Journal of Engineering and Applied Sciences 3 (1): 104-108, 2008
ISSN: 1816-949X

Study of Behaviour of Reinforced Concrete Frames with Slab Using SIFCON in Beam Column Joints

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Abstract: This study gives the comparative study of the behaviour of two bay two storey Reinforced Concrete Frames with slabs of 1/8 scale dimension using SIFCON in the beam column joint region and in the plastic hinge location adjacent to the joint and the conventional Reinforced Concrete Frame with slab. SIFCON is used in the parts of the structure where its properties are desirable such as beam column joints and in the plastic hinge locations adjacent to the joint. The specimens were subjected to lateral reversed cyclic load at the top storey. The displacement of the top storey, stiffness, ductility and energy absorption capacity were discussed. The results have shown that the SIFCON specimens performance were far better than conventional specimens.

Key words: Beam column joint, SIFCON, stirrup spacing, slabs, behaviour, concrete frames

INTRODUCTION

SIFCON is a special type of steel fibre reinforced concrete. It is Slurry Infiltrated Fibre CONcrete which differs from Steel Fibre Reinforced Concrete in two ways by mix and % volume of fibres. The mix is only motar or slurry against the concrete with fibres and the percentage of volume of fibres varies from 4-20% against 3% in SFRC. SIFCON possess high strength in compression, tension, shear, torsion and bending compared to Steel Fibre Reinforced Concrete (SFRC) and conventional specimens. It also possess excellent durability, energy absorption capacity, impact and abrasion resistance and toughness. Regarding the behaviour of SIFCON, the fibres are subjected to frictional and mechanical interlock in addition to the bond with the matrix. The matrix plays the role of transferring the forces between fibres by shear, but also act as bearing to keep the fibres interlocked. The material properties in respect of tension, compression, shear, flexural, torsion were studied by many authors (Lankard, 1987; Balaguru, 1987; Naaman and Hamrich, 1989; Krishnamoorthy *et al*., 1992). The studies about SIFCON in beam column connections were very limited (Naaman *et al*., 1997; Thirugnanam *et al*., 2001). No studies were focused on the usage of SIFCON in three dimensional structures. The main objective of the present study, is to evaluate the behaviour of SIFCON in three dimensional structures and hence they were in the joint region and in the plastic hinge location adjacent to the joint.

MATERIALS AND METHODS

The concrete mix M30 was used in the ratio 1:1.3:2.5 with 8 mm size of the aggregate and water cement ratio 0.5. The mortar mix used in the SIFCON specimen was 1:1 with sand passing through 1.18 mm sieve. Superplasticiser was added to the mortar to maintain the fluidity of the mix so that efficient inflltration of the slurry into the fibre bed could take place. Steel fibrea of crimped type having aspect ratio 80 (diameter 0.45 mm) and 8% volume of fibres was used in SIFCON specimens.

Description of the specimens: The two bottom most storeys of the seven storey frame were considered as the prototype and 1/8 scale model specimens were tested. The

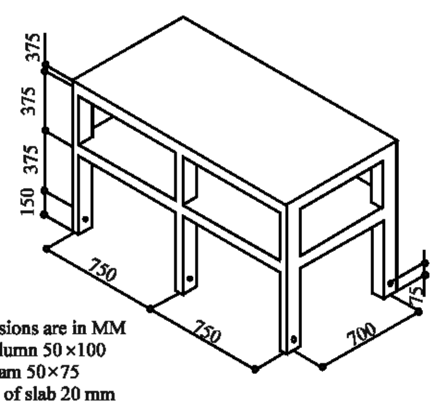

Fig. 1: Frame with slab

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Table 1: Details of the specimens

Specimen	Designated as	Joint matrix	Compressive strength N mm^{-2}	Flexural strength N mm^{-2}
Conventional	FCJS	Mix M30 1:1.3:2.2	32.7	5.7
SIFCON	FSJS	Slurry Infiltrated Fibre CONcrete 1:1	52.7	17.8

Fig. 2: Test set up

specimen were designed to earthquake loads as per IS1893 (Part-I) 2002 and detailed as per IS13920-1993. The details of the specimens are shown in Fig. 1 and tabulated in Table 1. The main reinforcement of the column was 4 Nos of 8 mm Ø twisted bars and 4Nos of 6 mm Ø mild steel bars for beam. 3 mm Ø mild steel bars were used as stirrups. The stirrups in columns was provided at 20 mm c/c to a distance of 2 d (2 times the depth) in conventional specimen and 40 mm c/c in SIFCON specimen. The stirrups in beams was provided at 16 mm c/c to a distance of 2 d (2 times the depth) in conventional specimen and at 32 mm c/c in SIFCON specimen. Mild steel bars of 3 mm diameter were provided at 75 mm centre to centre in both the longitudinal and transverse directions in the slab. The conventional specimen was provided with M30 mix. The joint region and to a distance 2d from the joint was provided with SIFCON and the remaining region was provided with mix M30. To measure the strains in reinforcement and concrete electrical strain gauges and demec points were used.

