International Journal for Modern Trends in Science and Technology, 8(05):510-514, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0805077
Available online at: http://www.ijmtst.com/vol8issue05.html

A Review on "Structural Behavior of Steel Tubes and Concrete Filled Steel Tubes(CFST) Retrofitted with Glass Fiber Reinforced Polymer(GFRP)"

Sumit Bhusari[1], Harshavardhan Rangari[2]

[1]Department of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India
[2]Assistant Professor, Department of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India
Corresponding author Email ID: sumitbhusari10@gmail.com@gmail.com

To Cite this Article
Sumit Bhusari and Harshavardhan Rangari[2]. A Review on "Structural Behavior of Steel Tubes and Concrete Filled Steel Tubes(CFST) Retrofitted with Glass Fiber Reinforced Polymer(GFRP)". International Journal for Modern Trends in Science and Technology 2022, 8(05), pp. 510-514. https://doi.org/10.46501/IJMTST0805077

Article Info
Received: 22 April 2022; Accepted: 16 May 2022; Published: 24 May 2022.

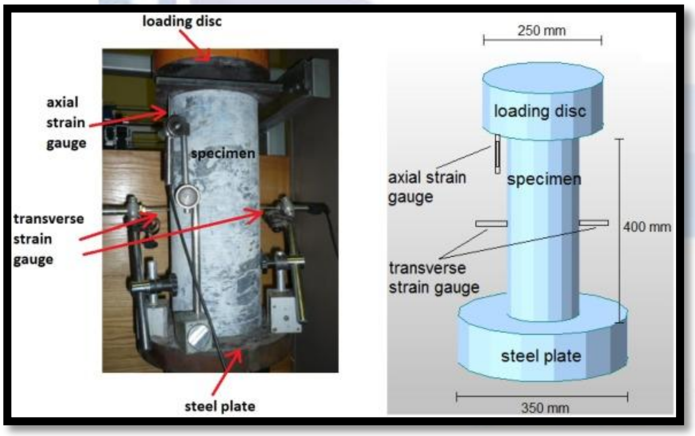
ABSTRACT

Concrete-Filled Steel Tubes (CFTs) are composite members consisting of an steel tube infilled with concrete. In current international practice, CFT columns are used in the primary lateral resistance systems of both braced and unbraced building structures. There exist applications in Japan and Europe where CFTs are also used as bridge piers. Moreover, CFTs may be utilized for retrofitting purposes for strengthening concrete columns in earthquake zones. This paper presents the results of an experimental study into the behavior of concrete-filled steel tube columns confined by fiber-reinforced polymer (FRP). Eleven columns were tested to investigate the effects of the FRP layer number, the thickness of the steel tube and concrete strength on their load capacity and axial deformation capacity. The experimental results indicated that the FRP wrap can effectively confine the concrete expansion and delay the local buckling of the steel tube. Both the load capacity and the axial deformation capacity of concrete-filled steel tube columns can be substantially enhanced with FRP confinement. A model is proposed to predict the load capacity of the FRP-confined concrete-filled steel tube columns. The predicted results are generally in good agreement with the experimental ones obtained in this study and in the literature.

Keywords-Concrete-filled steel tube (CFST) columns; Fiber-reinforced polymer (FRP); Axial load; Confinement

