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Experimental investigation on hybrid steel fibers reinforced self-compacting concrete under flexure

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Abstract

Using the self-compacting concrete (SCC) can shorten the time and decrease the costs of the building process. The incorporation of the randomly distributed steel fibers into brittle SCC improves its tensile parameters. The steel fibers can be effective in delaying propagation of micro- or macro-cracks according to geometrical parameters of fibers. To attract all types of cracks the fibers with different geometrical parameters should be used simultaneously. In the present paper, the influence of the combinations of straight and corrugated steel fibers with different lengths (6 mm, 35 mm) and cross-sectional shape on the compressive strength and flexural behavior of SCC was investigated. The total fibers volume ratio varied from 1.0 % to 3.0 %. Among the rheological parameters of self-compacting concrete, the hybrid fibers reinforcement did not influence workability but pronouncedly decreased passing ability. Thus, the mixes reinforced with the highest fibers volume ratios did not satisfy the requirements for the SCC. Based on the mechanical test results no apparent difference in the compressive strength was noted. The results showed that the flexural parameters were pronouncedly enhanced in the HFR-SCC due to the hybrid fiber addition and at low dosage rates depended on the proportions between the two applied types of fibers. However, using the highest summary amounts of fibers did not cause further increase in flexural parameters.

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Keywords: self-compacting concrete, hybrid mix of steel fibers, flexural tensile strength

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1. Introduction

Concrete is the most popular material used for structural applications, which parameters are being constantly modified to satisfy the requirements of the market. Nowadays, shortening of the time of the building process and decrease of the costs are desired from the economical point of view. It can be obtained by using the self-compacting concrete (SCC), which production is enabled by the application of superplasticizing chemical additives and/or mineral admixtures (e.g. fly ash). This kind of concrete fills the framework in a natural manner, passes through the obstacles and consolidates under its own weight with no need for vibration. The labor needed for placing and finishing the concrete is also minimalized as is the noise connected to the vibration [1-4]. The further improvements of concrete concerns its low tensile parameters, which are the major barrier to many applications [5]. The tensile strength, dynamic parameters and toughness of the self-compacting concrete can be considerably improved by application of short randomly distributed fibers. The effectiveness of the fibers in the matrix depends on their material, geometrical parameters (length, diameter, longitudinal profile, cross-sectional shape) and amount used [6]. The fibers are most effective in improving the post-cracking parameters of the matrix. Single type of fiber works only in some range of cracks. The micro fiber acts as a bridge to prevent the formation of micro-cracks, while longer ones are more effective in arresting macro-cracks. Combining the benefits of the fibers with various length should bring the significant effect in improving tensile parameters (synergy effect) [7]. Considering the material, the most effective in improving the parameters of concrete among steel, synthetic and organic fibers are the steel ones [6]. The mechanical parameters of concrete strongly depend on the amount of fibers, which in turn influences the rheological parameters of SCC. The workability and passing ability of SCC can be pronouncedly reduced by high amount of fibers. From that reason, to find an optimal combination of different types of fibers in self-compacting concrete the mechanical parameters should be analyzed in parallel to the rheological parameters.

The present paper deals with the hybrid fiber reinforced self-compacting concrete (HFR-SCC) which combines short and long steel fibers of a different shape to attract the cracks at different levels. The combination of exactly these types of fibers was not investigated before. Some attempts to compare the test results with the one in the literature were made. However, all of the researchers combined the different types of steel fibers in order to improve the parameters of concrete [1,3,5,7-9]. The total amount of fibers analyzed in the literature did not exceed 2 % and in the present research it was equal to 3 %.

2. Experimental study

The components of self-compacting concrete and their proportions used in the investigation are given in Table 1. The Glenium SKY 592 Superplasticizer was applied in the amount of 3.5 % of the mass of cement. The superplasticizer was based on polycarboxylate ether (concentration 20 %) and characterized by density of 1.07 g/cm^3. The 0.4 % of the mass of cement of stabilizer RheoMATRIX 100 with a density equal to 1.01 g/cm^3 were also used in the mix. The detailed procedure of preparation of self-compacting concrete can be found in [4].

Table 1. Composition of HFR-SCC mix.

Cement CEM I 42.5R (kg/m^3)	Natural sand (0–2 mm) (kg/m^3)	Coarse aggregate (2–8 mm) / (8–16 mm) (kg/m^3)	Water (kg/m^3)	Steel fibers (%) by volume	Superplasticizer (kg/m^3)	Stabilizer (kg/m^3)	W/C
450	750	570 / 300	200	1.0÷3.0	15.75	1.8	0.44

Two types of fibers with a different length (6 mm, 35 mm), longitudinal shape (straight, corrugated) and cross-sectional shape (circle, part of a circle) were used in the investigation (Table 2). Nine mixes contained combination of each fiber type with the amount equal to 0.5 %, 1.0 % and 1.5 %, which is the dosage weight of 39.25, 78.5 and 117.8 kg/m^3, respectively. The detailed proportions between the fibers in each mix and their designation are summarized in Table 3. The total volume ratio of fibers in the nine mixes was in a range of 1 ÷ 3 %. The research programme included the investigation of the properties of the mixes in a fresh state (L-Box tests, Slump flow tests). The analysis was focused on determination of the compressive and flexural parameters of HFR-SCC mixes at the