AN ANALYTICAL STUDY OF FLUTED CONCRETE FILLED STEEL TUBULAR COLUMNS

Rudreshkumar[1], Dr. B.R. Niranjan[2]

[1]Post graduate student, Dept.of civil engineering, UVCE, Bengaluru, India
[2]Professor, Faculty of civil engineering, UVCE, Bengaluru, India

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Abstract - An extensive study has been carried out on the behaviour of CFST triangular fluted columns subjected to concentric loading displacement, stress, and strain characteristics of columns. Study has been framed by analyzing Sixteen columns with varying number of flutes and the thickness of steel sheet. An analysis using ANSYS 19.2 program has been conducted on the columns and a detailed comparison has been conducted. Four cases of varying number of flutes with 3, 4, 5 & 6 and varying thickness of steel sheets 0.4mm, 0.6mm, 0.8mm & 1mm has been carried out. The materials represented in ANSYS 19.1 as Concrete and Steel Sheet elements depending upon the element description as provided. It is observed that the ANSYS FEA package is feasible in analyzing the behavioral characteristics of CFST triangular fluted columns. The increase in number of flutes in columns has direct influence on the load carrying capacity of columns with 6 numbers of flutes having maximum load carrying capacity and also posses least stress, least strain values and undergoes less deformation as compared to columns with 5, 4 & 3 numbers of flutes. The use of different thickness of sheets also has direct influence on load carrying capacity. The column with 1mm sheet thickness have maximum load carrying capacity, least stress, least strain values and subjected to lower deformation. The column with 1mm sheet thickness and 6 numbers of flutes have the maximum load carrying capacity of 165KN and subjected to least deformation of 0.84071mm. And column with 0.4mm sheet thickness and 3 numbers of flutes have less load carrying capacity of 137KN with larger deformation of 1.183mm.

Key Words: CFST-Concrete Filled Steel Tube, ANSYS, Triangular Flutes.

1. INTRODUCTION

Columns are the best known compression members though there are many types of compression members. Top chord members of trusses, bracing members and compression flanges of built up beams and rolled beams are few examples of compression members. Columns are usually thought of as upright members whose lengths are considerably larger than their cross sectional dimensions. Columns are termed “long” and “short” depending on their proneness to buckling. As the applied forces are increased in magnitude, the columns become unstable and develop a displacement in a direction normal to the loading axis. Then the columns are said to be in a buckled state. CFST is a composite structural member, which resists the applied loads through the composite action of steel as well as concrete. The interactive and integral behavior of concrete and structural steel elements makes it cost effective alternative. In addition to its improved load carrying capacity, it is also aesthetically pleasing. Since CFST confines concrete, the use of frame work can be discarded and the buckling strength increases. Due to the presence of concrete core, local buckling of steel tube is delayed and the strength deterioration after local buckling is moderated, both due to restraining effect of concrete. The strength of concrete is increased, due to confining effect provided by steel tube and on other hand the strength deterioration is not that severe because concrete does not spall due to the confinement. Drying shrinkage and creep of concrete are much smaller in these columns as compared to other structural forms. The structural properties of CFST columns include high strength, high ductility and high energy absorption capacity. The load carrying capacity and behavior in compression, bending and shear are all superior to reinforced concrete.

1.1 Parameters adopted for study are

- Different thickness of Steel sheets.
- Varying number of flutes.

2. FINITE ELEMENT MODLEING

2.1 General

The finite element model of Concrete Filled Steel Tube(CFST) was modeled using the software ANSYS Workbench 19.2. ANSYS is a commercial FEM package having capabilities ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis.

2.2 Geometric and Material properties

Table -2.1: Dimension of Column

Length	1160mm
Diameter	100mm
Number of flutes	3, 4, 5, 6
Thickness of steel sheet	0.4mm, 0.6mm, 0.8mm, 1mm
Flute Dimension	Base 18mm & Height 12mm

Table -2.2: Materials properties of Concrete

Modulus of Elasticity (E_c)	22360N/mm^2
Poisson's ratio	0.219

Table -2.3: Materials properties of Steel

Modulus of Elasticity (E_s)	82500N/mm^2
Poisson's ratio	0.235
Yield Strength	165N/mm^2

2.3 Modeling

All sixteen columns were modeled in CATIA software with required dimension, thickness of sheet, and number of flutes.

