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The Investigation of Fiber Reinforcement Self-Compacting Concrete and Fiber Reinforcement Concrete

Orod Zarrinkafsh[1,*], Mohesn Ramezan Shirazi[1], Hassan Moniri[1] and Mohammad Moniri[2]

[1]*Eastern Mediterranean University, Famagusta, Cyprus*
[2]*Department of Civil Engineering, IAU, Shahrood, Iran*

Abstract

Precisely, researches have been done on Fiber Reinforcement Self-Compacting Concrete (FRSCC) which can divide into two different fields, material serviceability and mechanical rheology investigations. The mechanical aspect of FRSCC has been investigated to provide the constitutive models of shear and flexure capacity, tensile or compressive zone data. The characteristics of FRC are determined by post-cracking behavior and FRSCC is controlled by SCC workability. By using FRSCC the costs and construction period reduce significantly and its ability to place irregular section in terms of congestion of stirrups and bars and thin section is another great aspect.

Consequently of this capability is to arrest cracks, fibers mixtures increased tensile strength, both at ultimate and at first crack, especially under flexural loading. The other ability of fibers are to hold matrix after extensive cracking. The transition failure from brittle to ductile by fibers is another ability of fibers which can absorb energy and survive under impact loading. In this study, investigate the fibers influence by two techniques, direct and inverse technique.

Keywords: Direct and inverse technique; Fiber; Post-cracking; Self-compacting concrete; Tensile strength

Introduction

Limiting the tensile crack to a certain location and preventing of excessive diagonal tensile cracking are other advantages of steel fiber [1]. Investigation has been lead to the development of SCC (FRSCC), which combines the greater ductility, durability and mechanical features, of FRC with the workability of ordinary SCC [2-5]. FRSCC has been effectively applied in practical structure [6]. FRSCC can improve the workability of SFRC and can modify the crack sections. The mechanical aspect of FRSCC has been studied by several researchers to provide the constitutive models of shear and flexure capacity, tensile or compressive zone data. In this part, major studies on FRSCC are reviewed to prepare an adequate background of FRSCC [7]. Researchers have studied about steel fiber self-compacting concrete (SFSCC) and fiber reinforced concrete (FRC) that find out the characteristics of FRC is determined by post-cracking behavior and SFSCC is controlled by SCC workability. By using SFSCC the costs and construction period reduce significantly and placing by its own weight in the thin and irregular section can be the turning point of this concrete. Researchers have studied about Fiber Reinforcement Self-Compacting Concrete (FRSCC) and Fiber Reinforced Concrete (FRC) that find out the characteristics of FRC is determined by post-cracking behavior and FRSCC is controlled by SCC workability. The capability to arrest cracks, make fibers mixtures to increased tensile strength, both at ultimate and at first crack, especially under flexural loading. The other ability of fibers is to hold matrix after extensive cracking. The transition failure from brittle to ductile by fibers is another ability of fibers which can absorb energy and survive under impact loading.

Direct Tensile Tests (Residual Post-Cracking Strength)

To investigation the fibers influence on residual post-cracking strength by direct tensile tests, notched prismatic, specimens (100 × 100 × 200 mm^3) have been used. As you can see in the Figure 1, for SCC, the diagrams illustrated brittle behavior and a sudden reduction in the residual strength with rise of the crack opening after the ultimate load. By localizing the macro crack little energy needs to propagate cracks [8]. As can be seen the differences in FRSCC diagram just after the peak load, before that both diagrams are the same. According to the diagram, starting micro crack and propagation relates to just before the peak of diagram. FRSCC post-peak behavior can be arranged as a three phase law. The first part relates to a stress reduction from peak to residual strength plateau. Fibers help to increase the residual strength and maintain crack opening where a residual strength is near to zero in SCC. The residual strength falling in softening martials during the

