A Study on "Strength and Behavior of Exterior Beam-Column Joint by using SCC and SFRSCC"

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Abstract— The beam-column joint is one of the most critical section in the design and construction of the structure. In these areas, a high percentage of transverse hoops in the core of the joint are needed in order to meet the requirement of strength, stiffness and ductility factor under cyclic inelastic flexure loading. The beam column joint subjected to cyclic loading require great care in detailing. Diagonal tension cracking is one of the main causes of failure of joint. The satisfactory performance of a beam column joint depends strongly on the lateral confinement of joint. The present study deals with the non-conventional reinforcement detailing of the beam column joint that provides inclined bars on the two faces of the joint core. The performance of beam column joint has been a research topic for many years. The anchorage length requirements for beam and column bars, the provision of transverse reinforcement, the design and detailing of the joint are the main issues. Several researches have reported their test results using SFRC in framed beam column joints. All these tests have shown the effectiveness of using steel fibers to increase the joint strength, ductility and the energy absorption capacity. Provision of high percentage of hoops leads to congestion of steel leading to construction difficulties. These difficulties can be removed by using self-compacting concrete (SCC).

Key words: SCC, Steel Fibre, Cyclic Loading, Beam-Column Joint

I. INTRODUCTION

Damages in reinforced concrete structures are mainly caused to shear force due to the inadequate detailing of reinforcement, the lack of the transverse steel and confinement of concrete in structural elements. Typically failures are brittle in nature, demonstrating inadequate capacity to dissipate and absorbs inelastic energy. The beam-column joints that are subjected to reverse cyclic loading which require great care in detailing. Diagonal tension cracking is one of the main causes of failure of joint. The satisfactory performance of a beam column joints depends strongly on the lateral confinement of joint. The present study deals with the non-conventional reinforcement detailing in the beam-column joint by providing inclined bars on the 2 faces of the joint core, which leads to reduction in compaction and construction difficulties due to congestion of reinforcement in the joint region. The performance of beam column joint seismic conditions has been a research topic for many years. The anchorage length requirements for beam and column bars, the provision of transverse reinforcement, the design and detailing of the beams are the main issues.

Normal Conventional concrete has been widely used as a construction material throughout the world because of the advantages of mould ability, durability, resistance to fire and energy efficiency. However the major deficiencies in conventional concrete are its poor tensile strength, low ductility, dimensional stability etc. Hence in order to improve the tensile properties, several new material have been developed in the recent past such as high performance concrete, high performance fiber reinforcement concrete, polymer modified concrete etc. Recently, Self-compaction of fresh concrete has been recognized as a means to improve the quality and constructability of concrete infrastructure. The self-compacting properties are generally achieved by high deformability of fresh concrete mix, good resistance against segregation and the low slump loss. The Steel fiber reinforcement is used to increase the tensile properties in Self compacting concrete.

A. *Concept of SCC:*

Self-compacting concrete is a mixture, which is suitable for placing in difficult condition and in structures with congested reinforcement without vibration. It is characterized by high powder content. The resulting concrete has an excellent surface finish. When large quantity of heavy reinforcement is to be placed in a reinforced concrete member, It is difficult to insure that formwork gets completely filled with concrete, Which is fully compacted without voids and honeycombs.

B. *Concept of SFRSCC:*

Beam column joint is one of the most vulnerable areas in the case of reinforced concrete framed structure. The congestion of steel reinforcement in the joints often leads to poor inadequate strength and ductility of the joint. One of the possible methods of overcoming this problem is by making use of self-compacting concrete in place of usual concretes. Also from the literature it is noted that addition of steel fibers to cementitious materials improves many of the engineering properties like tensile and flexural strength, Energy absorption capacity and ductility and fracture toughness. Considering this, an attempt has been made to study the effect of steel fibers on the strength and behaviour of self-compacting concrete beam – column joints.

II. MIX DESIGN OF SCC AND SFRSCC

A. *Materials required for SCC AND SFRSCC:*

The basic ingredients used in Self-compacting concrete mixes are practically the same as those used in the ordinary concrete. Following are the important materials used in SCC and SFRSCC.

