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Study On Concrete Filled Steel Tube

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Abstract: *The present study is an attempt to understand the behavior of Concrete filled steel tubular column under axial load. A concrete-filled steel tubular (CFST) column is formed by filling a steel tube with concrete. It is well known that concrete-filled steel tubular (CFST) columns are currently being increasingly used in the construction of buildings, due to their excellent static and earthquake-resistant properties, such as high strength, high ductility, large energy absorption capacity, bending stiffness, fire performance along with favorable construction ability etc. Recently, the behavior of the CFST columns has become of great interest to design engineers, infrastructure owners and researchers, therefore to understand the load deformation characteristics of composite columns critically, numerical finite element analysis using software package ANSYS is carried out in this paper. This paper focuses on modeling of concrete filled steel tube (CFST) column under axial loading.*
Keywords - *Ansys workbench, Concrete filled steel tube*

I. Introduction

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 multi storey buildings as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required. There are a number of different advantages related to such structural systems in both terms of structural performance and construction sequence. The inherent buckling problem related to thin-walled steel tubes is either prevented or delayed due to the presence of the concrete core. Furthermore, The Performance Of The Concrete In-Fill Is Improved Due To Confinement Effect Exerted By The Steel Shell. The Distribution Of Materials In The Cross Section Also Makes The System Very Efficient In Term Of Its Structural Performance. The Steel Lies At The Outer Perimeter Where It Performs Most Effectively In Tension And Bending. It Also Provides The Greatest Stiffness As The Material Lies Farthest From The Centroid.

The Models Developed In This Study Will Be Used In Future Research To Investigate The Interface Bond Of The Composite Sections. Research Will Proceed With The Use Of Contact Elements Located At The Interface Of The Two Materials. Once Theoretical Values Can Be Matched, The Effects Of Varying The Point Of Load Application Will Be Studied. Models Will Be Analyzed For Loading Of The Entire Cross-Section. Due To Limited Processing Capabilities, Symmetry May Be Utilized On Future Models To Allow For Smaller Element Sizes Along The Length Of The Tube. Some Elements In The Models Used In This Study Violated Shape Warning Limits. Reducing The Aspect Ratio Of The Elements May Increase The Accuracy Of The Models. The Scope Of This Study Was To Develop Finite Element Models That Accurately Predict Accepted Theoretical Capacities Of Hollow And Concrete Filled Tubular Columns. The Models Developed In This Study Will Be Modified In Future Research To Look Specifically At The Bond Behaviour At The Steel-Concrete Interface.

II. Brief Description of Software Used

Finite element method considers to be the best tool for analyzing the structures recently, many software’s uses this method for analyzing and designing. The most popular and the easiest to learn is Ansys Workbench software, it combines the strength of our core product solvers with the project management tools necessary to manage the project workflow. In Ansys Workbench, analyses are built as systems, which can be combined into a project. The project is driven by a schematic workflow that manages the connections between the systems.

III. Methodology

3.1 Material Specification

Steel: Young's Modulus E=200Gpa, Poisson's Ratio μ=0.3, Density P=7800kg/m^3.
Concrete: Young's Modulus E=25000Mpa, Poisson's Ratio μ =0.16 Density p=2400kg/m^3

3.2 Element Type and Meshes

For concrete simulation, it's been used the element solid 65, SOLID 65 is used for the three-dimensional modelling of solids with or without reinforcing bars (rebars). The solid is capable of cracking in tension and crushing in compression. For steel tubes simulation element shell 181 been used for that purpose, SHELL181 is suitable for analyzing thin to moderately-thick shell structures.

3.3. Boundary Conditions

For each of the two ends, two different types of boundary conditions were used. At the bottom end fixed, displacement degrees of freedom in 1, 2, 3 directions (U1, U2, U3) as well as rotational degrees of freedom in 1, 2, 3 directions were restrained to be zero. At the top end is roller support movable end rotational degrees of freedom are free and translation U2 is free remaining U1, U2 are restrained

3.4 Theoretical Buckling Analysis

Steel tube or columns are usually thought of as straight vertical members whose lengths are considerably greater than their cross-sectional dimensions. An initially straight tube or column, compressed by gradually increasing equal and opposite axial forces at the ends is considered first. When the applied loading is increased, the buckling deformation also increases. Buckling occurs mainly in members subjected to compressive forces. If the member has high bending stiffness, its buckling resistance is high. Also, when the member length is increased, the buckling resistance is decreased

3.5. Buckling Of an Ideal Column or Tube

The classical Euler analysis of this problem makes the following assumptions.
- The material of which the strut is made is homogeneous and linearly elastic (i.e. it obeys Hooke's Law).
- The column is perfectly straight and there are no imperfections.
- The loading is applied at the centroid of the cross section at the ends

Columns are analyzed by Euler Formula:
Critical Load, $Pcr = \pi^2 EI / Le^2$
Model was verified with the theoretical Euler critical buckling load formula.

