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Experimental Analysis of CFST (Concrete Filled Steel Tube) Column for Various End Condition Using ANSYS Software

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Abstract: *Concrete-Filled Steel Tube (CFST) columns have emerged as an effective structural solution due to their ability to combine the beneficial properties of steel and concrete. This study investigates the structural performance of CFST columns subjected to different end conditions using ANSYS finite element software. The analysis focuses on commonly used support conditions such as fixed-fixed, pinned-pinned, and fixed-pinned arrangements. Numerical modeling was carried out to evaluate stress distribution, deformation characteristics, buckling behavior, and load-carrying capacity under axial loading. The results indicate that end restraints significantly influence the overall behavior and stability of CFST columns. Columns with greater end restraint exhibit improved stiffness and higher load resistance compared to those with less restraint. The study demonstrates the effectiveness of finite element analysis in predicting the behavior of composite columns and provides useful insights for the design and application of CFST members in modern construction projects.*

Keywords: Concrete-Filled Steel Tube (CFST), Composite Column, ANSYS, Finite Element Analysis, End Conditions, Axial Loading, Structural Performance, Load-Carrying Capacity, Stress Distribution, Buckling Behavior.

I. INTRODUCTION

The construction industry continuously seeks structural systems that provide high strength, durability, and cost efficiency. Traditionally, Reinforced Cement Concrete (RCC) and structural steel have been widely used in buildings and infrastructure projects. However, each material has certain limitations when used independently. Composite construction has emerged as an effective solution by combining the advantages of different materials into a single structural element [1].

Concrete-Filled Steel Tube (CFST) columns are one of the most widely used composite members in modern construction. A CFST column consists of a hollow steel tube filled with concrete, where the steel tube acts as permanent formwork and provides confinement to the concrete core. This composite action enhances the load-carrying capacity, stiffness, ductility, and overall structural performance of the column [2][3].

The confinement effect developed by the steel tube improves the compressive strength of concrete, while the concrete core delays local buckling of the steel section. Due to these advantages, CFST columns have gained significant attention in high-rise buildings, bridges, industrial structures, and seismic-resistant construction projects [4][5].

The structural behavior of CFST columns is influenced by several factors, including material properties, geometric configuration, loading conditions, and support restraints. Among these factors, end conditions play a crucial role in determining the deformation characteristics, buckling resistance, and ultimate load capacity of the column [6][7].

With the advancement of computational techniques, finite element analysis has become an effective tool for studying the behavior of composite structures. ANSYS software enables accurate simulation of stress distribution, deformation patterns, and failure mechanisms under different loading and boundary conditions [8][9].

The present study focuses on the numerical analysis of CFST columns subjected to various end conditions using ANSYS software. The investigation aims to evaluate the influence of support conditions on the strength and stability of CFST columns and to identify the most efficient configuration for practical engineering applications [10].

II. PROBLEM STATEMENT

Concrete-Filled Steel Tube (CFST) columns are increasingly used in modern construction due to their high strength, improved ductility, and efficient composite action between steel and concrete. However, the structural performance of CFST columns is significantly influenced by their end support conditions, which affect load-carrying capacity, deformation behavior, and buckling resistance. Limited information is available regarding the comparative behavior of CFST columns under different boundary conditions such as fixed-fixed, pinned-pinned, and fixed-pinned supports. Therefore, there is a need to investigate and evaluate the effect of various end conditions on the structural response of CFST columns using finite element analysis. This study aims to analyze these variations through ANSYS software and identify the most effective end condition for enhanced strength, stability, and overall structural performance.

III . OBJECTIVES

- To develop a finite element model of a CFST column using ANSYS software.
- To analyze the behavior of CFST columns under different end conditions.
- To evaluate the stress distribution and deformation characteristics of CFST columns.
- To determine the ultimate load-carrying capacity under axial loading.
- To compare the structural performance of various end conditions and identify the most efficient support configuration.

IV. LITERATURE SURVEY

Han et al. (2010) presented an experimental investigation on Concrete-Filled Steel Tube (CFST) columns under axial compression. Their study highlighted the confinement effect provided by the steel tube, which significantly improved the compressive strength and ductility of the concrete core. The results demonstrated enhanced load-carrying capacity and delayed local buckling of the steel section.