Casting and curing of the specimen: The slab was casted monolithically with the beams and columns. Concreting was done in two stages for the specimens. Concreting upto the first storey level was done on the first day and the concreting of the second storey was completed on the second day. The specimen was cured for 28 days before

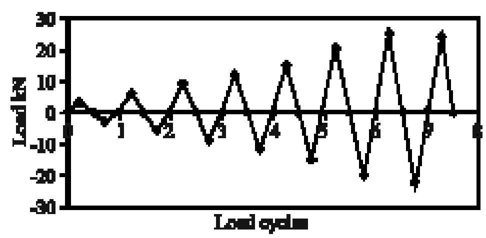

Fig. 3a: Loading sequence for FCJS

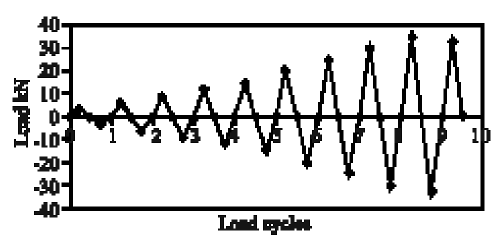

Fig. 3b: Loading sequence for FSJS

testing. Companion cubes and beams were made from each batch of concrete and cured as usual. They were tested for strength on the day of testing of the specimens.

Testing program: The specimen was mounted on the loading platform as shown in Fig. 2. The loading cycle shown in Fig. 3a and b was applied to the specimen manually using specially fabricated screw jacks. The load at the central node was two times the load applied at the end node. The load was gradually increased and the corresponding deflections were noted at the top storey and bottom storey using disc type deflectometers. The strains in the reinforcement and on the concrete were measured using electrical strain indicators and demec strain gauges, respectively.

RESULTS AND DISCUSSION

Load capacity and crack formation: The first crack load in Conventional specimen was 15 and 20 kN in SIFCON specimen. The cracks were formed at the junction of column with beam and slab at the bottom storey level in the middle and end frame in conventional specimen and in SIFCON specimen the cracks were formed in the end frame of the bottom storey level. The cracks were formed at the top slab in the top storey level when the load was 20 and 30 kN in Conventional and SIFCON specimen, respectively. Diagonal cracks were noticed in junction of the column and beam and slab in Conventional specimen and no diagonal cracks were noticed till the end in SIFCON specimen. No spalling of concrete was noticed in SIFCON specimen. The ultimate load was 25 and 35 kN in Conventional and SIFCON specimen, respectively.

Load deflection response: The hysteresis loops of the load versus displacement curve for the variousn load cycles applied at the top storey central node of the conventional and SIFCON specimen is represented in Fig. 4 and 5. When the deflection of the SIFCON specimen was compared with the deflection of the conventional specimen at the ultimate load i.e. at 25 kN it was nearly 43% lesser than conventional.

Stiffness: The stiffness of the specimen was calculated as the load divided by deflection for various load cycles and the variation is presented in Fig. 6. The stiffness was found to vary from 7.5-0.5 kN mm^{-1} in SIFCON specimen. During reverse loading the stiffness was found to vary from 5-0.12 kN mm^{-1} in Conventional specimen during forward loading and from 3.75-0.5 kN mm^{-1} in SIFCON specimen and from 3-0.16 kN mm^{-1} in Conventional specimen.

