COMPARATIVE ANALYSIS ON CFST UNDER AXIAL COMPRESSIVE LOADING USING ANSYS

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Abstract- *Concrete-filled steel tubular (CFST) columns are widely used in construction of high-rise buildings and peers of bridges to increase the lateral stiffness of the buildings, the axial load capacity, ductility, toughness, and resistance of corrosion of the columns. The CFST columns have much superior characteristics compared with traditionally reinforced concrete columns. The position of the concrete and steel tube in the cross-section of the CFST column is the most appropriate solution in terms of the strength and ductility. The steel tube, which is placed outside of the cross-section of the column, withstand the bending moment effectively. The concrete that is placed into the steel tube delay the local buckling of the steel tube and increase the axial load capacity of the column due to continually lateral confining. In this study, different shape of CFST column like rectangular and circular are modelled in ansys workbench 16.0 software as per code standard. Further it is compared to stress strain curve, load deflection curve subjected to axial loading.*

Keywords- Ansys workbench 16.0, Concrete filled steel tube

I. INTRODUCTION

1.1 GENERAL

Concrete filled steel tube is a composite material which is currently being increasingly used in the construction of buildings. The use of concrete-filled steel tubular beams in high rise buildings has become popular in recent years. Concrete filled steel tube beams can provide excellent seismic resistant structural properties such as high strength, high ductility and large energy absorption capacity.

In the present era, creation of infrastructure facilities for the development of a country is the most important task of Civil Engineers. A multi-storeyed building plays a vital role in the development of infrastructure facilities. In the light of construction of high rise buildings concrete filled steel tubes is one of such an innovative new building material, which can sustain worst combination of loads, with high stiffness and facilitating speeder construction and maintaining economy

The concrete-filled steel tube (CFST) column system has many advantages compared with the ordinary steel or the reinforced concrete system. One of the main advantages is the interaction between the steel tube and concrete: local buckling of the steel tube is delayed by the restraint of the concrete, and the strength of concrete is increased by the confining effect of the steel tube. Extensive research work has been done in Japan in the last 15 years, including the “New Urban Housing Project” and the “US-Japan Cooperative Earthquake Research Program,” in addition to the work done by individual universities and industries that presented at the annual meeting of the Architectural Institute of Japan (AIJ). This paper introduces the structural system and discusses advantages, research findings, and recent construction trends of the CFST column system in Japan. The paper also describes design recommendations for the design of compression members, beam-columns, and beam-to-column connections in the CFST column system.

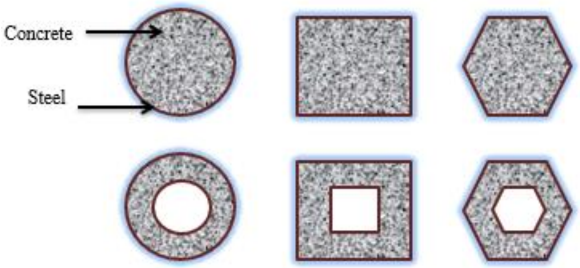


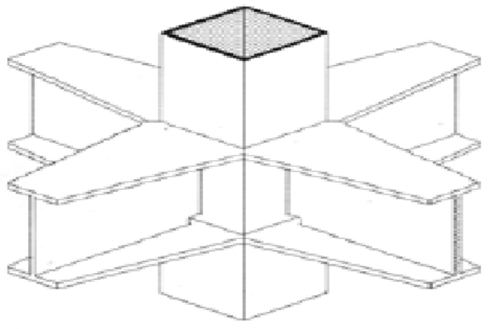
Fig.1.1 Cross-sections of solid and hollow CFST composite columns.

1.2 TYPES OF CFST

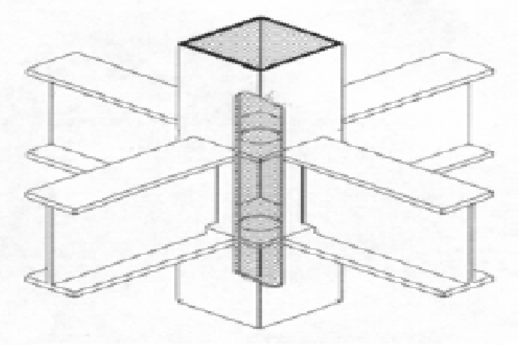
Concrete filled steel tube is designed on the basis of their application. It may be square, hexagonal and circular depends upon design and use of their application. Concrete filled steel tubes are divided into two types according to the form of the concrete core. These two types are solid and hollow concrete core CFSTs. In Fig.1.1 some shapes of CFST are shown which indicates these both types. Solid concrete core is made by placing the plain concrete in the steel tube and compaction is done by vibration. Hollow concrete filled steel tube is made by spinning method. The method of insertion of the wet concrete in the rotational mould is known as spinning method, where wet concrete is compacted by vibration using centrifugation due to rotation of the mould.

