Effect of Stiffeners on the Axial Load Carrying Capacity of Square Concrete-Filled Steel Tube Columns

Neethu Balachandran[1], Jeena Mathews[2]

[1]*M.Tech Student, Dept. of Civil Engineering, Sree Narayana Gurukulam College of Engineering, Ernakulam, Kerala, India*

[2]*Assistant Professor, Dept. of Civil Engineering, Sree Narayana Gurukulam College of Engineering, Ernakulam, Kerala, India*

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Abstract -*Concrete-Filled Steel Tubes (CFSTs) are composite members consisting of a steel tube infilled with concrete. CFST members utilize the advantages of both steel and concrete. In rectangular CFSTs, the concrete forms an ideal core to withstand the compressive loading, and it delays and often prevents local buckling of the steel. The steel tube prevents spalling of the concrete and minimizes congestion of reinforcement in the connection region, particularly for seismic design. Recent applications have also introduced the use of high strength concrete combined with high strength thin-walled steel tubes with much success. While many advantages exist, the use of CFSTs in building construction has been limited, due to lack of construction experience, lack of understanding of the design provisions and the complexity of connection detailing. The main aim of this paper is to conduct a study on bond behavior between steel tube and concrete infill in square CFSTs which were designed as short columns (slenderness ratio is 2.1), by providing stiffeners and subjecting the CFST columns to axial compression. Stiffeners are provided at equal depth throughout the specimen with three different configurations such as single stiffeners, diagonal stiffeners and T-shaped stiffeners. The results were compared and the axial load carrying capacity was found to be higher for CFST with diagonal stiffeners.*

Key Words: **Concrete-filled steel tubes, Buckling, Spalling, Seismic design, Bond behaviour, Axial compression, Single stiffeners, Diagonal stiffeners, T-shaped stiffeners**

1.INTRODUCTION

Concrete filled steel tube (CFST) columns have been popular for use as individual column elements. They comprise of a steel hollow section of circular rectangular or other shapes filled with plain or reinforced concrete. They are widely used in high rise and multistorey buildings. The tube serves as formwork in construction, which decreases labour and material costs. The CFST structural member has a number of distinct advantages over an equivalent steel, reinforced concrete, or steel-reinforced concrete member. The steel lies at the outer perimeter where it performs most effectively in tension and in resisting bending moment. The building which utilized concrete filled steel tubes was able to reduce the column dimension compared to ordinary column.

All previous studies conducted on concrete filled steel tubular columns reveals that it has an enhanced strength, ductility and energy absorption capacities[5]. Ultimate load of columns increases with increase in thickness of steel tube and also it is difficult to buckle under axial compression[7]. Concrete filled steel tubular columns with circular cross section had higher bearing capacity, better ductility and less deformation compared to square or rectangular cross section[1, 7]. Not only the cross-section but also local compression area ratio and end plate thickness also influence the buckling mode of CFST columns[6]. Failure modes of square CFST specimens are similar to those of circular specimens; however, due to the different confinement effect provided by square steel tube to concrete core, the buckling mode of tube walls and failure mode of concrete core are different from those of circular specimens[5, 7]. Specimens with low strength concrete show better ductility but lower load bearing capacity than those with high strength concrete[4]. Stiffened CFST columns provides better load carrying capacity and lower deformation compared to conventional CFST columns[2, 3]. Stiffening schemes can sometimes enhance the ductility also[1]. In most of studies test results obtained from experimental program or finite element analysis were compared with available design codes such as EC4, LRFD, AIJ, ACI, AISC etc. and most of the times found a good agreement with test results but Eurocode is unconservative in predicting design strength[7, 4]. Many studies have been carried out in stiffened CFST columns.

This paper deals with three different configurations of stiffeners such as single stiffeners, diagonal stiffeners and T-shaped stiffenersand arriving at the most suitable arrangement which enhances the ultimate load carrying capacity of CFST columns.

2. EXPERIMENTAL INVESTIGATION

2.1 Concrete Mix Details

A concrete mix of 25 MPa was used for this study. The concrete mix design was done as per IS 456:2000 and IS 10262:2009. The materials were tested for various properties needed for the mix design. Ordinary Portland Cement of grade 53 was used for the experiment. The coarse aggregates used were of size 10 mm and M-sand was used as fine aggregate. Admixture of type MASTER GLENIUM SKY 8433 produced by BASF Incorporation was added to increase the workability of concrete and to minimize the amount of water-cement ratio, for obtaining a desired slump range of 75 mm–125 mm for normal RCC work as per IS 456:2000, Cl.7.1. After various trials, a final mix ratio as shown in the table -1 was arrived for the entire casting.

