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# Experimental Evaluation Shear Strength of Steel Fibre Reinforced Concrete Deep Beam

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***Abstract*— The application of fibers to R.C.C. structural members would be one of the major areas of use in structural engineering. The fibers to R.C.C. have got an existing future in construction in days ahead. The objective of the present experimental investigation was to evaluate ultimate shear strength of Steel Fiber Reinforced Concrete deep beams without shear reinforcement. The purpose of this project is to present the results of investigations where the Steel Fiber contribute in the shear strength of the deep beam or not. The object was also to understand the deflection and the cracking behavior of SFRC deep beam without stirrups. Test data investigates the behavior of concrete deep beams reinforced with conventional steel bars and steel fibers subjected to two point symmetrical loading. Variables in test data are effective span to effective depth ratio of deep beam (1, 1.5 & 2), aspect ratio of fiber (50 & 80), and volume fraction of fibers (0%, 1%, 1.5% & 2% of fibers for 50 aspect ratio fibers and 0%, 0.5%, 0.75% & 1% for 80 aspect ratio fibers).Twenty four concrete deep beams of dimensions 800x300x150mm (8 Nos.), 800x400x150mm (8 Nos.),and 800x600x150mm (8Nos) were tested to destruction of applying gradually increased load of which 12 numbers of beams were casted with hook end steel fibers of 50 aspect ratio and next 12 numbers of beams were casted with 80 aspect ratio steel fibers. The influence of fibers content in the concrete deep beams has been studied by measuring the deflection of deep beams below point loads and the shear strength of concrete. Load deflection response, crack patterns, and modes of failures for SFRC deep beams are studied experimentally. In result we have found that after replacing all shear reinforcement in deep beam by increasing the percentage of steel fibers ultimate shear strength increases and there is significant influence in mode of failures of beam.**

***Index Terms*—Steel Fiber reinforced concrete, deep beam, ultimate shear strength, deflection, crack patterns, modes of failures.**

## I. INTRODUCTION

All Beams with large depths in relation to spans are called deep beams. In IS-456: 2000(Clause 29), a simply supported beam is classified as deep when the ratio of its effective span L to overall depth D is less than 2. Continuous beams are considered as deep when the ratio L/D is less than 2.5. The effective span is defined as the centre-to-centre distance between the supports or 1.15 times the clear span whichever is less.

Deep beams are structural elements loaded as simple beams in which a significant amount of the load is carried to the supports by a compression force combining the load and the reaction. As a result, the strain distribution is no longer considered linear, and the shear deformations become significant when compared to pure flexure.

Deep beams are often used as structural members in Civil Engineering works. Because of the geometric proportions of deep beams, their strength is usually controlled by shear rather than flexure, if normal amounts of reinforcements are provided.

Deep beams serve many uses applications in buildings and other structures. In buildings, a deep beam or transfer girder is used when for architectural purposes a lower column on the exterior facade is removed. A deep beam, sometimes the full depth of the floor -to- floor height is used to transfer the high axial forces of columns above to the supporting columns below. Foundation walls are sometimes also termed deep beams.

## II. RESEARCH SIGNIFICANCE

The application of fibre to R.C.C. structural members would be one of the major areas of use in structural engineering. The fibres to R.C.C. have got an existing future in construction in days ahead. During the construction of deep beam, due to heavy loads reinforcement in the beams are very dense so it is very difficult for placing and compaction of concrete. So for overcoming these problems of construction we can replace the amount of reinforcement by steel fibres. These fibres are mixed with the concrete during its preparation. By replacing the steel reinforcement by steel fibres we can increase the spacing of reinforcement or either we can replace total shear reinforcement in the deep beam this will leads to faster construction and hence cost reduction.

The objective of the present experimental investigation was to evaluate ultimate shear strength of Steel Fibre Reinforced Concrete deep beams without stirrups. Can we replace the shear reinforcement by steel fibres or not and what will be effect of fibres on the ultimate shear strength, crack patterns of SFRC deep beam without shear reinforcement.

Results from experimental program aimed at evaluating the shear behaviour of SFRC beams are presented. Data presented herein are considered unique in the sense that they provide information on the effect of parameters such as fibre geometry, shear strength and volume fraction, and longitudinal reinforcement ratio on the shear behaviour of relatively large SFRC deep beams.

International Journal of Engineering Research & Technology (IJERT)
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This paper presents experimental evidence that supports the use of the design procedures contained in IS456:2000 Code in reinforced concrete deep beams. This research presents the effectiveness of steel fibre in improving shear resistance of reinforced concrete beam. The object was also to understand the deflection and the cracking behaviour of SFRC deep beam without stirrups.

## III. EXPERIMENTAL PROGRAM

### *A. Test Materials*

Define Ordinary Portland cement of 53 grades, crushed sand having specific gravity 2.76 and maximum size of 4.75 mm as a fine aggregate, and natural basalt gravel of maximum size 20 mm as coarse aggregate were used. The concrete mix proportion was 0.40: 1: 1.54: 3.58 (water: cement: fine aggregate: coarse aggregate) by weight. The Hook end Steel fibres of aspect ratio 50 and 80 were used. There were two series of beams and for each series three cubes (150 mm x 150 mm x 150 mm) for compressive strength were cast as control specimens. All specimens were cured at least for 28 days

The followings are the investigational material properties found in laboratory.

