Behavior of Circular CFST Columns with Central Wood Piece Under Biaxial Loading

E.V.V.S.N.Sai Kausik, I.Siva Kishore, N.Sandeep Kumar, Ch. Mallika Chowdary

Abstract: Composite tubular columns have been used widely in the world as they have many outstanding structural properties such as highly compressive strength, large ductility and more energy absorption capacity. Study has been done to delve the behavior of Concrete Filled Steel Tubular (CFST) columns with central wood piece under biaxial loading through experimental results. Parameters such as Bearing Capacity and Deflection are discussed and compared for the specimens with and without central wood piece under biaxial loading. Based on the fundamental Structural Analysis and composite structures, the concept is mainly aimed at the initial behavior and service behavior of composite column. Here, biaxial loading is established by providing the eccentricity in the loading and analyzed the composite section.

Index Terms: Biaxial Loading, CFST, Composite tubular columns, Eccentric loading,Timber infill,Wood Piece.

I. INTRODUCTION

Concrete Filled Steel Tubular (CFST) Columns is a type of hybrid system in which Concrete and Steel act as a Composite member. Composite action between the steel tube and concrete is primarily expected in the transverse direction for a tubed column. Concrete inside the steel tube increases stiffness to the steel tube and prevents it from local buckling. In this type of system, no reinforcement and formwork required as the outer core i.e., Steel tube provides reinforcement properties and acts as formwork, thereby reducing the time and cost of the member.Load capacity of this hybrid member is increased as the concrete is confined inside the steel tube. As steel has high ductility and high strength, CFST Columns acquirefavorable ductility and high energy absorption capacities. In this type of CFST Column, Wood is used as the inner core which reduces the volume of concrete inside the CFST column and to prevent the inward failure of concrete.

Over the past few years, experimental studies have been conducted on the structural behaviour and structural performance of the CFST Columns.The structural behaviour of circular concrete columns with timber infill under axial compressionshowed that timber infill contributes noticeable ductility for these complex structures and solid timber infill counters the inward failure of concrete1. The accuracy of various lateral confining pressure models for sandwiched concrete in circular DCFST columns was examined by comparing Analytical solutions experimentally2.A Numerical Analysis algorithm was developed using Visual Basic and presented the mechanical behavior of short concrete filled steel tubular columns through Analytical studies3. The slender composite section aids composite actions than Stocky sections4whereas that ends of the columns are buckled and middle portion of the column is bulged for the larger diameter tubular columns under the compression5. Confinement mechanism and local buckling can be demonstrated based on Shanley Theory6.

The Thin walled CFST Columns under partial concentric compressive loading behaves as a ductile member for L/D ratio from 4.5 to 6 anda simplified model can predict the bearing capacity of the CFST Columns loaded partially to acceptable extent7. Experimental values are larger than the superposed estimated formulaandthe inner tube in concrete filled double skin tubular column has no influence on the confinement effect of concrete8.Timber and CFRP enhances the capacity-to-weight ratio of the composted member such that the strength of the composite member is approximately the summation of the individual strengths of the two materials9.

II. RESEARCH SIGNIFICANCE

As seen above, circular concrete filled steel tubular columns with central wood piece under biaxial loading have never been investigated in literature. On this basis, the presented work addresses the behavior of composite column under biaxial loading and to study the CFST columns intensively so that behavior can be determined approximately. The main aim was to study how the initial and service behavior was affected by bond strength between the wood piece, concrete core and the steel tube and the effect of eccentricity on the load carrying capacity and deflection.

III. EXPERIMENTAL PROGRAM

This experiment fixates on the behavior of the composite columns due to eccentric loading. Testing procedure for this experiment is conducted on Universal TestingMachine. The ends of the column were restrained and the load was applied. LVDT and displacement meters were fixed to determine the axial displacement according to the load which is applied eccentrically. The Strain gauges were placed at various points such as I, II, III and IV i.e., top, bottom and at the middle of the column.

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E.V.V.S.N. SaiKausik, Master of Technology Student, Civil Engineering Department, Koneru Lakshmaiah Education Foundation, Deemed to be University, Vijayawada, India.

I. Siva Kishore, Assistant Professor,Civil Engineering Department, Koneru Lakshmaiah Education Foundation, Deemed to be University, Vijayawada, India.

N. Sandeep Kumar, Assistant Professor, Civil Engineering Department, Koneru Lakshmaiah Education Foundation, Deemed to be University, Vijayawada, India.