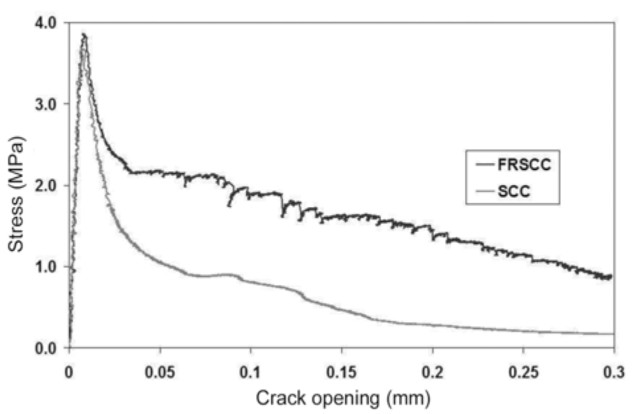

Figure 1: Crack opening versus residual post-peak strength crack opening in a direct tensile test on notched specimen [8].

***Corresponding author:** Orod Zarrinkafsh, Eastern Mediterranean University, Famagusta, Cyprus, Tel: +989113393991; E-mail: orod.zarrin@gmail.com

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growth of crack opening. Post peak residual strength which is plateau placed at the second phase. This plateau is fundamentally influenced by fibers properties (bond with the matrix, modulus of elasticity) and fiber content. Fibers create bridge in cracks and it cause stress concentration which leads to plateau. It is short but on the other hand, the amplitude of the residual strength is high. The third part corresponds to the sample's failure. It is related to the continuous fracture of fibers. As said by Turatsinze [8], the fibers can't resist against crack openings greater than 0.2 mm. One of the critical facts in theory of fiber reinforcement concrete is calculating residual stresses in tension for the cracked section. One of the useful methods to define the residual tension stresses is inverse technique. This method tried to drive the relationship of average stress-average strain in the crack zone in tension. According to result, residual stresses growth with increasing the amount of fiber content to 1% by volume of the element. By using this limit, the fiber efficiency increases proportionally, while, its effect becomes less significant. In the direct analysis tried to use structural response base on specified constitutive model, but on the other hand, in inverse analysis intend to determine parameters of model according to the response of structure. For given experimental moment-curvature curve, a stress-strain relationship was defined from the equilibrium equations of the axial forces and the bending moments. According to Figure 2 the residual stresses contain of the stresses because of fibers bond with concrete and stresses regarding to the effect of tension-stiffening. This figure clearly illustrates that residual stresses growth with increasing the amount of fiber content reaches to 1% by volume. By using this limit, the fiber efficiency increases proportionally, while, its effect becomes less significant [9-12].

Direct Technique: Moment–Curvature Analysis

Figure 3a shows the cross-section of a reinforced concrete beam under the influence of an external moment (M_{ext}). Figure 3b shows the layers that correspond to reinforcement and concrete. The thickness of layers (reinforcement) is dependent on the equivalent area condition. The direct analysis requires for assuming material laws for reinforcement (Figure 3f) as well as concrete in compression (Figure 3g) and tension (Figure 3h). This research tried to measure moment-curvature of beams in two different characteristic, steel fiber concrete and plain concrete, to find out the equivalent stress-strain of FRC in tension. The moment–curvature diagrams in experimental have been achieved in two behaviors: from concrete surface strains and from deflections, both in pure bending zone (Figure 3).

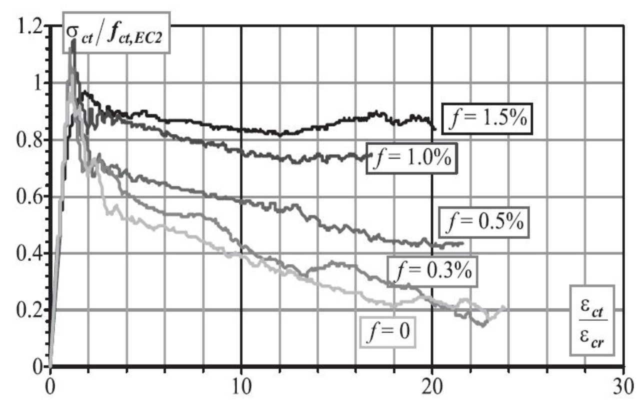


Figure 2: Average stress VS average strain relationships (SFRC) in tension (KAKLAUSKAS) [11].