1.3. STRUCTURAL SYSTEM

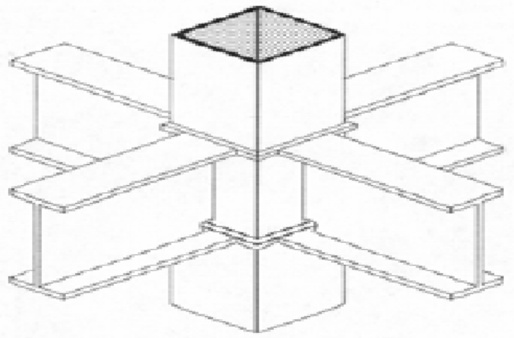
Figure 1.2 and Figure 1.3 shows typical connections between a CFST column and H-shaped beams often used in Japan. The connection is fabricated by shop welding, and the beams are bolted to the brackets on-site. In the case of connections using inner and through-type diaphragms, the diaphragm plates are located inside the tube, and a hole is opened for concrete casting. A cast steel ring stiffener is used for a circular CFST column. In the case of a ring stiffener and an outer diaphragm, there is no object inside the tube to interfere with the smooth casting of the concrete. Concrete casting is usually done by Tremie tube or the pump-up method. High strength and ductility can be obtained in the CFST column system because of the advantages mentioned below. However, difficulty in properly compacting the concrete may create a weak point in the system, especially in the case of inner and through-type diaphragms where bleeding of the concrete beneath the diaphragm may produce a gap between the concrete and steel. There is currently no way to ensure compactness or to repair this deficiency. To compensate, high-quality concrete with a low water-content and a super plasticizer for enhanced workability is used in construction.



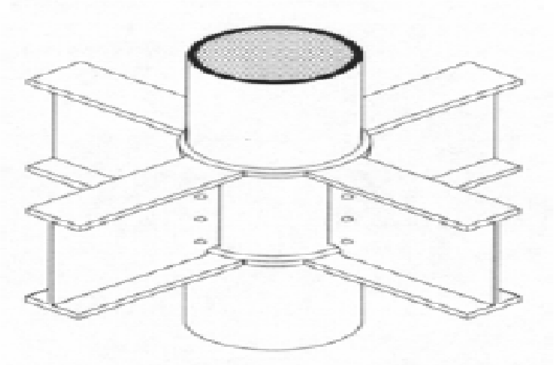
Outer diaphragm



Inner diaphragm



Through diaphragm



Ring stiffener

Fig1.3 Types of Diaphragm/ Stiffener

1.4 ADVANTAGES OF CFST COLUMN

1. The load carrying capacity of compression is high and the seismic behavior is very good.
2. The empty steel tube forms arch rib at first, whose weight is light. Hence, the bridge can leap over a very large span.
3. Erection and construction are easy to perform. The cost of engineering is decreased.
4. The problem of concrete cracking does not exist.

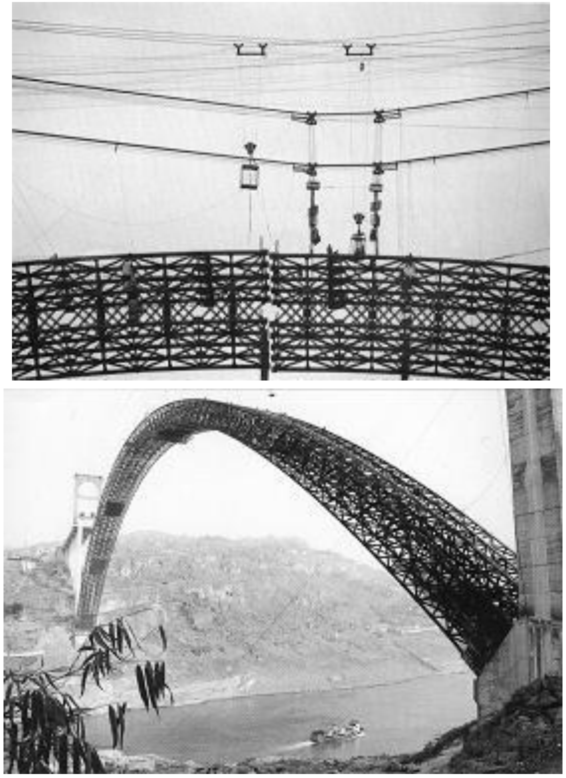


Fig.1.6 Arch rib being erected

OBJECTIVES OF STUDIES

1. To Prepare the geometry of CFST columns using Solid Works and then linking them to ANSYS to perform the rest of modal analysis.
2. To perform the analysis of circular CFST column section with rectangular CFST using mild steel and Duplex stainless steel
3. To compare normal stress, normal strain, shear stress, shear strain, deformation.
4. To study stress-strain curve as well as load-deformation curve.

2.1 MATERIAL MODELING

- The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyperelasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyperelastic materials. The geometrical representation of is show in SOLID186 fig 3.5.