Grade of concrete – M40
Cement - O.P.C. of 53 grade (Birla super brand)
Specific gravity of crushed sand -2.76
Specific gravity of 20mm crushed stone aggregates – 2.90
Specific gravity of 10mm crushed stone aggregates – 2.84
Fine aggregates zone – Zone II
Types of fibres – Hook end steel fibres
Aspect ratio of fibres – 50 & 80
Water – Potable water

### *B. Specimen Details*

Testing was carried out on 24 numbers beam specimens, Beams were simply supported on constant effective span of 600 mm. beams were tested under two point concentrated symmetrical loads. Deep beams of dimensions 800x300x150mm (8 Nos.), 800x400x150mm (8 Nos.),and 800x600x150mm (8Nos) were tested to destruction by applying gradually increased load. 12 numbers of beams were casted with hook end steel fibers of 50 aspect ratio and next 12 numbers of beams were casted with 80 aspect ratio steel fibers. Of these 12 beams one beam of each size is casted with conventional reinforcement and other 3 beams of each size were casted with 3 different percentages of steel fibers and similarly other 12 beams were prepared.

There were three series of beams having different depths of 30 cm, 40 cm and 60cm each series comprised of eight beams. The beam notation “D40 NRC F 0%” denotes the beam having overall depth D of 40 cm, NRC means normally reinforced concrete deep beams and F 0% denotes the percentage of fibres. Also “D40 AR50 F1.5%” denotes the beam having overall depth D of 40 cm and AR 50 means fibres of aspect ratio 50 were used in deep beam and F 0% denotes the percentage of fibres.

### *C. Testing Procedure*

The deep beams were tested in a 100T capacity Universal Testing Machine. All the beams were tested to failure under two– point loading system. The test set up for the beam is shown in figure 1.

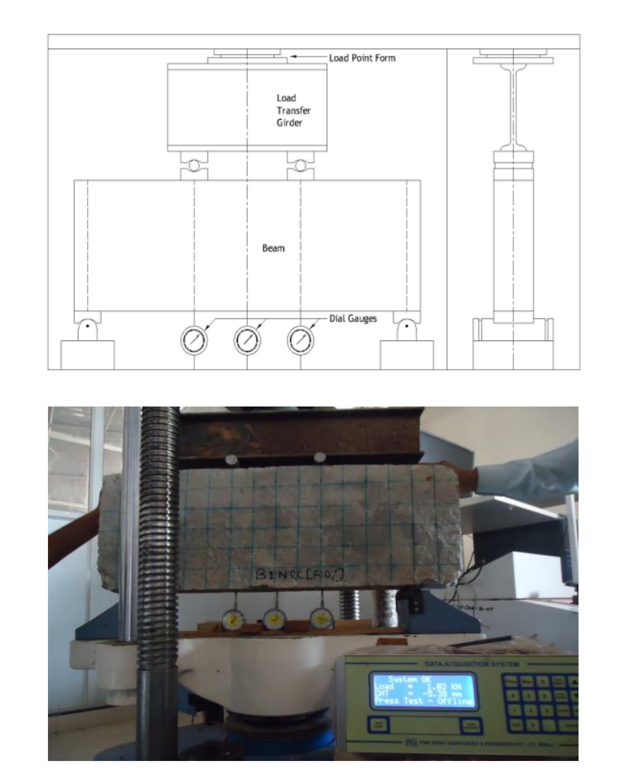


Fig 1 Test setup

Each of the beam specimens were mounted on roller supports on the Universal Testing Machine. Three dial gauges (least count 0.01 mm) were placed at the bottom fare of the beam at mid span and under the loading points. Two-point loads were obtained by placing the loading head on the top surface at the centre of the beam and distributing the load through a spreader beam. A small pre load was applied slowly to ensure that the beam was properly seated and the dial gauges were functioning properly. All the beams were simply supported with an effective span of 600 mm. Beams were centered on platform and levelled horizontally using level tube and vertically by adjusting the bearing plates. Load was applied gradually. Deflections at the mid-span and under the loading points were recorded at each load increment. During the test, crack propagation carefully marked. All the beams were loaded to failure.

Cubes of size 150mm that had been cast along with the beams were tested on the same day on which the respective beams were tested to ascertain the compressive strength of the concrete used in the beams. The cube tests were carried out to find compressive strength in a Compression Testing machine of 1000 ton capacity and these tests were carried out as per the recommendations of Indian Standard Codes of Practice.

## IV. RESULTS AND DISCUSSION

### *A. Behavior of deep beam during testing - crack patterns and modes of failure of beam :*

- In all the beam specimens, initiation of flexure cracks was from the bottom of the beams.
- In most of the cases, all the flexure cracks were almost vertical, while most of the shear cracks were inclined and their direction of propagation was towards the nearest load point irrespective of its place of origin from the observation and photographs of tested specimen regarding crack width.
- The predominant crack was observed in the flexure zone. Few thin cracks were observed in shear zone of D30 and D40 beam series, which shows that the shear strength is higher than flexural strength in D30 and D40 series beams.
- Sometimes predominant crack occurs in shear zone, but flexure cracks were formed prior to shear cracks and flexure cracks were few and thin. It was observed that the major diagonal shear cracks were formed all of a sudden before Ultimate load. At about 80 to 90 % of ultimate load, new inclined cracks were formed parallel to the line joining the load edge and support blocks.
- crack patterns and modes of failure of SFRC deep beam with 80 aspect ratio fibres shown in following figures.-

Fig 2 Crack Pattern of beam D30 NRC [F0%]

