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A Study On Performance Evaluation Of Steel Tubular Columns Infilled With Concrete By ANSYS

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Abstract - *The behaviour of steel tubular section filled with concrete CFST is analysed using finite element software ANSYS & Experimental results. The present study is an attempt to understand the failure load of steel tubular section filled with concrete column under axial loading for different shapes such as circular and rectangular. In this project modelling of various circular cross section of column is been simulated nonlinearly by finite element method. Models are to be loaded in a concentric axial compression by Universal Testing Machine, and the failure loads are to be extracted. All models to be simulated have length to diameter ratio (L/D) not exceeding the value of 4.5 to act as short column and therefore no slenderness would be taken in to account. Failure loads calculated by ANSYS are compared with the results obtained from experimental results. 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. The development of high rise buildings and the need to provide more rigid structural systems to sustain severe lateral loads due to seismic and wind conditions lead to the necessity for mixed steel and concrete systems. This leads to the invention of*
CFST (Concrete Filled Steel Tubular Columns). CFST is component with good performance resulting from the confinement effect of steel with concrete core and design
versatility. From experimental and numerical analysis have slight differences in deflection values. The concrete filled steel tubular column of shorter length shows better performance than that of concrete filled steel tubular column of larger length. Increased cross sectional area of tube causes less deflection, this type of CFST having better load carrying capacity. The CFST of shorter length shows better performance than that of concrete filled steel tubular column of larger length. Increased cross sectional area of tube causes less deflection .This type of CFST having better load carrying capacity. CFST column with wire mesh have better load carrying capacity compared to other CFST column, if any increment in height of the column.

Key Words: *Concrete-filled steel tubular (CFST) columns Finite element analysis (FEA), Universal Testing Machine*

1. INTRODUCTION

The Concrete Filled Steel Tube (CFST) Structural System is a system based on filling steel tubes with high-strength concrete. It is one of the modifications to composite steel concrete structures. CFST structure is a type of the composite steel concrete structures used presently in civil engineering and consists of steel tube and concrete core inside it. Combining the advantages of both hollow structural steel (HSS) and concrete, circular concrete filled steel tubes (CCFST) are being used widely in real civil engineering projects due to their excellent static and earthquake resistant properties, such as high strength, high ductility and large energy absorption capacity. Concrete filled steel tubes (CFST) are also used extensively in other modern civil engineering applications. In the past few decades, behaviour of CFST columns in axial compression and flexure has been studied but yet the knowledge gap is not fully filled up. It may be noted here that mechanical and economic 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. Composite Circular Concrete Filled Steel Tubes (CFST) have been used increasingly as columns, beams and beam columns in braced and un-braced frame structures. The two main types of composite column are the steel reinforcement concrete beam, which consists of a steel section encased in reinforced or unreinforced concrete, and the Concrete Filled Steel Tubular (CFST) beams, which consists of a steel tube filled with concrete. Due to the traditional separation between structural steel and reinforced concrete design, the procedure for designing CFST beam using the American Concrete Institute's (ACI) code is quite different from the Load and Factor Resistance Design (LFRD) method suggested by the American Institute of Steel Construction's (AISC).
Concrete filled steel tubular (CFST) members are widely used in high-rise and multi storied 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. CFST columns are first used in Japan in multi-storied buildings. They have many advantages compared to conventional concrete structural members and are extensively used in seismic zones involving very large applied moments. In framed structures CFST columns are used as beams, columns and girders. The steel tube serves as a formwork forecasting while the concrete reduces the construction cost. The tube acts as a longitudinal and lateral reinforcement for the Concrete core and no other reinforcement is needed. Further it enhances the core's strength and ductility. The concrete core delays bending and buckling of the steel tube and steel tube prevents the concrete from spalling. This significant feature made CFST columns, suitable for tall buildings in high seismic regions. The composite column is a structural element with proven behavior of its constituent materials, including high cross-sectional stiffness, high compressive strength, and fire resistance of the concrete and large ductility, high tensile resistance, high strength-to-stiffness ratio, and lightweight construction associated with steel. CFST columns provide large savings in cost by increasing the floor area by a reduction in the required size of columns. This aspect is significant in the design of tall buildings in cities where the cost of land is extremely high. When they are used as structural columns, especially in high-rise buildings, the composite members may be subjected to high shearing force as well as moments under wind or seismic actions. Although CFST beams are suitable for all tall buildings in high seismic regions, their use has been limited due to a lack of information about the true strength and the inelastic behavior of CFST members.