2.3.1 Build the Model in CATIA Software

Models have been created in two parts, Concrete as part-1 and Steel tube as part-2 with required dimension.

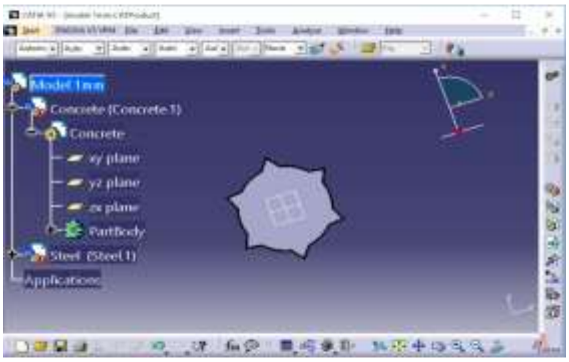

Fig-2.1: Part 1: Construction of Concrete part

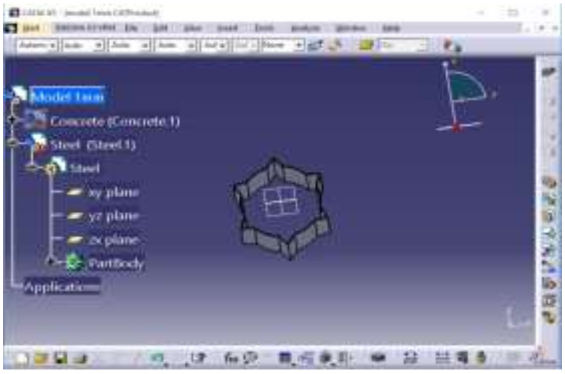

Fig-2.2: Part 2: Construction of Steel tube part

2.4 Procedure Carried out using ANSYS Workbench

Static Structural analysis has been selected, and material properties such as Young's modulus, poisson's ratio etc have been assigned for concrete and steel sheet. CATIA generated models were imported to ANSYS Workbench and Analyzed.

2.4.1 Meshing

The model has been divided into Finite elements called mesh. Here Edge size meshing with 50number of division have selected for all CFST columns.

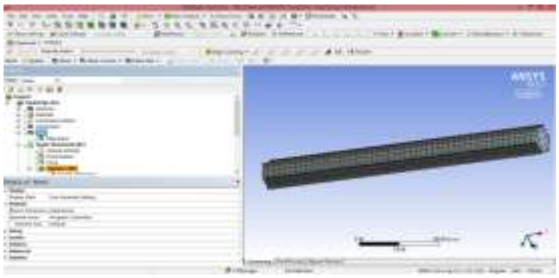

Fig-2.3: Meshing of Column

2.4.2 Setup

In this problem of static structure non linear buckling analysis has been considered. Fixed support has been assigned to one end of the column, and Axial load has been applied on other end of the column.

2.4.3 Analytical results

The solutions obtained from static structural analysis were Total deformation, Equivalent Von-mises stress, and Equivalent Von-mises strain.

