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Study and Buckling Analysis of Concrete Filled Steel Tubes Columns using ANSYS

Neetu Devi Singh[1], Shubha Vaghmarey[2]

[1]*Neetu Devi Singh, MM City, Raipur*
[2]*Shubha Vaghmarey: Assistant Professor, Dept. of Civil Engineering, MM City College, C.G, India*

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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.*

In the present research, the non-linear analysis of concrete filled steel tube (CFST) is done using ANSYS WORKBENCH 15 software. It has been found that performance of circular cross section depends on:-

1) *Diameter of Column*
2) *Length of Column*
3) *Thickness of Steel Tube*
4) *L/D ratio*
5) *D/t ratio*

Steel-Concrete composite columns are used extensively in high-rise building and bridges as a type of hybrid system, utilize the advantages of both steel and concrete. In such case, steel tube provides formwork for the concrete and the concrete prevents local buckling of the steel tube wall. Also the load-carrying capacity and behavior in compression, bending and shear are all superior to reinforced concrete.

Key Words: Concrete filled steel tubular column, high strength, high ductility, large energy absorption capacity, bending stiffness, fire performance along with favourable construction ability.

1. INTRODUCTION

1.1 GENERAL

Concrete filled steel tubes (CFST) are composite structures consisting of a steel tube infilled with concrete. In present international practice, CFST columns are used in the primary lateral resistance systems of both braced and unbraced building structures. CFSTs may be operated for retrofitting purposes for strengthening concrete columns in earthquake prone areas. Concrete filled steel tubes are generally used in Beams, Columns, Piers and caissons for deep foundations.

In innovative CFST structures, silica fume which is supplementary cementitious material, are usually added into the concrete mix to obtain higher strength and better performance of the structure. CFST columns having addition of silica with concrete in this way are known as high strength concrete filled steel tubular columns. For high strength concrete filled steel tubular columns, there is a composite action between these two essential elements which contributes the concrete to prevent inward buckling of wall of steel tube

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1.2 HISTORY

Pre 1960's

Revolution and requirement have been dynamism for the structural design throughout the history. As early in 1930's, the former SOVIET UNION constructed a 101m bridge by using concrete filled steel tubes. Nominal research and experience using concrete filled steel tubes formed anxiety of using CFST.

1960's - 1980's

In 1961 Kato Naka wrote the first technical journal on CFST in Japan which described circular CFST compression member used in power transmission tower. This technical paper study on the subject leading to addition of the architectural institute of the Japan (AIJ) standard for concrete and circular steel tubes as the composite structures, published in 1967. China and Japan made investments in research for setting the foundation of CFST.

1.3 TYPES OF CFST

Concrete filled steel tubes 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 tubes 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.

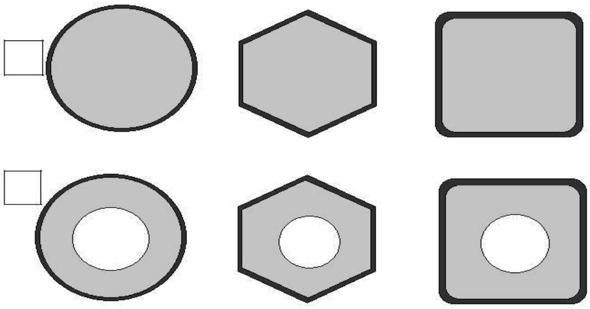


Fig.1.1 Cross-sections of solid and hollow CFST composite columns.

1.4 BEHAVIOUR OF CFST

Many previous studies have shown that square concrete filled steel tubes is not as good compare to circular concrete filled steel tubes. This is due to the confining pressure acts in concrete core by square steel tube is less and that's why local buckling more likely to occur. The structural behavior of the concrete filled steel tube is affected by the Poisson's ratio of both steel and concrete. At the initial stage of loading, Poisson's ratio of the concrete is lower than that of steel. Hence the steel tube does not contribute confining effect to the concrete. When the longitudinal strain increases, lateral expansion of the concrete gradually becomes greater than the expansion of the steel tube. At this stage of loading, steel tube becomes biaxially stressed and concrete core becomes triaxially stressed. So due to the biaxial stress in the steel tube, the steel tube cannot sustain normal yield stress and hence transfer the load from tube to core. The load transfer mechanism is same for both circular and square concrete filled steel tubes.

