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EFFECT OF MATRIX STRENGTH ON TOUGHNESS OF STEEL FIBRE REINFORCED CONCRETE

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ABSTRACT

Influence of matrix strength on toughness of two SFRC mixes have been investigated by four-point bend test. Flexural toughness properties obtained by ASTM C1018 method, and interpreted by JSCE SF-4 method, are compared for SFRC mixes tested. The test results showed that the matrix strength has the significant role on SFRC post-cracking behaviour.

Key words: Steel fibre reinforced concrete, toughness, four-point bend test

1. INTRODUCTION

The term of ‘Steel fibre reinforced concrete’ (SFRC) is made up with cement, various sizes of aggregates, which incorporate with discrete, discontinuous steel fibres [1]. X-ray photo of SFRC specimen's cut section is shown in fig. 1. Fibres are used for two major purposes, reduction of crack widths and obtaining a ductile post-crack behaviour. The modern use of fibre reinforced concrete started in the 1960s using straight, smooth discontinuous steel fibres. Steel fibres are the dominating material, but there are many others, such as polymeric fibres, mineral fibres and naturally occurring fibres.

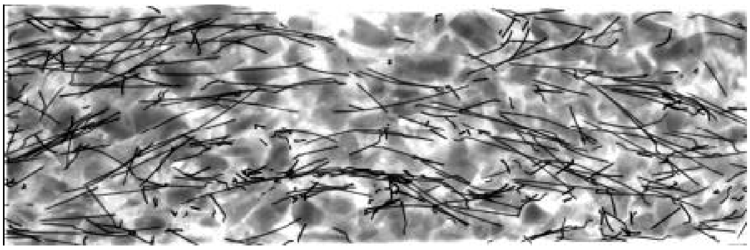

Figure 1. X-ray photo of SFRC specimen's cut section[2]

The most commonly used types of fibre reinforced concrete are those with steel fibres added in low volumes, up to about 1% per volume, in normal mix proportions with coarse aggregates. In such composites the elastic properties, strength and Young's modulus, are usually not affected. Instead, it is the improvement of toughness and the crack distributing properties that motivates the use of fibres. The influence of dosage, shape, aspect ratio and other fibre characteristics on SFRC performance have been subject of numerous investigation [1,2,5]. However, existing literature has not treated the relation between the matrix strength and SFRC properties.

Figure 2. Steel fibre with hooked ends

The composite behaviour of fibre reinforced concrete depends on the pull-out behaviour of a single fibre from the matrix, as well as on their orientation and distribution over the crack surface. Steel fibres with hooked ends are widely used for reinforcing concrete, fig.2. The hook significantly increases the maximum pull-out force compared with the same fibre type without a hook, due to the plastic deformation and friction of the hooked end. The hook also increases the frictional resistance once the fibres completely entered the straight channel (the fibre hook is not perfectly straight).

2. EQUIPMENT AND TEST PROCEDURES

Two different class of concrete, MB 25 and MB 40, have been used for manufacturing the test specimens. Three specimens are manufactured from each type of concrete. The specimens for bending tests have the dimensions 400×100×100 mm according to ASTM C 1018. In order to determine effect of the matrix strength on toughness of SFRC, investigations have been carried out on specimens of two class of concrete: MB 25 and MB 40. Both baches contained 40 kg/m^3 steel fibres with the dimensions: length 32 mm and diameter 0.6 mm. The compositions of these concretes are shown in table 1.

Table 1. Composition of concrete used for manufacturing the specimens

Components of concrete		**MB 25**	**MB 40**
Cement Cement plant Kakanj	Type	PC 30p 35 s	PC 30p 45 s
	Mass (kg)	390	430
Aggregate crushed limestone Kota Vareš (kg)	fraction 0-4 mm: 65 %	1100	1080 k
	fraction 4-8 mm: 35 %	600	580
Water (kg)		215	215
Additive Cementol SMB (0,4% of cement mass)		1,56	1,72
Water-cement ratio		0,55	0,50
Slump of concrete (cm)		7	7
Temperature of concrete (ºC)		19	19

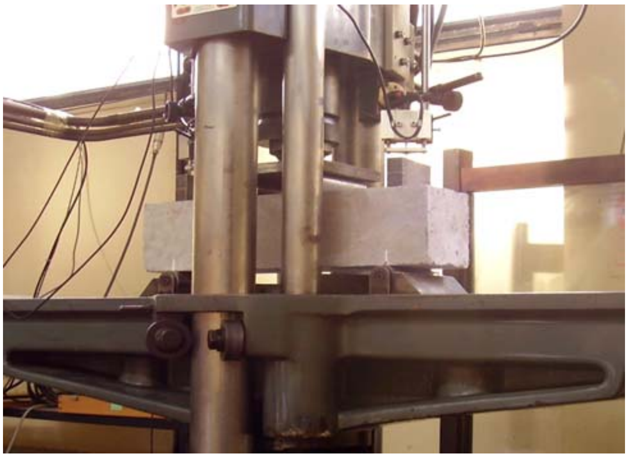

Figure 3. The set-up for four- points bend test of SFRC

The specimens were compacted on a vibrating table in order to assure a dense mix and an uniform distribution of fibres. The curing procedure was consisted on the keeping the specimens immersed in water for 55 days. The equipment, the definition of the test procedures and their accomplishment are controlled by software. The hydraulic power station of the equipment was prepared for a maximum loading of approximately 200 kN. The set-up of laboratory test performed is shown in fig. 3.