IV. Analysis of Hollow Steel Tubes

The results for the 5 hollow section tests are summarized in TABLE 1.

Table 1. Buckling of Hollow Steel Tube Section

Diameter (mm)	Thickness (mm)	Slenderness Ratio(mm)	Ultimate Load (kN) by FEM	Buckling Load (kN) by Theoretical
42.4	2.9	45	43.196	43.009
42.4	2.9	60	24.342	24.193
42.4	2.9	75	15.595	14.842
42.4	2.9	100	8.999	8.421
42.4	2.9	125	5.6235	5.234

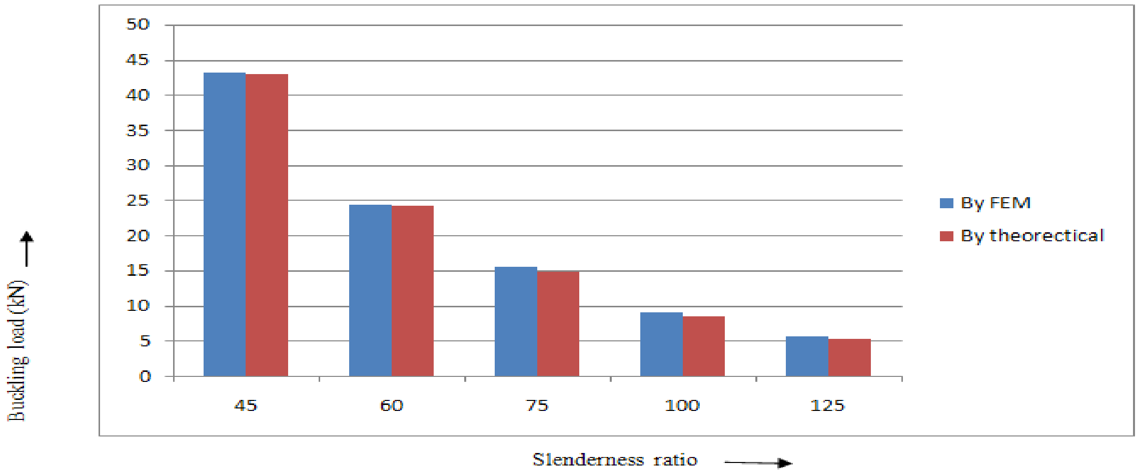

Fig.1. Buckling load of hollow steel tube v/s slenderness ratio

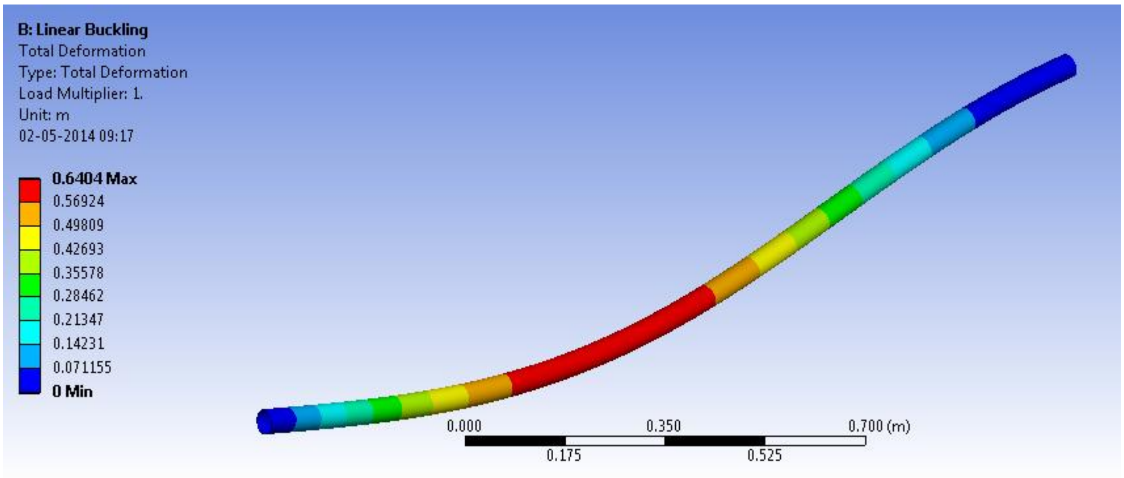

Fig.2. Deformation of hollow steel tube

V. Analysis of concrete filled steel tube

The results for the 5 concrete filled sections tests are summarized in TABLE 2.