Table -1: Concrete mix details

Mix	Cement	Fine aggregate	Coarse aggregate	w/c ratio	Admixture
M25	1	2.68	2.21	0.40	0.25 %

2.2 Specifications of Specimen

The dimensions of all square CFST column specimens were 175 mm x 175 mm in cross-section and 375 mm in length. Steel of grade used was Fe 250. The thickness of base plate and top plate was 8 mm. Steel of thickness 2mm was used for the steel tube and 3 mm was used for providing the stiffeners. Stiffeners having equal area were provided throughout the length of the column at a spacing of 76.2 mm. The cross-sectional areas of all the stiffeners were 600 mm^2. All other parameters were kept same for all the specimens for the purpose of comparing the effect of stiffener arrangement in axial load carrying capacity. CFST-C (Control specimen), CFST – I (Specimen with diagonal stiffeners), CFST – II (Specimen with single stiffeners), CFST – III (Specimen with T-shaped stiffeners) were shown in Fig -1.

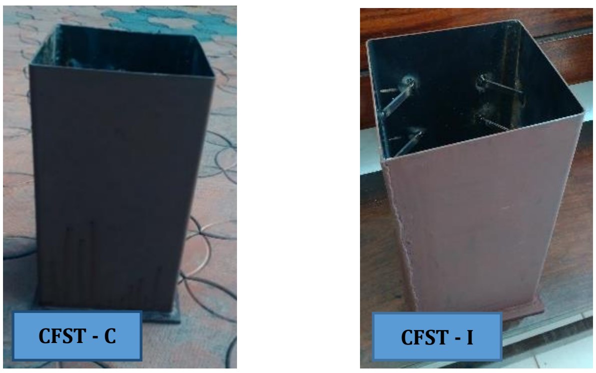

Fig -1: Types of CFSTs

Cross-sectional views of three configurations of stiffeners are shown in Fig -2.

(a) (b) (c)

Fig -2: Cross-sectional view of stiffener arrangement: (a)Diagonal stiffeners(CFST-I) (b)Single stiffeners(CFST-II) (c)T-shaped stiffeners(CFST-III)

2.3 Preparation of test specimen

The Concrete Filled Steel Tubes were filled with M25 grade concrete within Fe 250 surrounding steel. All the steel tubes and base plate were through welded. Base plate of 8 mm thick is provided at bottom and concrete mix is poured into it in four layers giving 25 blows of compaction in each layer. After casting they are cured for 28 days in curing tank. At the end of curing period another 8 mm thick steel plate was spot welded at the top. These columns were tested under compression in the loading frame and the ultimate failure load of the column have been recorded.

2.4 Test set up

After a curing period of 28 days in curing tank, all the specimens were tested for axial capacity in the compression testing machine of 3000 kN capacity. The testing procedure followed for all the specimens were same. The load was applied at a uniform rate till the specimens reached its ultimate failure. Ultimate load carrying capacity of the all the specimens were determined and compared. The test set up is shown in Fig -3.

Fig -3: Test set-up

3. RESULTS AND DISCUSSION

3.1 Axial load carrying capacity

The control specimen reached its ultimate load carrying capacity at 1610 kN and fails due to compression of concrete. While testing at 1994.5 kN, CFST- I reached its ultimate capacity. At 1529.5 kN, CFST-II reached its ultimate capacity. CFST – III reached its ultimate capacity at 1567.9 kN. Table -2 shows the different load values at which stiffened and unstiffened CFST columns failed.

Table -2: Ultimate load obtained from CTM

AXIAL LOAD CARRYING CAPACITY (kN)			
Control specimen	Stiffened specimens		
	CFST - I	CFST - II	CFST - III
1610	1994.5	1527.3	1520.6

3.2 Failure modes of CFST specimens

For CFST-I, local buckling was observed near the top plate on all four sides and a slight buckling near the bottom plate and near the mid-height. Fig -4 shows the failure mode observed.

