Behaviour of CFST Column Element with & Without Shear Studs under Axial Compression

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Abstract – ***In recent times, engineers have increasingly utilized composite members of concrete-filled steel tubes (CFSTs) in modern projects such as buildings and bridges. Concrete Filled Steel Structures (CFST) offers wide benefits like high strength, ductility, energy absorption with the combined benefits of steels and concrete. It also reduces the time consumption in constructing since it doesn't require shuttering works hence they are frequently used. Moreover, the CFST members are more economical and allow for rapid construction and cost savings by eliminating formwork and workmanship. Concrete filled steel tube is gaining more popularity now days in construction area. Concrete filled steel tube is component with good performance resulting from the confinement effect of steel with concrete and design versatility need. This Paper present a review the behavior of CFST comparing the models with & without shear studs differentiating position of shear studs. The composite actions of steel and concrete to occur there need a strong bond between steel and concrete interface. In the present study, it mainly focuses on design load carrying capacity of CFST using Euro code and Indian code &compares it with the analytical & experimental result. Analysis of CFST column using the Finite element method (ABAQUS) software and the experimental study is done on the selected case under concentric loading condition.***

Keywords: *CFST column, Finite Element (ABAQUS)*

1. INTRODUCTION

Concrete-filled steel tube (CFST) members are composite structures which evolved on the basis of the hollow steel tube (HST). For the hollow steel tube, local buckling of the flange may occur when the width-to-thickness ratio (B/t) is larger than a certain value. Thus, the plastic bending moment of an HST beam may not be achieved or maintained. Filling concrete is an efficient way to prevent local buckling and to enhance performance of HST beams. Although the filling concrete would increase the dead weight to a certain level, it is still considered an efficient way to enhance strength, stiffness and ductility of HST members. It proved that the increase in rotation angles of CFST members at ultimate moment can be three times larger than that of HST beams. CFST members can provide an excellent seismic resistance in two orthogonal directions as well as show good damping characteristics. They also show an excellent hysteresis behavior under cyclic loading when compared with HST tubes. CFST members have been used in tall structures and in retrofitting damage bridge piers. The use of CFST members in moment resisting frames eliminates the need for additional stiffness elements in panel zones and zones of high strain demand. Bridges with CFST members are expected to reduce noise and vibration levels when compared to ones with pure steel members. Moreover, CFST members have been proven to be cost effective in building structures.

The example of Aurora pedestrian arch bridge does demonstrate that the CFST is an appealing modular system and is easy to fabricate and erect. Many research efforts on the compressive behavior of CFST have been carried out in the past decades, however, the flexural performance of CFST is still very limited. It found that the flexural capacity of CFSTs was increased by 49% compared to the bare steel tube beam. Bridge also observed that the core concrete can provide approximately 7.5% more bending capacity than the hollow steel section. After these earlier studies, investigations were mainly focused on the depth-to-width ratio, shear span-to-depth ratio, and width-to-thickness ratio. Similarly, a favorable post-yield behavior of CFST member was reported. The distinguishing feature of ductile collapse and smooth loading process was further studied based on the unified theory. Finite element method, simplified analytical method and cross-sectional fiber analysis were proposed to predict the stiffness and bending strength. Found that the static strength of CFST member was significantly influenced by cyclic loading. Although previous studies have proved that the CFSTs had outstanding strength capacity, ductility, and seismic performance, the noted that the composite bending stiffness of CFST was similar to the theoretical stiffness of the bare steel tube due to the concrete cracking, also found that the concrete cracking in tension zone in the early loading stage would significantly decrease the ultimate capacity to a value extremely close to the stiffness of bare steel section.

It may be noted here that mechanical and economical benefits can be achieved if CFST columns are constructed taking advantages of high-strength materials. For example, high-strength concrete infill contributes greater damping and stiffness to CFST columns compare to normal strength concrete. Moreover, high-strength CFST columns require a smaller cross-section to withstand the load, which is appreciated by architects and building engineers. New developments, including the use of high strength concrete and the credit of the enhanced local buckling capacity of the steel has allowed much more economical designs to evolve. The main economy achieved by using high strength concrete in thin steel casings is that the structural steel cost is minimized and the majority of the load in compression is resisted by the high strength concrete .However, bare steel or reinforced concrete columns are still used more extensively than CFSTs due to the lack of knowledge and experience that Engineers have with CFST structural systems.

