A Thesis on

STUDY ON COMPRESSIVE STRENGTH OF CONCRETE FILLED STEEL TUBES

Submitted for partial fulfillment of the requirement for the award of degree

MASTER OF TECHNOLOGY

IN

Structural Engineering

By

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DECLARATION

I Mohammad Anas declare that thesis entitled **"STUDY ON COMPRESSIVE STRENGTH OF CONCRETE FILLED STEEL TUBES"** submitted by me in the partial fulfillment of the requirements for the award of the degree of Master of Technology (Structural Engineering) of Integral University, Lucknow. The thesis is record of my own work carried under the supervision and guidance of **Md Tasleem (Assistant Professor).** The Thesis has been composed by me and that the work has not been submitted for any other degree or professional qualification. I also declare that in case of any discrepancy I will be solely responsible. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

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CERTIFICATE

Certified that the thesis entitled **"STUDY ON COMPRESSIVE STENGTH OF CONCRETE FILLED STEEL TUBES"** is being submitted by **Mohammad Anas (2001431003)** in partial fulfillment of requirement for the award of degree of **Master of Technology in Structural Engineering** from **Integral University, Lucknow**, is a record of candidate's own work carried out by him under my supervision and guidance The results presented in this thesis have not been submitted to any other university or institute for the award of any other degree or diploma.

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Date : Mohammad Anas

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ABSTRACT

Concrete Filled Steel Tubes (CFSTs) were used in construction in the early 1900's. However, the research into CFSTs did not begin until the 1960s. From that time onwards, several studies were conducted on the CFSTs to fully understand their behavior with the aim of improving their performance. The proposed research presents an experimental study to investigate the effect of some the main influencing factors on the compressive behavior of circular CFST columns. The parameters of interest are mainly the concrete's compressive strength, Equivalent Elastic Strain**,** Equivalent Stress, the diameter-to-thickness ratio and the axially applied load.

Keywords: CFST; Confined concrete filled steel tube; CCFST; Axial load behavior; Deformation; Deformation; Nonlinear analysis; Strain rates; Composite column; Diameter-thickness ratio; Finite elements analysis; Ansys.

CHAPTER 1
INTRODUCTION

1.1 General

Now days, we see lot of structures, big and small, modern and old, what catches our eyes the most are the modern skyscrapers, these structures are made out of extraordinary attainments in science and engineering. Nowadays, the main focus has been shifted to constructing safe buildings keeping in mind the economic aspects of the project. As far as residential and commercial purpose is considered, generally, high-rise buildings, tall structures, towers and blocks are constructed. They may also be known as vertical city. Consist of the ability to give more ground space and accommodating more people in less space. Composite construction governs the non-residential high storey buildings sector. This has been the case for over twenty years. Its recognition is due to its strength and stiffness that can be achieved, with minimum use of material the reason why composite construction is frequently so good can be expressed in one simple way - concrete is good in compression and steel is good in tension. By combining these two materials together structurally these strengths can be exploited to result in a highly efficient and light weight design. Composite systems also offer benefits in terms of time saving construction, decreasing floor depth etc.

At the present time, the concrete filled steel tube columns are widely used in construction. Actually, this type of structural elements is favored in practice because of its small cross sectional area to load carrying capacity ratio. Hence, mega concrete columns in tall buildings' lower floors can be substituted by smaller sections of CFST columns. Moreover, CFST elements can be used as piers for bridges at congested areas. Therefore, such structural elements should be thoroughly investigated before used in critical structures. Despite being a research topic for around 50 years, the behavior of the CFST columns under different loading conditions is not fully studied. Thus, intensive parametric studies should be performed in order to fully understand the CFST columns behavior. This study, addresses some parameters that affect the CFST column behavior which are the steel tube outer diameter to thickness ratio, the concrete infill compressive strength, the loading rate, and adding admixtures like polymer and GFRC to increase the properties of concrete.

1.2 Background

Steel-concrete composite columns were used for over a century. At the beginning it was used to provide fire protection to steel structures. Afterwards, the concrete encased columns' strength properties were also considered in the design. However, the research into concrete filled steel tubes (CFST) did not begin until the 1960s.

Columns were hardly used from the Second World War till the initial 1970s. Combining concrete and steel had a number of motives, steel columns were frequent encased in concrete to give resistance against the fire, and the other hand concrete columns used with steel as a rebar providing. Till the 1950s, it was common to use a wet mix of less strength concrete and neglect the role of the good class concrete to the strength of the column. In 1956 Faber and Steven proved that it is good in economic aspects and it could be made by using good-class concrete and use these columns like a composite part. Method was discovered by stages from initial design ways for steel columns. Not centered on ultimate research on composite columns. In the era of 1980, many buildings were built by using of CFST columns. Many developed countries like USA, Japan, Germany, Singapore, Australia, Canada, Belgium etc., adopt this kind of composite sections to facilitate speedy construction. Because of the increased use of composite columns, many experimental and theoretical research works has been carried out to study the behaviour of the CFST columns.

1.3 Concrete filled steel tube

1.3.1 Introduction

Nowadays, the composite structural elements are increasingly used in tall buildings, bridges and other types of structures. Because of its composite effects, the disadvantage of two materials can be compensated for and the advantages can be combined providing efficient structural system. The steel-concrete composites are considered as an advantageous system for carrying large axial load benefitting from the interaction between the concrete and the steel section. The steel section reinforces the concrete to resist any bending moments, tensile and shear forces. The concrete in a composite column reduces the potential for buckling of the steel section in addition to resisting compressive loading. There are two types of steel-concrete composite columns which are commonly used in buildings. Those with steel section in-filled with concrete and those with steel section encased with concrete.

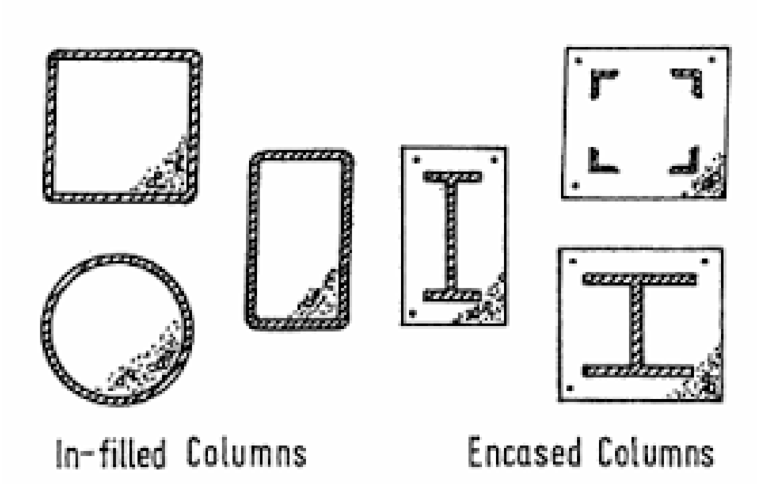


Figure 1: Types of composite column

The use of composite columns, encased or in-filled, results in significant reduction of the column size when compared to regular reinforced concrete columns needed to carry the same load. Hence, considerable economic savings can be obtained. Also, the column size reduction is advantageous where floor space is at a premium, such as in office blocks and car parking's. In addition, closely spaced composite columns connected with spandrel beams can be used around the outsides of the high rise buildings for lateral loads resistance by the tabular concept. Concrete encased steel composite sections are favored for many seismic resistant structures. When the concrete encasement cracks under severe flexural overloading, the stiffness of the section reduces but the steel core provides shear capacity and ductile resistance to subsequent cycles of overload. Additionally, the surface area of the enclosed steel sections is intact by the concrete cover, thus required no painting and fireproofing costs. Concrete filled steel tube (CFST) columns are favored for many earthquake resistant structures, columns in high rise buildings, bridge piers subject to high strain rate from traffic and railways decks. Concrete filled steel tubes necessitate supplementary fire resistant insulation if fire protection of the structure is crucial. The CFST structures have better constructability because the steel tubes can be used as the formwork and the shoring system for casting concrete in construction. Moreover, CFSTs provide high compressive and torsional resistance about all axes when compared with concrete encased steel composite sections.

1.3.2 Types of composite column

Concrete infill steel column uses the benefits of both the materials steel as well as the concrete. Generally steel hollow section of circular or rectangular fill with plain or reinforced concrete is mostly used in high-rise and multi-storey buildings as columns and as beams in low-rise industrial buildings where a healthy and effective structural system is needed. There are a number of various advantages about which to such structural systems in both ways of structural performance and construction order, the buckling problem in thin-walled steel tubes is either banned or reduce because of the existence of the concrete core, in addition to that, the ability of the concrete in-fill is improved due to its confinement effect applied by the steel shell. Another factor like distribution of materials in the cross section helps to make whole system efficient in term of its structural performance. Because of the steel cover provided on outer side, it behaves most efficiently in tension and buckling. It also gives the ultimate stiffness as the material lies furthest from the centroid. This, combined with the steel's high modulus of elasticity, gives the high impact to the moment of inertia. The concrete core gives the greater contribution to resisting axial compression by a flat plate that is created with a single casting. This results in considerable reduction in the use of concrete and steel.

1.3.3 Concrete Filled Sections

a) Circular Concrete Filled Steel Tubes (CCFST)
b) Square Concrete Filled Steel Tubes (SCFST)
c) Rectangular Concrete Filled Steel Tubes (RCFST)

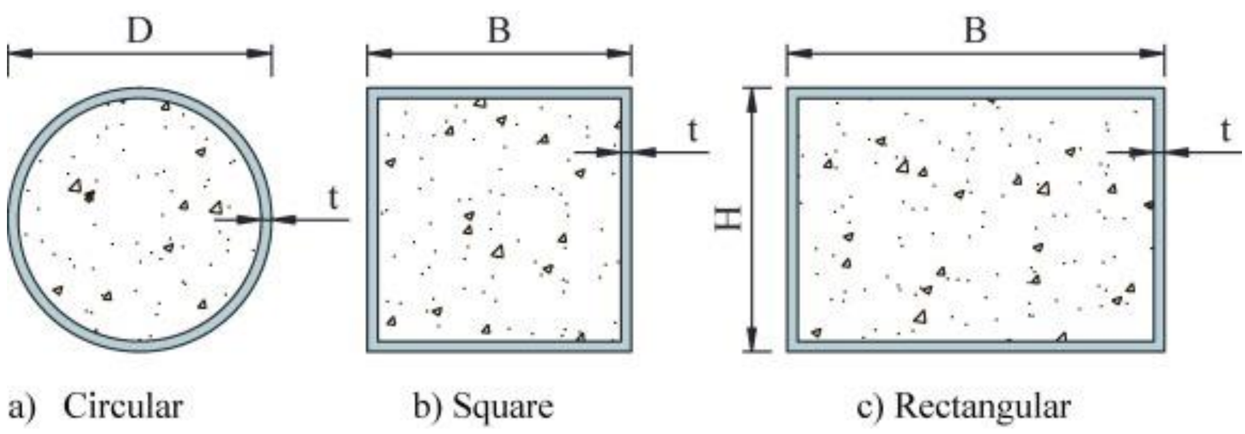
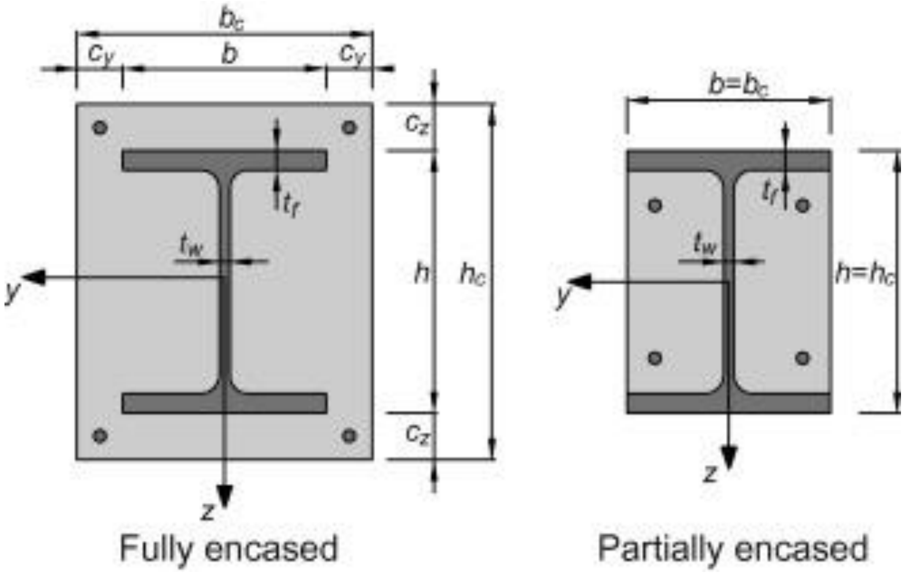


Figure 2: Concrete Filled Sections

1.3.4 Fully or Partially Encased Section

a) Fully encased Concrete Filled section
b) Partially encased Concrete Filled section



(a) **(b)**

Figure 3: Fully or Partially Encased Section

Figure 3(a) shows section in which concrete is filled inside the hollowed steel sections i.e., hollow tube, hollow box or hollow rectangular. Figure 3(a) shows the sections in which structural steel i.e. I-Section is fully encased with concrete or we can say that I-section is dipped in concrete with or without reinforcement. Figure 3(b) shows that sections are partially filled with concrete, with or without reinforcement.