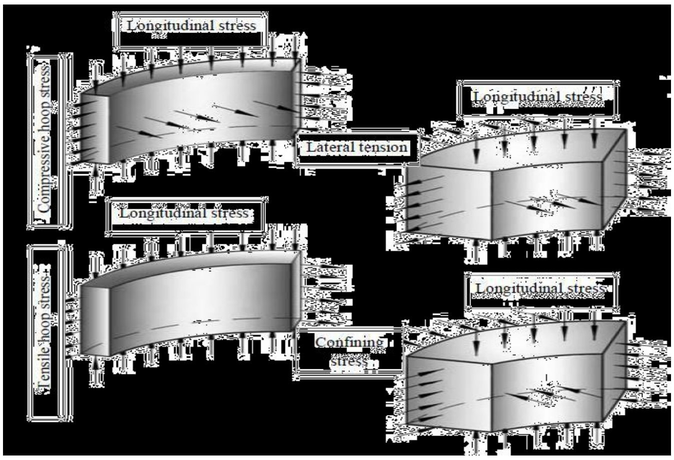


Fig 2.1 Stress condition in steel tube and concrete core at different stages of loading.

1.5 OBJECTIVES

In the present study, the non-linear response of concrete filled steel tubular columns using FE Modeling under the axial loading has been carried out with the purpose to examine the relative importance of several factors in the non-linear finite element analysis of concrete filled steel tubular columns. This includes the variation in load deformation graph and the crack patterns on the analytical results and the effect of the non-linear behavior of concrete and steel on the response of deformed CFST column.

The main objectives of the present study are as follows-

1. To model the concrete filled steel tubular columns using finite element software.
2. To compare the results of load carrying capacities by Eulers formulas and ANSYS software..

2. LITERATURE REVIEW

2.1 General

It would be difficult to present the detailed review of the literature related to FE modeling of concrete filled steel tubular columns so a brief review of previous studies on the application of the finite element method and experiment analysis of concrete filled steel tubular columns is presented in this chapter.

This literature review focuses on recent contributions related to concrete filled steel tubular columns, materials used for concrete filled steel tubular columns and past efforts most closely related to the needs of the present work.

2.2 Historical Background

With the advent of steel and reinforced concrete, the concepts in construction has changed from one of securing stability to that of stressing the materials to the optimum values. This has resulted in very light structures compared to the pre-19th century constructions. This has been made possible by eliminating in the newer materials, the short comings of poor tensile strength of the traditional materials.

The history of the first application of composite columns in construction industry dates back to the 1940's. The year 1970 marked the evolution of concrete filled steel tubes in Japan and this practice was followed by many countries around the world. On the basis of the research results, many countries have developed their design codes for use by their engineers. The current design standards and specifications have originated either from the steel or concrete design approach of that time.

2.3 Review On Composite Columns

Researchers like Elremaily and Azizinamini1 (2002) investigated the behavior of concrete-filled steel tube columns under seismic loads were also by testing six columns subjected to an axial load. Test conducted for cyclic lateral loads. An analytical model was developed to predict the capacity of circular CFST beam-columns accounting for the interaction between the steel and concrete. The developed analytical model was compared with the experimental data. Good concurrence was observed between the predicted values using the anticipated model and the experimental output. The CFST columns showed high ductility and maintained their strength till it fails. They concluded that the column capacity had significantly improved due because of the concrete strength gained from the confinement provided by the steel tube.

Morino and Tsuda2 (2003) introduced the structural system and discussed the advantages, research findings and recent trends of the CFT column system in Japan. Extensive research work has been done in Japan in the last 15 years, including the "New Urban Housing Project" and the "US-Japan Co-operative Earthquake Research Program", in addition to the work done by individual universities and industries that were presented at the annual meeting of the Architectural Institute of Japan (AIJ). A rational design method for the CFT column system has been established through extensive research by the AIJ. Authors concluded that the characteristics of CFT make the system especially applicable to high-rise and long-span structures, because the system's construction efficiency saves construction cost, time, and manpower.

2.4 Studies On Geometrical Effects

Shams and Saadeghvaziri5 (1999) presented an evaluation of the nonlinear response of concrete filled steel tubular columns that were subjected to axial loading. They developed a three-dimensional finite element model for CFST columns and compared the results against existing experimental values. They indicated that the stress-strain properties of the confined concrete were highly affected by the geometrical configuration of the columns as well as material properties of concrete. It was found that the confinement effect in circular columns was higher than that in square columns due to more uniform stress distribution. Concrete with a lower unconfined compressive strength exhibited higher confinement ratio than higher strength concrete. The amount of increase in the maximum compressive strength of concrete mainly depended on the D/t ratio, unconfined concrete compressive strength and cross-sectional shape. The strain at maximum stress depended on the D/t ratio and cross sectional shape.

Another interesting investigation was carried out by Zheng et al.6 (2000) that studied a rational ductility evaluation procedure for thin-walled steel structures. This method involved an elasto-plastic push-over analysis and failure criterion based on the empirical ductility equations proposed for stub-columns. Local buckling was considered as the failure criterion and they suggested that the local buckling could be neglected in the push over analysis, which facilitated practical application. The implementation of the proposed procedure was demonstrated by application to the ductility evaluation of some cantilever columns and one-storey frame. Extensive parametric analysis were carried out to investigate the relation of the stub column ductility to various parameters such as the flange width-thickness ratio, axial force, stiffeners slenderness ratio, cross sectional shape, and column aspect ratio. An elasto-plastic large deformation FEM analysis was employed and both residual stresses and initial deflections were taken into consideration. Consequently, empirical formulae were proposed.