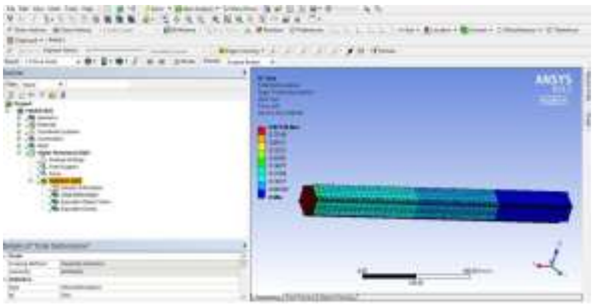

Fig-2.4: Total Deformation

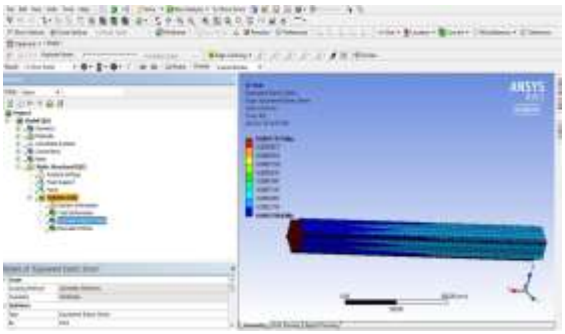

Fig-2.5: Equivalent Von-mises strain

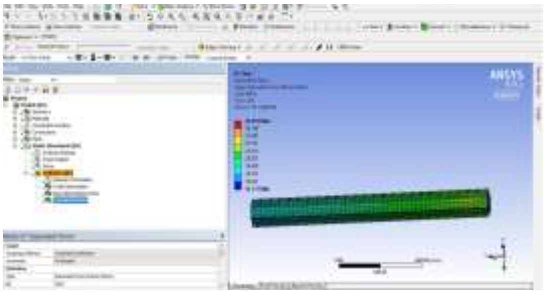

Fig-2.7: Equivalent Von-mises stress

3. Results and Discussion

Results of the study on the behaviour of CFST triangular fluted columns for different number of flutes and varying thickness of sheets under concentric loading conditions has been discussed here. Keeping in mind the concrete filled steel tubular columns as a structural members which develop confinement effects due to triaxial state of load of the concrete core and taking into account the geometric and material nonlinearities of the CFST columns when subjected to lateral displacement, a non linear analysis has been conducted using ANSYS Workbench 19.2 software.