2. LITERATURE REVIEW

2.1 Compressive behavior of circular concrete filled steel tubes

This paper presents an experimental study to investigate the compressive behavior of circular concrete filled steel tubes (CFSTs) when subjected to pure axial loading at a low rate of 0.6 kN/s. CFSTs of three different diameter-to-thickness (D/t) ratios of 54, 32, and 20 are measured in this study filled with two concrete's compressive strengths of 44 MPa and 60 MPa. The measured compressive axial capacities are compared to their corresponding theoretical values predicted by four different international codes and standards: the American Institute of Steel Construction (AISC), the American Concrete Institute (ACI 318), the Australian Standard (AS), and Eurocode Result comparisons also included some recommended equations found in the literature. It was found that the effect of (D/t) ratio on the compressive behavior of the CFST specimens is larger than the effect of the other factors. The underestimation of the axial capacities calculated by most of these codes reduces as the D/t ratio increases as verified by the experimental results. A nonlinear finite element (FE) numerical model using the commercial software package ABAQUS is also developed and verified using the presented experimental results.

2.2 Effect of carbon fibre reinforced polymer

In this study author has described, numerical simulations are carried out to evaluate the effect of carbon fiber reinforced polymer (CFRP) strengthening of full scale concrete-filled steel tubular (CFST) columns under vehicular impact. In recent years, the risk of damage or failure of axial load bearing structural members has increased rapidly due to increase of accidental vehicle/ship collision events. Therefore, suitable strengthening technique requirements to be developed to minimize the casualty and economic loss caused by vehicular collisions with structural columns. In this study, numerical simulations are carried out to evaluate the effect of carbon fiber reinforced polymer (CFRP) strengthening of full scale concrete-filled steel tubular (CFST) columns under vehicular impact. Numerical models of bare and CFRP strengthened CFST columns were first developed and validated in a recent study of the authors. The validated finite element (FE) models are extended to full scale columns. Realistic vehicle behaviour is simulated with simplified mass spring vehicle model. The outer diameter of steel section is kept same and the wall thicknesses are changed to account the slenderness effects of hollow steel sections. Both vehicle and column deformations are considered during the impact simulation as observed in practical situation. The dynamic impact study results show that adhesively bonded CFRP sheets provide enhanced impact resistance capacity of strengthened columns by reducing lateral displacement about 40% compared to ordinary CFST columns. A comprehensive parametric study is conducted by varying the vehicle velocity, vehicle mass, axial static loading, vehicle stiffness and CFRP bond length to examine the effects of these parameters on the structural responses of bare and wrapped columns. CFRP wrapping is found to be a promising strengthening technique to control global failure of full scale CFST columns subjected to vehicular impact.

2.3 EI of columns

This paper assessed and compared the EI of columns constructed with two concrete types (CFST and RC) and three cross sections (circular, rectangular and square) under different combinations of compression and bending. To better understand the environmental performance of columns and assist construction designers in achieving a balance between structural requirements and environmental safety, The BEPAS model categorized the columns' EI into two safeguard areas-ecosystem and natural resources, and then expressed the impacts using the EIV index in unit of "yuan". Based on the assessment results and M-N interactive curves, M-N-EI interactive curves were developed to present the EI of columns under various combinations of axial force (N value) and bending moment (M value). Thus, structural performance and environmental performance can be shown in a single figure to conveniently contribute decision-making. The M-N-EI interactive curves were also compared to optimize choices of environmentally friendly concrete types and cross-sections to satisfy structural bearing capacity requirements. Furthermore, the influences of various parameters, the H/B of rectangular columns, steel ratio of RC columns, steel strength, steel recycling rate and solid waste recycling rate, were analyzed. An engineering scenario was served as a case study to test the application and operation of the assessment methodology and M-N-EI interactive curves. The results indicate that the new curves can effectively express the EI of columns under different combinations of compression and bending and can potentially be used by the construction industry to achieve environmental goals and provide clear implications for practice.

2.4 Concrete filled steel tubular (CFST) columns.

This paper deals with the prediction of the initial rotational stiffness and moment resistance of bolted endplate joints between I-beams and hollow or concrete filled steel tubular (CFST) columns. A wide numerical analysis was carried out on a wide range of configurations of hollow and CFST columns subjected to transverse forces. Based on numerical simulation results, the stiffness models for the 'column side walls in tension and compression' and 'column face in bending' which is the most deformable part within a joint were proposed. The proposed models were then incorporated into the component method adopted in EC3 and EC4 to predict the initial rotational stiffness and moment resistance of bolted endplate joints. The obtained predictions were compared with the experimental results of 44 available tests to verify the validity of the proposed models. The comparison of results indicated that the proposed models are more reliable than the existing ones and thus could be incorporated into EC3 and EC4 guiding principle for the design of bolted endplate joints with hollow or CFST sections.