2.5 Studies On Slenderness Effects

Brain Uy9 (2000) carried out experimental study on the effect of steel plate slenderness limits. A numerical model developed elsewhere was augmented and calibrated with these results. The author developed a simple model for the determination of the strength-interaction diagram which was verified against both the test results and the numerical model developed. This model based on the rigid plastic method of analysis, was existent in international codes of practice, but did not account for the effects of local buckling, which were found to be significant with large plate slenderness values, particularly for large values of axial force. Based on the study, the author suggested some modifications for the inclusion of slender plated columns in design.

Brain Uy10 (2001) also carried out an extensive set of experiments on the strength of short concrete filled high strength steel box columns. In his study a numerical model was presented with these tests. Furthermore, comparisons with the Eurocode4 for composite columns were also undertaken and this was found to be un-conservative in its prediction of axial and combined strengths. Therefore a mixed analysis technique was presented, which treated concrete as rigid plastic and steel as linear elastic. This model was compared well with the numerical model presented and both these models were found to be conservative in predicting the test results.

2.6 Reviews On Finite Element Analysis

Chou et al.15 (2000) adopted finite element analysis on the post-buckling behavior of stub columns under axial compression. They have obtained numerical predictions on the load versus end-shortening characteristics and ultimate load capacity of the structures using a non linear finite element analysis. Standard design procedures were developed for post-buckling analysis for stub columns using finite element method. In this study they concluded that the ultimate load obtained using the design procedure consistently under estimated the experimental results and analytical predictions using BS 5950.

Some studies have also been conducted by Liang et al.16 (2000), as they studied the post-local buckling behavior of steel plates in thin walled CFST welded box columns using the finite element method. The effects of various geometric imperfections, residual stresses and B/t ratios on the post-local buckling characteristic were investigated. A new method was developed for evaluating the initial local buckling loads and post-local buckling reserve strength of steel plates with imperfections based on the load-transverse deflection relations associated with the theoretical analysis. The accuracy of the design models were verified by a classical solution and experimental results. The results indicated that the theoretical predictions for the ultimate strength of steel plates and CFST box columns using the proposed design models agree very well with the experimental data. Therefore, the authors proposed that effective width formula be used in the ultimate strength calculation of short thin walled CFST box columns that were subjected to an axial load.

2.7 Summary Of Review Of Literature

The behavior of CFST columns and its advantages over the existing conventional construction systems has now gained more importance and has attracted the attentions of researchers all over the world. From the literatures reviewed, it is evident that considerable progress over the last 40 years has been made in the investigation of CFST columns. For studies in the past waste materials were utilized as a replacement for aggregate in concrete. It not only reduced the cost of construction but also saved large quantity of natural sand used in construction industry

Behavior of circular thin walled steel tube with medium strength concrete or thick walled steel tubes with high strength concrete has been studied. In the past, the researchers have studied the behavior of CFST columns, which had the value of L/D = 2 to 5 with strength of concrete from 60 to 120 MPa. Some studies have been conducted for CFST columns with L/D ratio varying from 12 to 25. And so, in this study, the L/D ratio of the CFST columns has been varied from 2.5 to 12.5 and its behavior was studied with M 20 grade of concrete. Fiber Reinforced Concrete (FRC) has been used by some of the researchers instead of plain concrete for the purpose of high stiffness and high ductility than plain concrete filled columns. The lateral displacements of CFST columns were found to be less than the lateral displacements of plain concrete in-filled columns.

3.0 PROBLEM IDENTIFICATION

3.1 GENERAL

The mathematical model takes into account the combined influence of the physical and geometric characteristics of the columns such as their-

- Length
- Cross-Sectional area
- Casing Thickness
- Prism Strength of Concrete
- Yield Strength of Concrete
- Modulus of Elasticity of Steel
- Modulus of Elasticity of Concrete

3.2 BASIC PROBLEMS

There are many problems in relation with using the simple hollow steel columns or simple reinforced concrete column in terms of strength , resistance to axial load, shear or buckling. Some of the common problems arises are-

- In simple reinforced concrete, the high amount of confining lateral steel required by seismic design provisions for column can cause steel congestion.
- The high amount confining steel may hinder the placement of conventional concrete (CC).
- Dead weight of Reinforced Concrete Column is more, hence more load will be there on the foundation.
- Concrete can take up a good amount of compression but is not good enough for tension whereas steel can take up both compression and tension.
- At the end of life, concrete can be crushed and recycled but the material cannot be used for new building concrete. Therefore the scrap value of concrete is almost nil.
- In seismic zones, it is less preferred due to its brittleness and no flexibility leading to direct damage of the structure without warning.

