix [1-5].

Generally, fiber-reinforced concrete is a composite material consisting of a cement matrix (dense or porous) with a uniform or specified distribution of oriented or randomly located discrete fibers (fibers) of various origins throughout its volume. Currently, metal (mostly steel) and non-metallic (mineral, synthetic, etc.) high- and low-modulus fibers of various lengths and cross-sections are used for dispersed concrete reinforcement. At the same time, steel fibers are obtained by cutting low-carbon wire, foil or sheet steel, milling strips, and the turning process. Non-metallic fibers (glass, basalt, synthetic, etc.) are segments of monofilaments, complex filaments, and fibrillated films. The specified variety of fibers turned out to be sufficient to create a wide range of fiber-reinforced concretes of various compositions, densities, and strengths, which, in turn, allows a fairly large-scale and objective assessment of the effect of dispersed reinforcement on the physical and mechanical characteristics and durability of the resulting composite material [6, 7, 20].

One of the promising directions in the study of fiber-reinforced concrete technology is the rationale for the effectiveness of using basalt fiber as dispersed reinforcement. As is known, basalt fiber is distinguished not only by its high physical and mechanical properties but also by increased chemical resistance, temperature, light, and weather resistance, which is also important, by the simplicity of production technology and low cost [8,9].

The problem of fiber distribution in the cement paste environment and the concrete volume is one of the most important in manufacturing fiber-reinforced concrete [10, 11, 16, 18, 19]. Obtaining the maximum distribution of fibers in the volume of concrete solves several problems at once, such as clumping of the mixture, the formation of pores and voids, increased water demand, and as a result, insufficient strength of the resulting material. It is known [12] that fibers with the ratio of fiber length to diameter 1/d = 80–120 have the best "distributability" in concrete. An increase in the length of the fibers leads to the fact that they acquire cohesion in the mass of the concrete mixture. Our studies used basalt monofilament with a length-to-diameter ratio of 1/d = 90. Thus, our studies analyzed various methods for introducing basalt fibers into cement paste. The following methods have been considered:

option No. 1 - batch introduction of fiber into the finished (mixed with water) cement paste (10-20% of the total mass of the input fiber with continuous mixing of the cement paste);

option No. 2 - preliminary dry mixing with partial regrinding of cement with basalt fiber in a ball mill with metal balls;

option No. 3 - preliminary dry mixing of cement with basalt fiber in a spring mill (grinding is carried out by the impact, splitting, and grinding of the material between the turns of a rotating spring).

2 Methods

When performing experimental studies, Portland cement grade M400 of the Akhangaran cement plant was used as a binder. The chemical composition of the clinker of the Akhangaran cement plant was characterized by the content of the following oxides: CaO - 65.8%, SiO2 - 22.1%, Al2O3 - 4.5%, Fe2O3 - 4.2%, SO3 - 0.6%, MgO - 1, 7%, Na2O - 0.2%, K2O - 0.4%, p.p.p. - 0.2%. The mineralogical composition of Portland cement clinker was characterized by the content of the following minerals: C3S - 57.5%, C2S - 17.8%, C3A - 4.7%, C4AF - 12.5%. Regarding its physical and physical-mechanical properties, the Akhangaran Portland cement used in the research meets the requirements of GOST 10178-85 "Portland cement and slag Portland cement. Technical requirements." according to activity corresponds to the M400 brand. Basalt monofilament was used as a fiber - 10 μm in diameter, density - 2.65 g / cm2, tensile strength -3.5 GPa, obtained from basalt roving (a complex thread of continuous basalt fiber) produced by Trizol-N "(Navoi). The chemical composition of basalt fiber was characterized by the content of the following oxides: SiO_2 - 50.3%, Al_2O_3 + TiO_2 - 16.2%, Fe_2O_3 - 14.9%, CaO - 14.0%, MgO - 2.9%, Na_2O - 1, 2%, K_2O - 0.9%, p.p.p. - 0.1%.

The density of the cement stone was determined following the methods of GOST 12730.0-78 - GOST 12730.4-78. The compressive strength of cement stone was determined on 2x2x2cm cube samples by testing on a UMM-10 press following the methods of Russian State Standards GOST 310.4-81, GOST 10180-90, and GOST 18105-86. In each series of tests, the number of samples was taken at least three.

3 Results and Discussions

At the beginning of experimental studies, the influence of the method of introducing basalt fiber into the cement paste on its water demand and the compressive strength of the cement stone was studied. The resulting graphical dependencies are shown in Fig. 1 and Fig. 2.