Sr. No.	Name of the material
1	Cement
2	Fine Aggregate
3	Coarse Aggregate
4	Fly Ash
5	Steel Fibre
6	Water

7	Super plasticizer

Table 1: Materials Used in SCC and SFRSCC

B. Mix Proportion of SCC and SFRSCC:

In the present study, the various trial mixes are conducted from various mix design methods of SCC. To obtain SCC which satisfies various tests like filling ability test, passing ability test and segregation resistance test etc. on fresh SCC. After passing these tests, some successful SCC mixes are arrived. From such successful mixes, choose final mix of proportion after the cubes are cast and tested after 7 days and 28 days, it gives cube strength at 28 days as 37.4 N/mm^2 which is well above the mean target strength of M-30 concrete. So final mix proportion of M-30 is,

Particulars	Kg/m^3
Cement	365.50
Fly ash	140.15
Fine Aggregate	889.50
Coarse Aggregate	720
Water	241.23
Super plasticizer (0.4% of powder)	2.01

Table 2: Mix proportion of SCC

After getting mix proportions for SCC, to obtain SFRSCC, hooked steel fibres (0.5% and 0.75% of volume fraction) are added in SCC mix proportion. Fibres may be used to enhance the properties of SCC in the same way as for normal concrete.

C. Testing of SCC and SFRSCC:

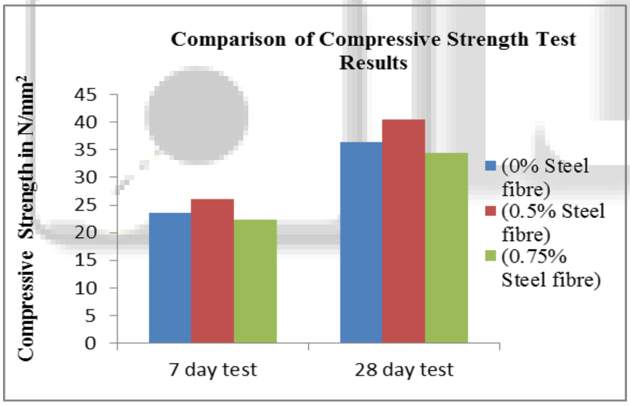


Fig. 1: Comparison of Compressive Strength Test Result

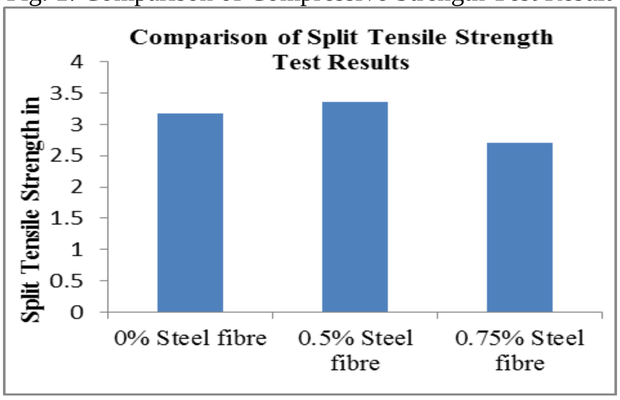


Fig. 2: Comparison of Split Tensile Strength Test Result

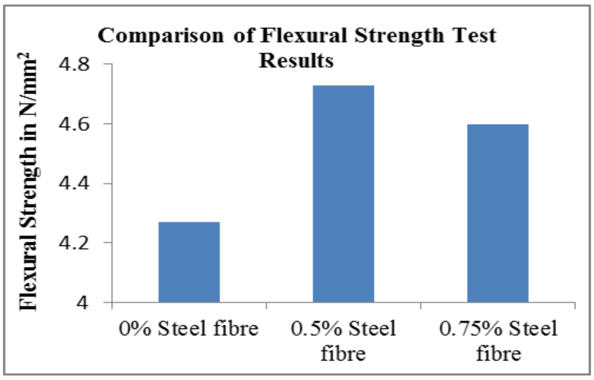


Fig. 3: Comparison of Flexural Strength Test Result

III. EXPERIMENTAL PROGRAMME AND TEST RESULTS

A. Design of Beam-Column Joint:

The Five specimens of Beam-Column joints are designed according to I.S. 13920:1993. Out of five specimens two specimens are detailed as per I.S. 13920:1993 and remaining three specimens are also detailed same but by replacing the stirrups at the joint region by diagonal cross inclined bars provided at the two joint faces for confinement of the joint. The column was reinforced with 4 numbers of 12 mm diameter HYSD bar and the beam was provided with an equal amount of reinforcement of 2 numbers of 12 mm diameter HYSD bars at top and bottom. 6 mm diameter MS bars were used for transverse ties in columns and stirrups in beams. The reinforcement details are shown in figure below-