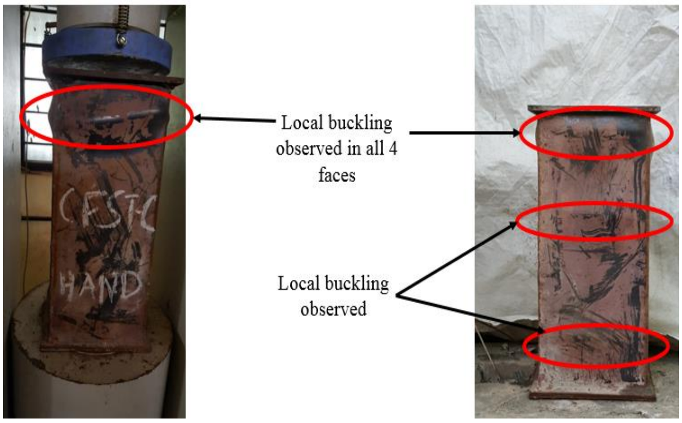

Fig -4: Failure mode of CFST-C

A slight local buckling was observed near the top plate of CFST-I. Fig -5 shows the failure mode observed.

Fig -5: Failure mode of CFST-I

Local buckling was observed near the top plate and also on the faces of CFST-II. Fig -6 shows the failure mode observed.

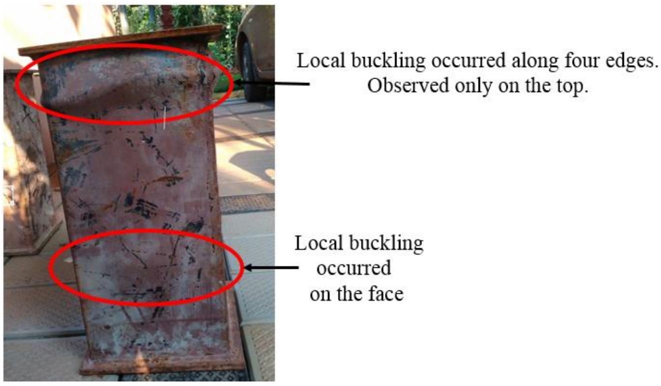

Fig -6: Failure mode of CFST-II

For CFST-III, local buckling was observed near the top plate and also on the faces. Fig -7 shows the failure mode observed.

Fig -7: Failure mode of CFST-III

4. CONCLUSIONS

Following conclusions are drawn based on the results obtained from experiment.

i. The provision of diagonal stiffeners in the CFST columns has proven to be an effective way to increase the axial load carrying capacity and also to reduce the local buckling of the steel tube.
ii. In this study, the average increase in axial load carrying capacity was 23.88 % for the specimen CFST – I.
iii. CFST - II and CFST - III act similar to that of control specimen in terms of ultimate load carrying capacity. And the stiffening scheme reduces the local buckling of the steel tube.
iv. Experimental results confirmed the tendency of the CFST columns to fail in local buckling near the top support due to insufficient stiffeners at that region.

REFERENCES

[1] Amit H. Varma, James M. Ricles, Richard Sause and Le-Wu Lu, "Experimental Behavior of High Strength Square Concrete-Filled Steel Tube Beam-Columns", Journal of Structural Engineering ©ASCE 2002, 309-318.

[2] C. S Huang, Y. K. Yeh, G. Y Liu, H. T Hu, K. C Tsai, Y. T Weng, S. H Wang and M. H Wu, "Axial Load Behavior of Stiffened Concrete-Filled Steel Columns", Journal of Structural Engineering © ASCE 2002, 1222-1230.

[3] Darshika k. Shah, M. D Vakil and M. N Patel, "Parametric Study of Concrete Filled Steel Tube Column", International journal of Engineering development and research 2014, 2, 1678-1682.

[4] Fa-xing Ding, De-ren Lu, Yu Bai, Qi-shi Zhou, Ming Ni, Zhi-wu Yu and Guo-shuai Jiang, "Comparative Study of Square Stirrup-Confined Concrete-Filled Steel Tubular Stub Columns under Axial Loading", Thin-Walled Structures, ELSEVIER 98, 2016, 443–453.

[5] Ke Wang and Ben Young, "Fire Resistance of Concrete-Filled High Strength Steel Tubular Columns", Thin-Walled Structures, ELSEVIER 71, 2013, 46–56.

[6] Lin-Hai Han, Wei Liu and You-Fu Yang, "Behaviour of Concrete-Filled Steel Tubular Stub Columns Subjected to Axially Local Compression", Journal of Constructional Steel Research, ELSEVIER 64, 2008, 377-387.

[7] Lin-Hai Han, Wen-Da Wang and Zhong Tao, "Performance of Circular CFST Column to Steel Beam Frames under Lateral Cyclic Loading", Journal of Constructional Steel Research, ELSEVIER 67, 2011, 876–890.