Table 2. Buckling of Concrete Filled Steel Tube Section

Diameter (mm)	Thickness (mm)	Slenderness Ratio(mm)	Buckling Load (kN) by FEM	Buckling Load (kN) by Theoretical
42.4	2.9	45	1011.5	1010.30
42.4	2.9	60	570.47	569.42
42.4	2.9	75	365.54	364.82
42.4	2.9	100	205.8	205.71
42.4	2.9	125	131.67	131.31

All tests show close agreement with the theoretically calculated value; the largest variance between experimental and expected capacity is 1%.

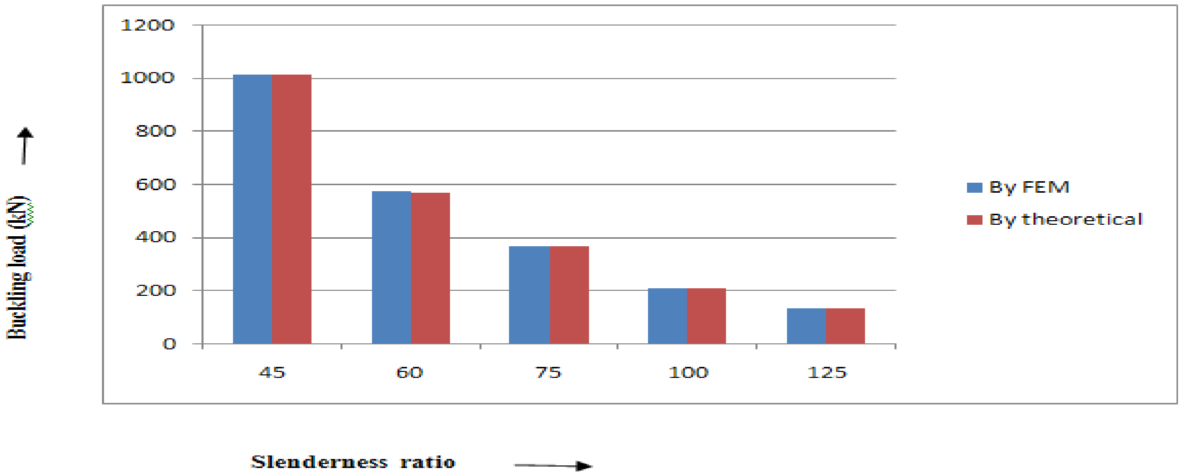

Fig.3. Buckling load of CFST v/s slenderness ratio

In this analysis low slenderness ratio specimen getting high buckling load and high slenderness ratio specimen getting low buckling load. From the above table, it is clear that the stresses are very high in the small slenderness ratio of CFST and the stresses are very less in the high slenderness ratio of CFST. The results show the Hollow Tube buckling load carrying capacity less compared to the CFST buckling loads.

