An Experimental Study On Shear Behavior Of Steel Fiber Reinforced Concrete Beam

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Abstract - The present study investigate the influence of Steel Fiber Reinforcement on the mechanical behavior of reinforced concrete beams in shear.The major test variables are the aspect ratio of steel fiber, shear reinforcement, shear span(a) to depth ratio(d).The test result show that the first crack shear strength increases as fiber is added and also ultimate shear strength increases and change the mode of failure. It is concluded that fiber reinforcement can reduce the amount of shear stirrups required and that the combination of fibers and stirrups meet the strength and ductility requirements.

Key Words:*Shear behaviour ,steel fibers, etc…*

1. INTRODUCTION:

The brittle nature of concrete causes the collapse to occur shortly after the formation of the 1st crack. If the structure is subjected to an overload, it should fail in a ductile flexural mode rather than a brittle shear mode and hence will be a well designed reinforced concrete structure.1 The addition of steel fiber improve the brittle characteristics to ductile one and increase first crack strength in shear.2,3 Addition of steel fiber to concrete improve ductile property and reduce crack width and spacing.8 Steel fibers can be used to improve shear capacity of RC beam and partially replace the stirrups. This relieves reinforcement congestion at critical sections like beam – column joints.8 Many studies are also available on the shear behavior of steel fiber reinforced concrete beams.3 But still more tests and studies are required towards a better understanding of the role of fibers in shear strengthening.7 In this paper an effort has been made to study shear beahaviour of RC beams containing steel fiber, to study the combination of stirrups and steel fibers for improvement in ultimate shear strength and first crack shear strength and ductility.

1.1 SHEAR ANALYSES OF REINFORCED CONCRETE BEAMS CONTAINING STEEL FIBERS:

Design Principals:

The factored shear resistance of beam is calculated as
$V_u=V_c+V_s+V_f$
Where , V_c = Shear resistance provided by concrete.
V_s = Shear resistance provided by transverse steel.
V_{fc} = Shear resistance provided by steel fiber.

For steel fiber reinforced concrete beam, the formula proposed by Narayanan and Darwish for comparison of shear strength with the experimental result is given below. In present work by using this formula theoretical value of shear strength is calculated and further compared with the experimental results.

$$\tau_{Fc} = 0.41\,\tau\,F$$

Where,
F= lf/df x Volume fraction of fiber x kf
lf/df = Fiber aspect ratio
Kf = Bond factor that accounts for differing bond characteristics of the fiber and for crimped fiber Kf=0.75
τ = Average fiber matrix interfacial bond stress = 4.15 Mpa.
τFc= Shear stress due to steel fiber

1.2 EXPERIMENTAL WORK:

The main aim of this experimental work was to study the shear behavior of steel fiber reinforced concrete beams for different aspect ratio, for different span to depth ratio (2.3 and 3.1) ,for varying shear reinforcement.

Materials and Procedure:

Tensile steel consist of 2 bars of 8mm diameter with yield strength of 415 N/mm2 also 2 bars of 8mm diameter are provided as nominal steel at top of beam and 6mm diameter steel is used for stirrups with yield strength 250 N/mm2.Shear reinforcement is varied by changing stirrups spacing. For all beams stirrups spacing is adopted as 95mm c/c, 125mmc/c, and 150mmc/c.

Table No 1: Properties of Crimped Steel

Type of Fiber	Tensile Strength (N/mm²)	Modulus of Elasticity(N/mm²)	Aspect Ratio
Crimped Steel Fiber	1300	2 x 10^5	40 60 80

ACC cement and locally available sand and aggregate were used in the experimentation. The specific gravity of fine and coarse aggregate was found to be 2.7 and 2.8 respectively. The percentage of steel fibers used in the experimentation was 0.5 by volume with aspect ratios 40,60 and 80. The properties of steel fibers are mentioned in Table No1.

Fiber: The mix proportion adopted in the experimentation was 1: 1.38: 2.82 with w/c ratio of 0.45 which corresponds to M25 grade concrete. The mix design was carried out according to I.S.10262-1982.