3.1 Comparison of results with different thickness of steel sheet

3.1.1 6-Number of Flutes

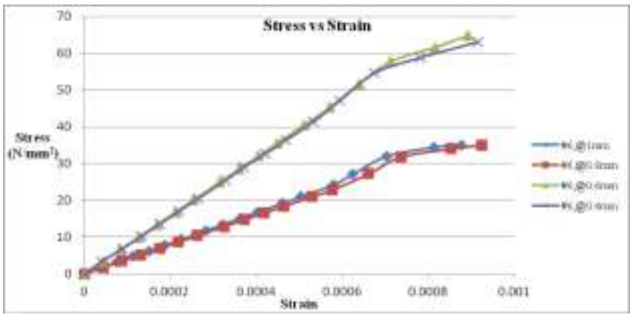

Chart-1: Stress vs Strain plots for 6-Number of fluted columns

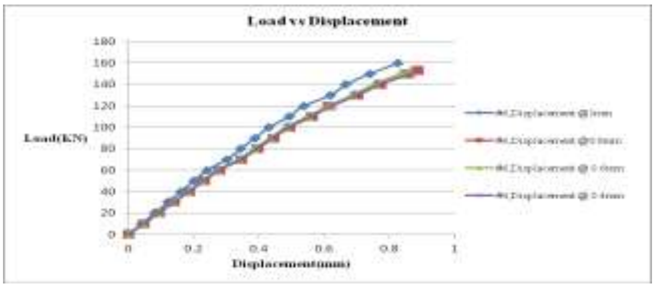

Chart-2: Load vs Deformation plot for 6-Number of fluted columns

3.1.2 5-Number of Flutes

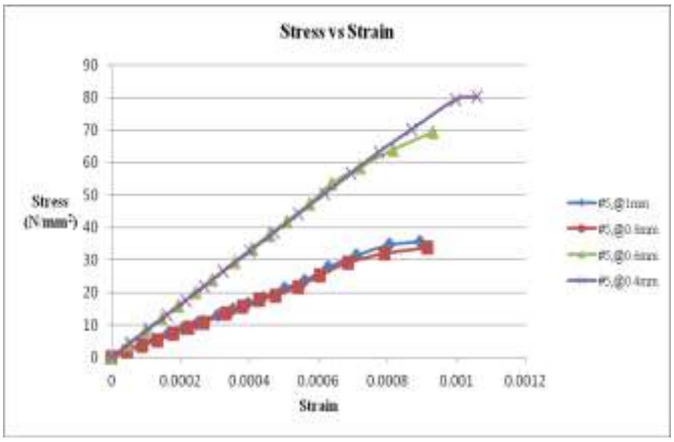

Chart-3: Stress vs Strain plots for 5-Number of fluted columns

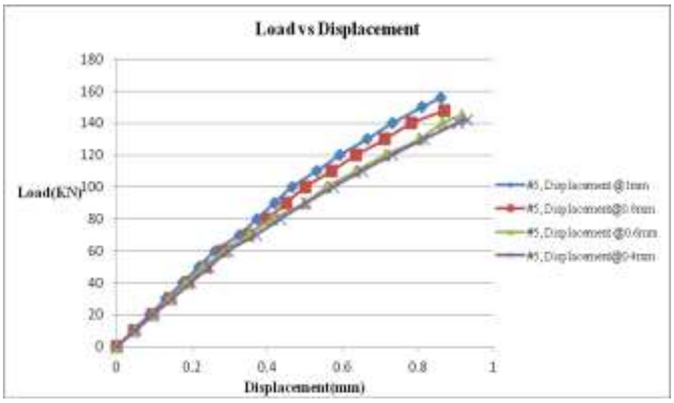

Chart-4: Load vs Deformation plot for 5-Number of fluted columns

3.1.3 4-Number of Flutes

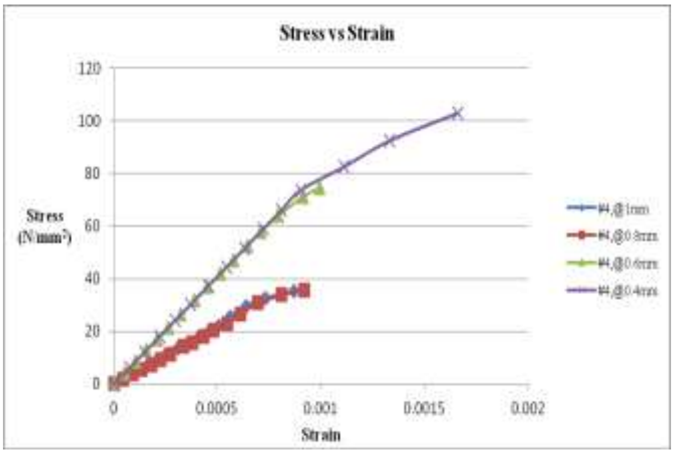

Chart-5: Stress vs Strain plots for 4-Number of fluted columns

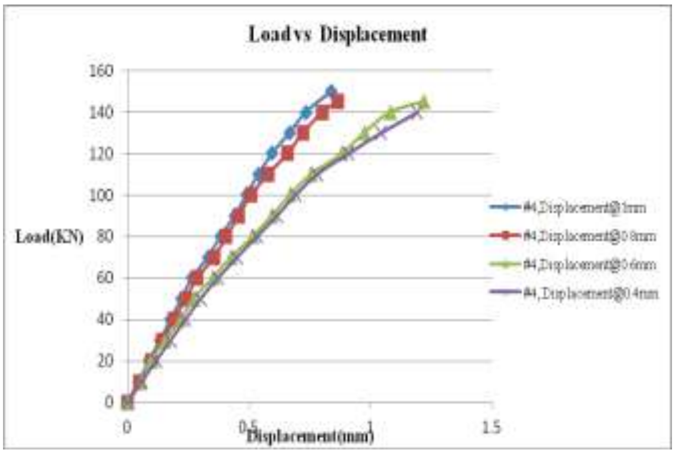

Chart-6: Load vs Deformation plot for 4-Number of fluted columns

3.1.4 3-Number of Flutes

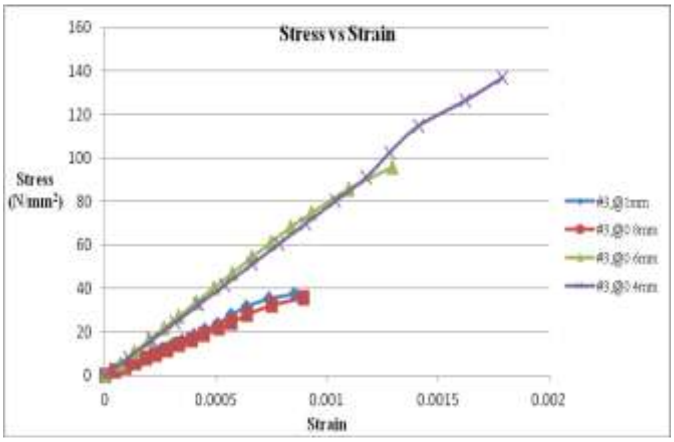

Chart-7: Stress vs Strain plots for 3-Number of fluted columns

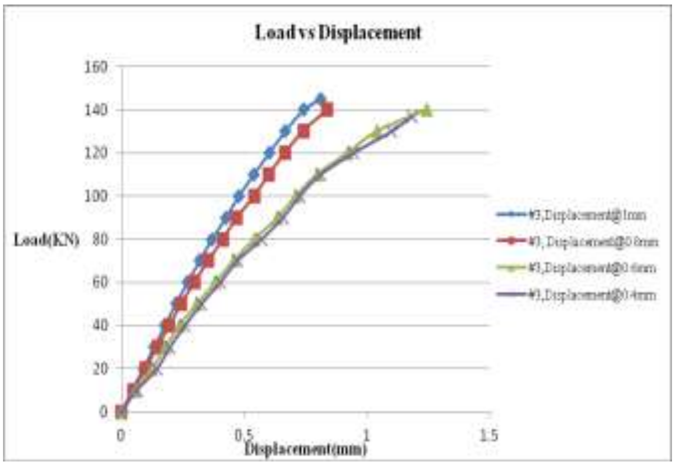

Chart-8: Load vs Deformation plot for 3-Number of fluted columns

3.2 Comparison of results with different Number of Flutes

3.1.5 1mm thick sheet

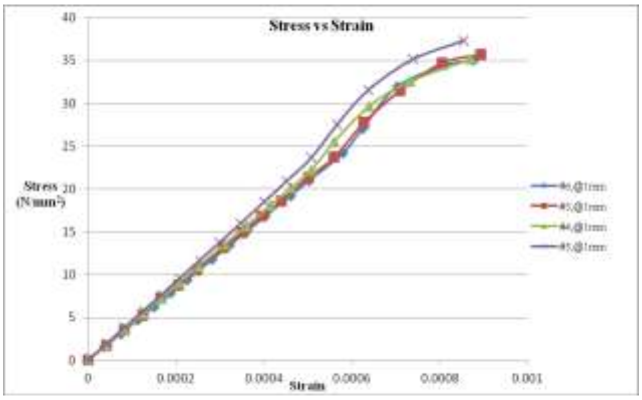

Chart-9: Stress vs Strain plots for columns with 1mm thick sheet

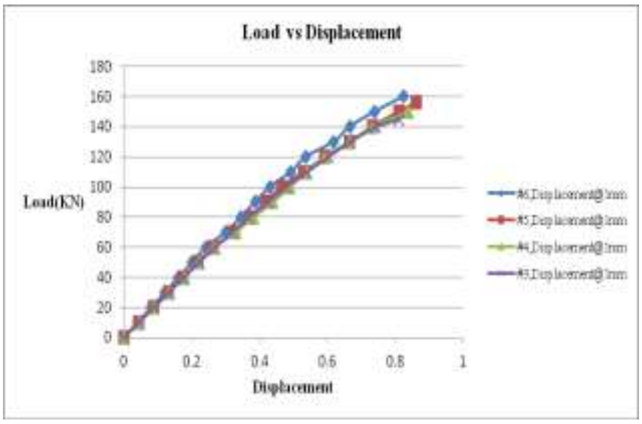

Chart-10: Load vs Deformation plot for columns with 1mm thick sheet

3.1.6 0.8mm thick sheet

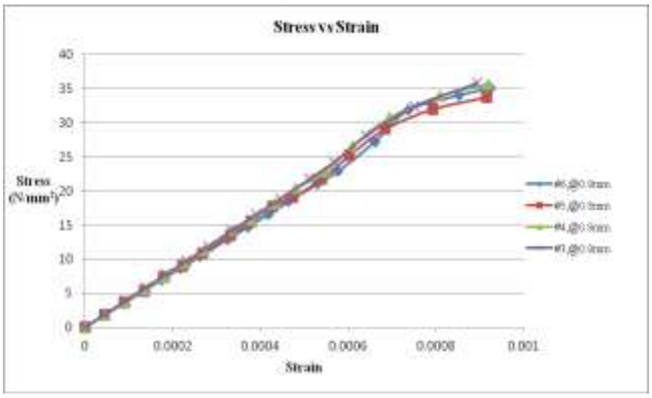

Chart-11: Stress vs Strain plots for columns with 0.8mm thick sheet