Figure 3.1 Failure of RC column

3.3 STEEL AS A PROBLEM RECTIFIER

In order to have a solution of all the problems discussed above and also to have a better usage of steel is as in tubular form instead of using them as reinforced steel bars. Steel can bend without cracking which acts as a warning in seismic zones. New steel made from scrapped steel uses about one third of the energy necessary for steel from virgin materials. Although initial cost may be high in this tubular concept but maintenance cost can be quite convenient as compared to RC columns and very important fact that these tubular steel can be recycled.

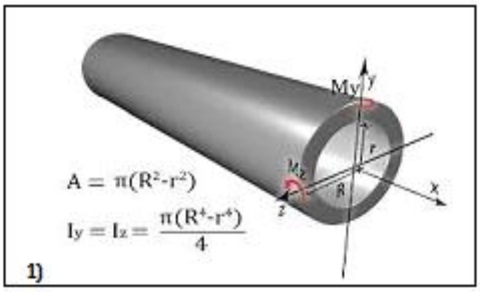


Figure 3.1 Hollow Steel Tube

4.0 METHODOLOGY

4.1 GENERAL

This chapter deals with the behavior of composite columns and its short term and long term behavior are discussed elaborately. The modes of failure and the bond between steel and concrete columns are discussed in the subsequent headings comprehensively. Codal provisions and method of design are also discussed in the last headings.

4.2 BEHAVIOUR OF COLUMNS

Short composite columns exhibit a failure mechanism characterized by yielding of steel and crushing of concrete. Medium length columns behave in-elastically and fail because of partial yielding of steel, crushing of concrete in compression and cracking of concrete in tension. Stocky concrete filled tubes are also susceptible to local buckling of the outer skin, and this is of importance in very thin walled tubes which are nowadays often used in building construction. A short or stocky column is so short that flexural buckling will not occur, although local buckling may occur. Stocky columns are designed primarily on the material strengths of the concrete and steel elements.

The column is usually defined as a structural member who carries only concentric axial compression. The member is a steel element and is subjected to bending as well as axial compression, as occurs when the load is applied eccentrically; it is referred to as a beam-column. The various national standards present load - moment interaction equations which are slenderness-dependent, and which must be satisfied for the strength limit state. Composite members subject to both compression and bending are referred to as columns. Because of the presence of both steel and concrete in a composite column, the behavior of such a member is a kin both to a steel beam column and a reinforced concrete column. Generally speaking, short or stocky composite columns are treated by the reinforced concrete approach based on section material strengths. Slender composite columns, which do not contain appreciable bending actions are treated by the steel approach which is based on a design strength that is affected by the slenderness of the column.

There are a few structural considerations that must be borne in mind when comparing and contrasting the fundamental behavior of encased columns and concrete filled steel tubes. Firstly, concrete filled steel tubes are susceptible to local buckling of the steel skin, the prospect of which in many cases is very thin. The second point pertains to the lateral confinement provided by the tube to the expansion of the concrete core in compression, which enhances the strength of short columns, but it is insignificant in slender columns. Thirdly, the steel skin inhibits the egress of moisture that contributes to creep and shrinkage effects. Research into monitoring the time dependent deformations of concrete filled tubes has indicated a reduced creep and shrinkage induced response.

In all column analysis approaches used at both ultimate and serviceability limits, it is assumed that there is full interaction between the concrete element and the steel element. This implies that the strain profile across the section remains linear, so that there is no step change or slip-strain across the steel / concrete interface, as is often assumed in composite beam design. This assumption is reasonable, since the area of the interface is generally and fairly large and hence a good bond is provided at relatively low bond stresses. It is worth noting that the bond stresses in composite columns are generally lower than those in beams, because the columns are mainly subjected to compression.

4.3 SHORT TERM BEHAVIOUR

In a short concentrically loaded concrete filled steel tube, the concrete core of the column is subjected to a confining stress, and as a result the column can carry considerably larger axial forces than if the concrete was unconfined. The results of tri-axial tests on concrete have illustrated this, where concrete subjected to a lateral confining pressure can carry a greater axial load than unconfined concrete. Of course, this is utilized in reinforced concrete construction where spirally reinforced columns provide a lateral stress that increases the axial load carried by the concrete core. However, the behavior of an axially loaded steel tube filled with concrete will vary according to the method in which the ands of the member are loaded as shown in Figure 3.1. Essentially, there are three fundamentally different methods of applying the loading, and these are discussed below.