1.3.5 Behavior of CFST during loading

In the initial concentric axial loading stages of the CFST column, both concrete infill and structural steel will deform longitudinally. Of course, it is assumed that the concentric loading is 20 applied uniformly across the CFST section. The Poisson's ratio of the concrete infill (ranges between 0.15-0.25) is smaller than that of structural steel (roughly 0.28) at these initial strains. Thus, the lateral expansion of the confining tube is larger than the confined concrete. As a result, localized separation between the two composite materials takes place along the column. Moreover, minimal interaction between the two materials occurs if any. The concrete and the steel bear their shares of the applied load independently during this phase. At a certain strain, the expansion of the concrete infill laterally increases until it reaches the lateral expansion of the steel. Keep in mind that the structural steel expansion remains constant in this stage and micro-cracking in the concrete begins to take place. This acceleration in the concrete expansion results in an interactive contact between the two materials. Hence, bond stresses are developed and the concrete will be subjected to tri-axial stresses while the structural steel to biaxial stresses. Longitudinal stress in the confining tube varies based on the transfer of force between the concrete and steel. The strain level at which confinement occurs is debated among researchers to range from 0.001 to 0.002. Some scientists such as Knowles and Park concluded that concrete confinement happens suddenly at a about (strain of 0.002) just as the concrete starts dilation. While other researchers as Tsuji, et al. and Zhang, et al. proposed a steady increase in the concrete confinement starting right after the occurrence of micro-cracking in the concrete (strain of 0.001), till full confinement is met at a strain around 0.002.

In the second stage of loading where the confinement of the steel tube on the concrete is present, circumferential stresses are developed in the structural steel due to two factors:

1. Longitudinal stresses from loading.
2. Lateral pressure from concrete dilation.

Based on the steel utilized in the composite element, the steel could have reached its capacity prior to their yield in this stage. If tube yielding occurs before this biaxial state of stress, the tube would not be able to sustain the normal yield stress, resulting in a transfer of load from tube to the concrete core. Conversely, if the confining tube has not yet yielded, the extra axial capacity needed from the steel tube before yielding will be reduced. Unlike the effect biaxial state of stress on the steel tube capacity, the concrete infill performance enhances when experiencing triaxial state of stress. The presence of confinement on the concrete infill increases its axial capacity. Despite the decrease in its steel tube capacity, the circular CFST column’s overall capacity increases because the increase in the concrete infill capacity due to confinement is far greater than the strength loss in the steel tube.

1.3.6 Failure modes of CFST

There are various modes of failure for the CFST based on their material properties and geometric configuration. However, the most dominant failure mode is the local buckling of the steel tube. When compared with the empty steel tube, the local buckling in the CFST column is delayed due to the presence of concrete infill. The concrete prevents the steel tube from buckling inward; instead it forces the tube to buckle in an outward mode as shown in Figure 2.

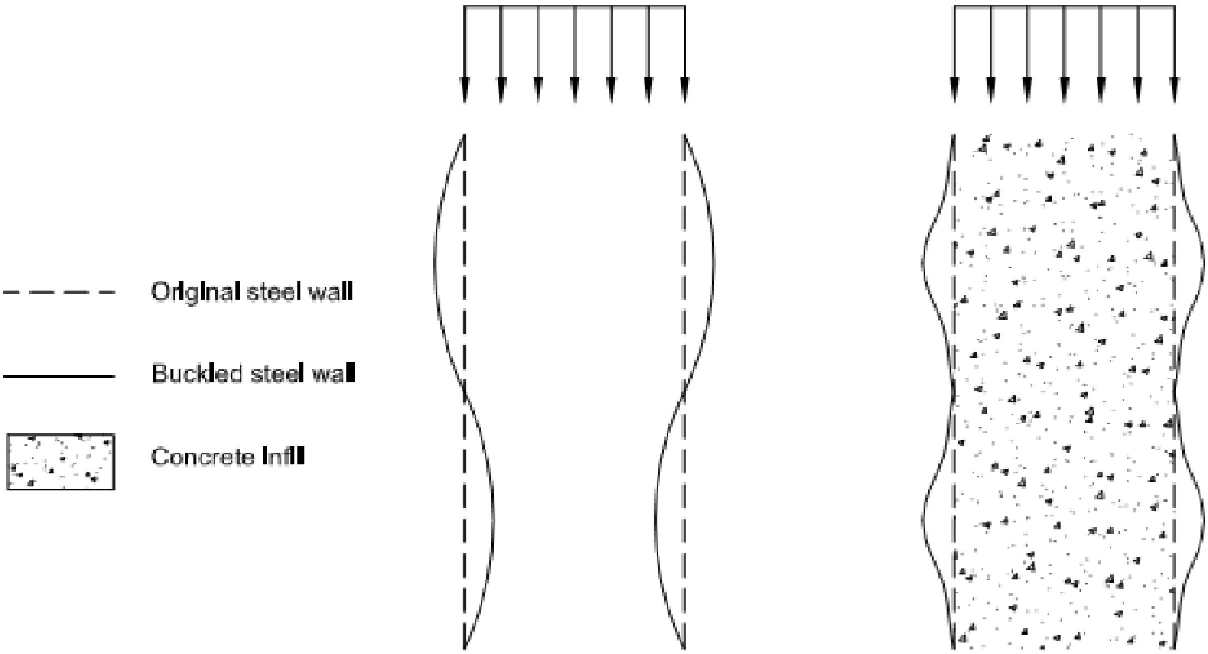


Figure 4: Changes in buckling mode with length due to the presence of infill

The outward buckling mode of the steel tube has three advantages for the behavior of the CFST element:

- The delay in tube buckling keeps the steel in the elastic range longer which often allows for the yield stress to develop before buckling.
- The element modulus does not decrease rapidly during this type of failure because the distance between the cross section’s edges increases.
- 54The localized steel tube buckling is forced to spread over a larger region of the column height limiting the occurrence of strain concentrations.

1.3.7 Advantages and Disadvantage of CFST columns

A designer could think of using larger steel cross sections instead of composite section in order to avoid complexity of construction. Or even mega RC column in high rise buildings. However, the bare steel sections and RC columns have several drawbacks that can be addressed by using steel-concrete composite columns, such as:

1- **Maintenance costs:** When exposed to air and humidity, the steel structures are vulnerable to corrosion, thus they have to be painted periodically. This issue occurs in the case of CFST structures but not in the encased concrete composite element because the steel section is protected by the surrounding concrete.

2- **Buckling failure:** The steel sections are considered economical because of their low strength to weight ratio. However, with the increased slenderness of the steel column the carrying capacity decreases because of the buckling failure domination. In the composite columns the concrete delays the buckling when compressively loaded which enhances the capacity of the element. Also, thinner steel section would be required in the presence of concrete thus the cost is reduced.

3- **Fireproofing costs:** The steel sections has high load carrying capacity at normal range temperatures, but its strength reduces immensely when exposed to high temperatures, thus fireproofing is essential. This issue occurs in the case of CFST structures but not in the encased concrete composite element because the steel section is protected by the surrounding concrete.

4- **Constructionability:** The structural steel tube in the CFST performs as in-place framework. Of course, fixing the steel tube for casting concrete is much easier and less time consuming than fixing and removing frame work. Also, the presence of steel tube minimizes the need for rebar fixing which is one of the most tedious work package in the RC construction.

5- **Ecology:** The reduction in wood consuming needed for the formwork is environmentally advantageous. Also, it is much easier to reuse the concrete and the steel of CFST elements compared to regular RC members.

6- **Cost:** Due to the previously mentioned reasons the cost of using CFST member in construction is more attractive than many other alternatives. For instance the reduction in labor cost needed for reinforcement fixing or removable frameworks.

1.4 Ansys Workbench as a tool for Finite Element Analysis

Finite element (FE) modeling results have been widely accepted due to the significant improvement in the FE modeling and analysis in recent years The FE model has been developed based on the recommendation in order to investigate the behavior of the CFST columns under axial compressive loading. The FE model developed for CFST to predict the load-deformation behavior of CFST columns. ANSYS is the most advanced, comprehensive and reputable finite element analysis and design software package available for Structural Engineering Projects. The system combines the states of art general purpose structural analysis features of Ansys with the high-end civil engineering specific structural analysis capabilities of Civil FEM/Workbench (FEA), making it a unique and powerful tool for a wide range of Civil Engineering Projects.

Ansys develops and markets finite detail evaluation software program used to simulate engineering problems. The software program creates simulated computer fashions of systems, electronics, or machine additives to stimulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and different attributes. Ansys is used to decide how a product will feature with exceptional specifications, without constructing check merchandise or engaging in crash tests. For example, Ansys software program may also simulate how a bridge will maintain up after years of traffic, a way to exceptional method salmon in a cannery to lessen waste, or a way to layout a slide that makes use of much less fabric without sacrificing safety.

Most Ansys simulations are achieved the use of the Ansys Workbench software program, which is one of the company's primary products. Typically Ansys customers break down large systems into small additives which can be every modeled and examined individually. A user may also begin with the aid of using defining the size of an object, after which including weight, pressure, temperature and different bodily properties. Finally, the Ansys software program simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic performance and different outcomes over time. Ansys additionally develops software program for facts control and backup, instructional studies and teaching. Ansys software program is offered on an annual subscription basis.

The Analysis Results of slab, beam, column, shear wall using Ansys is more accurate and useful in field of Structure Engineering. Ansys helps to get the major effect on any structure due to different loading on structure. Ansys divides the object into number of finite time using FEA to study each and every behavior of structure under deformation. It's generally used for research purpose for analysis of new composition of material used in structure by providing the mechanical properties in engineering data. Analysis Work of Ansys is accurate but is time taking and can even take hour or a week or a month depending on the type of structure analysis, meshing and loading.

1.4.1 The ANSYS Workbench Interface:

The ANSYS Workbench Interface is composed ordinarily of a Toolbox region, the Project Schematic, the Toolbar, and the Menu Bar. Depending at the evaluation kind and/or utility or workspace, one may additionally see different windows, tables, charts, etc. One manner to paintings in ANSYS Workbench is to pull an object consisting of a thing or evaluation device from the Toolbox to the Project Schematic or to double-click on an object to provoke the default action. You also can use the context menus, accessible from a proper mouse click on, for extra options. One can view their evaluation systems.

ANSYS Workbench combines the strength of 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. From the schematic, you can interact with applications that are native to ANSYS Workbench (called workspaces) and that display within the ANSYS Workbench interface and you can launch applications that are data-integrated with ANSYS Workbench, meaning the interface remains separate, but the data from the application communicates with the native ANSYS Workbench data.