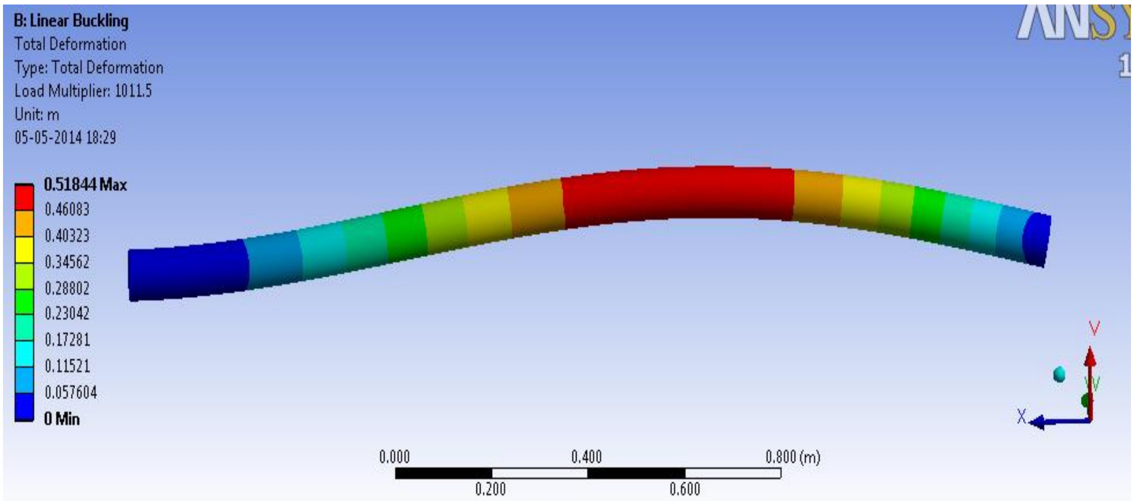

Fig.4. Deformation of concrete filled steel tube

VI. Analysis Of Short Column

A total of 5 concrete- filled steel tubes short columns were loaded and different thickness of 7 mm, 8.3mm, 8.9mm, 9.6mm and 4 mm were adopted for modelling the section. The total deformation, maximum stress and minimum stress were extracted. Also create 5 ordinary column with the same dimensions and done the same procedure.

Table 3. Deformation Of CFST And Ordinary Short Column

Sl no.	Diameter (mm)	Thickness (mm)	Length (mm)	D/T	L/D	Total Deformation of CFST(mm)	Total Deformation Of Ordinary Column(mm)
1	630	7	1890	90	3	1.823×10^{10}	1.963×10^{10}
2	720	8.3	2160	86.7	3	1.590×10^{10}	1.80×10^{10}
3	820	8.9	2460	91.8	3	1.404×10^{10}	1.740×10^{10}
4	1020	9.6	3060	105.8	3	1.142×10^{10}	1.412×10^{10}
5	89.3	4	270	22.3	3	1.027×10^{10}	1.37×10^{10}

Total deformation of CFST short column is less compared with ordinary column. But we couldn't see much variation like long column. From this we clear that CFST is less advantageous to short column

VII. Study on Circular and Square CFST

This section focuses on modelling of CFST column under axial loading. The main parameters of FEA are circular and square column with varying grades of concrete.

For the parametric study, it is necessary that area of concrete and steel tube in circular and square CFST column is made same for exact comparison. For that, outer width of square section is reduced to 177 mm as well as thickness of the steel tube is reduced to 6.2 mm in square column.

Table 4.Details of the Model

Dimension	**Type of Column**	
	Circular Column	***Square Column***
Outer Dimension (D) mm	200	177
Inner Dimension (d) mm	186	164.6
Thickness of Steel Tube (t) mm	7	6.2
Length of Column (L) mm	2000	2000
Grade of Steel (f_y) N/mm^2	350	350

VIII. Deformation behaviour of Circular and Square CFST

Figure 5 and figure 6 shows the deformation behaviour of circular and square CFST column under axial loading 4000kN. Table 2 illustrates the load versus deformation relationship of circular as well as square CFST member for grade of concrete 30 N/mm^2 under axial compression. Figure 4 shows the deformation of circular and square column for axial loading 4000kN for different grade of concrete 30, 50, 70 and 90 N/mm^2.