Fig 3 Crack Pattern of beam D30 AR80 [F0.5%]

Fig 4 Crack Pattern of beam D30 AR80 [F0.75%]

Fig 5 Crack Pattern of beam D30 AR80 [F1%]

Fig 6 Crack Pattern of beam D40 NRC [F0%]

Fig 7 Crack Pattern of beam D40 AR80 [F0.5%]

Fig 8 Crack Pattern of beam D40 AR80 [F0.75%]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016


Fig 9 Crack Pattern of beam D40 AR80 [F1%]

Fig 10 Crack Pattern of beam D60 NRC [F0%]

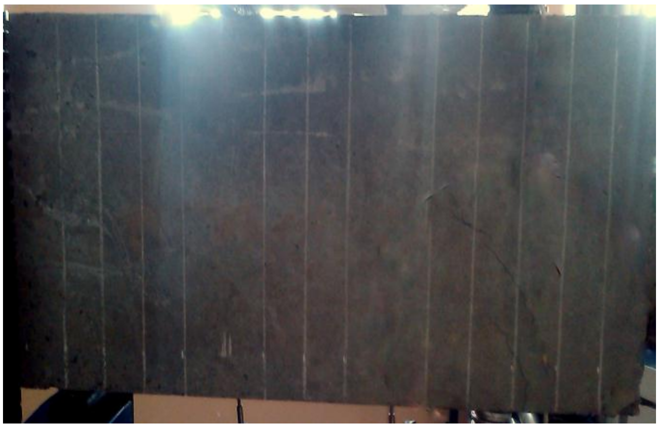

Fig 11 Crack Pattern of beam D60 AR80 [F0.5%]

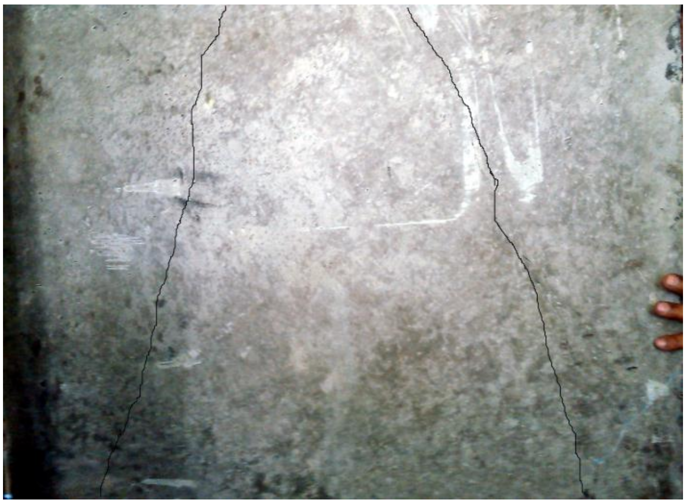

Fig 12 Crack Pattern of beam D60 AR80 [F0.75%]

Fig 13 Crack Pattern of beam D60 AR80 [F1%]

- D30 series of Beams having 0.5% & 1% of steel fibres, first crack are observed in flexure zone and then shear cracks are formed but in F0%, F0.75%, first crack is in shear zone.
- D40 series of beam F0% first crack observed in shear zone and F0.5%, F0.75% & F1% first crack observed in flexure zone.
- crack patterns and modes of failure of deep beam with 50 aspect ratio fibre used are shown in following figures.-

Fig 14 Crack Pattern of beam D30 NRC [F0%]

Fig 15 Crack Pattern of beam D30 AR50 [F1%]

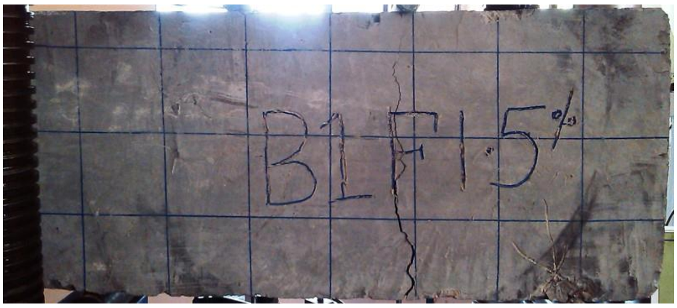

Fig 16 Crack Pattern of beam D30 AR50 [F1.5%]

Fig 17 Crack Pattern of beam D30 AR50 [F2%]


Fig 18 Crack Pattern of beam D40 NRC[F2%]

Fig 19 Crack Pattern of beam D40 AR50 [F1%]


Fig 20 Crack Pattern of beam D40 AR50 [F1.5%]


Fig 21 Crack Pattern of beam D40 AR50 [F2%]

Fig 22 Crack Pattern of beam D60 NRC [F0%]

Fig 23 Crack Pattern of beam D60 AR50 [F1%]

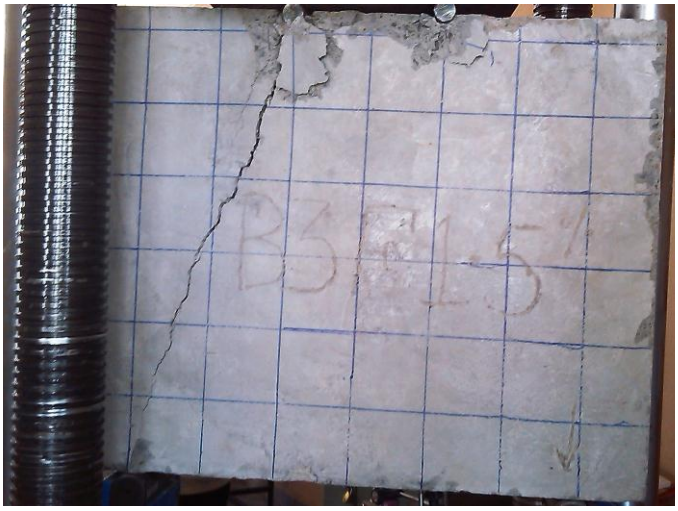

Fig 24 Crack Pattern of beam D60 AR50 [F1.5%]

