IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ANALYSIS OF THE PERFORMANCE OF CFST COMPOSITE COLUMNS WITH DOUBLE-PLATE CONNECTORS

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Framing systems consisting of special shaped columns and beam have become very popular, of which CFST -Concrete Filled Steel Tube columns have been significantly important. They consist of a hollow steel tube with normal or reinforced concrete filled inside. Together the steel tube and concrete act as a single system and have proven to be efficient as a structural member. They have excellent structural performance including high strength and ductility. They are highly advantageous over a regular reinforced concrete or steel member. The orientation of steel and concrete gives maximum strength and stiffness to the section. The steel resists bending moment and tension, enhancing the overall stiffness of the section. The concrete filled inside the tube resists the compressive load sand prevents local buckling of steel. Studies conducted show that CFST columns have increase in cyclic strength, ductility and damping. It is also very useful in construction field as it is not as costly as a reinforced concrete column.

Studies have been conducted on CFST columns of rectangular, square and circular cross-section and they are being used in various structures. Because of regular cross-section columns may tend to protrude from the walls and this can affect the aesthetic considerations. The CFST columns can be combined together to form special shaped columns, which can be used to solve this issue. Special shapes such as L, T, Cross and I shape can be achieved by connecting CFST columns using steel connection plates. Various connection techniques can be used such as perforated plate, spliced plate, single plate and double plate. Studies have been conducted to understand the mechanical properties of L-shaped CFST columns with various connection techniques and it was found out that double plate connected CFST columns in L-shape with concrete filled between the steel connection plates have higher bearing capacity. It was noted that the overall performance improved due to the presence of concrete between the steel tubes.

More studies need to be conducted on other specials shape and this study focuses on the use of corrugated steel plates as connection plates between the CFST columns. Corrugated steel plates have higher stiffness and durability. They are rust resistant and can withstand very hard conditions like snow, high wind and rainfall. This study focuses on conducting a uniaxial eccentric compression test on special shaped CFST columns connected using corrugated steel plates, to find the axial load bearing capacity and then compare the results with normal steel plate connected special shaped CFST column.

concrete-filled thin-walled steel tube (CFST) members were popularly applied for multi- and high-rise buildings, and they were sincerely favored and recommended by many engineers and scholars due to their excellent combination action provided by outside steel tube and infill concrete However, the deterioration in load carrying capacity caused by outward local buckling or corrosion on thin-walled steel tube was observed as well. Although a series of strengthening methods including welding steel plates and attaching bars to the inside surface of steel tubes were proposed to prevent the above problems, some drawbacks including increase in weight, difficulty in construction and deterioration in durability were also discovered. In an attempt to avoid these problems and to prevent outward bugles or corrosion, wrapping carbon fiber reinforced polymer (CFRP) strips on outside surface of the thin-walled steel tube.

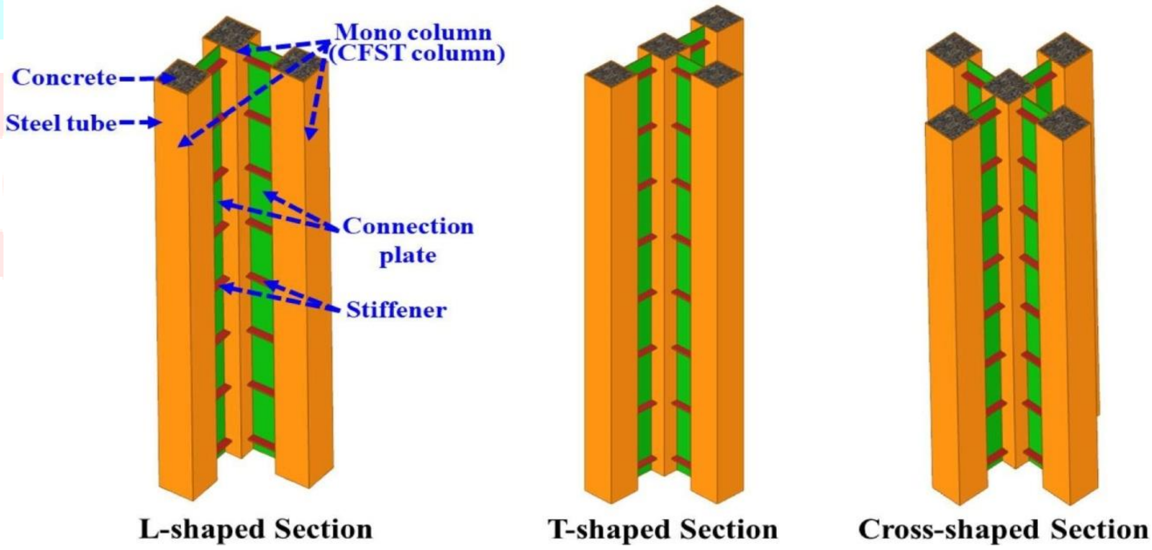

Fig 1.1 Special Shaped CFST Columns

1.2 ADVANTAGES OF SPECIAL SHAPED CFST COLUMNS

The use of special shaped CFST columns are advantageous in many ways such as.

1 They can be used for retro fitting purposes for strengthening of concrete columns in earthquake zones.

2 CFST columns can be used in structures with large compressive loading. The core concrete performs very well in compressive loading applications.

3 Uses the characteristics of both steel and core concrete , hence better load bearing capacity. Less creep and shrinkage.

4 Increased compressive strength due to steel tube confinement effect.

5 Delayed local buckling due to interaction between steel tube and concrete.

6 Special shaped columns can be hidden inside the walls and hence better aesthetics.

1.3 NEED FOR THE STUDY

They can be used for retro fitting purposes for strengthening of concrete columns in earthquake zones by providing CFST column with double plate connectors. By this method we can avoid structural failure and improve the load bearing capacity of structural members. CFST columns can be used in structures with large compressive loading. The core concrete performs very well in compressive loading applications. Uses the characteristics of both steel and core concrete , hence better load bearing capacity. Mainly focused on structure with Less creep and shrinkage in future .

1.4 OBJECTIVES AND SCOPE

1.4.1 Scope

- The work is limited to modeling and analysis of columns using ANSYS.
- The work is focused only on CFST columns made of rectangular steel tubes. Steel tubes of different cross-sectional shape can be used.

Material properties of the concrete filled inside the tubes can be changed.

1.4.2 Objectives

- To develop and compare models of Single-plate connected CFST columns normal steel connection plates and corrugated steel connection plates.
- To compare the mechanical properties of L-shaped double-plate connected CFST columns filled with concrete against double-plate connected CFST columns of other special shapes.
- To develop and compare models of Double-plate connected CFST columns normal with corrugated steel connection plates.
- FRP plates will be added to the column connection plates for improving bearing capacity of column.

1.4 ORGANIZATION OF THESIS

This thesis is organized as follows. In Chapter 1, "Introduction" a general description of Concrete Filled Steel Tubular Column (CFST) of different shapes, need for the study and scope and objectives are mentioned. Chapters 2, "Literature Review" includes a detailed review on various studies conducted in the past. In Chapter 3, "Methodology" the detailed methodology adopted for analysing the performance of CFST Composite column with Double plate connectors, Single plate connectors and CFRP added connection plates . In Chapter 4, "Results and Discussion" in which results obtained from Finite Element Analysis for all models are described. The thesis is concluded in Chapter 5, with the concluding remarks and scope for future study.

CHAPTER 2

LITERATURE REVIEW

This chapter aims at a brief review of the existing literature in the study of Special shaped CFST Columns. The investigations of the available literature is done mainly to understand the extend of developments and findings in the area till date and the same is summed up in the following main categories.

Zhihua Chen, Jie Liu, Ting Zhou, Xiangyu Yan4 and Xi Zhang (2020). In this journal the bearing capacity of double plate connected special shaped CFST column is done. Uniaxial compression test was conducted on double plate connected CFST columns with connection plates filled with concrete. The test phenomena ,load-axial displacement curves and strain analysis were examined. [1]

Ansymol Anaz et.al (2021)Study on Prismatic and Non-Prismatic Concrete Filled Steel Tube Columns encased with Engineered Cementitious Composite. This study examines the structural performance of CFST columns, encased with ECC, under various loading conditions. Nonlinear finite element models were developed using ANSYS to assess structural performance of these columns. Among the non-prismatic columns, the Inner core L shape showed better resistance to lateral loading.. [2]

Vishal V. Gore(2013) study on Performance of Concrete Filled Steel Tube (CFST) Section.This paper is mainy focussed on The CFST section resists applied load through the composite action of concrete and steel, this advantageous interactive behavior between steel tubes and concrete increases the strength of CFST section and hence it has become popular in recent days and is being used in structures such as bridges, electricity towers, buildings etc. Extensive works carried out on CFST in past years have indicated that the CFST sections possess high ductility, strength and stiffness properties. These properties are considered to be important, especially for the multi-storied buildings required to be erected in earthquake prone areas. [3]

Qing-Xin Ren et.al (2014) study the behaviour of axially loaded concrete filled steel tubular (CFST) stub columns with special-shaped cross-sections, i.e. triangular, fan-shaped, D-shaped, 1/4 circular and semi-circular.. The results showed that the tested special-shaped CFST stub columns behaved in a ductile manner, and the composite columns showed an outward local buckling model near the middle section. The cross-sectional strength decreases by 16.0%, 25.1%, 28.4%, 32.1% and 40.0% with the changing of sectional shape from circular section to 1/4 circular, D-shaped, fan-shaped, semi-circular and triangular section, respectively due to the reduction of the cross-sectional area of the special-shaped CFST columns. Generally, the failure modes of these five kinds of special-shaped specimens were similar to those of the square CFST stub columns. Compared with the reference hollow sectional specimens, both the cross-sectional strength and the ductility of the composite columns can be significantly increased due to the infill of the concrete core. [4]

Xianggang Liu et.al (2018) studied about research on special-shaped concrete-filled steel tubular columns under axial compression. Six L-shaped and twelve T-shaped concrete-filled steel tubular (CFST) stub columns subjected to axial compression. Finite element (FE) software ABAQUS was used to analyse special-shaped CFST columns. The stiffeners can effectively delay the local buckling of steel tubes, increase the buckling capacity, and increase the constraint effect for concrete. The cross-sectional dimension of specimens has no obvious effect on the ductility and the failure modes of T-shaped CFST stub column due to the restriction of steel plate stiffener, which affects the stiffness and the bearing capacity. [5]

Yongqian Zheng et.al(2020) studied about the Design of L-shaped and T-shaped concrete-filled steel tubular stub columns under axial compression. In this study, finite element (FE) models were developed to simulate the axial behaviour of unstiffened, stiffened, and multi-cell L-shaped and Shaped CFST stub columns. Predictions of the ultimate strength using Eurocode 4 and a previously reported design formula were compared with the FE results, in which unsatisfactory deviations were observed. New design models for the axial compressive strength and the stiffness were proposed by performing regression for different types of L-shaped and T-shaped CFST stub columns. The ultimate strength predictions based on Eurocode 4 are generally unsafe in the case of the small confinement effect for concrete for the unstiffened L-shaped and T-shaped CFST columns. [6]

Xiandong Chen et. al (2019) studied about the mechanical properties of special-shaped concrete-filled steel tube columns under eccentric compression Special-shaped concrete-filled steel tube (SCFST) columns . In this study, five groups of eccentric compression tests were conducted to study the mechanical properties of SCFST columns with respect to the axial force and bending moment around the centroid principal axis, using the eccentric distance and eccentric direction as the parameters. ABAQUS software was used to construct finite element models. A calculation method for the in-plane stability of the SCFST columns under axial force.Therefore, it can provide guidance in the engineering design of SCFST columns[7]

Zhen Wang et.al (2020) axial compressive performance of novel L-shaped and T-shaped concrete-filled square steel tube (L/T-CFSST) column was assessed in this study. Calculation results are in close agreement with the FEA and experimental results, and the proposed formula may provide a workable reference for practicing engineers. Result shoes that failure modes of L/T-CFSST stub columns ($H/D \leq 3$) and medium-long columns ($H/D > 3$) differ. Failure mode of stub columns is characterized by the yield and local buckling of the steel tube while that of medium-long columns is attributable to the buckling and bending failure of the column. [8]

Z.Y. Chen, Z.Y. Shen (2009) Tests were conducted on six L-shaped concrete-filled steel stub columns and one L-shaped steel hollow column. The influences of structural parameters on the axial bearing capacity of L-shaped Columns were investigated. For an L-shaped Column with a short limb, the stiffeners may improve the ductility of the specimens to the extent of 1.5 times although they were less effective in improving the bearing capacity. [9]

HanL.H,S.HHe,F.YLiao(2020) In this journal Behavior of concrete filled steel tubes(CFST) under axial tension was studied. A total of 18 specimens were tested and it was found that the tensile strength of steel tube can be increased due to the existence of the core concrete in CFST. [10]

2.1 CRITICAL REVIEW

The use of CFST columns are advantageous as they have increased concrete compression strength and delayed local buckling due to interaction between steel tube and concrete. These CFST columns can be used to make special shaped columns and studies need to be done on the mechanical properties to determine better design. The bearing capacity increased by increasing the strength and thickness of steel.When eccentricity increases the bearing capacity and stiffness decreases. For an L-shaped CFST Column, the stiffeners may improve the ductility of the specimens to the extent of 1.5 times although they were less effective in improving the bearing capacity. Eccentricity, material properties and steel tube thickness are the main factors which affect the bearing capacity of the CFST column.

After conducting the literature survey, the gap area identified is that the special shaped CFST columns with corrugated steel connection plates have not been investigated to find the axial compressive strength. The mechanical properties of special shaped CFST columns with corrugated steel connection plates can be compared to that when normal steel connection plates are used. CFST columns in various special shapes like T, I and cross shapes can be investigated.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

In this study modelling of CFST composite column with different plate connections and also compare the performance of different shaped CFST columns .Load diffliection graph and equalent stress diagrams are obtained .

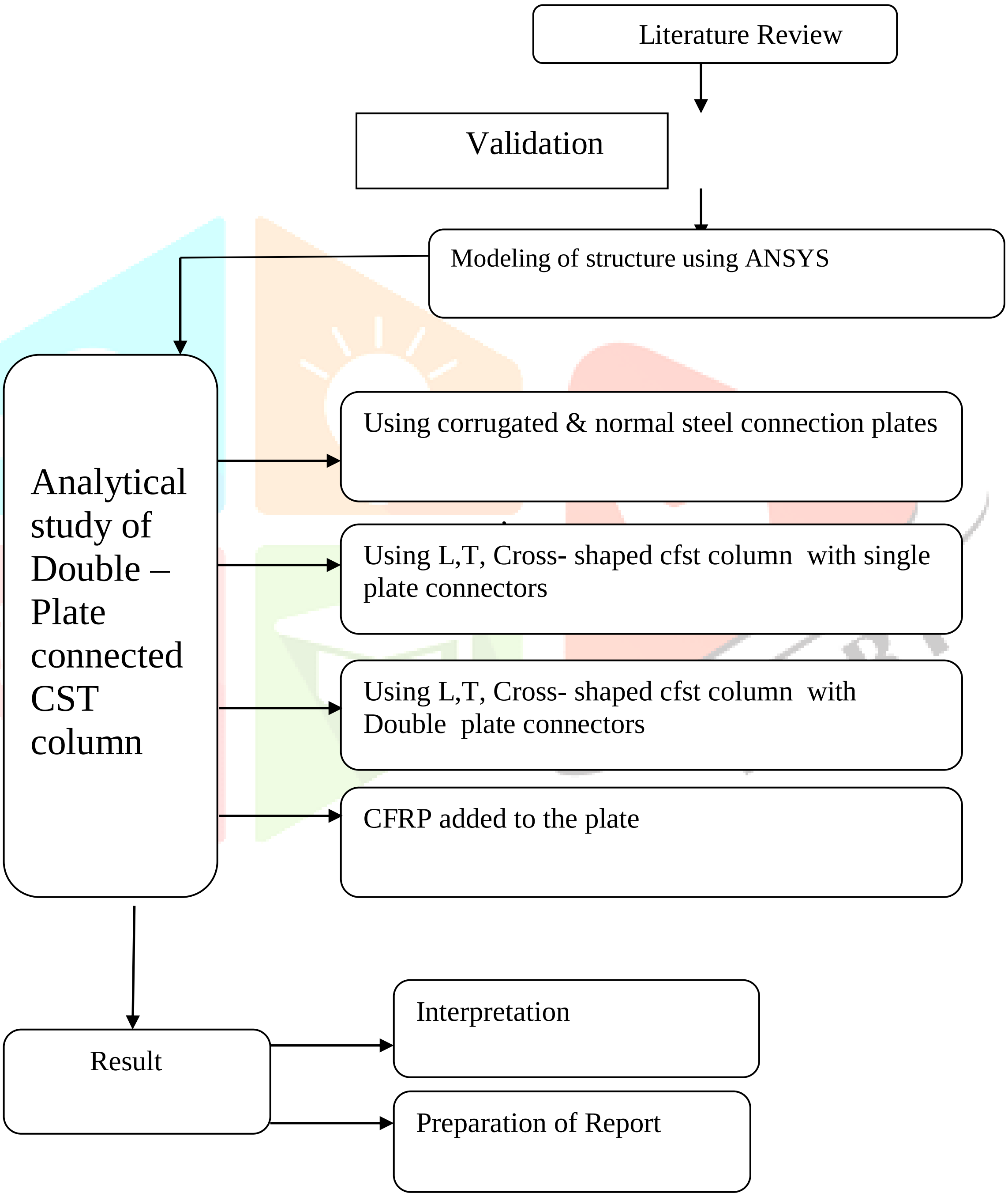

Fig. 3.1 Overview of methodology

3.1 FINITE ELEMENT METHOD

The finite element method (FEM) is a popular method for numerically solving differential equations arising in engineering and mathematical modeling. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The FEM is a general numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called finite elements. This is achieved by a particular space discretization in the space dimensions , which is implemented by the construction of a mesh of the object: the numerical domain for the solution , which has a finite number of points. The finite element method formulation of a boundary value problem finally results in a system of algebraic equations. The method approximates the unknown function over the domain. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. The FEM then approximates a solution by minimizing an associated error function via the calculus of variations .Studying or analyzing a phenomenon with FEM is often referred to as finite element analysis (FEA).

