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Experimental Study on The Strength and Behaviour of Concrete Infilled Light Gauge Steel Square Columns

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An experimental study on the strength and behaviour of concrete infilled light gauge steel square columns(CFSSC) has been carried out. Six specimens of CFSSC and three specimens of SSC with and without transverse stiffeners were tested under concentric compressive load. Based on the experimental results, a parameter representing the increase in strength of the composite column due to addition of concrete and stiffeners is proposed.

Keywords: CFSSC, SSC, Transverse stiffeners, Deformation, Square hollow box.

1. Introduction

The present work is an experimental study on the strength and deformation of concrete-filled steel square columns. Six specimens of concrete-filled steel square columns with and without transverse stiffeners were tested under concentric compressive load. For comparisons, three specimens of steel square columns with and without stiffeners were also loaded to failure. The scope of the present study is limited to compare the strength and ductility behavior of concrete-filled steel columns with that of closed steel columns, to observe the stiffening effects of transverse stiffeners on the strength and buckling mode in both types of columns and to observe experimentally the failure modes of test specimens. Higher compressive strength of the member, good toughness and good plasticity, economical benefit and simple method of construction and short time of completion etc.are the main significances of this paper.The concrete core of the column is subjected in a confining stress and as a result can carry a considerably larger axial stress than similar unconfined concrete.

In this paper, section 1 deals with ‘Introduction’, section 2 deals with ‘Literature Review’, section 3 deals with ‘Methodology’.Also section 4 deals with ‘Result & Discussion’, section 5 & section 6 deals with ‘Conclusion & Future Scope’ respectively.

2. Literature Review

Essentially there are three different methods of applying the loading:

I Only steel is loaded but not the concrete.
II Only concrete is loaded but not the steel.
III Both the steel and the concrete are loaded.

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The first recorded use of concrete filled tubes as columns was by Sewell in 1901. Khalil and Mouli (1990) published experimental results obtained on concrete filled rectangular hollow section columns. Dutta and Bhattacharya (1995) published experimental results obtained on concrete-filled light gauge steel tubular columns. Tests have conducted on 1000mm long and 100mm outer diameter columns of thickness 2.6mm.Paperon the load bearing capacity of concrete filled steel tube columns with and without shear connectors by Girigharan et al.(2015) observed the behavior of CFSS columns when shear connectors areused. In the existing literature, it is observed that most of the cases the researchers used thick steel plates or thin plates with small b/t ratio so that no local buckling occurred.

In addition, it is also observed that to prevent the local buckling most of the researchers used longitudinal stiffeners and the effects of longitudinal stiffeners are already exist in the literature. To transfer the load from beam to column uniformly and properly, lateral stiffeners may be used in the composite column at the location of beam-column joints. So, for betterunderstanding, it is needed to know the effects of lateral stiffeners in the concrete-filled steel column. Mainly, it is because of this that lateral stiffeners are used in the present study.

3. Methodology

3.1 Experimental Arrangement and Test Data

Nine specimens (six concrete-filled steel box columns and three steel box columns) have been tested to failure under concentric compression. Details of the test specimens are shown in this paper. The specimen designations SC, SCS, CSC and CSCS will appear later on in the following topics. Refer to steel column without stiffeners, steel column with stiffeners, concrete-filled steel column without stiffeners and concrete filled steel column with stiffeners respectively.

Each column was positioned on the supports taking care to ensure that its center line was exactly in line with the axis of machine. After that, a small load was applied slowly so that the column could settle properly on its supports. The column was then tested to failure by applying the compressive load in suitable increments. At each increment, load and dial readings (for deformation) were recorded.

