Shear Design Performance of Beams Reinforced with Steel Fibers and Stirrups

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Summary

Many researchers have established the effectiveness of steel fibers in shear strength enhancement in RC beams. Use of steel fibers as shear reinforcements can be attractive in load bearing structures as well as in thin concrete section where conventional reinforcements can not be used. Moreover, in reinforced concrete frames, relief of stirrups in congested areas, crack control and ductility improvement can also be achieved with use of steel fibers. The fact that steel fiber reinforced concrete (SFRC) is a ready to use material implies that fabrication of stirrups and manual labor required for fixing is reduced or avoided. These merits result in robust and faster structure construction in which cost savings can be made leading to adequate and affordable supply of shelter. However, practical application of SFRC in RC beam is hampered by lack of design guidelines. In this study, a simple shear design method for steel fiber RC beams is proposed and tested.

Key word: Shear design, Steel fiber reinforced concrete, RC beam, stirrup, shear strength

1. Introduction

Experimental investigations [e.g.1,2,3], have shown that SFRC possess improved shear resistance owing to an increase in post cracking tensile strength, which also delays the formation and growth of cracks [3]. Moreover, a smaller distance exists between fibers as compared to that between conventional stirrups, enabling greater effectiveness in crack-arresting mechanism and better distribution of tensile cracks and thus brittle failure modes (e.g. in shear) is minimized. Therefore, addition of fibers in adequate quantities can be effective in supplementing or replacing conventional shear reinforcement. This paper proposes a simple shear design method for SFRC beams and evaluates the performance for designed SFRC beams based on the proposed method referred in this paper as equivalent design method (EDM). The performance evaluation was based on six small and three large RC beams reinforced with stirrups and variable amount of steel fibers determined to match the number of stirrups.

2. Proposed equivalent design method (EDM)

The proposed Equivalent design method (EDM) is based on shear design for conventionally reinforced stirrup RC beams and the proposed design equations for SFRC beams. Design for shear is carried with the guide of an appropriate or desired conventional design code (e.g. BS8110). Then an equivalent amount of fiber content is determined based on the designed required number of stirrups using Eq.1. Strength check for SFRC is evaluated based on Eq.2. As a counter check, ACI committee 544 recommended formula for SFRC can be also applied.

$$v_f = \frac{N_s a_s l_s}{l_b A_b} \qquad \text{(Author's formula)} \qquad (1)$$

Where, v_f is the equivalent fiber fraction, N_s is the number of stirrups required and it corresponds to

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an equivalent fiber content, l_b is the beam length, b is the beam width, A_b is cross sectional area of the beam, a_s and l_s are the stirrup cross-sectional area and lab length, respectively.

$$\tau_{fc} = \frac{2}{3} K_1 \frac{d}{a} \left\{ 2.99 - \left[\frac{\sigma_{ct}}{\sigma_c} + \frac{1.99 K_1}{\sigma_c} \right] \left[\frac{3\sigma_{ct}}{2K_1} + 2.98 \right] \right\} + \sigma_{ct} \frac{d}{a} \quad \text{(Author's formula)} \qquad (2)$$

Where K_1 is a dimensional fiber concrete parameter, σ_{ct} is the tensile strength of plain concrete, σ_c is the average compressive strength, a/d is a shear span to depth ratio.

3. Design Performance

Bending shear tests (Fig.1) were conducted on large (1800×230×150mm) and small (400×100×100mm) beams whose shear reinforcement requirements were determined based on EDM. Fig.2 shows the typical load deflection response for the designed stirrup (SB1) and fiber (FB1) beams reinforced with 1% shear reinforcements. It is apparent from these figures that the fiber beams have a higher strength capacity than the equivalently stirrup beam.

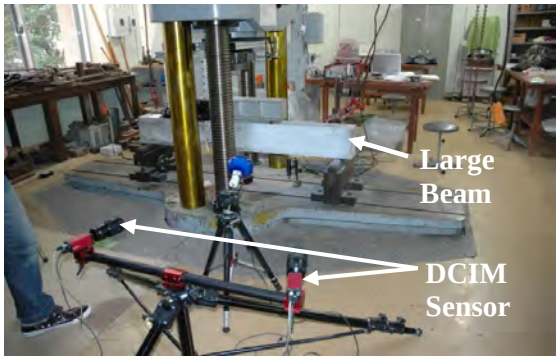
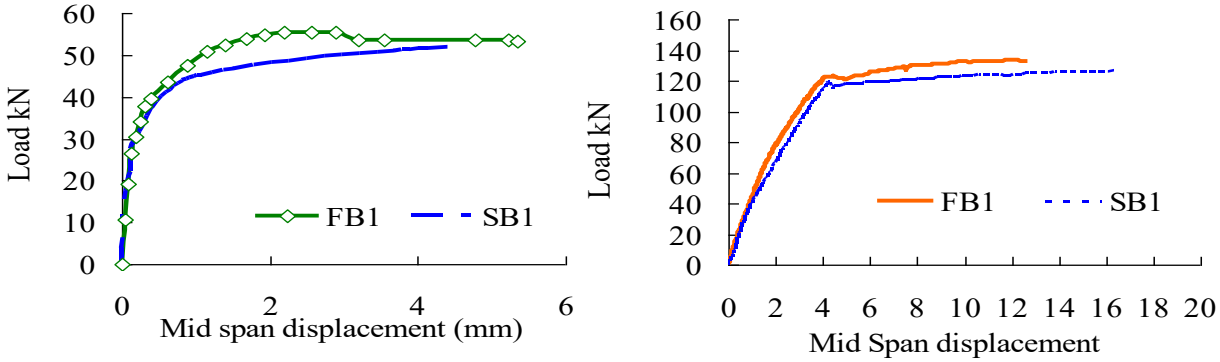


Fig.1 *Beam test set up for the large beam*



(a) Small beams (b) large beams

Fig.2 *Fiber/Stirrup reinforced beams load deflection response comparison*

4. Comments and Conclusions

As there is no documented specific method for design and utilization of steel fiber reinforced concrete (SFRC) as a structurally sufficient material in at least meeting minimum shear requirements, the proposals made in this paper are only meant to show the possibility of modifying and adapting existing conventional design methods for SFRC beams. Principally, the proposed EDM was found to be effective in the design for shear in steel fiber reinforced beams. Comparable performance in load carrying capacity between fiber reinforced and stirrup reinforced beams was established

5. Reference

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