Getting Started

Projects in ANSYS Workbench are built by adding and connecting systems. Each system is displayed in the Project schematic as a block of cells. You complete your analyses by working through each cell in order. In general, data flows from the top to bottom within systems and from left to right between systems. Output data from upstream cells is provided as input data to downstream cells.

Drag and Drop Object Handling

One of the easiest ways to work with systems in the project schematic is to drag-and-drop. Drag- and-Drop operations can be used to introduce systems to the schematic, move systems around, and to form connections between existing systems. For example, to add a system to the Project Schematic, place your cursor over the name of the desired system in the Toolbox, and while holding the left mouse button down, drag the system onto the desired location in the Project Schematic. This method offers you the flexibility to preview multiple locations. Static Structural where the system could be added and choose the best location for that system.

Right Mouse Button Usage

ANSYS Workbench allows you to access a significant portion of the functionality via the right mouse button, for almost any location in the Project Schematic; you can click the right mouse button to see a list of context- sensitive options.
Some options are common across different types of systems, and some options are unique to the specific cell or system and its current state.

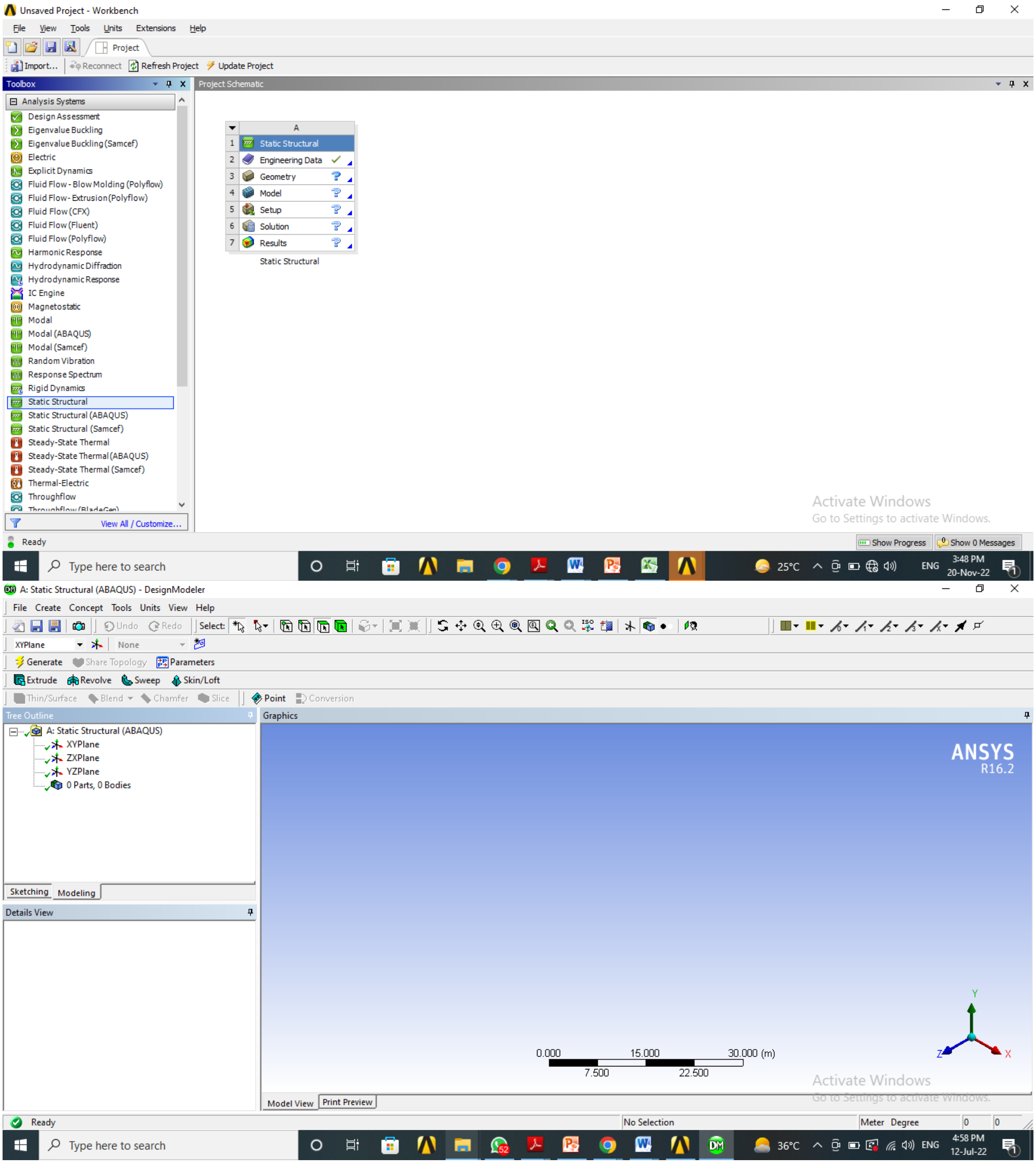


Figure 5: GUI of Ansys Workbench 16.2

CHAPTER 2
LITERATURE REVIEW

2.1 Review of research done in past

Some of the relevant literature on the topic "Study on Compressive Strength of Concrete Filled Steel Tubes" are covered here that deals with the seismic performance, stability parameters, concrete's compressive strength, Equivalent Elastic Strain**,** Equivalent Stress, the diameter-to-thickness ratio, fire resistance properties etc. This part of thesis aims to review the previous studies on CFST columns.

1. **Hassan, M. K., Sheikh, M. N., & Saha (2021); Behaviour and design of prefabricated CFST stub columns with PCC connections under compression.** The axial load-bearing capacity of the PCC columns depends primarily on the reinforcing material, binding bolts, and standard bolts. If coupling bolts are not included in PCC connection, PCC1 load capacity of column is 7% -12% less than the load capacity of the corresponding CFST columns. The load-deformation behaviour under compression of prefabricated CFST columns with PCC connections is compared with the load-deformation behaviour under compression of CFST columns without connections.

2. **Shuai Li, Lin-Hai Han , Fa-Cheng Wang, Chuan-Chuan Hou (2020); Seismic behavior of fire-exposed concrete-filled steel tubular (CFST) Columns.** CFST columns survived during combined fire exposure and continuous axial load. Residual deformation and pressure of CFST columns are similar to those under equilibrium fire exposure and axial load respectively. The residual deformation and stress of CFST columns are similar to that subjected to equal fire exposure and axial load sequentially, hence no further modification is needed.

3.Chuan-Chuan Hou, Lin-Hai Han (2019); Compressive behaviors of CFST stub columns at low temperatures relevant to the Arctic environment. At low temperatures, 63% of the CFST circular columns fail in the shear mode at ultimate compressive load while others fail in concrete crushing. Most of the square CFST (S-CFST) column failed in concrete crushing at their at its highest rigidity.

4. **Chuan-Chuan Hou, Lin-Hai Han (2018); Life-cycle performance of deteriorated concrete-filled steel tubular (CFST) structures subject to lateral impact Cfst columns fails mainly because of compression bending.** The combination of stable load, rust and impact brings significant damage to the loading volume of the CFST round column, much larger than the reduction of the damage caused by individual actions. The column ultimately fails due to compression bending. The coupling of sustained load, corrosion and impact brings notable deterioration to the loading capacity of the circular CFST column, which is even larger than the summation of deteriorations brought by the individual actions.

5. **Dong, C.X., Kwan, A.K.H., Ho, J.C.M. (2017); Effects of external confinement on structural performance of concrete-filled steel tubes.** The provision of external confinement with FRP folding mechanisms or metal rings could significantly increase the ductility of CFST columns. It was found that the provision of external confinement in the forms of either FRP wraps or steel rings can substantially increase the ductility of CFST columns.

6. **Jingfeng Wang, Na Zhang (2017); Performance of circular CFST column to steel beam joints with blind bolts.** Circular joints in the CFST column use blind bolts to perform better behavior in ductility and ultimate moment capacity. Providing blind bolt extensions and two internal welding rings in the connecting area can improve the structure of the moment connections. The circular CFST column joints using blind bolts performed better behavior in ultimate moment capacity and ductility. Ultimate moment capacities of the end plate joints are significantly affected by the end plate thickness, the bolt diameter, the bolt pretension force, the beam to column yield strength ratio. Providing the blind bolt extensions and two welding internal rings in the connection region could improve the structural properties of the moment connections.

7. **Wei Dong, Zhimin Wu, Xiangming Zhou , Yongjie Tan (2016): Experimental studies on void detection in concrete-filled steel tubes using ultrasound.** For CFST components without a void, the ultrasonic waves penetrate the wall of the steel and concrete and propagate directly. In the case of CFST members with a de-bonding void, the ultrasonic waves pass through the vacuum along the wall of the steel tube and then pass through the concrete in a straight line. The chromatogram of the distribution of ultrasonic wave travel time based on the derived densified matrix can be drawn using MATLAB. For the CFST

members without a void, the ultrasonic waves penetrate the steel tube wall and concrete and are transmitted in a straight line. In the case of CFST members with a de-bonding void, the ultrasonic waves bypass the void area along the wall of the steel tube and then travel through the concrete along a straight line.

8. **Wang, Yan-lei; Cao, Ming-min; Sun, Hui-jie (2015); Time-dependent reliability analysis of circular CFST stub columns under environmental corrosion.** The thickness of the steel tube has little effect on the reliability of the stub columns, and the live load rate has a significant impact on the reliability in the first two decades. The resistance and reliability of circular CFST stub columns decrease over time under corrosive environments.

9**. Yao Yao , Xin Xin Hu (2015); Cooling behavior and residual strength of post-fire concrete filled steel tubular columns.** The behavior of the CFST column under natural fire differs from that of conventional fire. The duration of the fire, the cross-sectional diameter and slenderness has a significant impact on the residual volume of the CFST columns after natural fire exposure.

10. **Han, Lin-Hai; Hou, Chuan-Chuan; Wang, Qing-Li (2014); Behavior of circular CFST stub columns under sustained load and chloride corrosion.** It was found that with increasing rust levels, ductility and ultimate strength of the columns would decrease. The combined effect on the CFST stub round column is stronger than that of the square coloumn, making the power loss of the circular one greater than that of a square coloumn, as long as the loading and rust conditions are the same.

11. **Liao, Fei-Yu; Han, Lin-Hai; Tao, Zhong (2013); Behaviour of CFST stub columns with initial concrete imperfection: Analysis and calculations.** The maximum limit of the proposed scale is 0.05%, which can be used by engineers and architects to control the circumferential gap in real CFST structures. For a CFST stub column with a circumferential gap, as the gap ratio is equal to or less than 0.05%, the concrete will contact its outer tube before the peak load of the column is attained.

12. **Yang, You-Fu; Cao, Kai; Wang, Tian-Zheng (2013); Experimental behavior of CFST stub columns after being exposed to freezing and thawing.** CFST columns loaded axially after freezing and thawing exposure have a stable load versus deformation responses

and great ability against deformation. The ultimate strength and elastic modulus would increase with the increasing of steel ratio and the decreasing of number of freeze–thaw cycles.

13. **Hou, Chao; Han, Lin-Hai; Zhao, Xiao-Ling (2016); Concrete-filled circular steel tubes subjected to local bearing force.** It was found that CFST behaved in a ductile manner under local bearing forces and generally, serviceability is in control. It was observed that the corresponding capacity of CFST is significantly higher than that of the reference hollow section and plain concrete specimens, due to the confinement effects between the steel tubular chord and the concrete core.

14. **D. Lam; X.H. Dai; L.H. Han; Q.X. Ren; W. Li (2012): Behaviour of inclined, tapered and STS square CFST stub columns subjected to axial load.** It was found that a reduction factor should be introduced to account for the influence of the inclined and tapered angle to the maximum compressive capacity. The relationship of load reduction factor to the angle is nearly linear and not sensitive to the cross sectional dimensions for tapered and STS columns but sensitive for the inclined columns. It was observed that the corresponding capacity of CFST is significantly higher than that of the reference hollow section and plain concrete specimens, due to the confinement effects between the steel tubular chord and the concrete core.