2.5 Proposed an innovative frame structure

This paper proposed an innovative frame structure composed of concrete-encased steel beams and concrete encased concrete filled steel tube (CFST) columns for long span building, and two one-bay and one-storey specimens were tested under lateral low cyclic loading. The testing process, such as cracks developments and failure patterns were observed, and the seismic performance such as hysteretic behavior, skeleton curves, rigidity degradation, energy dissipation, and residential deformation were investigated. Additionally, the strain variations for longitudinal bars, flanges of H-shaped steel and steel tube in potential zone of the plastic hinges of beams and columns were analyzed. The test results indicated that two specimens both behaved perfect energy dissipation and ductility even prestressed; and the initial cracks of prestressed specimen was restrained and appeared later than that of un prestressed one due to the prestressing effects; otherwise, during the whole loading the circular strains of steel tubes in the bottom of columns varies unevenly, and steel tubes in compressive zone could supply effective constraint on corresponding concrete. According to the strain variations, the sequence of plastic hinges of the two specimens presented that they occurred on the beam ends firstly and then on the bottoms of columns and mechanism of energy dissipation for beam plastic hinges and a delayed occurring of plastic hinges on column bottom were expected.

3. MATERIAL AND METHODOLOGY

3.1 Design steps using Erocode 4 (EC4)

The design of composite columns and composite compression members with concrete fully and partially encased H-sections, and concrete filled rectangular and circular hollow sections. It is applicable to columns and compression members with steel all grades and normal weight concrete of strength classes.

In general, a composite column should be checked at the ultimate limit state for:

- Geometric limits of various elements of the steel sections against local buckling under compression.
- Resistances of cross-sections and members to internal forces and moments.
- Buckling resistance of the members, depending on their effective slenderness.
- Local resistances to interfacial shear forces between the steel sections and the concrete.
- Local resistances of the cross-sections at load introduction points.

3.2 Design methods

The code gives two methods for isolated composite columns in braced or non-sway Frames:

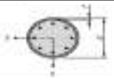
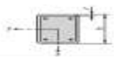
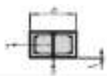
- General design method for composite columns applicable to both prismatic and non-prismatic members with either symmetrical or non-symmetrical cross-sections.
- Simplified design method specifically developed for prismatic composite columns with doubly symmetrical cross-sections.

The use of the simplified design method is presented in detail. It should be noted that when the limits of applicability of this method are not satisfied, the general design method should be used.

3.3 Local buckling

The effects of local buckling may be neglected for a steel section fully encased and for other types of cross-section provided the maximum values are not exceeded:

Table -1: Sample Table format Maximum Values (D/T), (H/T) and (B/T) With Fy N/Mm²

Cross Section		Max (d/t), max(h/t) & max(b/t)
Circular hollow steel section		$Max\ (d/t) = 90\frac{235}{f_y}$
Rectangular hollow steel sections		$Max\ (h/t) = 52\sqrt{\frac{235}{f_y}}$
Partially encased I sections		$Max\ (b/t_f) = 44\sqrt{\frac{235}{f_y}}$

4. RESULTS AND ANALYSIS

4.1 Analytical Load Carrying Capacity

Table-1: Load carrying capacity of circular section (KN)

Sr. No	Outer Dia (D) in mm	Thickness (t)	Inner Dia (d) in mm	Length	Load carrying capacity (KN)
1	80	4	72	600	357.59
2	80	4	72	650	472.66
3	80	4	72	700	296.43
4	80	4	72	750	858.09

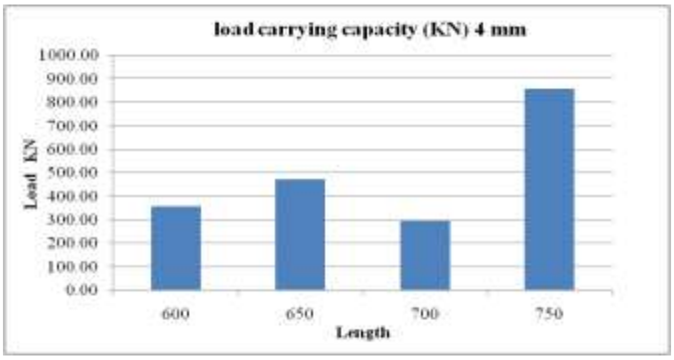


Chart -1: Name of the chart Load carrying capacity of circular section (KN)