3.2 INTRODUCTION TO ANSYS

Ansys was founded in 1970 by John Swanson, who sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, the company acquired numerous other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and physics analysis. Ansys became a component of the NASDAQ-100 index on December23, 2019.

Ansys develops and markets engineering simulations of software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to simulate computer models of structures ,electronics ,or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

Most Ansys simulations are performed using the Ansys Workbench system, which is one of the company's main products. Typically , Ansys users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluidflow, temperature distribution, electro magnetic efficiency and other effects over time. Ansys also develops software for data management and back up, academic research and teaching. Ansys software is sold on an annual subscription basis.

Ansys can work integrated with other engineering software on desktop by adding CAD and FEA connection modules ANSYS can import CAD data and also enables to build geometry with its pre-processing abilities. Similarly, in the same pre-processor, finite element model, which is required for computing is generated after defining loadings and carrying out analysis, results can be viewed as numerical and graphical. ANSYS can carry out advanced engineering analysis quickly, safely and practically by its variety algorithms ,time-based loading features andnon-linearmaterialmodels.

Ansys Work bench is a platform which integrates simulation technologies and parametric CAD system with unique automation and performance. The power of ANSYS Workbench comes from ANSYS solver algorithm with years of experience Furthermore, the object of ANSYS Workbench is verification and improving of the product in virtual environment.

All designers to researchers can benefit from ANSYS software, the fidelity of the result is achieved through the wide variety of material models available ,the quality of element library ,the robustness of the solution algorithm sand the ability to model every problem ,from single parts to very complex assemblies with hundreds of components interacting through contacts or relative motions.

3.3 ELEMENTTYPE

3.3.1 solid186

SOLID186 is a higher order 3-D20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x,y,and z directions.The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto plastic materials, and fully incompressible hyper elastic materials.

SOLID186 is available in two forms:

- Homo generous Structural Solid
- Layered Structural Solid

SOLID 186 Homogeneous Structural Solid is well suited to modeling irregular meshes(such as those produced by various CAD/CAM systems). The element may have any spatial orientation. It is shown in Figure4.1.

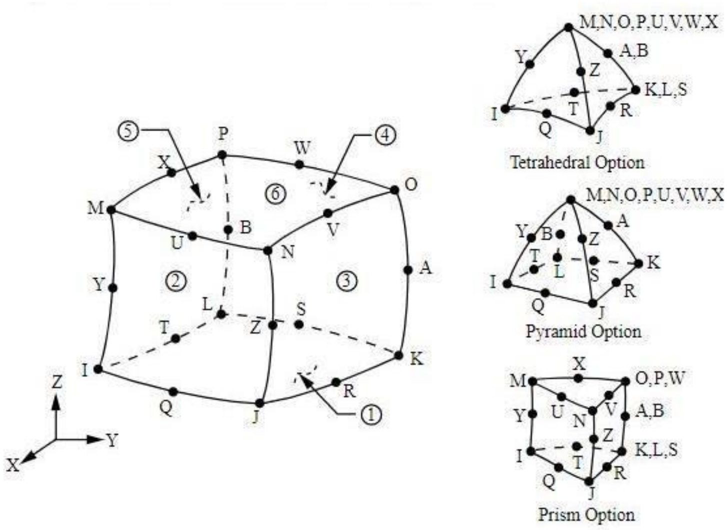

Fig.3.1 Solid186 Geometry

SOLID186 Layered Structural Solid to model layered thick shells or solids. The layered section definition is given by ANSYS section commands. A prism degeneration option is also available. In addition to the nodes, the element input data includes an isotropic material properties. Anisotropic material directions correspond to the layer coordinate directions which are based on the element coordinate system.

3.3.2 solid65

SOLID65 is used for 3-D modeling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete while the rebar capability is available for modeling reinforcement behaviour. Other cases for which the element is also applicable to reinforced composites (such as fiberglass), and geological materials (such as rock). The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y,and z directions. The concrete element is similar to a 3-D structural solid but with the addition of special cracking and crushing capabilities. The most important aspect of this element is the treatment of nonlinear material properties. The concrete is capable of cracking (in three orthogonal directions), crushing, plastic deformation, and creep.

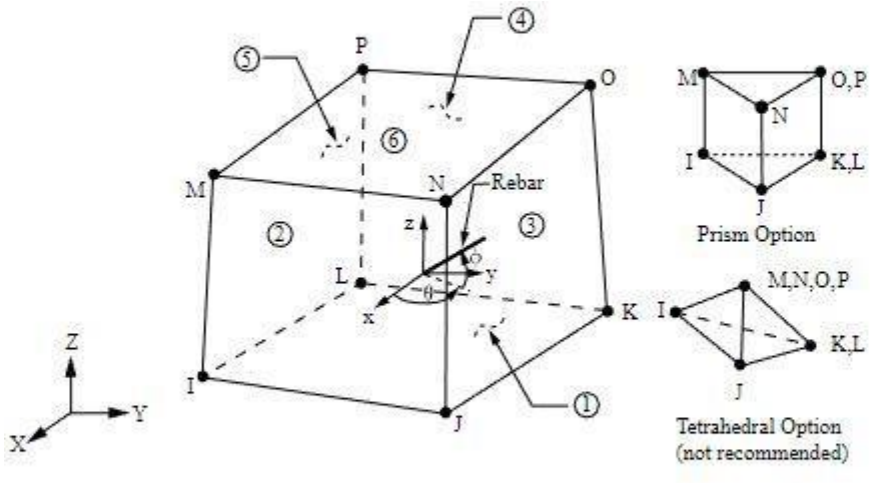

Fig 3.2 SOLID65 Geometry

3.3.3 shell 181

SHELL181 is suitable for analysing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. (If the membrane option is used, the element has translational degrees of freedom only).The degenerate triangular option should only be used as filler elements in mesh generation. SHELL181 is well-suited for linear ,large rotation, and/or large strain nonlinear applications. Change in shell thickness is accounted for in nonlinear analyses.

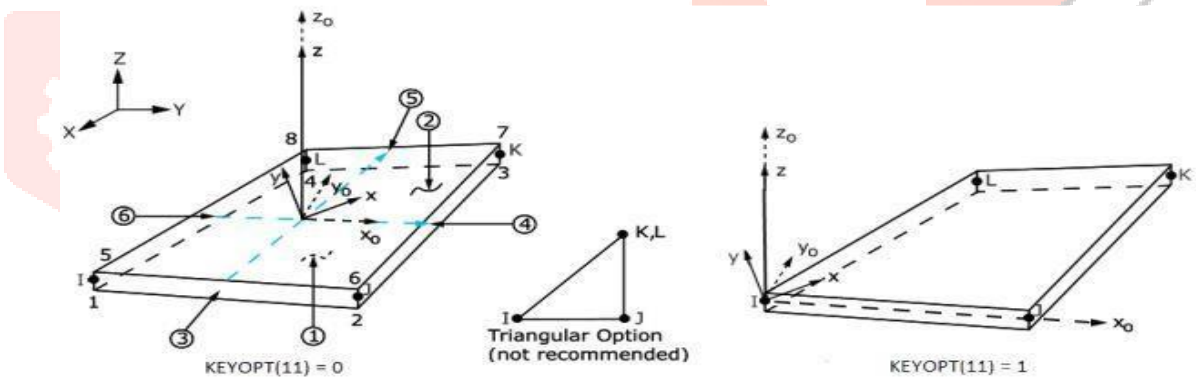

Fig 3.3 shell181 geometry

3.4 MATERIAL PROPERTIES

3.4.1 GENERAL

To investigate the structural behaviour of CFST with different column arrangement of T, cross and L shaped column with steel plate connections were developed using ANSYS. Solid 180 Models were used to model T, cross and L shaped CFST.SOLID186 is a higher order 3D 20-node solid element that exhibits quadratic displacement behaviour. The element is defined by 20 nodes having six degrees of freedom per node; translations and rotations in x, y and z-directions.

3.4.1.1 GEOMETRY

The geometry of the specimen is kept same as that of the specimens in the base journal. Cross, L shaped and T shaped columns were considered for the analysis. The columns steel tube thickness is took as demonstrated in the figures shown below. The thickness of steel tube is equal to 3mm with yield strength 306 MPa and stiffeners having thickness 3mm with yield strength 306 MPa and specimen length is taken as 900 mm.

Table 3.1 Material properties

Properties of Outline Row 3: Concrete

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	2500	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.4E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young'...	
8	Young's Modulus	32.837	GPa
9	Poisson's Ratio	0.2	
10	Bulk Modulus	1.8243E+10	Pa
11	Shear Modulus	1.3682E+10	Pa
12	Bilinear Isotropic Hardening		
13	Yield Strength	36.9	MPa
14	Tangent Modulus	4000	MPa
15	Tensile Yield Strength	0	Pa
16	Compressive Yield Strength	0	Pa
17	Tensile Ultimate Strength	5E+06	Pa
18	Compressive Ultimate Strength	4.1E+07	Pa

3.4.2 MATERIAL PROPERTIES END PLATES

Table 3.2 Material properties of end plate

Properties of Outline Row 4: END

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young'...	
8	Young's Modulus	206	GPa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.7167E+11	Pa
11	Shear Modulus	7.9231E+10	Pa
12	Strain-Life Parameters		
20	S-N Curve	Tabular	
24	Tensile Yield Strength	2.5E+08	Pa
25	Compressive Yield Strength	2.5E+08	Pa
26	Tensile Ultimate Strength	4.6E+08	Pa
27	Compressive Ultimate Strength	0	Pa

3.4.3 MATERIAL PROPERTIES STEEL STIFFNER

Table 3.3 Material properties of steel stiffener

Properties of Outline Row 6: STEEL TUBE

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young'...	
8	Young's Modulus	206	GPa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.7167E+11	Pa
11	Shear Modulus	7.9231E+10	Pa
12	Bilinear Isotropic Hardening		
13	Yield Strength	306	MPa
14	Tangent Modulus	2060	MPa
15	Strain-Life Parameters		
23	S-N Curve	Tabular	
27	Tensile Yield Strength	2.5E+08	Pa
28	Compressive Yield Strength	2.5E+08	Pa
29	Tensile Ultimate Strength	4.6E+08	Pa
30	Compressive Ultimate Strength	0	Pa

3.5 MODELING

3.5.1 OBJECTIVE -1

- To develop and compare models of double-plate connected CFST columns normal steel connection plates and corrugated steel connection plates.

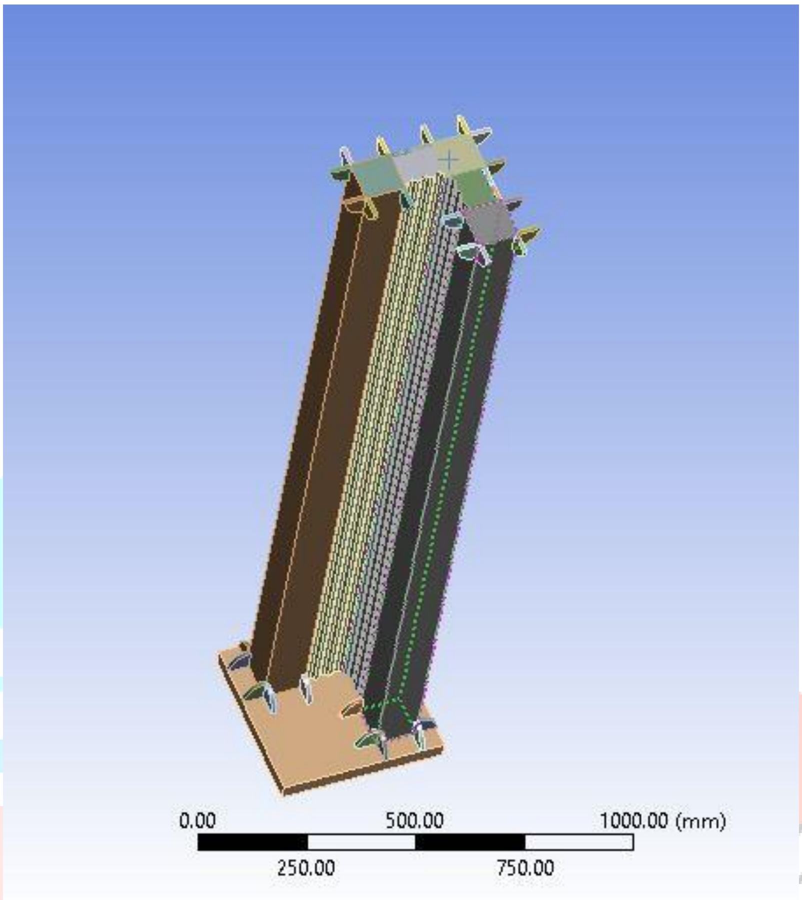

Fig 3.4 Geometry Trapezoid

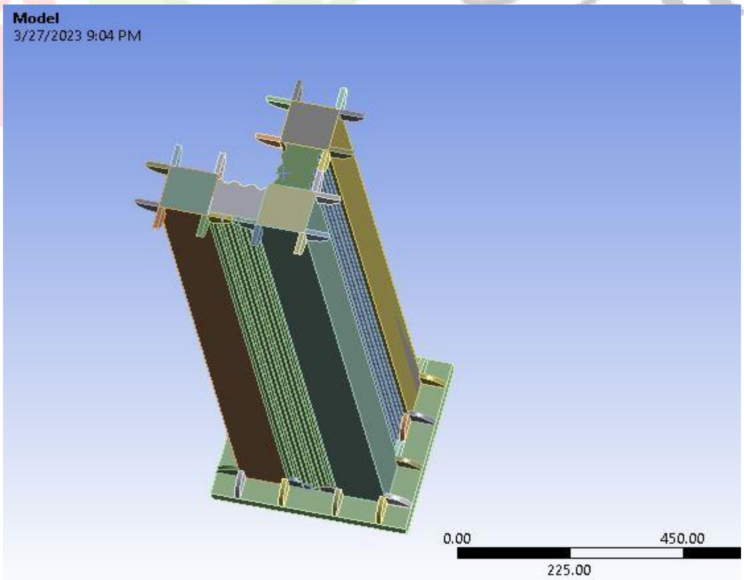

Figure: 3.5 geometry sinusoidal

3.5.1.1 MESHING

Meshing divides the whole component into a finite number of small elements as per requirement. Size of the element must be as small as possible to achieve accuracy. In this analysis, fine mesh was adopted to achieve maximum accuracy in results. Solid models are converted into a finite element model after meshing.

