Performance of Beam-Column Joint using Steel Fibers

M. A. Tantray

Abstract*: The ever increasing failure of structures, loss of life and staggering economic losses due to earthquake have raised the concern against earthquake safety to alarming level. Devastating failures in past have witnessed the performance of beam-column junctions governing the global response of structures. Congestion of reinforcement and construction difficulties has escalated the attention required for improved performance of RC beam-column joints. In current study, an attempt has been made to carry out experimental investigations on effect of steel fiber reinforcement near beam column junction on the performance of the joint. The percentage of steel fiber incorporated in the specimen has been fixed at 1.5 % by volume. The effectiveness of measure was experimentally verified. The specimens were tested under horizontal loading and their behavior was discussed with emphasis on strength, stiffness, displacement ductility and failure mechanism. Special attention was also paid to crack width study. It was obtained that specimen with steel fiber had reduced crack width and increased joint efficiency.

***Index Terms*: Fibre reinforced Concrete, Steel Fiber, Beam Column Joint, Crack Width, Stiffness**

I. INTRODUCTION

During the design of any framed structure safety against eart hquake is the most important criteria to be considered. Deva stating earthquakes in last few decades have emphasized the susceptibility of structures to earthquake failures [1][2]. Rein forced Concrete (RC) framed structures being the most com mon configuration type have suffered the most. This type of construction commonly serves its purpose efficiently under d esign vertical loads. However, the performance of such struc tures under seismic loads has exposed the susceptibility of th is construction type [3]. Reinforced concrete framed structur es generally develop inelastic deformations when they are su bjected to strong seismic excitations. Earthquake induced en ergy is dissipated through the formation of plastic hinges pre ferably in the beams rather than in columns. The design appr oaches should be taken into consideration in such a way to gi ve emphasis on the beam column joints since the failure of t hese regions can affect the integrity and stability of the struct ure as a whole. As beam column joints are one of the most cr itical and inaccessible regions in any structure therefore it is difficult to repair them once they are damaged. The emphasi s of this study is to understand and compare measure for stre ngthening beam-column joints [4][5].

BeamColumn joint has not been the area of research in past as they were assumed to act as rigid joints with no contributi on to deformations but recent earthquake failures have confir med the case otherwise. As the cases of joint failures during earthquake were increasingly reported so was the need to un derstand joint behavior. In succeeding years, the behaviour o f, joints, was, found, to, be, dependent, on,a, number, of, factors, related, with, their, geometry;, amount, and, detailing, of, reinforcement, concrete, strength, and, loading, pattern., In, Indian, practice, the, joint, is, usually, neglected, for, specific, design, with, attention, being, restricted, to, provision, of, sufficient, anchorage, for, beam, longitudinal, reinforcement., This, may, be, acceptable, when, the, frame, is, not, subjected, to, earthquake, loads, but, won't work, for, seismic, loads. [6-11]

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Steel Fiber Reinforced Concrete Joint (SFRC Joint)

Steel fiber reinforced concrete (SFRC) is a mix that contains spasmodic distinct steel fibers distributed randomly and unif ormly dispersed. Quantity and quality of fibers influence the mechanical properties of concrete. The incorporation of steel fibers considerably increases the tensile strength ductility an d toughness of reinforced concrete [12]. The only complicati on with the use of steel fibres is workability. The workability of SFRC is affected by the workability of plain concrete con tent of fibres used and fiber aspect ratio (l_f / d_f). Usually the workability of SFRC is improved by limiting the aggregate s ize adding admixtures and reducing water to cement (w/c) ra tio. Previous research work done on SFRC strongly recomm ends that the volume fraction of SFRC (V_f) be limited to 2 % and the maximum aspect ratio (l_f / d_f) to 100.

Selection of steel fiber

On the basis of availability out of three types i.e Crimped Dr amix Irregular fibres . Hooked end Dramix steel fibre was ch osen as shown in Figure 1. The basic dimension of this fibre was 62mm x0.95mm with 45 degree hooked ends which are generally considered to slowly deform during pullout from c oncrete ensuring a controlled ductile failure.The fibre contnt of 117kg/m3 was adopted corresponded to 1.5% by volume of concrete matrix. Firstly cement aggregate and water were mixed then steel fibres were mixed to the concrete. Wooden boards were used in the joint region to separate conventional concrete with the SFRC. Specimen was cured for 28 days an d testing was done.