- This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discretize the concrete slab, which are also able to simulate cracking behavior of the concrete under tension (in three orthogonal directions) and crushing in compression, to evaluate the material non-linearity and also to enable the inclusion of reinforcement (reinforcement bars scattered in the concrete region). The element SHELL43 is defined by four nodes having six degrees of freedom at each node. The deformation shapes are linear in both in-plane directions. The element allows for plasticity, creep, stress stiffening, large deflections, and large strain capabilities The representation of the steel section was made by the SHELL 43 elements, which allow for the consideration of non-linearity of the material and show linear deformation on the plane in which it is present. The modeling of the shear connectors was done by the BEAM 189 elements, which allow for the configuration of the cross section, enable consideration of the non-linearity of the material and include bending stresses as shown in fig 3.4. CONTA174 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses. The geometrical representation of CONTA174 is show in fig 3.1. Contact pairs couple general axisymmetric elements with standard 3-D elements. A node-to-surface contact element represents contact between two surfaces by specifying one surface as a group of nodes. The geometrical representation of is show in TARGET 170 fig 3.2.

- The TARGET 170 and C0NTA 174 elements were used to represent the contact slab-beam interface. These elements are able to simulate the existence of pressure between them when there is contact, and separation between them when there is not. The two material contacts also take into account friction and cohesion between the parties.

