Erudite Journal of Engineering Technology and Management Sciences

Vol. 4, No. 2, June 2024, pp. 01-04

Journal homepage: http://www.ejetms.com

A Review on Concrete Filled Steel Tube Columns Subjected to Axial Compression

D. Venu Gopal Reddy[1*], G. Jagadeesh[1], S. Vamsi[1], B. Kiran Kumar Reddy[1], P. Dhananjaya[1], P. Narasimha Reddy[1]

[1] Department of Civil Engineering, Sri Venkateswara College of Engineering and Technology (Autonomous) (SVCET), Chittoor, India

Corresponding Author Email: dvenugopalreddy@gmail.com

https://doi.org/10.5281/zenodo.13744374

Received: 20 March 2024
Accepted: 25 May 2024

Keywords:
Axial compression, Concrete, Composite columns, Self-compacting concrete, Confinement, Micro-steel fiber

ABSTRACT

Concrete-filled steel tube (CFST) columns have emerged as a popular structural element in modern construction due to their superior load-bearing capacity and ductility under axial compression. This review paper synthesizes the existing research on the behavior of CFST columns subjected to axial compression, focusing on their mechanical properties, structural performance, and failure mechanisms. The combination of steel and concrete in CFST columns offers enhanced strength, stiffness, and energy absorption, making them suitable for high-rise buildings, bridges, and other critical infrastructure. This paper also explores the impact of various factors such as material properties, cross-sectional shapes, and slenderness ratios on the performance of CFST columns. Furthermore, the review highlights advancements in analytical models and numerical simulations that predict the behavior of CFST columns under different loading conditions. By providing a comprehensive understanding of the current state of research, this paper aims to guide future studies and practical applications in the design and optimization of CFST columns.

1. INTRODUCTION

Introduction of the composites like steel and concrete transformed the construction philosophy over time. From achieving stability to optimising material utilisation, numerous deficiencies in constructions have been overcome, and opportunities to achieve good tensile strength, ductility, durability, and structural stability have been created.

To analyse the research effort, thorough review on literature in the topic of composite columns is conducted. The literature of CFST members was thoroughly assessed, categorised, and provided below.

The underlying test work for increasing the composite strength of steel shaft and solid section frameworks was likely completed by 1930. Versatile plan methods based on standard bar hypothesis had been developed, and the composite framework was beginning to attract the attention of creators and innovators. Examiners were also looking at the unknown concerns of composite activity, with considerable primary study being done in research foundations in many countries. [1].

Unfortunate fires in wood constructions were common in mediaeval times, but the consequences were far less severe than in the later period at the beginnings of modern discontent, when towns were booming and factory lines with significant fire risks were being built. When the use of iron outlines became a possibility about 1790, with the fabrication of the major iron shafts and segments, it looked to designers and draughtsmen that the flame-resistant building had become a reality.

A brief audit of writing in the area of CFST section has been attempted to basically analyse the examination activities done in the region of cement filled steel rounded composite sections. The most recent examination on the CFST part has been basically reviewed and categorised. They are discussed in the subsequent sections.

2. STUDIES ON COMPOSITE COLUMNS

Many scholars have done extensive study on concrete filled steel tube columns over the last 50 years in order to understand the relevance of CFST. The benefits of these tubular members have piqued the interest of academics all over the world. This section lists and discusses the related issue of steel - concrete composite members.

Shanmugam and Lakshmi (2001) [2] offered a review study on scholars' experimental and analytical work on composite columns. This research discussed the characteristics involved in affecting the experimental investigation of composite columns that impact bond strength, column buckling, stress behaviour, and concrete confinement effect.

Giakoumelis and Lam (2004) [3] investigated the axial capacities of circular CFST columns using 15 specimens with an outer diameter of 114 mm and two different wall thicknesses of 3.6 mm and 5.0 mm and a length of 300 mm. All specimens had concrete grades ranging from 30 to 100 MPa. It is found that the axial capacities enhanced as the concrete grade increased. The impact of concrete bond with the steel tube became extremely important in improving the strength of the CFST specimens. The axial capabilities were also compared to code projections by the authors. When EC4 and ACI/AS code predictions were compared to experimental outcomes, EC4 had more conservative findings, whereas ACI/AS forecasts were 35% lower than the test results.