15 **Lin-Hai Han; Yong-Jin Li; Fei-Yu Liao (2011): Concrete-filled double skin steel tubular (CFDST) columns subjected to long-term sustained loading.** Long-term deformation of CFDST columns increases relatively fast at an early stage, whilst the process tends to stabilize after about 100 days. Long-term sustained loading decreases the ultimate strength of the CFDST column whilst increases the corresponding deformation.

16**. Yuyin Wang; Yue Geng; Gianluca Ranzi; Sumei Zhang (2011): Time-dependent behaviour of expansive concrete-filled steel tubular columns.** The strength of the specimens subjected to sustained loading was higher than the one observed for the specimen remained unloaded during the long term test. It was found that the assumption of linear creep may be applicable to ECFST specimens with initial concrete compressive stresses of the order of 80% of the concrete strength.

17**. Brian Uy; Zhong Tao; Lin-Hai Han (2011): Behaviour of short and slender concrete-filled stainless steel tubular columns.** The short composite columns under combined actions of axial force and bending moment exhibited very ductile behaviour. The overall strength and stability of the CFST columns were enhanced by the in-filled concrete. There is no obvious difference between CFSST columns and conventional carbon steel CFST columns in terms of test observations and failure modes.

18. **Qing Quan Liang (2009): Strength and ductility of high strength concrete-filled steel tubular beam–columns.** Increasing the depth-to-thickness ratio significantly reduces the section’s axial performance, axial ductility, flexural stiffness and strength and curvature ductility. Increasing the concrete compressive strength considerably reduces the same above properties.

19**. JIANG, S (2005): Behavior of concrete filled rectangular steel tubes (cfrst) subjected to biaxial eccentric compression after high temperature.** It was found that the main factors influencing the bearing capacity of CFRST are constant high temperature and steel strength. Concrete strength has little effect on the bearing capacity

20. **BAOZHU, C (2005): Experiments On New Joints Of Concrete Filled Steel Tube Truss.** It was found that the failure mode was local buckling of steel tubes. But for specimens of CFST, circular local buckling appeared in steel tubes at the bottom of gusset plate and the concrete was crushed under ultimate load. The CFST joints had better ductility than HST joints.

21. **Stephen P. Schneider , Donald R. Kramer and Douglas l. Sarkkinen (2004): The Design and Construction of Concrete filled steel tube column frames.** A girder connection continuous through the CFT column core will clearly have the potential to sustain a large seismic event.

22**. Kenji Sakino ; Hiroyuki Nakahara ; Shosuke Morino ; and Isao Nishiyama (2004) : Behavior of Centrally Loaded Concrete-Filled Steel-Tube Short Columns.** The difference between the ultimate strength and the nominal load of circular CFT columns, which is provided by confining the concrete, can be estimated as a linear function of the tube yield strength. The capacity reduction factor due to local buckling of the square steel tube wall was empirically derived based on the test results of hollow square steel tube columns with a thin wall.

23. **P.B.M.R. Bogahawaththa ; K. P. Madhuranga ; K. Baskaran; Hidallana-Gamage H. D. (2000) : Study on Concrete Filled Steel Circular and Square Tubes**. Circular steel tubes offer much more post-yield axial ductility than the square or rectangular tube sections. The axial capacity of CFST increases as the concrete infill increases and decreases with D/t ratios. Member stiffness and ductility also decrease as the increase of D/t ratios.

24. **Kenji Sakino ; Hiroyuki Nakahara ; Shosuke Morino ; and Isao Nishiyama (1998): AXIALLY LOADED CONCRETE-FILLED STEEL TUBES.** Circular steel tubes provide more post-yield axial ductility than that of a square or rectangular tube. In small steel-filled concrete columns filled with concrete, small D / t values provide a significant increase in yield load.

25. **Jerome F. Hajjar; and Brett C. Gourley (1996) : REPRESENTATION OF CONCRETE-FILLED STEEL TUBE CROSS-SECTION STRENGTH.** The expression found in the test is a two-dimensional, simple, basic function that controls the behavior of CFTs: the ratio of the width to the strength of the steel tube, and the amount of concrete compressive strength in the yield stress of the steel tube. The expression found in the experiment was general and accurately represents the cross-section strength of CFTs having a wide range of cross-section dimensions and material strengths. The equation is a function of two, simple, fundamental parameters governing the behavior of CFTs: the width-to-thickness ratio of the steel tube, and the ratio of the concrete compressive strength to the yield stress of the steel tube.

2.2 Inference

On the basis of above literature review, following major inferences can be drawn

1- Circular steel tubes offer much more post-yield axial ductility than the square or rectangular tube sections

2- Most of the square CFST columns failed in concrete crushing at their peak resistances.

3- It is very much possible to look at the CFST system as an alternative to the reinforced concrete system.

4- The characteristic of concrete-filled steel tubular members is that the structural properties can be improved due to the composite action between steel tube and filled concrete.

5- Some typical applications of concrete-filled steel tubular members are in buildings, bridges, high towers and other few structures.

2.3 Research Gap

- Different types of concrete can be used to check for the better results.
- There is little research covering hexagonal CFST columns and therefore the need to explore this field has been identified.
- Retrofitting of CFST columns have also not been used widely.

2.4 Objective

- To study the behaviour of circular concrete filled steel tubes analytically using Ansys.
- To compare the result with conventional column of same strength.
- Analytical investigation of CFST columns using different types of concrete i.e. GFRC and Polymer concrete.
- To find the compressive strength, equivalent elastic strain and equivalent stress.
- To compare the results and put the comments forward.

CHAPTER 3

APPROACH & METHODOLOGY

3.1 METHODOLOGY

1. Analytical (using Ansys) investigation of CFST columns under an axial compressive load.
2. Different types of concrete were taken into consideration viz.
   - M30 Concrete without steel tubes
   - M30 Concrete with steel tubes
   - M30 Concrete with Polymer admixture
   - M30 Concrete with GFRC admixture
3. Different properties like relative deformation, equivalent elastic strain, and equivalent stress was found out and compared.

3.2 Material Properties

Steel and concrete materials are used to develop a composite model. Properties such as the compressive strength of concrete and the yield strength of steel influence the final strength of CFT. And the ultimate strengths of CFT columns is influenced by the geometric features of the tubes such as cross section, slenderness ratio. Mild steel plate with the average thickness of 2.0 mm, height 4000 mm and diameter 400 mm was chosen for the experiment. The average properties of the steel and concrete are presented in the tables below.

S.NO	PROPERTIES	CONCRETE M30
1	Modulus of elasticity (MPa)	27386
2	Density (Kg/m3	2365
3	Poisson's ratio	0.15
4	Compressive strength (MPa)	30
5	Tensile ultimate strength (MPa)	3.83

Table 1: Properties of concrete

S.NO	PROPERTIES	CONCRETE M30
1	Modulus of elasticity (MPa)	200000
2	Density (Kg/m3	7850
3	Poisson's ratio	0.27
4	Tensile yield strength (MPa	275
5	Tensile ultimate strength (MPa)	475

Table 2: Properties of Steel Tube

3.3 Model Details

Four columns of dimensions given in Table-3 is modelled for analysis. In these columns mild steel were used. The loading on all the columns is kept the same. The columns are modelled and analyzed using ANSYS 16.2. Table-4 shows the nomenclature of column.

S. No.	Description	Specifications`
1	Steel type	Mild Steel
2	Diameter of steel tube	400mm
3	Thickness of steel tube	2mm
4	Height of Column	4000mm
5	Grade of Concrete	M30

Table 3: Details of CFST Columns

S. No.	Case Type	Detail
1	Case- 1	M30 Concrete without steel tubes
2	Case- 2	M30 Concrete with steel tubes
3	Case- 3	M30 Concrete with Polymer admixture
4	Case- 4	M30 Concrete with GFRC admixture

Table 4: Types of Cases

The analysis of the models will be done on ANSYS Workbench ver. 16.2. There is an inbuilt material data library by which we will change its mechanical properties. Concrete and steel is taken by ANSYS library and properties of polymer concrete and GFRC are inserted and modified as per the requirement and then a geometry is created of the required model to analyze and apply dense tetra meshing for finite element analysis (FEA) of models. After this we will apply loads and supports boundary condition then add parameters (Total Deflection, Stress, Strain) to check the results of each model.

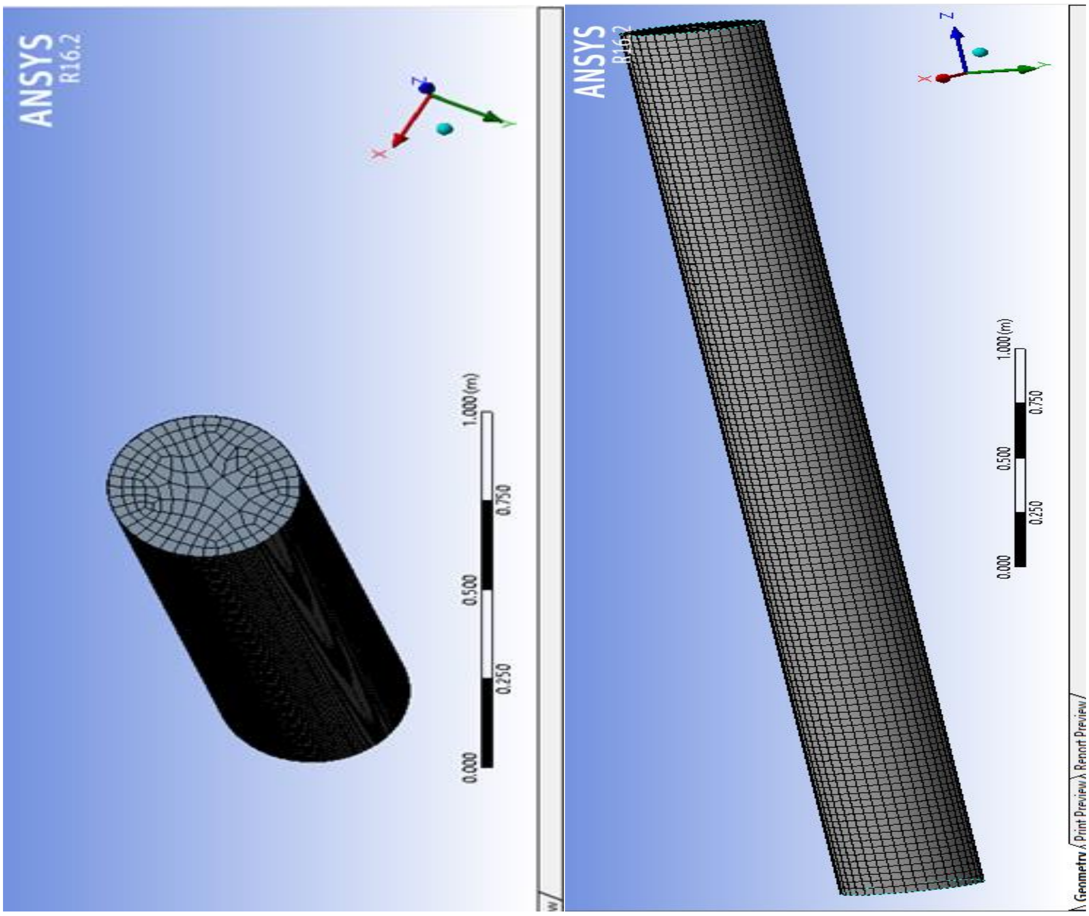


Figure 6: Meshing of concrete Encased Column

CHAPTER-4

RESULT AND DISCUSSION

4.1 Validation of the Analytical Model

The experimental results used in the validation of composite columns in this study were taken from a variety of sources, mentioned in the reference.

4.2 Analytical Results

4.2.1 Total Deformation

All the columns are fixed at the bottom. Fig 7. shows case I of composite column showing the contour diagram after analysis. It generated maximum deflection of 5.8148mm (red portion).