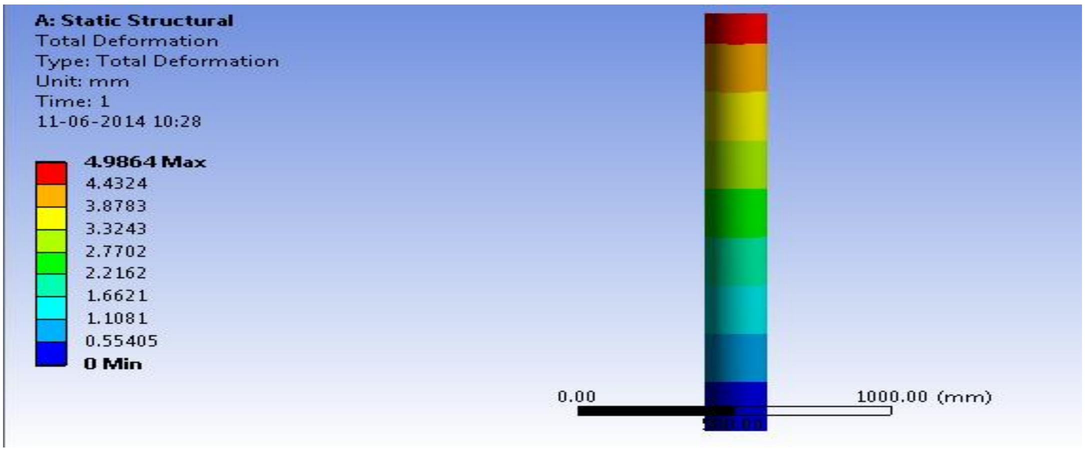

Fig.5. Deformation of Circular CFST

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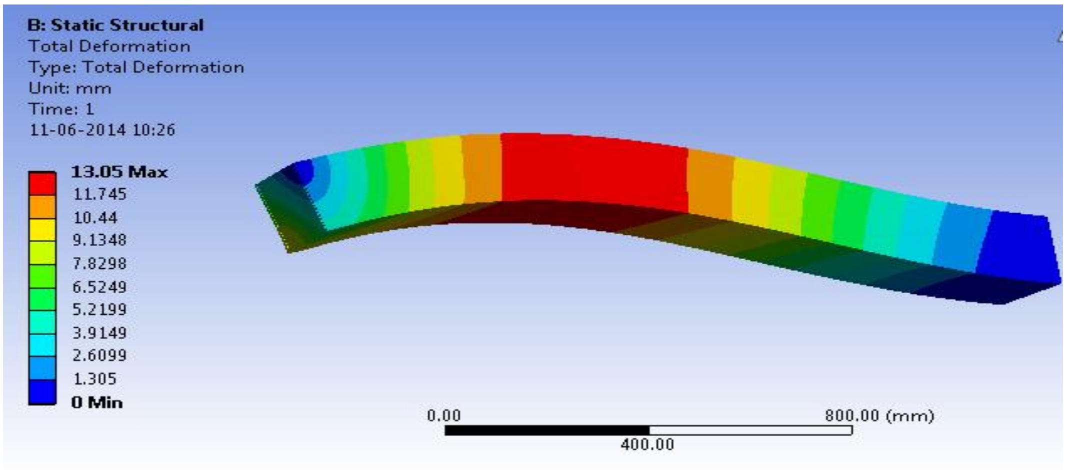

Fig.6. Deformation of Square CFST

Table.5. Deformation Behaviour of CFST

Load (kN)	Deformation (mm)	
	Circular Column	*Square Column*
1000	1.246	3.262
2000	2.493	6.525
3000	3.739	9.787
4000	4.986	13.05
5000	6.233	16.312

The above table shows deformation characteristics of 5 circular concrete filled steel tubes and 5 square concrete filled steel tubes under different loading.

Table.6. Deformation For Different Grade Of Concrete

F_{ck} (N/mm^2)	Deformation (mm)	
	Circular Column	*Square Column*
30	4.98	13.05
50	3.98	9.87
70	3.56	6.52
90	2.49	6.12

The above table indicates that the deformation of circular and square concrete filled steel tubular column under different grade.