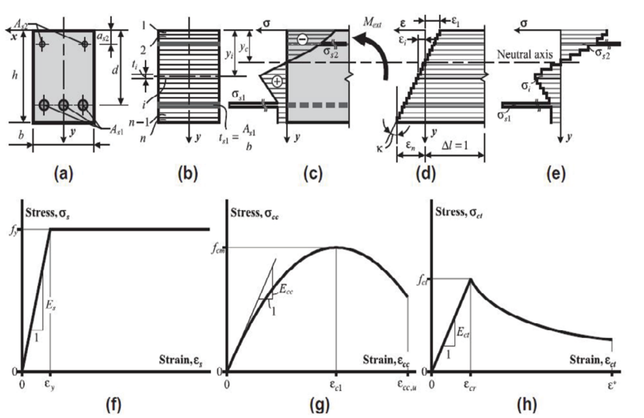


Figure 3: (a-e) Layer section model, (f) Constitutive laws for SFRC, (g) and (h) Fibrous concrete (compression and tension) [12].

FRC Constitutive Concept in Compression

Fibers can't modify load bearing capacity, yielding and ductility. It just effects the distribution of cracks and kinetics. The stresses decrease in stirrups by fibers but it doesn't mean that we are allowed to substitute fibers instead of stirrups. On the other hand, using fibers can reduce bar reinforcement ratio and makes a beam stiffer. They mention that for aggressive environments, stainless steel fiber should be used [8]. Transfer stress through a crack is the key role of fibers and therefore it can restrain the propagation and opening of cracks and increases the mechanical properties, mostly the post-cracking performance [13-18]. Researchers have observed that after flexural cracking the dense of crack network have been increased [14,19]. And remarked that fibers in control of crack are better, and can reduce the cracks width [20]. Additionally, the fibers effect on stiffness, ultimate load, load bearing capacity, shear strength has sharp increase [21-23]. Figure 4a illustrations the failure pattern of SCC beam which doesn't have fibers. By developing and widening of diagonal cracks, the resistance in aggregate link decrees abruptly and it can be neglected. Near the longitudinal reinforcement can observe the dowel failure and concrete spelling action. The following explanations have been taken by comparing two beams (SCC and FRSCC) from Figure 4a and 4b.

1. The distributed fibers can absorb some part of shear forces.

2. The three-dimensional fibers can resist the diagonal cracks; thus, a great residual compressive strength in uncracked zone can be well-maintained.

3. Fiber bridging increase the resistance of aggregate interlocking significantly. And those fibers that are erect to the diagonal cracks, can increase the shear strength visibly Figure 4b.

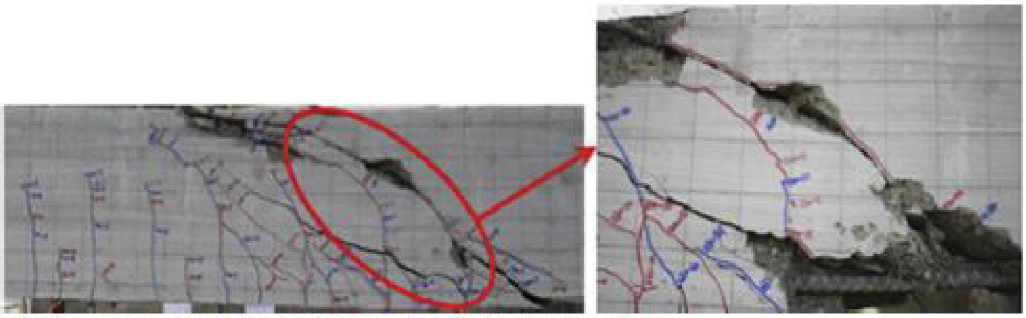
4. The spelling and dowel failure around the bending steel prevent significantly. In this case, the fibers that are in the same direction of longitudinal bars have more sufficient effect in compare to other orientations.