2. GEOMETRIC PROPERTIES

The Concrete Filled Steel Tubular columns are circular in shape with the diameter of concrete core and steel tube being 152.4mm, 101.6mm and 76.2mm respectively column making the thickness of steel tube varies from 4.2 to 3.4 mm. The height of the column is 300 mm & 500 mm.

3. MATERIAL PROPERTIES

3.1 Concrete

Table -1: Properties of concrete

Properties	Values
Compressive Ultimate Strength (N/mm^2)	25
Youngs Modulus (mpa)	2.5×10^4
Poissons Ratio (μc)	0.2

3.2 Steel

Table -2: Properties of steel

Properties	Values
Tensile Yield Strength (N/mm^2)	415
Youngs Modulus (mpa)	2×10^5
Poissons Ratio (μs)	0.3

3.3 Wire Mesh

Table -3: Properties of wire mesh

Properties	Values
Length b/w one mesh to other (mm)	25
Diameter (mm)	0.55
Density (g/cc)	7.8
Aspect ratio	65
Ultimate tensile strength (MPa)	800

4. FE MODELLING

Three types of thirteen models are prepared. Out of them only one type is shown below.

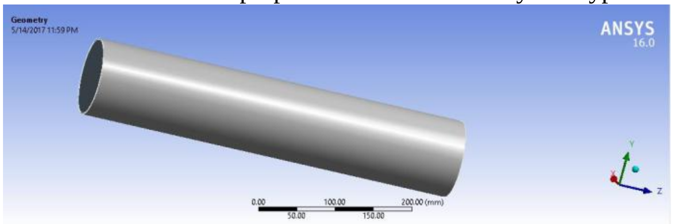

Fig -1: Model

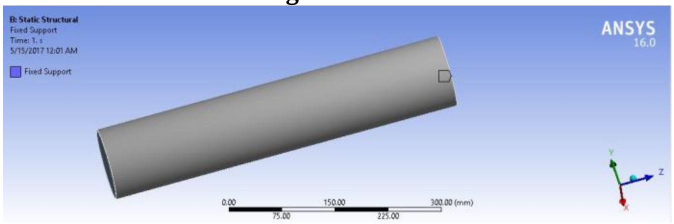

Fig -2: Support

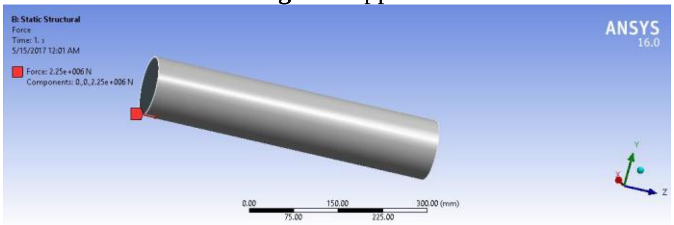

Fig -3: Loading

5. EXPERIMENTAL STUDY

In order to validate the basic mechanical concepts of CFST columns, 12 specimens were tested under axial compression by Universal Testing Machine. Four plain concrete cylinders with a diameter 152.4mm & 101.6mm having length of 300mm & 500mm respectively were first tested to provide the compressive strength of the concrete used in all the specimens. One hollow steel tube infilled with plain concrete specimens were tested to provide the benchmark behavior data. Two CFST specimens with chick mesh were tested. Testing parameters for the CFST specimens were the one layer of wire mesh and without the gap between the inner steel tube and the chick mesh. Such cushion effect was designed to delay the participation of the wire mesh for possibly maximizing the deformability while minimizing the unnecessary strength enhancement.

5.1 Materials required

5.1.1 Steel

The hollow steel tube has a circular cross section with the size of 152.4mm diameter, 4.2mm thickness and 500 mm & 300 mm height. Its yield strength is given as 415MPa in the manufacturer specification details.

5.1.2 Cement

Ordinary Portland Cement (OPC) confirming to IS 12269:1987 is used which has specific gravity of 3.13.

5.1.3 Fine aggregate

Natural river sand is used as fine aggregate. Fineness modulus of sand is 2.26 and has specific gravity of 2.59.

5.1.4 Coarse aggregate

The Coarse aggregate are obtained from a local quarry is used. The coarse aggregate with a maximum size 20 mm having a specific gravity 2.84 has been taken for mixes. Crushed granite stones of size 20 mm and 10 mm are used as coarse aggregate.

