Comparative Study on Performance of Beam Column Joint using Different Fibres

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Abstract

Concrete is one of the most resourceful and environmental friendly building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam, slabs and column in a high-rise building. In RC buildings, portions of columns that are common to beams at their intersections are called beam column joints. Beam-column joints have a crucial role in the structural integrity of the buildings. Review of literature indicates that numerous studies were conducted in the past to study the behaviour of beam-column joints with normal concrete. However, those recommendations are not intended for the fibre reinforced concrete. Some indicates that this material is an alternative to the confining reinforcement in the joint region. So the comparative study of the performance of different fibres in beam column joint has a greater importance and relevance in the field of RCC framed structures. This thesis aims to study the behaviour of beam column joint by evaluating the performance of fibre reinforced concrete. The incorporation of fibres in beam column joint is analysed in this study. The use of different types of fibres such as steel, glass and polypropylene are evaluated.
Keywords: Beam-Column Joint, Steel Fibre, Glass Fibre, Polypropylene Fibre, Moment Resisting Capacity

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I. INTRODUCTION

Concrete is the most used constructive material all over the world. Compared with other constructive materials it has the less cost/strength ratio. A lot of research has been done on improving the concrete strength. There was need to see the improvement in strength with addition of fibres in high-rise building in addition to rebar. In RC buildings, portions of columns that are common to beams at their intersections are called beam column joints. When forces larger than these are applied during earthquakes, joints are severely damaged. Repairing damaged joints is difficult, and so damage must be avoided. In reinforced concrete structures, beam–column joints are critical members for transferring forces and moments between beams and columns. Due to the moments reversal across beam-column joints when subjected to seismic action, higher joint shear forces are formed in the joint cores. As a result, beam–column joints are designed to have sufficient strength to maintain the stability and integrity of the structures. The beam–column joint is considered as the most critical zone in a reinforced concrete moment resisting frame.

The structural analysis of frames is commonly based on the assumption that the joints formed at the beam–column intersections behave as rigid bodies. The design codes' provisions did not safeguard against premature joint shear failure because the resulting design cannot ensure that the joint shear stress will be significantly lower than the joint ultimate strength in order to ascertain the development of the optimal (ductile) failure mechanism with plastic hinges forming in the beams while columns remained essentially elastic, to conform to the requisite ''strong column-weak beam'' tenet of capacity design. An improved model was also proposed in order to ensure that beam–column joints are kept intact during strong earthquakes. Problems of diagonal cracking and crushing of concrete in the joint region can be controlled by two mean, namely providing large column sizes and providing closely spaced closed loop steel ties around column bars in the joint region. Providing closed loop ties in the joint requires some extra effort. However, this may not always be possible particularly when the beams are long and the entire reinforcement cage becomes heavy. Beam-column joints have a crucial role in the structural integrity of the buildings. For this reason they must be provided with adequate stiffness and strength to sustain the loads transmitted from beam and columns.

Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. Fibre can be circular or flat. Fibres are often described by a convenient parameter called 'Aspect Ratio'. The aspect ratio of the fibre is the ratio of its length to an equivalent fibre diameter. Each type of fibre has its own characteristic properties and limitations. The weak matrix in concrete, when reinforced with steel fibres, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Because of the vast improvements achieved by the addition of fibres to concrete, there are several applications where Fibres Reinforced Concrete (FRC) can be intelligently and beneficially used.

A study on Glass fibre reinforced concrete beam-column joint shows that the Glass fibre concrete joint had a higher ultimate moment capacity, had better ductility, and was more damage tolerance than ordinary Beam-Column joint. The study shows that hoops in the joint could be replaced with glass fibres [4]. Another work is carried out to determine the behavior of steel fibres used for reinforced concrete frame structures. Tests were carried out on a total of 20 full scale interior beam-column joints. Geometry and reinforcements were selected according to existing buildings, designed solely to gravity loads under strong beam-weak column concept. Two types of beam reinforcement have been included in the experimental program. Tests were carried out by subjecting specimens to gravity Results show that the strengthening techniques and the axial loads applied on columns can have significant influence on the seismic behaviour of the joints [8]. An experimental study on strengthening of beam-column joints considered three typical modes of failure namely flexural failure of beam, shear failure of beam and shear failure of column. The study concluded that the shear failure was very brittle and hence retrofitting should be done in such a manner that the eventual failure occurs in the beam in flexure [12]. Another study is made to found that the shear resistance of SFRC joints was greater than that of conventional joints. It was observed that SFRC increased the shear and moment capacities. It was also observed that the failure mode for SFRC specimens was ductile [13].

II. EXPERIMENTAL STUDY

A. General:

In this study, investigations were carried out to evaluate performance comparison of ordinary concrete and fibre reinforced beam-column joint specimen. The experimental programme consisted of casting and testing of four numbers of exterior reinforced concrete beam-column joint specimens made of M25 grade concrete. Dimensions and reinforcement details are shown in Table I and Table II. Out of these specimens one is normal RC joint with reinforcement as per code IS 456: 2000 and other three specimens had nominal reinforcement with the incorporation of Steel, Glass and Polypropylene fibres.

