EXPERIMENTAL STUDY OF STEEL FIBER REINFORCED CONCRETE CORNERS

Faizan Elahi[1], Vikas Garg[2],

[1]*M. Tech Student, Civil Engineering Department, GRIMT, Radaur, Haryana, India*
[2]*HOD, Civil Engineering Department, GRIMT, Radaur, Haryana, India*

Abstract - Beams and columns are major components is most civil engineering structure. They are combined in such a way as to carry the acting loads to enclose the desired space and to fulfill the various other design requirements. Their roles are complimentary as they influence each other at joints. Reinforcement details at corners play an important role in influencing the behavior of a member. Corners and joints should be able to carry the moments of at least magnitude as the calculated failure moments for the adjoining sections.

Various detailing systems are in use. The primary cause of failure in opening corners may be diagonal tension and the efforts are being made in evolving an arrangement, which is capable of taking tensile loads at the corners. Concrete is weak in tension. It is due to internal flaws and micro-cracks present in the concrete. The use of randomly distributed discrete fibers to improve the physical properties of the matric is an age-old concept.

The addition of randomly distributed discrete fibers in the mortar-concrete matrix, concrete can be potentially modified to perform in a more ductile form. This results in a composite or two-phase system where in presence of one phase improve the basic properties of the other phase. Two-phase concepts of materials led to the development and use of raw materials in which the weak matrix is reinforced by strong stiff fibers to produce a composite material with superior properties and performance. The primary advantage of this system is the development of post-crack load carrying capacity of concrete is contrast to usual norm of brittle failure, witnessed in plain concrete.

Steel Fiber Reinforced Concrete is used in a number of applications in order to enhance the performance of a plain and reinforced concrete. Steel fibers are pieces of short length and smaller cross-section having certain characteristics properties. Fiber reinforced concrete is a concrete made of hydraulic cement, containing fine and coarse aggregate and discontinuous discrete fibers. Steel fibers are distributed in the concrete mix irrespective of their orientation to produce composite material giving rise to isotropic properties. The percentage of steel fiber varies from 0.25 percent 2.0 percent while higher percentages are restricted from the consideration of practical difficulty of balling of fibers during mixing and placing. In the present study hooked fibers and crimped fibers have been used.

The fibers of different length and diameter in different volume fraction (V_f) and constant aspect ratio have been used in the various samples. These samples were then cast and tested after curing. The results obtained from testing were then compared and it is found that with the use of fibers in concrete there is a significant improvement in joint efficiency, ductility, toughness and better serviceability.

***Key Words*: Steel Fiber, SFRC (Steel Fiber Reinforced Concrete), Compressive Strength, Split Tensile Strength, Deflections, Portal Frame**

1. INTRODUCTION

Most of the civil engineering structures have beams and columns to carry the acting loads, to enclose the desired space and to fulfill various other design requirements. Studies are being done on the behaviour of these elements. The importance of adequately designed joint details is often overlooked. Much time is spent on learning how to design beams and columns, whereas little time is given to the design of corners or joints. The poor tensile strength of concrete results in premature failure. The detailing of reinforcement in corners is more critical which are expected to share a major burden of the tensile loads acting at corners.

Investigation are needed to be arrived out from material point of view. The basic weakness of corners is the poor tensile performance of the plain concrete matrix. This needs to be achieved by improving the mechanical properties of the matrix afforded by addition of steel fibers. This should be done in combination with detailing arrangement in influencing the behavior of corners. Some investigation has been done on this, but further studies are needed as the corner's behavior varies with the types of fiber, the fiber aspect ratio, the volume fraction of fibers.

The addition of fiber improves many engineering properties such as tensile strength, flexural strength, and fracture toughness, resistance of fatigue, of impact and thermal shock or spalling. The degree of enhancement of the properties of the hardened concrete depends upon the type, size, shape, volume fraction and aspect ratio of the fibers. The addition of fibers makes conventional plain concrete more versatile and flexible in the method of production and more competitive as a construction material. Cement concrete reinforced with random fibers is called "fiber reinforced concrete".

1.1 STEEL FIBER REINFORCED CONCRETE

Steel fiber reinforced concrete (SFRC) is an ordinary concrete containing discontinuous, discrete fibers of short length and small diameter. SFRC is a concrete made of hydraulic cement, containing fine and coarse aggregate and discontinuous discrete fibers. As referred by ACI committee 544, the composite has potential for many more applications, specially, in the area of structural elements. Its current field of application includes highway and airfield.