5.1.5 Wire mesh

Material is made by galvanized iron wire, black iron wire, 304 310 316 321 stainless steel wire, brass, other materials on request. Weaving in normal twist, reverse twist, double twist.

5.2 Test procedure for compressive strength of concrete cylinder

All specimens were tested in Universal testing machine having load capacity of 1000kN. The column were tested under axial loading. Deflection meter were fixed at the bottom part of the UTM axially to measure deflection with respect to the applied load. Load was applied axially to the column at an increment of 5 kN. For each load increment the deformations were recorded. All specimens were subjected to load up to failure. The load was applied gradually till the ultimate load and the deflections were measured at various load stages. Compressive strength of the specimen is calculated by dividing the maximum load carried by the specimen during the test with the average cross-sectional area. Determine and express the result to the nearest 10 psi (0.1 MPa).

8. MIX DESIGN

The mix proportions of M25 concrete and mix ratio of concrete 0.5: 1: 1: 2 by weight of water, cement, fine and coarse aggregate. Mix proportion for M25 grade of concrete is 1:1:2 (cement: fine aggregates: coarse aggregates). The mix design of concrete grade was carried out in accordance to the Indian standard code. The coarse aggregate was well graded with a maximum size of 12mm, the fine aggregate was river sand with a fineness modulus of 2.4. Mix proportion of cement, sand, aggregates of 1:1.2:2.37 and a water cement ratio of 0.4 are used in this paper. All specimens were cast from the same delivery of materials (sand, aggregates and cement)

9. DETAILS OF SPECIMENS

Table -4: Details of column specimens

Specimen Notation	Inner Diameter (Di) mm	Outer Diameter (Do) mm	Length L mm	Wire mesh Diameter (dc)
C1	-	152.4	500	-
C2	-	152.4	300	-
C3	-	101.6	500	-
C4	-	101.6	300	-
C5	76.2	101.6	300	-
C6	76.2	152.4	300	-
C7	101.6	152.4	300	-
C8	76.2	101.6	500	-
C9	76.2	152.4	500	-
C10	101.6	152.4	500	-
C11	101.6	152.4	500	0.55
C12	76.2	152.4	500	0.55

All the specimens consist of concrete filled with steel tubular column, Circular Hollow Steel tube & hollow steel tube with wire mesh of diameters 152.4mm, 101.6mm & 76.2mm and having a thickness of 4.2mm to 3.6mm. It is filled with grade of concrete M25. A total of 12 column specimens were tested for axial compression.

10. CASTING AND CURING OF CFST COLUMNS

To obtain the characteristic compressive strength of the concrete used for each CFST casting group, standard 152.4mm & 101.6 mm diameter by 300mm & 500mm high cylinders were cast. To provide results with adequate confidence limits, a minimum sample size of four cylinders were cast for each group. Hollow tubular columns were outer having 152.4 mm with inner 101.6 mm diameter & 0uter having 152.4mm with inner 76.2 mm diameter with 300 mm & 500 mm height respectively concrete filled in between the steel tubular column with three equal layers and compacted progressively to ensure uniformity of concrete properties. Hollow tubular column provided with reinforcement mesh in outer surface of inner tubular column.

The CFST column were allowed to stand for 24 hours. After this initial setting period, cylinders were transferred into water bath. At the age of testing (generally 28 days), specimens were removed, weighed recorded. The curing conditions of the concrete cylinders were adopted after compression testing reported in section

11. RESULTS AND DISCUSSIONS

Table -5: Total deformation

Specimen Details	Ultimate load carrying capacity (kN)	Deflection Obtained from UTM	Deflection obtained from ANSYS
C1	2250	31.83	31.019
C2	2300	32.5	31.951
C3	1520	31.3	30.638
C4	1680	31.9	30.072
C5	1250	37	37.089
C6	1795	32.45	33.38
C7	825	36.01	36.718
C8	1300	37.5	36.594
C9	1800	32.5	32.412
C10	900	37	39.208
C11	1980	31	31.019
C12	2400	27	25.616
C13	2170	29.5	28.753