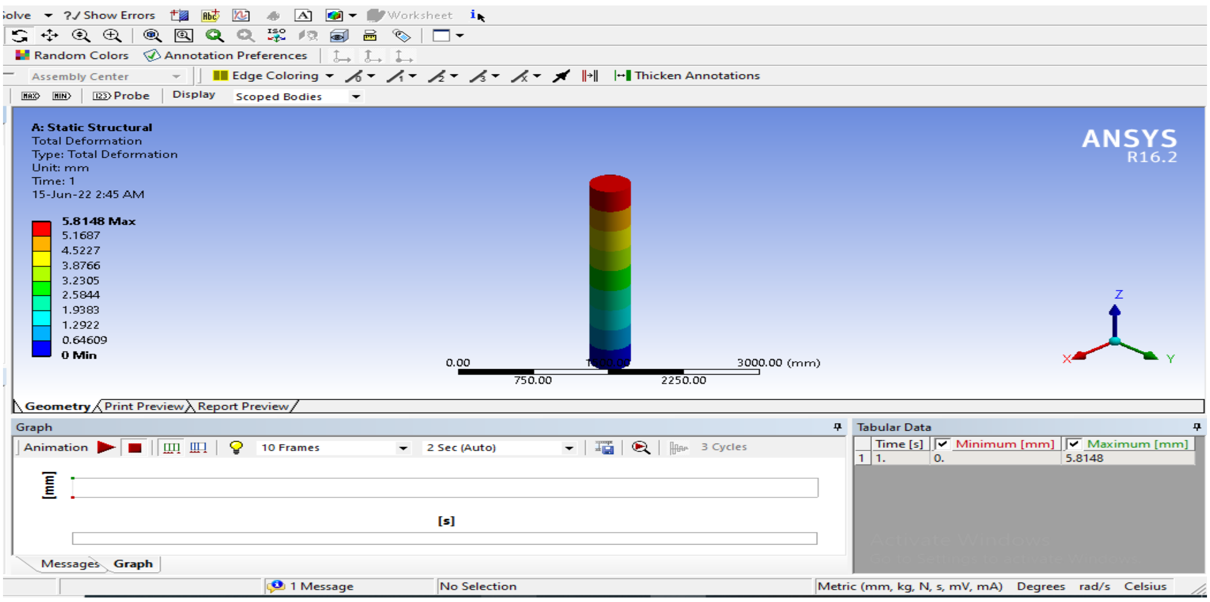


Figure 7: Total Deformation (Case 1)

The column is fixed at the bottom. Fig 8. shows case 2 of composite column showing the contour diagram after analysis. It generated maximum deflection of 5.4282mm (red portion).

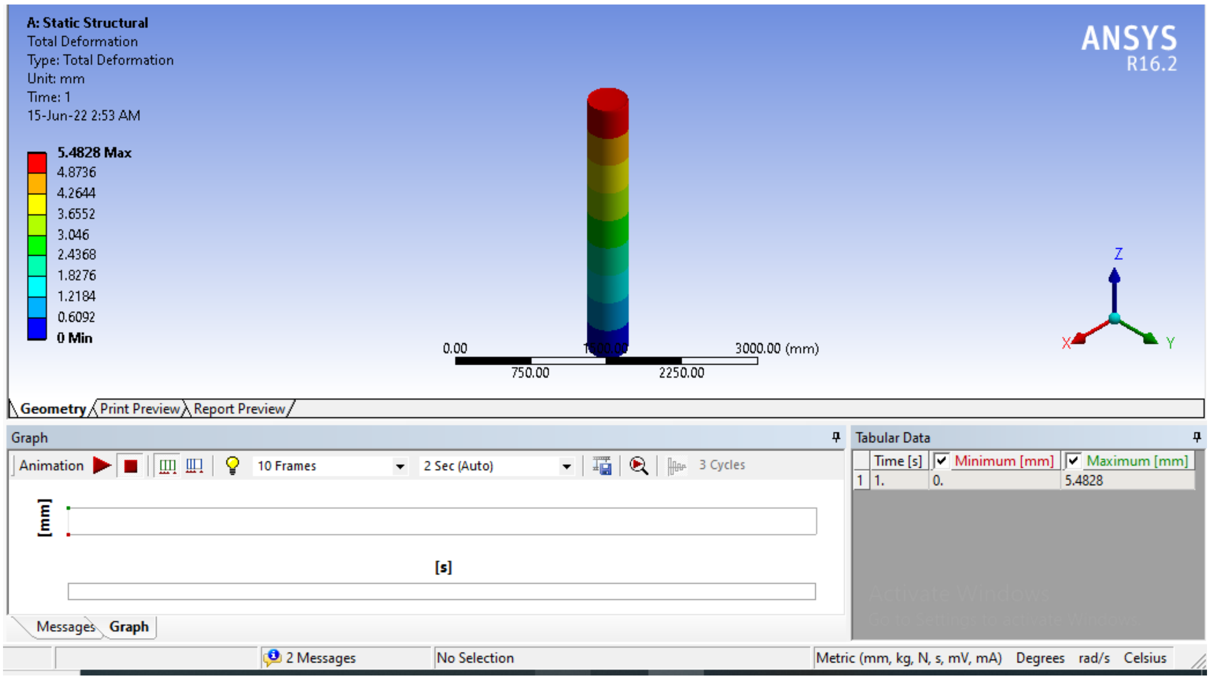


Figure 8: Total Deformation (Case 2)

The column is fixed at the bottom. Fig 9. shows case 3 of composite column showing the contour diagram after analysis. It generated maximum deflection of 4.4782 mm (red portion).

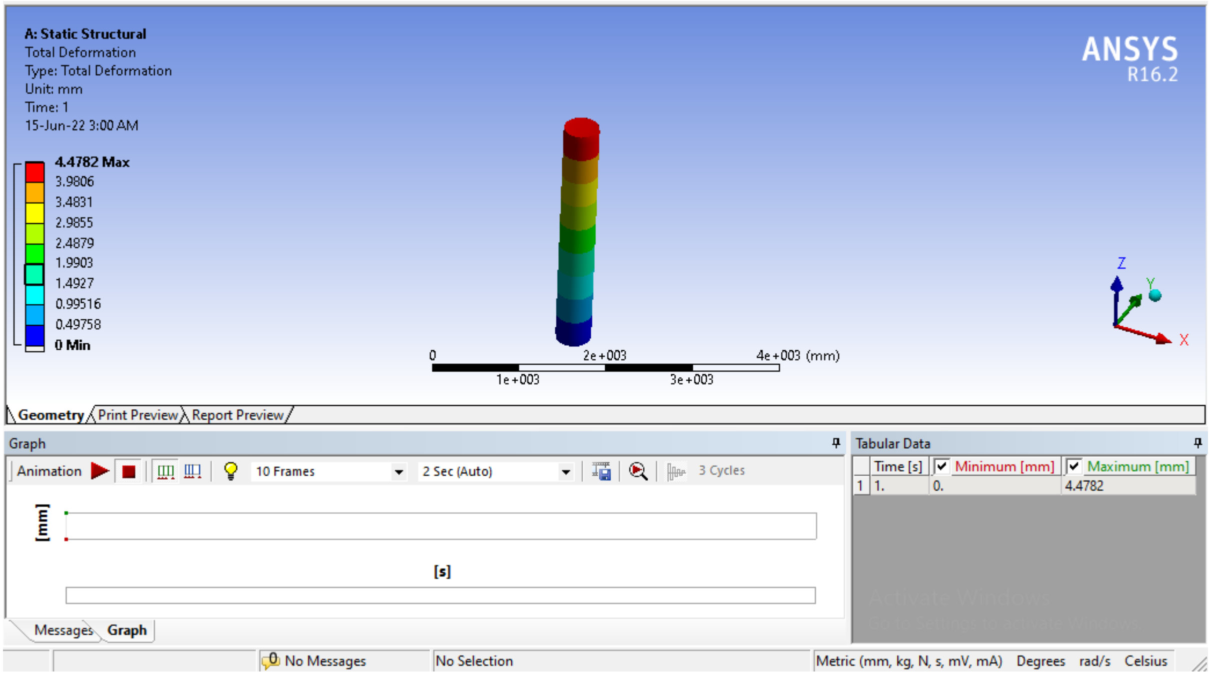


Figure 9: Total Deformation (Case 3)

The column is fixed at the bottom. Fig. 10 shows case 4 of composite column showing the contour diagram after analysis. It generated maximum deflection of 4.1322 mm (red portion).

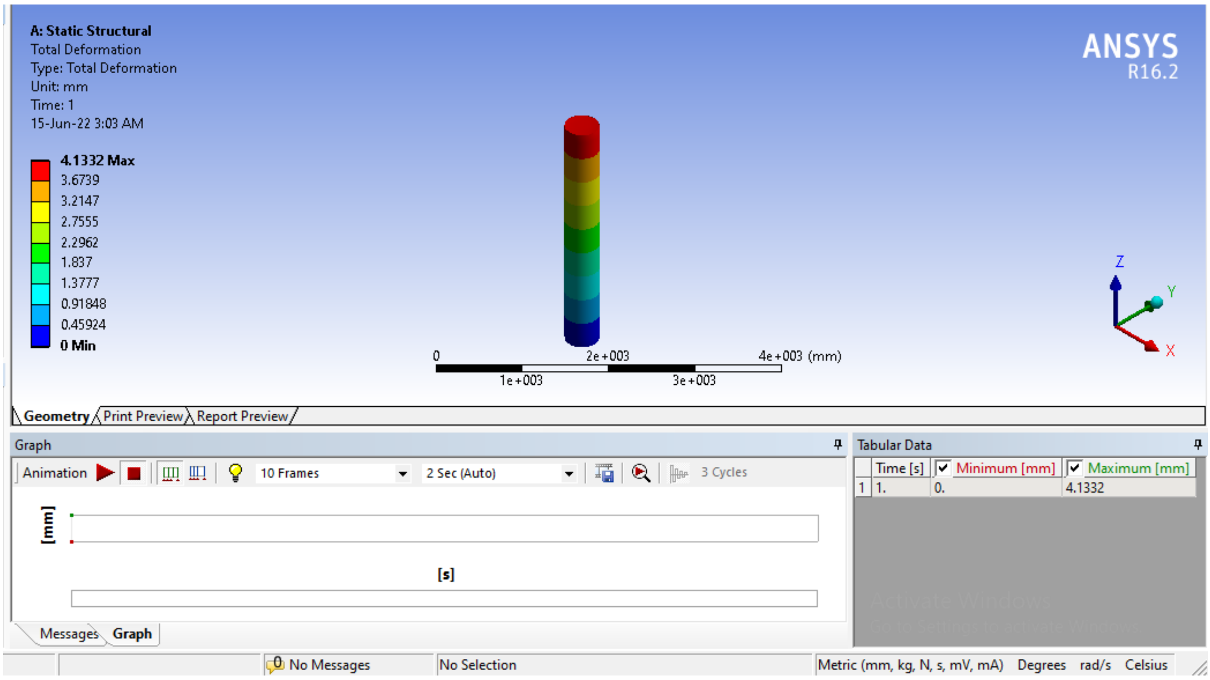


Figure 10: Total Deformation (Case 4)

S No.	Case	Total Deformation
Case- 1.	M30 Concrete without Steel Tube	5.8148mm
Case- 2.	M30 Concrete with Steel Tube	5.4828mm
Case- 3.	Polymer Concrete in Steel Tube	4.4782mm
Case- 4.	GFRC Concrete in Steel Tube	4.1322mm

Table 5: Total Deformation

4.2.2 Equivalent Stress

Equivalent stress is used when there is a multi-axial stress state with multiple stress components acting at the same time in the structure. In such case we can use selected criterion to transform the whole stress tensor into a single equivalent component that can be treated as a tensile stress and thus compared with material's strength easily. Various criteria may be utilized but among them there is one with incomparably larger popularity than the others von Mises yield criterion or otherwise maximum distortion energy criterion. It's commonly used in engineering as for example Finite Element Analysis programs use it as a default stress measure.

The column is fixed at the bottom. Fig 11 shows case 1 of composite column showing the contour diagram after analysis. It generated equivalent stress of 53.456 MPa.