II. Testing Method.

Specimen with and without steel fibers are tested under pure positive (opening) moment using the basic loading arrangement shown in figure 3. The linearly increasing load is applied in increments using a manually operated hydraulic jack of capacity 1000 KN. A time interval of around 10 min is to be given between two increments of load so as to allow the crack growth to stabilize. The applied load was measured using a sensitive proving ring. Deflections and consequent changes in the corner angles were measured using dial gauges having a least count of 0.01 mm. Readings of the dial gauges are to be recorded at each load increments. All specimens are to be tested till failure [13]. The loading arrangement, location of the dial gauges on concrete and steel is shown in Figure 2 and 3

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As the test proceeded, load reading horizontal displacements of the specimen legs at each stage of loading development and propagation of cracks load at first crack and the mode of failure of the specimen are to be noted in Table 1.

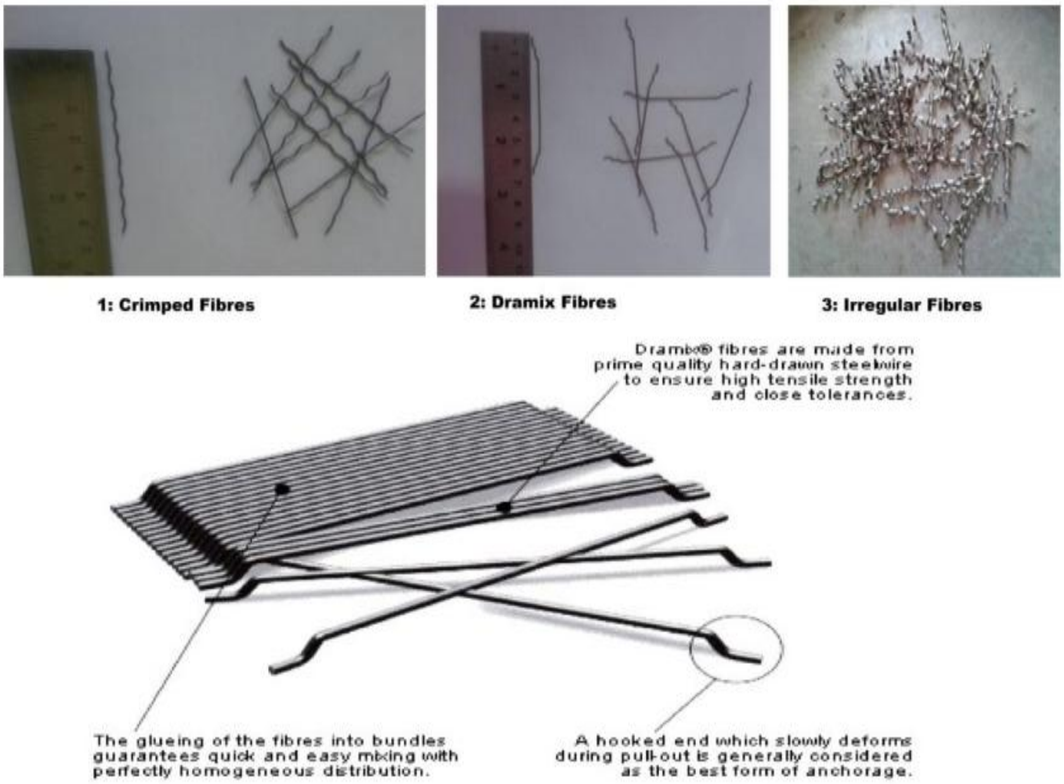

Figure 1 Selection of steel fibre

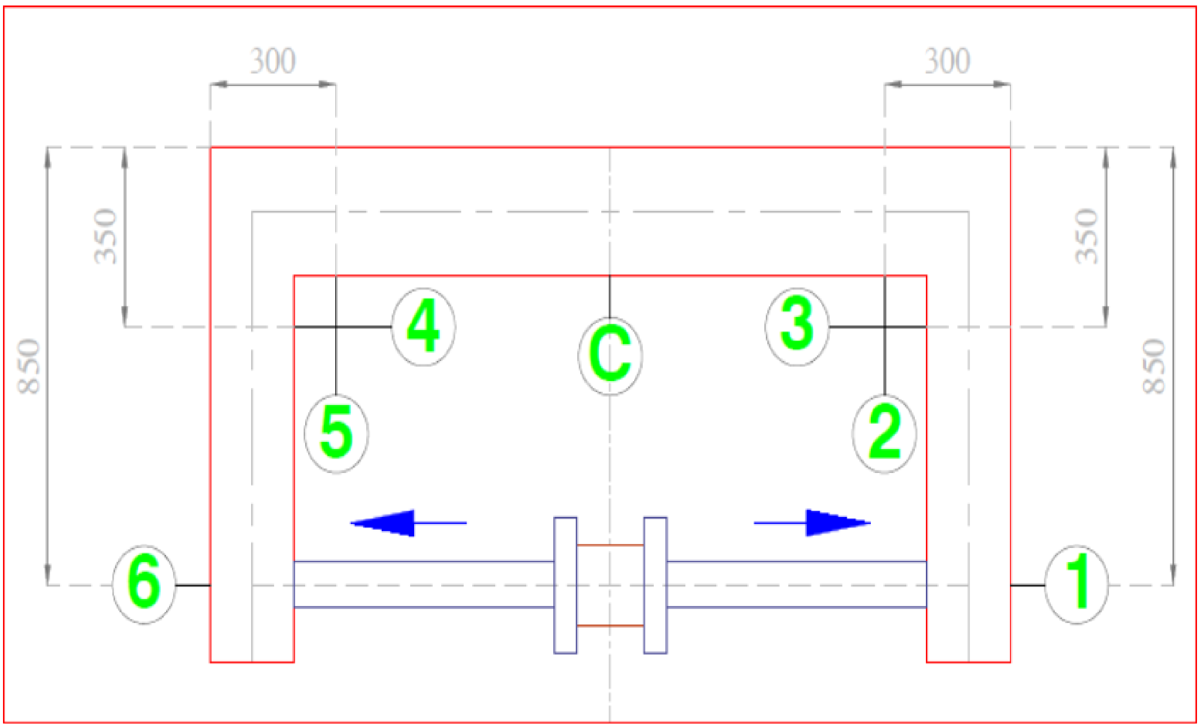

Figure 2 Position of dial gauges

Figure 3 Testing of SFRC Joint Model

Table 1. The observations of the models.

Parameters	**Value (Basic model)**	**Value (model with steel fibers)**
Yield Strength	3.32 KN	11.62 KN
Ultimate Strength	14.94 KN	19.92 KN
Ultimate displacement	10.695 mm	20.065 mm
Yield displacement	3 mm	9.41 mm
Stiffness	3.87 KN/mm	1.234 KN/mm
Ductility Ratio	1.571	1.714
Crack Initiation load	2.14 KN	3.32 KN
Crack width at failure	1.1 mm	.72 mm

III. RESULTS AND DISCUSSIONS

This section presents the comparison of results obtained from experimental investigation of the two models. Tabulated results of different parameters obtained are discussed in this chapter

1. Load-Displacement behavior of beam-column joint.
Figure 4 and 5 compares displacement of specimen when subjected to horizontal loading. It can be observed that steel fiber reinforced concrete (SFRC) joint have shown large displacement with respect to the load applied to the model without steel fibers (base model).

2. Displacement ductility factor
Displacement ductility factor which was determined by taking ratio of yield displacement to ultimate displacement was compared for the models. It was observed that inclusion of steel fiber results in increase in ductility of joints. The Fig 6 shows the variation in ductility factor between 2 models.