The fine aggregate ,cement and coarse aggregates were dry mixed in a mixer for 60seconds.The required quantity of steel fibers were added into the dry mix and homogeneously agitated for 3 minutes. This homogeneous concrete mass was poured into the beam moulds which were kept on the vibrating table. The cross section of beam was 100x150mm with 1200mm span. The concrete was consolidated in three layers by using just the required vibration time needed for a good compaction. After consolidation the top surface was finished smooth and they were covered with wet gunny bags. After 24 hours, the specimens were demoulded and transferred to the curing tank wherin they were allowed to cure for 28 days. After 28 days of curing, the specimens were tested for their respective strengths.

2.Instrumentation and Test Procedure:

The beams were tested under 2 point loading condition. (Fig 1) They were statically tested to failure at equal 5 KN increment of load. During loading the midspan deflection & deflection at 300 mm from two supports was measured by using dial gauge (0.01). Load and deflection readings were recorded for each stage.

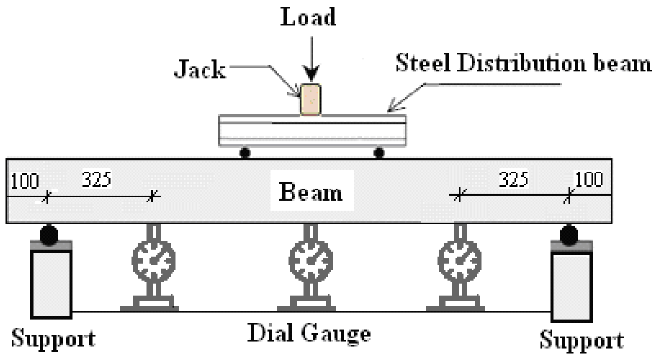

Fig. 1: Experimental Set-up

Test Results and Discussion:

Table No 2 shows the experimental results of beams having shear span to depth ratio 2.3 and Table No 3 shows the experimental results of beams having shear span to depth ratio 3.1.These results include shear strength, maximum deflection and mode of failure of beams. Fig 2, 3, 4 shows loads vs deflection for a/d = 2.3 and Fig 5,6,7 shows load vs deflection for a/d =3.1 From these results it is observed that,

1) Cracking Shear strength:

All the reinforced beam containing steel fiber showed the increase in first crack shear strength about 37.50%, 75.04%,117.55% in 40SFRC, 60SFRC, 80SFRC beams respectively than the beam without steel fiber(WSF).

2) Ultimate shear strength:

For a/d=2.3, the shear strength is increased over a control beam of without steel fiber by 9.61%, 15%, 25% for 40SFRC, 60SFRC, 80SFRC beams having stirrups spacing 95mmc/c. For the beams having stirrups spacing125mmc/c, it is increased by 26.53%, 28.19%, 71.42% for40SFRC, 60SFRC, 80SFRC beams respectively and for beams having stirrups spacing150mmc/c, it is increased by 19.28%, 25.71%, 40.72% respectively.

For a/d = 3.1, the shear strength is increased over a control beam of without steel fiber by 1.75%,7%,14.03% for 40SFRC, 60SFRC, 80SFRC beams having stirrups spacing 95mm c/c. For beams having stirrups125mmc/c, it is increased by, 6%, 8%, 16% for 40SFRC, 60SFRC, 80SFRC beams respectively and for beams having stirrups 150mmc/c, it is increased by, 6%,8%, 16% for 40SFRC, 60SFRC, 80SFRC beams respectively.

Table3:Experimental and analytical Results of all beams with mode of failure for a/d=2.3

Stirrups Spacing (mm)	Beam Type	Fiber content%	Aspect Ratio	τv_{exp} N/mm^2	τv_{pred} N/mm^2	Avg Defl. (mm)	Mode of Failure
95	CB WSF	-	-	2.02	1.92	30.66	Shear Failure
	SFRC	0.5	40	2.21	2.17	29.33	Shear Failure
	SFRC	0.5	60	2.33	2.30	31.00	Flexure Failure
	SFRC	0.5	80	2.52	2.43	34.00	Flexure Failure
125	CB WSF	-	-	1.91	1.66	29.33	Flexure Failure
	SFRC	0.5	40	2.41	1.91	32.00	Flexure Failure
	SFRC	0.5	60	2.44	2.04	31.66	Flexure Failure
	SFRC	0.5	80	3.25	2.20	40.00	Flexure Failure
150	CB WSF	-	-	1.79	1.50	25.50	Shear Failure
	SFRC	0.5	40	2.14	1.75	28.00	Flexure Failure
	SFRC	0.5	60	2.25	1.88	28.00	Shear Failure
	SFRC	0.5	80	2.52	2.01	33.00	Flexure Failure