Load the Steel and not the Concrete - This condition of loading may not increase the axial capacity of the column above that of the steel tube alone, because the Poisson's effect causes the steel tube to separate from the concrete, once the adhesive chemical bond between the concrete and steel has exceeded. The column will generally fail at the maximum load which the hollow steel tube alone can carry, but the concrete core may tend to delay the column local buckling. For slender columns, the failure load will increase significantly due to the increase in flexural stiffness.

Load the Concrete and not the Steel - In this principle, which is the most favorable loading method, the concrete takes the maximum load as the steel does not resist axial load, but only provides a confining stress to the concrete in an analogous manner to a spirally reinforced concrete column. However, since there is some adhesion between the steel and concrete, the condition is hard to attain as some axial load is produced in the steel.

Load the Steel and Concrete - This is the method most often encountered in practice, and it may be enforced by welding stud shear connectors to the inside of the steel tube where practicable. If the steel is axially stressed in compression as well as circumferentially because of the expansion of the concrete, it will be subjected to a state of biaxial stress which, in accordance with the von-Mises' yield criterion, will reduce the yield stress in the circumferential direction. This has the effect of lowering the confining effect, and hence reduces the maximum load on the concrete. Though the reduction in the confining effect is offset, since the steel now carries some of the compressive force the load-carrying capacity of the column is increased by this steel and concrete.

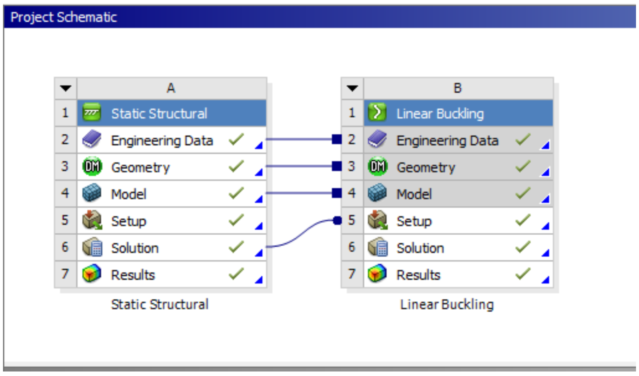
5.0 MODELLING

5.1 ABOUT THE SOFTWARE

For many engineering problems analytical solutions are not suitable because of the complexity of the boundary conditions, the material properties and the structure. The finite element method is the representation of a body or a structure by an assemblage of subdivisions. ANSYS is finite element based software which gives good results on analysis of any structural elements.

The finite element model of the Concrete filled Steel Tube (CFST) was modeled using the software ANSYS 15. ANSYS is a commercial FEM package having the capabilities ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. The finite element model was modeled using direct modeling by both Bottom Up approach and Top Down approach.

5.2 MODELLING IN ANSYS



	A	
1	Static Structural	
2	Engineering Data	✓
3	Geometry	✓
4	Model	✓
5	Setup	✓
6	Solution	✓
7	Results	✓

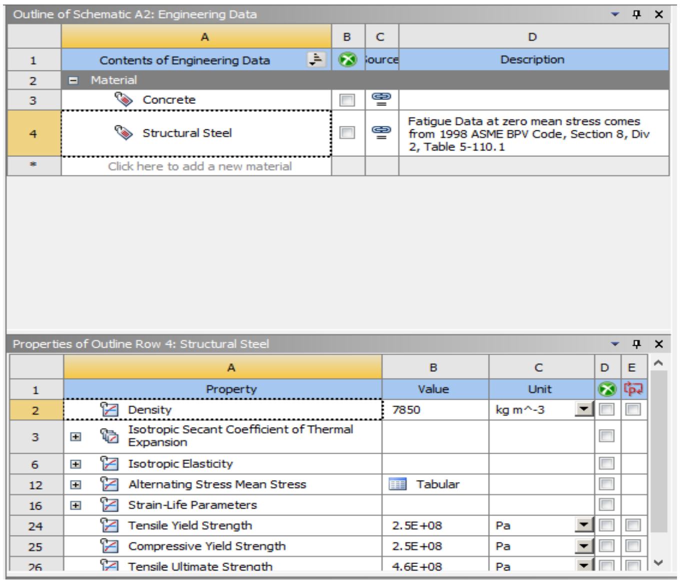
Static Structural

	B	
1	Linear Buckling	
2	Engineering Data	✓
3	Geometry	✓
4	Model	✓
5	Setup	✓
6	Solution	✓
7	Results	✓

Linear Buckling

1)

Fig 5.1:- Input data required for CFST COLUMN



	A	B	C	D
1	Contents of Engineering Data		›ource	Description
2	Material			
3	Concrete	☐		
4	Structural Steel	☐		Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material			