As a result of its many desirable properties, concrete tends itself to a variety of innovative designs. Concrete processes high compressive strength, stiffness, low thermal and electrical conductivity but it is brittle and weak in tension. These two deficiencies, however, has been improved by development of fiber reinforced concrete composite.

Steel fibers in reinforced concrete are distributed irrespective of their orientation to produce two-phased composite material in which presence of one phase improves the basic properties of the other phase. Two-phase concept of material led to the development and use of new materials in which the weak matrix is reinforced by strong stiff fibers to produce a composite material with superior properties and performance. Fibers in the concrete acts as 'crack arrestors. When the load imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly. Steel bars of different diameter in the country have the same beneficial effect because they act as long continuous fibers. But the short discontinuous fibers have the advantage, as these are uniformly mixed as dispersed throughout concrete.

1.2 Steel Fiber

Fiber is small piece of reinforcing material having smaller cross-section and having certain characteristic properties. A parameter describing the fiber is its aspect ratio which may be defined as the fiber length divided by its equivalent diameter. The equivalent fiber diameter is the diameter of the circle of having an area equal to the cross-sectional area of fiber. The typical aspect ratio ranges from about 30 to 150 for length of 1 mm to 75 mm.

The typical percentage of steel fibers in concrete ranges from 0.25 percent to 2.0 percent. Balling of fibers is the difficulty that comes into way when higher percentages are added.

Generally round and flat fibers are used. Round steel fibers are produced by cutting are chopping wires having diameter between 0.25 mm to 2.0 mm. Flat steel fibers having cross-section ranging from 0.15 mm to 0.40 mm in thickness and 0.9 mm in width are produced by sharing sheets and flattening wires.

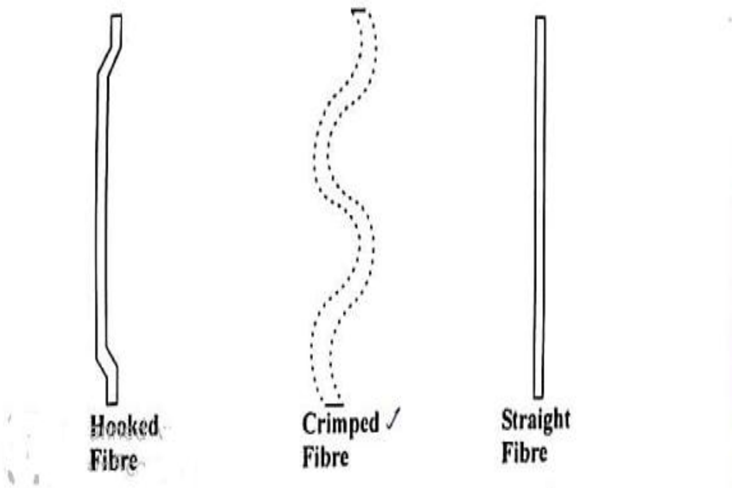

Figure -1: Types of Steel Fibers

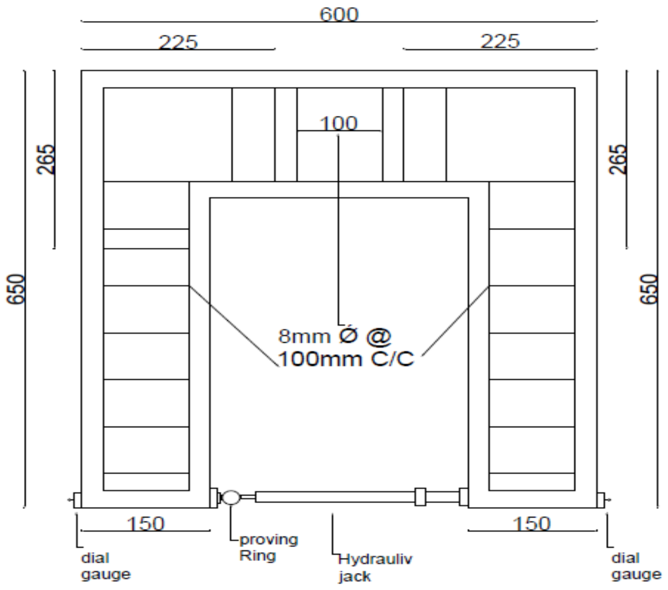

Figure 2: Steel and Testing Arrangement of Specimen

2. RESULTS

Different volume fraction (0.5%, 1.0%, 1.5%) of round crimped steel fibers and hooked steel fibers were used. The testing of concrete specimen without any fibers was performed and deflection were determined. Deflection of concrete specimens containing different percentages of fibers, length and diameter was determined after 28 days of curing.