Table3:Experimental and analytical Results of all beams with mode of failure for a/d=3.1

Stirrups Spacing (mm)	Beam Type	Fiber content%	Aspect Ratio	τvexp N/mm2	τv pred N/mm2	Avg Defl. (mm)	Mode of Failure
95	CB WSF	-	-	2.21	1.92	29.33	Shear Failure
	SFRC	0.5	40	2.25	2.17	29.66	Shear Failure
	SFRC	0.5	60	2.37	2.30	29.00	Flexure Failure
	SFRC	0.5	80	2.53	2.43	31.33	Flexure Failure
125	CB WSF	-	-	1.94	1.66	29.00	Shear Failure
	SFRC	0.5	40	2.06	1.91	27.66	Flexure Failure
	SFRC	0.5	60	2.10	2.04	29.00	Flexure Failure
	SFRC	0.5	80	2.25	2.20	31.33	Flexure Failure
150	CB WSF	-	-	1.75	1.50	26.33	Shear Failure
	SFRC	0.5	40	1.98	1.75	29.33	Flexure Failure
	SFRC	0.5	60	2.04	1.88	30	Shear Failure
	SFRC	0.5	80	2.17	2.01	30.33	Flexure Failure

3) For a/d = 3.1, the shear strength is increased over a control beam of without steel fiber by 1.75%,7%,14.03% for 40SFRC, 60SFRC, 80SFRC beams having stirrups spacing 95mm c/c. For beams having stirrups125mmc/c, it is increased by, 6%, 8%, 16% for 40SFRC, 60SFRC, 80SFRC beams respectively and for beams having stirrups 150mmc/c, it is increased by, 6%,8%, 16% for 40SFRC, 60SFRC, 80SFRC beams respectively.

4) Mode of Failure: The mode of failure is changed from shear to flexure by adding steel fibers. Also spalling of concrete is reduced by adding steel fiber.

5) Load Deflection Characteristics:

In general the entire beam shows the linear behavior from initial loading up to the occurrence of the 1st crack.After the formation of cracks, all the beam exhibited nonlinear load deflection characteristics.There was also increase in ductility due to fibers.

