Shear Capacity of Fiber Reinforced Concrete Beams with and without Shear Reinforcement

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Abstract - Generally, most of the studies have predicted the shear strength of Steel Fiber Reinforced concrete (SFRC) beams without shear reinforcement, which give wide range of equations considering different parameters. These equations are still in research papers and are not included by any design codes. When steel fibers are added to RC beams, these mechanisms become even more complex. The study is insufficient on shear behavior of Concrete beams with fiber termed as High Strength Steel Fiber Reinforced Concrete (HSSFRC). The major Objectives of study are to understand the behavior and ultimate shear strength study of SFRC specimens with and without shear reinforcement. To understand the shear transfer mechanism of SFRC beams with and without web reinforcement will be carefully illustrated in it.

Key words - High strength concrete, High strength steel fiber reinforced concrete, Shear strength mechanism, Steel fiber reinforced concrete,

I. INTRODUCTION

Concrete is one of the most popular and significant construction materials in the construction industry. Because of the huge quantity of concrete being used today even small improvement in the material properties will produce a significant technological impact and financial benefits. In this regard, modern materials like fiber reinforced concrete could contribute to a larger extent. In the recent past the construction industry demand for High Strength Concrete (HSC) has increased substantially.

Steel fiber reinforced concrete is a composite material made of hydraulic cements, fine and coarse aggregate, and a distribution of discontinuous, small steel fibers. It may also contain pozzolans and admixtures commonly used with conventional concrete. Among the various types of fibers, steel fibers are most widely used in the concrete industry. Steel fiber remains the most used fiber of all (50% of total tonnage used).

Unreinforced concrete has low tensile strength and low strain capacity at fracture. These shortcomings are traditionally overcome by adding reinforcing bars or prestressing steel. Reinforcing steel is continuous and is specifically located in the structure to optimize performance. In general, SFRC fails only after the steel fiber breaks or is pulled out of the cement matrix. Fibers are discontinuous and are generally distributed randomly throughout the concrete matrix. They are used in structural applications with conventional reinforcement. Because of the flexibility in methods of fabrication, fiber reinforced concrete can be an economic and useful construction material.

The failure of plain concrete beams may be attributed to the absence of both longitudinal and shear reinforcement. The addition of longitudinal reinforcement increases the flexural strength. To bridge cracks and transfer the stress to the concrete, the beam will exhibit more flexural cracks due to the ability of the longitudinal reinforcement. The RC beams without shear reinforcement may fail due to shear action. Therefore, the shear span becomes an important factor which affects the crack propagation, collapse mechanism, and strength of the RC beam.

[Richart] and [Moretto] experimentally stated that web reinforcement shall be effective in an RC beam after the formation of diagonal cracks. After diagonal cracks the web reinforcement takes care of redistributed stresses in form of tension. This tension shall be transferred to the surrounding concrete.
resulting in formation of additional diagonal cracks. Therefore the web reinforcement slows the propagation of diagonal cracks, thus improving the shear capacity of concrete in compression region. It is also effective in preventing a premature splitting failure along the tensile reinforcement. Further the web reinforcement controls crack opening, and hence, helps aggregate interlock resist shear.

Theoretical models to fully understand shear behaviour through principles such as the Compression Field by [Collins] and Modified Compression Field theories by [Vecchio and Collins]. To prevent shear failures, beams are traditionally reinforced with stirrups. In general, the use of stirrups is costly because of the labor cost associated with reinforcement installation. Also, casting concrete in beams with closely-spaced stirrups could be complex and might lead to improper compaction leaving voids and associated poor bond between concrete and reinforcing bars.

The necessity for more experimental data for HSSFRC beams weakening in shear and the little knowledge on the shear behaviour of HSSFRC beams are the primarily motivations for this study. Considering the cost of SFRC, it is obvious that its cost is more than normal concrete. Therefore to make composite structures cost efficient, it shall be more sensible to use the fibers in stress concentration regions. In particular, this study was aimed to evaluate the shear capacity of steel fiber reinforced concrete beams with and without shear reinforcement.

II. EXPERIMENTAL

Ordinary Portland cement conforming to 53 grade IS 12269:1989, local river sand conforming to grading zone II of IS 2386(PT4):1963 and the grading limits confirmed to IS 383:1970 and The properties of coarse aggregate were found with reference to IS 2386(PT4):1963 and the grading limits confirmed to IS 383:1970 of size 20mm are used for the study. Conplast 337 is used as superplasticizer. Mix proportion used for study is given in Table-I.

![Fig 1. Details of load points](image)

As the investigation motive is to study the shear behaviour, the beams were designed such that the flexural failure is avoided. Thus 2.7% of longitudinal tension reinforcement is provided in form of 2-12mm diameter bars in first layer and 1-10mm diameter bars in the second layer. The percentage of longitudinal reinforcement is kept constant through the investigation. The shear reinforcement greater than minimum specified limit was provided in form of 8mm diameter bars @ 100mm c/c.

The straight steel fibers used in the experimental programme were produced by cutting galvanized wire of 24 Gauge (0.5mm diameter). The dosage of Fiber volume fractions used in concrete mix was, 0.4, 0.8 & 1.2 percent. All steel fibers were free from loose mill scales, rust and coats of paints, oil or other coating.

Based on the parameters to be varied the cross section of the beams are selected as 100mm x 175 mm.
Formwork for casting the beams was fabricated using wooden planks. Based on the shear span to depth ratio (a/d), the length of the beams worked out to be 1.0m.

The beams casted were tested using 100 Ton loading frame. The instruments used during the testing were: LVDTS, Load cell, Data acquisition system shown in Fig 2.

III. RESULTS AND DISCUSSION

Test results of SFRC beams without shear reinforcement and with varying volume fraction of fibers are presented in the form a graph plotted with Load in kN on Y-Axis and Deflection in mm on X-Axis.

The above Fig 3 & 4 shows the shear capacity of fiber reinforced concrete beams increased with increase in percentage of fibers. Test results of SFRC beams with shear reinforcement and with varying volume fraction of fibers are presented in following figures.

The above Fig 5 & 6 shows the shear capacity of fiber reinforced concrete beams increased with increase in percentage of fibers. And comparing this with beams without shear reinforcement, we can conclude that there is additional shear capacity whereas providing shear reinforcement.

The Load-Deflection response of SFRC beams has been studied. The objective was to improve the understanding of the behaviour of SFRC concrete beams. Beamswithout fibers failed in a brittle manner. The shear capacity of the HSSFRC beams with and without shear reinforcement increased with increase in fiber content. Moreover, the main differences in shear strength between SFRC beams with and without shear reinforcement were highlighted.
The beams with shear reinforcement have additional shear capacity than the beams without shear reinforcement. All the beams tested in this investigation failed in shear. Beams without fibers failed in a brittle manner. Non-fibrous beams showed deep cracking compared to the fibrous concrete beams. The addition of fiber enhanced the post ultimate ductility of the members.

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