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BASALT FIBER AS A COMPONENT FOR MICRO REINFORCEMENT OF CEMENT COMPOSITES

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Abstract:

The experience of basalt fiber application in the construction industry is summarized. Researches of physical and mechanical and corrosion properties of basalt fiber have been done.
The paper describes physical-mechanical and corrosive properties of basalt fiber obtained by different technologies. The perspectives of development and application of basalt fiber have been determined.

Keywords: Basalt fiber, cement stone, corrosion resistance, micro reinforcement, fiber.

Obtaining effective construction materials and products, to which today more and more high requirements are imposed, can be achieved by using technologies that use composite materials. One of the perspective structural materials is dispersion-reinforced concretes. Such materials combine a matrix with comparatively low tensile strength and fibers with considerable tensile strength and higher modulus of elasticity compared to the matrix.

However, as a rule, the potential of disperse reinforcement is not fully realized due to the low efficiency or the extremely high cost of components for micro-reinforcement of concrete. For example, steel fibers have low specific surface area, polypropylene fibers have low adhesion to cement stone, organic fibers have insufficient strength, and kevlar and carbon fibers are overpriced.

Obviously, basalt fiber can become the most effective component for microarraying of cement composites.

It is connected with its natural properties, simplicity of production and technological peculiarities of its application.

Basalt fiber surpasses steel in strength and, due to its small diameter (5-12 microns), has a much greater adhesive surface with the cement stone and a chemical affinity to it. At the same time, the relative elongation at break of basalt fibers is two times lower than that of steel, which allows it to more effectively prevent the formation of microcracks in concrete under loading.

However, insufficient study of the resistance of fibers in cement systems limits the scope and extent of application of fiber concrete in construction.

One of the ways to increase the resistance of glass fiber is the use of alkali-resistant fiber with high content of zirconium oxide. However, the high cost and complexity of its production technology restrains its use [1].

As a result of research, scientists from V.G. Shukhov Moscow State Technical University found that the high-performance characteristics of fiber concrete based on reinforcing fibers of different origin allow recommending these materials for road pavement construction [1-6].

Studies [7-11] have established that all mineral fibers, regardless of the chemical composition, enter into chemical interaction with solutions simulating the environment of hardening concrete on Portland cement. In terms of chemical resistance, determined by the amount of absorbed CaO, dissolved SiO2, bound alkali and the change in strength, mineral fibers can be lined up: alkali-free > alkaline > quartz > basalt > zirconia. Researches of various properties of basalt fiber (BB) have been carried out by foreign and domestic organizations, for example, by Faculty of Material Sciences (M.V. Lomonosov Moscow State University), Laboratory of Basalt Fiber (LBF), Institute of Material Science of Academy of Sciences of Ukraine, Research Institute of Reinforced Concrete, Central Research Institute of Promstructions, LatNIIBuilding, ArmNIIISV, Basaltex Masureel Group, Department of Textiles (Ghen University Belgium) and others. However, the available data on the corrosion resistance of basalt fiber in cement matrices are private and contradictory, which, in turn, creates a difficulty for the wide use of cement-basalt composites in construction.

There are grounds [12] to assume that the kinetics of oxidative corrosion, i.e., the speed of the process and the mode of its course (inside or on the fiber surface), may significantly depend on the nature of cation distribution in glassy matrix. Depending on composition of initial natural raw material (igneous rocks of gabbro-basalt group), possible subcharging and technological parameters of basalt melt dispersion, fiber materials with different micromorphology and type of heterogeneities can be produced.

The team of scientists headed by V.I. Putlyaev, A.V. Knotko, and A.V. Garshev [12] have established that during thermal treatment of unsuppressed (with Ca and Na content corresponding to natural basalt, the samples

B-L, B-I and B-H) of glass at the first stage of the oxidation process magnetic nanoparticles (>20 nm according to SEM data) (Mg2Fe)3O4 of non-magnetic glass matrix are formed (i.e., oxidation proceeds as an internal reaction), and further crystallization of plagioclases and pyroxenes occurs. In glasses enriched with CaO, (B-P) crystallization of plagioclases and pyroxenes occurs simultaneously with release of spinel phase, masking the latter on diffractograms. Analyses of cation distribution in the fiber cross section have shown that annealing under oxidizing conditions leads to an increase in Ca concentration at the fiber surface in case of unsupplemented material (B-L) and Na concentration in case of glass with increased CaO content (B-R). The observed differences can be related to the difference in diffusion mobility of cations, which, in turn, is determined by their location in the cavities or channels of the aluminosilicate framework, the ratio of which in the material is determined, first of all, by the ratio of Si and Al contents in it.

Hydrolysis of the samples in an acid medium resulted in a certain decrease in the alkali metal content, without significant changes in their behavior in oxidative annealing.