Chart-12: Load vs Deformation plot for columns with 0.8mm thick sheet

3.1.7 0.6mm thick sheet

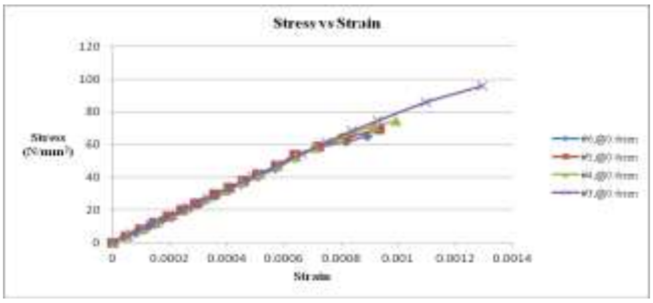

Chart-13: Stress vs Strain plots for columns with 0.6mm thick sheet

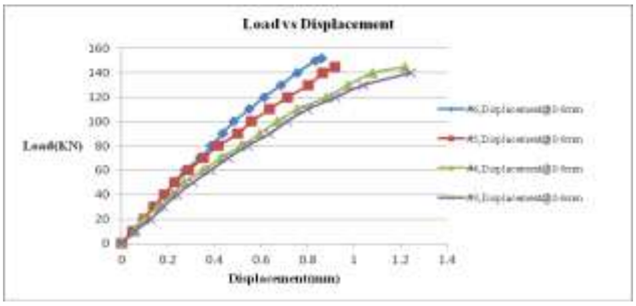

Chart-14: Load vs Deformation plot for columns with 0.6mm thick sheet

3.1.8 0.4mm thick sheet

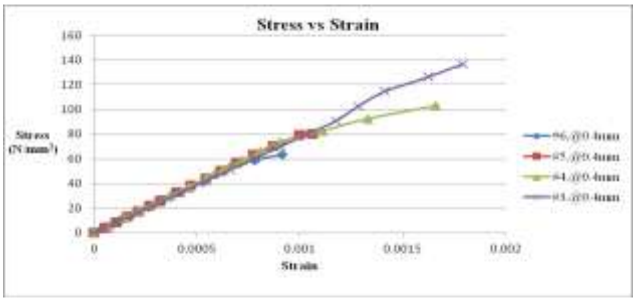

Chart-15: Stress vs Strain plots for columns with 0.4mm thick sheet

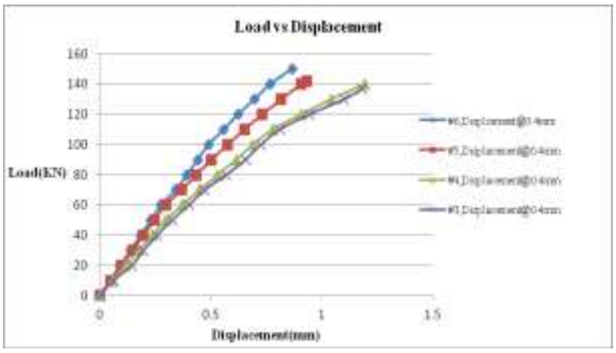

Chart-16: Load vs Deformation plot for columns with 0.4mm thick sheet

4. CONCLUSIONS

4.1 General

- The study conducted to analyze the behavior of CFST triangular fluted columns under concentric loadings using ANSYS FEA package has been successfully and effectively adopted.
- Fluted columns are well suited for Concrete Filled Steel Tubular. However, the contribution of flutes towards the strength and other characteristics depends on the number of flutes and thickness of steel sheet.
- Column with 6 number of flutes and 1mm thick sheet have load carrying capacity of 165KN, which is maximum among all the columns and subjected to displacement of 0.84071 which is minimum among all the columns.
- Column with 3 number of flutes and 0.4mm thick sheet have load carrying capacity of 137KN, which is minimum among all the columns and subjected to displacement of 1.183 which is maximum among all the columns.

4.2 Comparison of Results with Different Thickness of Steel Sheet

➢ **STRENGTH**