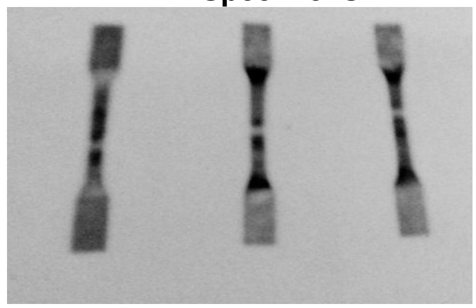
3.1.1. Procedure of preparing column

Steel properties were measured with tensile coupons taken from different parts of the original steel plates. Coupons test were carried out according to ASTM (1993) specifications. Coupons test were carried out in the INSTRON universal testing machine of capacity 50KN in the “Laboratory of Naval Architecture and Ocean Engineering Department, IIT, Kharagpur”. Concrete cubes and column tests were carried out in a Mohr and Federhoff universal testing machine of capacity 3000KN in the “Structural Laboratory of Civil Engineering Department, IIT, Kharagpur”. Essential steps of procedure of preparing column are noted below:

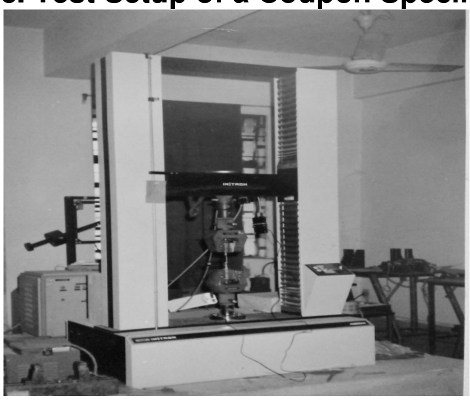
Figure 1: Essential Steps of Procedure of Preparing Column

a. Materials Collection

b. Preparation of Typical Coupon Specimens



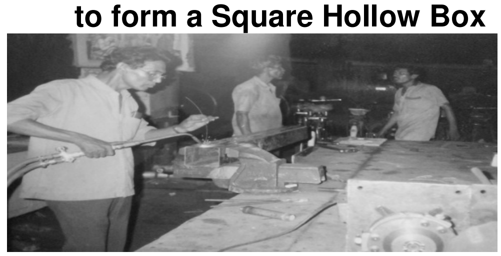
c. Test Setup of a Coupon Specimen



d. Test Setup of Cube

e. Steel Plate Channel with Stiffeners

f. Two Channels are Welded Together to form a Square Hollow Box



g. TestSetup with a Column Specimen

h. Nine Tested Column

Table 1: Properties * of Steel Plates

Ultimate stress (N/mm^2)	Yield stress (N/mm^2)	Proportional Limit (N/mm^2)	Modulas of elasticity (N/mm^2)
451.06	340	298	2.02×10^5
Poisson's Ratio = 0.285		* Average of three coupons	

Table 2: Properties of Concrete

Mix Proportion	Water-Cement Ratio	f_{ck} (for CSC)	f_{ck} (for CSCS)	E(for CSC)	μ
1:2:4	• 0.45 * • 0.50**	25.06 N/mm^2	11.04 N/mm^2	0.276×10^5 N/mm2	0.192
*For unstiffened column			**For stiffened column		

3.2: Numerical Calculation:

Strength increase parameter (λ):

A. Proportionate Method: The formula is as follows: $P_U=(A_C+nA_S)f_C\lambda$

Where, P_U= Ultimate load of the composite column

A_C=Area of core concrete

A_S= Area of steel tube

n = Modular ratio

f_C=Yield stress of concrete

λ=Strength increase parameter

1. CSC : $54.7 \times 1000 \times 9.807=(11236+7.08 \times 864) \times 25.06\lambda$

   $\lambda = 1.23$

2. CSCS: $38.25 \times 1000 \times 9.807 = (11236+10.66 \times 864) \times 11.04\lambda$

   $\lambda = 1.66$

B. Strength increase parameter α due to concrete :

1. Load carried by SC =14.2 tons

   Load carried by CSC =54.7tons

α =54.7/[14.2+(25.06 X 11236/ 9.807 X 1000)] = 1.27 (confining effect)

2. Load carried by SCS= 15.5tons

   Load carried by CSCS= 38.25 tons

   = 67.14tons (modified)

   α =38.25/[15.5+ (11.04X11236/9.807X1000)]

   =1.42 (confining effect)

3. Strength increase parameter β due to stiffeners

   1.β =15.5/14.2 =1.09 (without infill concrete)

   2. β=67.14/54.7=1.23 (with infill concrete)

The increase in strength is not merely the addition of two individual capacity, but for the confinement of concrete, the strength increases by a certain factor λ. The strength increases factor λ obtained in the present study is (a) 1.23 for CSC (b) 1.66 for CSCS.All in all, in previous studies, most of the researchers used thick steel plates with small b/t ratio and longitudinal stiffeners. But, in present study, thin steel plates and lateral stiffeners are used.