Fig 25 Crack Pattern of beam D60 AR50 [F2%]

*B. Load Deflection Response of beams*

- Load deflection response for SFRC deep beams with 80 aspect ratio fibres are shown in the form of load vs. deflection graph below -

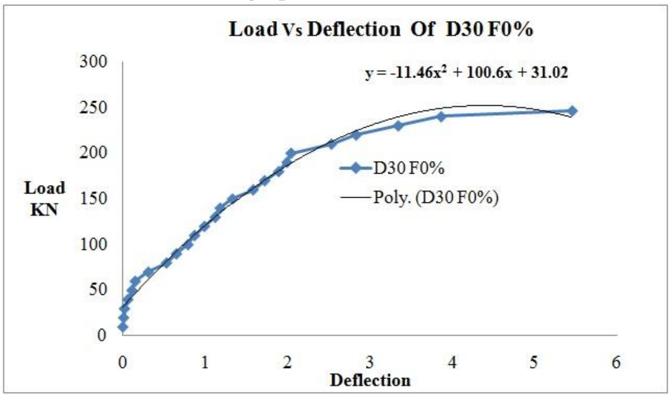


Fig 26 Load Deflection curve of beam D30 NRC80 [F0%]

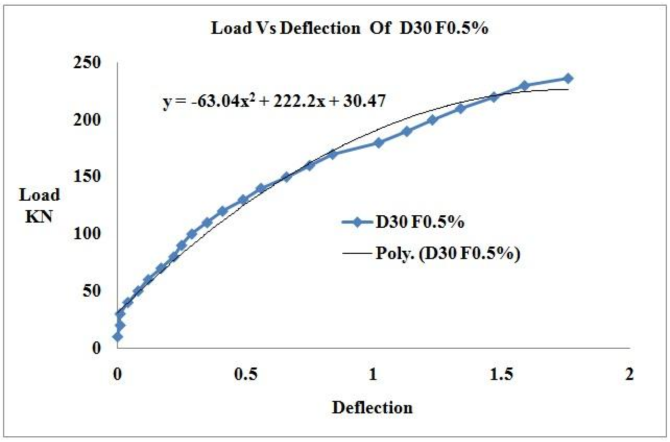


Fig 27 Load Deflection curve of beam D30 AR80 [F0.5%]

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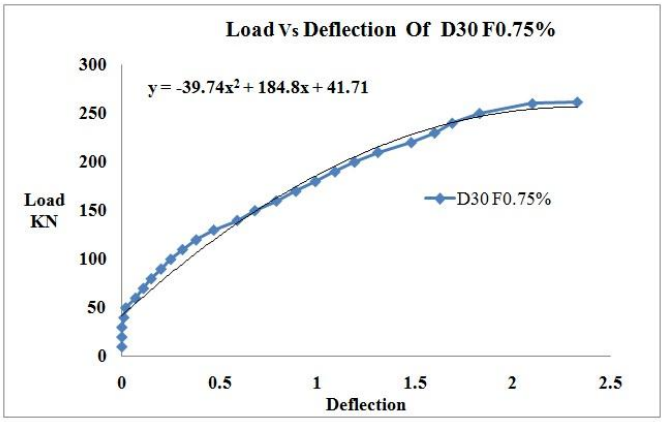


Fig 28 Crack Load Deflection curve of beam D30 AR80 [F0.75%]

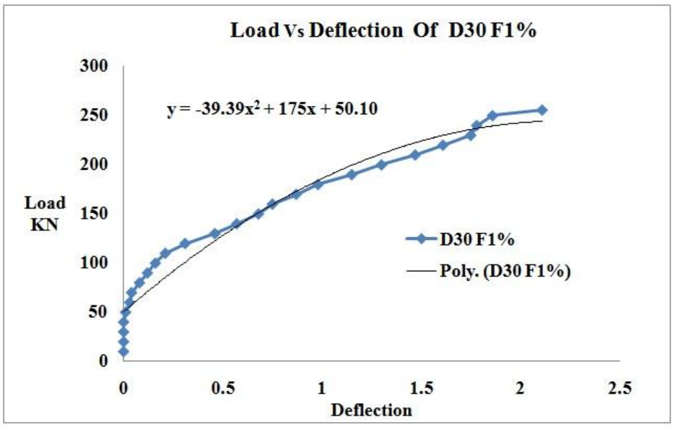


Fig 29 Load Deflection curve of beam AR80 [F1%]

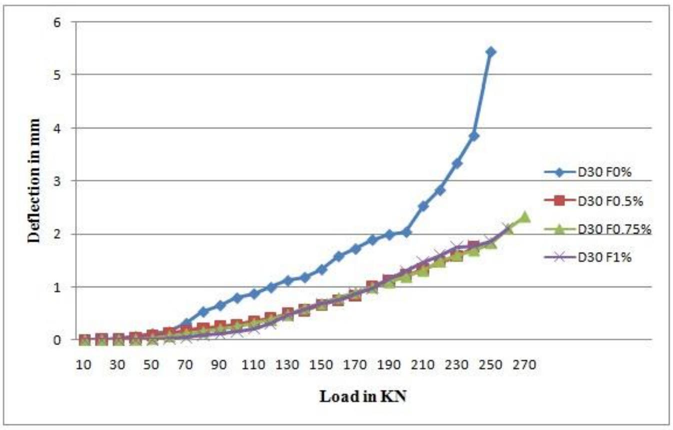


Fig 30 Comparative Deflections of D30 Series of Deep Beam.