3. Stiffness Behavior
Stiffness is the essential variable in performance of joints. It is defined as the load required to cause unit deflection of beam-column joint. Ultimate stiffness for various specimens has been estimated considering deflection at ultimate load. The plot for ultimate stiffness is shown in Fig 7.

4. Crack Width Analysis
Crack width analysis was done by plotting load v/s crack width graph for specimens. The graphs for crack width for base model and model with steel fibers are shown in Figure 8 and Figure 9 respectively. Load corresponding to the propagation of first crack was also compared with the ultimate load that the specimen has sustained and is plotted in figures below.

5. Cost- Benefit Analysis
The cost analysis of the specimens was compared to evaluate the feasibility and economy of each measure. The Figure 10 shows the cost difference between the models with and without the steel fibers.

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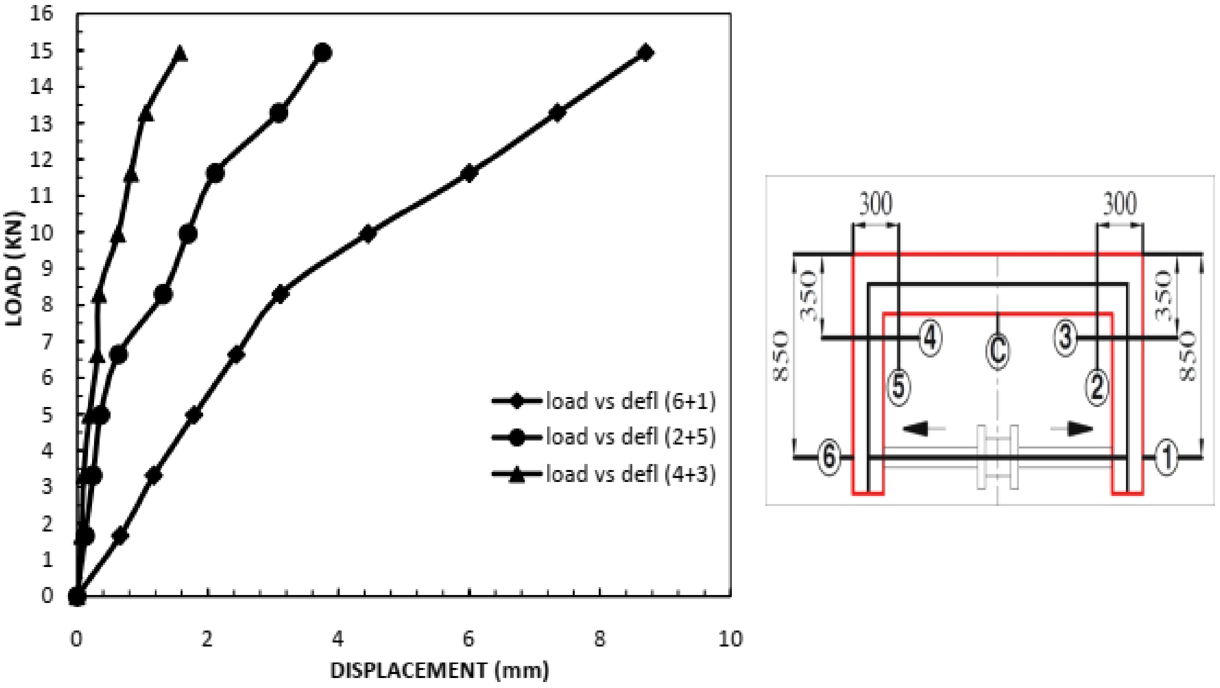

