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Analytical Study on Structural Behavior of Concrete Filled Rectangular Fluted Column

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ABSTRACT—

Concrete-filled steel tube (CFST) columns combine the advantages of ductility, generally associated with steel structures, with the stiffness of a concrete structural system. In order to reduce the dead weight of composite columns and to increase the confinement and durability of the concrete filled rectangular fluted steel column were adopted. Adding rectangular Flutes on the surface of circular columns improve aesthetics of the columns making them look slender and add a rhythm to it. Two reference model such as outward rectangular fluted columns and inward rectangular fluted column were validated for the parametric study. The provision of fluted rectangular steel column improve the bond strength between the concrete and steel tubes and to increase the load carrying capacity of the column. The parameter consider in this study included the concrete grade, thickness of the steel plate and steel grade. Number of flutes are varied to understand the performance of flutes in structural strength enhancement of Concrete filled rectangular fluted steel tube columns (CFRFST). ANSYS FEA is used to study the load carrying capacity and deformation characteristics of Concrete-Filled Rectangular Fluted Steel Tube Columns (CFRFST). The results of the analytical study provides us valuable information on the ultimate load bearing capacity , load deflection characteristics were discussed.

Keywords—. concrete filled rectangular fluted steel tube column(CFRFST), ANSYS

Introduction

A steel-concrete composite column is a compression member, comprising either a concrete encased steel section or a concrete-filled tubular section of steel and is generally used as a load-bearing member in a composite framed structure. Since the start of research in steel concrete composite columns in the early 1900s, many design methods and different applications have evolved.In a composite column both the steel and concrete resist the external loading by interacting together by bond and friction. In composite construction, the bare steel sections support the initial construction loads, including the weight of structure during construction. Concrete is later cast around the steel section, or filled inside the tubular sections. The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. The subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections. Supplementary reinforcement in the concrete encasement prevents excessive spalling of concrete both under normal load and fire conditions. Steel concrete composite columns are used in bridge piers to take vehicle impact load; in arch bridges in high rise buildings to maintain the same size of column by varying the reinforcement, to avoid formwork and to attain fire resistance.With the use of composite columns along with composite decking and composite beams it is possible to erect high rise structures in an extremely efficient manner. There is quite a vertical spread of construction activity carried out simultaneously at any one time, with numerous trades working simultaneously. For parking purpose, in multi-storied buildings soft storey is introduced to overcome rocketing cost of land / space scarcity. In such cases the columns are being made in larger sizes that in turn occupy more space. Concrete Filled Steel Tubular columns

FIGURE.1.1 QIANMEN SUBWAY STATION IN BEIJING

1.1 ADVANTAGES OF CFST COLUMN

1. Increased strength for a given cross sectional dimension.
2. Increased stiffness, leading to reduced slenderness and
3. Good fire resistance in the case of concrete columns.
4. Corrosion protection in encased columns.
5. Erection of high rise building in an extremely efficient manner.
6. Formwork is not required for concrete-filled tubular sections
7. Increasing buckling resistance

1.2 BEHAVIOUR OF CFST COLUMNS

Since steel and concrete are two materials with different stress-strain curves, determination of the effective structural property of a CFST element becomes a difficult task. The important parameters affecting the load-deformation behaviour, the ultimate strength and the failure mechanism of CFSTs under a given loading condition are;

1. Shape of the cross section
2. D/t ratio
3. Slenderness ratio
4. Grades of concrete and steel Type and
5. Rate of application of loading and
6. Boundary conditions.
7. The degree of concrete confinement

1.3 FAILURE MODES OF CFST COLUMN

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. Short composite columns exhibit a failure mechanism characterized by yielding of steel and crushing of concrete. Medium length columns behave inelastically and fail by partial yielding of steel, crushing of concrete in compression and cracking of concrete in tension. When the load applied to a column is eccentric in the stronger plane of bending and the slenderness for buckling in that plane is much less than that for minor-axis buckling, failure in a biaxial mode is possible. In columns subjected to biaxial bending, the neutral axis changes its position continuously by a combination of translation and rotation. Stiffness along the whole length of the column varies due to an uncracked concrete section near the ends with an increasing frequency of cracking nearer the centre . When compared with the empty steel tube, the local buckling in the CFST column is delayed due to the presence of concrete infill.