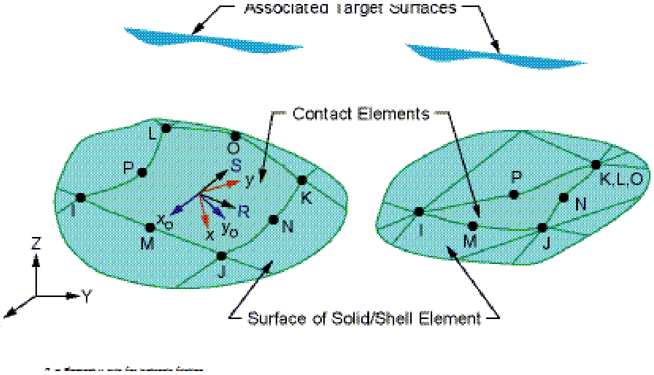


Fig.no. CONTA 174

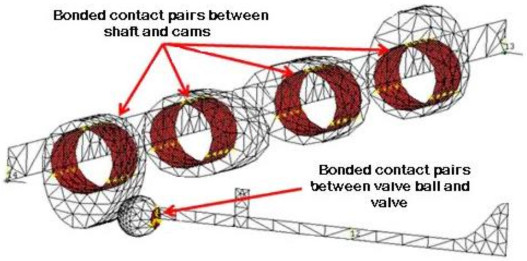


Fig.no. TARGET 170

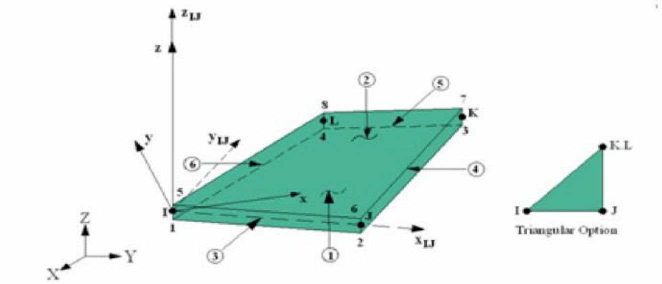


Fig.no.3.3 Shell 43

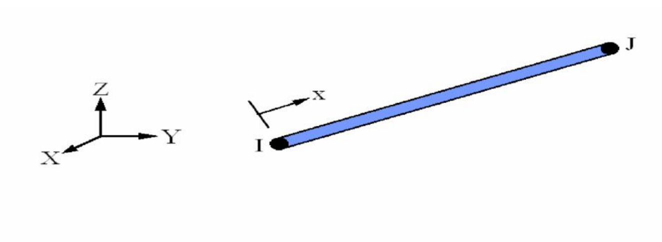


Fig.no.3.4 Beam 189

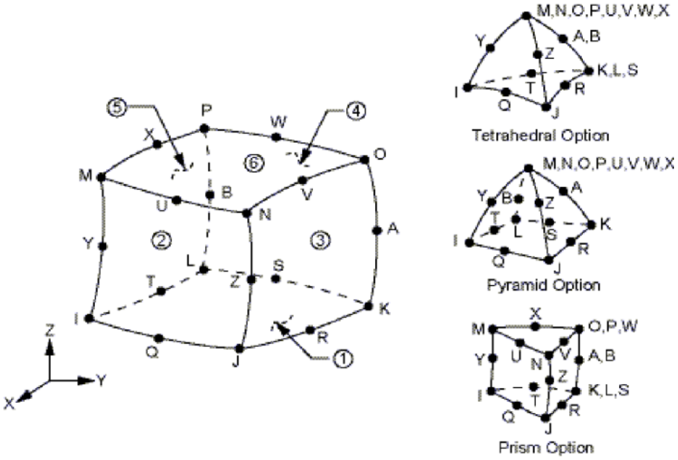


Fig 3.5 Solid 18

2.2 Material properties

Sr.No.	Material	Property	Value
1	Concrete	Compressive strength fsc(MPa)	30
2	Structural steel	Yield strength f_{sy}(MPa)	275
		Ultimate Tensile strength f_{su}(MPa)	410
		Young's modulus Es(MPa)	200×10^3
		Poisson's ratio µ	0.3
		Ultimate tensile strain et	0.25
3	Duplex steel	Yield strength f_{sy}(MPa)	435
		Ultimate Tensile strength f_{su} (MPa)	530
		Young's modulus E_s(MPa)	200×10^3
		Poisson's ratio µ	0.31
		density	7.8

Table 3a. properties of materials used

2.3 Numerical Modelling

This section focuses on modelling of CFST column under axial loading. The main parameters of FEA are circular and rectangular column For the parametric study, it is necessary that area of concrete and steel tube in circular and Rectangular CFST column is made same for exact comparison. For that, outer width of rectangular section 175 x 165 mm is reduced to 163 x 153 mm as well as thickness of the steel tube is reduced to 6.0 mm in Rectangular column.

Dimension	Type of Column	
	Circular Column	*Rectangular column*
Outer Dimension (D) mm	200	175 x 165 mm
Inner Dimension (d) mm	186	163 x 153 mm
Thickness of Steel Tube (t) mm	7.0	6.0
Length of Column (L) mm	2000	2000

Table 3b. Details of the Model

III. RESULT AND DISCUSSION

Analytical study of CFST with conventional mild steel model and DUPLEX steel

To study finite element model of the Circular and Rectangular CFST section with duplex steel and conventional mild steel model using ANSYS workbench 16 model created. Mechanical properties of duplex steel like Poissons ratio - 0.31, Tensile strength – 530 MPa, Density 7.8 gm./cm3 are inserted. Boundary condition one end fixed and other free support is used. In 6 steps upto 300 KN axial load at Centre is applied with 50 KN each increment. For each load total deformation, Normal stress (in MPa), Normal strain, Shear Stress, Shear Strain, mode shape and natural frequency are found. For that deformation vs. load and stress vs.strain graph are found compered. Results obtained are as below.