- The load carrying capacity of column with 6 number of flutes and 1mm thick sheet is 7.8%, 8.5% and 10% greater than columns with 0.8mm, 0.6mm and 0.4mm thick sheet respectively.
- The load carrying capacity of column with 5 number of flutes and 1mm thick sheet is 5.4%, 7.5% and 9.85% greater than columns with 0.8mm, 0.6mm and 0.4mm thick sheet respectively.

- The load carrying capacity of column with 4 number of flutes and 1mm thick sheet is 3.45%, 3.45% and 7.1428% greater than columns with 0.8mm, 0.6mm and 0.4mm thick sheet respectively.
- The load carrying capacity of column with 3 number of flutes and 1mm thick sheet is 3.57%, 3.57% and 5.84% greater than columns with 0.8mm, 0.6mm and 0.4mm thick sheet respectively.

➢ **STIFFNESS**

- Column with 6 number of flutes and 0.4mm thick sheet is 4%, 6.5% and 17% more deformable than the column with 0.6mm, 0.8mm and 1mm thick sheet respectively.
- Column with 5 number of flutes and 0.4mm thick sheet is 2%, 7% and 15% more deformable than the column with 0.6mm, 0.8mm and 1mm thick sheet respectively.
- Column with 4 number of flutes and 0.4mm thick sheet is 10.38%, 38% and 43% more deformable than the member with 0.6mm, 0.8mm and 1mm thick sheet respectively.
- Column with 3 number of flutes and 0.4mm thick sheet is 3.3%, 40% and 45.7% more deformable than the column with 0.6mm, 0.8mm, 1mm thick sheet respectively.
- All the column members have failed near the supports showing failure due to local buckling.