The chart 1 shown that load carrying capacity of circular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the circular section of concrete filled steel tube column is 858.09 KN and minimum load carrying capacity of the circular section of concrete filled steel tube column is 296.43 KN

Table-2: Load carrying capacity of circular section (KN)

Sr. No	Outer Dia (D) in mm	Thickness (t)	Inner Dia (d) in mm	Length	load carrying capacity (KN)
1	80	3	74	600	360.89
2	80	3	74	650	327.70
3	80	3	74	700	301.70
4	80	3	74	750	269.72

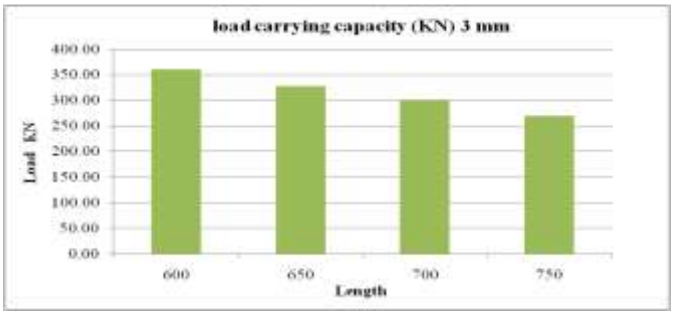


Chart -2: Load carrying capacity of circular section (KN)

The chart 2 shown that load carrying capacity of circular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the 600 mm circular concrete filled steel tube column is 360.89 KN and minimum load carrying capacity of the 750 mm circular section of concrete filled steel tube column is 269.72 KN

Table-3: Load carrying capacity of circular section (KN)

Sr. No	Outer Dia (D) in mm	Thickness (t)	Inner Dia (d) in mm	Length	load carrying capacity (KN)
1	80	2	76	600	347.81
2	80	2	76	650	299.55
3	80	2	76	700	235.08
4	80	2	76	750	236.20

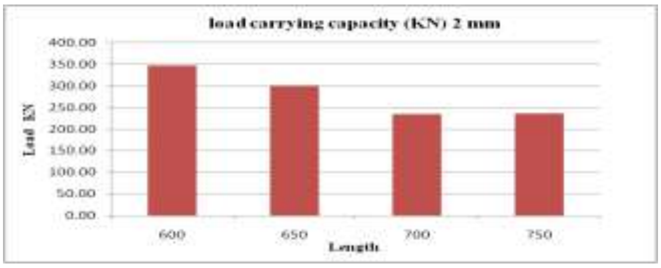


Chart -3: Load carrying capacity of circular section (KN)

The chart 3 shown that load carrying capacity of circular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the 600 mm circular concrete filled steel tube column is 347.81 KN and minimum load carrying capacity of the 700 mm circular section of concrete filled steel tube column is 235.08 KN

Table-4: Load carrying capacity of rectangular section (KN)

Sr. No	Longer Dim D in mm	Thick ness (t)	Shorter Dim B in mm	Length	load carrying capacity (KN)
1	80	2	40	600	207.79
2	80	2	40	650	176.25
3	80	2	40	700	155.77
4	80	2	40	750	140.35

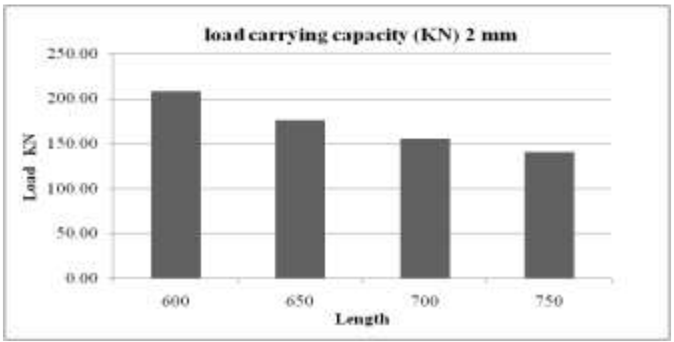


Chart -4: Load Carrying Capacity of Rectangular Section (KN)

