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The properties and application of composite materials on the example of concretes with the addition of steel and synthetic fibers

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Abstract

The properties of fiber-reinforced concretes are currently the subject of many studies due to the possibility of using that type of material in various fields of building engineering. The fiber- reinforced concretes are composite materials, that consist of a concrete matrix and fibers. There are applied many kinds of fibers, for example made of steel, polypropylene or glass. The addition of fibers to the concrete has a beneficial effect on many of its features, including increased impact strength, reduced shrinkage and it also improves concrete strength. The paper presents the possibilities of using reinforced concretes with the addition of steel and propylene fibers.

Keywords: fiber- reinforced concrete, steel fibers, synthetic fibers, concrete composites

1. Introduction

The basic definition of composites indicates that they are materials consisting of at least two components connected at the macroscopic level, which as a result of this combination create a material with new properties [3]. Composite materials have been used in construction, but also in industry, for many years. A special type of composite material used in construction is fiber-reinforced concrete. Fiber-reinforced concrete is a combination of concrete mix with various types of fibers. In this connection, concrete performs the function of a matrix, while fibers - a "structural" function [5,6]. The following fibers are used: steel, polypropylene, glass, graphite or carbon [10], most often - plastic fibers (e.g. polypropylene) and steel.

Modern fiber-reinforced concretes in the currently known form began to be used in the period after World War II. The first type of fibers used after World War II were glass fibers. Currently, the properties off fiber-reinforced concretes are of interest to researchers around the world.

2. Types of fibers used as the addition to concrete mix

The beginning of the use of concrete is determined to ancient ages. The first use of this material in Poland took place in the Middle Ages. As a result of research, concrete and reinforced concrete are improved, among others, through the use of various additives. Among them there are fibers designed to improve the strength and mechanical properties of concrete. As an additive, the following fibers can be used: polyamide, carbon, glass, HDPE, polyethylene, polypropylene, polyvinyl and steel. Individual types of fibers differ significantly in strength properties and dimensions. The smallest are polyvinyl fibers, whose smallest diameter is 3 μm, and the length – 2mm. The largest of the fibers used as the addition to concrete are steel fibers, whose diameter reaches 1mm, and the length - even 60mm [7].

In addition to the influence of the addition of fibers on the mechanical and strength properties of concrete, discussed in the following paragraphs, it is worth mentioning of the change in rheological properties, such as workability, which may deteriorate with the addition of fibers to the mixture [7]. This problem is certainly important due to issues

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involving the production of concrete elements with the addition of fibers (steel and polypropylene), especially in "in situ" conditions. Therefore, it is worth to pay special attention to the recommendations of manufacturers, which indicate the method of laying the mixture with the addition of fibers.

Figure 1. The dimensions of fibers used as the addition to the cement concrete

3. Advantages of concrete with added fibers and examples of application

Among the many advantages of concrete, there should be mentioned durability and strength. The disadvantages include the possibility of scratches, and consequently – corrosion of reinforcement – in reinforced concrete elements [8]. Due to this, there is the desire to improve concrete through the use of various additives, that are designed to improve physical and mechanical properties, affect consistency or strength. The addition of fibers to concrete has a positive effect on many of its features, although it should be noted that the type of fibers added to the mix is very important. Due to the strength and properties of steel fibers, the addition of such fibers to the concrete mix, has usually a much greater impact on its characteristics than the addition of polypropylene fibers.