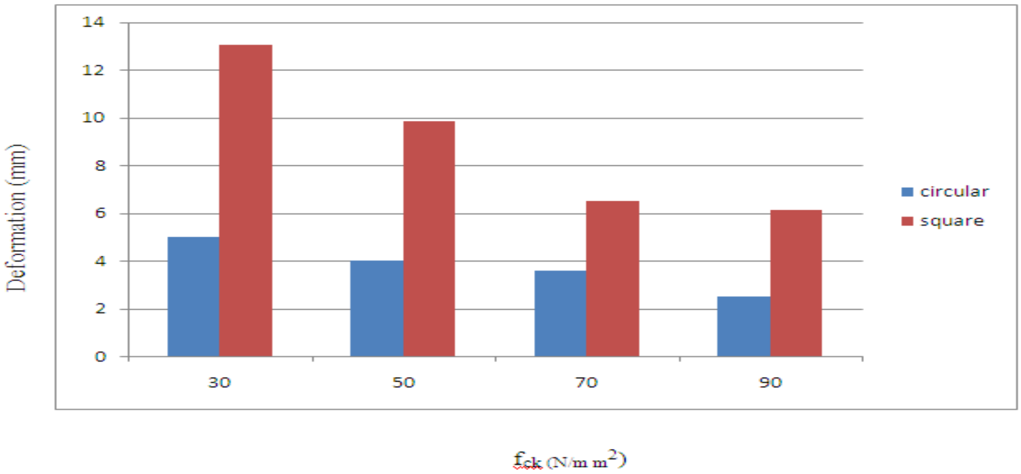

Fig.7. Deformation for Different Grade of Concrete

It was found that, deformation in a circular CFST column is less than Deformation in Square CFST column. Less Deformation in circular section is due to higher moment of inertia and confining effect. Initially the load versus deformation behavior is linear, but later it attains ductility. Deformation decreases with increasing grade of concrete. For Axial load, deformation in circular section is 61.8, 59.6, 45.3, 59.2 percentage less than Square section for grade of concrete 30, 50, 70, 90 N/mm^2 respectively. For higher grade of concrete decreasing in deformation is less compared to normal strength of concrete.

IX. Stress Distribution in Circular and Square CFST

Fig.8 and Fig .9 shows the stress behaviour of circular and square CFST column under axial loading 4000 kN. Fig.10 illustrates the stress distribution graph of circular and square CFST member for grade of concrete 30 N/mm^2 under different load.

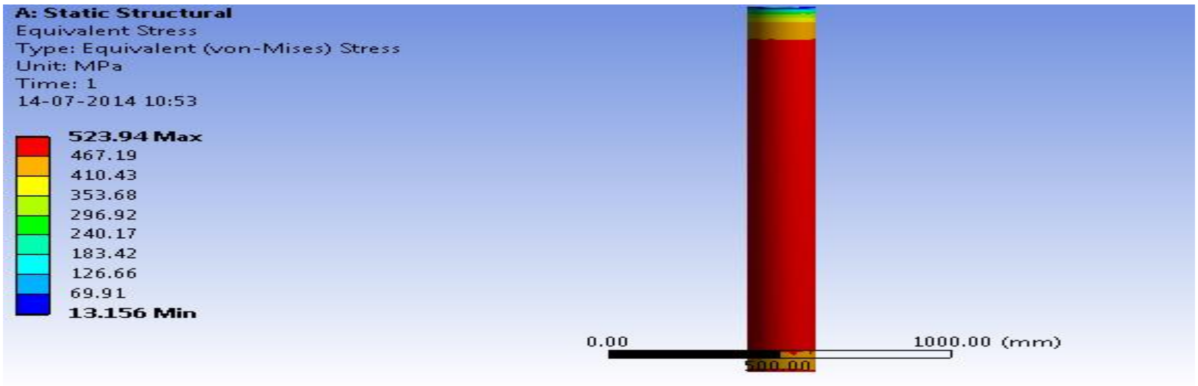

Fig.8. Stress in Circular CFST

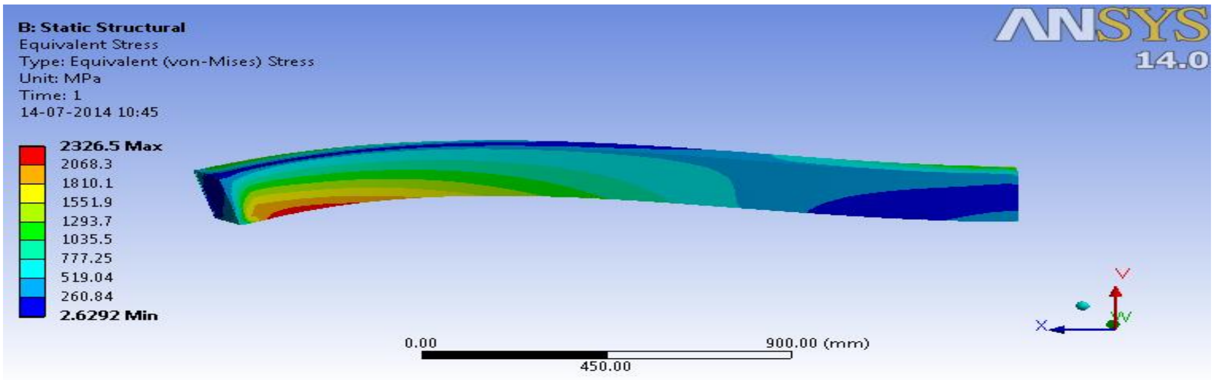

Fig.9. Stress in Square CFST

Table.7. Stress Behaviour of CFST

Load (kN)	Maximum Stress (Mpa)	
	Circular Column	*Square Column*
1000	130.98	581.62
2000	261.97	1163.2
3000	392.95	1744.9
4000	523.94	2326.5
5000	654.92	2908.1

The above table represents maximum stress in circular CFST and square CFST under different loading. From the stress diagram of square concrete filled steel tube and circular concrete filled steel tube , it is clear that the stress concentration is more at the edges of square column while in circular column, due to confining effect, stress concentration is equal throughout the whole section. The Fig. 10 shows the graphical representation of stress in circular and square CFST under different load. It shows that stress is higher in square CFST than circular CFST under loading.