Han L. H et al. (2005) [4] investigated the behaviour of CFST columns in testing. The compressive load of circular hollow steel tube columns was found to be significantly lower than that of still tubular concrete-filled columns. The study reveals that confining the concrete core significantly increased the capacity of the steel tube column. As a result, confinement plays an important role in the formation of axial capacity in CFST columns.

Yu, Ding et al., (2007) [5] tested stub columns with regular concrete and self-compacting concrete loaded concentrically in compression to failure. This work addressed stub column confinement. Notch holes were bored at various locations in the specimens, and it was discovered that the confinement effect rises when the complete slot of holes is reduced. However, when the dimensions were raised, confinement reduced and the concrete core showed little strength, reducing the axial capacity of the specimens.

de Oliveria et al., (2009) [6] investigated the confinement effect in CFST columns by taking into account characteristics such as concrete strength and column slenderness. The concrete strength ranged from 30 to 100 MPa, with L/D values of 3, 5, 7, and 10, indicating that raising the ratio had a higher impact on reducing load capacity. Furthermore, the concrete grade is directly proportional to the axial capacity of the columns. The experimental findings were compared to EC4, AISC-360:2005, and CAN/CSA S16-01:2001, and it was determined that EC4 provided the closest values to the test results. It is demonstrated that there is a 2.4 percent and 2.3 percent disparity between experimental findings and EC4 and CAN/CSA codes, respectively.

Beck et al. (2009) [7] conducted 36 CFST specimens subjected to compressive stress to give a reliability-based evaluation of design code. In addition, 57 experimental data from diverse literatures were compared with different code predictions to determine the predictability of CFST column outcomes. This comprises a few issues such as model flaws, steel concrete strength, dead and live loads, and so on. It was discovered that the dependability index for the EC4 code was 2.2 lower than for the other codes.

Goode et al., (2010) [8] published 1817 concrete filled steel tube experimental data and compared it to EC4 axial capacity estimates. End moment was calculated for circular, rectangular hollow, and concrete filled stub and long columns. The results revealed that rectangular CFST columns produced conservative results when the concrete strength is less than 75 MPa. It is also established that EC4 provides safe prediction techniques for long slender columns and concrete strength up to 100MPa.

Dundu (2012) [9] tested 24 CFST columns that were concentrically loaded for failure. The criteria studied include length, diameter, concrete grade, and steel yield strength. Flexural buckling in long slenderness ratio columns and overall flexural buckling in stockier columns were detected. When axial capacity data were compared to EC4 and SANS 10162-1, it was determined that EC4 is 13.6 percent conservative with test results and SANS 10162-1 is 8.4 percent conservative. The columns were all rather ductile.

Abed et al. (2013) [10] tested circular CFST with three different D/t ratios and two concrete grades under axial stress. He determined that the D/t ratio has a greater impact on the column than other factors. The experimental findings were compared to the design results of ACI-318, AS, and EC4, and a finite element numerical model was built to validate the experimental results.

Evirgen et al. (2014) [11] investigated the structural behaviour of CFST columns by performing axial compressive load experiments on 48 concrete filled steel tube and 16 hollow steel tube columns. The b/t ratio, concrete compressive strength, and geometric forms of the columns are all taken into account here. For this investigation, circular, rectangular, square, and hexagonal forms were used. Circular specimens are shown to be the most efficient members in terms of ductility and axial stress. All of the specimens were modelled with ABAQUS software, and there was only a 15-20% variation in experimental and software results.

Tokgoz (2015) [12] investigated the compression and biaxial bending behaviour of plain and steel fiber CFSST columns. The L/D ratios under consideration are 12, 15, and 20. Concrete strength, column cross-section, steel fiber proportion in volume, and column slenderness were all factors evaluated. This research presents the ultimate strength and load verses deflection curves. The plain and steel fiber CFSST columns are also theoretically investigated. A comparison of experimental and theoretical results revealed that experimental results demonstrated effective understanding in the research of CFSST column behaviour.