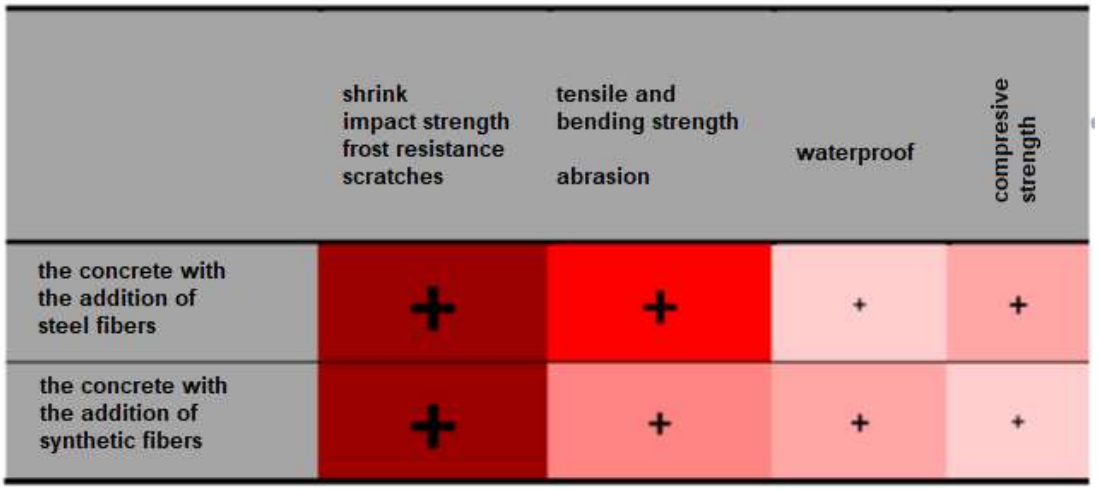

Figure 2. The influence of the addition of fibers to the properties of cement concrete [4,7]

Fibers, both steel and polypropylene, are produced by many factories. Steel used for the production of fibers usually has a yield strength of 500MPa to 1500MPa, but there are fibers made of steel with a yield strength of up to 2300MPa [1]. The tensile strength of polypropylene fibers oscillates around 500MPa. The addition of fibers, both steel and polypropylene, has a positive effect on such properties of concrete as: shrinkage, impact strength or frost resistance. The dosage of steel fibers should not exceed 160 kg/m^3. In general, this amount ranges from 30 to 90 kg/m^3. In turn, polypropylene fibers are added in an amount of approx. 1-4 kg/m^3.

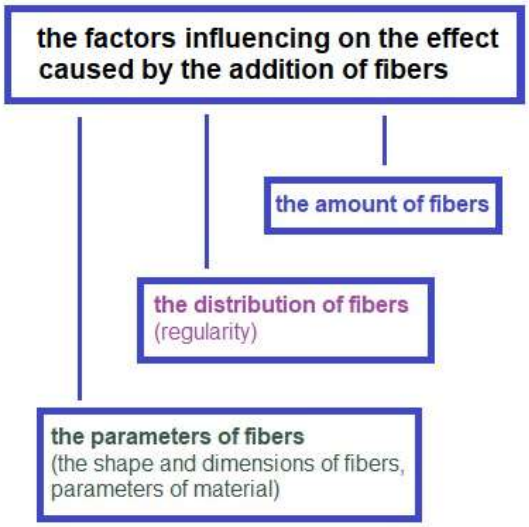

Figure 3. The factors influencing on the effect caused by the addition of fibers to the cement concrete [5]

Steel fibers quite significantly affect the tensile and bending strength of concrete, and also improve its abrasion resistance. The effect of the addition of synthetic fibers in this range is slightly smaller (Figure 2). The magnitude of the effect caused by the addition of fibers affects not only the strength of the material from which they are made and their quantity, but also the distribution in the matrix or parameters such as shape, length and diameter (Figure 3). For steel fibers, different shapes of fiber ends are used to improve cooperation with the matrix (Figure 4).

Figure 4. Sample shapes of steel fibers

Concretes with distributed reinforcement are used in many structural and non-structural elements of buildings and structures. First of all, they are used as an additive to the concrete mix used to make floors. The increase in impact strength, reduction of shrinkage, as well as improvement of concrete strength make it an excellent material for making floors in industrial halls where there are high static and dynamic loads. The technology and method of making floors depends on many factors, including the quality of the subsoil. In particularly difficult conditions, due to the higher strength of the material used for fiber production, dispersed reinforcement made of steel is used [1].