Figure 4 load displacement curve for model without fiber

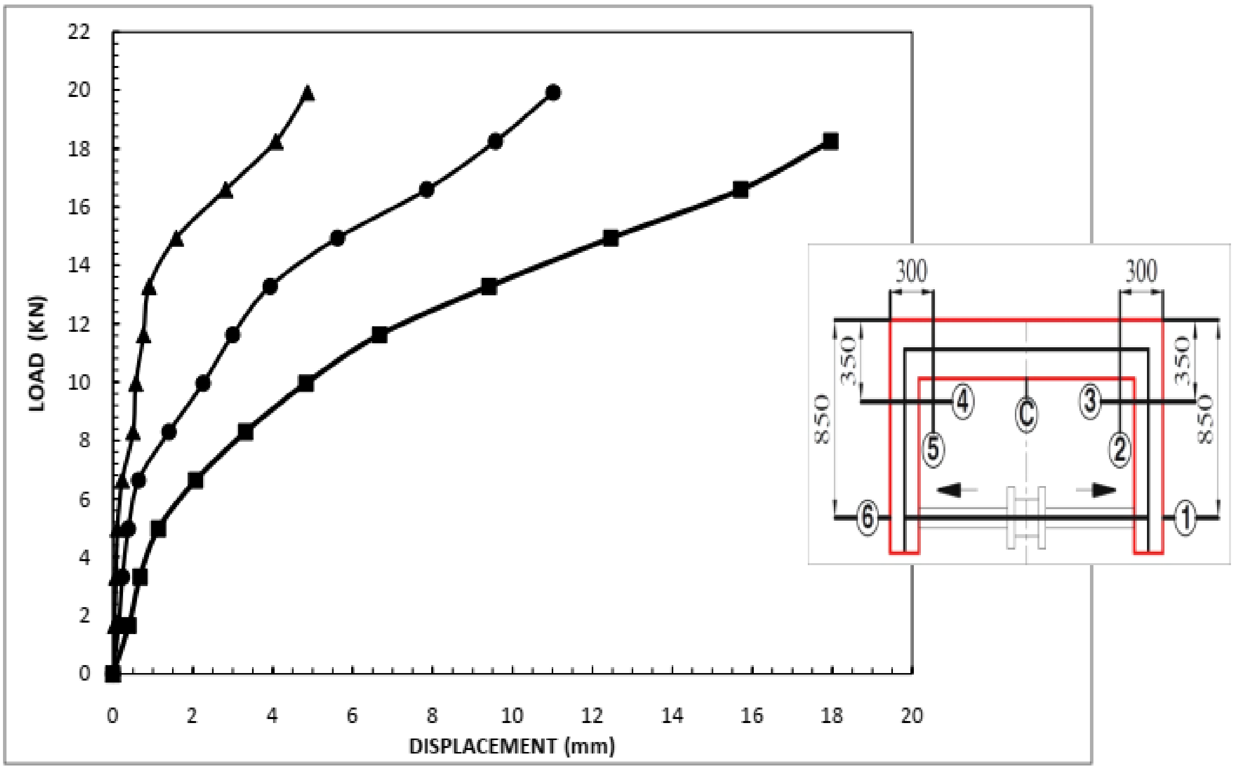

Figure 5 load displacement curve for model with fiber

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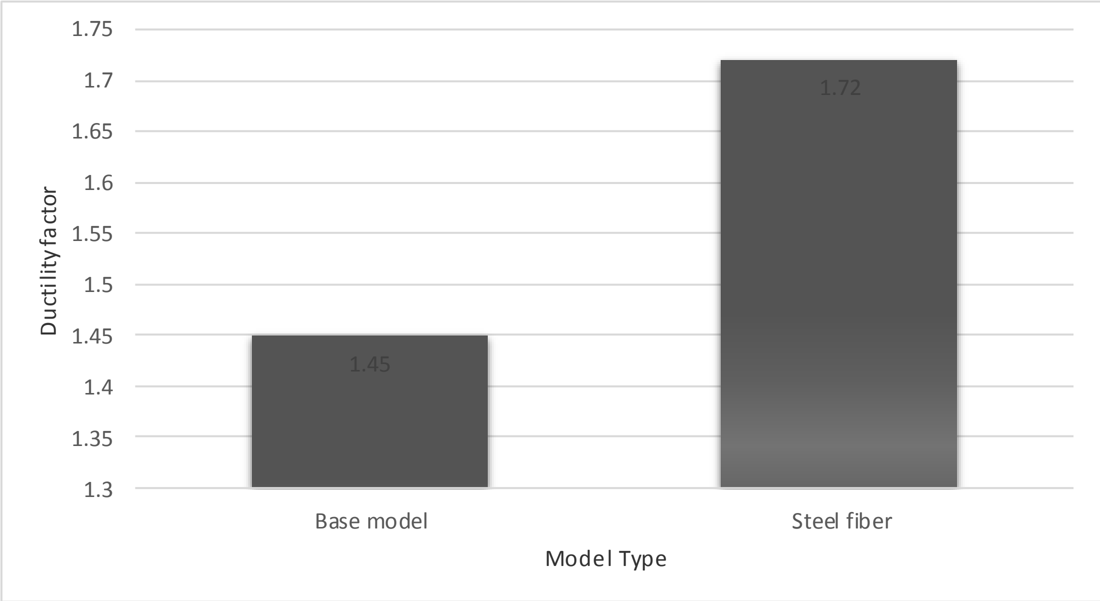