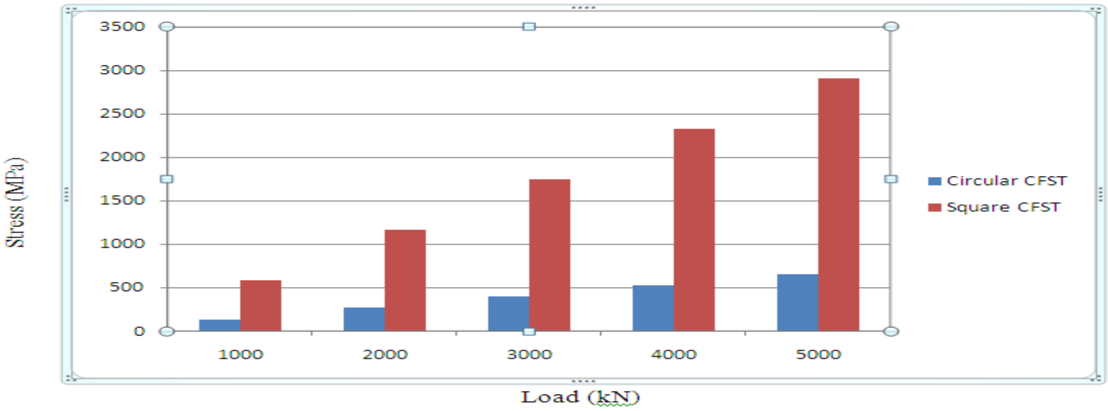

Fig.10. Stress in Circular and Square CFST

X. Result and Discussion

A Finite element analysis is carried out to find buckling strength of Hollow Steel Tube and CFST structures. Hollow Steel Tube and CFST members are mainly used in columns of multi-storey structures, bridge piers, earthquake resisting structure and other industrial applications. The results summary is as follows.

- Initially both Hollow Tube and CFST geometries are built
- Buckling analysis is carried out in both Hollow Tube and CFST domain
- The stresses are very high in the small slenderness ratio of Hollow Tube region and for nonlinear analysis the stresses are very less in the high slenderness ratio of CFST.
- The results show the Hollow Tube buckling load carrying capacity less compared to the CFST buckling loads.

Initially both theoretical and analysis values are compared to check Finite element solution with theoretical calculations. Also graphical plots are represented to find effect of thickness, diameter, and slenderness ratio on stress and buckling strength estimates.

This study focuses on modelling of concrete filled steel tube (CFST) column under axial loading. The main parameters of FEA are circular and square column with varying grades of concrete (30, 50, 70, 90 N/mm^2). It is concluded that the deformation of the column is decreasing 10-15 percentage with increasing grade of concrete. The deformation was influenced by the shape of the CFST section. The circular section leads to better behaviour than square section due to better confinement.

The study is an investigation of the behaviour of circular and square concrete filled steel tubes (CFST) subjected to axial loading. Parametric study of 8 CFST columns was performed using finite element analysis. Based on the results of the study, the following conclusions can be drawn.

1. The deformation is in circular section is smaller compared to square section. This is because circular section takes confining effect better than square section.
2. The equivalent stress value becomes constant after achieving its ultimate strength.
3. Deformation decreases with increasing grade of concrete, but for higher grades of concrete decreasing in deformation are less.
4. Stress concentration is more at the edges of square column while in circular column, due to confining effect, stress concentration is equal throughout the whole section.

XI. Conclusion

Most design engineers have treated the CFST system as an alternative to the steel system, trying to cut the cost by reducing the steel consumption. However, it is also possible to look at the CFST system as an alternative to the reinforced concrete system. In this study, three-dimensional finite element models have been developed to investigate the force transfer by natural bond and the interaction between the steel tube and the concrete core of concrete-filled steel tubes under loading. Both material and geometric nonlinearities are considered in the analysis. Concrete filled steel tubular columns axial capacity significantly affected with the cross-section of the column, concrete's compressive strength and yield strength of the steel tubes.

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