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Investigation On Flexural Properties of Hybrid Fibre Reinforced Self-Compacting Concrete

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Abstract

The paper considers compressive and flexural parameters of self-compacting concrete reinforced with combination of steel and polypropylene fibers. Three volume ratios of steel fibers (0.5%, 1.0%, 1.5%) were mixed with two amounts (0.3%, 0.9%) of two types of polypropylene fibers. The influence of hybrid fibers on the compressive strength of SCC was negligible and comprised in the range of -5 to 11% of the strength of the matrix. Based on the flexural tensile tests on hybrid fibre-reinforced mixes it was noticed that steel fibers play the most important role in enhancement of the mechanical parameters. Meanwhile, in the hybrid mix of polypropylene fibers only slightly improve the toughness, irrespectively of the length of the PP fibers. The highest applied amount of the longest polypropylene fibers indeed improved the flexural parameters of the SCC matrix reinforced with steel fibers but on the other hand such concrete did not satisfy the requirements for SCC in the fresh state.

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Keywords: self-compacting concrete, hybrid fibers, steel fibers, polypropylene fibers, flexural tensile strength.

1. Introduction

Self-compacting concrete (SCC) is a new type of a cement-based material, which due to its high deformability and resistance to segregation fills the framework in a natural manner and consolidates under its own weight with no need for vibration. Among its advantages over the traditionally vibrated concrete, which are widely discussed in [8], the SCC reduces the overall costs of the structure and ensures more space for designers because it can be used even in

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very complicated framework with a congested reinforcement. The composition of SCC is based on the same ingredients as in conventional concrete, however, they are applied in different proportions [1].
As any other cement-based materials, the SCC has a brittle nature, therefore to improve its tensile mechanical properties as well as the behaviour under the impact different kinds of fibers can be applied. Fibers are spread uniformly in the matrix, which prevents or delays initiation and propagation of matrix cracking. This supplement changes large single cracks into a system of multiple smaller cracks, which is desired from safety and durability point of view [2]. According to the material and geometrical parameters like: diameter, length, aspect ratio, longitudinal profile and cross-sectional shape, the fibers enhance the mechanical parameters of the matrix under tension and flexure [4,5]. Among the fibers available in the market the best performance can be observed for steel fibers. However, steel fibers cannot ensure the required safety of the concrete structures to their users during fire, which has nowadays become an important aspect. The process of destruction of concrete under high temperature can be delayed by addition of the polypropylene fibers (PP), [3].
The investigations presented in the paper are focused on the simultaneous influence of the steel as well as polypropylene fibers on the compressive and flexural mechanical parameters of the SCC matrix. The analysis will help to answer the question whether a separate influence of each type of fibers on the SCC matrix overlaps and the synergy effect appears.

2. Experimental investigation

The composition of the mixes is presented in Table 1 and the detailed description of its preparation can be found in [6]. In the present paper the hybrid mixes were prepared with the use of steel and polypropylene fibers. Three volume ratios of steel fibers: 0.5%, 1.0% and 1.5%, which is the dosage weight of 39.25, 78.5 and 117.8kg/m^3, were tested. The examined steel fibers were 35mm long with a sector of the circle cross-section and corrugated longitudinal shape (Table 2). The considered polypropylene fibers had two lengths: 19mm and 38 mm (Table 2) and were added in the amounts of 0.3% and 0.9%, which is the dosage of 2.7 and 8.1 kg/m^3, respectively. The different combinations of steel and polypropylene fibers can be found in Table 3, where the rheological parameters of hybrid fibre-reinforced self-compacting concrete (HFR-SCC) including slump-flow and L-box tests are also summarized.
The mechanical properties of the HFR-SCC mixes were tested in compressive and flexural tensile tests at the age of 28 days. The compressive tests have been carried out in 3000kN hydraulic compression testing machine on cubes with dimensions of 150×150×150 mm. For every mix 6 specimens have been tested with a constant loading rate.
The flexural tensile parameters were tested in three-point bending tests on three beams for each mix with dimensions of 100×100×400mm (Fig. 1). The mid-span deflection increased constantly with the rate of deflection equal to 0.2mm/min, until the deflection reached 2 mm.

3. Test results and discussion

The extensive studies on the influence of only polypropylene fibers on the mechanical parameters of the SCC matrix has been performed by the authors in [6].

3.1. Properties of mixes in the fresh state

In general, fresh parameters decrease with an increase in the amount of fibers, which is a well-set knowledge [7]. The mixes prepared with the use of only steel fibers satisfied the requirements for the SCC in the fresh state. All the hybrid mixes conformed to the demanded range of slump flow test (550÷850mm), except for those containing 0.9% of the 38mm PP fibers. The passing ability of all hybrid mixes investigated in L-box tests, where 0.9% of both investigated PP fibers was applied, was not satisfied. Considering the summary amount of fibers it can be concluded that for the $V_f > 1.4\%$ the hybrid mixes did not satisfy the requirements for the SCC. This trend was observed without regard for superplasticizer amount. In all hybrid mixes the increase in porosity in comparison to plain SCC was observed.

3.2. Compressive strength