

A comparative study of Strength Properties of Exterior Beam- Column joint**¹K. Anbuvelan and ²Dr. K. Subramanian**¹Research Scholar, Anna University, Chennai – 600025, India.²Professor & Head, Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore – 641014, India.

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ABSTRACT

Recent earthquake in different parts of the world have revealed against the importance of design of reinforced concrete structures with high ductility. Strength and ductility of structures depend mainly on proper detailing of the reinforcement in beam-column joints. Under seismic zones, the beam column joint is subjected to forces in multiple directions. Conventional concrete loses its tensile resistance which leads to failure. To overcome this problem only by proper ductile detailing. In this work there is an attempt is made to evaluate the strength properties of Plain and Steel Fiber Reinforced Concrete bare frames against the response of lateral loading. IS: 456-2000 & IS:13920-1993 codes are considered. Based on this code, two specimens as per IS:456-2000 & two specimens as per IS:13920-1993 code provisions the reinforcement details are followed for with and without fibers bare frame. Lateral loads are applied simultaneously to the top and middle of beam-column joints. First crack, ultimate load and drift are noted. The experimental results of Plain Concrete bare frame are compared to fire bare frame for final conclusion.

Key words: High Performance Concrete, Exterior Beam-Column joint, Metakaolin, Steel fiber.

INTRODUCTION

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high-rise building. It is readily available in urban areas at relatively low cost. Concrete is strong under compression, but weak under tension. As such, a form of reinforcement is needed. The most common type of concrete reinforcement is via steel bars. The advantages to using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. The disadvantages to using concrete include poor tensile strength, and formwork requirement.

Research Significance:

The beam - column joint is resisting forces against both horizontal and vertical directions, which is particularly vulnerable failure during lateral forces i.e., earthquake. For achieving a strong beam-column joint, the incorporation of fibers and cementitious materials in concrete is must resist the lateral forces

and increases the strength, durability, stiffness and is one of the possible alternative solutions for reducing congestion of traverse reinforcement.

Review Of Literature:

Ganesan. N, Indira. P. V. [1] deals with exterior beam-column joints that employ steel fiber reinforced concrete and natural rubber latex under cyclic loading. Test results have indicated that the capacity of the joint increased.

Mustafa. et al [2] reported that, the study on the effect of steel fiber reinforced concrete on the behavior of the exterior. Beam-column joints subjected to reversed cyclic loading shows the usage of steel fiber reinforced concrete in beam-column joints can be an alternative solution for minimizing the density of traverse reinforcement.

Ganesan. et al [3], evaluated the High Performance Concrete beam-column joints subjected to cyclic loading using steel fiber. Test results indicate that the provision of SFHPC in beam-column joints enhances the strength, ductility and stiffness, and is one of the possible alternate

solutions for reducing the congestion of transverse reinforcement in beam-column joints.

Bindhu. et al [4] reported that, the specimens with inclined bars as confining reinforcement exhibited higher strength with minimum cracks in joint and increases in axial load improved the load carrying capacity of joint. Ganesan. et al [5] reported that the application of steel fiber reinforced high performance concrete on beam-column joints, the ultimate load carrying capacity is increased to 40% for 1% fiber content. Displacement ductility values show an increase of 3.5 times that that of High Performance Concrete specimen in the case of monotonic loading. Curvature ductility also increased to a maximum of 2.35 times comparing with High Performance Concrete specimens.

Perumal. et al [6], the hybrid fiber combinations of 1.5% of steel fiber and 2.0% of Polypropylene have best performance considering the strength, energy, dissipation capacity and ductility factor.

Perumal. P & Thanukumari [7], evaluates the behavior of M60 concrete using fiber cocktail in exterior beam-column joint under reversed cyclic loading. The test results show that the addition of Polypropylene fiber to the Steel fiber is optimized for a percentage of 0.2, which produces the high value of energy absorption, curvature ductility factor and minimum rotation and strain in reinforcement.

Bindhu. K.R. Jaya. K.P. [8], the test specimen with diagonal confining bars have shown better performance, exhibiting higher strength with minimum cracks in the joint. From the analytical study it is observed that the provision of cross diagonal reinforcement increased the ultimate load carrying capacity and ductility of joints in the both upward and downward loading conditions.

Bindhu. K. R. & Sreekumar.K.J.[9] Additional reinforcement in the shape of diagonal collar stirrups in beam improves the strength and ductility to an extent of 98% and 54% respectively when comparing to specimen detailing as per IS: 13920-1993.