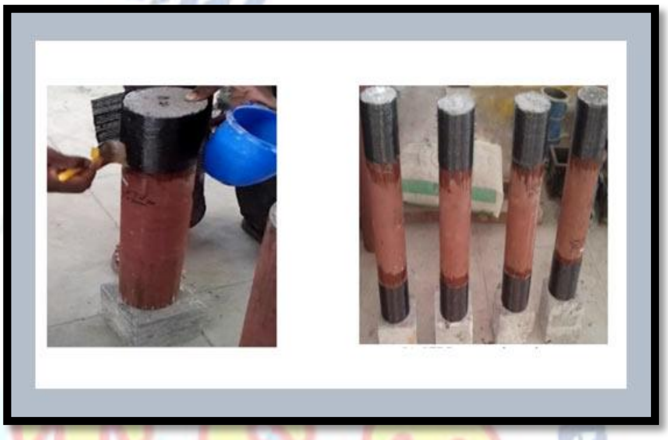
1. INTRODUCTION

Steel-concrete composite columns were used for over a century. At the beginning it was used to provide fire protection to steel structures. Afterwards, the concrete encased columns' strength properties were also considered in the design. However, the research into concrete filled steel tubes (CFST) did not begin until the 1960s. At the present time, the concrete filled steel tube columns are widely used in construction. Actually, this type of structural elements is favored in practice because of its small cross sectional area to load carrying capacity ratio. Hence, mega concrete columns in tall buildings' lower floors can be substituted by smaller sections of CFST columns. Moreover, CFST elements can be used as piers for bridges at congested areas. Therefore, such structural elements should be thoroughly investigated before used in critical structures. Despite being a research topic for around 50 years, the behavior of the CFST columns under different loading conditions is not fully studied. Thus, intensive parametric studies should be performed in order to fully understand the CFST columns behavior. This study, addresses some parameters that affect the CFST column behavior which are the steel tube outer diameter to thickness ratio, the concrete infill compressive strength, the loading rate, and the GFRP jacketing.The CFT structural member has a number of distinct advantages over an equivalent steel, reinforced concrete, or steel-reinforced concrete member. The orientation of the steel and concrete in the cross section optimizes the strength and stiffness of the section. The steel lies at the outer perimeter where it performs most effectively in tension and in resisting bending moment. Also, the stiffness of the CFT is greatly enhanced because the steel, which has a much greater modulus of elasticity than the concrete, is situated farthest from the centroid, where it makes the greatest contribution to the moment of inertia. The concrete forms an ideal core to withstand the compressive loading in typical applications, and it delays and often prevents local buckling of the steel, particularly in rectangular CFTs. Additionally, it has been shown that the steel tube confines the concrete core, which increases the compressive strength for circular CFTs, and the ductility for rectangular CFTs. Therefore, it is most advantageous to use CFTs for the columns subjected to the large compressive loading.



[Fig.1.1: Behaviour of FRP]

In contrast to reinforced concrete columns with transverse reinforcement, the steel tube also prevents spalling of the concrete and minimizes congestion of reinforcement in the connection region, particularly for seismic design. Numerous tests have illustrated the increase in cyclic strength, ductility, and damping by filling hollow tubes with concrete. Recent applications have also introduced the use of high strength concrete combined with high strength thin-walled steel tubes with much success. When high strength concrete and thin-walled steel tubes are used together, the more brittle nature of high strength concrete is partially mitigated by the confinement from the steel tube, and local buckling of the thin steel tube is delayed by the support offered by the concrete.



[Fig.1.2: FRP Wrapped Concrete Filled CFT (CCFT) Columns]

OBJECTIVES

1. Developing an experimental database for creep and shrinkage of CFST under axial and flexural loading conditions, and
2. Investigating the behaviour of CFST beams and columns with different levels of fiber reinforcement

Analysis of structure behaviour on CFST-
Axial Load-Axial Shortening Behavior
Effect of Fiber-Reinforced Polymer (FRP) Confinement
Effect of the Thickness of the Steel Tube
Effect of Concrete Strength
Behavior of Confined Concrete
Lateral Expansion Behavior
Strain Efficiency of FRP Wrap

2. LITERATURE REVIEW

Sr. No	Paper Title	Findings
1	Behavior of FRP wrapped concrete filled steel tubular columns	Experimental results of CFT columns were compared with computed load carrying capacity of the existing design codes.

		Of all the codes compared, DL/T 1999 showed the least variations and is found to be more viable to predict ultimate load carrying capacity of CFT columns. Load strain plots obtained from experimental study reiterate the fact that CCFT columns wrapped with two layers of CFRP showed enhanced strength and ductility compared to other CCFT columns.
2	BEHAVIOR OF CONCRETE FILLED STEEL TUBE (CFST) UNDER DIFFERENT LOADING CONDITIONS	CCFST samples with two different concrete infill compressive strengths of 44MPa and 60MPa and three (/) ratios of 54, 32, and 20 are tested under a loading rate of 60KN/sec. It was noticed that the dominant failure mode is the explosive rapture of the wraps in the mid-height region of the columns.
3	Behavior of FRP-Confined Concrete-Filled Steel Tube Columns	The experimental results indicated that the FRP wrap can effectively confine the concrete expansion and delay the local buckling of the steel tube. Both the load capacity and the axial deformation capacity of concrete-filled steel tube columns can be substantially enhanced with FRP confinement. A model is proposed to predict the load capacity of the FRP-confined concrete-filled steel tube columns.

3. PROPOSED METHODOLOGY

The circular steel tubes were accurately cut and machined to the required length. The insides of the steel tubes were wire brushed, and deposits of grease and oil were removed.