Yu et al. (2011) conducted a comparative study between CFST columns and conventional reinforced concrete columns under different loading conditions. The research showed that CFST columns exhibited superior strength, stiffness, and deformation characteristics, making them more suitable for high-rise and heavy-load structures.

Tao et al. (2013) developed a nonlinear finite element model to analyze the behavior of CFST stub columns. Their work emphasized the importance of accurately modeling the interaction between steel and concrete to predict realistic structural performance. The numerical results showed good agreement with experimental observations.

Cai et al. (2018) investigated the performance of circular CFST columns subjected to eccentric loading. The study revealed that load eccentricity significantly influences stress distribution and ultimate load capacity. It was concluded that proper consideration of loading conditions is essential for safe and economical design.

Li et al. (2019) analyzed the seismic behavior of CFST columns using finite element techniques. The results indicated excellent energy dissipation capacity and improved ductility under cyclic loading, demonstrating the suitability of CFST members for earthquake-resistant structures.

Sachin et al. (2025) performed a comparative analysis of circular and square CFST columns using ANSYS software. Their findings showed that circular CFST columns provided better confinement, lower deformation, and higher load-carrying capacity compared to square sections, highlighting the influence of cross-sectional geometry on structural performance.

Comparison Table

Author & Year	Method Used	Advantages	Limitations
Han et al. (2010)	Experimental study on CFST columns under axial compression	Improved strength and ductility due to confinement effect	Limited to axial loading conditions
Yu et al. (2011)	Comparative analysis of CFST and RCC columns	Higher load capacity and stiffness than RCC columns	Did not consider different support conditions
Tao et al. (2013)	Nonlinear Finite Element Analysis (FEA)	Accurate prediction of CFST behavior	Requires complex modeling and validation
Cai et al. (2018)	Study of CFST columns under eccentric loading	Better understanding of stress distribution	Focused only on eccentric loading effects
Li et al. (2019)	Finite Element Analysis under cyclic loading	Excellent seismic and energy dissipation performance	Limited investigation of static loading
Sachin et al. (2025)	ANSYS-based comparative analysis of CFST sections	Circular sections showed better confinement and strength	Limited to specific geometries and loading conditions

V. WORKING OF SYSTEM

1. Literature Review and Problem Identification

The study begins with a detailed review of research papers, journals, and technical reports related to CFST columns. This helps in understanding the behavior of composite columns and identifying the influence of different end conditions on structural performance.

2. Selection of Material Properties

Suitable material properties for the steel tube and concrete core are selected based on standard design codes. These properties are used to accurately represent the composite action between steel and concrete in the numerical model.

3. Development of CFST Model in ANSYS

A three-dimensional CFST column model is created in ANSYS software. The geometry of the steel tube and concrete core is defined, and appropriate finite elements are assigned for structural analysis.

4. Application of Boundary Conditions

Different end support conditions such as Fixed-Fixed, Pinned-Pinned, and Fixed-Pinned are applied to the model. These conditions simulate practical support arrangements used in structural engineering.

5. Meshing and Contact Definition

The model is divided into small finite elements through meshing. Proper contact interaction is defined between the steel tube and concrete core to ensure realistic load transfer and confinement effects.

6. Application of Axial Load

Axial compressive load is applied to the top surface of the CFST column. The loading is applied gradually to observe the structural response under increasing load levels.

7. Simulation and Analysis

The finite element analysis is performed in ANSYS to obtain stress distribution, deformation behavior, buckling characteristics, and load-carrying capacity of the column under different end conditions.

8. Result Comparison and Evaluation

The results obtained for various support conditions are compared to identify the most effective end condition. The performance is evaluated based on strength, stiffness, deformation, and overall structural stability.

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VI. SYSTEM DESIGN

System Overview:

1. Input Stage

The system begins with the selection of CFST column parameters such as steel tube dimensions, concrete grade (M20, M25, and M30), material properties, and end support conditions. These parameters serve as input data for finite element modeling in ANSYS.