Perumal.P & Thanukumari.B.[10] the results of reversed cyclic loading test performed on one fourth scaled exterior beam column joint model, indicate that the fibre reinforced concrete is an appealing alternative to conventional confining reinforcement for providing adequate ductility. The incorporation of 1.5% of steel and 0.2% of polypropylene fibre have best performance considering the energy dissipation capacity and ductility factor but the ultimate load carrying capacity is reduced by adding Polypropylene Fibre.

Material Properties:

The materials consisted of 53-grade Ordinary Portland Cement, Natural River Sand, Crushed

Granite Coarse Aggregate of maximum size 12.5mm, Ordinary portable water for mixing and curing and a Super Plasticizing admixture. Steel fibre used in this investigation was procured from Beakart, Belgium. Figure – 1 shows the experimental setup, Table – 1 show the Properties of Steel fibre and Table – 2 shows the Properties of Metakaolin.

Tests On Concrete:

Descriptions Of Tests:

(a) Compressive Strength Test

Three cubes from each grade of concrete mix are prepared and tested as per I.S.: 516-1959 at 7 days, 14 days and 28 days.

(b) Flexural Strength Test

Flexural Strength measurements are made on beam specimens according to I.S.: 516-1959 at 7 days, 14 days and 28 days.

(c) Split Tensile Strength Test

Split Tensile Strength Test has been carried out in compression testing machine. The casting and testing of the specimens were done as per IS: 5816-1970 at 7 days, 14 days and 28 days.

From the results it was observed that the hardened strength of concrete increases with the addition of optimum dosage of Metakolin and Steel fiber in Plain concrete. Also the strength of M2 increases in comparison with M1 for 7, 14 & 28 days of curing.

Experimental Investigations:

– Specimen Description:

Dimensions of Frame models and their reinforcement details:

Specimen Geometry: Single Bay Double storey

Column Details:

Size: 150mm x 100mm

Reinforcement: Main 4 nos., 8 mm diameter + 4 nos., 6mm diameter

Distributor reinforcement 6mm diameter@50 mm c/c

Beam Details:

Size: 100mm x 150mm

Reinforcement: Top 2 nos., 8 mm diameter + 2 nos., 6mm diameter

Bottom 2 nos., 8 mm diameter + 2 nos., 6mm diameter

Distributor reinforcement 6mm diameter @50 mm c/c

Experimental Methodology:

The specimen is subjected to two lateral loading points at the left hand side and the LVDT is placed in four positions of right hand side. First LVDT is placed in the right top corner of the first storey roof joint, second LVDT is placed in the mid of the first storey, the third LVDT is placed in bottom of top storey joint, and the fourth LVDT is placed in the middle of bottom storey. The foundation is fixed one and the loading is given on the left hand side of the specimen and the readings can be noted from LVDT which is placed on the Right hand side of the loading frame. The first crack is noted and the load is applied up to the ultimate failure of the specimen. The drift readings are noted with reference to the LVDT. Two dial gauges are fixed at the base of the specimen to measure the uplifting of the foundation if any. Cracks are observed while loading is applied

up to the ultimate level. The diagonal cracks are observed in the beam column joints and the corresponding load applied was noted.

Results And Discussion

All the four bare frames, the specimens were tested till it collapses. The ultimate load and the corresponding drift were measured for all the frame specimens. Figure 1 shows the overview of the reinforcement details, Figure – 2 shows the Overview of reinforcement details in beam-column joint, Figure – 3 shows Overview of concrete casting setup, Figure – 4 shows the Overview of experimental setup and Figure – 5 shows the Crack failure pattern in beam-column joint.

Table 1: Properties of Steel fibre

Sl. No.	Description	Details
1.	Dramix -60	Dramix® fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. Dramix® RC-65/60-BN is a cold drawn wire fibre, with hooked ends, and glued in bundles.
2.	Geometry	Performance class: 65, Aspect ratio 45 (= l/d): 67, 3200 fibres / kg
3	Tensile strength	on the wire: 1000 N/mm ²