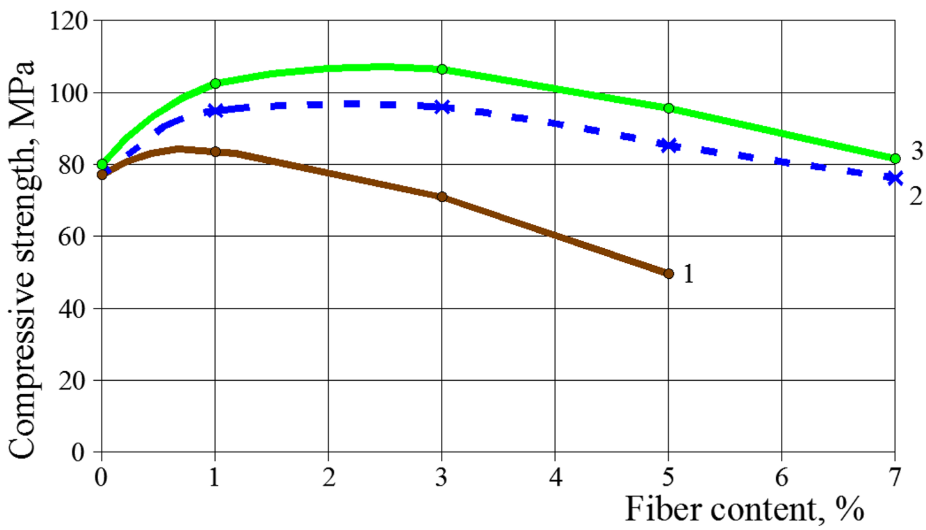

Fig.1. Dependence of strength of basalt fiber cement stone on method of introduction and content of fiber. 1 is option No. 1; 2 is option number 2; 3 is option number 3.

Analysis of the data obtained shows that the best way to introduce basalt fiber into the mixture is pre-mixing with partial grinding of a dry mixture of cement with fiber in a spring mill (option No. 3). This method of introducing basalt fiber at a percentage of 2-5% shows the highest compressive strength of the cement stone. On the 3rd day of storage at a humidity of W=95-100%, the strength of samples of basalt fiber cement stone obtained by regrinding cement with basalt fiber in a spring mill was 108.5 MPa, which exceeds the strength of the control composition without fiber by 34% and the strength of the composition obtained mixing and a final grinding in a ball mill with metal balls, 10% at 2% fiber content and 15% at 3% fiber content. Notably, the compositions obtained in a spring mill with a one-minute grinding and those obtained in a ball mill with metal balls at a 30-minute grinding do not have lumps and are easily mixed. Compositions obtained by portionwise introduction into the finished mixture with its continuous mixing and grinding in a ball mill with rubber plugs have the worst fiber distribution and clumping. The maximum content of basalt fiber that could be introduced in this way was 5%; while the compositions did not have cohesion, the water demand of the mixture increased sharply (Fig. 2).

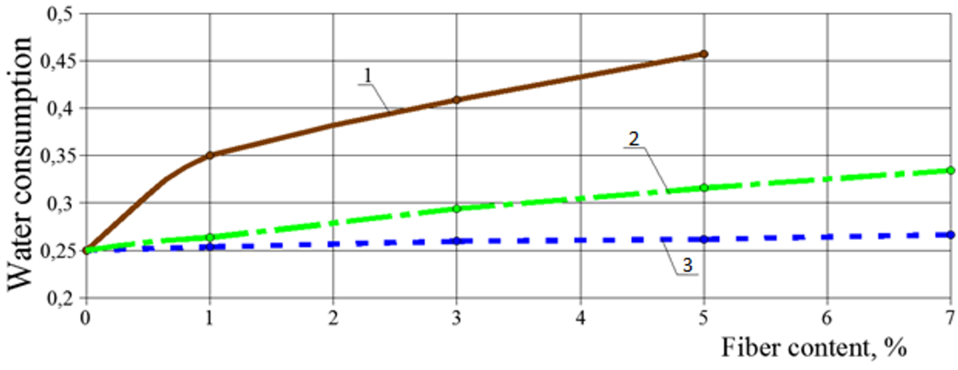

Fig. 2. Dependence of water demand of basalt fiber cement mixture on method of introduction and content of fiber. 1 is option No. 1; 2 is option number 2; 3 is option number 3.

Analysis of the obtained research results shows that the best way to introduce basalt fiber into the mixture is also the method corresponding to option No. 3. With this method of introducing basalt fiber into a dry mixture of cement binder, the water demand of the mixture practically does not increase. The distribution of basalt fiber in the cement matrix depends not only on the method of its introduction into the composition but also on the medium in which the mixing process takes place - the grinding of basalt fiber - plays an important role. To identify the most favorable environment, experimental studies were carried out, the results of which are shown in Fig.3.