Ch.Mallika Chowdary, Assistant Professor, Civil Engineering Department, Bapatla Engineering College ,Bapatla, Andhra Pradesh, India.

Table I:Material Properties of Specimen

Materials	Description
Yield stress of steel tube	415 MPa
Modulus of elasticity	205GPa
Concrete Compressive strength	36.1MPa
Modulus of elasticity	30.06GPa
Wood orientation	Parallel to grain
Stress grade of Wood	8MPa
Modulus of elasticity	12.5GPa

A. Specimen details

Three different sizes were designed with three specimens for every size and the properties for these tubes are tabulated in Table I. Overall 9 specimens were used for this testing procedure in which for every size of the tube, one of the specimens was cast without wood piece and the remaining two with central wood piece. Wooden pieces taken were of square shape with a minimum of 20mm gap from the inner diameter of the steel tube to the corner of the wood piece such that it allowed the aggregates to fill in this specimen. These tubes were all shaped from a mild steel sheet of 3mm and 4mm thickness in to the required dimensions as shown in the Table II and then each specimen was welded using 3mm arc welding electrodes to the base plates of square shape. For all these specimens, nominal strength of tubes was taken as 415MPa. As shown in the Fig.1 and Fig.2 timber infill was placed in such a way that the axis of the timber infill and the axis of the axis of the composite member coincides. These tubular columns were cast using Self Compacting Concrete with a characteristic compressive strength (f_{ck}) of 36MPa approximately at 28 days considering that the vibrators could not be used to achieve compaction. While casting concrete into these steel tubes, three cubic specimens were cast and cured them all under same conditions.

Fig.1: Casting of CFST Columns

B. Material Properties

The cubes were tested as per standards and the compressive strength and Youngs modulus were found to be 36.1MPa and 30.06GPa respectively. For the properties of steel tube, standard tensile tests were conducted, yield strength and modulus of elasticity were calculated. Here, wood assumed to be a homogeneous material and the strength and modulus of elasticity are taken as 8Mpa and 10GPa after conducting sample tensile and compressive tests.

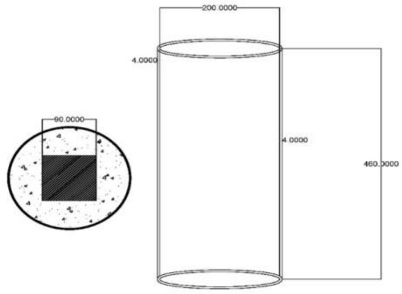

Fig. 2: Geometric Features of specimen

C. Test Setup and Measurements

This experiment was conducted using Universal Testing Machine in the Structural Laboratory of the K L University and this test apparatus shown in Fig.3.

Fig. 3: Universal Testing Machine

Firstly, the specimen is erected on the Universal Testing Machine and the load cell was aligned as per the eccentricity mentioned in Table III and the schematic view of the experimental setup can be seen in Fig.4. In this experiment, different eccentricity values are chosen for the two different e/d ratios.

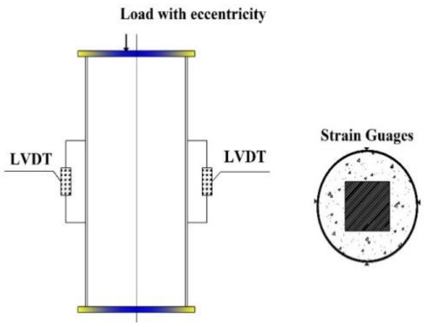

Fig. 4: Schematic view of experimental setup

Due to the shrinkage property of the concrete, steel tube, concrete and wood piece were not in same horizontal plane. To establish steel, concrete and timber to work together, a layer of sand was paved on top surface of the concrete. The graduation scale was calibrated to minimize the percentage of error. The strain values for the corresponding load values were recorded. Fig.4 represents the schematic setup of the specimen on the machine.

The whole experiment was conducted in four stages and the procedure is as follows:

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(1) In the first stage, 10% of the expected ultimate load was taken. The ultimate load was expected which was calculated from the strength of these materials and duration of this stage was about 2-3 min.
(2) In the next stage i.e., elastic and plastic stage 40-50% of the load was taken.
(3) Afterwards loading up to 70 % was applied gradually. Load was applied slowly and gradually in this stage.
(4) Furthermore, load was applied at a rate of 1mm per minute. Application of load was stopped when the ends of the specimen failed due to buckling.