2.1. SPECIMEN WITHOUT FIBERS(S_0)

On testing this specimen, it is observed that there is decrease in deflection in case of C1 having 0.5% of crimped fibers than in case of S0 (specimen without any fibers) by 8.47% at 1KN load, decrease in deflection by 5.76% at 2KN load and decrease in deflection by 6.63% at 3KN load. And decrease in deflection of H1 having 0.5% of hooked fibers than in case of S0 by 18.49% at 1KN load, decrease in deflection by 17.38% at 2KN load and decrease in deflection by 13.03% at 3KN load.

2.2. SPECIMEN C_1, C_2 and C_3 HAVING FIBERS

(A.R = 40, F.L = 36mm, DIA=0.9mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of C2 having 1.0% fibers than in case of C1 having 0.5% of fibers by 14.94% at 1KN load, decrease in deflection by 12.84% at 2.0KN load and decrease in deflection by 7.42% at 3KN load. And decrease in deflection of C3 having 1.5% fibers than C2 by 18.81% at 1KN load, decrease in deflection by 13.91% at 2KN and decrease in deflection by 6.43% at 3KN load.

2.3. SPECIMEN C4, C5 and C6 HAVING CRIMPED FIBERS

(A. R=40, F. L=48mm, DIA=1.2mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of C5 having 1.0% fibers than deflection in case of C$ having 0.5% of fibers by 15.61% at 1KN load, decrease in deflection by 13.82% at 2KN load and decrease in deflection by 7.62% at 3.0KN load. And decrease in deflection of C6 having 1.5% fibers than C5 by 16.11% at 1KN load, decrease in deflection by 14.36% at 2KN and decrease in deflection by 6.74% at 3KN load.

2.4. SPECIMEN C_7, C_8 and C_9 HAVING FIBERS

(A. R=40, F. L=60mm, DIA=1.5mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of C8 having 1.0% fibers than deflection in case of C7 having 0.5% of fibers by 15.45% at 1KN load, decrease by 10.41% at 2KN load and decrease in deflection by 5.64% at 3.0KN load. And decrease in deflection of C9 having 1.5% fibers than C8 by 9.65% at 1KN load, decrease in deflection by 8.37% at 2KN and decrease in deflection by 4.22% at 3KN load.

2.5. SPECIMEN C_{10}, C_{11} and C_{12} HAVING FIBERS

(A. R=40, F. L=80mm, DIA=2mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of C11 having 1.0% fibers than deflection in case of C10 having 0.5% of fibers by 13.14% at 1KN load, increase by 8.23% at 2KN load and increase in deflection by 4.44% at 3.0KN load. And decrease in deflection of C12 having 1.5% fibers than C11 by 23.16% at 1KN load, increase in deflection by 22.72% at 2KN and increase in deflection by 16.21% at 3KN load.

2.6. SPECIMENS H1, H2 and H3 HAVING CRIMPEED FIBERS

(A.R-40, F. L=36mm, DIA=0.9mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of H2 having 1.0% fibers than deflection in case of H1 having 0.5% of fibers by 14.42% at 1KN load, decrease in deflection by 11.93% at 2KN load and decrease in deflection by 7.35% at 3.0KN load. And decrease in deflection of H3 having 1.5% fibers than H2 by 9.11% at 1KN load, decrease in deflection by 11.14% at 2KN and decrease in deflection by 7.04% at 3KN load.

2.7. SPECIMENS H4, H5 AND H6 HAVING CRIMPED FIBERS

(A. R=40, F. L=48mm, DIA=1.2mm)

On testing these three specimens is observed that there is decrease in deflection in case of H5 having 1.0% fibers than deflection in case of H4 having 0.5% of fibers by 11.93% at 1KN load, decrease in deflection by 11.27% at 2KN load and decrease in deflection by 6.46% at 3.0KN load. And decrease in deflection of H6 having 1.5% fibers than H5 by 12.04% at 1KN load, decrease in deflection by 10.87% at 2KN and decrease in deflection by 6.12% at 3KN load.