Lu et al. (2017) [13] conducted an experimental investigation on steel fiber reinforced self-stressing and self-compacting CFST columns subjected to bending. The goal of this project was to show how steel fibers and concrete self-stress affect CFST columns. The thickness of the steel tube, the strength of the concrete, and the proportion of steel fiber in volume were all examined. Although specimens indicated sufficient ductility, steel fibers did not affect the cause of failure in CFST. Self-stressing showed only a minimal impact on column flexural capacity and stiffness. The accuracy of test results was compared to a formula developed to predict the flexural capacity of the columns.

Using self-stressing and self-compacting concrete, Lu Y, Liu Z, et al. (2017) [13] investigated the bond behaviour of CFST columns made using steel fibers. Adjusting parameters such as concrete grade and steel fiber volume are used to execute the push out test on 90 CFST columns. The concrete grades were 40, 50, and 60, with steel fiber amounts of 0, 0.6, and 1.2 percent. Bond strength ranges from 0.5 to 2.51 MPa between self-stressing and self-compacting concrete. The bond strength varies with the amount of steel fiber used. Finally, formulae for estimating the bond strength of CFST columns are developed, and the forecasts outperform design codes.

Wang W, Ma H, et al. (2017) [14] investigated size effect of circular CFST columns having diameters of 219 mm, 426 mm, and 630 mm with D/t ratios of 55 and 88, respectively. All specimens were subjected to axial compression to establish their ultimate bearing capacity. The results revealed that as the size rose, the peak nominal stress reduced at larger D/t ratios. The hoop stress decreased significantly as the confinement effect of steel tube increased. The axial capacity rose as column size grew, and it is impacted by both D/t and column size. Size-related models for various D/t ratios are developed, and experimental findings are compared with the model to demonstrate its accuracy in forecasting column axial capacity.

Lu Y, Liu Z, et al. (2018) [15] investigated the feasibility of CFST stub columns using steel-polypropylene hybrid fibers. All of the specimens are subjected to axial compression and their failure mechanisms are tested. In all, 16 stub columns with wall thicknesses of 5 mm, exterior diameters of 113 mm, and lengths of 399 mm are studied with varying grade strength. This research depicts the failure mechanisms, ductility, and ultimate section capacity of stub columns. The results showed that hybrid fiber had no significant effect on column failure. The behaviour of the columns with hybrid fiber reinforced concrete is more ductile.

Ahmad et al. (2019) [16] investigated the axial properties of circular CFST columns made of GGBFS concrete. The parameters investigated were the L/D ratio and the compressive strength of concrete with 0, 15, 25, and 35% cement substitution to GGBFS. It was discovered that CFST specimens containing GGBFS had higher compressive strength than control mixes, and that increasing the amount of GGBFS tended to enhance the capacity of CFST columns. These axial capacities were then compared to EC4, AIJ, and DL/T code provisions in order to determine the axial load of GGBFS CFST specimens. The accuracy in forecasting the axial capacities of the columns was supplied by EC4 and DL/T.

Liu et al. (2019) [17] investigated the behaviour of CFST columns infused with steel fibers and recycled aggregate concrete (RAC) in order to improve the use of RAC. Axial compression is applied to 54 CFST columns reinforced with steel fiber and RAC. The criteria that vary include RAC replacement, steel fibers, concrete grade, and column wall thickness. It is determined that when the RAC concentration increases, the concrete strength decreases. However, introducing steel fibers increases ductility. The capacity and rigidity of the CFST columns are also improved by the use of self-stressing concrete. The experimental results are compared to a design equation.

Yu F, Chen et al. (2020) [18] presented the results of axial load testing on 15 recycled self-compacting CFST columns. This study investigates the impact of replacing recycled aggregate (RA). D/t ratio, concrete grade strength, mode of failure, load deformations, compressive loads, and stress-strain relationships were all examined and given in this study. Buckling was seen in the centre of the columns, and axial capacity and stress strain were reduced when recycled aggregate and D/t ratios were increased. All of the variables in this study are inversely proportional to the axial capacities, stress-strain relationships, and confinement ratios. A formula was created and tested against the experimental findings, demonstrating high accuracy in predicting the values.