Figure 6 Displacement Ductility factor

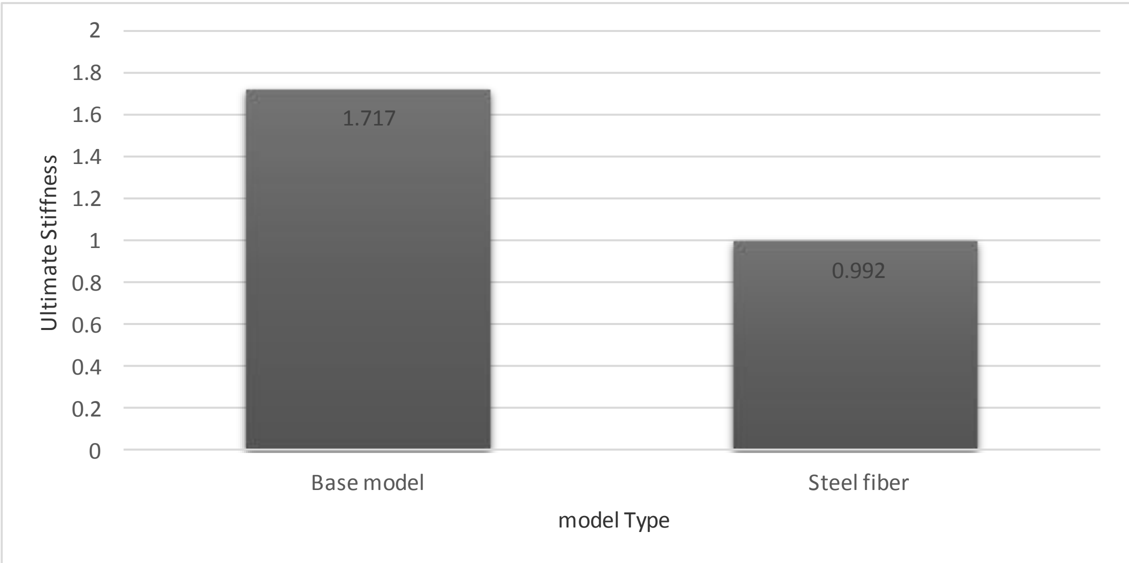

Figure 7 Ultimate Stiffness for various models

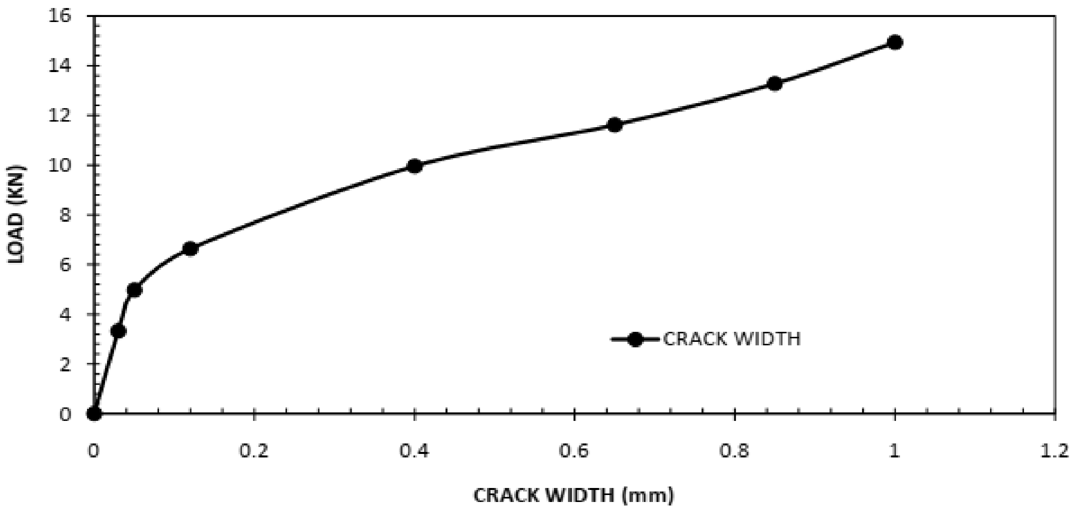

