



Strength Assessment of Concrete-Filled Steel Tubes (CFST) Through DOE and ANOVA: Influence of Cross-Section and Slenderness

¹ Mr. Pankaj Rawool, ² Mr. Rupesh Deshbhratar, ³ Mr. Vinay Bhatkar, ⁴ Mr. Krishna Gaikwad,

⁵ Mr. Pawan Tiwari

¹ Assistant Professor, ² Assistant Professor, ³ Assistant Professor, ⁴ Assistant Professor, ⁵ Assistant Professor

¹ Department of Mechanical Engineering,

¹ Thakur College of Engineering and Technology, Mumbai, India

Abstract : Concrete filled steel tube is also known as CFST or CFT. It is a combination of concrete and steel tubes. It is used as a replacement to RC (Reinforced Concrete) structures. Concrete-filled steel tubular (CFST) provides many benefits related to structures and building materials. The concrete-filled steel tubular (CFST) structure offers many structural benefits which includes resistance to fire, provides more ductility with increase in strength and act as a damper to resist the vibration forces acting on the structures. It reduces the construction time and cost of building structures. It has far advantages in engineering structures due to the high strength capacity. This study was aimed to investigate compressive strength of different cross-sections adopting DOE and ANOVA techniques. The study summarized the comparative analysis of compressive strength and buckling load of CFSTs for two different cross-sections, L/D ratios.

IndexTerms - CFST, DOE, compressive strength, buckling, L/D ratio..

I. INTRODUCTION

Concrete filled steel tubular (CFST) members provides the advantages of both steel and concrete. It is made of plain concrete or reinforced concrete filled in a hollow steel tube of different cross sections. Circular and Rectangular are two different cross sections used for the experimentation purpose. They are mostly used in buildings and bridges to provide more resistance to the shear and bending stresses acting on the structures.

The concrete-filled steel tubular (CFST) structure offers many structural benefits which includes resistance to fire, provides more ductility with increase in strength and act as a damper to resist the vibration forces acting on the structures. It reduces the construction time and cost of building structures. It has far advantages in engineering structures due to the high strength capacity. Overall structural performance is increased due to use of different materials in the structures. The steel is at the outer of the tube where it resists tension and bending forces. It is at the farthest distance from the centroid, so it provides more stiffness. This increases the modulus of elasticity due to which its moment of inertia is increased. The concrete in the center provides resistance to the compression.

Due to its simple construction and more strength, there has been vast increase in use of concrete filled steel tubes. Concrete is mostly used with the hollow steel tubes. The hollow steel tubes are used to support the construction load acting on the structures. The structures are made of reinforced concrete slab which are kept on steel decks supported by concrete filled steel tubes.

II. OBJECTIVES AND SCOPE

The objective of this study was to test the specimen at different parameters, having cross-section areas under compression and bending loads to analyze their rigidity and strength.

III. LITERATURE REVIEW

Mr. ALOK BHAKTIRAM RATHOD [1] CFST is the member with concrete filled into steel tubes. It is a new structure that evolved and developed based on SRC Structures, spiral stirrup structures and steel tube structures. Concrete-filled steel tubular (CFST) structure offers numerous structural benefits, and has been widely used in civil engineering structures. This report reviews the development of the family of concrete-filled steel tubular structures up to date and effectively presents a detail study on CFST members. The research development on CFST structural members in most recent years, particularly in China, is summarized and discussed. The current design approaches from various countries are examined briefly. Some projects in China utilizing CFST members are also introduced.

S.S.G.B.C.O.E.T., BHUSAWAL [2] Concrete filled steel tubular (CFST) members utilize the advantages of both steel and concrete. They comprise of a steel hollow section of circular or rectangular shape filled with plain or reinforced concrete. They are widely used in high-rise and multistory buildings as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required.

HARIKRISHNA M.S[3] Concrete filled steel tubes (CFT) uses the advantage of both steel and concrete. Infill concrete in steel tube delays local buckling. Steel tube reinforces the concrete to resist tensile forces. Improves its compression stress and ductility.