At a certain load after 70% of the ultimate expected load, displacement control was adopted for the loading rate.

Table III: Eccentricity values

Specimen name	Test type	Eccentricity e[mm]	e/d
TCA	without wood piece	8	0.08
TCWTA-1	with wood piece	8	0.08
TCWTA-2	with wood piece	12	0.12
TCB	without wood piece	12	0.08
CWTB-1	with wood piece	12	0.08
TCWTB-2	with wood piece	18	0.12
TCC	without wood piece	16	0.08
TCWTC-1	with wood piece	16	0.08
TCWTC-2	with wood piece	24	0.12

Table II: SpecimenDimensions

Specimen	Diameter D [mm]	thickness t [mm]	Length L[mm]	D/t	square timber infill side [mm]
TCA	100	3	360	33.33	-
TCWTA-1	100	3	360	33.33	40
TCWTA-2	100	3	360	33.33	40
TCB	150	4	410	37.50	-
TCWTB-1	150	4	410	37.50	75
TCWTB-2	150	4	410	37.50	75
TCC	200	3	460	66.67	-
TCWTC-1	200	3	460	66.67	90
TCWTC-2	200	3	460	66.67	90

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this experimental investigation, there is no significant effect on the capacity due to the eccentricity. The region under the loading is in the compression and the other region is in the tension zone. The bond strength between different materials do not have major impact on the capacity for the reason that in this type of composite structures, hoop stress is developed, and the relative slip cannot be seen. The results of the experiment were given in Table IV.

Table IV: Ultimate load and Deflection values

Specimen name	Ultimate load	Ultimate deflection
TCA	1234	7.6
TCWTA-1	1138	7.15
TCWTA-2	1152	7.3
TCB	1777	6.25
TCWTB-1	1574	6
TCWTB-2	1508	6.1
TCC	2365	7.25
TCWTC-1	2057	6.95
TCWTC-2	1876	7.2

A. Ultimate Load

The deviation of the loading capacity of the specimen with 100mm diameter, thickness 4mm and length 360mm with and without wood piece under eccentric loading is shown in the Fig.5. From the above chart, specimen with wood piece has less strength when compared to the one which doesn't have wood piece. The Fig.6 shows the variation of ultimate load of the circular specimen with 150mm diameter and 410mm length. Likewise, the specimens with wood piece in these specimens have the lower ultimate load capacity. Fig.7 represents the ultimate load capacity of the 200mm diameter with 460mm length specimens.

B. Modes of Failure

Slenderness ratio of the three different sizes were small hence these were all short columns. During the first stage, the specimen acts as elastic material and no deflection was observed visually. During the second stage, minor volume expansion in the steel tube was noticed but the axial deformation still not coherent. When it reached 70% of the ultimate load hoop stress was developed in the concrete. In this stage, deflections in the specimens were observed distinctly. During this stage, the one of the ends of the specimen was buckled inwards as the load was applied eccentrically.

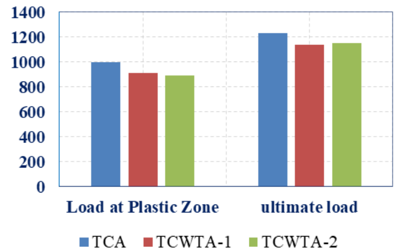

Fig. 5: Load for 100mm diameter specimen

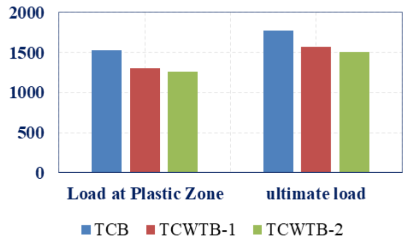

Fig. 6:Load for 150mm diameter specimen

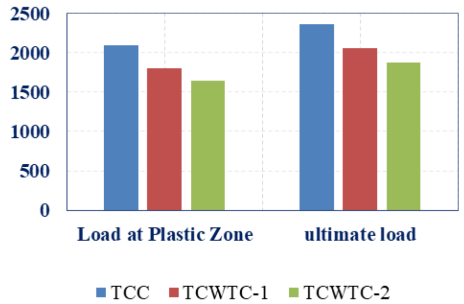

Fig. 7: Load for 200mm diameter specimen

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C. Load-Displacement

Although these specimens were made of different materials such as Steel, Concrete and Timber, it acted as a homogeneous material. Fig.8, Fig.9 and Fig.10 represents the variation of the axial deformation with the load. With the increase in the eccentricity of the load, the axial deformation of the specimen increases. The specimen with wood piece had higher deformation when compared to the other without wood piece.