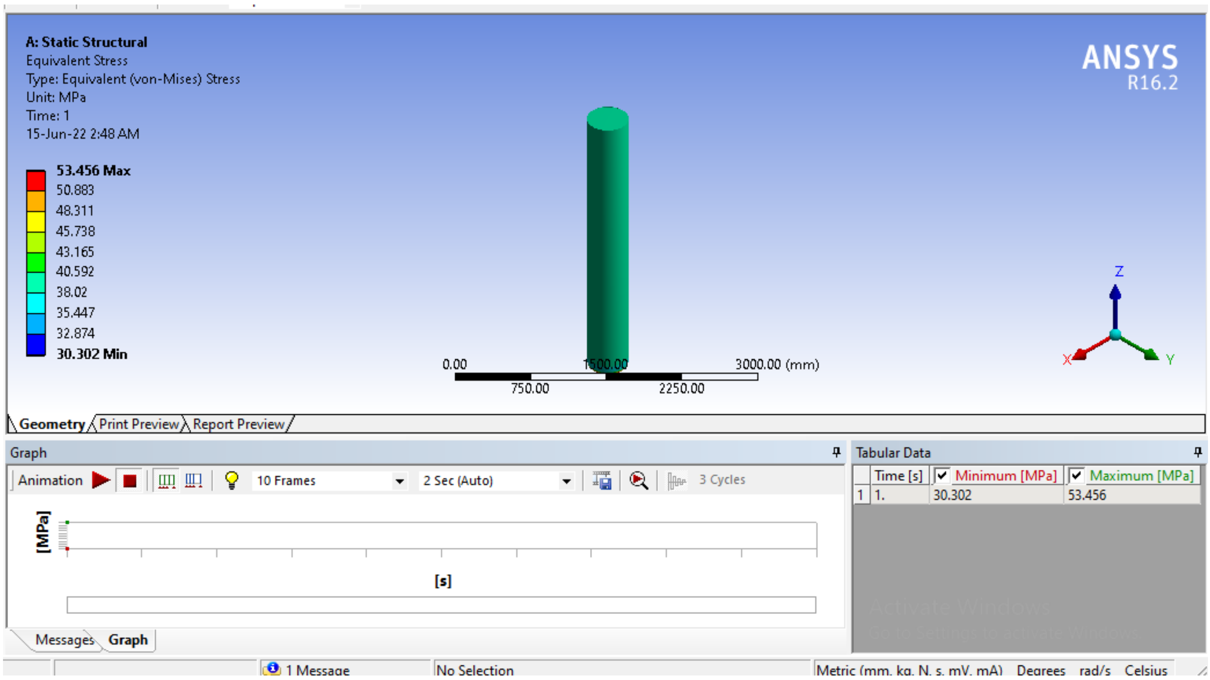


Figure 11: Equivalent Stress (Case 1)

The column is fixed at the bottom. Fig 12 shows case 2 of composite column showing the contour diagram after analysis. It generated equivalent stress of 335.12 MPa.

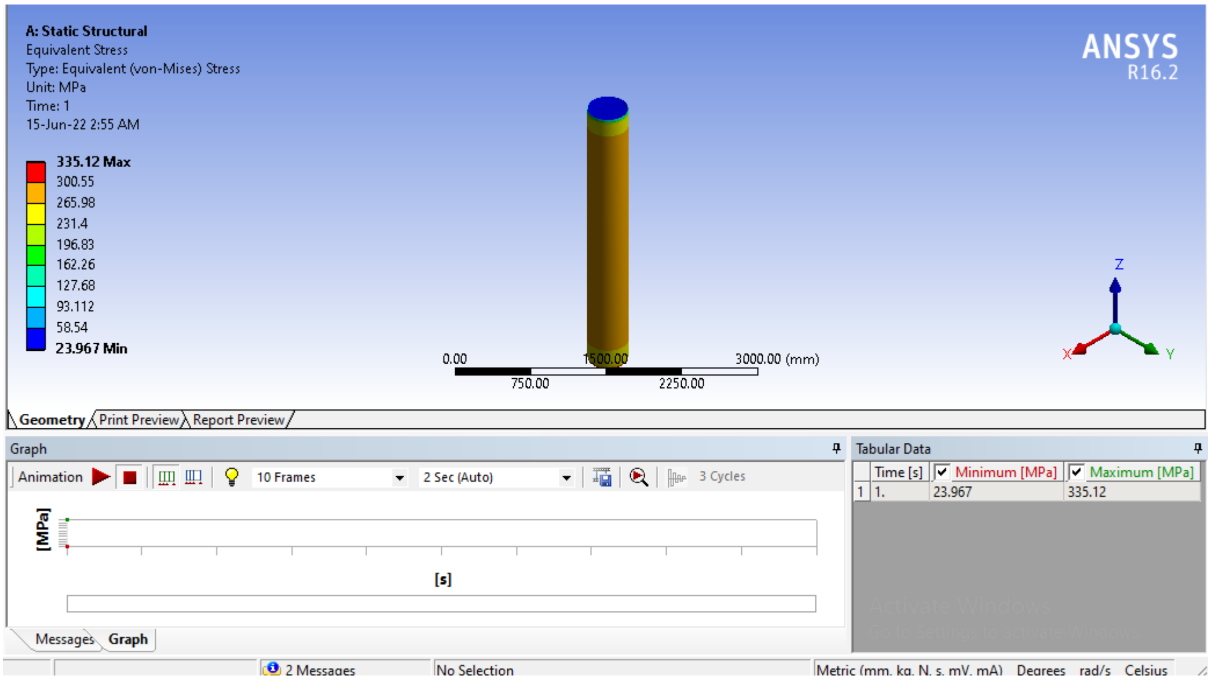


Figure 12: Equivalent Stress (Case 2)

The column is fixed at the bottom. Fig 13 shows case 3 of composite column showing the contour diagram after analysis. It generated equivalent stress of 237.73 MPa.

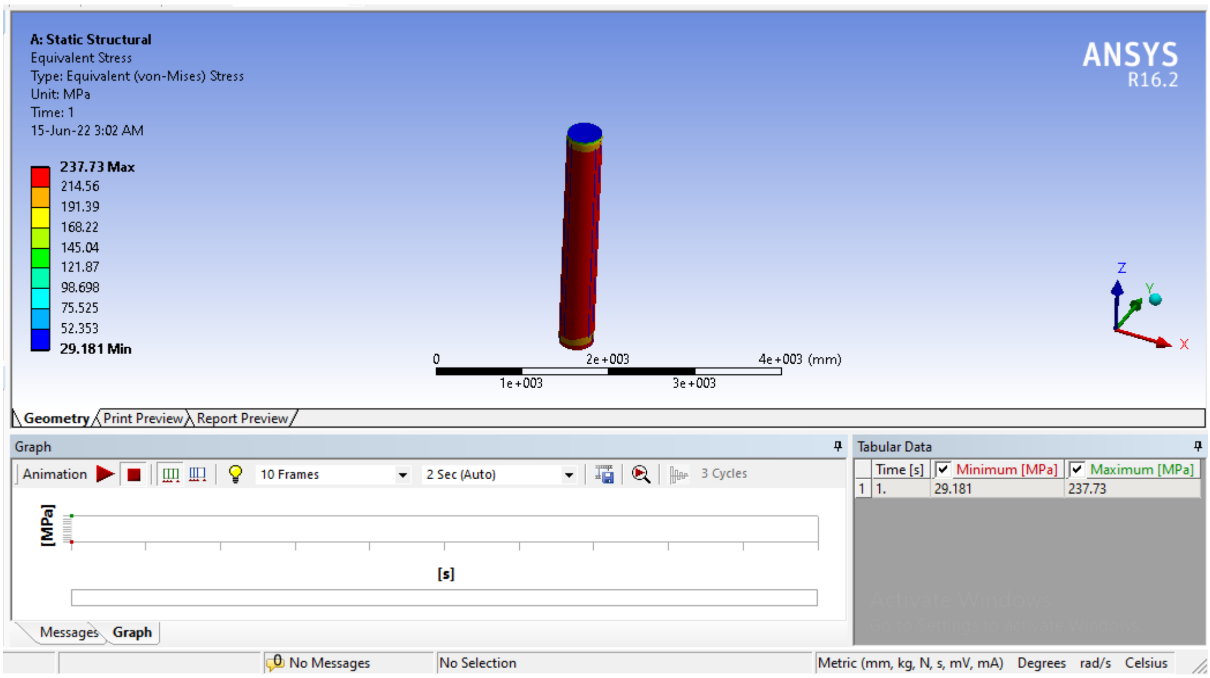


Figure 13: Equivalent Stress (Case 3)

The column is fixed at the bottom. Fig 14 shows case 4 of composite column showing the contour diagram after analysis. It generated equivalent stress of 219.71MPa.

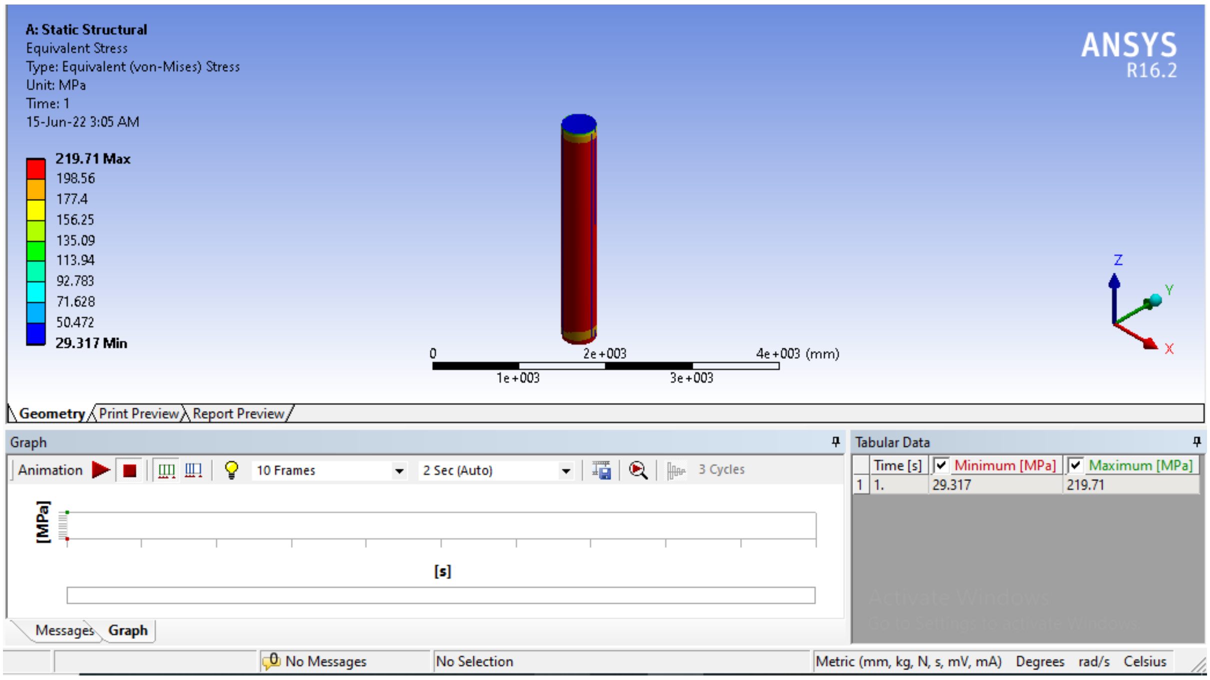


Figure 14: Equivalent Stress (Case 4)

S No.	Case	Mnimum Equivalent Stress (MPa)	Maximum Equivalent Stress (MPa)
Case- 1.	M30 Concrete without Steel Tube	30.302	53.456
Case- 2.	M30 Concrete with Steel Tube	23.967	335.12
Case- 3.	Polymer Concrete in Steel Tube	29.181	237.73
Case- 4.	GFRC Concrete in Steel Tube	29.317	219.71

Table 6: Equivalent Stresses

4.2.3 Equivalent Elastic Strain

Equivalent stress, as a scalar, is a straightforward variable for reporting stress results on a body, although it does not provide complete information on the state of stress. Equivalent elastic strain is defined as the limit of strain values of strain to which an object will rebound and return to its original shape after removal of the load. It was discovered that as we kept on improving the concrete characteristics and compressive strength keeping the axial loading constant, the strain found was directly proportional to the stiffness of the CFST structural system. Maximum elongation is discovered when the specimen is examined without the use of steel tube and further strain reduces by the addition of steel tubes and by making the concrete more dense and rigid.