Dispersed reinforcement is also used as an addition to concrete used to make structural elements, especially foundations, e.g. foundation slabs, tunnel elements, etc. Fiber-reinforced concretes are also widely used in road construction and in airport surfaces.

4. Strength tests of concretes with the addition of steel fibers

Strength tests of concrete with the addition of steel fibers are carried out on cubic and cylindrical samples, samples in the shape of beams [2] and plates [9].

The most important are the tests carried out on beams, used to determine of the equivalent resistance to bending [4]. It highlights a very important feature of concrete with the addition of fibers. Samples made of this composite are not brittle damaged during loading, because after the formation of scratches, the fibers still transfer part of the tensile stresses. The diagram of the deflection dependence on the bending force for an ordinary concrete mix and for a mixture with the addition of steel and synthetic fibers is shown in Figure 5.

Strength tests carried out on cubic and cylindrical samples, indicate an increase in the tensile strength of concrete by approx. 25% which depends on the amount and type of fibers added [2]. Also, the analysis of the destruction of plate samples indicates an increase of several percent in the maximum destructive force in the case of samples with the addition of dispersed reinforcement [9]. It is worth noting that the deflection of the examined elements with the addition of dispersed reinforcement at the time of destruction was even twice lower than for samples without the addition of fibers. It is also important that the addition of dispersed reinforcement significantly influenced the method of destruction of samples in the tests. Scratching during sample loading progressed slower and smoother.

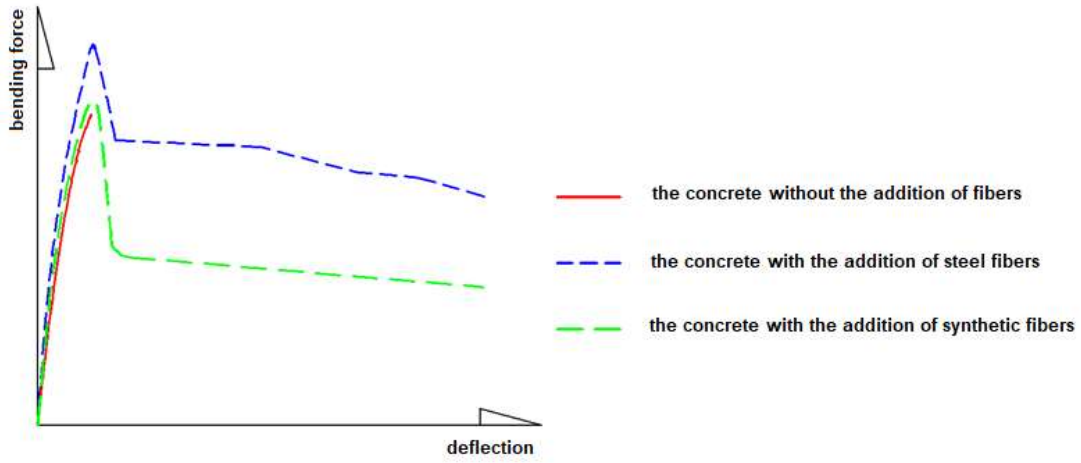

Figure 5. The dependence of deflection of bending force in the experiments made on beam-shaped samples [4]

5. Conclusions

The use of dispersed reinforcement in the form of steel and synthetic fibers, as an addition to the concrete mix, has a beneficial effect on its strength and mechanical properties, especially in terms of scratch formation and tensile strength. The most advantageous solution in structural elements is the use of a combination of traditional reinforcement made of steel bars and an admixture of fibers, which results in a significant increase in the strength of the elements. An important problem during making the elements of fiber-reinforce concrete is the correct distribution and compaction of the mixture with correctly distributed fibers.

The use of fiber-reinforce concrete in construction may result in a reduction in the time of construction execution, but also in a reduction in the cross-section dimensions of structural elements.

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