Hui Liua,b, Yongxiang Wangb, Minghua Hea, Yongjiu Shia, Haim Waismanb [4]Concrete-filled steel tubular (CFST) columns are widely used in infrastructure applications and thus usually are subject to long-term service loading. However, understanding the influence of sustained loading on the ultimate performance of these structural members is still lacking. The objective of this work is to develop a constitutive model to account for strength and ductility change of CFST columns under sustained loading, validated by experimental data reported in the literature.

IV. DESIGN

The two different cross section selected for experimentation were as shown in figure1:

- Circular cross-section
- Rectangular Cross section

Construction of CFST is quite simple as compared to other concrete beams. The structures are made of reinforced concrete slab which are kept on steel decks supported by concrete filled steel tubes. Concrete is mostly used with the hollow steel tubes. The hollow steel tubes are used to support the construction load acting on the structures.

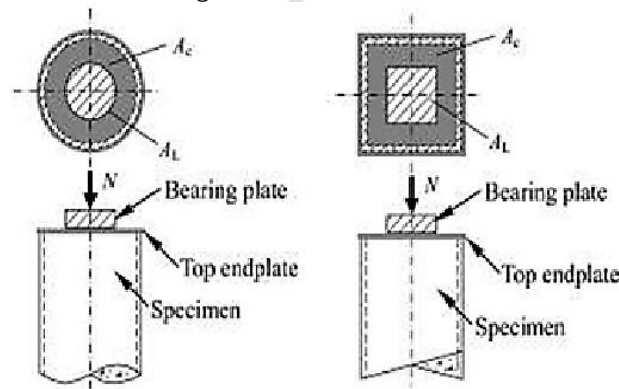


Fig1: Cross-section of CFST Columns under test

4.1 Selection of Materials:

Steel: Steel (grade 304) is an alloy of iron and carbon and several other elements. It derives its properties from combination of heat treatment, chemical composition and manufacturing processes. It has high tensile strength. It is mostly used in construction of buildings, bridges due to its low cost.

Table 1: Contents of Steel material

Element	Approx. %
Carbon	0.08
Manganese	2
Phosphorous	0.045
Sulfur	0.03
Silicon	1
Chromium	18-20
Nickel	8-10.50

Concrete: Quantities of materials selected for making concrete such as cement, sand and aggregates are of proportions 1:2:4(M15). It is calculated by absolute volume method.



Fig 2: CFST Specimens before compression test

4.2 Test Methods adopted

The test specimens were prepared as per industry standards and 3 control factors were identified as follows-

- Tube length to depth ratio (L/D)
- Displacement (δ)
- Tube shape (cross-section)

The experiments were designed using Minitab software which suggested to carry out Full factorial design. Each parameter was varied within two reference limits, which were also treated as levels for these parameters. To conduct the experiments with two levels and three factors total 8 experiments were tested. ($2^3=8$). In each experiment the deflection of the specimen under gradually applied compressive load was recorded on UTM. The results obtained are documented thereafter to derive concluder evidences.

V. RESULTS

This report summarizes the Design of Experiments (DOE) analysis performed on steel–concrete composite rods with varying cross sections (Circle and Square), L/D ratios, and displacement levels. The goal is to evaluate their compressive strength behavior.

Table 2: Deflection of CFST Specimens during compression

Sr No	Cross Section	Length Of Specimen (mm)	L/D Ratio	Displacement (mm)	Load (kN)
1	Circle	330.2	13	5	7.76
2	Circle	330.2	13	10	8.76
3	Circle	457.2	18	5	11.16
4	Circle	457.2	18	10	12.44
5	Square	330.2	13	5	15.76
6	Square	330.2	13	10	18.16
7	Square	457.2	18	5	18.20
8	Square	457.2	18	10	16.92

Table 2 illustrates the experimental investigation recorded during compression test performed on CFST Specimens under gradually increasing loads.



