Experimental Study on Impact of Steel Fibers at Various Zones in Reinforced Cement Concrete Beams

Saravanarajan N, Selvakumar K, Siva sankar A

***Abstract*— It is now well established that one of the important properties of steel fiber reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading. This paper presents the results of an experimental investigation for enhancing the shear and flexural capacities of reinforced concrete (RC) beams using steel fiber at different zones. Volume fraction (Vf) of the fibers used in this study is 1 % to the volume of concrete. The beams are tested under two-point loading as per IS after 28 days curing. Ultimate loads, cracking patterns have been compared with those of the RC beams without steel fiber. A total of six concrete beams of size 100 * 150 * 1100mm, one is control beam and remaining five with randomly distributed discrete steel fiber at different zones henceforth noted as fiber reinforced concrete (FRC) beam, were performed to determine the most economical structure in the perspective of ultimate strength and shear capacity of steel fibers.**

***Index Terms*— steel fiber reinforced concrete, Volume fraction, shear capacity.**

I. INTRODUCTION

Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers– each of which lend varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities.

Steel fiber reinforced concrete is a composite material having fibers as the additional ingredients, dispersed uniformly at random in small percentages. The energy required for mixing, conveying, placing and finishing of SFRC is slightly higher. Steel fibers are added to concrete to improve the structural properties, particularly tensile and flexural strength. The extent of improvement in the mechanical properties achieved with SFRC over those of plain concrete depends on several factors, such as shape, size, volume, percentage and distribution of fibers. Segregation or balling is one of the problems encountered during mixing and compacting SFRC. This should be avoided for uniform distribution of fibers.

Types of steel fiber are crimped, hook ended, straight, paddled, deformed, irregular. Round fibers are the most common type and their diameter ranges from 0.25 to 0.75 mm. Rectangular steel fibers are usually 0.25 mm thick, although 0.3 to 0.5 mm wires have been used in India. Deformed fibers in the form of a bundle are also used. The main advantage of deformed fibers is their ability to distribute uniformly within the matrix. The most common applications are tunnel linings, slabs, and airport pavements. Many types of steel fibers are used for concrete reinforcement

The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. Hence aspect ratio is generally limited to an optimum value to achieve good workability and strength. Grey suggested that aspect ratio of less than 60 are best from the point of handling but an aspect ratio of about 100 is desirable from strength point of view.

Though steel fiber reinforced concrete has numerous advantages, it has certain concerns that are yet to be resolved completely.

There are complications involved in attaining uniform dispersal of fibers and consistent concrete characteristics.

The use of SFRC requires a more precise configuration compared to normal concrete.

Another problem is that unless steel fibers are added in adequate quantity, the desired improvements cannot be obtained. However, as the quantity of fibers is increased, the workability of the concrete is affected. Therefore, special techniques and concrete mixtures are used for steel fibers. If proper techniques and proportions are not used, the fibers may also cause a finishing problem, with the fibers coming out of the concrete.

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II. EXPERIMENTAL PROGRAM

A. Methodology

The experimental programme consist of casting, testing of reinforced concrete beams, with 1% of steel fiber in various zone such as shear and tension. Six reinforced concrete beams were casted. Each beam consisted of 1 % of steel fiber in various zone without shear reinforcement.

B. Materials used

1 Cement

Ordinary Portland cement (OPC) - 53 grade was used for the investigation. It was tested for its physical properties in accordance with Indian standard specifications.

2 Fine Aggregate

The fine aggregate obtained from river be of kavery. Clear from all sorts of organic impurities was used in this experimental program. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.77. The grading zone of fine aggregate was zone 11 as per Indian standard specifications.

3 Coarse Aggregate

The coarse aggregate used were of two grades, non-reactive and available in local quarry. One grade contained aggregates passing through 20 mm sieve and retained on 10 mm size sieve and had a specific gravity of 3.06.

4 Water

Ordinary tap water used for concrete mix in all mix.

5 Reinforced steel

HYSD bars of 10 mm diameter were used as main reinforcement. 8 mm diameter mild steel bars were used for shear reinforcement. The reinforcement details are shown in Fig 1 and Fig 2.

