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Flexural behaviour of small steel fibre reinforced concrete slabs

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Abstract

Influence of length and volumetric percentage of steel fibres on energy absorption of concrete slabs with various concrete strengths is investigated by testing 28 small steel fibre reinforced concrete (SFRC) slabs under flexure. Variables included; fibre length, volumetric percentage of fibres and concrete strength. Test results indicate that generally longer fibres and higher fibre content provide higher energy absorption. The results are compared with a theoretical prediction based on random distribution of fibres. The theoretical method resulted in higher energy absorption than that obtained in experiment. A design method according to allowable deflection is proposed for SFRC slabs within the range of fibre volumetric percentages used in the study. The method predicts resisting moment–deflection curve satisfactorily.

Keywords: Concretes; Cracking; Energy absorption; Fibre reinforcement; Flexural behaviour; Slabs; Steel fibres; Structural design; Tests

1. Introduction

Fibres considerably reduce brittleness of concrete and improve its mechanical properties. Fibre concrete can be used in structural slabs. These slabs can be used for example in structural ceilings, pedestrian bridges and industrial floors.

In 1980, Ghalib [1] proposed a design method based on ultimate strength criteria for small steel fibre reinforced concrete (SFRC) slabs. This method is based on test results of eight steel fibre reinforced two-way slabs. Since then, no new method has been proposed for designing fibre concrete slabs and ACI committee 544 [2] has recommended the same method for design of slabs with small spans. However, the committee has recommended that this method should not be used for slabs with dimensions larger than those tested by Ghalib.

In 1999, Marti et al. [3] tested circular and square slabs under point loading with continuous simple supports along the perimeter. They also presented some formulations, which estimated the results of their slab tests with specific dimensions. However, they stated that additional tests on slabs with other parameters are required to further verify their proposed formulations.

The objective of this research study was to experimentally determine flexural strength, load–deflection curve and energy absorption of small concrete slabs using various percentages of steel fibres. Influences of fibre length and concrete strength were also investigated. Moreover, presenting a design method based on allowable deflection was the other objective of this study.

2. Research significance

Numerous research studies have been performed on mechanical properties of fibre concrete and concrete structural members reinforced with fibres under various loading conditions. However, studies on behaviour of concrete slabs reinforced with fibres considering various parameters are limited.

In the present investigation, influence of percentage and length of fibres on strength and energy absorption of concrete slabs with two different concrete strengths is studied. According to theoretical evaluation, design bases for application are presented.

3. Experimental program

Fourteen concrete mixtures with four different fibre contents, two different fibre lengths and two concrete strengths were designed.

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The slabs were square with dimensions of 820 × 820 mm and thickness of 80 mm. Four corners of slabs were seated on roller points which provided clear span length of 680 mm. Point load was applied by stroke mode of an actuator on 80 × 80 × 10 mm steel plate placed at slab centre. The displacement at the loading point was increased at rate of 1.5 mm/min. Sensitive linear voltage differential transducers were used to measure the deflection at slab centre.

The compressive strengths of 152.4 × 304.8 mm cylindrical plain specimens were 30 and 45 MPa at the age of 28 days. Details of experimental program are given in Table 1. Mix proportions for the 30 and 45 MPa concretes are presented in Table 2. Similar mixes were used for SFRC specimens. The volumetric percentages of steel fibres, i.e., the ratios of the volume of fibres to the volume of matrix were 0.5, 1.0 and 1.5, which correspond to 25, 50 and 75 kg of steel fibres for mix proportions used in the tests. Cement type I along with river aggregates was used. Sand had a fineness modulus of 2.7 and coarse aggregates had a maximum aggregate size of 19 mm (3/4 in.). The superplasticiser corresponded with ASTM C494 Type F. The crimped shape steel fibres had a rectangular cross-section. Shape properties of steel fibres are given in Table 3.

4. Experimental results and discussion

The average test results for each pair of slabs are presented in Table 4. Also flexural test results of slabs are shown as load–deflection and absorbed energy–deflection curves in Fig. 1a–e.

4.1. Ultimate strength of slabs and energy absorption characteristics

Presence of steel fibres in concrete did not significantly influence the ultimate strength of slabs. Small variation in the ultimate strength was due to changes in compressive strength of concrete caused by addition of fibres. Essentially, ultimate strength corresponds to initiation of

Table 1
Experimental program

Concrete strength (f'_c, MPa)	Fibre type	Fibre volumetric percentage	Specimen number	Number of cylindrical specimens	Number of slabs
30	–	0	1	3	2
	jc25	0.5	2	3	2
		1.0	3	3	2
		1.5	4	3	2
	jc35	0.5	5	3	2
		1.0	6	3	2
		1.5	7	3	2
45	–	0	8	3	2
	jc25	0.5	9	3	2
		1.0	10	3	2
		1.5	11	3	2
	jc35	0.5	12	3	2
		1.0	13	3	2
		1.5	14	3	2
Total number of specimens				42	28

Table 2
Mix proportions of concrete (m^{-3})

Concrete strength (MPa)	Cement (kg)	Fine aggregates (kg)	Coarse aggregates (kg)	Water (kg)	Superplasticiser	Water–cement ratio
30	400	800	1000	192	0.5% = 2 kg	0.48
45	450	750	1000	166.5	1.5% = 6.75 kg	0.37

Table 3
Shape properties of steel fibres

Fibre type	Length (L, mm)	Width (W, mm)	Thickness (T, mm)	Equivalent diameter (d_f, mm)	Aspect ratio (L/d_f)
jc25	25	0.8	0.35	0.597	41.9
jc35	35	1.0	0.35	0.668	52.4