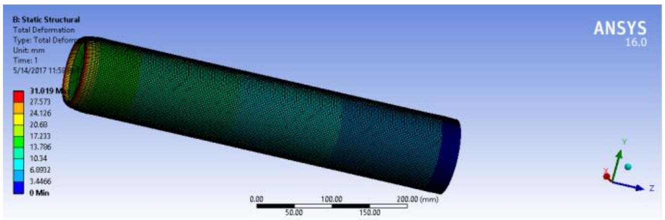

Fig -4: Deformation- specimen C1

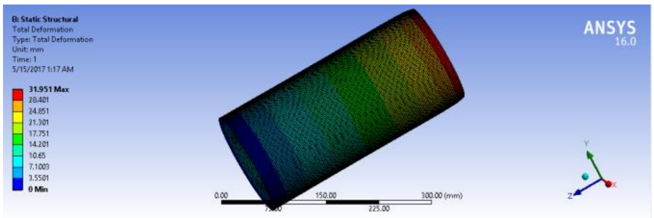

Fig -5: Deformation- specimen C2

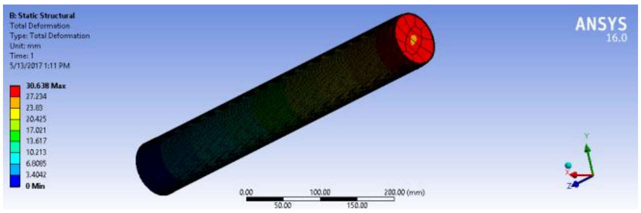

Fig -6: Deformation- specimen C3

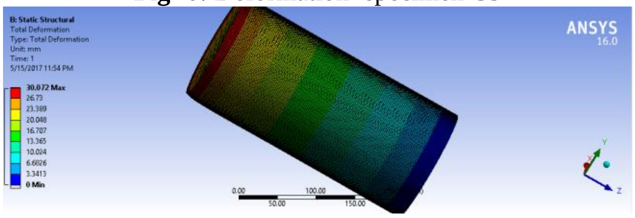

Fig -7: Deformation- specimen C4

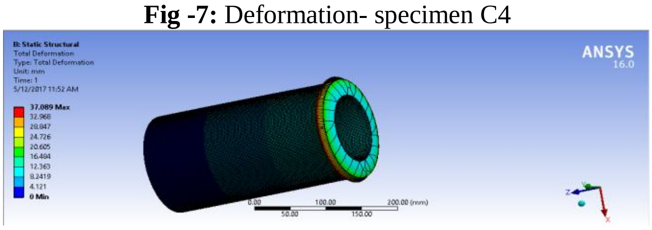

Fig -8: Deformation- specimen C5

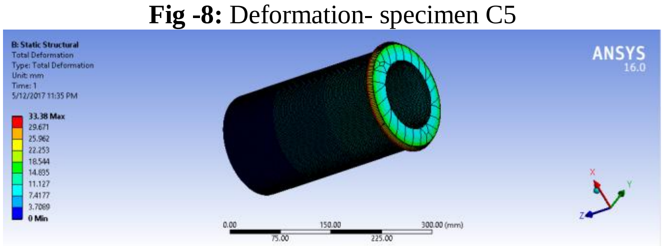

Fig -9: Deformation- specimen C6

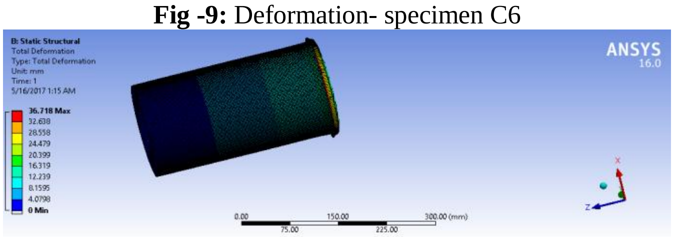

Fig -10: Deformation- specimen C7

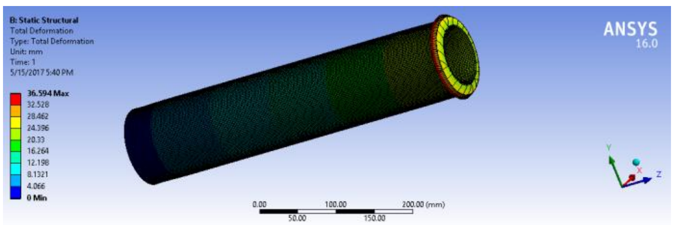

Fig -11: Deformation- specimen C8

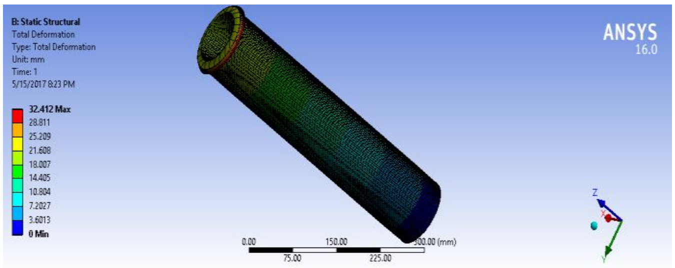

Fig -12: Deformation- specimen C9

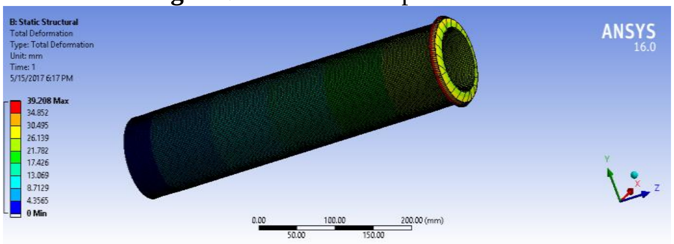

Fig -13: Deformation- specimen C10

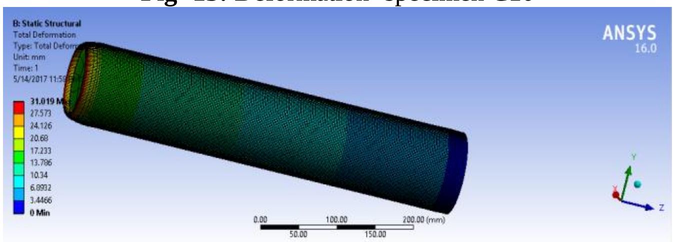

Fig -14: Deformation- specimen C11

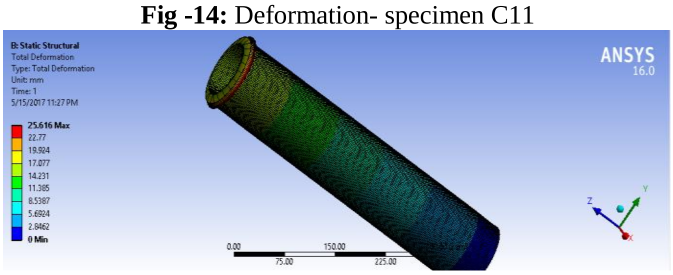

Fig -15: Deformation- specimen C12

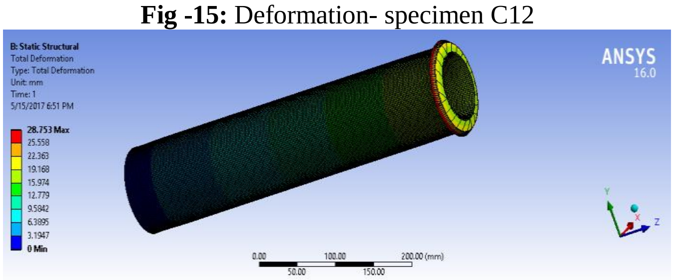

Fig -16: Deformation- specimen C13

Experimental and numerical analysis have slight differences in deflection values. The concrete filled steel tubular column of shorter length shows better performance than that of concrete filled steel tubular column of larger length. Increased cross sectional area of tube causes less deflection. This type of CFST having better load carrying capacity.

Hollow CFST column shows better performance, load carrying capacity, less deflection & stiffness than CFST column. The wire mesh provided CFST column (C11, C12, C13) shows better performance compared to other columns. This is because of the uniform stress transfer capacity of wire mesh due to its small diameter and uniform orientation of reinforcement. Which improves the structural behavior of columns. CFST of C11 & C12 and takes load of 1980 & 2400 kN causes deflection of 31 mm& 27 mm.This values indicates the better performance of concrete filled steel tubular column with wire mesh. Concrete filled steel tubular column with wire mesh have better load carrying capacity compared to other CFST column, if any increment in height of the column.

12. CONCLUSION

- The CFST of shorter length shows better performance than that of concrete filled steel tubular column of larger length.
- Increased cross sectional area of tube causes less deflection .This type of CFST having better load carrying capacity.
- CFST column with wire mesh have better load carrying capacity compared to other CFST column, if any increment in height of the column.
- Cross-sectional area of the steel tube has the most significant effect on both the ultimate axial load capacity and deformation of column. Concrete filled steel columns with relatively higher concrete area proportionately increased the ultimate strength.
- The experiments have shown that strength increase in circular concrete filled steel columns with wire mesh almost all concrete filled steel columns behaved in a fairly ductile manner.

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