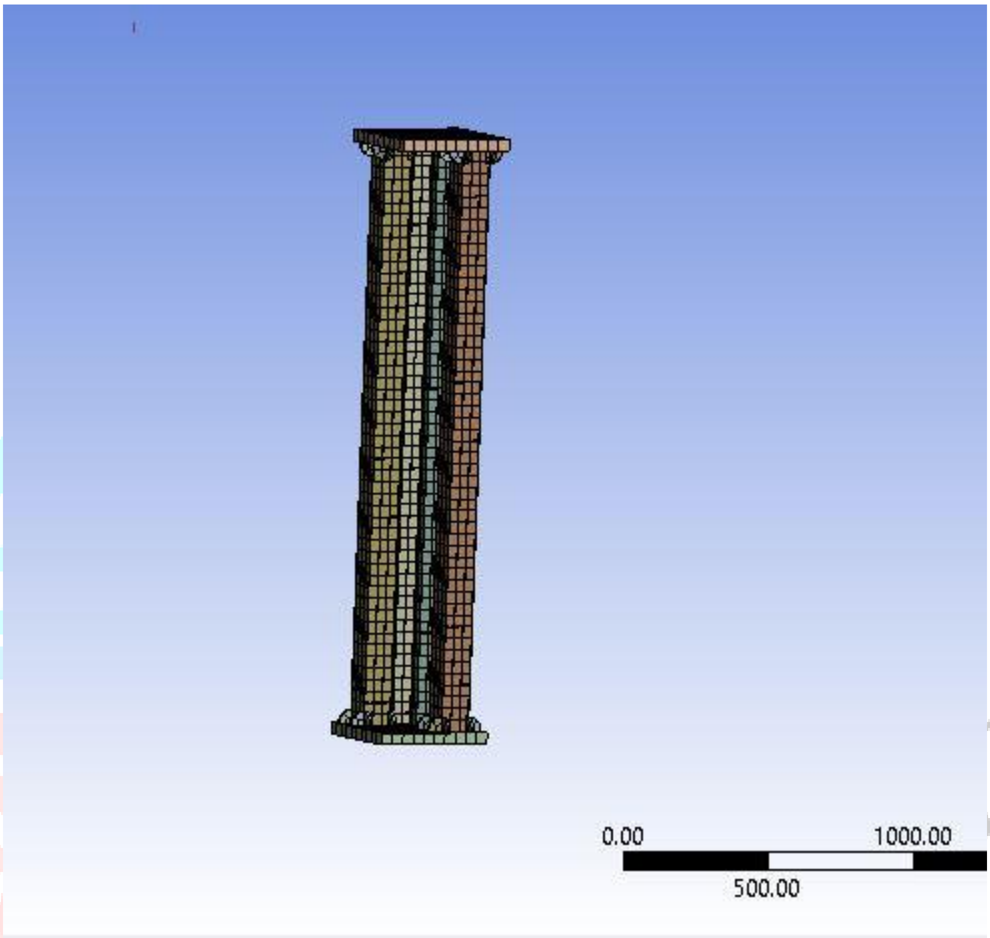

Fig 3.6 Mesh generated

3.5.1.2 LOADING AND BOUNDARY CONDITIONS

To simulate real conditions column were modeled with one end fixed and another end free. Load was applied only in one direction. Behaviour of specimen under axial load under axial load was studied using ANSYS.

Fig 3.7 Application of loads in T section

3.5.2 OBJECTIVE 2

- To compare the mechanical properties of L-shaped double-plate connected CFST columns filled with concrete against double-plate connected CFST columns of other special shapes.

3.5.2.1 FINITE ELEMENT MODELLING

To investigate the structural behaviour of special shaped concrete filled steel tubular columns with holes on its stiffness plates central portion and also to compare the results with the hole arrangement in zig zag manner by using ANSYS Software.

3.5.2.2 SCOPE

Stiffener plate in special shaped CFST is capable of providing good ductile property and to enhance the energy carrying capacity. sinusoidal and trapezoidal shapes normally increases the energy absorption capacity and after that it can sustain the stable condition of the structure to some more extend. This idea of providing holes through the central alignment of the steel plate also comparing alignment with that of zig zag alignment of holes will helps to figure out which version will come in a way which provides better structural performances than other. This study using the software ANSYS helps us to find out which alignment is providing a better performance and this is a good way to understand whether providing plate cross section sinusoidal and trapezoidal in the steel tube stiffeners is beneficial or not by comparing the results with the results obtained from objective 1

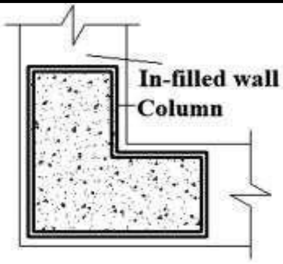

Fig 3.8 Shape of L-shaped cfst column

3.5.2.3 GEOMETRY

The geometry of the specimen is kept same as that of the specimens in the base journal. L shaped cross and T shaped columns were considered for the analysis. The columns steel tube thickness is took as demonstrated in the figures shown below. The thickness of steel tube is equal to 3mm with yield strength 306 MPa and stiffeners having thickness 3mm with yield strength 306 MPa and specimen length is taken as 900 mm. The position and arrangement of the holes in the steel plate stiffeners are as per the base journal. In case of the first arrangement of holes through the centre portion of the steel plate and the second case of the arrangement is in a zig zag manner as shown.

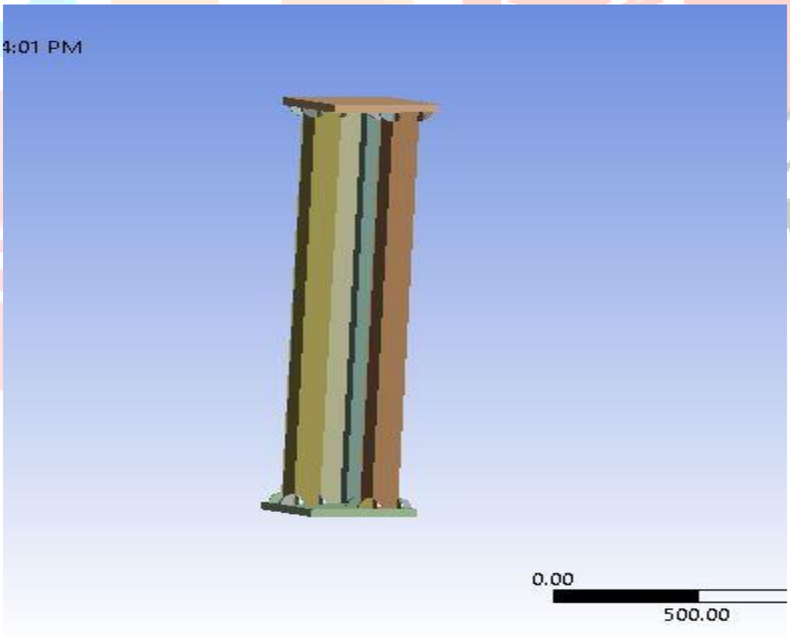

Fig 3.9 geometry of L-shaped cfst column

- CFST tubes were connected using single steel plate to form T-shaped CFST column.
- Steel plates of 6 mm thickness was used to connect the CFST tubes.

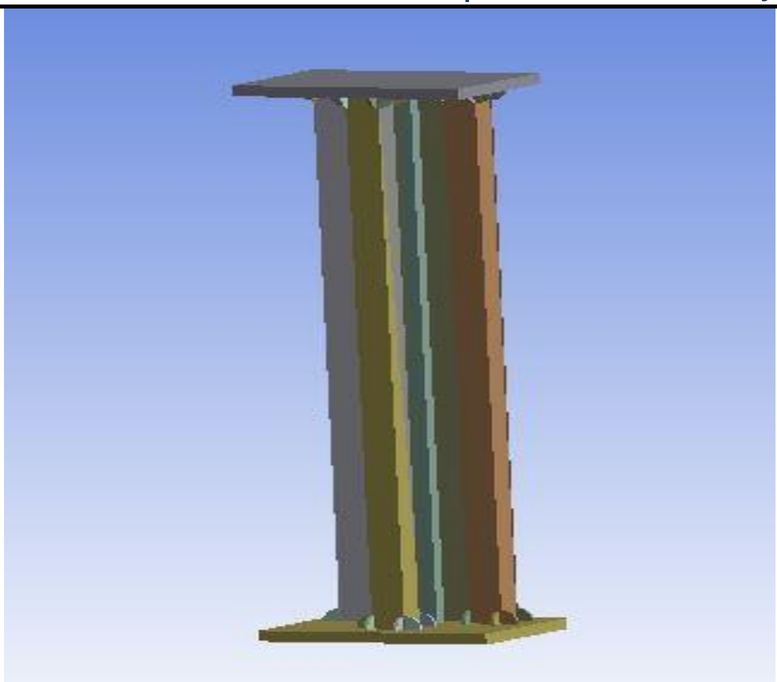

Fig 3.10 geometry of t-shaped cfst column

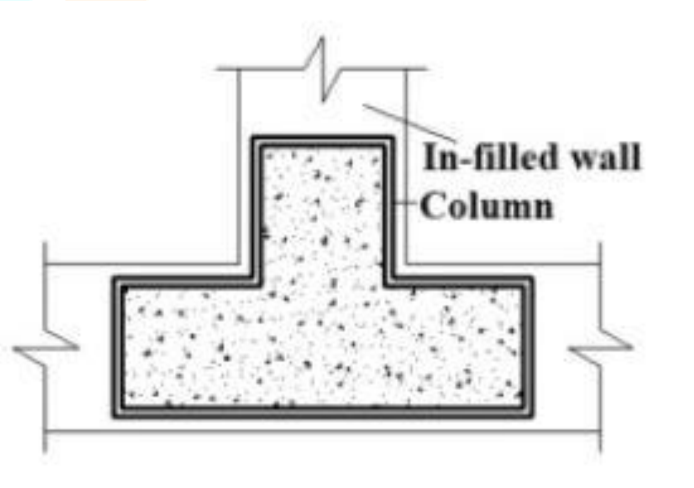

Fig 3.11 geometry of t-shaped cfst column

- CFST tubes were connected using single steel plate to form T-shaped CFST column. Steel plates of 6 mm thickness was used to connect the CFST tubes

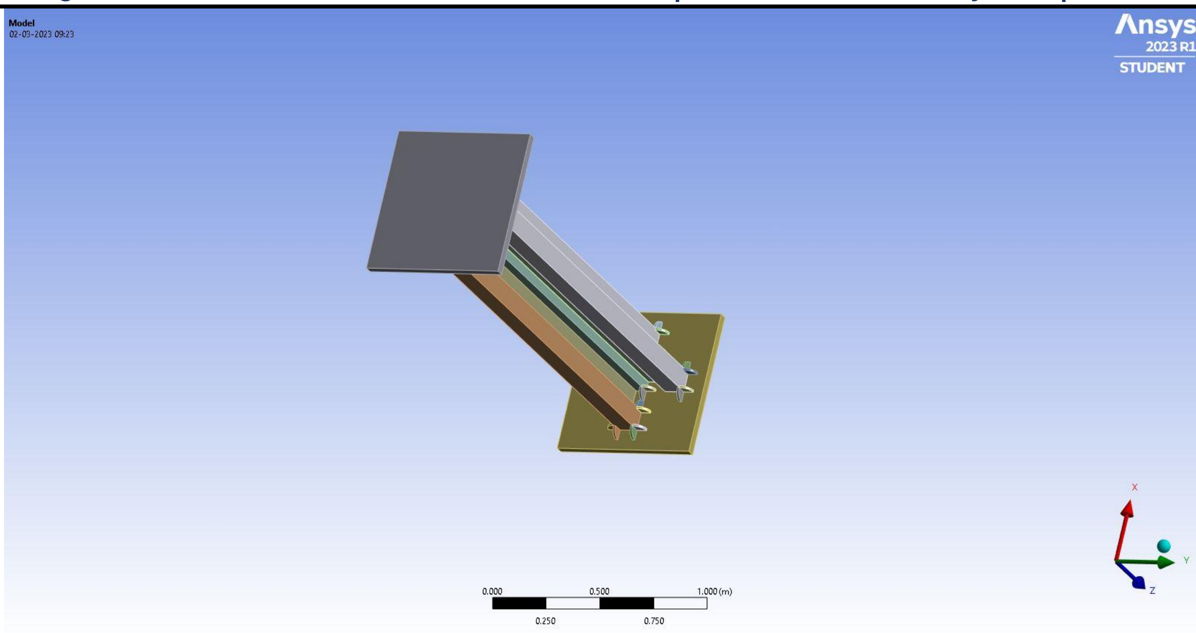

Fig 3.12 geometry of cross-shaped cfst column

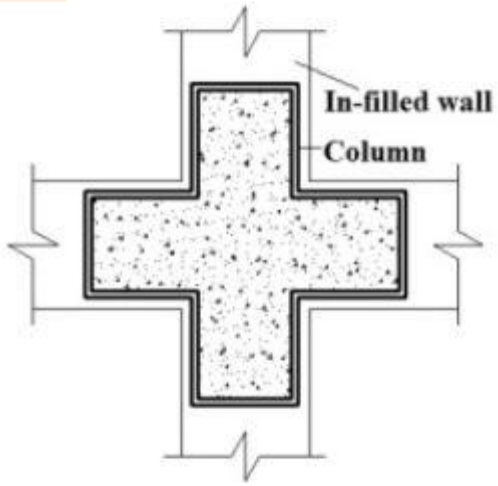

Fig 3.13 geometry of cross-shaped cfst column

Meshing divides the whole component into a finite number of small elements as per requirement. Size of the element must be as small as possible to achieve accuracy. In this analysis, fine mesh was adopted to achieve maximum accuracy in results. Solid models are converted into a finite element model after meshing.