Fig 3: CFST Specimens after compression test (a) circular specimens with L/D as 13 (b) circular specimens with L/D as 18 (c) rectangular specimens with L/D as 13 (d) rectangular specimens with L/D as 18

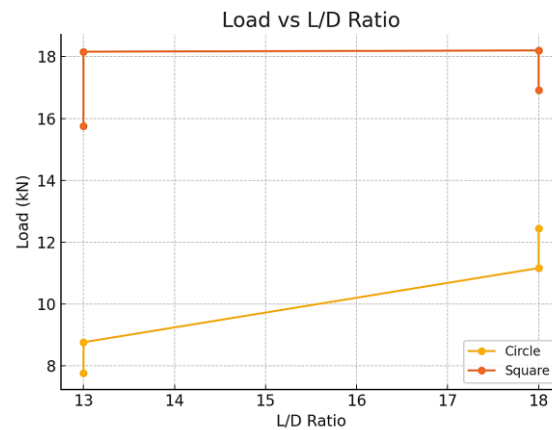


Fig 4: Load vs L/D ratio

Key Conclusions from DOE Study-

- Effect of Cross-section: Square composite rods consistently show higher compressive load capacity than circular ones. Square geometry offered better confinement and load-bearing efficiency.
- Effect of L/D Ratio: In fig 3 increasing L/D from 13 to 18 increased load capacity for circular sections. For square sections, load was generally high for both L/D ratios, with a slight rise or stability. Longer specimens (higher L/D) distribute stresses better in circular rods. Square rods are less sensitive to L/D changes because they are inherently stiffer.
- Effect of Displacement: Higher displacement (10 mm vs 5 mm) generally corresponds to higher load values, meaning: Material response is ductile, and strength increases up to tested displacement.
- Only one anomaly (Square, L/D=18) showed slight reduction — likely due to local buckling or internal instability. Square composite rods outperformed circular rods in compressive strength across all conditions. Increasing L/D ratio improved strength in circular rods but has marginal effect on square rods. Displacement increase generally correlates with higher load capacity—indicating stable plastic deformation.

VI. CONCLUSION

This study mainly presents an experimental investigation of short concrete-filled steel tube columns under a concentric load. A stiffening scheme is also proposed to enhance the behavior of square and circular cross-sectional columns in terms of ultimate tensile strength and to check the ductility. A nonlinear finite element analysis will be carried out to study the effects of variable cross-sectional shape and stiffener on axial stress distribution at a typical cross section. Various important points will be taken under consideration:

- Without stiffeners, only the load–strain relationship for the specimen shows elastic and perfectly plastic behavior, while the remaining specimens exhibit strain-softening characteristics. The reduction in strength of the specimen can be improved with the help of proper arrangement of stiffener after reaching the ultimate load, and can even change the behavior of strain softening characteristics to achieve elastic–perfectly plastic behavior.
- The stiffness computed by directly superposing the stiffness of the steel tube and the core concrete is significantly overestimated.

VII. ACKNOWLEDGEMENT

We sincerely thank our, HOD Dr. Udhav Nimbalkar guide for continuous support and motivation our colleagues and our parents for guidance and support for carrying out our DOE study.

REFERENCES

- [1] 1. ASTM. 1991 ,,,ASTM standards in building codes: specifications, test methods, practices, classifications, terminology, "" Philadelphia.
- [2] British Standards Institution ~BST1994. Design of composite steel and concrete structures. Euro code 4, ENV 1994-1-1, London.
- [3] Elwi, A. A., and Murray, D. W. ~1979!. ,,,A 3D hypo elastic concrete constitutive relationship."" J. Eng. Mech. Div., Am. Soc. Civ. Eng.,
- [4] 4. Cheng Hongtao, Dissertation of the doctoral degree in engineering(D), Harbin Institute of Technology, Harbin 2001.
- [5] 5. Zhong Shantong, Concrete Filled Steel Tubular Structures (M), Heilongjiang ScienceTechnical Publishing House, Harbin, 1995.
- [6] Design Regulation of Composite Structures(S), DL/T 5085-1999
- [7] Design Regulation of Composite Structures---- Square CFST Members(S), GJB4142-2000.
- [8] Bazant Z.P. and Kim S.S. Plastic-Fracturing Theory for Concrete.(J), Journal of Engineering Mechanics Division. 1979, 105(EM3)