Table – 1
Dimensions of Specimens

Member	*Dimensions*
Column size	*200 x 200 x 1000*
Beam size	*200 x 200 x 800*
Beam Column Joint	*200 x 200 x 200*

Table – 2
Details Of Reinforcement For Beam-Column Joint Specimens

Normal RC Joint Specimen			
Column		*Beam*	
Column main bars	*Column ties*	*Beam main bars*	*Beam stirrups*
4 nos of 12mm Ø	*8mm Ø bars @ 150mm c/c*	*2 nos of 12mm Ø at top & 2 nos of 12mm Ø at bottom*	*8mm Ø bars @ 150mm c/c*
Fibre RC Joint Specimen			
Column		*Beam*	
Column main bars	*Column ties*	*Beam main bars*	*Beam stirrups*
4 nos of 12mm Ø	*8mm Ø bars @ 250mm c/c*	*2 nos of 12mm Ø at top & 2 nos of 12mm Ø at bottom*	*8mm Ø bars @ 250mm c/c*

B. Preparation of Specimens:

Preparation of specimens include different stages like (i) Fabrication of reinforcement cage (ii) Placing of the reinforcement (iii) Concreting of the specimens and (iv) Curing of the specimens. This is clearly explained in the following section.

C. Fabrication of reinforcement cage and Placing:

The reinforcement required for the preparation of the beams and columns were calculated as per SP-16 and IS 456: 2000. The inner surface of the formwork was oiled and the reinforcement cage was placed in position. Steel mould with reinforcement for casting specimen is shown in Fig 1. Care was to maintain the cover of reinforcement in all faces and was done by providing concrete cover blocks.

D. Concreting Of the Specimens:

The required quantity of cement, fine aggregate, course aggregate and water for the optimum mix were weighed and prepared a uniform concrete mix.(20% extra was taken for any case of wastage). Mixing was done using a concrete mixer. The mixing was continued until uniform colour was achieved and water was slowly added and mixed. This was continued until a uniform mix required consistency was obtained. The concrete was filled in the prepared formwork as soon as the mixing was over and a needle vibrator was used for compacting the concrete. After filling to the top of the mould, the top surface was leveled using a trowel. Then the specimens were kept undistributed for 24 hours.

Fig. 1: Steel Mould with Reinforcement

Fig. 2: Beam Column Joint With Specimen

E. Curing Of the Specimens:

After 24 hours, the formwork was stripped off and the specimen was taken out and curing is done by covering with wet jute sacks. The specimen should be curd for 28 days. The beam column joints (with mould) and the specimen ready for testing are shown in Fig 2.

F. Testing of Specimen:

The specimens casted were tested after 28 days for their break load capacity using loading frame of capacity 100 tonne. The exterior beam column joint specimen was placed on the loading frame which had a capacity of 1000kN with both the ends of column are fixed. A constant load of 200kN which is about 20% of the axial capacity of the column, was applied to the columns for holding the specimens in position and to simulate column axial load. A hydraulic jack of 500kN or 50T was used to apply load at the bottom of beam. Fig 3 shows the experimental test set up for the exterior beam-column joint. The specimens casted were tested for their failure load. The load was applied at a constant rate without shocks and increased continuously. From the observed results, load at first crack, ultimate load and failure pattern were found out.

Fig. 3: Beam-Column Joint Placed On Loading Frame For Testing

III. RESULTS AND DISCUSSIONS

A. General:

In the present investigation an attempt has been made to determine the performance of different types of fibres on beam-column joint by examining their breaking load capacity. For this specimens were casted and tested. A total of 12 beam-column joint specimens were prepared. All the prepared control and designed beam-column joint specimens were tested to failure and the test results are discussed in the following sections.

B. Evaluation of First Crack Load and Ultimate Load:

First crack is the load corresponding to the first visible crack. The first crack load, and ultimate load obtained for each specimen are given in Table IV. Designations of the specimens are given in the table below.

Table - 3
Designation of Specimens

Designation	*Specimen*
CM	*Control Mix*
PFCC	*Polypropylene Fibre Cement Concrete*
GFCC	*Glass Fibre Cement Concrete*
SFCC	*Steel Fibre Cement Concrete*

Table – 4
First Crack Load and Ultimate Load

Specimen	*First Crack Load (kN)*	*Percentage Increase In First Crack Load (%)*	*Ultimate Load (kN)*	*Percentage Increase In Ultimate Load (%)*
CM	*13*	*-*	*20*	*-*
PFCC	*20*	*54*	*22*	*10*
GFCC	*19*	*46*	*24*	*20*
SFCC	*27*	*108*	*30*	*50*