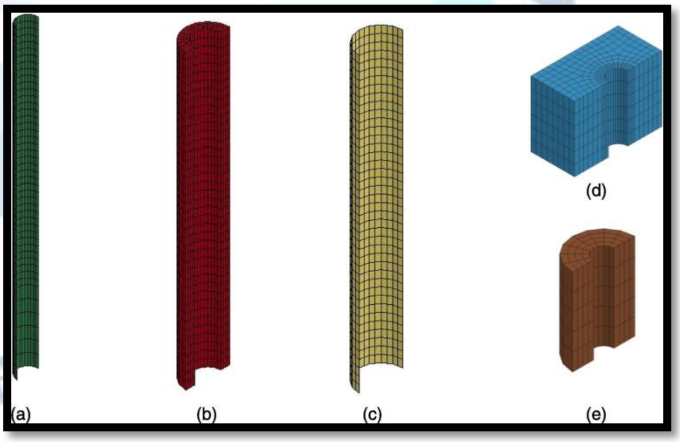
A stiffened end-cap of 10 mm was attached at the base of the steel tube. Concrete was filled in layers and vibrated by a poker vibrator.

The specimens were left to cure in the laboratory for 28 days, and then, the CFRP or GFRP was wrapped. The FRP wrap was formed by using the wet lay-up method with fibers in the hoop direction.

The steel tube surface was first cleaned with alcohol, and then, a single continuous fiber sheet was wrapped around the steel tube to form a wrap with the required number of plies, with the finishing end of the fiber sheet overlapping its starting end by 150 mm.

A paddler roller was used to squeeze out the air bubbles and ensure a uniform bond thickness. Prior to testing, the top surface of the concrete core was roughened with a wire brush, and a thin layer of high-strength cement was poured on the roughened surface.

This procedure was adopted to minimize the effect of concrete shrinkage, so that the steel tube and the concrete core can be loaded simultaneously during testing.



[Fig.4.1: Finite Element Modeling]

Preparation of Specimens-

The circular steel tubes were accurately cut and machined to the required length. The insides of the steel tubes were wire brushed, and deposits of grease and oil were removed. A stiffened end-cap of 10 mm was attached at the base of the steel tube. Concrete was filled in layers and vibrated by a poker vibrator. The specimens were left to cure in the laboratory for 28 days, and then, the CFRP or GFRP was wrapped. The FRP wrap was formed by using the wet lay-up method with fibers in the hoop direction. The steel tube surface was first cleaned with alcohol, and then, a single continuous fiber sheet was wrapped around the steel tube to form a wrap with the required number of plies, with the finishing end of the fiber sheet overlapping its starting end by 150 mm. A paddler roller was used to squeeze out the air bubbles and ensure a uniform bond thickness. Prior to testing, the top surface of the concrete core was roughened with a wire brush, and a thin layer of high-strength cement was poured on the roughened surface. This procedure was adopted to minimize the effect of concrete shrinkage, so that the steel tube and the concrete core can be loaded simultaneously during testing.

Test Setup and Instrumentation-

The tests were conducted using a universal testing machine with a capacity of 5000 kN. The test arrangement for the specimens. The load was applied in increments of 50 kN before peak load. Each load interval was maintained for 2–3 min. The load was slowly applied near and after the maximum load to investigate the post-peak behavior of the columns. Two linear variable differential transducers (LVDTs) were located vertically to measure the axial shortening. For each FCCFST specimen, eight strain gauges were placed on the steel to measure the vertical deformations and perimeter expansion of the steel tube at mid-height, and four strain gauges were mounted to the mid-height of the FRP wrap to observe the lateral confinement, as shown in Figure 1b. The layout of the strain gauges mounted to the steel tube of each CFST specimen was exactly the same as that for the FCCFST specimens. To assure uniform compression, preliminary tests within the elastic range were conducted by carefully adjusting the position of the specimen, based on the measurements of strain gauges attached at the mid-height of the test specimen. The adjustment was terminated until the difference between the measured strain and the average value was no more than 5%.