3. CONCLUSION

This paper provides an overview of the research done by researchers on CFST with various concrete grades, mineral admixtures replacements, and so on, to improve the axial capabilities of the columns. Several experimental efforts on CFST were carried out and compared with various design codes based on a comprehensive literature review. There is, nevertheless, a shortage in identifying the axial capacity that displays an accurate result in determining the experimental test findings.

References

1. Zhao XL, Han LH, Lu H Concrete filled tubular members and connections. London: Spon press; 2010.
2. Shanmugam NE, Lakshmi B. State of the art report on steel – concrete composite columns. Journal of Constructional Steel Research 2001; 57(10): 1041-80.
3. Georgios Giakoumelis and Dennis Lam. 2004. "Axial Capacity of Circular Concrete Filled Tube Columns." Journal of Construction Steel Research 60: 1049-1068.
4. Han, L. H., Yao, G.H. and Zhao, X.L. 2005. " Tests and calculations for hollow structural steel (HSS) stub columns filled with self-consolidating concrete (SCC)." Journal of Constructional Steel Research 61:1241-1269.
5. Yu, Feng et al. 2020. “Experimental and Theoretical Investigations of Recycled Self-Compacting Concrete Filled Steel Tubular Columns Subjected to Axial Compression.” Construction and Building Materials 248: 118689.
6. De Oliveira, W. L. A., De Nardin, S., de Cresce El, A. L. H., & El Debs, M. K. (2009). Influence of concrete strength and length/diameter on the axial capacity of CFT columns. Journal of Constructional Steel Research, 65(12), 2103-2110.
7. Beck, A. T., de Oliveira, W. L., De Nardim, S., & ElDebs, A. L. (2009). Reliability-based evaluation of design code provisions for circular concrete-filled steel columns. Engineering Structures, 31(10), 2299-2308.
8. Goode, C. D., Kuranovas, A., & Kvedaras, A. K. (2010). Buckling of slender composite concrete ‐ filled steel columns. Journal of Civil Engineering and Management, 16(2), 230-237.
9. Dundu, M. 2012 "Compressive strength of circualr concrete filled steel tube columns." Thin-Walled Structures 56:62-70.
10. Abed, F., AlHamaydeh, M., & Abdalla, S. (2013). Experimental and numerical investigations of the compressive behavior of concrete filled steel tubes (CFSTs). Journal of Constructional Steel Research, 80, 429-439.
11. Evirgen, Burak, Ahmet Tuncan, and Kivanc Taskin. 2014. “Structural Behavior of Concrete Filled Steel Tubular Sections (CFT/CFSt) under Axial Compression.” Thin-Walled Structures 80(February 2018): 46–56.

12. Tokgoz, Serkan. 2015. “Tests on Plain and Steel Fiber Concrete- Fi Lled Stainless Steel Tubular Columns.” Journal of Constructional Steel Research 114: 129–35.
13. Lu, Y., Liu, Z., Li, S., & Li, W. (2017). Behavior of steel fibers reinforced self-stressing and self-compacting concrete-filled steel tube subjected to bending. Construction and Building Materials, 156, 639-651.
14. Wang, Wenjing, Hua Ma, Zhenbao Li, and Zhenyun Tang. 2017. “Size Effect in Circular Concrete-Filled Steel Tubes with Different Diameter-to-Thickness Ratios under Axial Compression.” Engineering Structures 151: 554–67.
15. Lu, Y., Liu, Z., Li, S., & Li, N. (2018). Bond behavior of steel fibers reinforced self-stressing and self-compacting concrete filled steel tube columns. Construction and Building Materials, 158, 894-909.
16. Ahmad, S., Kumar, A., & Kumar, K. (2020, February). Axial performance of GGBFS concrete filled steel tubes. In Structures (Vol. 23, pp. 539-550). Elsevier.
17. Liu, Zhenzhen, Yiyan Lu, Shan Li, and Jiancong Liao. 2019. “Axial Behavior of Slender Steel Tube Filled with Steel-Fiber-Reinforced Recycled Aggregate Concrete.” Journal of Constructional Steel Research 162: 105748.
18. Yu, Feng et al. 2020. “Experimental and Theoretical Investigations of Recycled Self-Compacting Concrete Filled Steel Tubular Columns Subjected to Axial Compression.” Construction and Building Materials 248: 118689.