Figure 8 Load (KN) v/s Crack width (mm) for model with fiber

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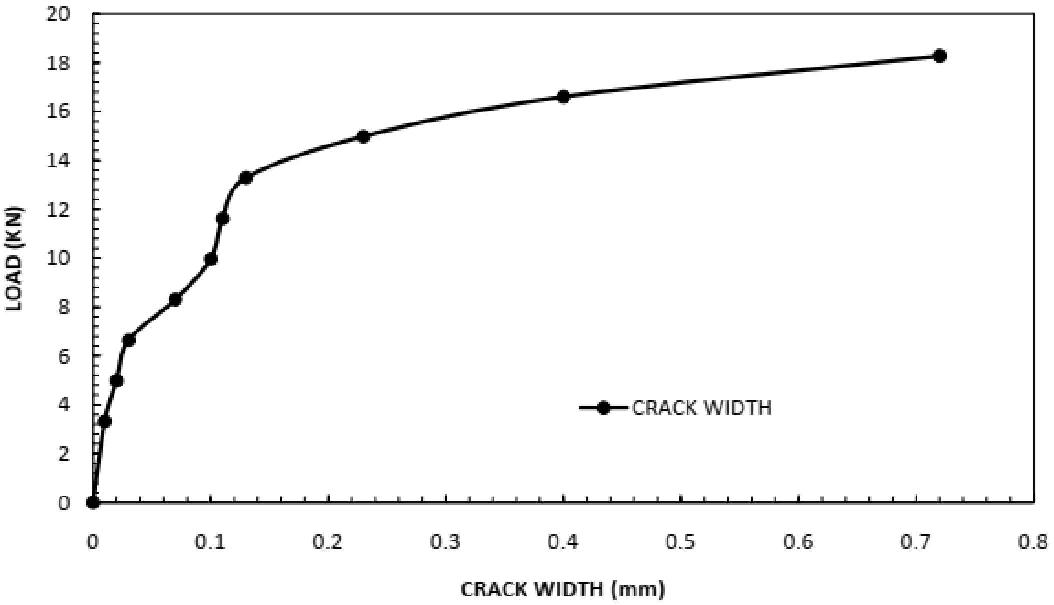