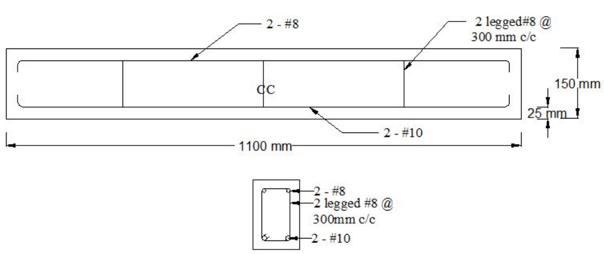

Fig 1 With web reinforcement

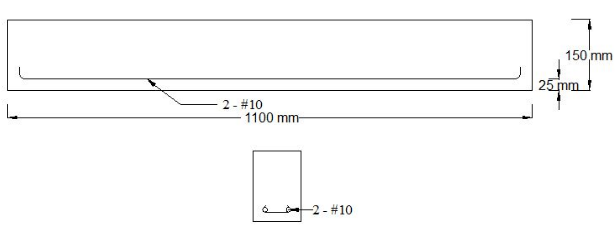

Fig 2 Without web reinforcement

C. Casting of beams

Six beams were casted for this experimental test program. The details of six beams are as follows and shown in following fig.4.1 to 4.6.

F1 - Control beam without web reinforcement.

F2 - FRC beam without web reinforcement.

F3 - FRC at flexural zone without web reinforcement.

F4 - FRC at shear zone without web reinforcement.

F5 - FRC at both shear and flexural zone without web reinforcement.

CB – Control beam with web reinforcement.

D. Experimental setup

All the specimens are tested in the universal testing machine (UTM) of 1000 KN. The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam has washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beam will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shear, enabling the bending capacity of the central portion to be assessed. If the shear capacity of the member is to be assessed, the load will normally be concentrated at a suitable shorter distance from a support.

Two-point loading can be conveniently provided by the arrangement shown in the Fig 3. The load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high strength plaster or some similar material. The test member is supported on roller bearing acting on similar spreader plates.

The UTM must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and possibly strain measurements is an important consideration, as is safety when failure occurs.

The specimen was placed over the two steel rollers bearing leaving 50 mm from the ends of the beam. The remaining 1000 mm was divided into three equal parts of 330 mm and two point loading arrangement was done as shown in Fig 3. Loading was done by hydraulic jack of capacity 100 KN. Dial gauges of least count 0.01 mm were used for recording the mid span deflection of the beams. The dial gauge was placed just below the center of beams.

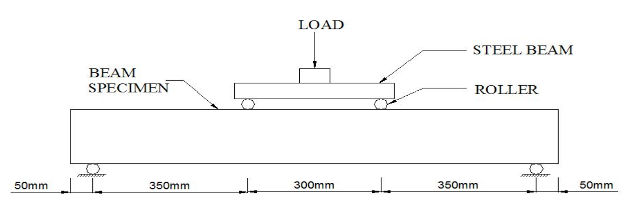

Fig 3 Loading arrangement

III. RESULT AND DISCUSSION

A. Failure modes

A number of failure modes have been observed in the experiments of RC beam strengthened in flexure and shear by FRC. These include flexure failure, shear failure and crushing of concrete at the top. Concrete crushing is assumed to occur if the compressive strain in the concrete reaches its maximum permissible strain. The controlled beam and FRC strengthened beam were tested to find out their ultimate load carrying capacity. The development and propagation of cracks were recorded on the surface of specimens during the test. It is well known that the shear span-to-depth (a/d) ratios of specimens affect the crack development and failure modes. But it was observed that due to the use of steel fiber reinforcement at different depth level of the beams, shear compression failure mode occurred in these specimens. Similar observations were also made for the controlled beam specimens. The test results were shown in table I

B. Test results

1 Beam F1

From the test result it was observed that in the region of the end span, shear cracks were initiated from the bottom level of such beams at a load approximately 20 kN and propagated with increase in load and widened with the elevated load till the final failure occurred at on an average load of 55 kN. The mode of failure was observed to be shear crushing of the concrete which was shown in Fig 4.

Fig 4 Control beam without web reinforcement

2 Beam F2

For specimen F2 which was fully steel fiber reinforced without stirrups, no cracks were visible on the sides of the beam initially. On the other hand, diagonal shear crack was observed near the middle of shear spans . Finally, the beam failed at a load of 76 kN. It was observed for the fully fiber reinforced concrete beams that in the region of the mid span, flexure cracks were initiated from the bottom level of such beams and further propagated with increased load. It is evident for the test results that there was an average increase of 38% in ultimate load capacity of fully FRC beam specimens as compared to control beam specimen. The mode of failure was observed to be combined shear and flexural of such beam specimens which was shown in Fig 5.