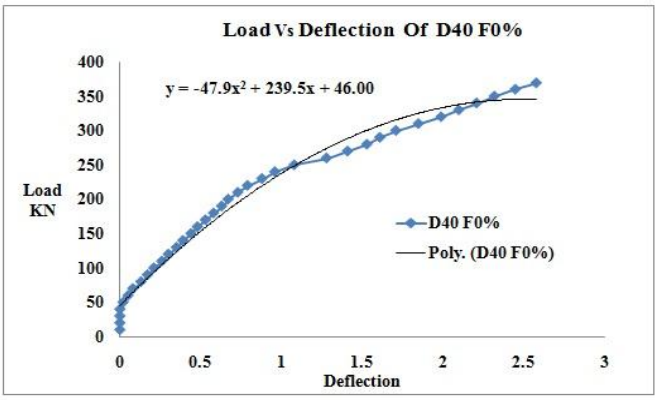


Fig 31 Load Deflection curve of beam D40 NRC80 [F0%]

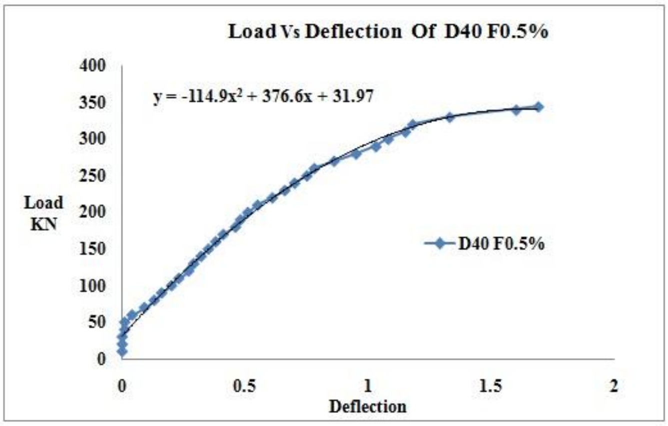


Fig 32 Load Deflection curve of beam AR80 [F0.5%]

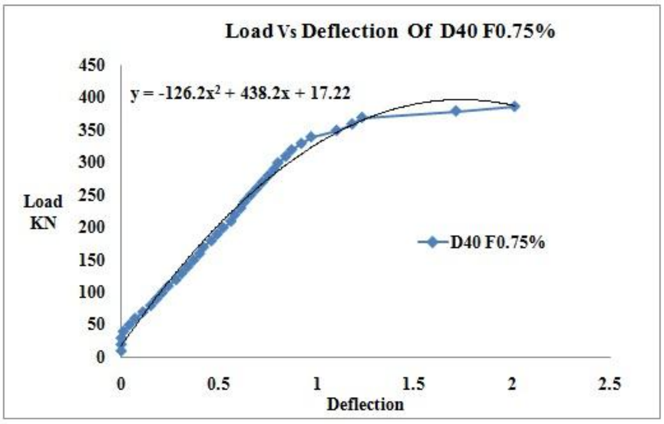


Fig 33 Load Deflection curve of beam D40 AR80 [F0.75%]

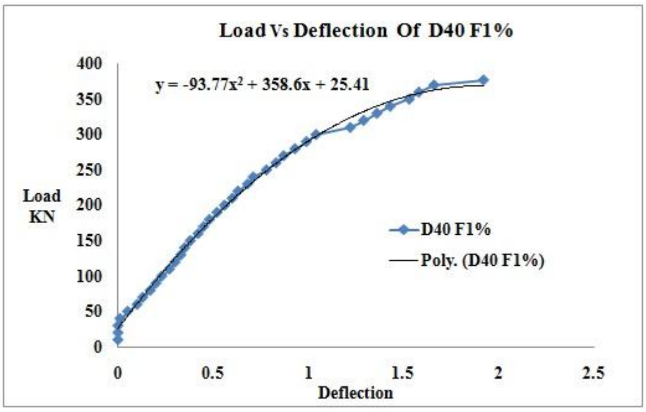


Fig 34 Load Deflection curve of beam D40 AR80 [F1%]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