4. Result and Discussion

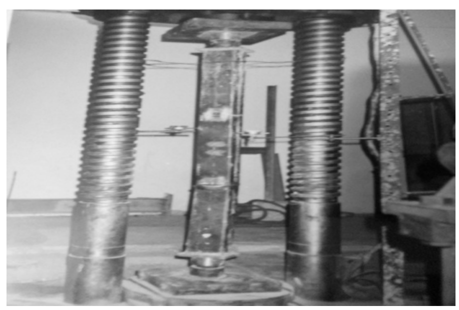
In 1995, B. Dutta and S.K. Bhattacharyya obtained the value of strength increase parameter (λ) due to concrete infilled was higher than 2 from light gauge (2.6mm) steel tubular column but in present study, λ is lower than 2 by experimenting light gauge (2mm) steel square columns. All the steel panels in the concrete infill column deformed outward because deformation toward the interior was prevented by the infill concrete. The failure mode of column was a local buckling mode, with no sign of overall buckling for the steel section without infill concrete. The occurrence of local plate buckling does not necessarily lead to the ultimate collapse of the column. After applying load, the elements of deformation in the form of local buckling were observed in figure for SC, SCS, CSC and CSCS.

Figure 2: Steel Column without Stiffeners

Figure 3: Steel Column with Stiffeners

Figure 4: Concrete-Filled Steel Column with Stiffeners

Figure 5: Concrete-Filled Steel Column without Stiffeners



Failure Modes: In the case of concrete filled column, the following important phenomena were observed:

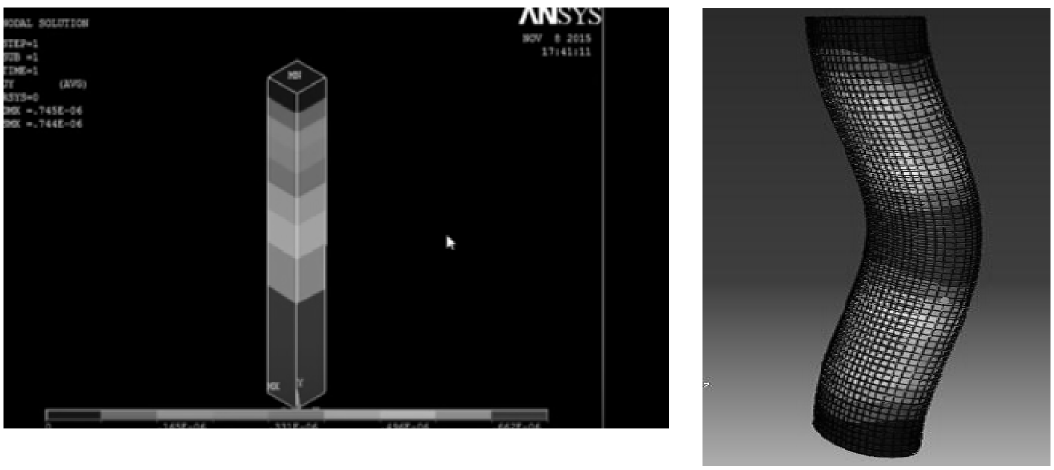
- I The local deformations of the plates at several locations.
- II The deformation of steel plates in all faces was towards outside of the section.
- III The increase in deformation became faster after local buckling, and cracks in the weld.