The column is fixed at the bottom. Fig 15 shows case 1 of composite column showing the contour diagram after analysis. It generated equivalent elastic strain of 0.0019519 mm.

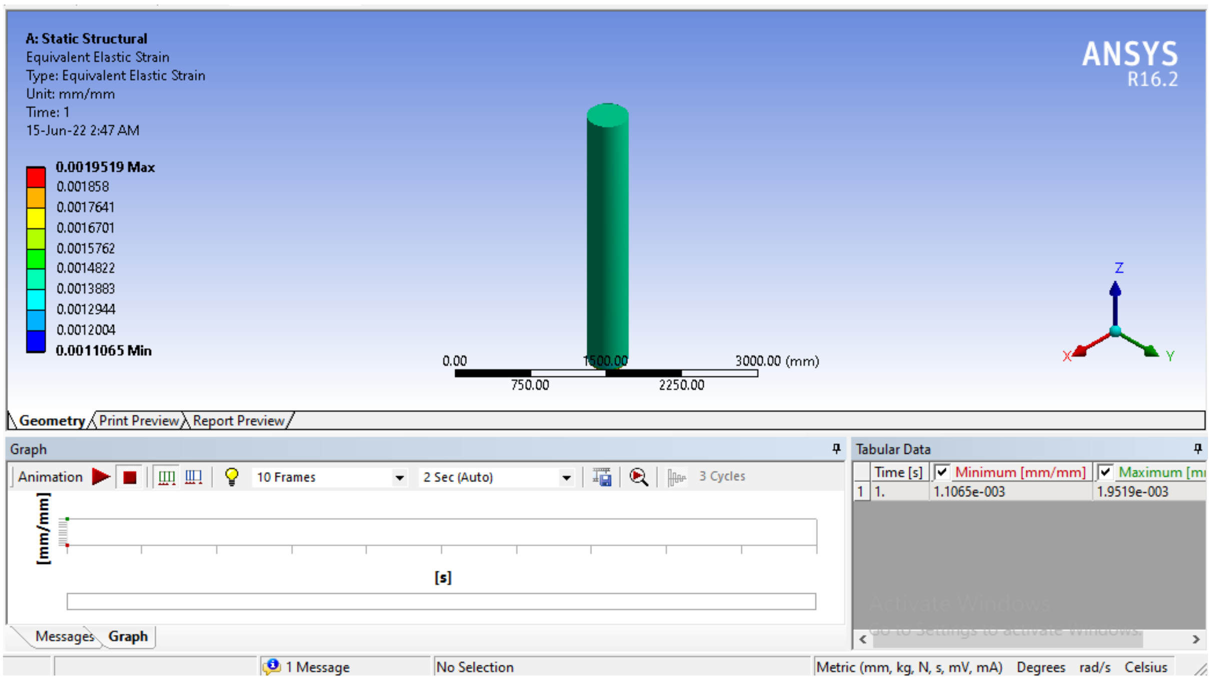


Figure 15: Equivalent Elastic Strain (Case 1)

The column is fixed at the bottom. Fig 15 shows case 2 of composite column showing the contour diagram after analysis. It generated equivalent elastic strain of 0.0016756 mm.

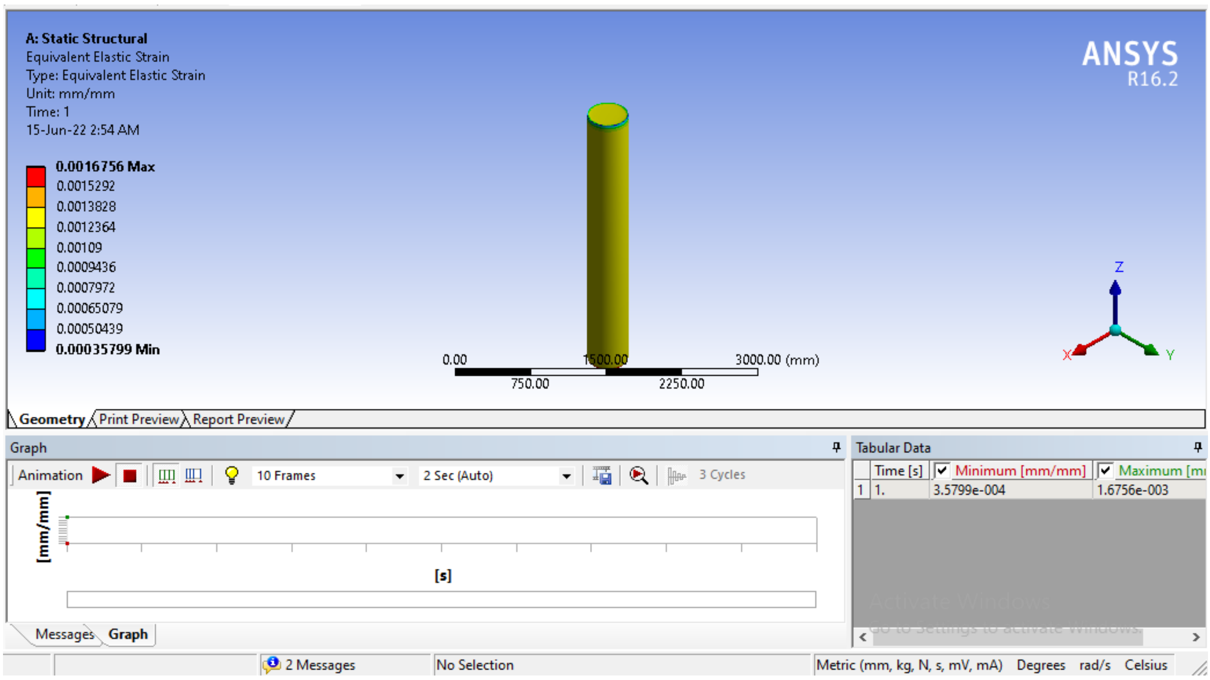


Figure 16: Equivalent Elastic Strain (Case 2)

The column is fixed at the bottom. Fig. 17 shows case 3 of composite column showing the contour diagram after analysis. It generated equivalent elastic strain of 0.0012050 mm.

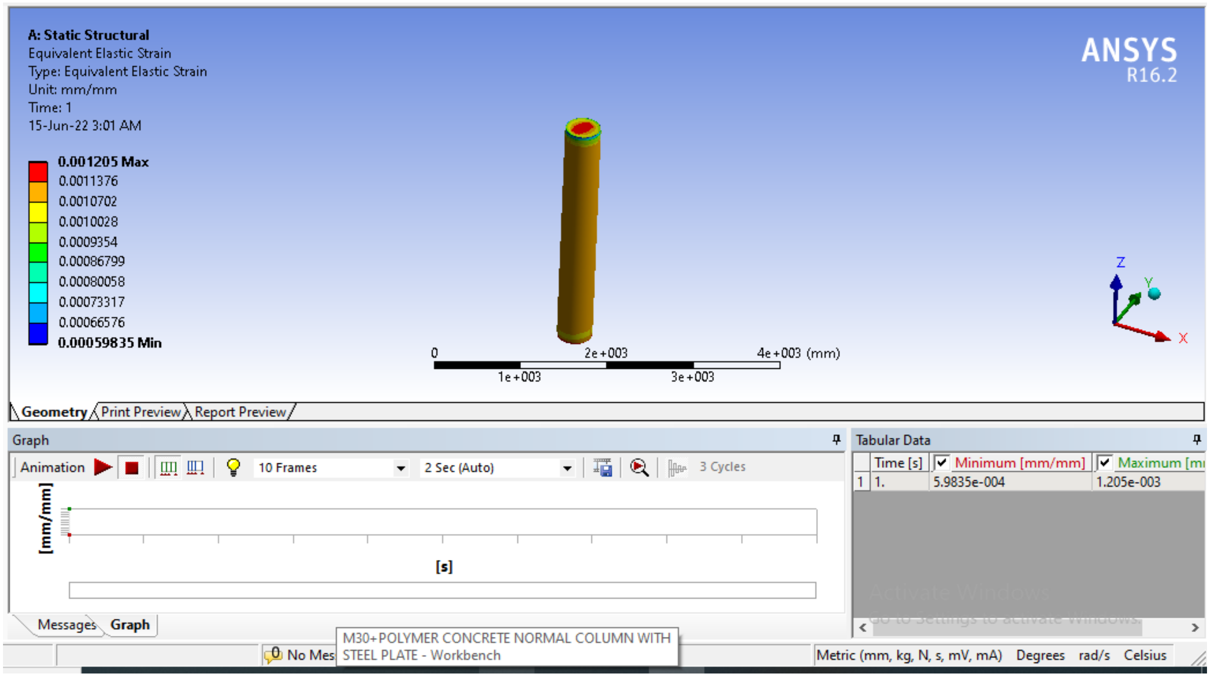


Figure 17: Equivalent Elastic Strain (Case 3)

The column is fixed at the bottom. Fig. 18 shows case 4 of composite column showing the contour diagram after analysis. It generated equivalent elastic strain of 0.0011062 mm.

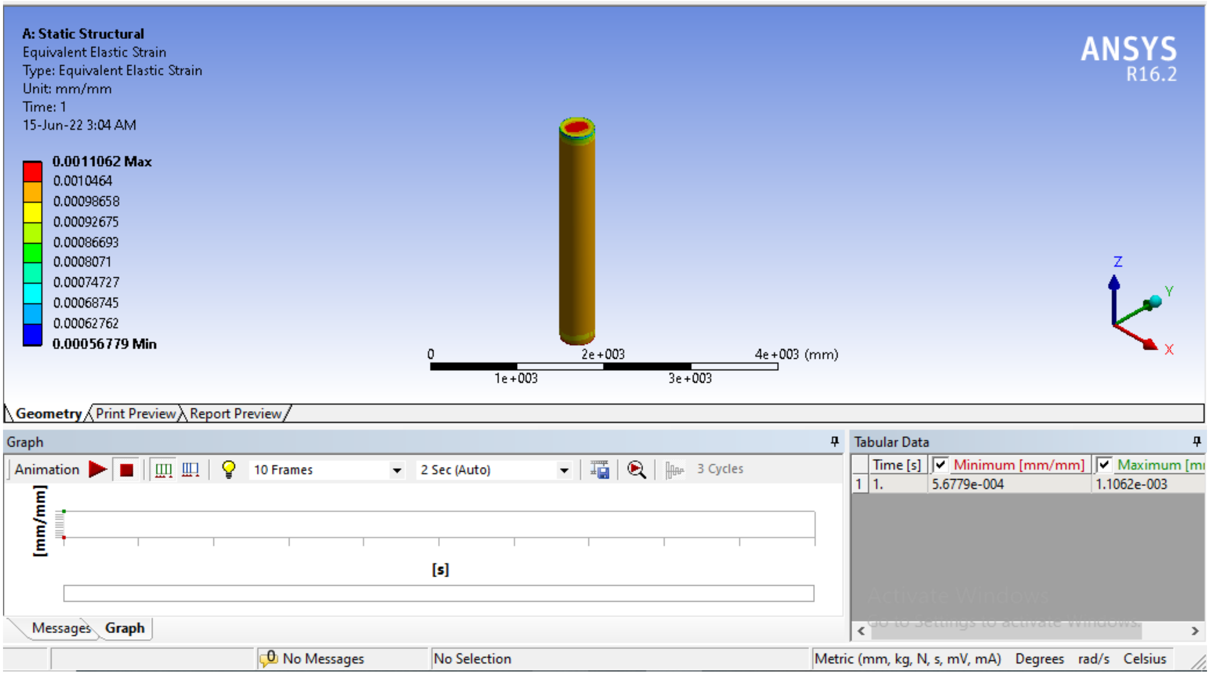


Figure 18: Equivalent Elastic Strain (Case 4)

S No.	Case	Minimum Strain (mm)	Maximum Strain (mm)
Case- 1.	**M30 Concrete without Steel Tube**	**0.0011065**	**0.0019519**
Case- 2.	**M30 Concrete with Steel Tube**	**0.00035799**	**0.0016756**
Case- 3.	**Polymer Concrete in Steel Tube**	**0.00059835**	**0.0012050**
Case- 4.	**GFRC Concrete in Steel Tube**	**0.00056779**	**0.0011062**

Table 7: Total Strain

4.3 Graphical Representation

Fig. 19 shows a graphical representation of M30 Concrete without Steel Tube, M30 Concrete with Steel Tube, Polymer Concrete in Steel Tube and GFRC Concrete in Steel Tube. It is evident from the graph that Case1 generates greater deflection i.e. 5.8148mm on the other hand Case generated lesser deflection i.e. 4.1322mm.