However, according to the scientists A.A. Dalenkevich, K.S. Gumargaliev, S.S. Marakhovskaya, and A.V. Sukhanov [13], the chemical resistance of DB to aggressive media (acid and alkaline) determined, as a rule, by the degree of their strength change after some time of exposure (aging) in these media depends on their chemical composition, the nature of aggressive medium and the temperature and time conditions of exposure. The ratio of silicon, aluminum, calcium, magnesium and iron oxides in basalt composition is very important [14-16].

It is the presence of iron oxides in the silicate framework of the BAS that gives them increased, as compared to CB, chemical and thermal resistance [14, 17, 18]. In the case of surface-active media (alkalis, solutions of some salts, etc.), along with the chemical composition, the state of the fiber surface layer [14-20], i.e., thermal or technological prehistory of the fiber, is also of great importance.

Uniform distribution of fibers over the volume of matrix is one of the problem areas in technology of basalt-fiber concrete preparation. At the same time the solution of this problem will allow to obtain fiber composites with high operational characteristics and high durability.

The main parameters influencing the quality of fiber concrete mixture along with physical and mechanical properties of matrix and reinforcing fibers are: uniformity of fiber distribution in mixture, their maximum concentration in mixture (maximum percentage of reinforcement which can be achieved), "clumpability" of fibers (their ability to roll up into clump-granules) in the process of mixing [21-26].

From the point of view of uniform, disperse distribution of fibers throughout the composite structure, fiber reinforcement is based on the assumption that the concrete matrix material transmits the applied load by means of tangential forces acting on the interface, and, if the fiber elastic modulus is greater than the matrix elasticity, then the main share of applied stresses is taken by fibers, and the overall strength of the composite is proportional to their bulk content [24, 25].

The method of A.A. Paschenko, which improved the numerical calculation of the rate of interaction of the components of basalt fibers with the components of the matrix, was used as the basis for estimating the durability of fiber-reinforced concrete. The calculations show that it is possible to predict reliably the longevity of composite up to 100 years.

The critical length of fibers Lkr is the minimal length of fibers at which they are broken in a composite material (CM). The value of Lcr depends on the strength of the bond between the matrix and the fibers and on the diameter of the fibers. As calculations show, already at L/Lcr=10 the strength of a composite material with discrete fibers reaches 95% of the strength of a material with continuous fibers [23, 25].

The manufacturing process of dispersion-reinforced concrete consists of three main technological stages: obtaining fiber reinforcement, preparation of fiber-reinforced concrete mixture, laying the mixture into the mold.

When considering in the literature the main methods of preparation and placement of fiber reinforced concrete mixtures, such as: the method of mixing the components

In consideration of basic methods of fiber concrete mixture preparation, such as: method of mixing of components, method of vibroextrusion, method of spraying of components, method of contact molding, method of vibration immersion of fibers [21, 26], the main attention is paid to the problem of fibers caking before introduction into the mixer and rolling of fibers into lumps-granules during preparation of fiber concrete mixture.

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Technological peculiarity of basalt crude fiber is its brittleness. In the process of mixing, the fibers are not lumpy, but are intensively crushed, so the main attention is proposed to be paid to maintaining the length of fibers, providing the required structural properties of basalt-fiber concrete, and the system "mixer - mortar mixture" is proposed to consider as a "crusher" for the fiber.

Thus, the main task of technology of basalt-fiber concrete mixture preparation is to provide geometrical characteristics of fibers corresponding to maximum strength of composite material. Namely, the share of fibers with length L = 10-Lcr should be maximum.

In the course of experiments, the authors [26] have established that the following factors influence the fiber length: viscosity of the mortar mixture, its density, speed of mixing.

In order to track the quality of basalt-fiber concrete mixture and to predict the quality of structures, the scientific community is working on selecting and justifying the criterion reflecting the state of fibers in the mixture and directly affecting the physical and mechanical characteristics of basalt-fiber concrete.

The combination of matrix with low tensile strength with fibers having considerable tensile strength and higher initial modulus of elasticity in comparison with matrix is typical for structural fiber concrete. When using basalt-tofiber concrete in road construction, special attention is paid to the damping abilities of the road pavement, which ensures a stable tensile strength of the composite.

Application of basalt fibers for concrete reinforcement will allow making the constructions of complex configuration (artificial constructions in the transport construction, road surfaces, high-strength overlaps, underground water channels, etc.); it will solve the problems of frost-resistance and durability of the products, as basalt fibers do not yield to electrochemical corrosion unlike the usual reinforcement, which is an electric conductor and is exposed to cathode effect; it will reduce the total weight of constructions.

Besides, fiber will replace traditional reinforcement, connected with application of structural steel reinforcement, will reduce its volumes, thereby reducing labor costs and prime cost of the finished product.

Thus, the introduction of basalt fiber in the structure of the cement stone makes it possible to solve the urgent task of the modern construction and road-building industry - preservation of strength characteristics along with reduction of the amount of cementing stone, in addition to reducing the amount of cement.

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