2.8. SPECIMENS H7, H8 AND H9 HAVING CRIMPED FIBERS

(A. R=40, F. L=60mm, DIA=1.5mm)

On testing these three specimens, it is observed that there is decrease in deflection in case of H8 having 1.0% fibers than deflection in case of H7 having 0.5% of fibers by 14.93% at 1KN load, decrease in deflection by 10.78% at 2KN load and decrease in deflection by 5.78% at 3.0KN load. And decrease in deflection of H9 having 1.5% fibers than H8 by 12.54% at 1KN load, decrease in deflection by 9.15 at 2KN and decrease in deflection by 5.63% at 3KN load.

2.9. SPECIMENS H10, H11 AND H12 HAVING CRIMPED FIBERS

(A. R=40, F. L=80mm, DIA = 2.0mm)

On testing these three specimens, it is observed that there is increase in deflection in case of H11 having 1.0% fibers than deflection in case of H10 having 0.5% of fibers by 15.54% at 1KN load, increase in deflection by 8.90% at 2KN load and increase in deflection by 6.08% at 3.0KN load. And increase in deflection of H12 having 1.5% fibers than H11 by 14.97% at 1KN load, increase in deflection by 21.23% at 2KN and increase in deflection by 12.58% at 3KN load.

2.10 Discussion

In the present study, it is found that with the addition of fibers at corners or joints, there is considerable decrease in deflection. This decrease in deflection is up to 8.47% in case of crimped fibers and up to 18.49%, in case of hooked fibers. Curves are drawn for deflection against load for specimen without fibers and specimen having 0.5% of crimped and hooked fibers.

It is found that with the increase in volume fraction of fibers there is decrease in deflection. This decrease is up to 18.81% in case of crimped fibers (specimen C2 – C3). But the deflection increases with increase in volume fraction as in the case of specimen C11 and C12 having 1.0% and 1.5% fibers volume fraction respectively. This increase in deflection is up to 23.16%

It is found that in case of hooked fibers also, the deflection decreases with increase in fiber volume fraction. This decrease is up to 14.93% in case of specimen H7 and H8. But the deflection increases with increase with increase in volume fraction as in case of specimen H11 and H12 having 1.0% and 1.5% fiber volume fraction respectively. This increase in deflection is up to 21.23% in case of specimen H12 as compared to H11.

It is observed that in all cases deflection in specimens having hooked fibers was less than specimens having crimped fibers. At same aspect ratio, fiber length and applied load the deflection is considerably less in case of hooked fibers. It is found that hooked fibers are more effective than crimped fibers.

In the present study, when the fiber length is increased from 36mm to 60mm along with diameter from 0.9mm to 1.5mm, the deflection goes on decreasing but with the further increase in fiber and diameter to 80mm and 2.0mm respectively, the deflection increase.

3. CONCLUSION

Addition of fibers to concrete significantly decrease deflection in concrete. With the addition of even 0.5% of crimped and hooked fibers, the deflection decreases considerably. With the increase in volume fraction of fibers, deflection in concrete decrease. Also, with the increase in length of fibers along with the diameter of fibers, there is decrease in deflection. But when fibers of length 80mm and diameter 2.0mm has been used, the deflection increase. Therefore 1.5% of fibers having length 60mm and diameter 1.5mm (aspect ratio 40) may be considered as the optimum value. Some conclusion from the present study are as follows:

1. Deflection decrease by the use of steel fibers in concrete.

2. There is up to 8.5% decrease in deflection with the use of 0.5% of crimped fibers when compared to specimen without fibers.

3. There is up to 18.5% decrease in deflection with the use of 0.5% of hooked fibers when compared to specimen without fibers.

4. In general, the deflection decreases with the increase in volume fraction of fibers in the concrete.

5. There is up to 23% decrease in deflection with the increase in volume fraction of fibers from 1.0% to 1.5%.

6. Hooked steel fibers are effective than crimped steel fibers.

7. The fibers length of 60mm with diameter 1.5mm may be considered as the optimum value.

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BIOGRAPHIES

Mr. Faizan Elahi, PG Student, Department of Civil Engineering, GRIMT, Affiliated Kurukshetra University, Kurukshetra, Haryana.