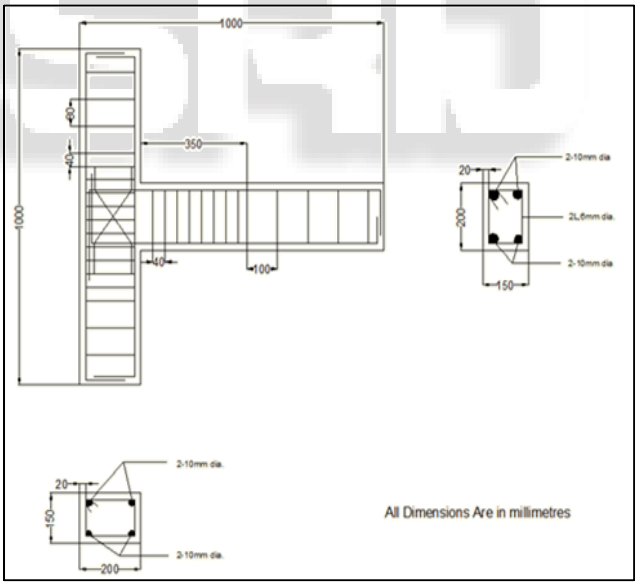


Fig. 4: Reinforcement details as per I.S. 13920:1993 and diagonal cross inclined bar

B. Description of Beam-Column joint Specimen:

There are five specimens of Beam-Column joint is to be casted. All specimens are casted with M30 grade concrete. The description of specimens is shown in the following table-

Sr. No.	Specimen No.	Steel Fibre Content (% volume fraction)	Detailing of Specimen	Concrete
1	Specimen 1	0	Conventional	Normal R.C.C. without Plasticizer
2	Specimen 2	0	Conventional	Normal R.C.C. with Plasticizer
3	Specimen 3	0	Non-Conventional	SFRSCC (0%)

4	Specimen 4	0.5	Non-Conventional	SFRSCC (0.5%)
5	Specimen 5	0.75	Non-Conventional	SFRSCC (0.75%)

Table 3: Description of Beam-Column Joint Specimen

C. Testing of Specimen:

All the specimens were tested in a Loading Frame of 1000 kN Capacity. The specimen was mounted in a vertical position. A constant axial load equal to 20% of the theoretical axial load capacity of the column was applied to keep the column in vertical position. A hydraulic jack of capacity 10 tonne is used to apply the load at the free end of the beam. To record the load precisely, a load cell is used. The increment of loading selected was 1 KN. The beam was then loaded gradually up to 1 KN, then unloaded to zero load and reloaded to the next increment of load, this pattern of loading was continued for each increment until failure. The deflection at the point of loading during test was measured using a dial gauge with a least count of 0.01 mm.

D. Experimental Set Up:

The test set up is shown schematically in fig.5. The joint assemblages are subjected to axial load and reverse cyclic load. One end of the column is given an external hinge support and other end is laterally restrained by a roller support to get moment free rotation at both ends. Cyclic loading is applied by 10 tonne hydraulic jack, which is fixed on strong reaction floor. Reverse cyclic load is applied at 50 mm from free end of the beam portion. The test is load controlled and the specimen is subjected to an increasing cyclic load up to the failure. To record loads precisely, load cells are used.

Fig. 5: Experimental Set Up

E. Behaviour of Specimens:

In all the specimens cracks appeared near the joint. In case of Beam-Column Joint with conventional detailing diagonal cracks also occurred in the Beam-Column joint region. As the loading is increased, additional cracks are formed. With further increase in loading, the cracks propagated up to the beam. Specimens without fibres developed more and wide cracks at the joint region. Specimens with fibres and cross inclined bars in joint region shows very less diagonal cracks which are occurred in Beam-Column joints with conventional detailing. A tested specimens is shown in Fig.4.4.