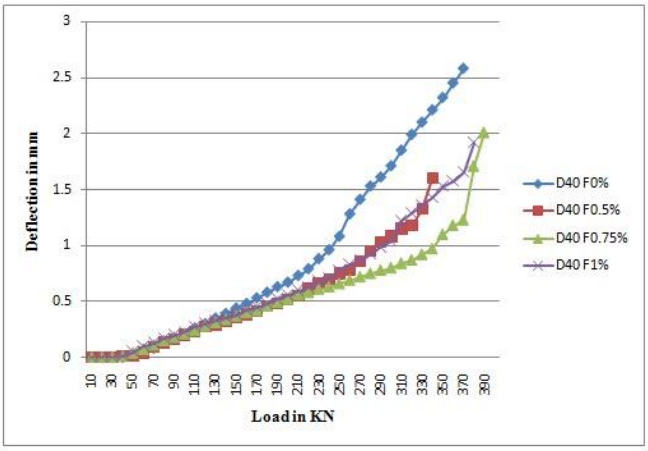


Fig 35 Comparative Deflections of D30 Series of Deep Beam

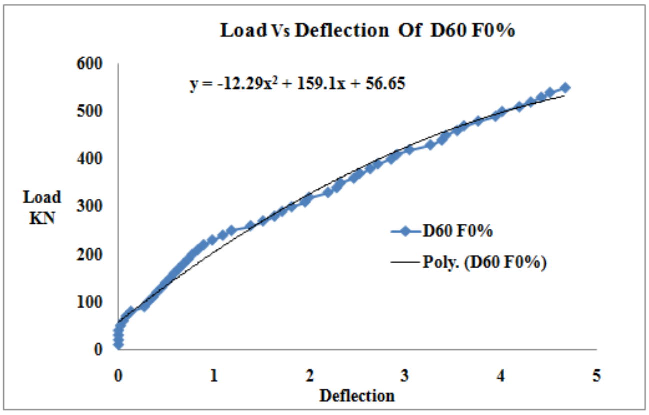


Fig 36 Load Deflection curve of beam D60 NRC80 [F0%]

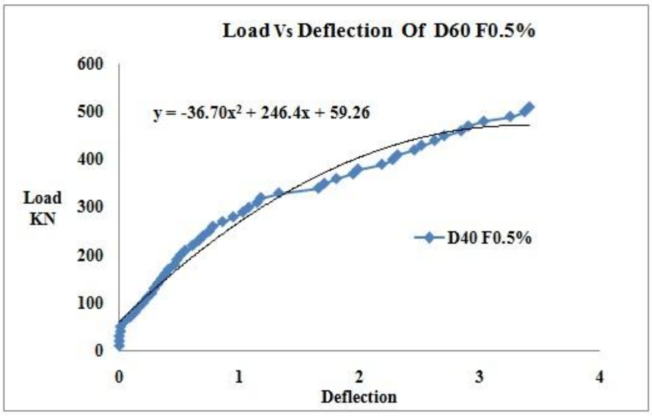


Fig 37 Load Deflection curve of beam D60 AR80 [F0.5%]

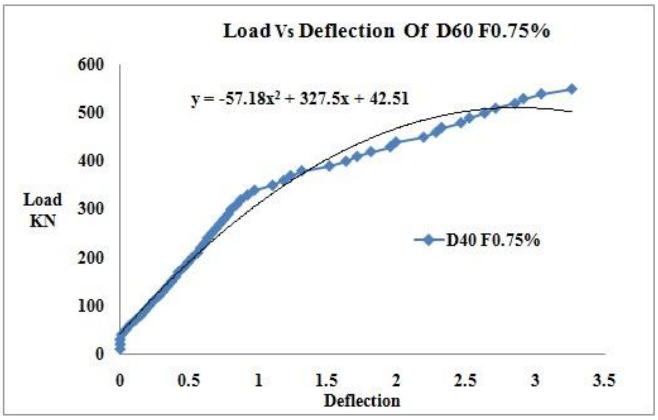


Fig 38 Load Deflection curve of beam D60 AR80 [F0.75%]

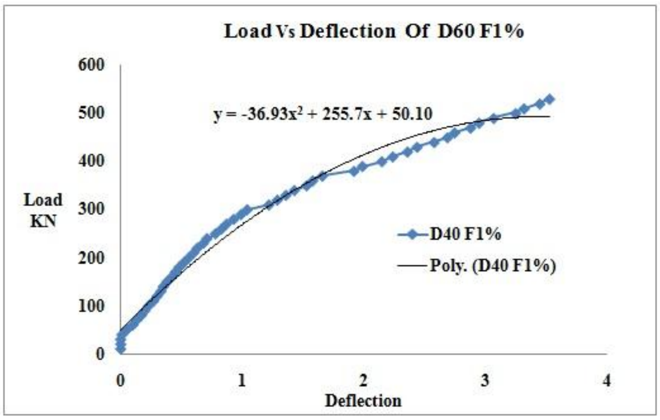


Fig 39 Load Deflection curve of beam D60 AR80 [F1%]

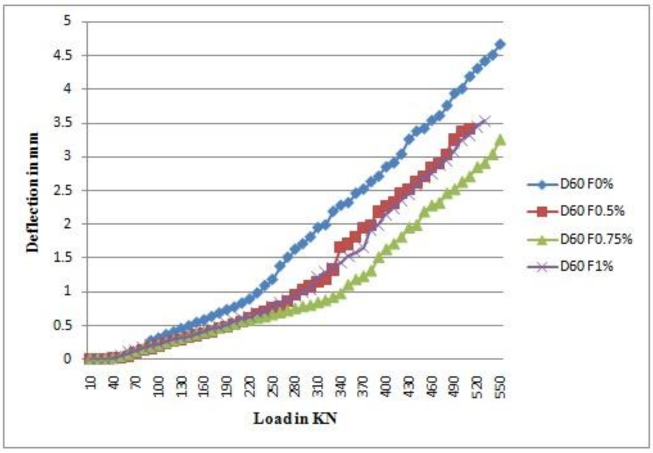


Fig 40 Comparative Deflections of D60 Series of Deep Beam

- Load deflection response for SFRC deep beams with 50 aspect ratio fibres are shown in the form of load vs. deflection graph below. –