The chart 4 showed that load carrying capacity of rectangular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the 600 mm circular concrete filled steel tube column is 207.79 KN and minimum load carrying capacity of the 750 mm circular section of concrete filled steel tube column is 140.35 KN

Table-5: Load carrying capacity of rectangular section (KN)

Sr. No	Longer Dim D in mm	Thicknes s (t)	Shorter Dim B in mm	Leng th	load carrying capacity (KN)
1	80	3	40	600	676.62
2	80	3	40	650	163.61
3	80	3	40	700	189.63
4	80	3	40	750	248.62

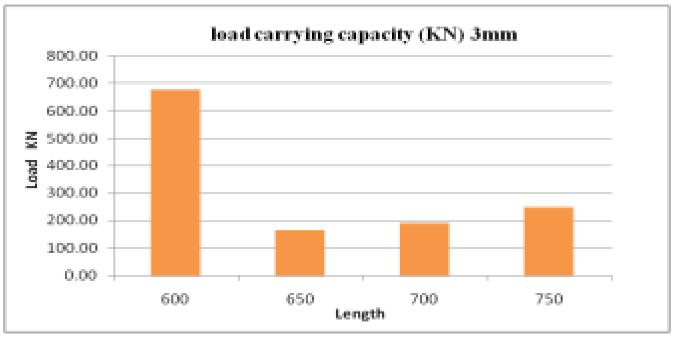


Chart -5: Load Carrying Capacity of Rectangular Section (KN)

The chart 5 showed that load carrying capacity of rectangular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the 600 mm circular concrete filled steel tube column is 676.72 KN and minimum load carrying capacity of the 650 mm circular section of concrete filled steel tube column is 163.61 KN

Table-6: Load Carrying Capacity of Rectangular Section

Sr. No	Longer Dim D in mm	Thick ness (t)	Shorter Dim B in mm	Length	load carrying capacity (KN)
1	80	4	40	600	458.20
2	80	4	40	650	253.10
3	80	4	40	700	354.00
4	80	4	40	750	256.30

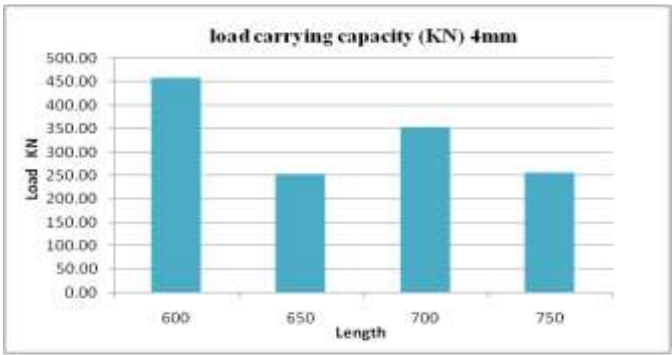


Chart -6: Load Carrying Capacity of Rectangular Section (KN)

The chart 6 showed that load carrying capacity of rectangular concrete filled steel tube column. The result is obtained for Maximum load carrying capacity of the 600 mm circular concrete filled steel tube column is 458.20 KN and minimum load carrying capacity of the 650 mm circular section of concrete filled steel tube column is 253.10 KN

5. CONCLUSIONS

The study of analytical behaviour of concrete filled steel tubular columns of different cross-sections with and without shear connectors (circle, rectangle) using ABAQUS. Experiments were also conducted selecting circular type with and without shear connectors..The axial load capacities of CFST columns with concrete of compressive strength 20 Mpa have been studied. The steel tube used was of grade Fe 250.The proposed study comprised the evaluation of ultimate axial load capacity The proposed study can be used to predict the ultimate axial load capacity of CFST column. The influence of spacing of shear connectors has also been included in this study.

The behavior of concrete filled steel tube columns provided with and without shear studs has been studied in respect of load carrying capacity and reduction of local buckling. The variation in load carrying capacities as obtained by software analysis is as given below:

a. The circular CFST column are optimized section 750 mm length and 80 mm diameter in circular concrete filled steel tube columns with and without shear studs analyzed in which the optimized section is 750 mm length, 4 mm thickness, outer diameter 80 mm and inner diameter 40 mm of section load carrying is 858.09 KN

b. The rectangular CFST column are optimized section 750 mm length and 80 mm diameter in circular concrete filled steel tube columns with and without shear studs analyzed in which the optimized section is 600 mm length, 3 mm thickness, outer diameter 80 mm and inner diameter 40 mm of section load carrying is 676.62KN

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