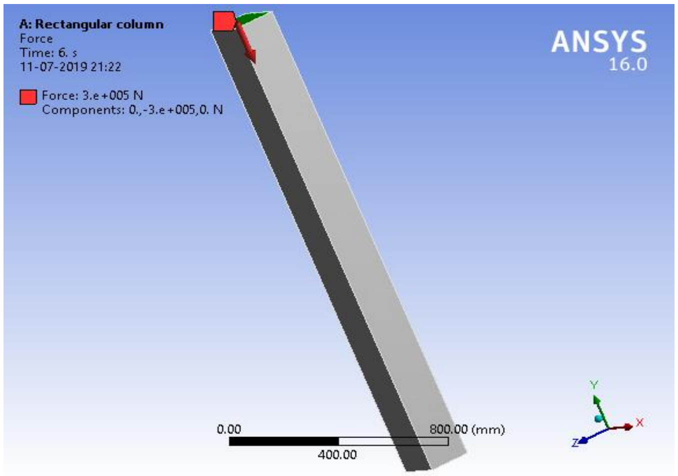


Fig 1 Model of Rectangular CFST tube

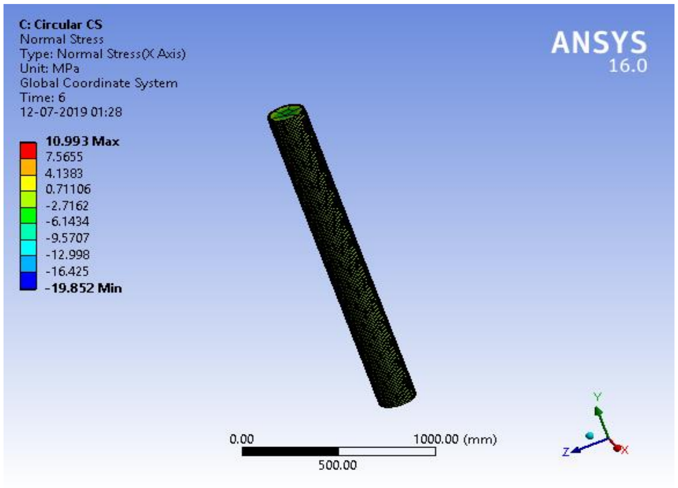


Fig 2 Max normal stress on Circular CS section under axial loading

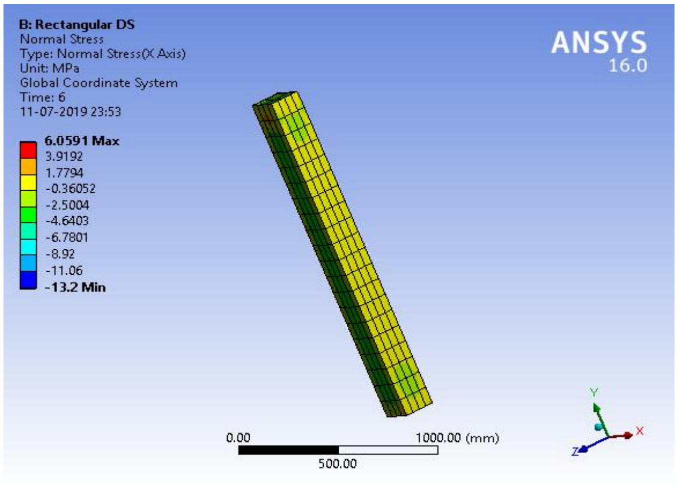
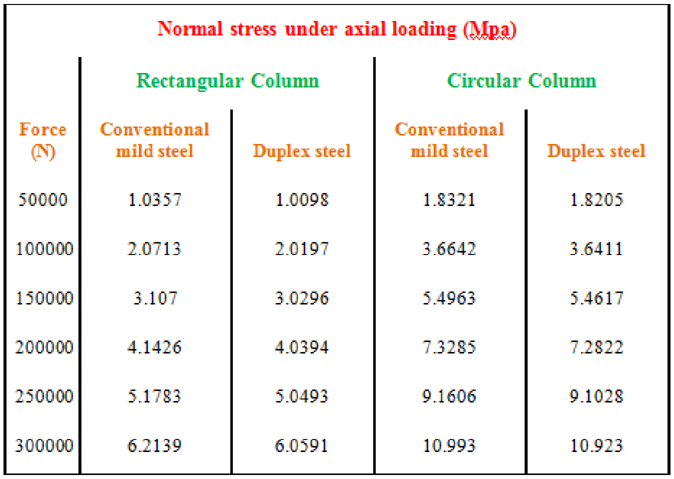


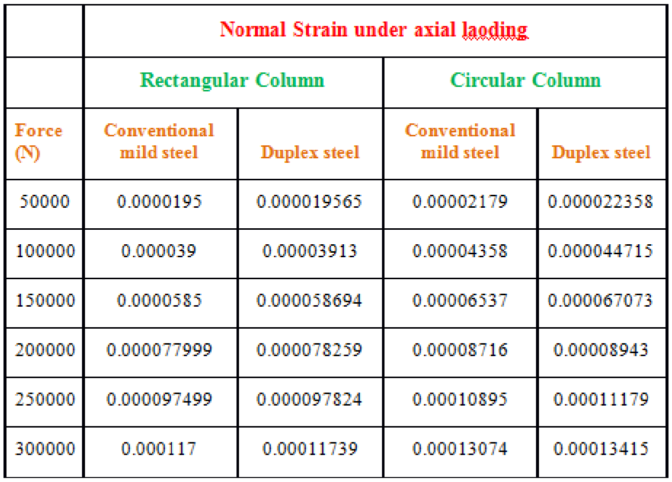
Fig 3 Max normal stress on Rectangular DS section under axial loading

After analysis stress, strain and deformation for each step result are obtained are listed as below for axial loading



Normal stress under axial loading (Mpa)				
	Rectangular Column		Circular Column	
Force (N)	Conventional mild steel	Duplex steel	Conventional mild steel	Duplex steel
50000	1.0357	1.0098	1.8321	1.8205
100000	2.0713	2.0197	3.6642	3.6411
150000	3.107	3.0296	5.4963	5.4617
200000	4.1426	4.0394	7.3285	7.2822
250000	5.1783	5.0493	9.1606	9.1028
300000	6.2139	6.0591	10.993	10.923

Table No.a Normal stress of circular and rectangular CFST



	Normal Strain under axial laoding			
	Rectangular Column		Circular Column	
Force (N)	Conventional mild steel	Duplex steel	Conventional mild steel	Duplex steel
50000	0.0000195	0.000019565	0.00002179	0.000022358
100000	0.000039	0.00003913	0.00004358	0.000044715
150000	0.0000585	0.000058694	0.00006537	0.000067073
200000	0.000077999	0.000078259	0.00008716	0.00008943
250000	0.000097499	0.000097824	0.00010895	0.00011179
300000	0.000117	0.00011739	0.00013074	0.00013415

