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Analysis of Technical Literature Allowing Determining Effective Areas of Use of Metal Fibers as Dispersed Reinforcement

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Modern construction is directly related to the tasks of increasing the efficiency of construction production, reducing the cost and labor costs of technological processes, rational use of material and energy resources, the use of new progressive materials. Dispersion reinforced concrete is one of the most promising structural materials. Such concretes are one of the types of a wide class of composite materials that are increasingly used in various industries today. Dispersion reinforcement is carried out by fibers - fibers evenly distributed over the volume of the concrete matrix. [1].

The Russian scientist V.P.Nekrasov was the first in the world to design a fiber-reinforced concrete structure in 1909, and research on methods of manufacturing fiber-reinforced concrete and calculating structures from it has been widely developed since the 60s of the 20th century. The first large-scale practical use of fiber concrete in the 20th century can be dated back to 1976, when it was used for the construction of a runway. But at that time, this material was not widely used, since the technology of production of fiber concrete and the fiber itself were imperfect at that time.

Currently, there has been a significant increase in interest in the use of fibers as the basis of building structures, especially when such fibers are used as reinforcement. Such interest is caused by the desire of specialists, to whom modern construction imposes ever higher requirements, to significantly improve the physical performance of concrete structures. Environmental pollution is also taken into account due to the constant increase in the consumption of natural resources, increased energy consumption, increased emissions and increased production. As you know, the amount of energy required for the production of concrete is minimal compared to the amount of energy required for the production of steel, aluminum, glass. Concrete reinforcement leads to a corresponding increase in the energy consumption of the material. [2,3].

The use of fibers as reinforcement to eliminate the insufficient strength of concrete materials can create prerequisites for obtaining new types of concrete with wider application possibilities in construction. As in the case of traditional reinforced structures, fiber reinforcement transfers the load applied to the concrete matrix material through shear forces acting at the interface between the fibers, and thus the fibers occupy the bulk of the stresses.

The world experience of research and application of dispersed reinforced concrete shows that the use of fiber provides:

- improvement of the strength characteristics of concrete, increasing its crack resistance, resistance to impact and friction, static strength when exposed to various forces;
- improving the operational reliability of structures under the influence of an aggressive environment by improving the structure of concrete;
- reduction of the working section of the structure, in some cases, reduction of consumption or complete rejection of the use of fittings.

The analysis of the technical literature made it possible to determine the effective directions of using various types of fibers as dispersed reinforcement and to identify some patterns that can be considered generally recognized:

- the properties of fiber concrete are determined by the type of fiber and concrete used, their quantitative ratio and largely depend on the state of contacts at the phase boundary;
- a significant increase in the strength characteristics of the composition compared to the original concrete while maintaining the achieved level over time is provided by the use of high-tech fibers that give the matrix chemical resistance and a high modulus of elasticity;
- the type of fibers, their relative length and percentage in the mixture should be determined based on the requirements for products and structures, taking into account the adopted technology, a greater or lesser degree of deviation of these parameters from optimal values reduces the efficiency of dispersed reinforcement;
- the introduction of fibers with optimal reinforcement parameters contributes to improving the structure and properties of the initial concrete, increasing its durability and service life.

At this point in time , fibers for dispersed reinforcement are classified as follows:

- modulus of elasticity:

high-modulus (metal, glass, etc.);
low-modulus (polypropylene, etc.);

- by origin:

natural (basalt, asbestos, etc.);
artificial (viscose, polyamide, etc.);

- by material:

metal (steel);
non-metallic (mineral, synthetic).

Table 1 Characteristics of the fiber [6].

Fiber type	Fiber characteristics	Fiber length, mm	Fiber diameter, mm	Standard tensile strength, MPa	Modulus of elasticity, MPa
Harex 32´1.2	Milled from slabs with anchors	32	1,2	600	200000
ФСП-В 30´0.8	Wavy chopped wire	30	0,8	860	190000
ФСП-Люкс 15´0.3		15	0,3	2450	190000
ФСЛ 40´0.8	Variable profile cut from steel sheet	40	0,8	580	210000
ФСП-А 30´0.3	Chopped from wire with anchors	30	0,3	2650	190000

Fig. 1 Type of steel fiber.