5. The fibers decrease the strain in stirrups and longitudinal steel at ultimate stress.

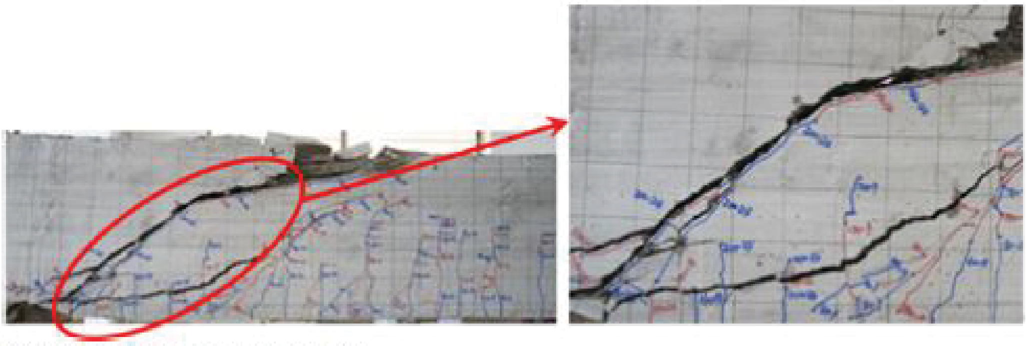
6. The tensile capacity increase by steel fibers and somewhat absorb tensile stress [24].

Conclusion

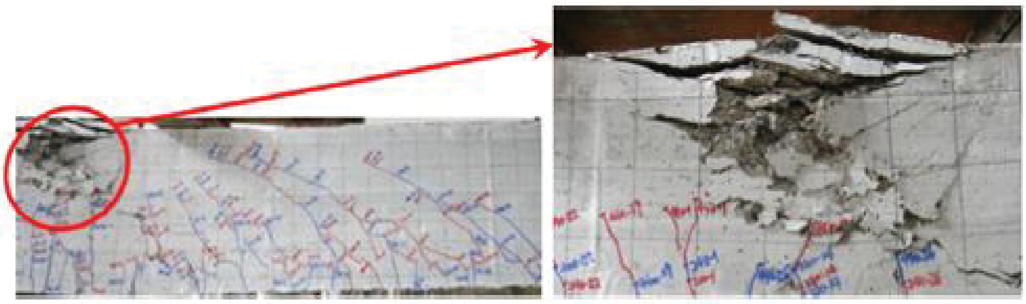
In the concrete, fibers by creating bridges through cracks provide



(a) SFSCCB0- 150 with failure of dowel action, spalling, and strong brittle diagonal cracking.



(b) SFSCCB25- 150 with less brittle diagonal failure.



(c) SFSCCB50- 150 with ductile flexural failure.

Figure 4: Failure and crack pattern of beams with 0.22% of stirrup ratio (Yining Ding) [24].

further resistance against crack. Limiting the tensile crack to a certain location and preventing of excessive diagonal tensile cracking are other advantages of steel fiber. The capability of fibers to arrest cracks, cause tensile strength increase, both at ultimate and at first crack, especially under flexural loading, the other ability of fibers are to hold matrix after extensive cracking. The transition failure from brittle to ductile type by fibers is another ability of fibers which can absorb more energy. The differences in FRSCC diagram just after the peak load, before that both FRSCC and SCC diagrams are the same. In the FRSCC, fibers help to increase the residual strength and maintain crack opening where a residual strength is near to zero in SCC. The residual strength falling in softening martials during the growth of crack opening. Fibers can't modify load bearing capacity, yielding and ductility. It just effects the distribution of cracks and kinetics. The stresses decrease in stirrups by fibers but it doesn't mean that we are allowed to substitute fibers instead of stirrups. On the other hand, using fibers can reduce bar reinforcement ratio and makes a beam stiffer. They mention that for aggressive environments, stainless steel fiber should be used.

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