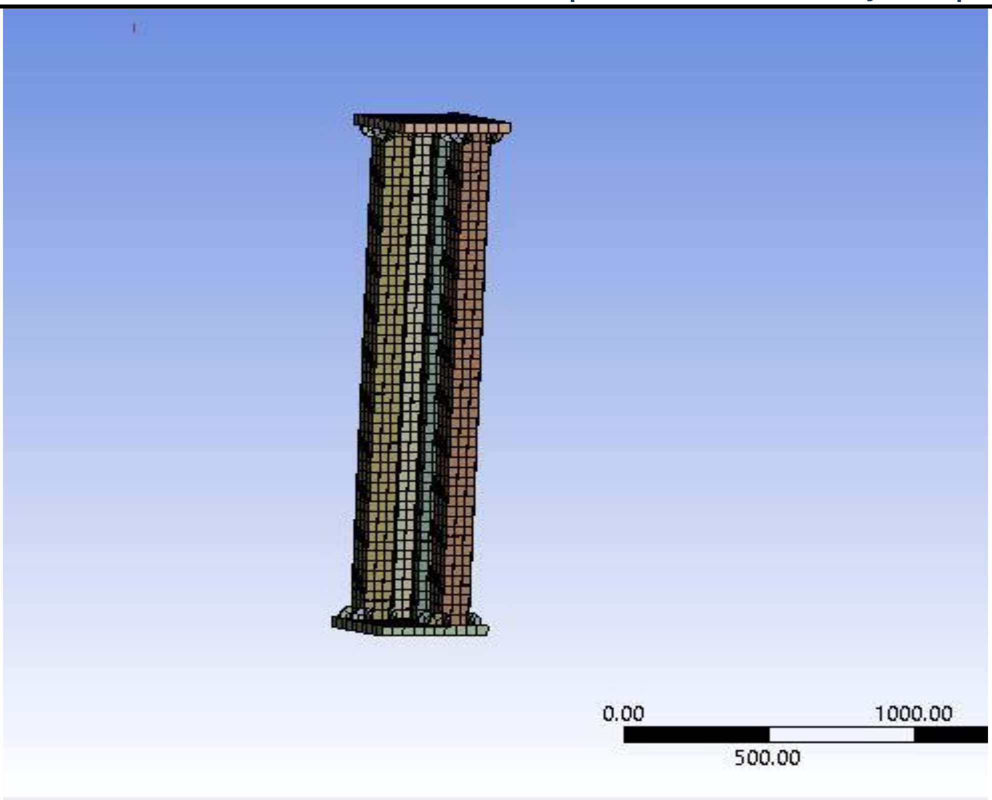

Fig 3.12 mesh with L section

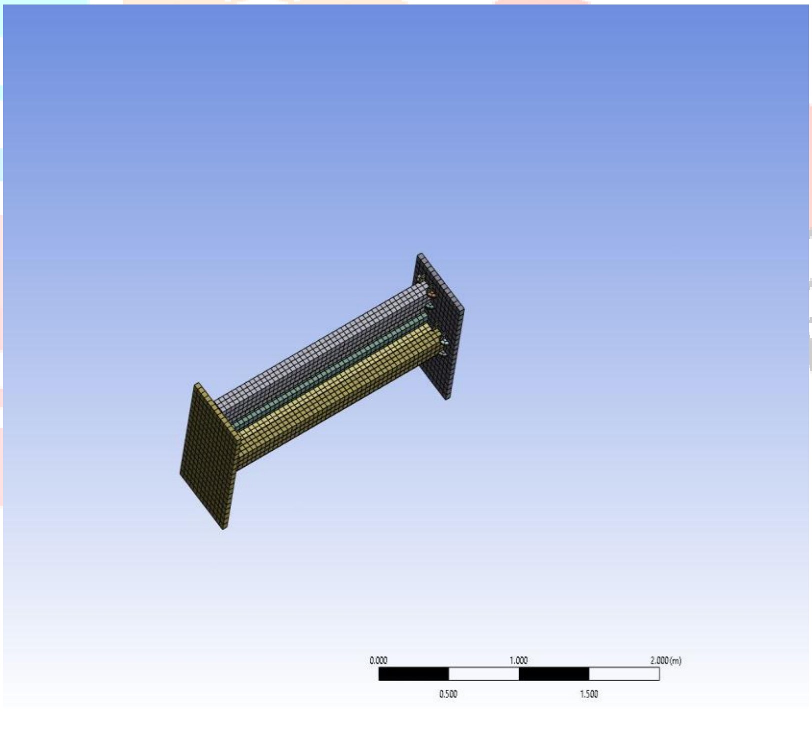

Fig 3.13 Mesh With T Section

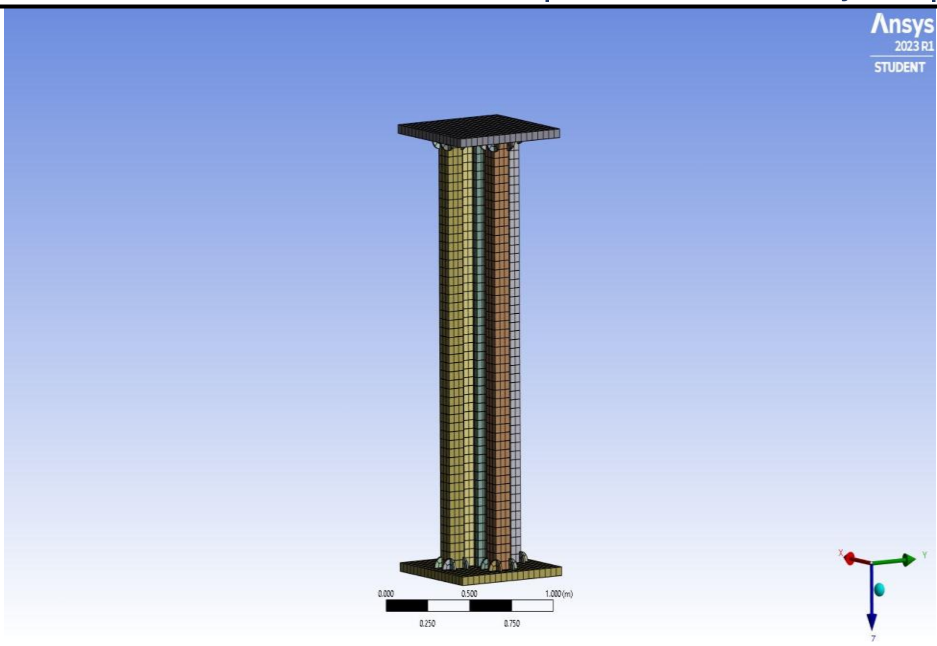

Fig 3.14 mesh with cross section

3.5.2.5 LOADING AND BOUNDARY CONDITIONS

To simulate real conditions column were modelled with one end fixed and another end free. Load was applied only in one direction. Behaviour of specimen under axial load under axial load was studied using ANSYS.

3.5.3 OBJECTIVE 3

- Columns are connected with double corrugated steel plate.
- To determine which special shape has highest load bearing capacity when connected using double corrugated steel plate.
- CFST tubes were connected using sinusoidal corrugated steel plate and trapezoidal corrugated steel plate to form T-shaped and Cross shaped CFST column.
- Steel plates of 6 mm thickness was used to connect the CFST tubes.

3.5.3.1 FINITE ELEMENT MODELLING

To investigate the performance of L shaped cross and T shaped columns with corrugation elements by using ANSYS Software.

3.5.3.2 SCOPE

This study using the software ANSYS helps us to find out which alignment is providing a better performance and this is a good way to understand whether providing end plate connection is beneficial or not by comparing the results with the results obtained from objective 1.

3.5.3.3 GEOMETRY

The geometry of the specimen is kept same as that of the specimens in the base journal. L shaped cross and T shaped columns with corrugation were considered for the analysis. The columns steel tube thickness is took as demonstrated in the figures shown below. The thickness of steel tube is equal to 3mm with yield strength 306 MPa and stiffeners having thickness 3mm with yield strength 306 MPa and specimen length is taken as 900 mm. Here the end plate connections are provided in the L and T shaped non-prismatic columns.

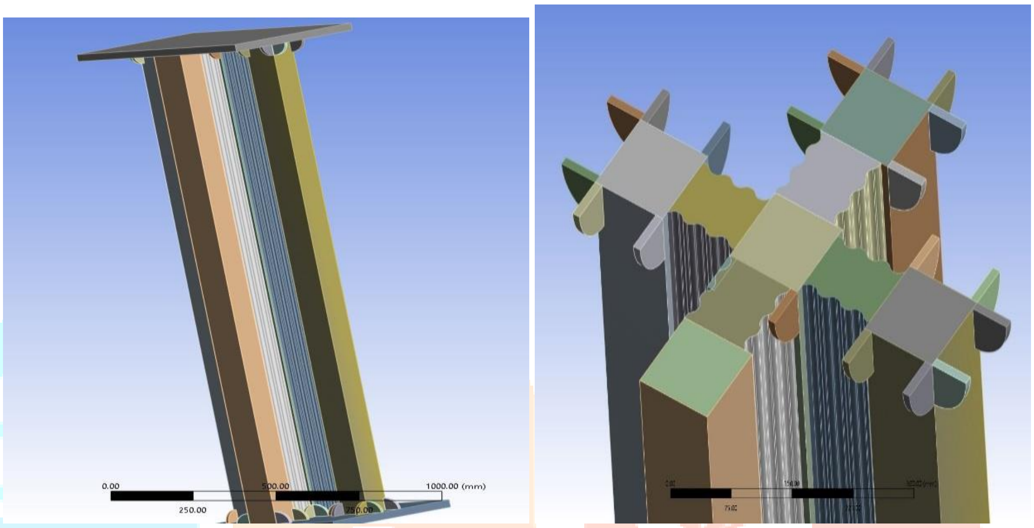

Fig 3.15 Cross-shaped CFST Column with Sinusoidal Corrugated Steel Plates

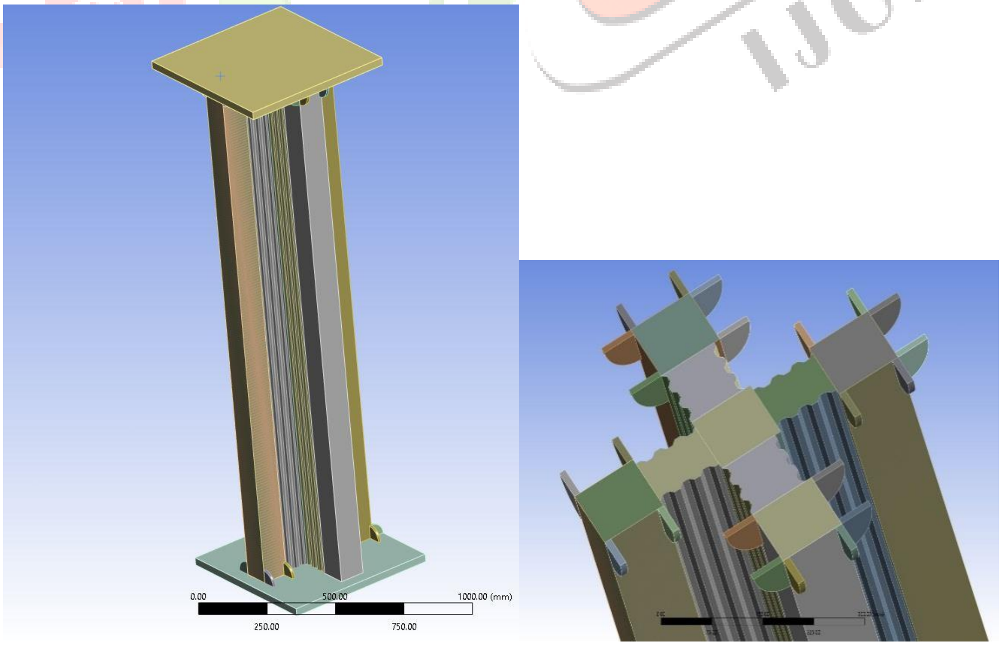

Figure 3.16 : Cross-shaped CFST Column with Trapezoidal and Sinusoidal Corrugated Steel Plates

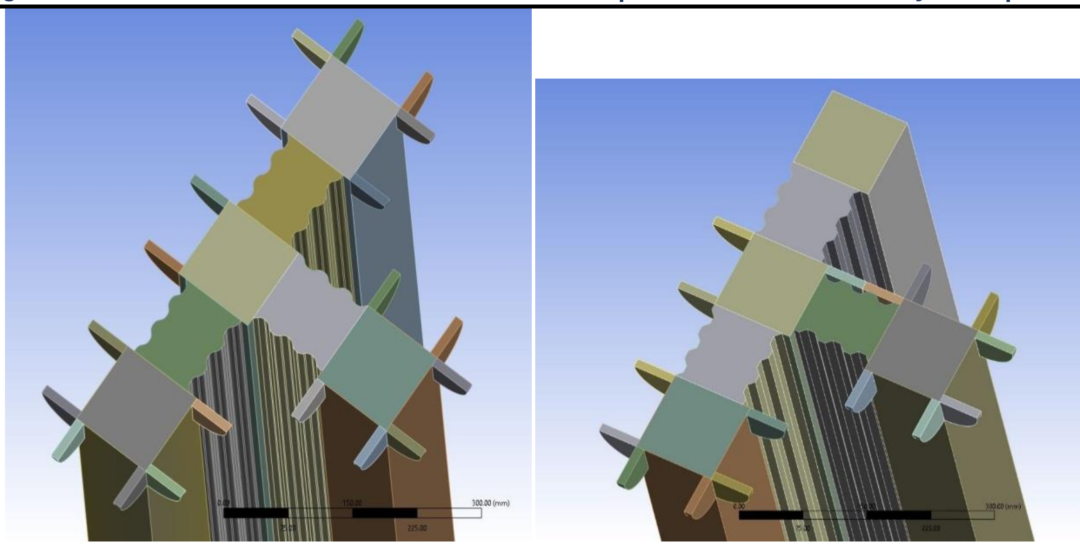

Figure 3.17 T-shaped CFST Column with trapezoidal Sinusoidal Corrugated Steel Plates

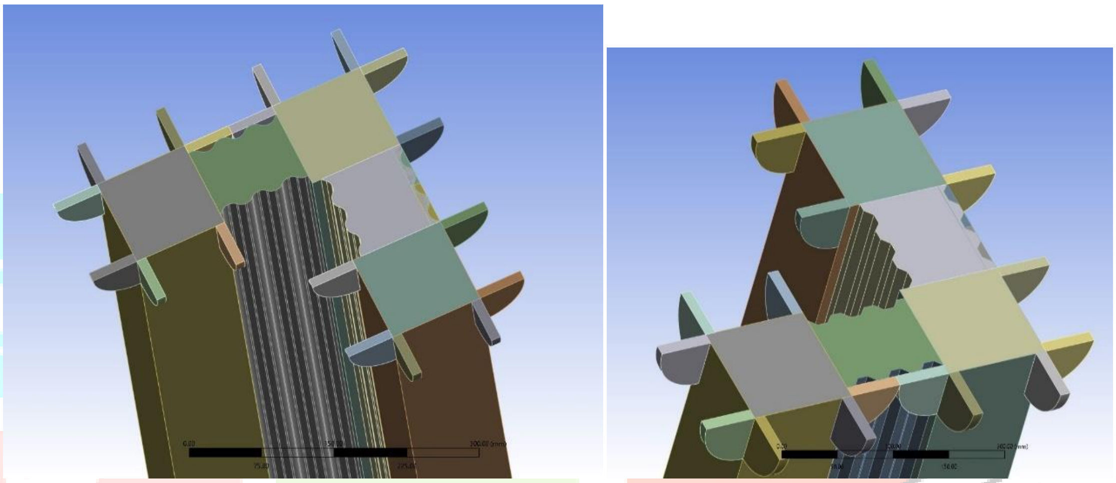

Figure 3.18 L-shaped CFST Column with trapezoidal Sinusoidal Corrugated Steel Plates

3.5.3.4 MESHING

Meshing divides the whole component into a finite number of small elements as per requirement. Size of the element must be as small as possible to achieve accuracy. In this analysis, fine mesh was adopted to achieve maximum accuracy in results. Solid models are converted into a finite element model after meshing.

3.5.3.5 LOADING AND BOUNDARY CONDITIONS

To simulate real conditions column were modelled with one end fixed and another end free. Load was applied only in one direction. Behaviour of specimen under axial load under axial load was studied using ANSYS.

3.5.4 OBJECTIVE 4

To investigate the performance cross shaped columns with double plate with CFRP elements and Trapezoidal plates are used .

3.5.4.1 FINITE ELEMENT MODELLING

To investigate the performance cross shaped columns with CFRP elements by using ANSYS Software.

3.5.4.2 SCOPE

This study using the software ANSYS helps us to find out which alignment is providing a better performance and this is a good way to understand whether providing end plate connection is beneficial or not by comparing the results with the results obtained from objective 1.

3.5.4.3 GEOMETRY

The geometry of the specimen is kept same as that of the specimens in the base journal. L shaped cross and T shaped columns with corrugation were considered for the analysis. The columns steel tube thickness is took as demonstrated in the figures shown below. The thickness of steel tube is equal to 3mm with yield strength 306 MPa and stiffeners having thickness 3mm with yield strength 306 MPa and specimen length is taken as 900 mm. Here the end plate connections are provided in the L and T shaped non-prismatic columns.

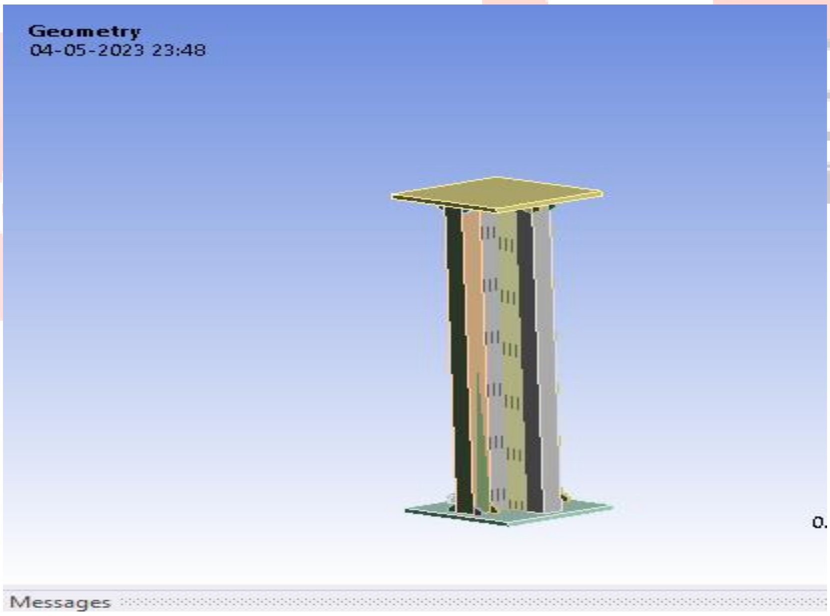

Figure :3.19 T-shaped CFST Column withCFRP

3.5.4.4 MESHING

Meshing divides the whole component into a finite number of small elements as per requirement. Size of the element must be as small as possible to achieve accuracy. In this analysis, fine mesh was adopted to achieve maximum accuracy in results. Solid models are converted into a finite element model after meshing.