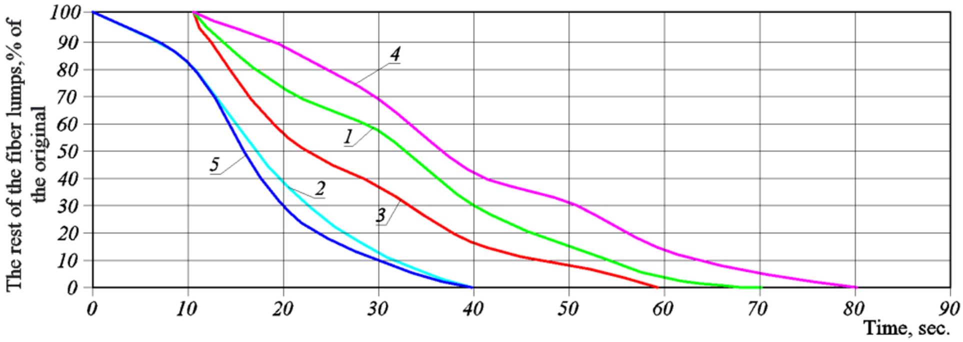

Fig. 3. Dependence of rest of fiber lumps on mixing time and grinding medium 1 is cement, 2 is sand, 3 is limestone, 4 is zeolite-containing rock, 5 is ground sand-lime brick

The joint grinding of basalt fiber with all types of materials was carried out at approximately the same grinding fineness, i.e., with a specific surface area of 3000-3200 cm2/g. With this specific surface value, the average particle size is from 5 to 9 microns, which allows material particles to penetrate between the fibers during grinding in a spring mill, the principle of which is compression with partial grinding due to a spring rotating around its axis. In this case, the hardness of the material should also be taken into account; during grinding, the material's particles must be crushed and push the fibers apart. After the joint grinding of the powder and basalt fiber from the resulting mixture, an analytical sample of 10 samples of 0.1 g each was made from the mixture's total mass obtained per the instructions of GOST 8.207-76. For each sample, the amount of fiber in the mixture was counted. The research results are shown in Table.1. A count of the number of fibers and their distribution along the length is presented.

Table 1. Change in length of basalt fiber depending on grinding medium

Name	The total amount of fiber in 0.1 gr. finished mixture, pcs	The amount of fiber in % of the total quantities				
		L = 7-9 mm	L = 5-7 mm	L =3-5 mm	L = 1-3 mm	L = ≤1 mm
Quartz sand	322	4	12	17	24	43
Ground silicate brick	587	12	19	26	22	21
Cement	712	21	28	26	17	8
Limestone	623	19	27	31	16	7
DSP	535	12	19	27	32	10

An analysis of the results obtained shows that the highest storability of basalt fiber is ensured by joint grinding with cement. In this case, both the total amount of fiber and its distribution along the length during grinding should be considered. Given the known geometric dimensions of the basalt fiber and the true density, it is possible to calculate the percentage of the fiber after it is distributed in the mill. The research results show that basalt fiber has the highest storage capacity when grinding together with cement, i.e., after grinding until the fiber is completely distributed in the mixture, 2.71% remains at the initial content of 3%. At the same time, the percentage distribution of the fiber along the length after grinding is of great importance here. With a decrease in length, the reinforcing properties of the basalt fiber are lost. It should also be noted that when grinding with cement in the length range from 9 to 3 mm, 75% of the total fiber remains, and in the case of grinding with quartz sand, for example, only 33% of the fiber remains in this length range. The total amount of basalt fiber in the length range from 9 mm to 1 mm in mixtures also varies in a fairly large range: from 712 to 322 pieces.

4 Conclusions

As a result of the experimental studies, it was found that of the various methods for introducing basalt fiber into the cement matrix of basalt fiber-reinforced concrete, the most effective in terms of increasing the strength of the composite material, provided that the water demand of the fiber-reinforced concrete mixture remains unchanged, is preliminary dry mixing of cement with basalt fiber in a spring mill. Established empirically, the optimal method for introducing basalt fiber into the composition of the filled cement binder by short-term (within 50-60 s) mixing of all components in a spring mill provides not only a uniform distribution of basalt fiber in the filled cement binder but also its mechanical activation, which has a positive effect on final physical and mechanical properties of the composite material. From the point of view of ensuring the persistence of basalt fiber, it was found that cement, in terms of its hardness and grinding ability, is most suitable for joint grinding than the other materials considered: quartz sand, ground silicate brick, limestone, and zeolite-containing rock.

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