Table No.b Normal strain of circular and rectangular CFST

This result can show graphically as below,

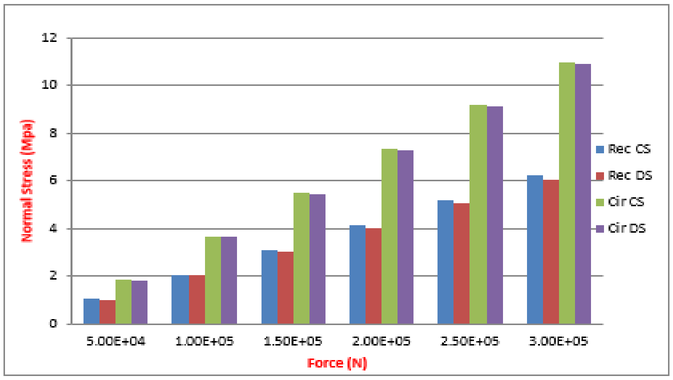


Fig.4 Load vs. normal stress variation under axial load

The above Fig. shows the graphical representation of stress in circular and rectangular CFST under different load. It shows that stress is higher in circular CFST than rectangular CFST under loading.

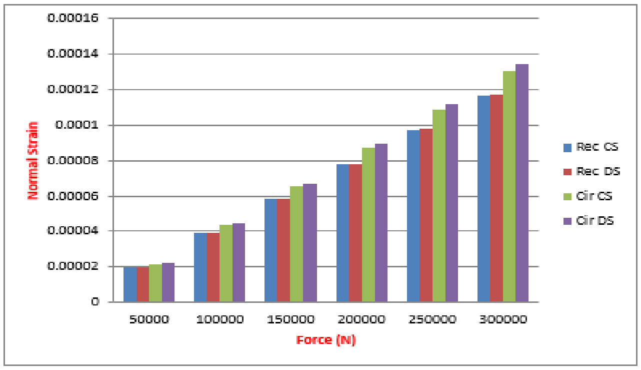


Fig.5 Load vs. normal strain variation under axial load

After calculation stress strain graph plotted which are as below,

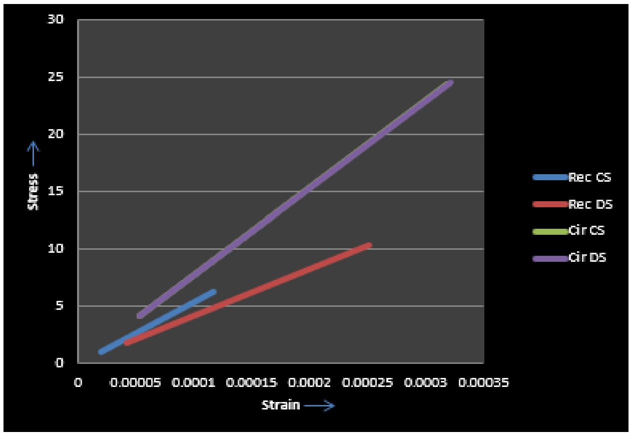
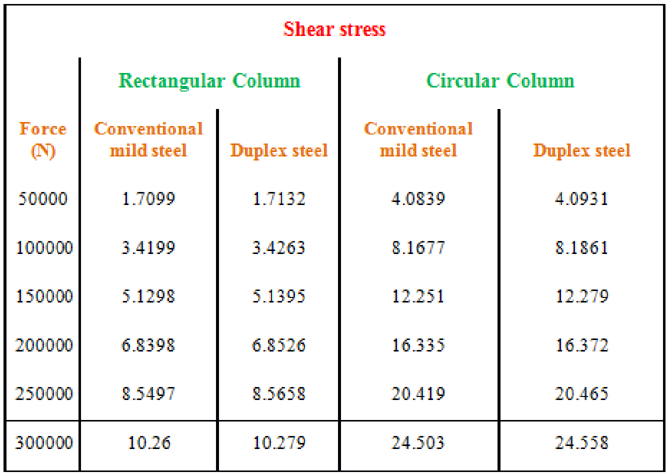


Fig.6 Comparison of stress Vs strain curve for Circular as well as rectangular CFST using Conventional and duplex steel



Shear stress				
	Rectangular Column		Circular Column	
Force (N)	Conventional mild steel	Duplex steel	Conventional mild steel	Duplex steel
50000	1.7099	1.7132	4.0839	4.0931
100000	3.4199	3.4263	8.1677	8.1861
150000	5.1298	5.1395	12.251	12.279
200000	6.8398	6.8526	16.335	16.372
250000	8.5497	8.5658	20.419	20.465
300000	10.26	10.279	24.503	24.558