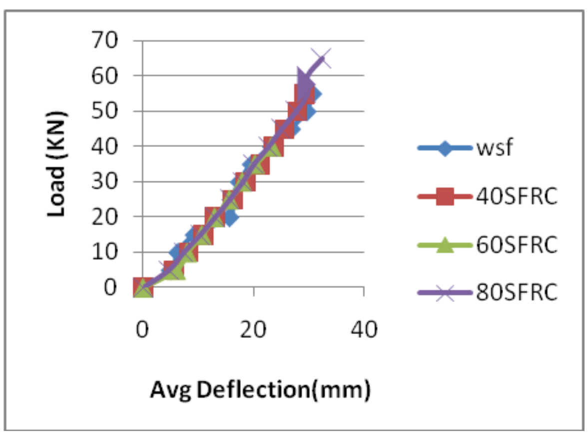

Fig 2: Load vs Deflection for beam of Sv 95mmc/c , a/d=2.3

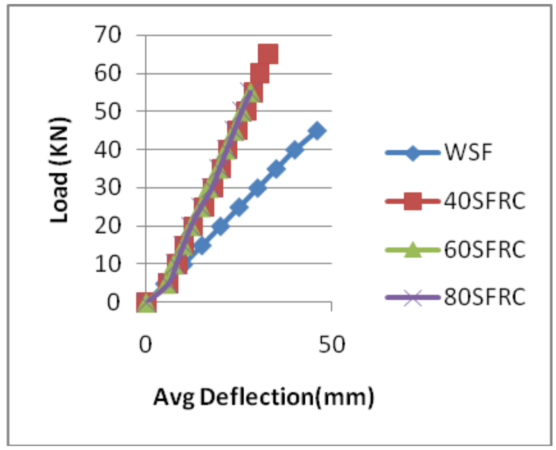

Fig 3: Load vs Deflection for beam of Sv 125mmc/c of a/d=2.3 beam

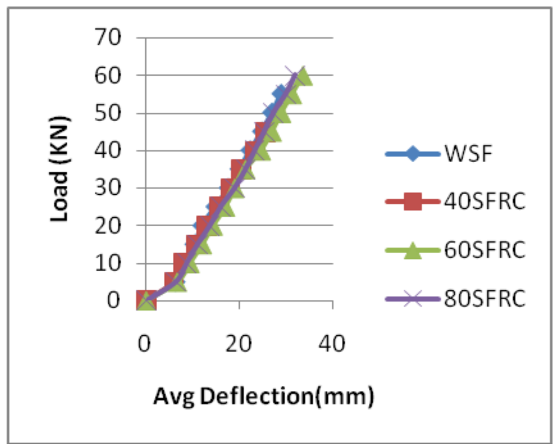

Fig 4: Load vs Deflection for beam of Sv 150mmc/c of a/d=2.3 beam

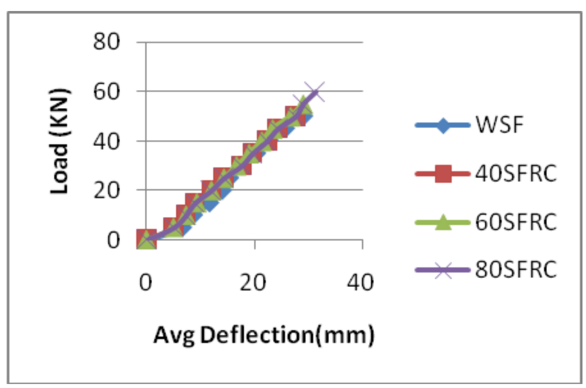

Fig 5: Load vs Deflection for beam of Sv 95mmc/c of a/d=3.1 beam

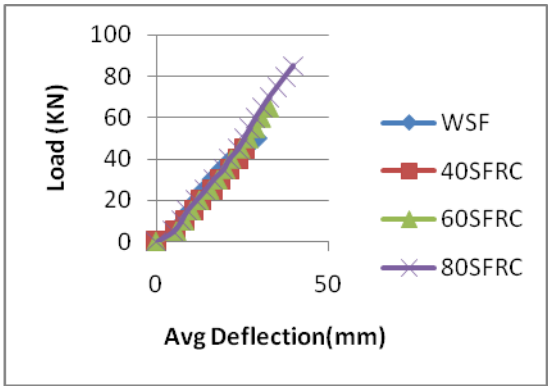

Fig 6: Load vs Deflection for beam of of Sv 125mmc/c of a/d=3.1

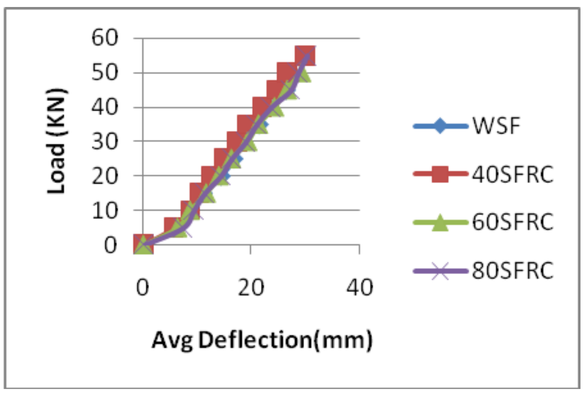

Fig 7: Load vs Deflection for beam of Sv beam 150mmc/c of a/d=3.1 beam

Conclusions:

From the present experimental study on the shear behavior of steel fiber reinforced concrete beams, the following conclusions may be drawn.

1) The addition of steel fibers increases tensile properties of concrete and improve resistance to cracking.
2) The mode of failure changed from shear to flexure when the steel fiber is added in the concrete.

3)As aspect ratio increases, the shear strength increases.

4)The combination of stirrups and fibers meet the ductile property and reduce the shear reinforcement.

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