The analysis of the trainability of fibroconcrete shows fibroconcrete with the use of steel has been sufficiently studied and researched. At present, there are a number of technical conditions and GOST standards for the use of steel fiber concrete, while fiber concrete using basalt, polypropylene, glass fibers has not been studied enough.

Steel fiber concrete is a construction composite material, which is concrete reinforced with steel fiber. The strength of the steel fiber concrete depends on the class of the initial concrete matrix, the type and size of the steel fiber, the nature of its surface, the geometry and the size of the cross section of the element. The increase in the compressive strength is directly proportional to the fiber content and reaches 140-150% with 2-3% reinforcement. In general, the crack resistance limit of this type of concrete increases from 30 to 80% compared to reinforced concrete — when cracks open up to 0.05 mm by 6-10 times.

It is believed that steel fiber concrete in comparison with concrete shows an increase in properties:
- the limit of proportionality in tension and bending is 2 times;
- tensile strength – 2.5 times;
- bending strength – 3.5 times;
- compressive strength – 1.5 times;
- impact strength – 10 times;
- crack resistance when cracks open up to 0.2 mm – 3-3.5 times;
- ability to deform – 2-10 times;
- wear resistance – 2 times;
- frost resistance – 1.5-2 times;
- heat resistance – 5-7 times;
- corrosion resistance – 2 times.

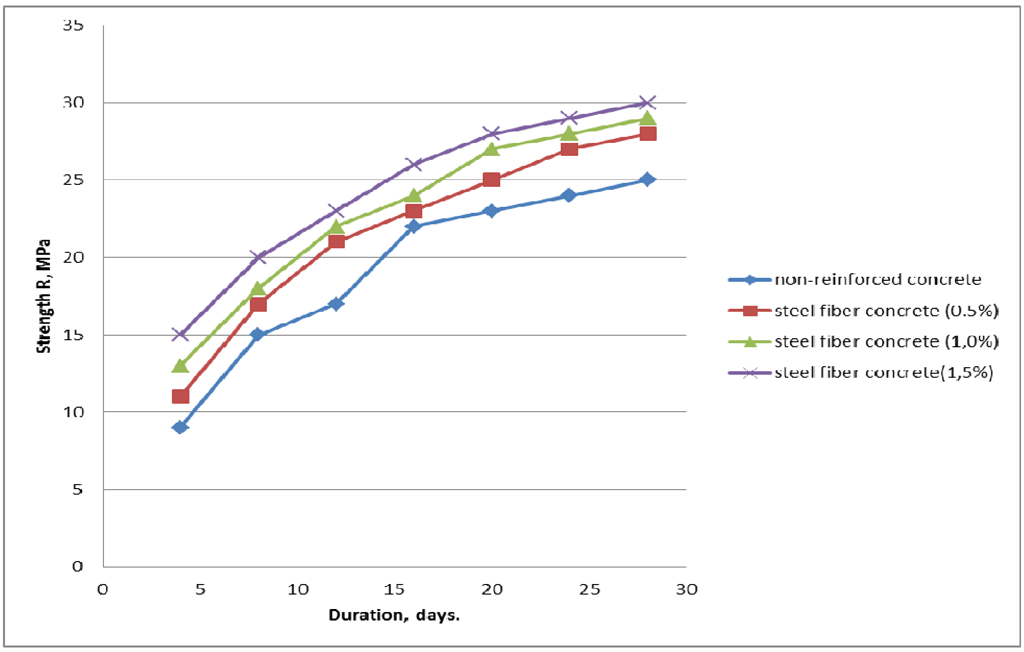

Fig. 2 Strength growth of steel fiber concrete at a temperature of 22 ° C.