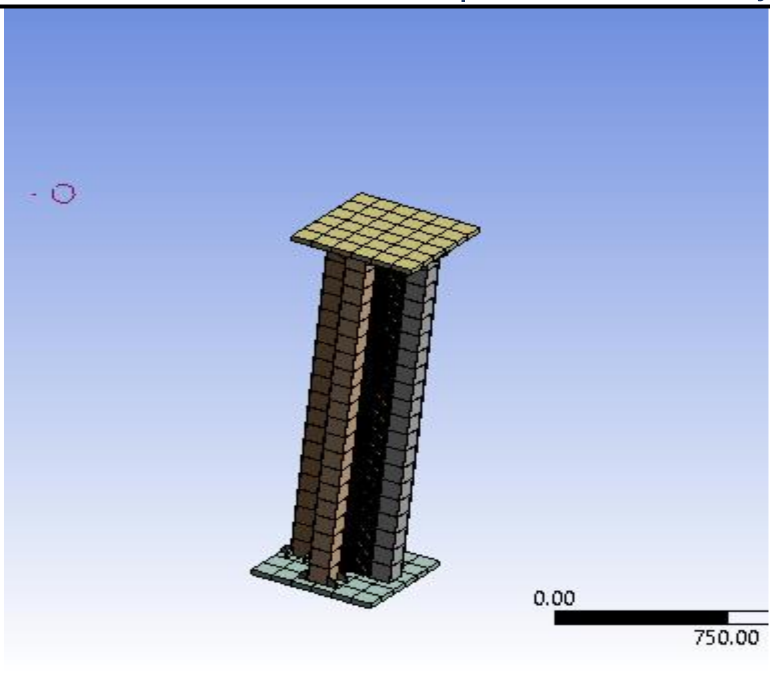

Figure :3.20 meshing of T-shaped CFST Column withCFRP

3.5.4.5 LOADING AND BOUNDARY CONDITIONS

To simulate real conditions column were modelled with one end fixed and another end free. Load was applied only in one direction. Behaviour of specimen under axial load under axial load was studied using ANSYS.

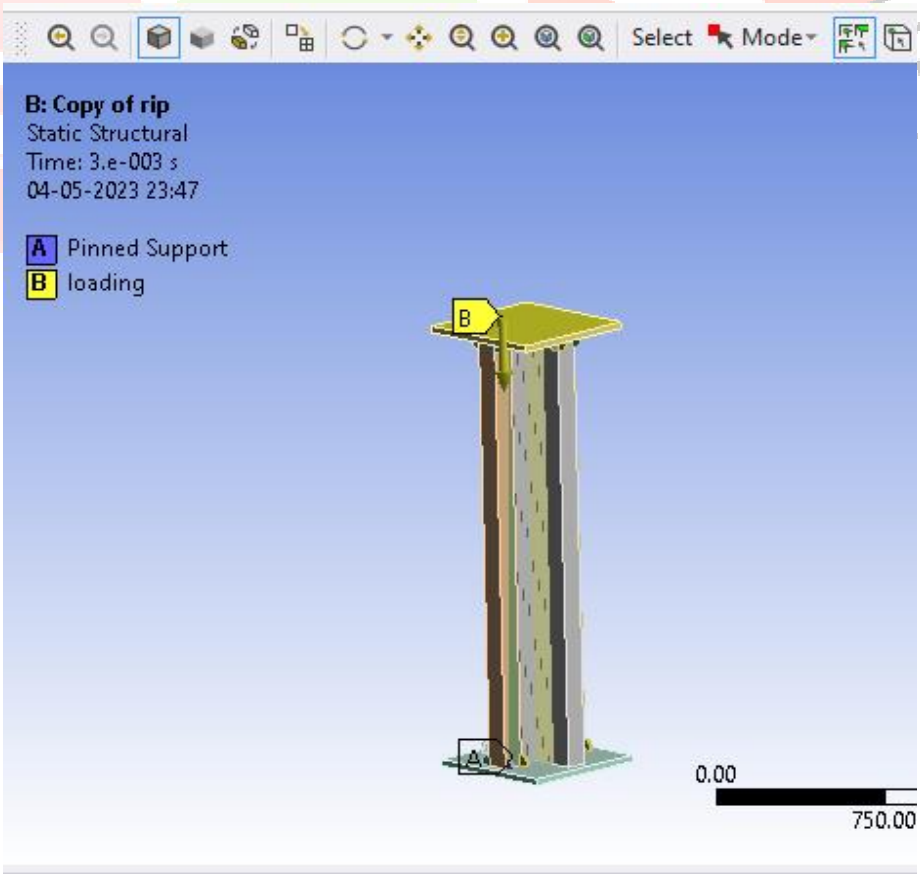

Figure :3.21 Boundary condition of T-shaped CFST Column with CFRP

cfrp

Density	2e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2.5e+05 MPa
Poisson's Ratio	0.2
Bulk Modulus	1.3889e+05 MPa
Shear Modulus	1.0417e+05 MPa
Tensile Ultimate Strength	2500 MPa

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 VALIDATION OF THE SOFTWARE

The journal "Uniaxial Eccentric-Compression Performance Analysis for Double-Plate Connected Concrete-Filled Steel-Tube Composite Columns" is referred for validation. Five L-shaped double plate connected CFST columns under uniaxial eccentric compressive load was studied in this journal. From journal it is found that the failure mode of the specimen corresponded to buckling failure. ANSYS WORK BENCH is used for validation.

Table 4.1Material Properties of concrete from journal

Concrete	Compressiveultimatestrength–34.42MPa
	Density,ρ – 2500 kg/m^3
	Elastic modulusE_c -27578 MPa
	Bulk modulus, B–1.532×10^{10}Pa
	Poisson 'sratio, μ –0.2

Table 4.2 Material Properties of steel tube from journal

Steel Tube	Yield strength – 370MPa
	Density,ρ – 7850 kg/m^3
	Elastic modulus E_c-1.89×10^{5}MPa
	Bulk modulus, B–1.575×10^{11}Pa
	Poisson's ratio,μ – 0.3Tensile Ultimate Strength-464MPa

Table 4.3 Material Properties of Steel plate from journal

Steel Plate	Density,ρ – 7850 kg/m^3
	Young'smodulus,E –196GPa
	Tensile yield strength –450MPa
	Tensile ultimate strength– 600MPa
	Poisson'sratio, μ–0.3

4.1.1 Geometry

The dimensional details of the CFST column and connection steel plate are shown below. Shoe plate of thickness 10 mm was provided and end plate of thickness 40 mm is provided.

Table 4.4 Dimensional details of CFST Column

Length of column, L	100 mm
Thickness of column	6 mm
Height of column	2000 mm

Table 4.5 Dimensional details of Connection Steel plate

Length	100 mm
Thickness	6 mm

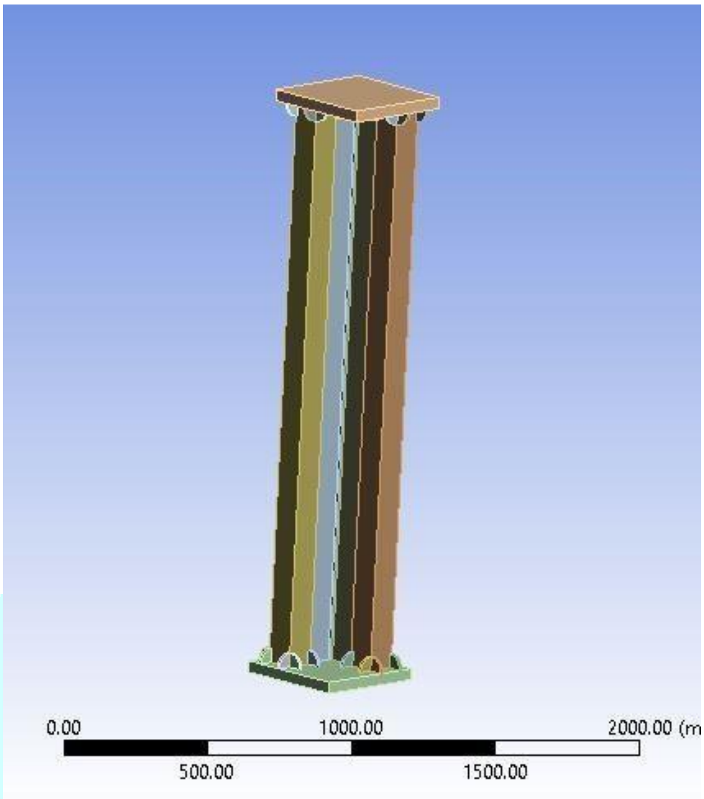

Fig.4.1Model Created in ANSYS

4.1.2Meshing

Meshing is considered as the most important part in any of the computer simulations because it can show drastic changes in results obtained.Meshing means creating some grid points called "nodes". It is done with the help of different tools and options available in the software. The results are calculated by solving the relevant governing equations numerically at each node of the mesh.The pattern and relative positioning of the nodes also affect the solution, 25 computational efficiency and time.This is why good meshing is very essential for a sound computer simulation to give good results. Hexahedral meshing was done in the model. Total number of nodes is 83140 and total number of elements 21420.

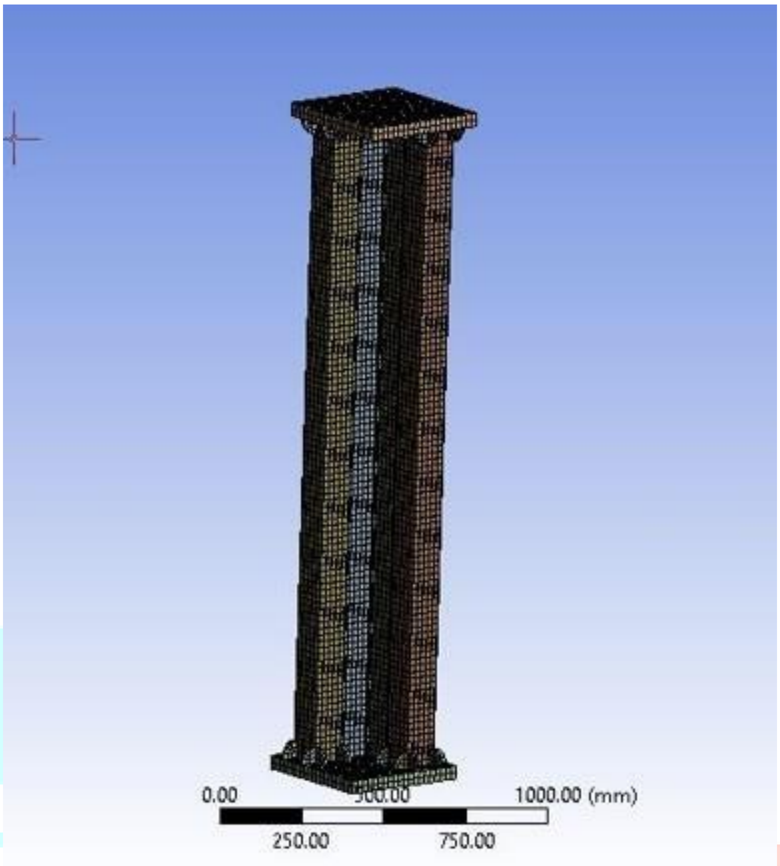

Fig.4.2Meshing

4.1.3 Boundary Condition

The boundary condition is bottom is pinned and the loading is given from the top edge. The displacement is provided on plates along Y direction.

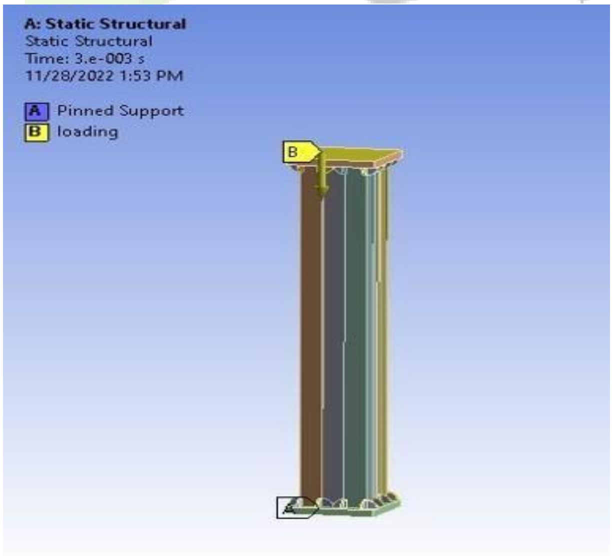

Fig.4.3Boundary condition

4.1.4 Analysis

Non-linear analysis is carried out in the L shaped CFST column under uniaxial eccentric compression test.

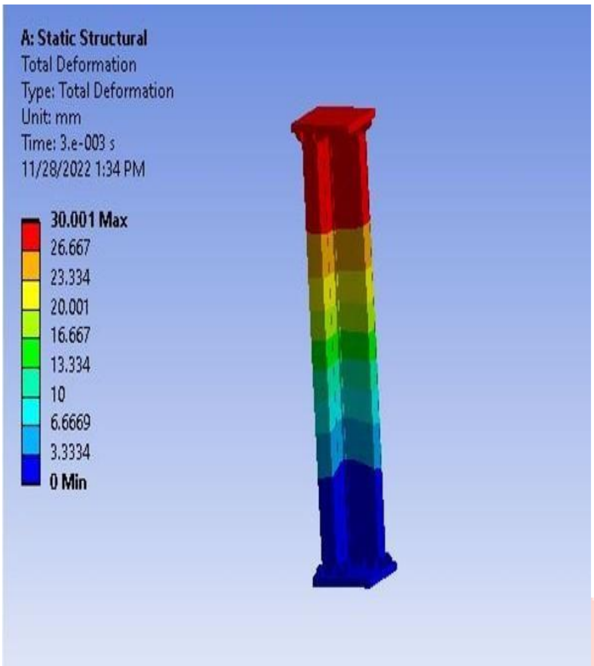

Fig 4.4 Deformation of the L-shaped CFST Column

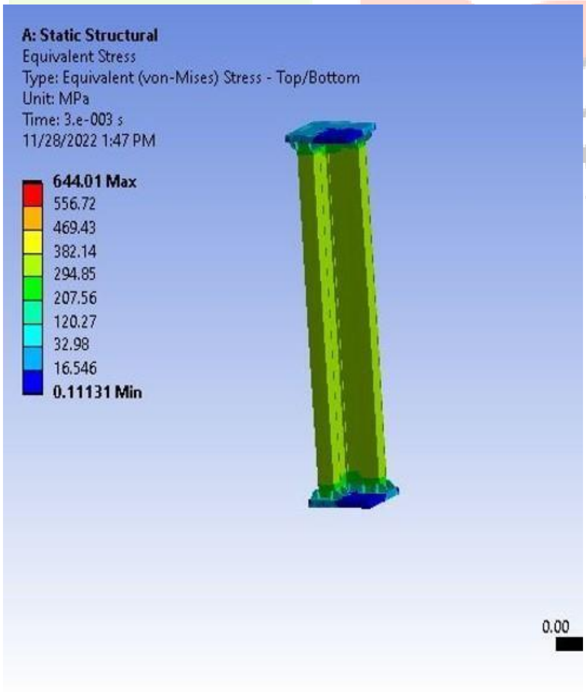

Fig 4.5 Equivalent stress in L-shaped CFST Column

4.1.5 Results

The results obtained from the analysis model is compared the experimental model in the journal. Load deformation curve is plotted from the analysis. Figure 5.7 shows the load deformation curves of the experimental model and the analyzed model. The displacement load values from the analysis conducted in Ansys is shown in Table 5.6. The ultimate load was found out as 4220 KN.

