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Investigation on concrete reinforced with two types of hooked fibers under flexure

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Abstract

Steel fiber reinforced concrete (SFRC) is a material widely used for structural applications. The effectiveness of the steel fibers in the concrete matrix is strongly affected by the shape of the fibers. Because the steel fibers with various geometrical parameters are currently available, the knowledge about their influence on concrete response is needed. The paper presents the investigation on concrete reinforced with new type of fibers which are crimped along the length with additional hooks at the ends. To estimate the effect of this kind of fibers on the mechanical parameters of SFRC the typical hooked fibers were also investigated. The compressive and three-point flexural tensile tests were performed on specimens where three fiber contents were applied: 0.32 %, 0.45 % and 0.57 %. The results indicate that the fracture energy did not differ apparently, whereas in the equivalent tensile strengths some differences were noted due to the change of fiber shape. The difference was only observed in the shape of the load-deflection curves obtained from the tests with a use of two fiber types. However, the compressive strength and flexural tensile strength at the limit of proportionality were more affected by crimped and hooked fibers than typical hooked ones. It shows that the new type of fiber may delay the formation of the cracks in the SFRC.

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Keywords: steel fiber reinforced concrete, flexural parameters, hooked fibers

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1. Introduction

Fiber reinforced concrete is a material that found wield field of applications in structural engineering as a material with improved brittleness and ductility comparing to plain concrete. Application of randomly distributed short fibers significantly improves the tensile strength, post-peak behavior under tension and compression as well as the response to dynamic loading of concrete [1-3]. The effectiveness of the fibers in the concrete matrix is affected by many factors like: fiber material, volume ratio and geometrical parameters of fibers, their orientation in the matrix and strength of the matrix. Considering the material used for fibers, besides synthetic, organic, glass etc., steel is the most commonly used, because the biggest enhancement in mechanical parameters can be obtained by incorporation of this kind of fibers into brittle matrix [1-8]. The greatest variety of the types of fibers can be found among the steel ones [4]. One of the most important geometrical parameters of the fibers is their length and aspect ratio (length/diameter). However, keeping these parameters constant, the longitudinal and cross-sectional shape of the fibers plays the most important role in affecting the mechanical parameters of the matrix [2]. Any deformation of straight fiber improves the bond between the fiber and the concrete matrix, and as an effect enhances the mechanical parameters of steel fiber reinforced concrete (SFRC). Currently produced fibers can be hooked, crimped, twisted, flattened and many others. The cross-section of the fiber may be circular, rectangular, part of a circle or other irregular [1,2,4]. The length of the fibers is crucial as fibers attract the cracks according to their length. Thus, the best improvements are noted in the hybrid composites, where fibers made from different materials or with different geometrical parameters are mixed [1,9]. However, the producers started to supply the fibers with mixed longitudinal shapes. The combination of different shapes may bring some additional benefits in mechanical parameters of concrete. This kind of fibers were not widely investigated, thus, the knowledge about the response of concrete reinforced with these fibers would be interesting and needed.

The present paper deals with a new fiber type which joints two kinds of the longitudinal shapes of fibers: hooked and crimped. The straight part of a traditionally hooked fiber is additionally crimped along its length. In order to evaluate the influence of this kind of fibers on the mechanical parameters of SFRC the results were compared to the typical hooked fibers of similar length and aspect ratio. The flexural parameters of SFRC were analyzed, as commonly done to evaluate the effect of fibers on concrete matrix [3,5-8].

2. Experimental study

The composition of concrete matrix is presented in Table 1. The plasticizer used was Pantarhit 50 (BV). In the investigation three different volume fractions of 0.32 %, 0.45 % and 0.57 % were adopted, using two types of fibers described in Table 2. Both types of fibers had hooks at the ends, however, one type was additionally crimped along its length. The diameters of the fibers were the same (0.5mm), while lengths of the fibers were equal to 50 mm and 55 mm for hooked (H) and crimped and hooked (CH) fibers, respectively. Thus, the aspect ratios of the fibers were comparable.

Table 1. Composition of SFRC mix.

Cement CEM I 42.5R (kg/m^3)	Natural sand (0–2 mm) (kg/m^3)	Fine aggregate (2–8 mm) (kg/m^3)	Coarse aggregate (8–16 mm) (kg/m^3)	Water (kg/m^3)	Steel fibers (%)	Plasticizer (kg/m^3)	W/C
350	635	830	488	168	0.32; 0.45; 0.57	7	0.44

The analysis was focused on determination of the compressive strength and flexural parameters of SFRC mixes at the age of 28 - days. For each mixture, four cubes with the dimensions of 150 × 150 × 150 mm^3 were tested in compression. Tests were performed with a constant strain rate using servo-hydraulic testing machine. The flexural behavior was investigated in three-point bending tests on four notched beams for each mix with the dimensions of 150 × 150 × 600 mm^3 (Fig. 1). The span of the beam was equal to 500 mm. During the tests the mid-span deflection increased constantly with the rate of deflection equal to 0.2 mm/min until the deflection reached 5 mm. The crack