The technological processes of manufacturing a homogeneous fiber-concrete mixture depend on the type and quantity of fiber reinforcement (fiber), its geometric parameters (especially the ratio of length to diameter), the volume of cement dough in the concrete matrix, the specified parameters of workability, the maximum size of a large aggregate, the sequence of input components, the method of feeding fiber into the mixer, the type of mixer used and the mixing mode of the fiber concrete mixture.

The amount of fibers injected into concrete in most cases ranges from 0.3 to 2% by volume. Their sizes can be very diverse. Steel fibers are usually used with a length of 1 to 70 mm and a diameter of 0.25 to 1 mm.

Most often, the destruction of fiber concrete occurs due to the pulling of fibers from concrete as a result of a violation of the bond at the fiber –matrix interface, and thus, by increasing the adhesion strength of the fiber to the matrix, it is possible to maximize the use of the strength properties of the fiber itself, up to its rupture at the moment of destruction of the composite. The adhesion of the fiber to the concrete matrix of the composite is the result of the combined manifestation of adhesion, friction and mechanical engagement in the area of their contact with the cement stone. The influence of each of these factors on the anchoring of fibers in the matrix can be different and depends on the composition, structure and properties of cement stone, as well as on the fiber material, their shape and size. Thus, the main mechanism for increasing the strength of dispersed reinforced concrete is to increase the adhesion strength of the reinforcing fiber to the concrete matrix of the composite.

When implementing graphical constructions of fiber diameters in this system , the following was revealed:
- fibers with a diameter of up to 0.4 mm, when placed by volume, practically do not contact the pores or contact no more than in the section under consideration;
- placement of fibers with a diameter of 0.5 to 0.8 mm causes contact with 3 to 5 pores with a diameter of up to 0.3 mm and one with a diameter of up to 0.5 mm;
- with an increase in the diameter of the fiber over 1.0 mm, the contact of the fiber surface is already carried out with 5 pores with a diameter of up to 0.3 mm and 3 – 4 with a diameter of 0.5 mm.

Calculations show that in the first case, the proportion of fiber contact surface losses is up to 3%, in the second – up to 20%, and then does not exceed 27% with an increase in the diameter of the anchor element (Fig.3).

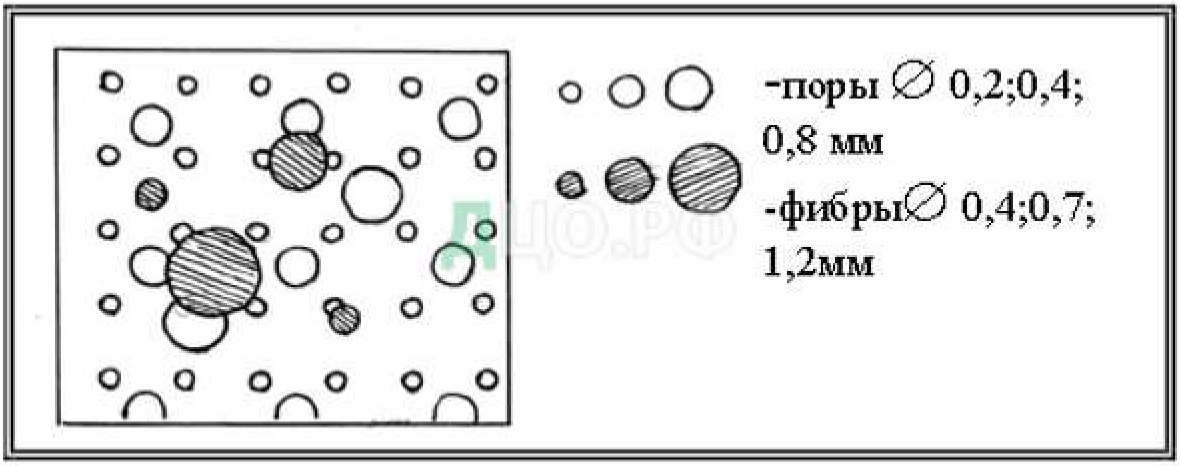

Figure 3 Placement of metal fibers relative to Concrete pores

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