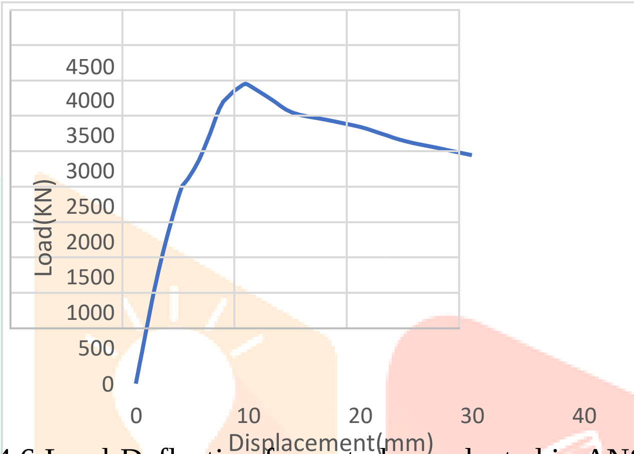

Fig 4.6 Load-Deflection from study conducted in ANSYS

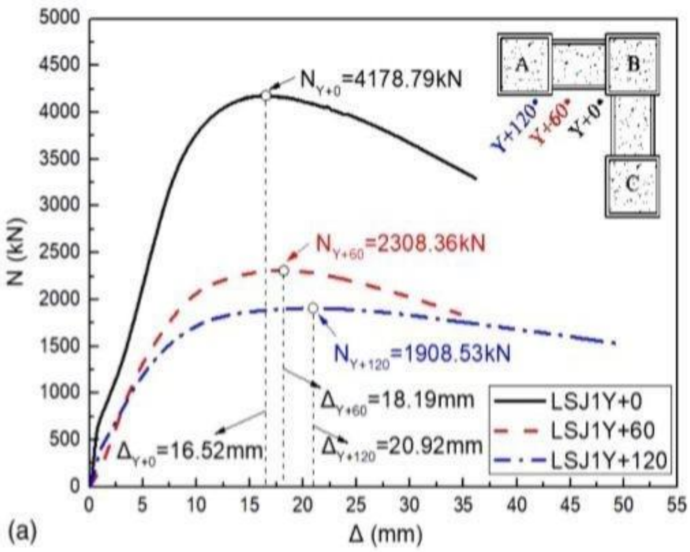

Fig 4.7 Load-Deflection from study conducted in Journal

Table 4.6 Displacement-Load values fromAnsys

Displacement (mm)	**Load(KN)**
0	0
2	1.58E+03
4	2.74E+03
4.525	2.87E+03
5.05	2.99E+03
5.8375	3.23E+03
6.625	3.53E+03
7.80062	3.99E+03
9.5781	4.22E+03
10	4.23E+03
12	4.03E+03
14	3.83E+03
17	3.73E+03
20	3.63E+03
22	3.53E+03
24	3.43E+03
27	3.33E+03
30	3.23E+03

The ultimate load from the journal was obtained as 4178 KN and ultimate load from the analysis in Ansys was obtained as 4220KN. The percentage variation in load is 1.0052% .So, the ANSYS software is validated and can be used for the analysis.

4.1.6 INTERFERENCE

The main journal paper studied the axial load bearing capacity of L-shaped double plate connected CFST columns under various eccentricities of load application. A model was created in ANSYS, the material properties and geometry of the concrete, steel plate and steel tube were defined and analysis was completed. The journal paper is validated in ANSYS Workbench Software for axial loading and only1.00526% of variation is observed.

4.2 RESULT

4.2.1.2 EQUIVALENT STRESS

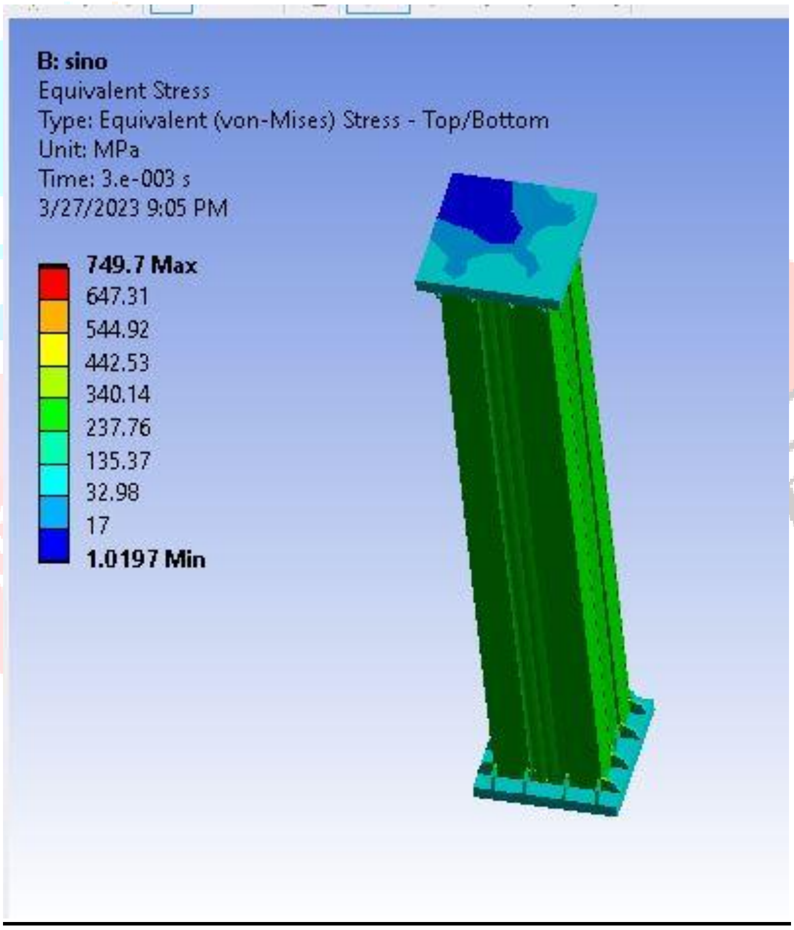

Fig 4.9 Equivalent stress sinusoidal

Maximum value of equivalent stress is 749.7 Mpa. Maximum equivalent stress occurred at the center. Minimum value of equivalent stress is 1.0197 Mpa.

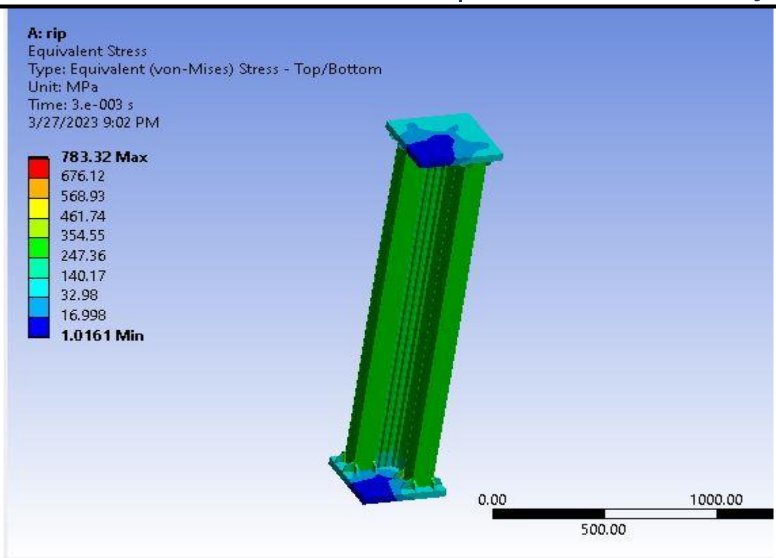

Figure 4.10: Equalent stress Trapezoid

Maximum value of equivalent stress 783.32 Mpa. Maximum equivalent stress occurred at the center. Minimum value of equivalent stress is 1.0161 Mpa.

4.2.1.3 LOAD - DISPLACEMENT GRAPH

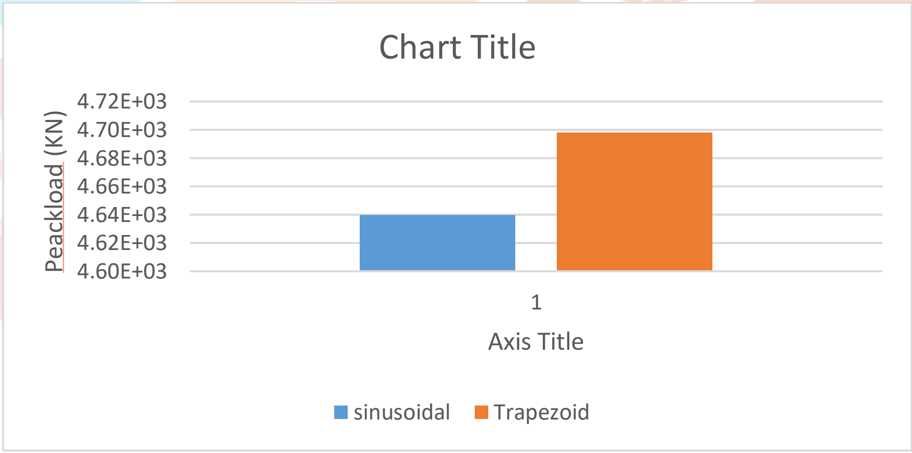

Fig 4.11 Load displacement graph of sinusoidal and trapezoidal

LOAD - DISPLACEMENT GRAPH-COMPARISON

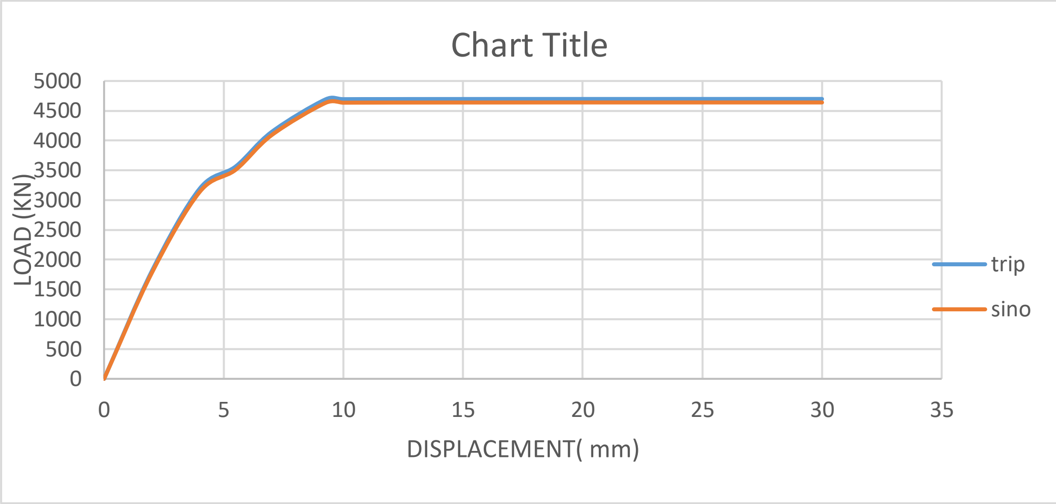

Fig 4.12 Combinations of load displacement graph of sinusoidal and trapezoidal

4.2.1.4 ANALYTICAL RESULTS AND COMPARISON

Columns are subjected to axial forces and table below shows the comparison of load displacement curve values of sinusoidal and trapezoidal. When comparing the ultimate load value, the ultimate load value of trapezoidal column is higher than that of sinusoidal which means that L sinusoidal shaped concrete filled steel tubular column performed well as compared to the trapezoidal one. At the initial stage column will be in elastic when ultimate load is reached the column fails. When comparing the yield point trapezoidal yields before the non-prismatic L sectionsinusoidal and trapezoidal of concrete filled steel tubular columns, which means that yield strength of LCFST sinusoidal and trapezoidal is more than that of columns.

Table 4.7Comparison of results

COLUMN TYPE	LATERAL DEFORMATION (mm)	ULTIMATE LOAD (kN)
trapezoidal	9	4700
sinusoidal	8	4600

When comparing trapezoidal CFST column yield at a range of 4700kN but the CFST with stiffener plates connected between the column section yield at a load range of 2500 kN which means that the yield strength of the section is improved in the second case. From the graph it is also clear that the ductility and the toughness behaviour is improved a lot when it comes to the second case.

4.2.1.5 RESULT

- Load carrying capacity is improved a lot by the introduction of steel plate stiffeners.
- Ductility and toughness of the material is also improved, so that the material gain its ability to absorb more energy before its fracture.

- trapezoidal CFST can perform well than sinusoidal CFST which can absorb more energy before the fracture.

Table 4.8 Comparison of equivalent stress results

COLUMN TYPE	EQUIVALENT STRESS(Mpa)
trapezoidal CFST	783
sinusoidal LCFST	749.7

4.2.2 RESULT OBTAINED

4.2.2.1 TOTAL DEFORMATION

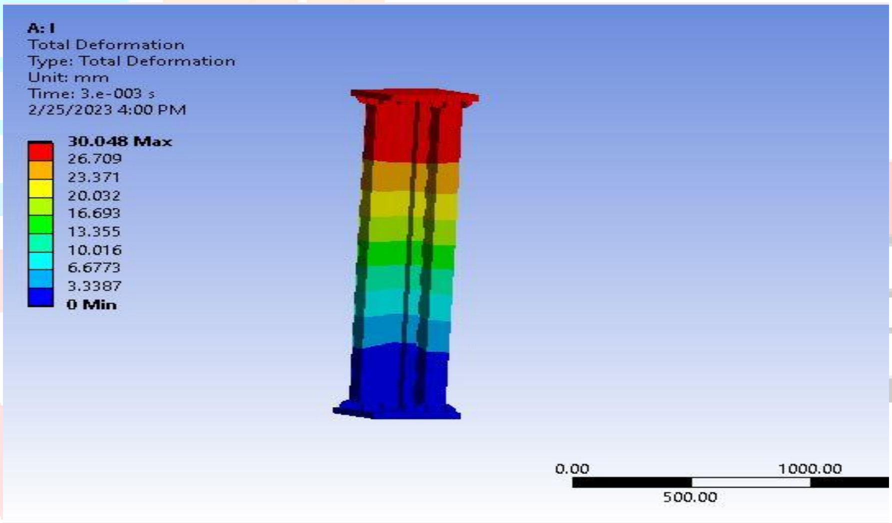

Fig 4.13 Total Deformation Of L-Shaped Cfst Column

The total deformation of is shown in Fig.5.5. Maximum deformation is at center shown in yellow to orange shades and minimum at the edge shown in blue shades. The maximum total deformation is about 30.048 mm

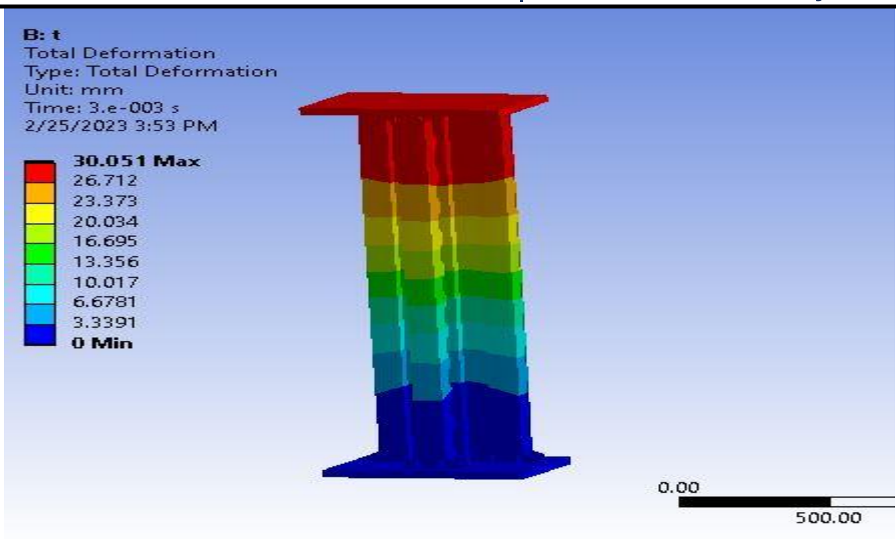

Figure:14total Deformation Of T-Shaped Cfst Column

The total deformation of is shown in Fig.5.5. Maximum deformation is at center shown in yellow to orange shades and minimum at the edge shown in blue shades. The maximum total deformation is about 30.051mm

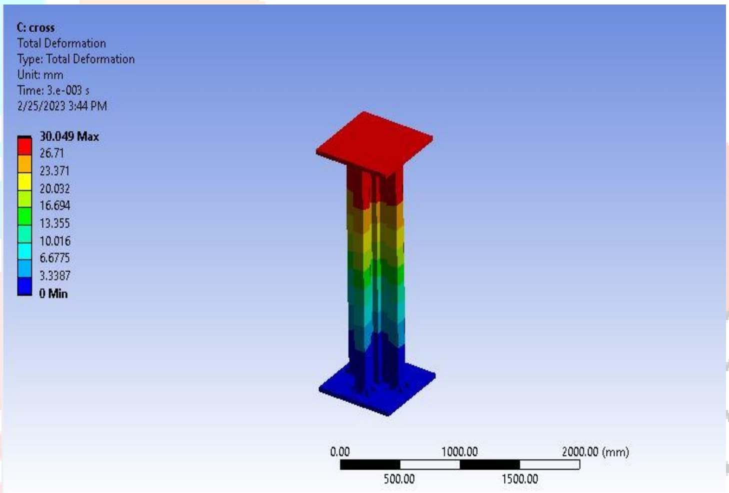

Figure:15total Deformation Of Cross-Shaped Cfst Column

The total deformation of is shown in Fig.5.5. Maximum deformation is at center shown in yellow to orange shades and minimum at the edge shown in blue shades. The maximum total deformation is about 30.049 mm