Table No.c. Shear stress of circular and rectangular CFST

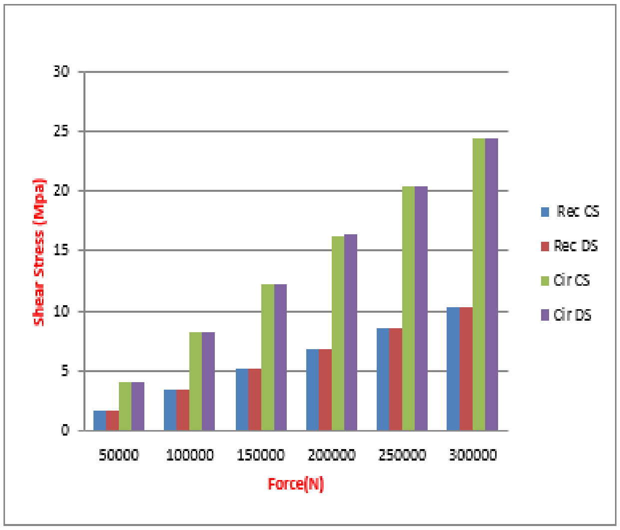
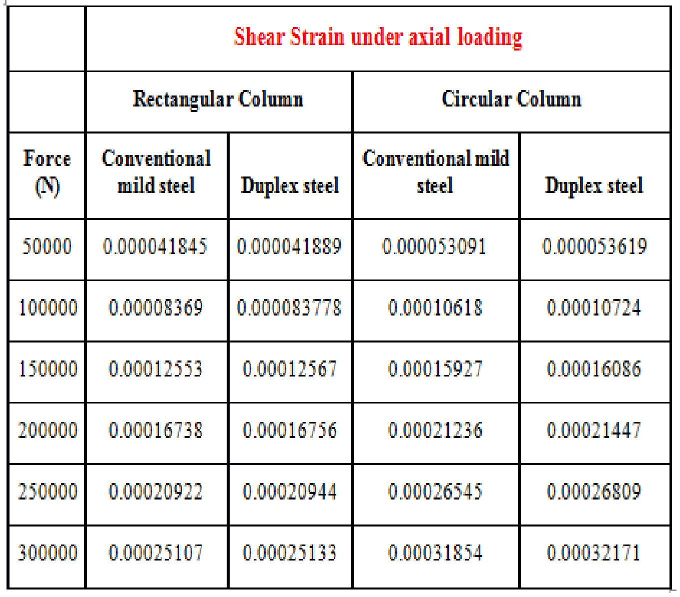


Fig.7 Load vs. shear stress variation under axial load



	Shear Strain under axial loading			
	Rectangular Column		Circular Column	
Force (N)	Conventional mild steel	Duplex steel	Conventional mild steel	Duplex steel
50000	0.000041845	0.000041889	0.000053091	0.000053619
100000	0.00008369	0.000083778	0.00010618	0.00010724
150000	0.00012553	0.00012567	0.00015927	0.00016086
200000	0.00016738	0.00016756	0.00021236	0.00021447
250000	0.00020922	0.00020944	0.00026545	0.00026809
300000	0.00025107	0.00025133	0.00031854	0.00032171