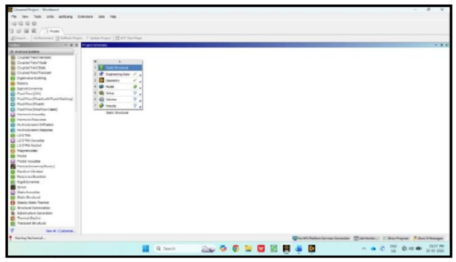

Fig.1.Material Properties Window / Geometry Dimensions

2. Geometry Development

A three-dimensional model of the Concrete Filled Steel Tube (CFST) column is created in ANSYS. The model consists of an outer circular steel tube and an inner concrete core to represent the composite action accurately.

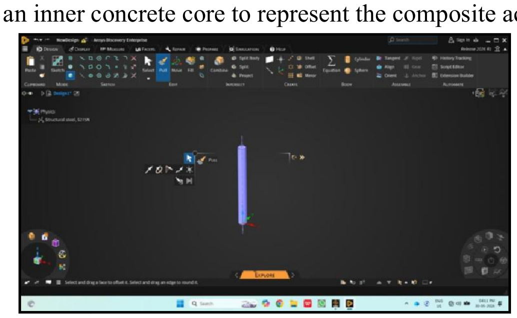

Fig.2.CFST Geometry Model

3. Meshing Process

The developed geometry is divided into small finite elements using the meshing tool. Proper mesh generation improves the accuracy of stress and deformation prediction during analysis.

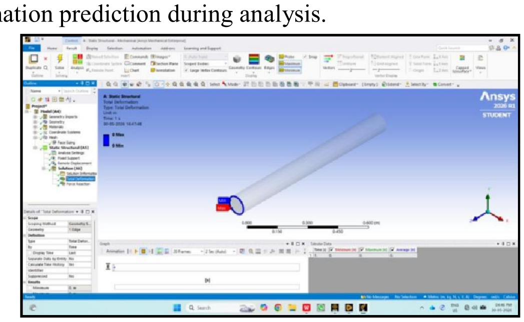

Fig.3 Meshed Model

4. Boundary Conditions and Loading

Different end conditions such as Fixed-Fixed, Fixed-Pinned, and Pinned-Pinned supports are applied. Axial compressive load is then applied at the top surface of the CFST column to study its structural response.

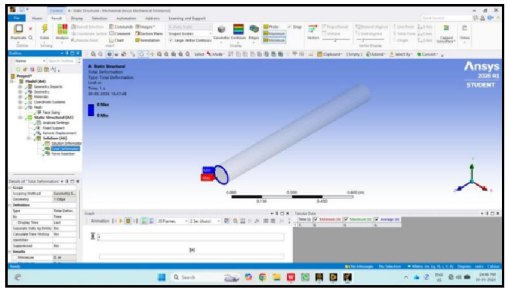

Fig.4 Support Conditions and Load Application

5. Finite Element Analysis

The ANSYS solver performs numerical calculations to determine stress distribution, deformation behavior, buckling characteristics, and load-carrying capacity of the CFST column under different support conditions.

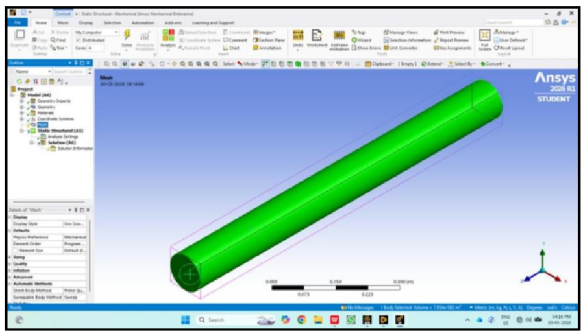

Fig.5 Solution/Analysis Window

6. Steel pipe selection

A circular hollow steel section having an outer diameter of 100 mm was selected.

Fig.6 Steel Pipe selection

7. Concrete Filling Procedure

After the fabrication and welding of the Circular Concrete Filled Steel Tube (CFST) specimens, the concrete filling process was carried out using M20, M25, and M30 grade concrete to evaluate the influence of concrete strength on the structural performance of the columns.