Figure 9 Load (KN) v/s Crack width (mm) for model with fiber

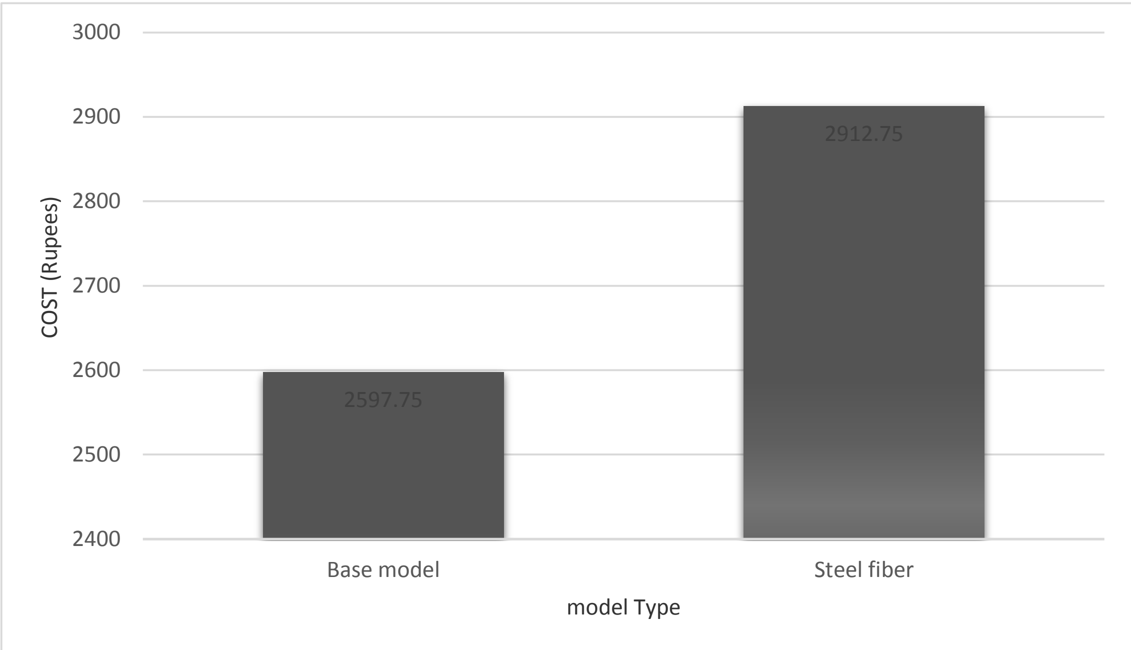

Figure 10 Cost Analysis of various models

IV CONCLUSION

In the present work which was reported in preceding sections investigations were made regarding contribution of the method in strengthening of beam/column joint. The purpose of this investigation was to evaluate the performance of beam/column joint strengthened by steel fibers and to compare the same with the base model. Based on experimental investigations following conclusion were drawn.

1. Basic specimen failed due to the advancement of tensile cracks at the junction between beam and column, the cracks propagated further leading to quick reduction in stiffness.
2. It is found that specimen casted with steel fiber percentage of 1.5% has shown 14.02% increase in joint efficiency and about 20% increase in ductility displacement although it was noted that the ultimate stiffness of the sample had dropped.
3. By performing crack behavior comparison for models it was noticed that the specimens with steel fibers outperformed the base model. A vertical crack was formed at the intersection of both the specimens. Model with steel fiber has undergone large displacement without developing wider cracks as compared to other model depicting higher ductility
4. A detailed costbenefit analysis has been carried out for various models and it has been

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found out that efficiency of base model is not overwhelmi ng compared to model with steel fibers. As the fibers utiliz ed are inexpensive.

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5. Associate Professor at NIT Srinagar from 1-07-2008 to 01-07-2012
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Research Publications

1 Steel Fibre based Concrete in Compression in International Journal of Advanced Engineering Technology Vol.II/IssueI/Jan-March 2011/96-111

2 Influence of Steel fibres on the shear strength of concrete Journal of Engineering, Computers & Applied SciencesVol I /No.I Oct-2012/88-92 3Modelling of Deep Beams using Neural Network in Indian Journal of Engineering Inventions Vol I/Issue 9Nov-2012/20-26

4 Shear strength of deep beams loaded with steel fibres in International Journal of Advanced Engineering Technology Vol.II/Issue II July-Aug 2012/36-41

5 Design aid for Shear Strength of Steel fibre based Concrete in Indian Concrete Journal January-2010, pp 37-42 6 Steel Fibre Based Concrete in its fresh state in ICI-Journal N0.1027/ F3504048619 -June 2008/13-22

7 Shear behaviour of SFBC Concrete in Journal of Structural Engineering January-2013; pp 24-28

8 Stress strain behaviour of FBC concrete in Journal of Civil Engineering July -2013; pp 35-41

9 Experimental Investigation on transmission of light in green buildings in International Research Journal of Engineering and technology March- 2017

Technical Skills

- Seismic Design of Steel Structures
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