This result can show graphically as below,

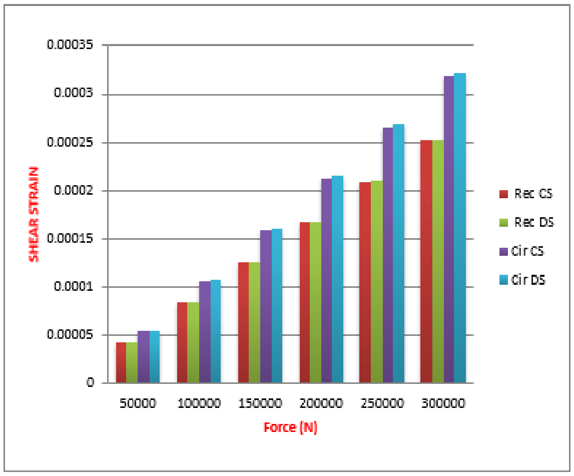


Fig.8 Load vs. deformation variation under axial load of STS CFST section

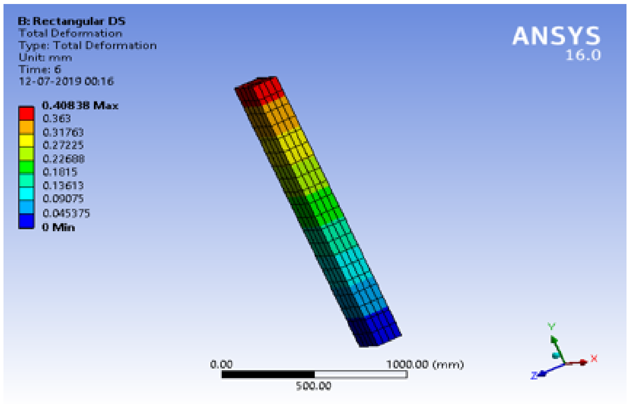


Fig.9 Max Deformation of Rectangular DS section under axial loading

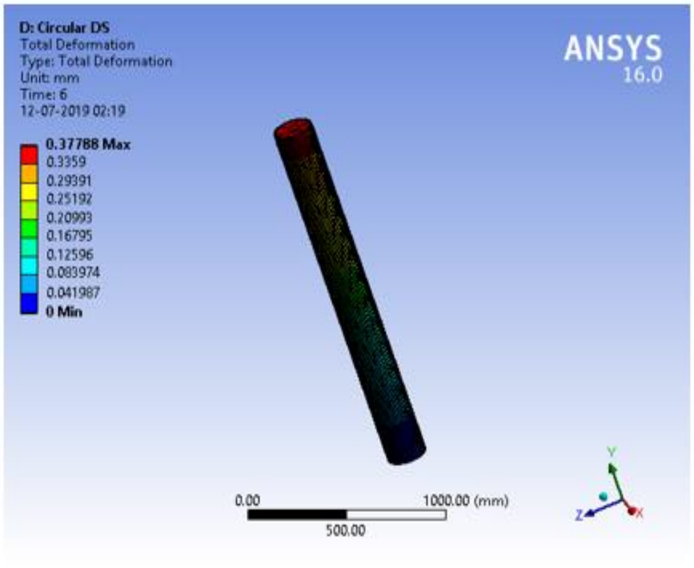


Fig.10 Max Deformation of circular section under axial loading

Total Deformation				
	Rectangular Column		Circular Column	
Force (N)	Coventional mild steel	Duplex steel	Conventional Mild steel	Duplex steel
50000	0.068101	0.068063	0.063027	0.06298
100000	0.1362	0.13613	0.12605	0.12596
150000	0.2043	0.20419	0.18908	0.18894
200000	0.2724	0.27225	0.25211	0.25192
250000	0.34051	0.34031	0.31514	0.3149
300000	0.40861	0.40838	0.37816	0.37788

Table no.e Total deformation for various sections under axial loading

This result can show graphically as below

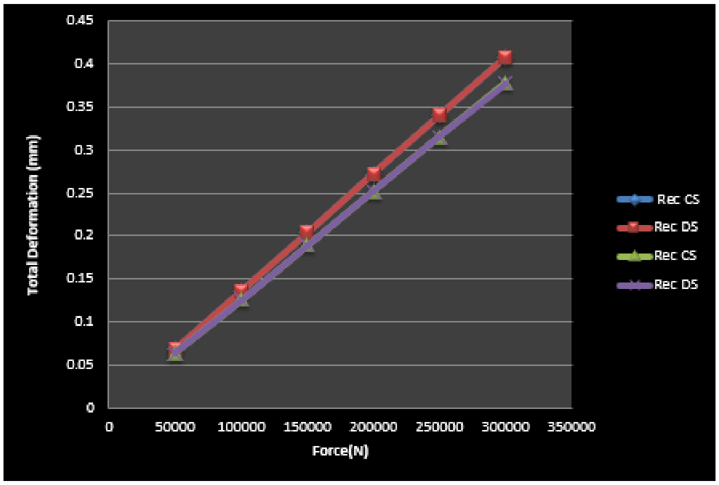


Fig.11 Load vs. deformation variation under axial load

V.CONCLUSION

This study focuses on modelling of concrete filled steel tube (CFST) column under axial loading using several codes of practices; the Euro Standard (BS-EN1994-1-1-2004) and the American Standard (AISC). The study also involves investigation of the behaviour of circular and rectangular concrete filled steel tubes (CFST) subjected to axial loading. Parametric study of 4 CFST columns was performed using finite element analysis with increasing load with steel having different mechanical properties..

It is concluded that,

- The stresses are very high in Circular CFST than rectangular as well as in Conventional steel CFST Sections.
- The results show the Circular CFST load carrying capacity is less as compared to the rectangular CFST for both conventional steel and duplex steel. Also graphical plots are represented to find effect of shape and materials used for CFST.
- The deformation of the CFST is decreased by 60% in circular than rectangular having duplex steel and

deformation of the conventional steel CFST is decreased by 0.01 % than duplex steel having same geometry.

- The deformation was influenced by the shape of the CFST section. The circular section leads to better behaviour than rectangular section due to better confinement.

FUTURE SCOPE

Followings can be extensions of CFST column study:

1. Design of CFST column subjected to both axial compression and bending moment.
2. Use more standards in the design, like British standard, Chinese standard, Canadian standard etc., for the sake of comparison.
3. Design other types of composite columns such as square hollow section, concrete encased sections, and partially encased concrete sections.
4. Include shear connectors in the design.
5. Include reinforcement in the design.
6. Design the mesh element separately instead of using the automatic method found in ANSYS.
7. Design of a slender composite columns (high length/diameter ratio)
8. Perform experimental results and compare the results with the codes and FEM analysis.
9. Perform cost study to find the most economical section for a given load by preparing a spreadsheet software.
10. Perform cost study to find the most economical type of column; composite column, steel column and reinforced concrete column.
11. Find the effects of different Poisson’s ratio for the concrete infill in FEM analysis.
12. Design CFST columns with pin connected ends using FEM analysis and compare them with fixed connections assumed in this study.
13. Compare the results in this study with the results of the load applied to the concrete core only

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