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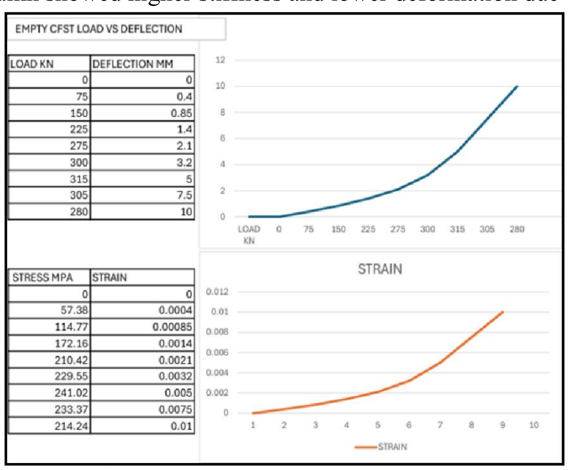
Fig.7.Concrete Filling Procedure

VII. RESULTS

4.1 Comparative Specimen Data (Experimental)

Empty CFST (Fixed Condition)

The fixed-end empty CFST column showed higher stiffness and lower deformation due to better end restraint.



EMPTY CFST LOAD VS DEFLECTION

LOAD KN	DEFLECTION MM
0	0
75	0.4
150	0.85
225	1.4
275	2.1
300	3.2
315	5
305	7.5
280	10

STRESS MPA	STRAIN
0	0
57.38	0.0004
114.77	0.00085
172.16	0.0014
210.42	0.0021
229.55	0.0032
241.02	0.005
233.37	0.0075
214.24	0.01

Fig.8 Empty CFST(Fixed Condition)

Empty CFST (Hinged Condition)

The hinged column exhibited greater deformation and a higher tendency for buckling.

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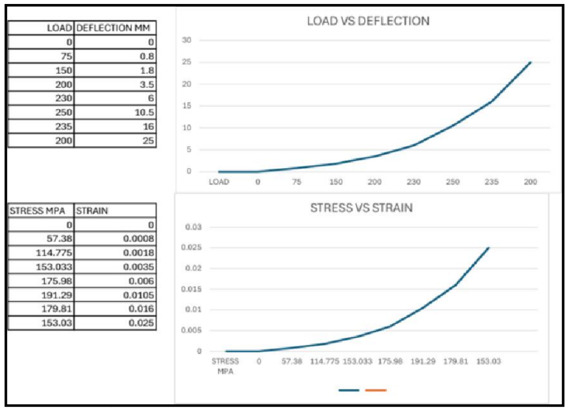


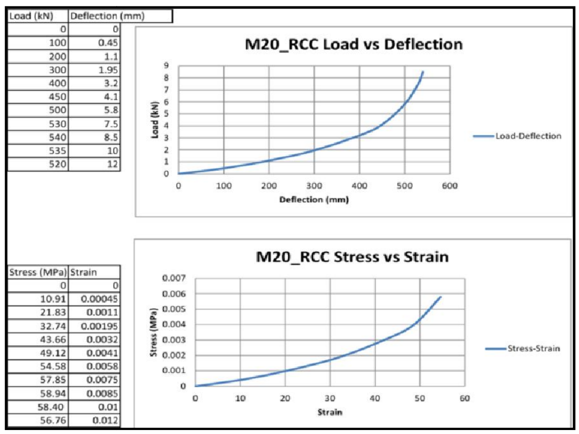
LOAD	DEFLECTION MM
0	0
75	0.8
150	1.8
200	3.5
230	6
250	10.5
235	16
200	25

STRESS MPA	STRAIN
0	0
57.38	0.0008
114.775	0.0018
153.033	0.0035
175.98	0.006
191.29	0.0105
179.81	0.016
153.03	0.025

Fig.9.Empty CFST(Hinged Condition)

M20 RCC

The RCC specimen showed lower load resistance compared to the CFST specimen.