Axial Load-Axial Shortening Behavior-

The axial load-axial shortening curves for the specimens, in which the axial shortening is the average value of the two LVDTs. The relationships between axial load and axial shortening up to the ultimate state of the specimens can be seen in these figures. For the FCCFST specimens, the ultimate state is defined as the state when the explosive rupture of the FRP wrap occurs at the mid-height region. The load at the ultimate state of the FCFST specimens is the same as their maximum load. The ultimate state for the CFST specimens is defined as the state when the load reaches their maximum load. The initial portion of axial load-axial shortening responses of a FCCFST specimen essentially followed the curve of the corresponding CFST specimen till a characteristic axial shortening was attained, which is the point when the axial load of specimen t4C40 increased up to about 75% of its ultimate load. After attaining the characteristic strain, the axial load-axial shortening relationships of FCCFST specimens show a higher modulus than those of the CFST specimen and eventually exhibited an almost linear behavior until the rupture of the FRP in the mid-height region happened. The experimental results for all specimens. Here, Ny is the axial load when the steel tube yielded; Nf is the axial load when the fracture of the FRP wrap was audible or visible; Nu and δu are the ultimate load and the axial shortening of the specimens at the ultimate state; εf is the maximum hoop strain of the FRP at the ultimate state. As expected, the additional FRP confinement led to enhancements in both load capacity and axial deformation capacity, and the degree of enhancement increased with the increasing of the FRP layer number for both CFCCFST and GFCCFST specimens.

IV. 4. OUTCOMES

• A total of eleven specimens, including seven CFRP-confined concrete-filled steel tube (CFCCFST) specimens, three glass fiber-reinforced polymer (GFRP)-confined concrete-filled steel tube (GFCCFST) specimens and one CFST specimen, were tested under axial load.

• The circular steel tubes were accurately cut and machined to the required length. The insides of the steel tubes were wire brushed, and deposits of grease and oil were removed. A stiffened end-cap of 10 mm was attached at the base of the steel tube. Concrete was filled in layers and vibrated by a poker vibrator. The specimens were left to cure in the laboratory for 28 days, and then, the CFRP or GFRP was wrapped.

- The FRP wrap was formed by using the wet lay-up method with fibers in the hoop direction. The steel tube surface was first cleaned with alcohol, and then, a single continuous fiber sheet was wrapped around the steel tube to form a wrap with the required number of plies, with the finishing end of the fiber sheet overlapping its starting end by 150 mm. A paddler roller was used to squeeze out the air bubbles and ensure a uniform bond thickness.

- Prior to testing, the top surface of the concrete core was roughened with a wire brush, and a thin layer of high-strength cement was poured on the roughened surface. This procedure was adopted to minimize the effect of concrete shrinkage, so that the steel tube and the concrete core can be loaded simultaneously during testing.

ACKNOWLEDGMENTS

The authors would like to express an acknowledgement to the Faculty of Civil Engineering Department and management of V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India, for providing the facilities such as the Structural laboratory and advanced Structural laboratory to accomplish this study. The author also wishes to acknowledge cooperation given by laboratory technician from Faculty of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India, to complete this study.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Lam, L.; Teng, J.G. Strength Models for Fiber-Reinforced Plastic-Confined Concrete. J. Struct. Eng. 2002, 128, 612–623.

[2] [2] Standard Test Method for Tensile Properties of Polymer Matrix Composite Material; ASTM D3039/D3039M-08; American Society for Testing and Materials (ASTM), West Conshohocken, PA, USA, 2006.

[3] [3] Yu, T; Hu, Y.M.; Teng, J.G. FRP-confined circular concrete-filled steel tubular columns under cyclic axial compression. J. Constr. Steel Res. 2014, 94, 33–48.

[4] [4] Liu, L.; Lu, Y.Y. Axial bearing capacity of short FRP confined concrete-filled steel tubular columns. J. Wuhan Univ. Technol. Mater. Sci. Ed. 2010, 25, 454–458.

[5] [5] Dong, J.F.; Wang, Q.Y.; Guan, Z.W. Structural behaviour of recycled aggregate concrete-filled steel tube columns strengthened by CFRP. Eng. Struct. 2013, 48, 532– 542.

[6] [6] Fam, A.; Qie, F.; Rizkalla, S. Concrete-filled steel tubes subjected to axial compression and lateral cyclic loads. J. Struct. Eng. 2004, 130, 631–640.

[7] [7] Samaan, M.; Mirmiran, A.; Shahawy, M. Model of Concrete Confined by Fiber Composites. J. Struct. Eng. 1998, 124, 1025–1031.

[8] [8] Tam, V. W. Y., Wang, Z.-B., and Tao, Z. (2014). Behaviour of recycled aggregate concrete filled stainless steel stub columns. Mater. Struct. 47 (1-2), 293–310. doi:10.1617/s11527-013- 0061-1

[9] [9] Wang, Y., Chen, J., and Geng, Y. (2015). Testing and analysis of axially loaded normalstrength recycled aggregate concrete filled steel tubular stub columns. Eng. Struct. 86, 192–212. doi:10.1016/j.engstruct.2015.01.007