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

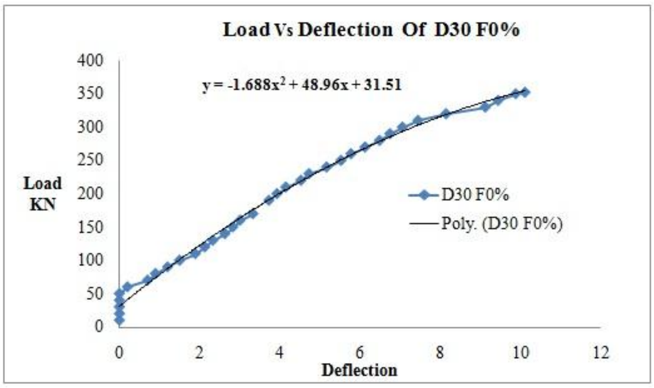


Fig 39 Load Deflection curve of beam D30 NRC50 [F0%]

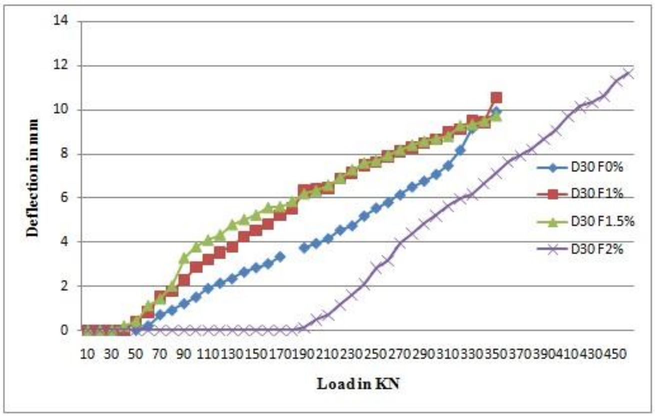


Fig 39 Comparative Deflections of D30 Series of Deep Beam

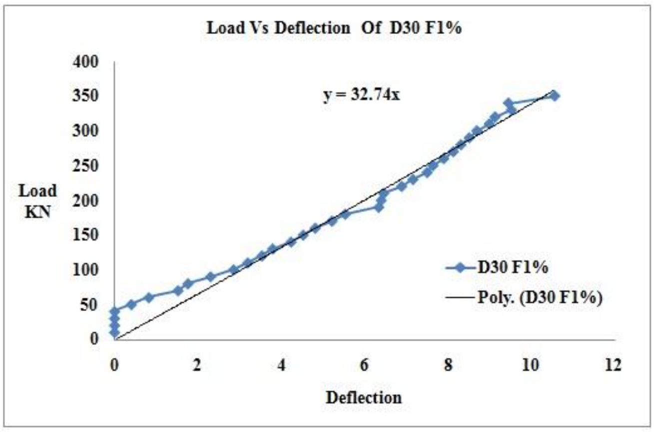


Fig 39 Load Deflection curve of beam D30 AR50 [F1%]

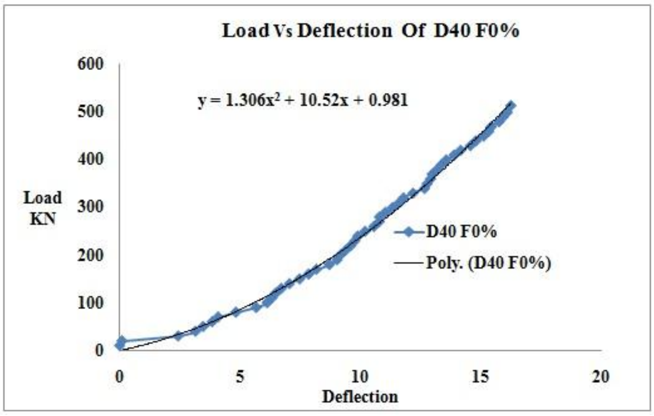


Fig 39 Load Deflection curve of beam D40 NRC50 [F0%]

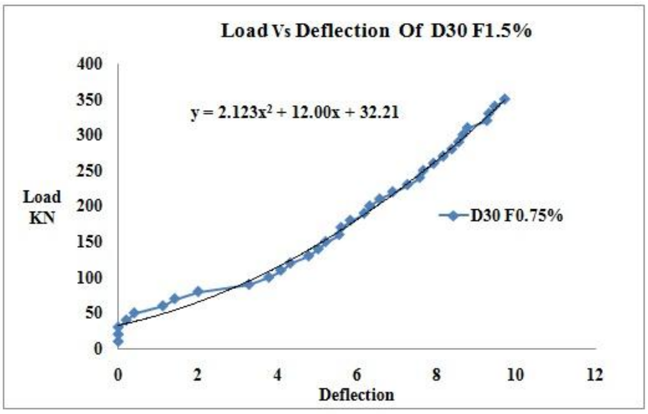


Fig 39 Load Deflection curve of beam D30 AR50 [F1.5%]