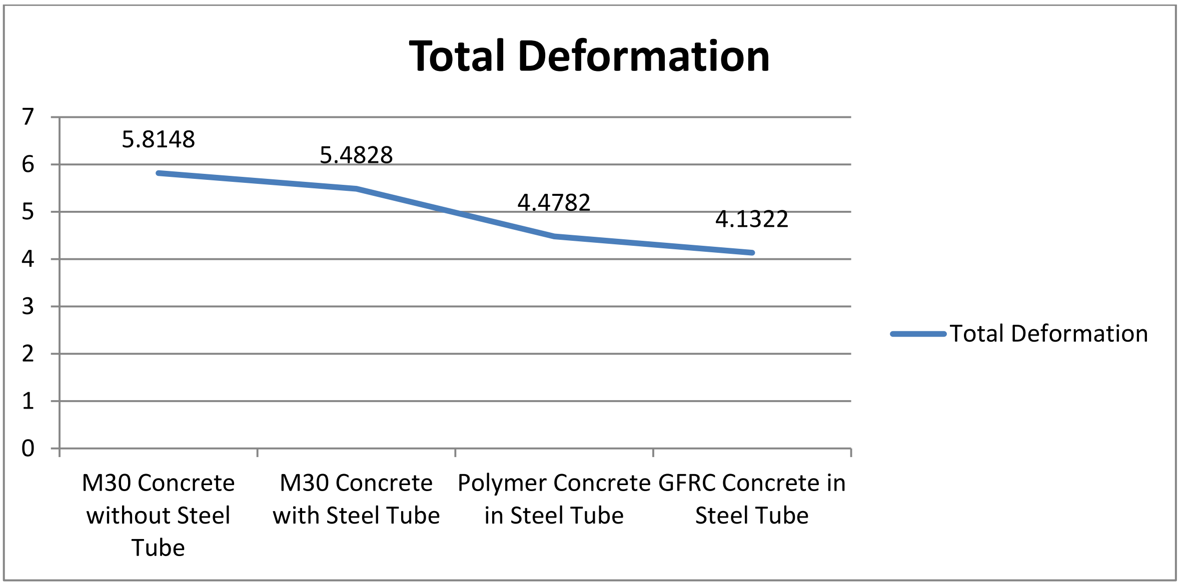


Figure 19: Total Deformation Chart (mm)

Fig. 20 shows a graphical representation of Strain Deformation Chart of M30 Concrete without Steel Tube, M30 Concrete with Steel Tube, Polymer Concrete in Steel Tube and GFRC Concrete in Steel Tube.

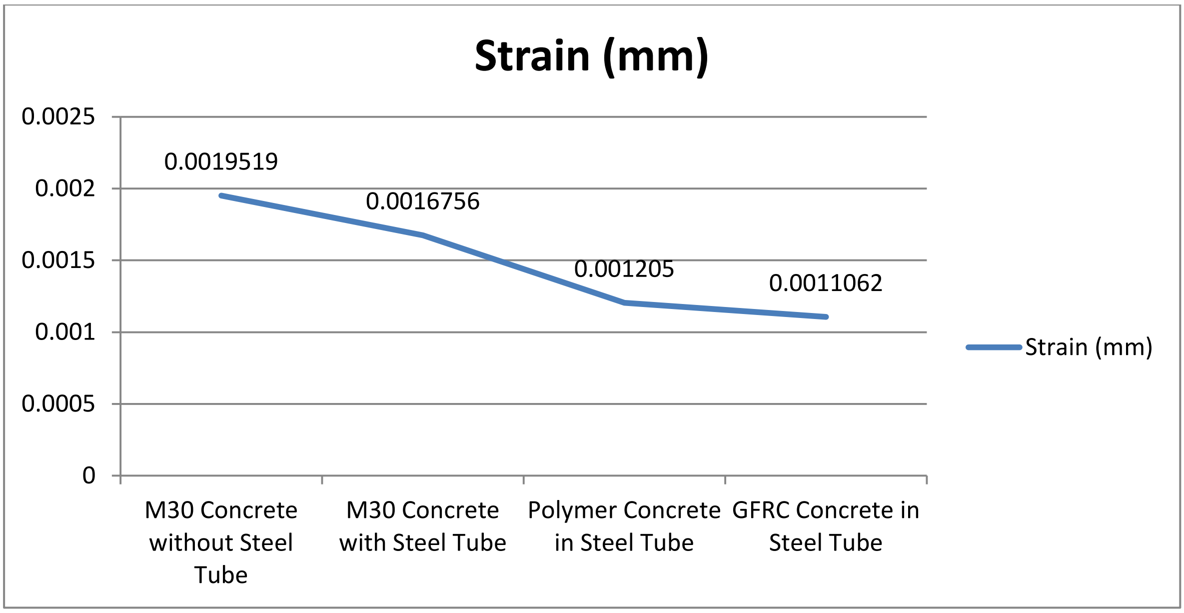


Figure 20: Strain Deformation Chart

Fig. 21 shows a graphical representation Equivalent Stress Chart of M30 Concrete without Steel Tube, M30 Concrete with Steel Tube, Polymer Concrete in Steel Tube and GFRC Concrete in Steel Tube.

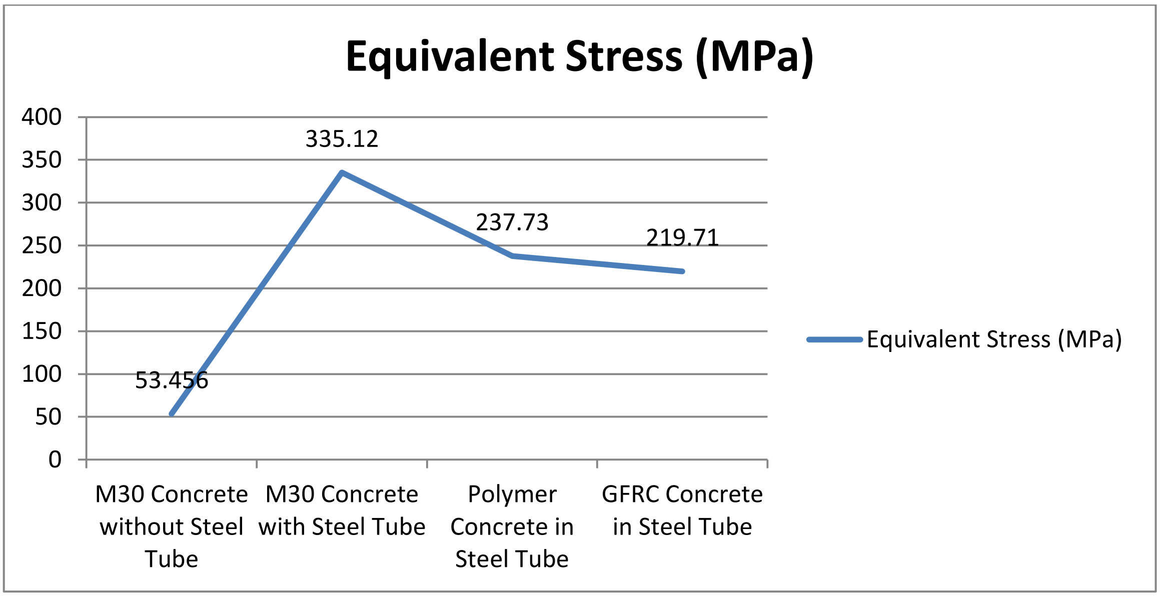


Figure 21: Equivalent Stress Chart

4.4 Comparative Study

After the static analysis from ANSYS 16.2 we have the following comparative representation of the test models of different composite columns made up M30 Concrete without Steel Tube, M30 Concrete with Steel Tube, Polymer Concrete in Steel Tube and GFRC Concrete in Steel Tube, for Deflection, Equivalent stress & Total Strain.

S No.	Case	Total Deformation	Equivalent Stress (MPa)	Strain (mm)
Case- 1.	**M30 Concrete without Steel Tube**	**5.8148mm**	**53.456**	**0.0019519**
Case- 2.	**M30 Concrete with Steel Tube**	**5.4828mm**	**335.12**	**0.0016756**
Case- 3.	**Polymer Concrete in Steel Tube**	**4.4782mm**	**237.73**	**0.0012050**
Case- 4.	**GFRC Concrete in Steel Tube**	**4.1322mm**	**219.71**	**0.0011062**

Table 8: Summary of all the Results

CHAPTER-5
CONCLUSION

5.1 Conclusion

From the above results, it is concluded that there is a sure benefit of using concrete filled steel tubes rather than conventional concrete column. It seems in analysis of CFST column, conventional concrete column generate greater deflection on the other hand in case of CFST columns, deflection is less, and also it is minimum when GFRC is added as an admixture. As per analysis results, GFRC encased section have large effective stress as compared with conventional concrete encased section. It can be said that CFST column have great compressive strength as compared to conventional concrete column. The compressive strength of CFST columns under axial loading can be extensively improved by using admixtures such as polymer and GFRC in core concrete.

As the high strength concrete infill is used the strength of columns also increases. Therefore it is concluded that use high strength infill concrete is much more effective to get extra strength with same size CFST column along with low deformation.

The scope of CFST has been extended greatly by researchers and engineers with rapid development of research and application of CFST structures in USA, UAE, China and all over the world. Characteristic of CFST is that the structural properties can be improved due to the composite action between steel tube and in filled concrete. CFST can be treated as an alternative system to the steel or RC element.

Codal Provisions

There are a large number of Indian Standard (IS) codes available for virtually every aspect of civil engineering you can think of. During one's professional life, one normally uses only a few of them, depending on the nature of the work one is engaged in. Civil engineers involved in the construction activities of large projects usually have to refer to a large number of IS codes as such projects require the use of various construction materials in many different structures such as buildings, roads, steel structures, all kinds of foundations and what not. Different formulae were proposed over the years to calculate the axial capacity of the CFST columns. For instance, some of them accounted for the increase in the in filled concrete strength while other just ignored it. Conceptually, the American Concrete Institute (ACI-318-11) and Australian Standard (AS 3600-2009) use the concept of reinforced concrete design in their formulation without any consideration to the concrete confinement effects [56], [57]. The American Institute of Steel Construction (AISC) formula is based on the structural steel. While the exclusively used for composite elements design, Eurocode 4 (BS EN 1994-1-2:2005) combine both these approaches.

List of codes taken into consideration during the research process are-

IS: 456 – code of practice for plain and reinforced concrete

IS: 2386 – methods of tests for aggregate for concrete. (nine parts)

IS: 1489 – specifications for PPC (Portland pozzolana cement)

IS: 4031 – chemical analysis and tests on cement

IS: 456; 10262; SP 23 – codes for designing concrete mixes

IS: 9103 – specifications for concrete admixture

IS: 432; 226; 2062 – mild steel of grade I

IS: 432; 1877 – mild steel of grade II.

IS: 1566 – specifications for hard drawn steel wire fabric for reinforcing concrete.

IS: 2062 – specifications for steel for general purposes

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