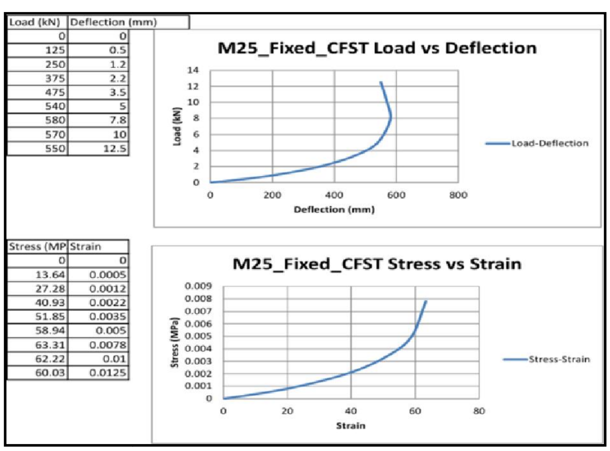
Load (kN)	Deflection (mm)
0	0
100	0.45
200	1.1
300	1.95
400	3.2
450	4.1
500	5.8
530	7.5
540	8.5
535	10
520	12

Stress (MPa)	Strain
0	0
10.91	0.00045
21.83	0.0011
32.74	0.00195
43.66	0.0032
49.12	0.0041
54.58	0.0058
57.85	0.0075
58.94	0.0085
58.40	0.01
56.76	0.012

Fig.10 M20 RCC

M25 CFST (Fixed & Hinged)

The M25 specimens exhibited higher strength and lower deformation than M20 specimens. The fixed condition gave superior performance.



Load (kN)	Deflection (mm)
0	0
125	0.5
250	1.2
375	2.2
475	3.5
540	5
580	7.8
570	10
550	12.5

Stress (MP	Strain
0	0
13.64	0.0005
27.28	0.0012
40.93	0.0022
51.85	0.0035
58.94	0.005
63.31	0.0078
62.22	0.01
60.03	0.0125

Fig.11.M25 CSFT

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M30 RCC

The M30 RCC column performed better than lower-grade RCC columns but remained less effective than CFST columns.

Load (kN)	Deflection (mm)
0	0
150	0.65
300	1.5
450	2.9
550	4.5
600	6.3
630	8.8
620	11.5

Stress (MP	Strain
0	0
15.5	0.00065
31	0.0015
46.5	0.0029
56.8	0.0045
62	0.0063
65.1	0.0088
64.1	0.0115

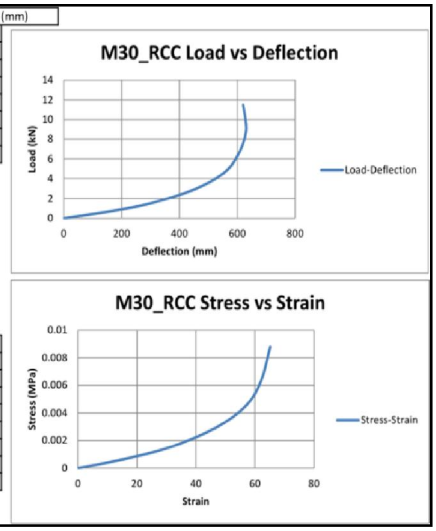

Fig.12.M30 RCC

VIII. CONCLUSION

This study investigated the behavior of Concrete Filled Steel Tube (CFST) columns under different end conditions using experimental observations and ANSYS analysis. The results demonstrated that CFST columns provide superior strength, stiffness, and load-carrying capacity compared to conventional RCC columns due to the effective composite action between steel and concrete. Among the various support conditions, fixed-end columns exhibited better structural performance with lower deformation and higher stability than hinged-end columns. It was also observed that increasing the concrete grade from M20 to M30 enhanced the overall performance of the columns. The M30 CFST column with fixed end condition showed the best results in terms of strength and deformation control. The study confirms that CFST columns are an efficient and reliable structural solution for modern construction applications requiring high strength and stability.

IX. FUTURE SCOPE

The present study can be extended by investigating the behavior of CFST columns under different loading conditions such as cyclic, seismic, impact, and eccentric loads. Future research may also consider various cross-sectional shapes, steel tube thicknesses, concrete grades, and slenderness ratios to achieve a broader understanding of structural performance. Advanced numerical simulations and full-scale experimental testing can be carried out to validate the results more accurately. The use of high-strength materials, fiber-reinforced concrete, and innovative composite systems can further enhance the efficiency of CFST columns. Such studies will contribute to the development of improved design guidelines and promote the wider application of CFST structures in modern high-rise and infrastructure projects.

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