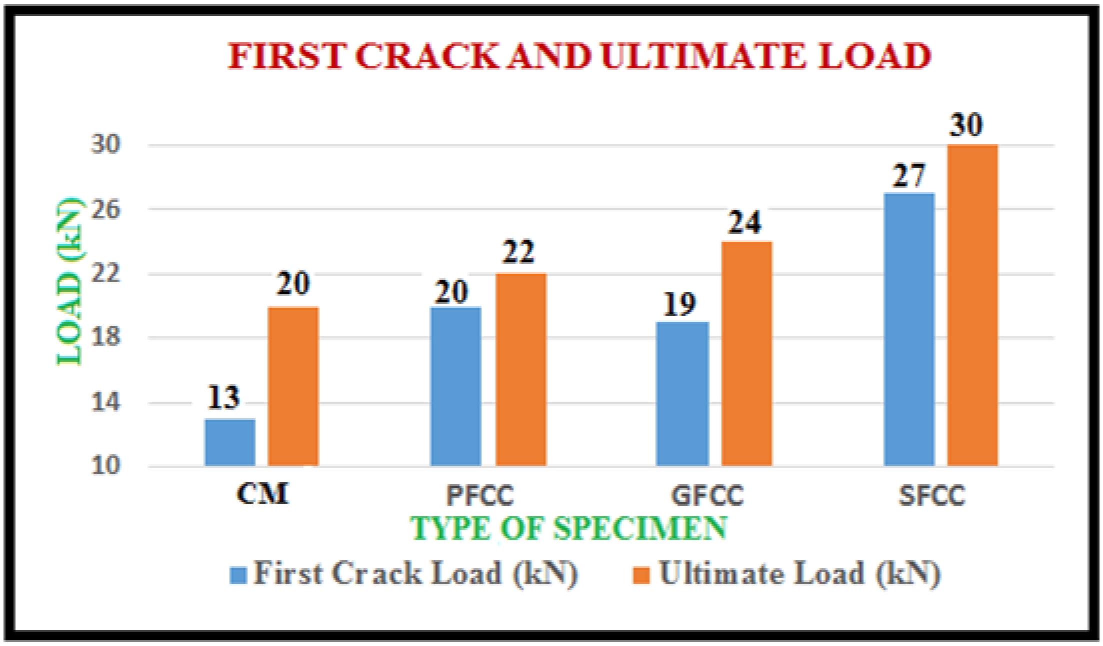

Fig. 4: Graphical Representation Of First Crack And Ultimate Load

From Table it is clear that the fibre modified specimens shows remarkable improvement in first crack load and ultimate load compared to the control specimen. The results shows an increase of about 54% in the first crack load and 10% intensification in ultimate load for PFCC specimen compared to NCC specimen. In the case of GFCC an increase of 46% and 20% in the load carrying capacities at first crack and ultimate load. An escalation of 108% at first crack and 50% at ultimate load for SFCC compared to control specimens.

C. Failure Pattern:

The typical failure at ultimate load and a closer view of crack pattern of CM and modified beam column joints are shown in Fig 5 and Fig 6. Failure patterns of cracks developed for all specimens are almost near the joint after the first crack load. With further increase in loading, the cracks propagated into the beam and initial cracks started widening. The cracks are developed primarily due to the micro cracks developed in concrete. While increasing load, the existing cracks started propagating and combining small cracks. It can be observed that the failure of modified specimens happened due to the widening of crack and just a single main crack was formed at 2 cm away from the beam column joint. But many cracks was observed in normal concrete specimen. In both cases failure was characterized by the formation of vertical cracks at the beam column interface. The width of cracks were more in CM. The SFCC specimen had only lesser number of cracks.

Fig. 5: Failure pattern of PFCC Beam Column Joint

Fig. 6: Failure pattern of SFCC Beam Column Joint

The cracks widened as the load reached the ultimate resulting in the failure of the specimen. Thus the addition of fibre in normal concrete was found to adaptive to increase the moment resisting capacity of beam column joint.

IV. Conclusions

In reinforced concrete structures, beam-column joints are critical members for transferring forces and moments between beams and columns, and its behaviour has a significant influence on the response of the entire structure. Beam column joint in the moment resisting frame have traditionally being neglected in design process while the individual connected elements, that is, beam and column, have received considerable attention in design. Research on beam column joint of reinforced concrete moment resisting frame was started only in the 1970's. The 1993 version of IS 13920-1993 incorporated some provision on the design of beam column joints. However, the provisions are inadequate to prevent the sudden failure of the moment resisting frame. This research proposes a provision for increase the performance of beam column joint by the incorporation of fibres. Based on the experimental studies conducted on Beam-Column Joints, the following conclusions were drawn.

1) The Beam-Column joint with fibres has high strength than ordinary joint.
2) The joint with fibres can take high peak loads.
3) The joint with fibres give high post-cracking ductile behaviour taking higher loads.
4) The Fibre incorporated Joint shows a better performance in joint panel failure.
5) Among the fibre used steel fibre reinforced concrete inhibits high strength at first crack and ultimate load.
6) Even though the performance at ultimate load has not very much influence for Glass Fibre and P Polypropylene Fibre reinforced concrete, but shows a marginal increase in the resistance at first crack.

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