Table 3: Comparison between the Failure Load of Steel and Concrete Column With and Without Stiffeners

Steel Column without stiffener(SC)	Steel Column with stiffener(SCS)	Concrete Steel Column without stiffener(CSC)	Concrete Steel Column with stiffener(CSCS)
14.2tonnes	14.6tonnes	57.0tonnes	39.0tonnes

The proposed model was used to numerically simulate concrete infill steel square column. The accuracy of the numerical model is evaluated based on the difference between the experimental and ANSYS peak load capacities. The model must also be able to successfully capture the deformed shape of the composite member. The final deformed shape of the concrete filled steel square column is indicated below:

Figure 6: Concrete-Filled Steel Column without and with Stiffeners



5. Conclusion

In order to design an earthquake resistant frame by utilizing efficient properties of concrete filled steel square members, the design of beam to column connections becomes very important. In this regard, transverse stiffeners may be used at the said connections. Very few experimental studies are available such that a clear understanding of the effects of transverse stiffeners of concrete-filled columns is insufficient. Based on the experiment performed on the square column sections, the following conclusions may be drawn:

a. The comparative study between two types of columns showed that high ductility as well as high strength can be expected from concrete-filled columns.
b. It was also found that the significant stiffening effects of transverse stiffeners on the strength can be expected in both the steel column and concrete-filled column.
c. Concrete infill square columns can sustain large deformation without buckling of the wall of the tube.

It should be emphasized here that the discussion and conclusions of the present investigation are based on the results of a few tests in which only one size of thin-walled steel square column was used and in which all nine tests were carried out on columns of the same length.

There are few limitations of this experiment. They are noted below:

a. Due to the addition of the transverse stiffeners, the residual stresses may develop locally. As a result, column strength would be affected. So, special care is to be taken during connection of the stiffeners to column sections.
b. Before failure of both SC & CSC, the material may go into the stage of plastic flow as poisson's ratio would become as high as 0.5.
c. If the imperfections in the steel column can be avoided during fabrication stage, the failure of concrete infill column may be ensured by overall buckling rather than local buckling effect.

6. Future Scope

It may be recommended that, for future experimental work, the lack of straightness of columns should be recorded before testing. This would give the initial shape of the column, which would then be included in the data for the theoretical evaluation of the failure load.

For a better understanding of the behavior of such composite columns, it would be useful to test short, medium and long specimens from a range of square hollow sections. Very little information has been available on the fire resistance of composite column. Proper precautions to prevent differential temperature effects and future research in this field will also be very helpful to enhance the use of composite column.

References

Dai, X., & Lam, D. 2010, Numerical modeling of the axial compressive behavior of short concrete-filled elliptical steel columns, Journal of Constructional Steel Research, *Vol. 66, Pp. 931-942*.

Ellobody, E., Young, B. & Lam, D. 2006, Behavior of normal and high-strength concrete-filled steel tube circular stub columns, Journal of Constructional Steel Research, *Vol. 62, Pp. 706-715*.

Hu, H.T., Huang, C.S., Wu, M.H., &Wu, Y.M. 2003, Non-linear analysis of axially loaded concrete-filled tube columns with confinement effect, Journal of Structural Engineering, *Pp.1322-1329*.

Jiang, A.Y., Chen, J., & Jin, W.L. 2013, Bending strength on thin-walled centrifugal concrete-filled steel tubes. Research Journal of Applied Sciences, Engineering and Technology, Pp. 801-811.

Mander, J.B., Priestley, M.J.N., & Park, R. 1988, Theoretical stress-strain model for confined concrete. Journal of Structural Engineering,Vol. 114 Pp.1804-1826.

Patil, V.P. 2012, Finite element approach to study elastic instability of concrete filled steel tubular columns under axial load, International Journal of Technology and Advanced Engineering.

Saenz, L.P. 1964, Discussion of 'Equation for the stress-strain curve of concrete' by P. Desayi and S. Krishnan. Journal of American Concrete Institute, *Vol. 61, Pp. 1229-1235.*

Starossek, U., Falah, N., & Löhning 2008, Numerical analysis of the force transfer in concrete-filled steel tube columns, The 4th International Conference on Advances in Structural Engineering and Mechanics, Jeju, Korea. EN 1994-1-1 2004. Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings, CEN.