4.3 Comparison of Results with Different number of flutes

➢ **STRENGTH**

- Load carrying capacity of column with 1mm thick sheet and 6 number of flute is 5.8%, 10%, and 13.8% greater than columns with 5,4 and 3 number of flutes respectively.
- Load carrying capacity of column with 0.8mm thick sheet and 6 number of flute is 3.38%, 5.52%, & 9.29% greater than columns with 5,4 & 3 number of flutes respectively.
- Load carrying capacity of column with 0.6mm thick sheet and 6 number of fluted column is 4.8%, 4.8% and 8.6% greater than column with 5, 4 and 3 number of fluted column.
- Load carrying capacity of column with 0.4mm thick sheet and 6 number of fluted column is 5.6%, 7.2% and 9.5% greater than column with 5, 4 and 3 number of fluted column.

➢ **STIFFNESS**

- Column with 3 number of flutes and 1mm thick sheet is 10%, 13% and 22% more deformable than the column with 4, 5 and 6 numbers of flutes.
- Column with 3 number of flutes and 0.8mm thick sheet is 4.7%, 7.1% and 8.5% more deformable than column with 4, 5 and 6 numbers of flutes.
- Column with 3 number of flutes and 0.6mm thick sheet is 2%, 35% and 44% more deformable than the column with 4, 5 and 6 numbers of flutes.
- Column with 3 numbers of flutes and 0.4mm thick sheet is 2.5%, 26% and 36% more deformable than the column with 4, 5 and 6 numbers of flutes.
- All the column members have failed near the supports showing failure due to local buckling.

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