Fig. 6(a): Specimen 1

Fig. 6(b): Specimen 2

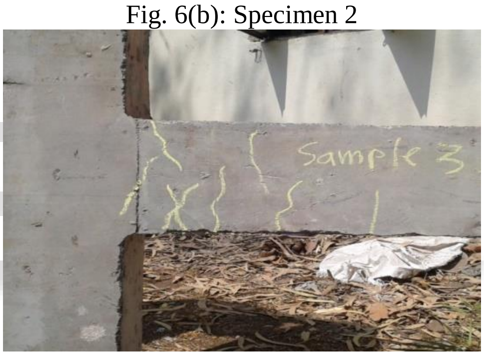


Fig. 6(c): Specimen 3

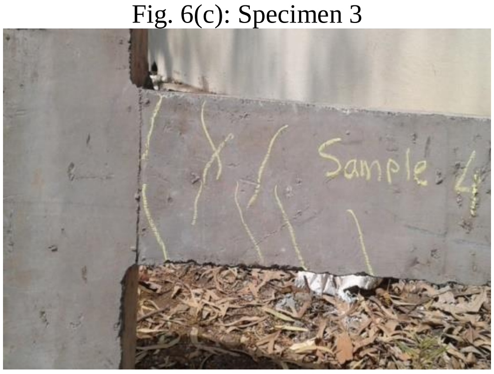


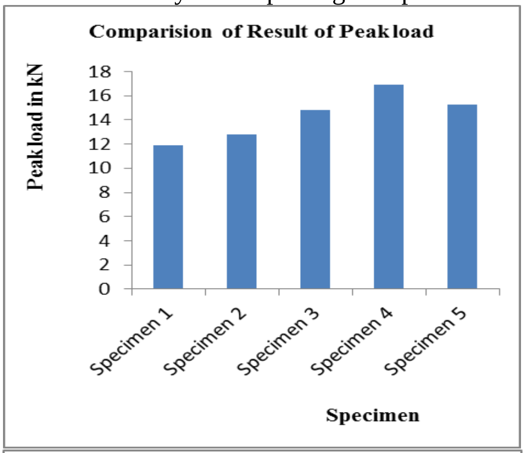
Fig. 6(d): Specimen 4

Fig. 6(e): Specimen 5

Fig. 6: Tested Specimens

F. Analysis of Test Results:

The results obtained from test on beam-column joints at 14 days. Significant increase in first crack load and ultimate load were found with the increase in fibre content. The ultimate load is increases at 0.5% of fibres and the ultimate load is decreases at 0.75% of fibres. Addition of fibres above 0.75% did not enhance the ultimate strength. This may due to steel fibres at higher percentage of fibre content, which caused difficulty in compacting the specimens.



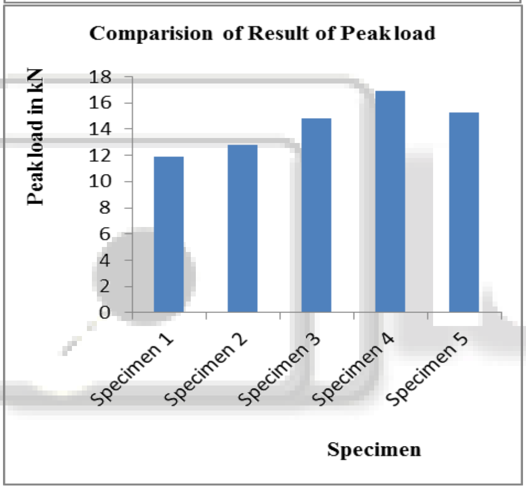


Fig. 7: Comparison of Result of Peak load

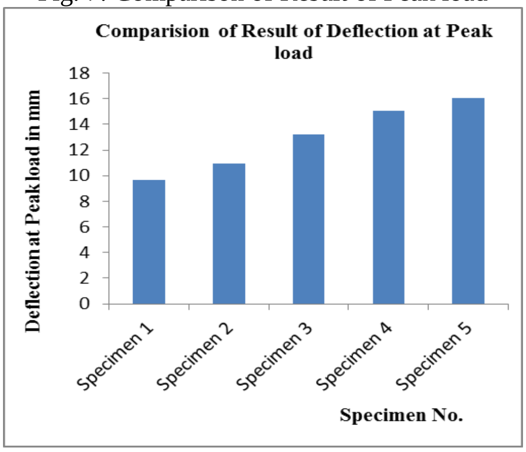


Fig. 8: Comparison of Result of Deflection at Peak load

IV. CONCLUSION

The following conclusions are based on experimental study:

1) Mix design for SCC is performed. The tests for Compressive Strength, Flexural Strength and Split Tensile Strength of various Specimens is performed. The results shows that the specimen with 0.5% steel fibre and cross inclined bar gives Optimum results compared to other Specimens.
2) It is seen that addition of steel fibreupto 0.5% in the core of Beam-Column joint, there is increase in the ultimate load. On the other hand, 0.75% addition of steel fibre shows decrease in ultimate load.
3) The Specimen having joint region with cross inclined bar shows very less cracks in the Beam-Column joint region due to adequate shear resisting capacity.
4) Cracking pattern of the Specimen shows that Specimens are failed due to developing cracks at the interface between beam and column.
5) Deflection at peak load is significantly increased with increase of fibre content.

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