However, some problems remains with the ASTM C 1018 method such as extraneous deformations, stability problems and the decision of location of the first crack in the curve. For that reason, the JSCE-SF4 method has been used for the intrepretation of the results. Both, ASTM C 1018 and JSCE SF4, methods are based on evaluation of the recorded load versus mid-span deflection curve for a four-point bend test, fig. 3. Load-deflection curves are the most common method of quantifying the energy a beam absorbs during its load induced flexural deflection.

The area under the curve represents the energy absorbed by the beam and is often reffered to as the toughness, [4].The JSCE-SF4 method provides an absolute value of the flexural toughness. The toughness factor can be considered as an average flexural strength for deflections up to $L/150$. As compared to the ASTM method, there is no need to determine the point of first crack and the evaluated values are not as sensitive to instabilities in test results. This principle, that includes examination according to one standard and interpretations of the results according to the other standard, is often used in the field of cement based composites [3].

3. THE TEST RESULTS

Representative load-deflection curves for tests are shown in fig.4, and the values of the absolute toughness and the toughness factors are shown in fig. 5.

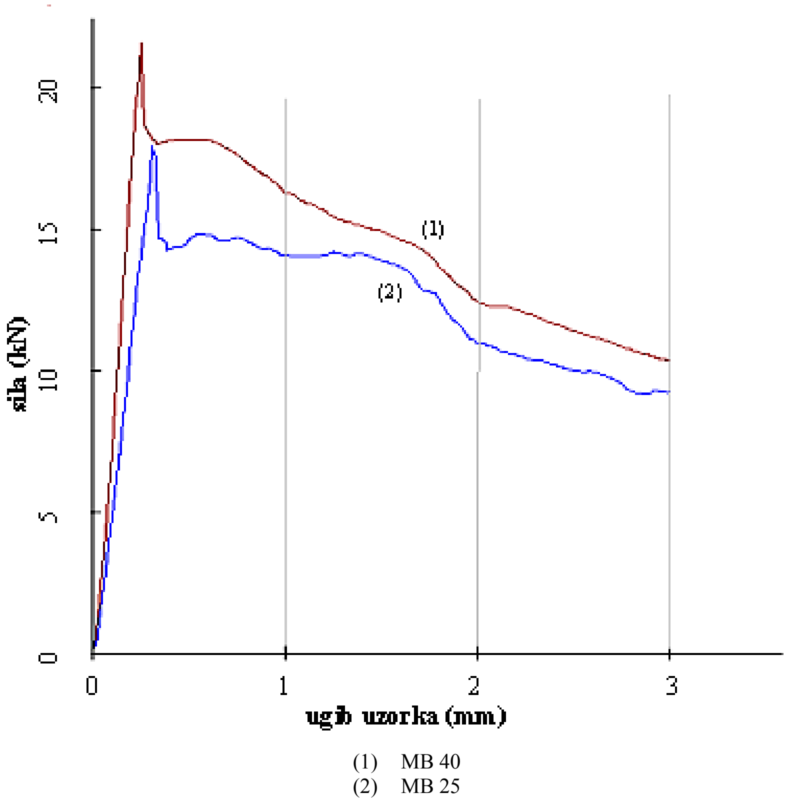

Figure 4. Load - deflection curves from four-point bend tests of two different class SFRC

From the load-deflection relationship it was evaluated the absolute value of flexural touughness, and the toughness factors, and the results are shown in table 2.

Table 1. The absolute toughness and the toughness factors of SFRC (JSCE SF4)

	T (Nm)	f (Mpa)
MB 25	16,67	2,50
MB 40	29,80	4,47

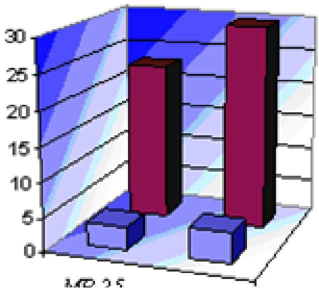

Figure 5. Influence of the matrix strength on absolute toughness and toughness factors of SFRC

The test results clearly show that the matrixs strength has the significant role in the SFRC behaviour. The shape of the postpeak load-deflection relationship was deeply dependent on the matrix strength. Increase in the toughness of SFRC class MB 40 is explained by improoved adhesion between fibres and matrix. As a consequence the fibres that bridging cracks have better ancoring and it is harder to pull-out the fibres from matrix. In addition, the spalling of matrix is reduced and this result in higher toughness of SFRC.

4. CONCLUSIONS

For the range of parameters evaluated in this programme, significant differences in toughness of SFRC associated with changes in matrix strength are clearly identified. Absolute toughness and toughness factors of SFRC depend on matrix strength; the higher the matrix strength, the higher the absolute toughness and the toughness factors. This is due to better ancorage of fibres in the matrix and reduced spalling of matrix in SFRC manufactured from higher strength concrete.

5. REFFERENCE

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