4.2.2.2 EQUIVALENT STRESS

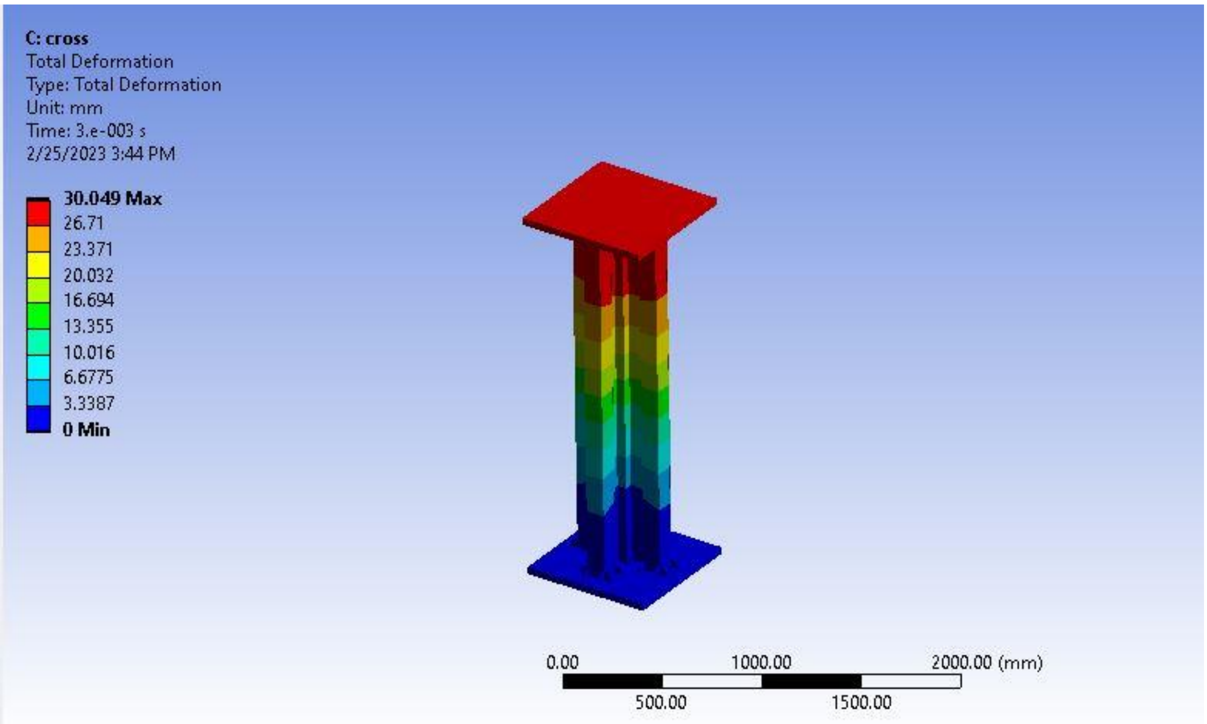

Fig 4.16 Equivalent Stress Of L-Shaped Cfst Column

The total deformation of is shown in Fig.5.5. Maximum deformation is at center shown in yellow to orange shades and minimum at the edge shown in blue shades. The maximum total deformation is about 30.049 mm

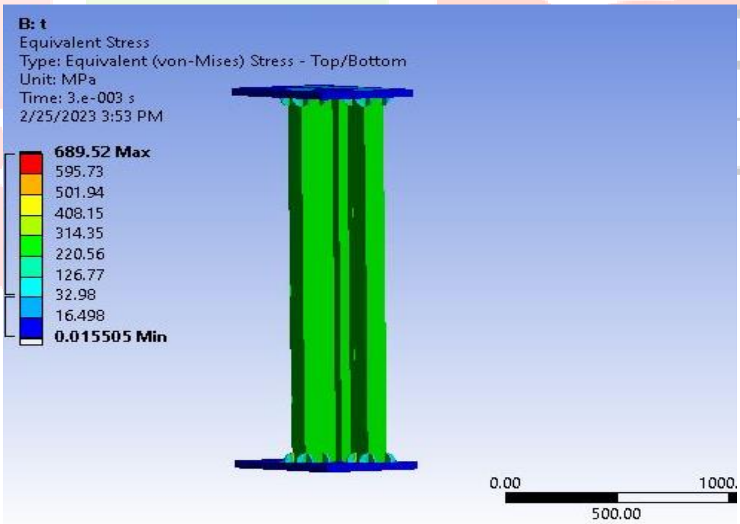

Fig 4.17 Equivalent Stress Of T-Shaped Cfst Column

Maximum value of equivalent stress is 689.52 Mpa.Maximum equivalent stress occurred at the center. Minimum value of equivalent stress is 0.015505 Mpa.

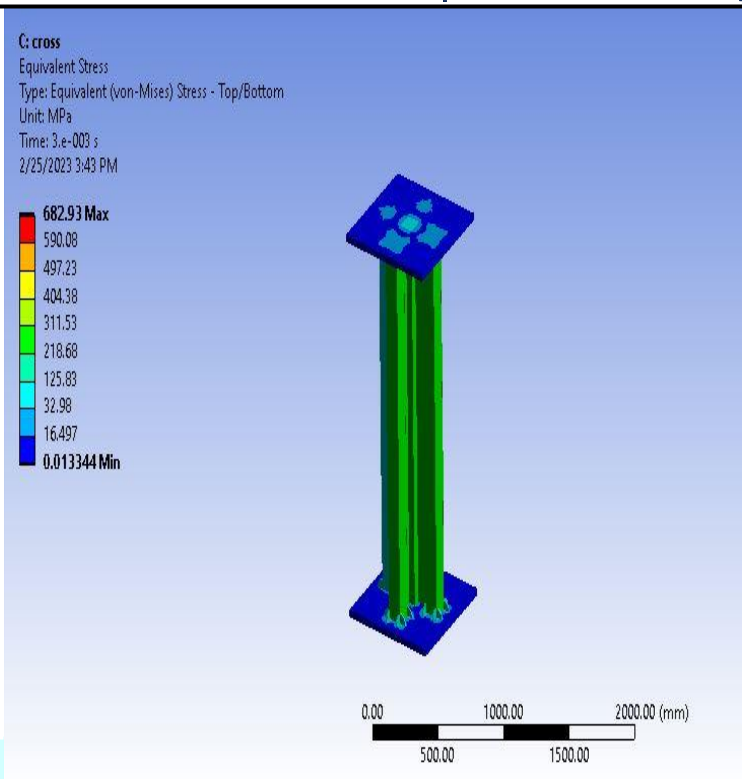

Fig 4.18 Equivalent Stress Of Cross-Shaped Cfst Column

Maximum value of equivalent stress is 682.93 Mpa.Maximum equivalent stress occurred at the center. Minimum value of equivalent stress is 0.013344 Mpa.

4.2.2.3 LOAD - DISPLACEMENT GRAPH

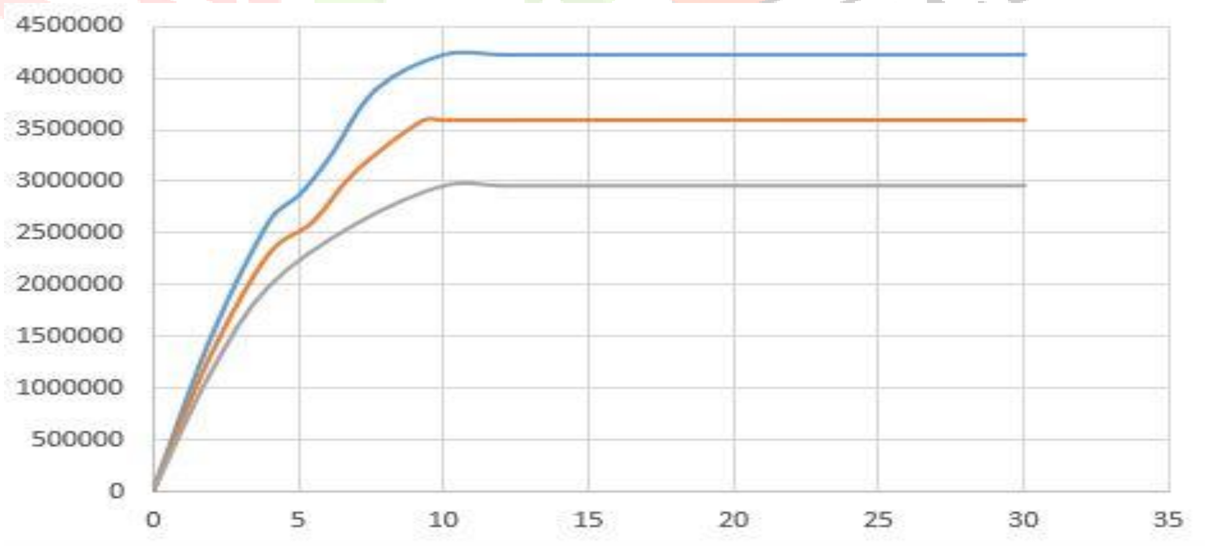

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Fig 4.19 Result obtained from with different

- From the results in load deflection obtained from analysis using ANSYS, it was observed that Cross-shaped CFST Column connected with single plate has the higher value.
- L-shaped CFST column with single plate has the lowest load-deflection value.

Table 4.9 Comparison of results

COLUMN TYPE	DEFORMATION(mm)	ULTIMATE LOAD(kN)
L- SHAPED CFST	30.048	3000000
T- SHAPED CFST	30.051	3600000
CROSS-SHAPED CFST	30.049	4250000

4.2.2.4 TOTAL DEFORMATION

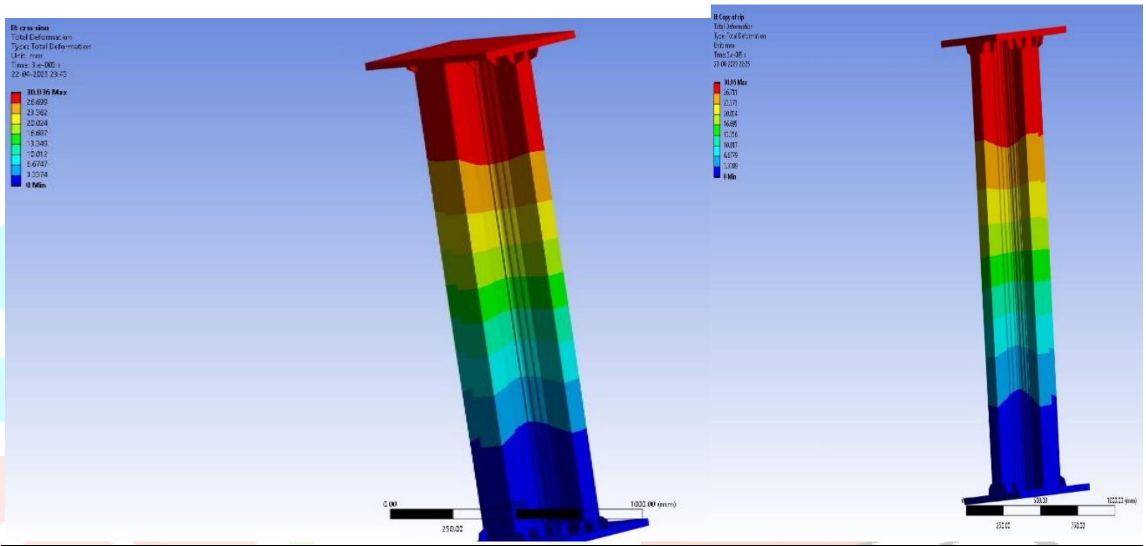

Fig 4.20 **Total Deformation Of Cross-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

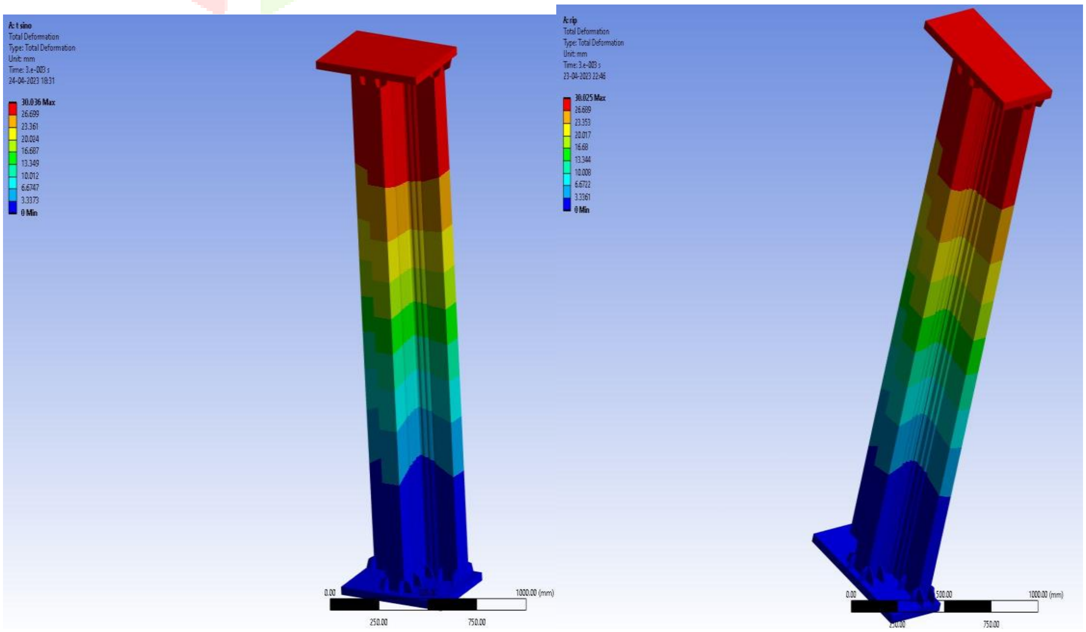

Fig 4.21 **Total Deformation Of T-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

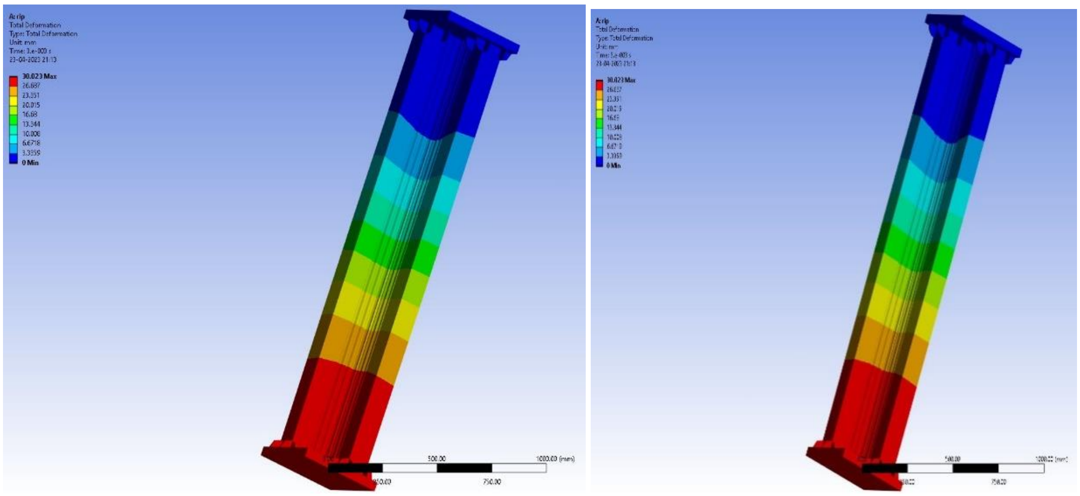

Fig 4.22 **Total Deformation Of L-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