Details from BEAKERT Belgium

Table 2: Properties of Metakaolin #

Sl. No	Properties	Observed Values	Specification Limit
01	Brightness (%) (ISO)	76.8 %	75 – 80%
02	Bulk density (Gms. / Lit.)	297	270 - 370
03	Oil Absorption(Gm / 100 Gm)	60.11 %	45 – 65%
04	Water demand (Gm / 100 Gm)	N/A	N/A
05	Particle Size Analysis :		
	(a) D (50) -50 % particle Below	N/A	N/A
	(b) % Below 10 µm	N/A	N/A
	(c) % Below 2 µm	N/A	N/A
06	Moisture (Ex. Work) (%)	0.36 %	0.5 % Max
07	Specific Gravity	N/A	N/A
08	pH (10% Aq.Slurry)	6.11	5.0 – 8.0
09	Viscosity Concentration (% Solid for 500cps.)	N/A	N/A
10	Residue (On 400#) (%)	0.36 %	1.0 % Max
11	Flow point (ml./100Gm)	N/A	N/A

Table 3: Mix Design Details

Grade of concrete	Cement	Fine aggregate	Coarse aggregate	W / C
M1*	1	1.36	2.20	0.28

Table 4: Details of Specimen

Name of the Property	M1*			M 2*		
	7 days of curing	14days of curing	28 days of curing	7 days of curing	14days of curing	28 days of curing

Compressive strength	3	3	3	3	3	3
Flexural strength	3	3	3	3	3	3
Split tensile strength	3	3	3	3	3	3

Total no. of specimens: 54

* M 1 = PLAIN CONCRETE (M60), M2 = PLAIN CONCRETE (M60) + PARTIAL REPLACEMENT OF META- KAOLIN IN CONCRETE BY OPTIMUM DOSAGE (10%) + ADDITION OF STEEL FIBRE BY OPTIMUM DOSAGE (1.5%)

Table 5: Compressive strength test results

Mix I.D.	7 days strength, MPa	14 days strength, MPa	28 days strength, MPa
M 1*	51.26	56.29	62.44
M2*	54.78	61.92	63.28

Table 6: Flexural strength test results

Grade of concrete	7 days strength, MPa	14 days strength, MPa	28 days strength, MPa
M1*	5.72	6.32	7.14
M2*	9.61	10.24	13.11

Table 7: Split tensile strength test results

Grade of concrete	7 days strength, MPa	14 days strength, MPa	28 days strength, MPa
M1*	4.03	4.38	4.67
M2*	7.33	8.08	8.57

Table 8: Details of Bare Frame Specimens

Mix	As per IS: 456 – 2000 detailing	Specimen I.D.	As per IS: 13920 – 1993 detailing	Specimen I.D.
M1*	01	PC - 01	01	PC - 02
M2*	01	SFRC - 01	01	SFRC - 02

Table 9: Experimental test results of plain and fibre bare frames

Mix I.D.	First cracking load in KN	Ultimate load in KN
PC - 01	4.0	41.0
PC - 02	10.0	66.66
SFRC - 01	16.0	104.0
SFRC - 02	14.0	96.60