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7850	kg m^-3	☐	☐
3	Isotropic Secant Coefficient of Thermal Expansion			☐	
6	Isotropic Elasticity			☐	
12	Alternating Stress Mean Stress	Tabular		☐	
16	Strain-Life Parameters			☐	
24	Tensile Yield Strength	2.5E+08	Pa	☐	☐
25	Compressive Yield Strength	2.5E+08	Pa	☐	☐
26	Tensile Ultimate Strength	4.6E+08	Pa	☐	☐

Fig 5.2:- Properties of CFST materials

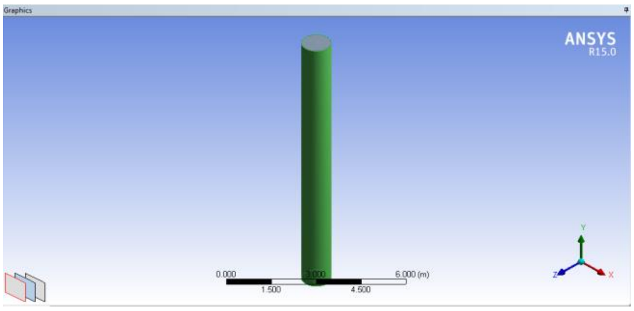


Fig 5.3:- Model of CFST column

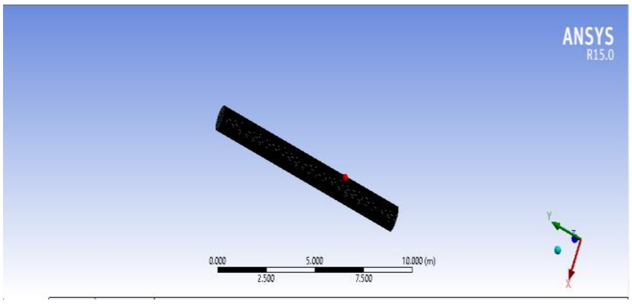


Fig 5.4:- Meshing of CFST column

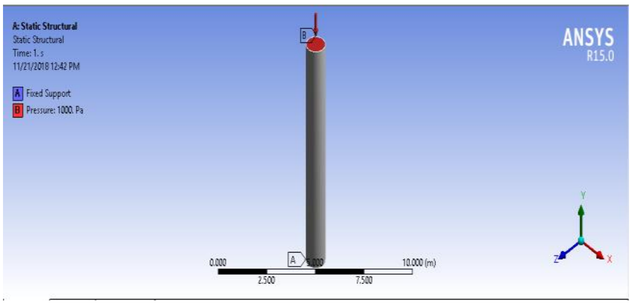


Fig 5.5:- Force and Supports acting on CFST column

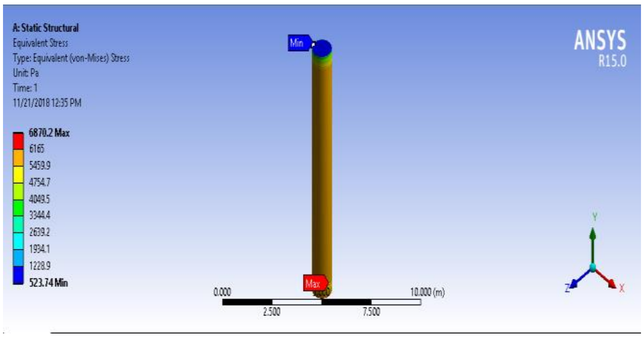


Fig 5.6:- Equivalent Stress acting on CFST column

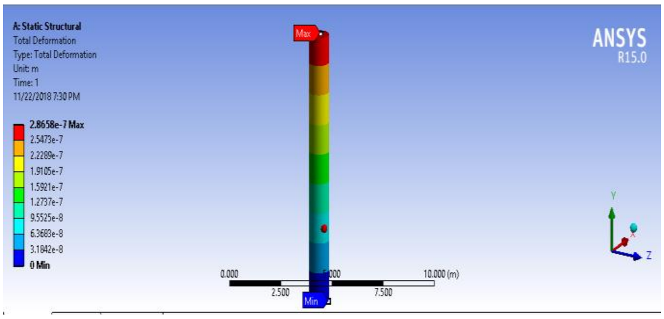


Fig 5.7:- Total Deformation on CFST columns

6.0 RESULTS AND DISCUSSIONS

Table 6.1 Variation of crippling load for different L/D ratios

L/D	CRIPPLING LOAD(KN)
21.76	205.54
19.63	294.34
17.95	402.78
16.40	554.54
15.14	734.64
12.90	1391.36

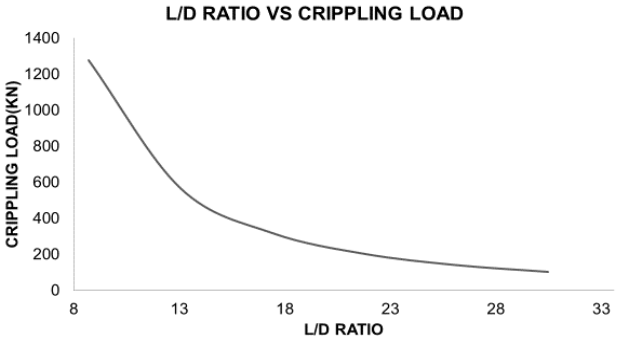


Fig 6.1 Graph showing variation of crippling load for different L/D ratios

From the above graph, as value of L/D ratio increases value of crippling load decreases gradually