4.2.2.5 EQUIVALENT STRESS

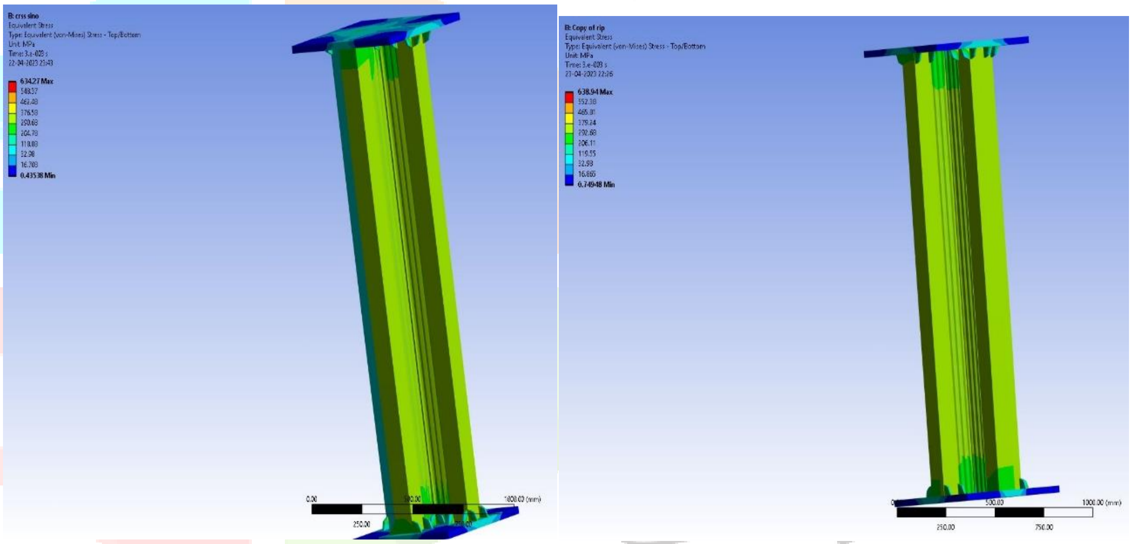

Fig 4.23 **Stress Of Cross-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

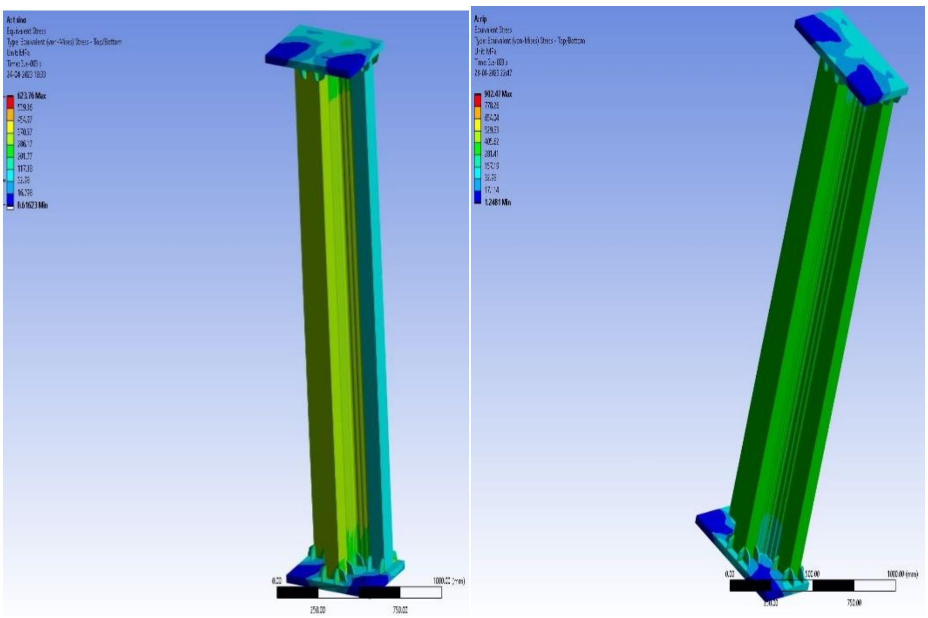

Fig 4.24 **Stress Of T-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

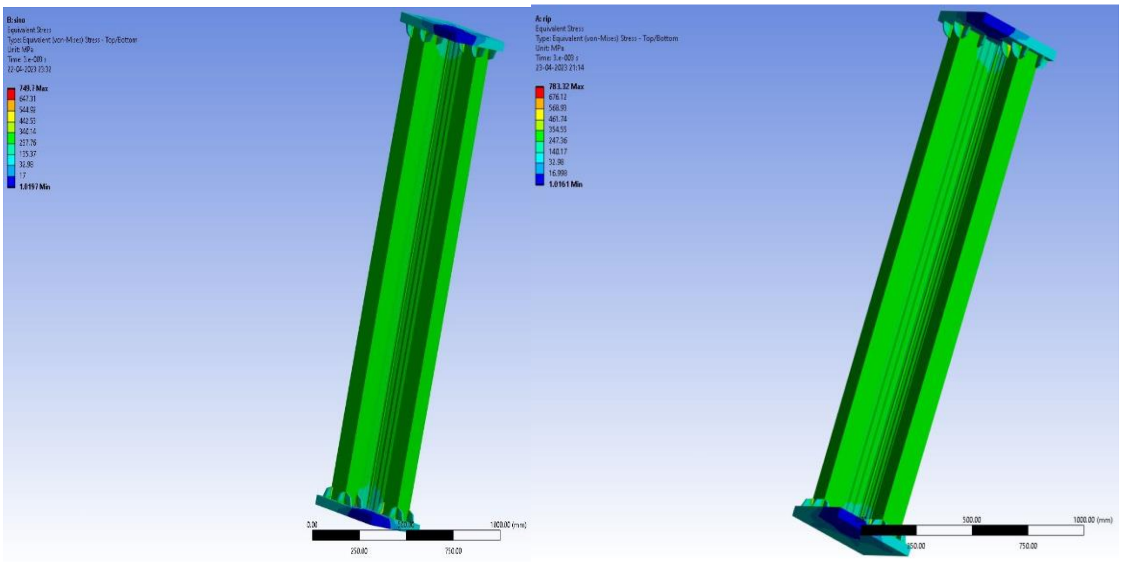

Fig 4.25 **Stress Of L-Shaped Cfst Column With Trapezoidal And Sinusoidal Corrugated Steel Plates**

4.2.2.6 LOAD - DISPLACEMENT GRAPH

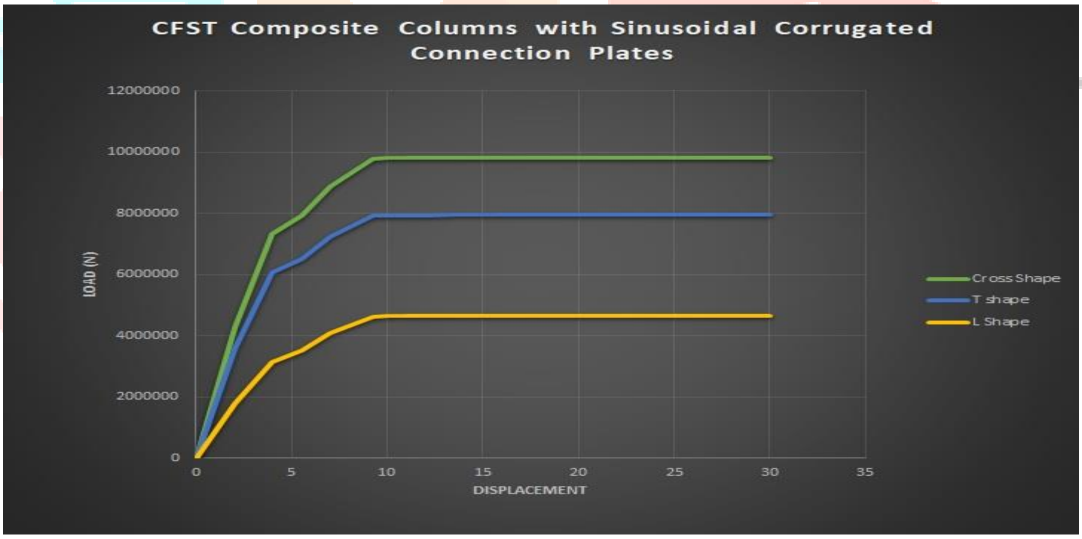

Fig 4.26 comparison of results with l-shaped cfst column with sinusoidal corrugated steel plates

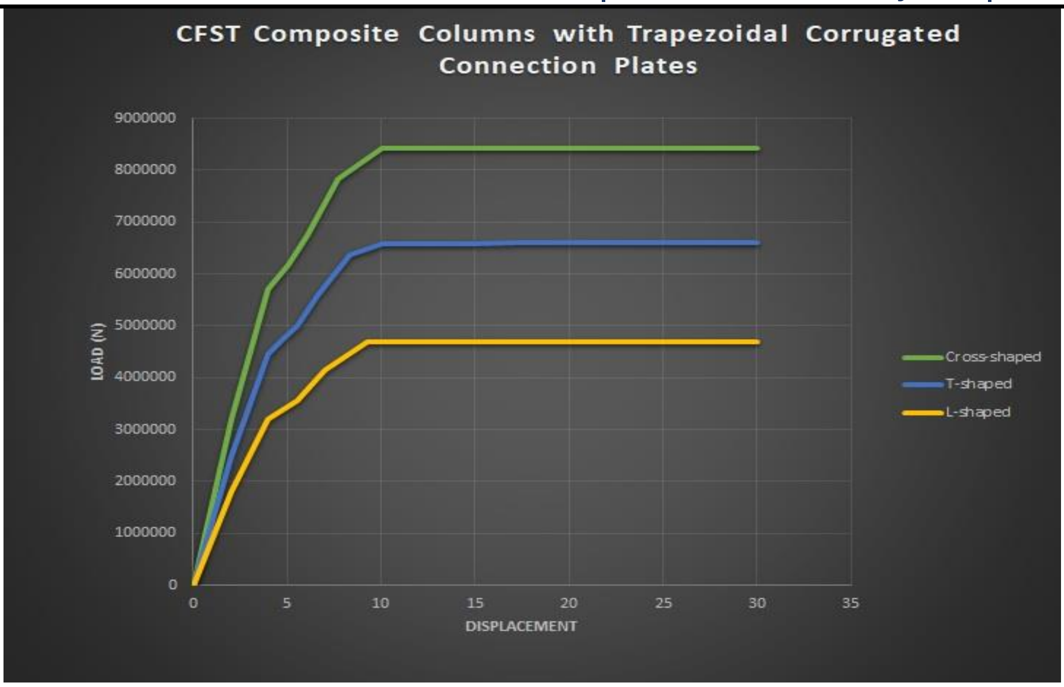

Figure: 4.27 comparison of results with l-shaped cfst column with trapezoidal corrugated steel plates

Table 4.10 Comparison of results

COLUMN TYPE	DEFORMATION (mm)	ULTIMATE LOAD(kN)	EQ. STRESS(MPa)
T CFST TRAPEZOIDAL	30.036	4800000	623.76
T CFST SINUSOIDAL	30.025	800000	912.47
L CFST TRAPEZOIDAL	30.023	6600000	749.7
L CFST SINUSOIDAL	30.023	4300000	783.32
CROSS CFST TRAPEZOIDAL	31.036	8400000	434.27
CROSS CFST SINUSOIDAL	31.05	9500000	638.94

4.2.3.1 TOTAL DEFORMATION

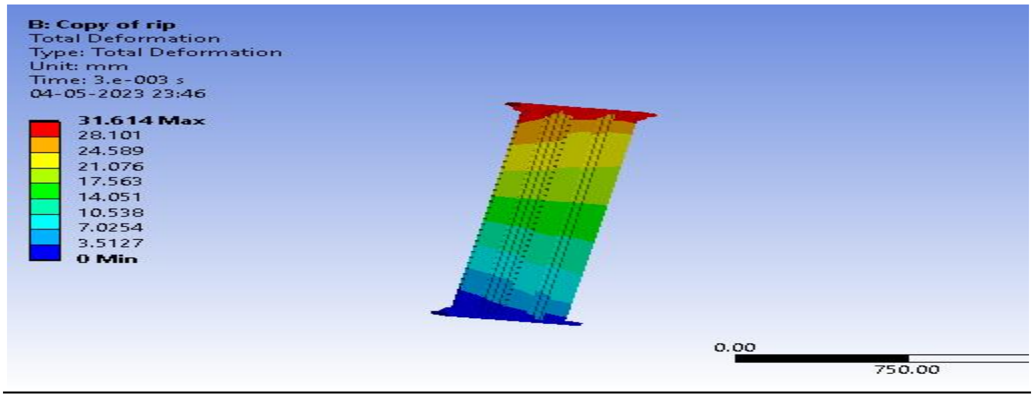

Figure: 4.28 **Total Deformation Of** T-Shaped Cfst Column With Cfrp

4.2.3.2 EQUIVALENT STRESS

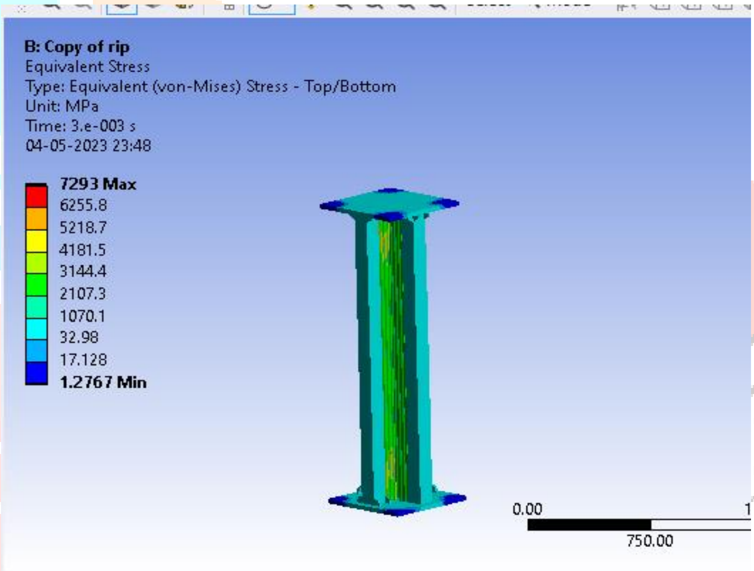

Figure: 4.29 **Stress Of**t-Shaped Cfst Column With Cfrp **Plates**

4.2.3.3 LOAD - DISPLACEMENT GRAPH

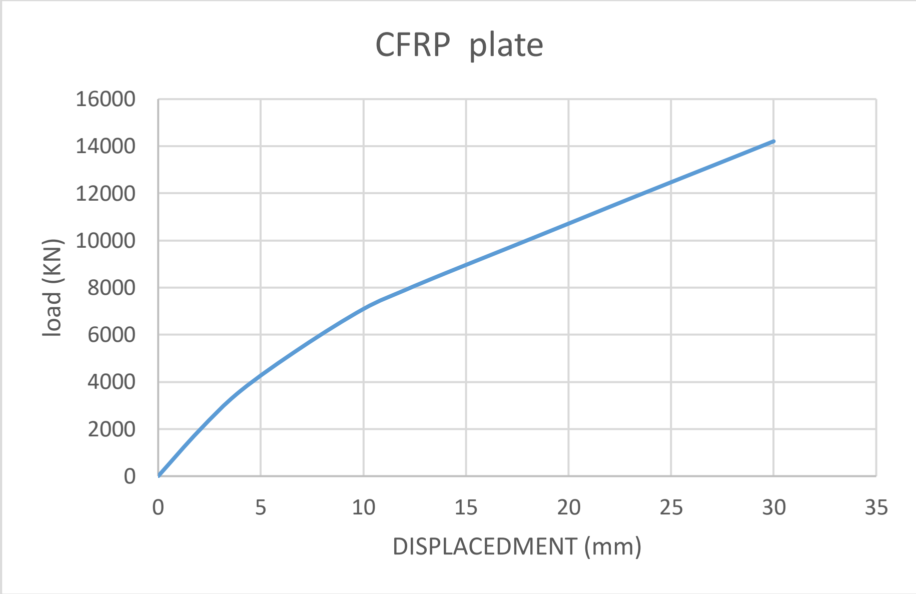

Figure: 4.30 comparison of results with l-shaped cfst column with sinusoidal corrugated steel plates

CHAPTER 5

CONCLUSIONS

- The studies are conducted in CFST column with Normal and corrugated connection plates.Corrugated plate in the sinusoidal shape having more safest method of construction and having most load bearing capacity.The Maximum force from the analysis was obtained for Cross shaped CFST column with Trapezoidal corrugated double steel plate connection.
- It was observed that special shaped CFST Columns with trapesoidal corrugated steel plate has better results when compared with trapezoidal corrugated steel plate, 16.3% increase.
- CFST Columns with corrugated steel plates have higher axial load value when compared with normal steel connection plates
- It was observed that CFST Columns with trapesoidal corrugated steel plate with CFRP has better results .

5.1 SCOPE FOR FUTURE WORK

Further study can be done by considering Concrete Filled Steel Column (CFST) with different Plate connectors. Here the studies are done in RCC structures with composite column in Earthquake zone. These studies also can be done in steel structures

and composite structures in order to evaluate the performance of CFST composite column with connection plates of different shapes and different connections.

Further studies can also be done on irregular shaped structures.

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