Fig 5 FRC beam without web reinforcement

3 Beam F3

On the other hand, for the F3 this was used with steel fiber reinforced in flexural zone without stirrups. It was also observed for this beam that in the region of the end span, shear cracks were initiated from the bottom level of such beams and continues to propagate with increasing load. While the ultimate load was recorded as 62 kN with 13% average increase in load capacity over and above the control beam F1. Shear compression mode of failure was observed for such types of beam specimen which was shown in Fig 6

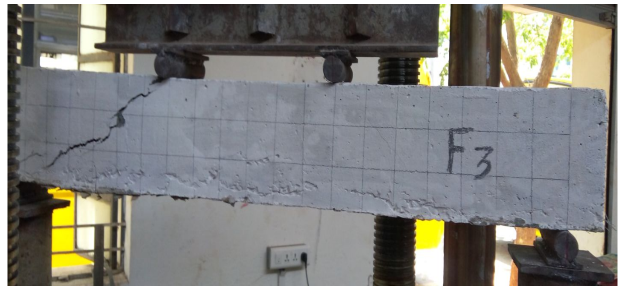

Fig 6 FRC at flexural zone without web reinforcement.

4 Beam F4

The beam F4 was used with steel fiber reinforced in shear zone without stirrups. The ultimate load was recorded as 66 kN with 20% average increase in load capacity over and above the control beam F1. Shear compression mode of failure was observed for such types of beam specimen which was shown in the Fig 7.

Fig 7 FRC at shear zone without web reinforcement.

5 Beam F5

For specimen F5, which was reinforced with steel fiber in both shear and flexural zone without stirrups, the first crack was occurred at the bottom mid span of the beam. This beam exhibited the first crack at a higher load than the control beam F1 due to the presence of the steel fiber. It was observed for specimens reinforced with steel fiber up to half depth of the beam that in the region of the mid span, flexure-shear cracks were initiated from the bottom level and continues to propagate with increased load. The corresponding failure load occurred at 72 kN. The enhancement of the failure load was observed which is of the order of average 31% higher in comparison to that of the control beam. The mode of failure was observed to be shear and flexure of such specimens which was shown in Fig 8.

Fig 8 FRC at both shear and flexural zone without web reinforcement.

6 Beam CB

It was observed from the Reinforced Concrete Beam with web reinforcement (i.e. beam CB) that in the region of the mid span, flexure-shear cracks were initiated from the bottom level of such beams and propagated with increase in load; whereas the shear cracks started appearing and continued to propagate and widened with the elevated load till the final failure occurred at on an average load of 78 kN. The mode of failure was observed to be combined shear and flexural of such beam specimens which was shown in Fig 9.

Fig 9 Control beam with web reinforcement.

I. Test result

Sl. No.	Beam designation	Ultimate load (kN)	Mode of failure
1	F1	55	shear crushing
2	F2	76	combined shear + flexural
3	F3	62	Shear compression
4	F4	66	Shear compression
5	F5	72	combined shear + flexural
6	CB	78	combined shear + flexural

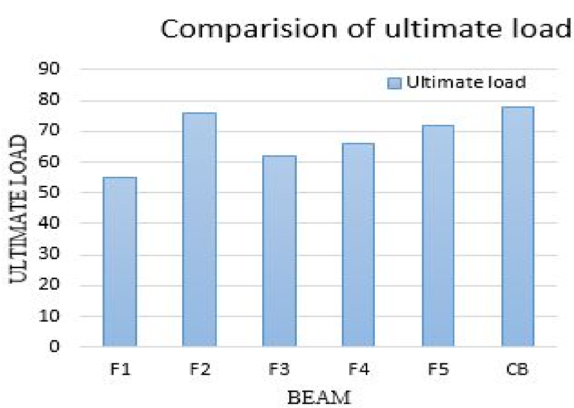

Fig 10 Comparision of ultimate load

CONCLUSION

In this experimental investigation the flexure and shear behavior of reinforced beams with fibers at various zone is studied. The following conclusions are drawn from this experimental study.

1. The load carrying capacity of fiber reinforced concrete beams were found to be greater than that of control beams.
2. The shear strength of the FRC beam is increased 38% compared to that of control beam.
3. 95% of load carrying capacity was attained when fiber in shear and flexure zone, instead of using fiber for full depth.
4. The above point shows that the reduction in 37% of volume of fiber result in only 5% loss in ultimate load.
5. The ultimate load of FRC beam without web reinforcement and conventional beam with web reinforcement was nearly the same.
6. From this investigation, the beams with fiber in shear, flexure and both shear and flexure zones were withstands the load carrying capacity of 13%, 20%, 31% greater than the control beam (F1) respectively.

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