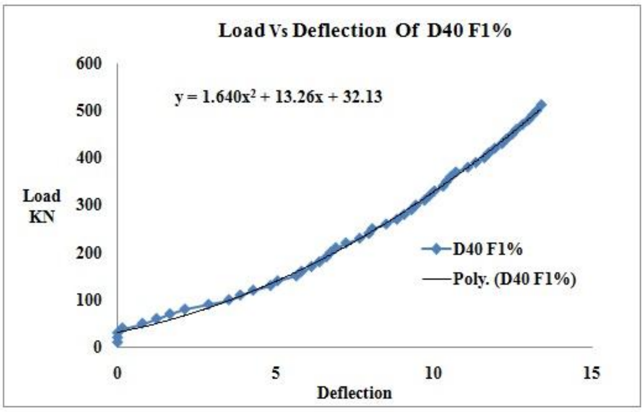


Fig 39 Load Deflection curve of beam D40 AR50 [F1%]

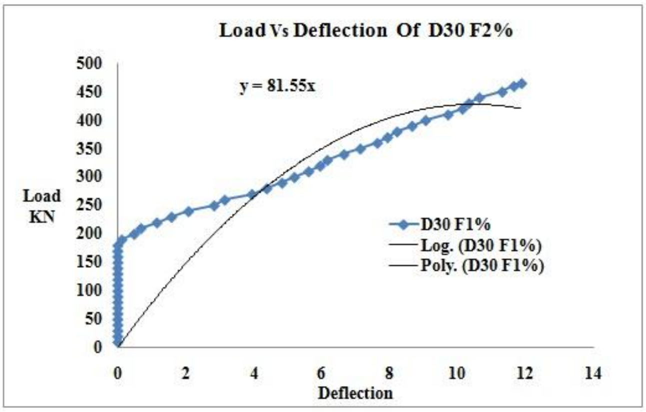


Fig 39 Load Deflection curve of beam D30 AR50 [F2%]

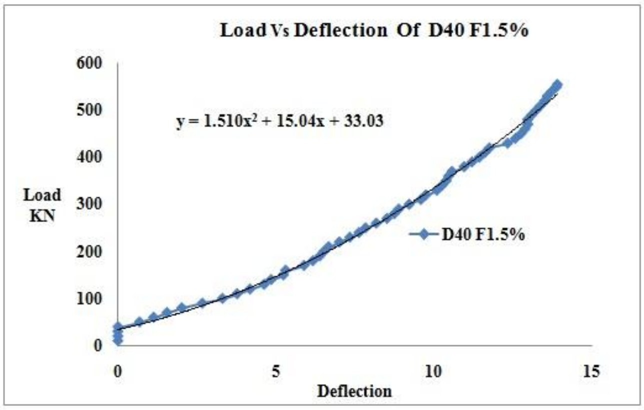


Fig 39 Load Deflection curve of beam D40 AR50 [F1.5%]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

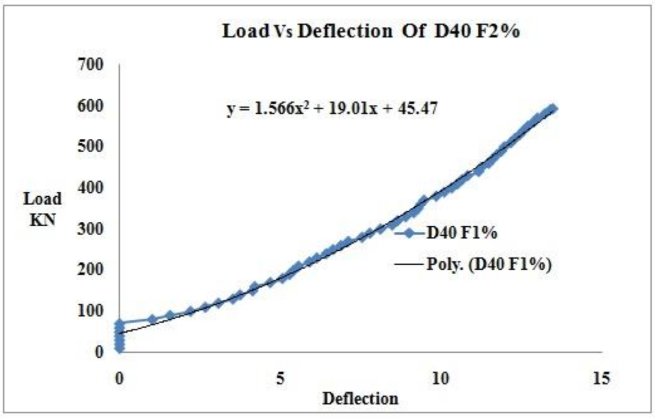


Fig 39 Load Deflection curve of beam D40 AR50 [F2%]

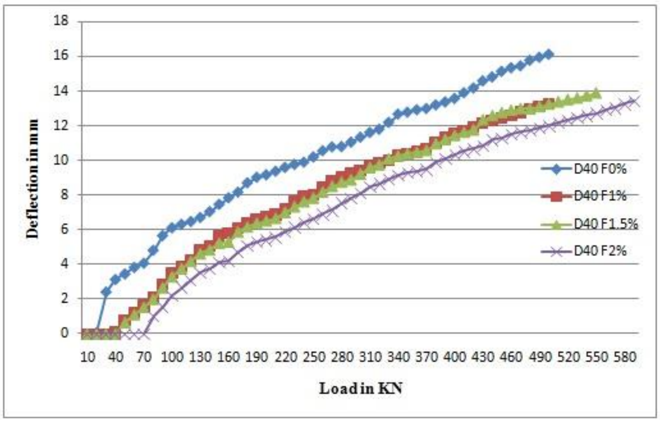


Fig 39 Comparative Deflections of D60 Series of Deep Beam

## V. CONCLUSION

- Additional of steel fibers increase the compressive strength of concrete matrix and also increase in the Shear capacity of the beam
- Steel fibre of aspect ratio 80, at 0.75% of steel fibre by volume of the beam it's ultimate strength will be greater than normally reinforced concrete deep beam.
- For 2% addition of steel fibre of 50 aspect ratio ultimate shear strength will be greater than normally reinforced concrete deep beam.
- Inclusion of steel fibres (Hook End Type) in the concrete beam improves the shear strength of R.C.C. beams without stirrups.
- Steel fibres can be used to replace stirrup completely with proper design of concrete.
- The replacement of vertical stirrups by steel fibres provided effective reinforcement against shear failure.
- The deflection of deep beam minimum in fibrous concrete Deep Beam as compared to R. C. Deep Beam. The minimum deflection observed in Deep beam with Fibres 0.75%.
- First crack load on deep beam 50 to 75% to the ultimate load of respective beam

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