Table 6.2 Variation of crippling load in ANSYS for different L/D ratios

L/D	ANSYS(KN)
21.76	212.09
19.63	307.22
17.95	421.2
16.4	578.99
15.14	761.6
12.9	1457.7

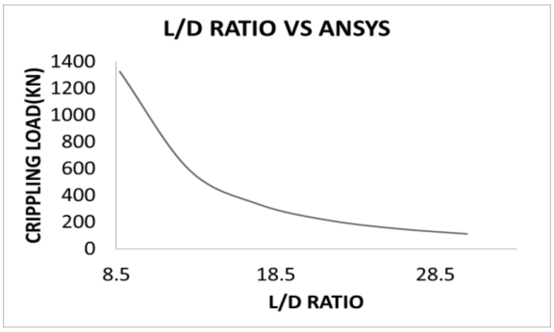


Fig 6.2 Graph showing variation of crippling load in ANSYS for different L/D ratios

- From the above graph, as value of L/D ratio increases value of crippling load in ANSYS decreases gradually

Table 6.3 Comparison of crippling load and ANSYS for different L/D ratios

L/D	CRIPPLING LOAD (KN)	ANSYS(KN)
8.71	1277.43	1324.9
13.06	567.19	590.59
17.41	318.60	331.66
21.76	203.54	213.09
26.12	142.048	148.9
30.42	105.361	111.04

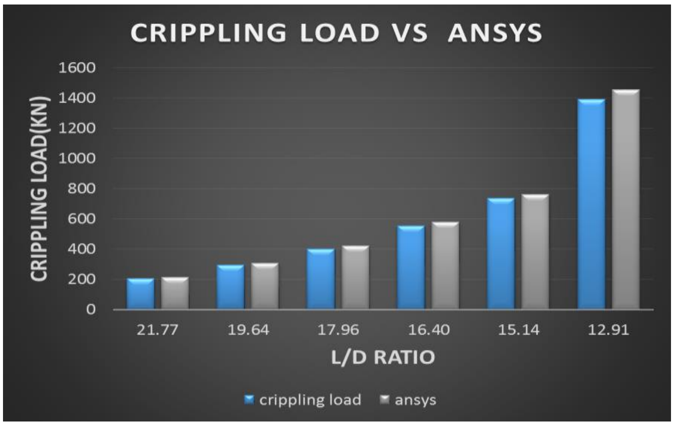


Fig 6.3 Graph showing variation of crippling load and ANSYS for different L/D ratios

- Graph shows the variation of crippling loads by EULERS formula and ANSYS for different values of L/D ratio

Table 6.4 Variation of crippling load for different D/t ratios

D/t	CRIPPLING LOAD(KN)
38.28	205.54
42.43	293.55
46.4	402.78
50.8	554.54
55.03	734.64
60	1391.36

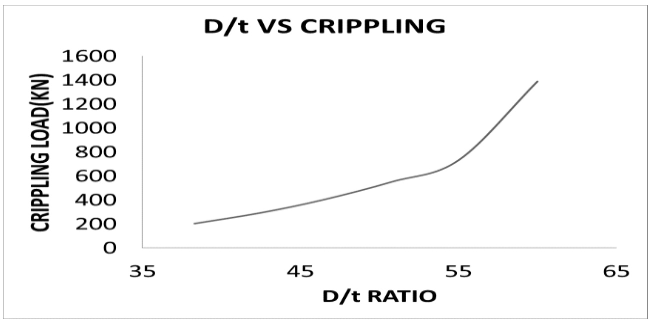


Fig 6.4 Graph showing variation of crippling load for different D/t ratios

- From the above graph, as value of D/t ratio increases value of crippling load increases gradually

Table 6.5 Variation of crippling load in ANSYS for different D/t ratios

D/t	ANSYS(KN)
38.28	213.07
42.43	306.24
46.4	420.22
50.8	581
55.03	762.6
60	1456.9

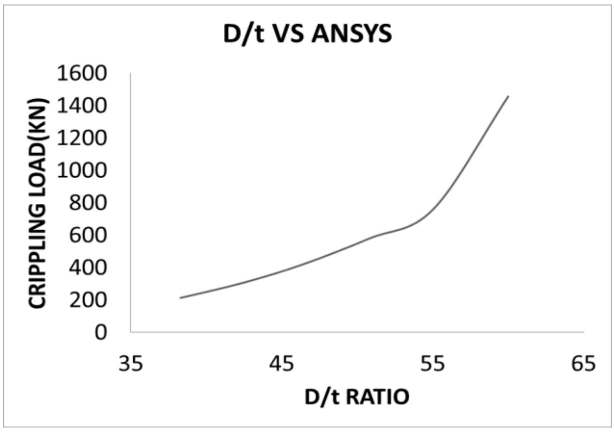


Fig 6.5 Graph showing variation of crippling load in ANSYS for different D/t ratios