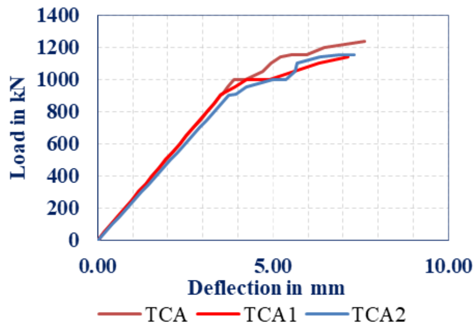

Fig.8:Load-deflection for 100mm diameter specimens

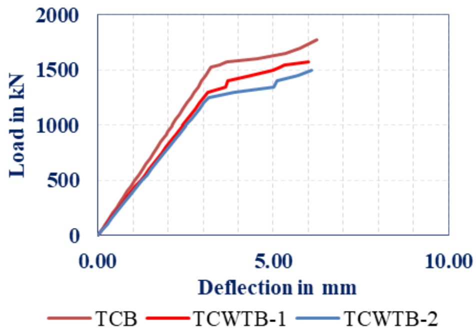

Fig.9: Load-deflection for 150mm diameter specimens

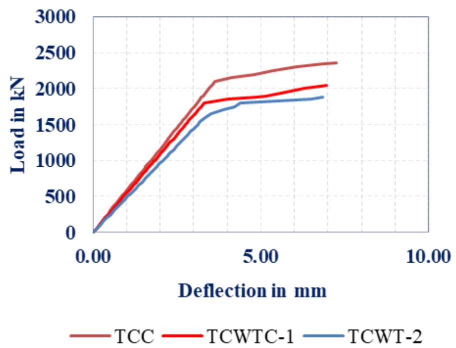

Fig.10: Load-deflection for 200mm diameter specimens

V. COMPARISON WITH TEST RESULTS

Fig.11 shows the disparity of the Strain Energy with the e/d ratio for the different specimens with wood piece. The effect of eccentricity in Strain Energy is least for the smaller diameter when compared to those with larger diameter. For the specimens with less diameter, the effect of e/d ratio in the load carrying capacity is imperceptible also the effective Modulus of Elasticity for the hybrid specimen decreases with the increase of the area of concrete and increases with the thickness of steel tube.

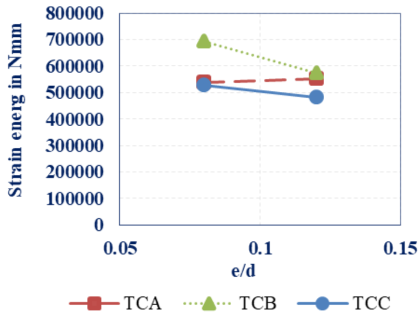

Fig.11: Variation of strain energy with e/d ratio

VI. CONCLUSIONS

In this experiment, Short columns with wood piece and without wood piece were tested under Biaxial Loading. Corresponding to the results obtained in the experiment the following conclusions are obtained:

1) The bearing capacities of the Specimens with and without wood piece obtained experimentally suggests that the discrepancy is below 15%
2) Wood piece in the inner core provides the confinement to the concrete inner wards and can be used as a substituent for the inner steel tube in the Double skin concrete filled steel tubular columns.
3) There is no much disparity in these members due to the eccentricity of the loading within the limit e/d<10
4) Hoop stresses are developed in the middle portion due to the concrete.
5) The steel tube protrudes in middle of the specimen and the ends of the member fails due to buckling.