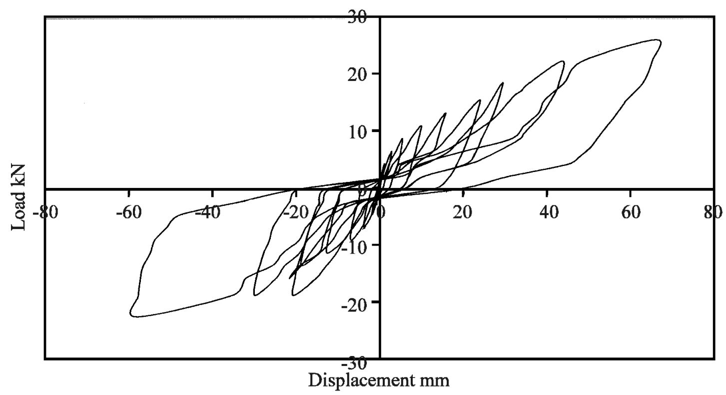

Fig. 4: Load displacement-FCJS

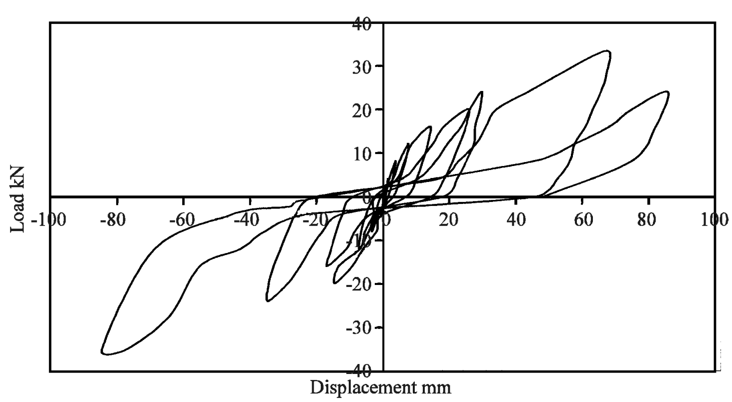

Fig. 5: Load displacement-FSJS

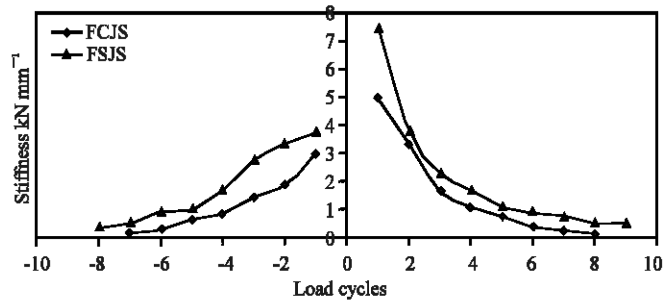

Fig. 6: Stiffness vs load cycles-salab

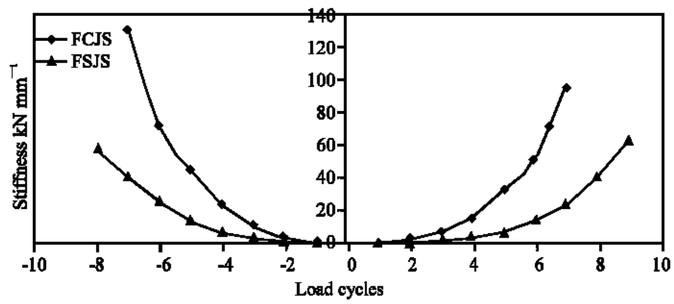

Fig. 7: Cumulative ductility vs load cycles-slabs

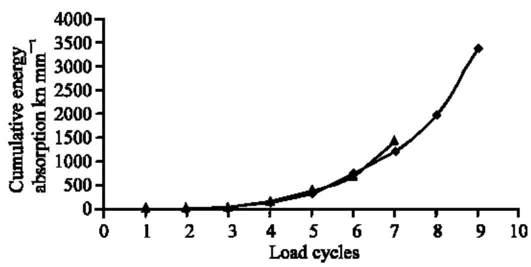

Fig. 8: Load cycles vs cumulative energy absorption-slabs

Ductility: Displacement ductility at any load level was calculated as the ratio of the displacement at the level and the yield displacement. Ductility at maximum load level in each sycle was calculated. Cumulative ductility versus load cycles is presented in Fig. 7. The ductility of SIFCON was found to be more than Conventional specimen.

Energy absorption capacity: The energy absorption capacity during various load cycles was calculated as the area under the hysteresis loops of the load versus deflection diagram. The energy absorption capacity of the SIFCON was 3365.67 kN mm^{-1} and that of conventional was 1449.8 kN mm^{-1}. Cumulative energy absorption versus load cycles is shown in Fig. 8.

CONCLUSION

The ultimate load of SIFCON is observed to be 40% more than Conventional specimen.

No spalling of concrete and diagonal cracking were noticed in SIFCON specimen due to the confining action of the steel fibres.

The stiffness of the SIFCON specimen was nearly about 50% more than Conventional specimen.

The cumulative ductility of SIFCON was 35% lesser than conventiona specimen since it is very stiffer.

SIFCON absorbs 132% more energy than Conventional specimen.

The increase of stirrup spacing in SIFCON decreases the steel congestion in the joint and it does not affect the joint behaviour.

The deflection was found to be very less compared to conventional and acted as a rigid body.

REFERENCES

Balaguru, P., 1987. Behaviour of SIFCON. Proc. Int. Symp. FRC, Madras, pp: 7.25-7.98.

Ductility Detailing for RC structures subjected to seismic forces-code of practice. IS, 13920-1993. BIS, New Delhi.

Indian Standard Code of Practice for Earthquake Resistant Design of Structures. IS, 1893-2002 (PartA). BIS, New Delhi.

Krishnamoorthy, T.S., K. Balasubramaniam and V.S. Parameswaran, 1992. SIFCON Civil Eng. Construction Rev., pp: 31-35.

Lankard, D.R., 1987. SIFCON: Slurry Infiltrated Fibre Concrete. Proc. Int. Symp. FRC Madras, pp: 7.15-7.23.

Naaman, A.E., J.K. Wright and H. Abdou, 1987. SIFCON connections for seismic resistant frames. Concrete Int., 9: 34-39.

Naaman, A.E. and J.K. Homrich, 1989. Tensile properties of SIFCON. ACI Mater. J., pp: 247-268.

Thirugnanam, G.S., P. Govindan and A. Sethurathanam, 2001. Ductile behaviour of SIFCON structural members. J. Struct. Eng., 28: 27-32.