Fig. 1: Overview of experimental setup

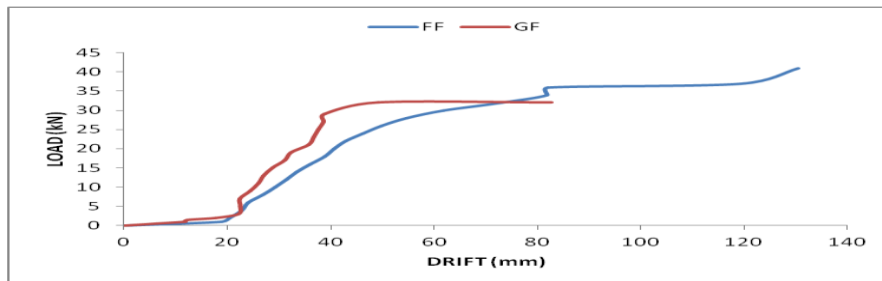


Fig. 2: Load Vs Drift Curve for PC - 01

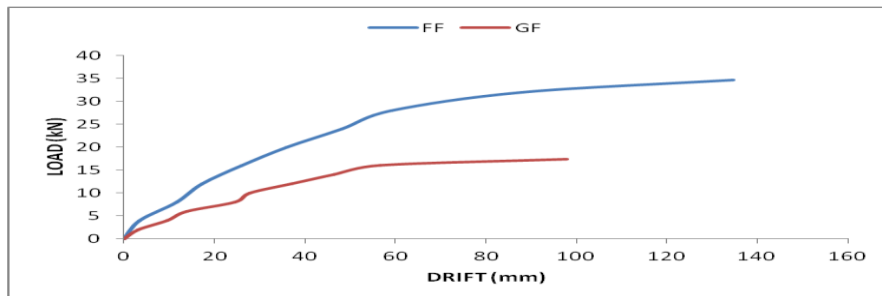


Fig. 3: Load Vs Drift Curve for SFRC - 01

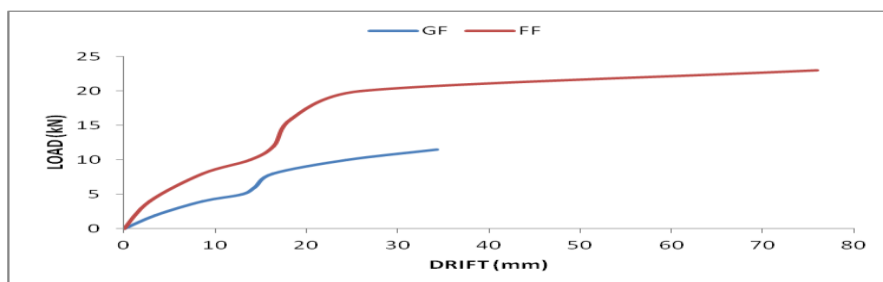


Fig. 4: Load Vs Drift Curve for PC - 02

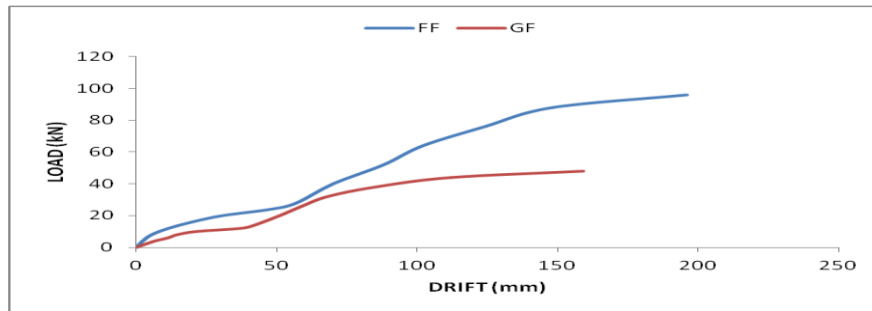


Fig. 5: Load Vs Drift Curve for SFRC - 02

Results And Discussion

All the four bare frames, the specimens were tested till it collapses. The ultimate load and the corresponding drift were measured for all the frame specimens. Figure – 1 shows the Overview of experimental setup. Table – 9 shows the experimental test results of bare frames. Figure – 2 & 3 shows load vs drift curve for PC-01 and SFRC -01. Figure 4 & 5 shows load vs drift for PC-02 and SFRC -02. From the Table – 9, the strength of the bare frame PC-02 has increased to an extent of 150% for first cracking load and 62.58% for ultimate load compare to PC – 01. Similarly for SFRC -01 has improved in strength of 12.5% & 7.11% for first cracking and ultimate load comparable to SFRC -02. Addition of steel fibers in bare frame shows the improvement in 300% & 250% for initial cracking load comparable to plain concrete bare frame and for ultimately it is found to be 153% and 135%. In general the ductility detailing of IS: 13920-1993 shows better improvement in performance in first cracking and ultimate load condition for SFRC. From the figure 2 & 3 it is concluded that as the load increases the drift increases. Figure – 2 shows the non-linear behavior and Figure – 3 shows the linear behavior. In the case of Figure 4 & 5 shows better improved load carrying capacity compared to Figure 2 & 3.

Conclusions:

1. The Efficiency of joints is enhanced by Steel Fiber Reinforced Concrete compared to Plain Concrete.
2. The Ultimate strength of Steel Fiber Reinforced Concrete - 02 frames increased up to 90%.
3. The Ultimate strength of Steel Fiber Reinforced Concrete - 02 frames using reinforcement detailing obeying ductility code partitioning and strength increased up to 142%.
4. Steel Fiber Reinforced Concrete joints undergo large displacements without developing wider cracks, when compared to the Plain Concrete

joints. This indicates that the steel fibers impart high ductility, which are essential properties of the beam-column joints.

5. Addition of fibers to the beam-column joints decreased the rate of stiffness degradation appreciably when compared to the joints without fibers.

6. During testing it has been noted that the addition of fibers could improve the dimensional stability and integrity of joints.

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