REFERENCES

1. Ghazijahani, T.G., Jiao, H. and Holloway, D, "Concrete-filled circular steel tubes with a timber infill under axial compression," *Journal of Structural engineering*, Vol. 143, Issue 7, 2017, p.04017037.
2. Liang, Q.Q., "Nonlinear analysis of circular double-skin concrete-filled steel tubular columns under axial compression," *Engineering Structures*, Vol. 131, 2017, pp.639-650.
3. Choi, K.K. and Xiao, Y., "Analytical studies of concrete-filled circular steel tubes under axial compression," *Journal of structural engineering*, Vol. 136, Issue5, 2009, pp.565-573.
4. Hassanein, M.F., Patel, V.I. and Bock, M., "Behaviour and design of hexagonal concrete-filled steel tubular short columns under axial compression," *Engineering Structures*, Vol. 153, 2017, pp.732-748.
5. Zhu, L., Ma, L., Bai, Y., Li, S., Song, Q., Wei, Y., Zhang, L., Zhang, Z. and Sha, X., "Large diameter concrete-filled high strength steel tubular stub columns under compression," *Thin-Walled Structures*, Vol. 108, 2016, pp.12-19.
6. Xiao, Y., He, W. and Choi, K.K., "Confined concrete-filled tubular columns," *Journal of structural engineering*, Vol. 131, Issue3, 2005, pp.488-497.
7. Yang, Y.F. and Han, L.H., "Concrete filled steel tube (CFST) columns subjected to concentrically partial compression," *Thin-Walled Structures*, Vol. 50, Issue1, 2012, pp.147-156.
8. Uenaka, K.,Kitoh, H. and Sonoda, K., "Concrete filled double skin circular stub columns under compression," *Thin-walled structures*,Vol. 48, Issue1, 2010, pp.19-24.

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9. Ghazijahani, T.G., Jiao, H. and Holloway, D., "Rectangular steel tubes with timber infill and CFRP confinement under compression: Experiments," *Journal of Constructional Steel Research*, Vol. 114, 2015, pp.196-203
10. European Committee for Standardization, Eurocode 4: Design of Composite Steel and Concrete Structures, CEN, 1994.

AUTHORS PROFILE

Mr.E.V.V.S.N. Sai Kausik is student of Master of Technology in Structural Engineering from KoneruLakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India. He has completed Bachelor of Engineering in Civil Engineering from Andhra University, Visakhapatnam, Andhra Pradesh, India in 2015. His research interests include Composite Structures and Modern Concrete Materials.

Mr. I. Siva Kishore is working as Assistant Professor in Department of Civil Engineering at KoneruLakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India. He has completed Master of Technology in Structural Engineering from Birla Institute of Technology, Mesra in 2014 and Bachelor of Engineering in Civil Engineering from Andhra University, Visakhapatnam, Andhra Pradesh, India in 2011. He awarded scholarship from TEQUIP, Government of India to pursue post-graduation. His research interests include Composite Structures, Repair and strengthening of concrete structures using traditional materials and fiber reinforced polymers (FRP). He has published 15 Scopus Indexed research papers in international journals and conferences and guided 5 number of masters and 13 number of bachelor's dissertation work. He is a member of Editorial Board, EPHP Journal (International Journal of Science and Engineering ISSN: 2454 - 2016) and IAME Publications (International Journal of Civil Engineering and Technology IJCIET), Reviewer of SSRJ International Journal of Civil Engineering (SSRJ-IJCE) and Board member of SSRJ International Journal of Engineering and Technology (SSRJ-IJETT).

Mr. N. Sandeep Kumar is working as Assistant Professor in DepartmentofCivilEngineering at KoneruLakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India. He has completed Master of Technology in Geotechnical Engineering from Andhra University, Visakhapatnam Andhra Pradesh, India in 2016 and Bachelor of Engineering in Civil Engineering from IIIT Nuzvid, Andhra Pradesh, India in 2014. He awarded scholarship from MHRD, Government of India to pursue post-graduation. His research interests include composite structures, Ground Improvement Techniques and Slope Stability Analysis. He has guided 5 number of bachelor's dissertation work. He is a Life time member of International Society for Research and Development (ISRD) and member of International Association of Engineers.

Mrs. Ch. Mallika Chowdary is working as Assistant Professor in Departmentof CivilEngineering at SRK Institute of Technology, Vijayawada, Andhra Pradesh. She has completed Master of Technology in Structural Engineering from Bapatla Engineering College, Bapatla, Andhra Pradesh, India in 2013 and Bachelor of Technology from Bapatla Engineering College, Bapatla, Andhra Pradesh, India in 2011. Her research interests include Composite Structures, Repair and strengthening of concrete structures using traditional materials and fiber reinforced polymers (FRP) and Earthquake Engineering. She has published 12 research papers in international journals and conferences and guided 5 number of masters and 13 number of bachelor's dissertation work.