- From the above graph, as value of D/t ratio increases value of crippling load in ANSYS increases gradually

Table 6.6 Comparison of crippling load and ANSYS for different D/t ratios

D/t	Crippling load(KN)	ANSYS(KN)
38.23	205.54	213.07
42.43	293.55	306.24
46.4	402.78	420.22
50.8	554.54	581
55.03	734.64	762.6
60	1391.36	1456.9

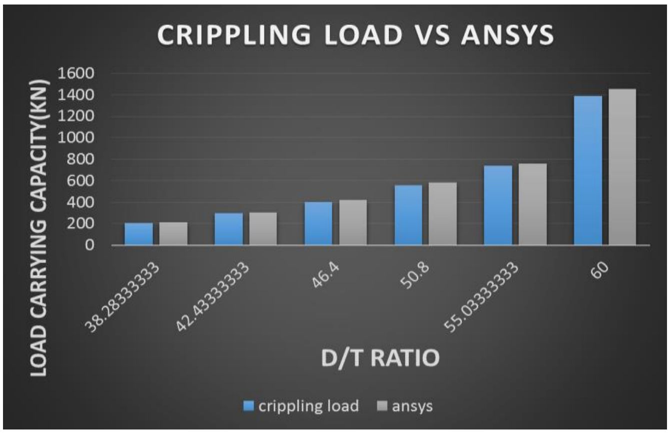


Fig 6.6 Graph showing variation of crippling load and ANSYS for different D/t ratios

- Graph shows the variation of crippling loads by EULERS formula and ANSYS for different values of D/t
- From the above graph, as value of D/t ratio increases value of crippling loads in Euler's formula and ANSYS increases gradually.

Table 6.7 Deformation and Stress corresponding to various thickness of CFST concrete

Thickness(mm)	Stress(MPa)	Deformation(mm)
2	2.2312	0.054743
2.5	1.7128	0.053766
3	1.423	0.053153
3.5	1.1672	0.052685
4	0.9876	0.052321
5	0.7501	0.051488
6	0.5881	0.051222

7.0 SUMMARY AND CONCLUSIONS

7.1 SUMMARY

Role of concrete and steel in construction is so prolific that research and developmental efforts to augment, modify and supplement these two materials are a continuous process. Towards this, introduction of new materials or new technology either in construction or in design to compensate for weaknesses in both materials is on the rise. Concrete composites, confined concrete, concrete filled steel tubular sections.

7.2 CONCLUSIONS

Based on these extensive experimental and analytical investigations, important conclusions have been arrived at and they are as follows:

- For composite column with concrete filled circular sections, the confinement effect of concrete increases the resistance to axial load.
- As the value of L/T ratio increases, the load carrying capacity of the CFST columns decreases
- As the value of D/t ratio increases, the load carrying capacity of the CFST column increases.
- The local buckling of steel tube gets delayed due to the in-filled concrete.
- Results of the numerical simulations were compared with the theoretical formulae. Apparently, good agreement has been obtained from the comparison.
- The buckling failure can be avoided and the load carrying capacity can be increased by lowering the slenderness ratio for CFST columns.
- It was observed from the analysis of different data, the failure mode of the CFST composite column depends on slenderness ratio.
- When the slenderness ratio is very less, the column fails due to local buckling of steel nearer to the support and crushing of concrete under direct compression. When the

slenderness ratio is large, the column fails by elastic buckling.

2) SCOPE FOR FURTHER RESEARCH WORK

1. A detailed study needs to be made on beam column and column-column connections to the CFST columns.
2. Further research is required to consider general boundary conditions and the effect of this on the load-deflection behavior of the concrete filled steel tubular columns. This could provide more helpful recommendations for various design aspects.
3. The study of confinement effect can be extended to other L/D ratios and D/t ratios and the behavior can also be studied for different support conditions.
4. Experimental investigations can also be carried out on eccentrically loaded composite columns.
5. The study can also be extended to cyclic loading and transverse loading.
6. In the present investigation to study the influence of confinement of concrete M 30 grade of concrete alone has been used. The study can also be extended to cover other higher grades of concrete.
7. Experimental investigations can also be carried out on design and detailing of shear connectors between steel and concrete interface, when the moment is the predominant force.

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