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

FIGURE.1.2 OUTWARD BUCKLING OF CFST STUB COLUMNs

1.4 FLUTED COLUMNS

Greeks and Romans used fluted columns that had narrow channels running up and down them. Doric columns usually had 20 flutes, while Ionic columns usually had 24 flutes. Some flutes come to points between the flutes, while others have a flat top to each crest. Fluted columns improve aesthesis of the columns making them look slender and a rhythm to it.

Structurally, adding flutes to the columns can increase their moment of inertia and thus increasing the load resistance of the column. Studies were conducted to analyse the performance of triangular and rectangular flutes and it was found that rectangular flutes gave higher moment of inertia and load resistance.

Figure.1.3 Fluted Concrete Columns

1.5 OBJECTIVE

1. To study the performance of outward and inward of rectangular fluted CFST column.
2. To inspect the effect of variation in the number of flutes.
3. To conduct the static structural analysis under axial loading condition.
4. To determine the ultimate load carrying capacity of the section.

1.6 SCOPE

1. This study focuses on structural behavior of concrete-filled steel tube columns with rectangular flutes under axial loading.
2. Number of flutes are varied to determine the strength characteristics of CFST column.
3. The finite element analysis is done using ANSYS software to study the load carrying capacity and deformation characteristics of concrete-filled rectangular fluted steel tube columns (CFRFST).

2. LITERATURE SURVEY

C. S. Huang; Y.-K. Yeh; G.-Y. Liu; H.-T. Hu; K. C. Tsai; Y. T. Weng; S. H. Wang; and M.-H. Wu [2002] "Axial Load Behavior of Stiffened Concrete-Filled Steel Columns" This study investigates the axial load behavior of concrete-filled steel tubular (CFT)columns with the width-to-thickness ratios between 40,70 and 150, and proposes an effective stiffening scheme to improve the mechanical properties of square and circular cross-sectional CFT columns. Seventeen specimens were tested to examine the effects of cross-sectional shapes, width-to-thickness ratios, and stiffening arrangements on the ultimate strength, stiffness, and ductility of CFT columns. . The failure modes of the specimens indicate that the stiffening scheme effectively delays local buckling . The axial stresses at the stress concentration areas indicate that the proposed stiffening scheme improves the confinement of steel tube on the core concrete. The enhanced mechanical properties achieved by applying the proposed stiffening scheme to a square CFT column should also be valid for a CFT column.

Dr. B.R Niranjan, 1 Eramma. H [2013] "Effect of Shape of Cross-section and Its Performance for Concrete Filled Steel Fluted Column" An attempt has been made to use this composite structural member as a column with a modification of flutes on the steel tube for rectangular flutes and for triangular flutes. Confining concrete by providing triangular and rectangular shape fluted steel tube has been investigated by a well planned experimental work on twenty six concrete filled steel fluted columns (CFSFC). The parameters chosen for the study are Geometry of the specimen,Different L/D ratios ,Longitudinal reinforcement . Three series of specimens having different L/D ratios, 2500mm long have been tested with M20 grade of self compacting concrete (SCC). Generally the failure occurs by either local buckling or yield failure. It has been found that Euro code gives a better design method which yields values nearer to experimental values. It is observed that the load resistance is better marginally in the case of rectangular fluted columns as compared to the triangular fluted columns.

A.K. Ahuja Ziyad, A. Khaudhair P.K. Gupta [2014] "Computational study on performance of circular concrete filled steel tubular columns" The structural behaviour of circular concrete filled steel tubular (CFST) columns with different geometries and filled with different grades of concrete, have been investigated analytically using the numerical results of three dimensional non-linear finite element model, which has been developed using commercial finite element code ANSYS. The steel tubes were having different lengths, diameters, and thicknesses, while the concrete cores were having different compressive strength. The study is focused on the parameters that include: steel tube thickness (t), outer diameter of steel tube (D), ratio of D/t and grade of concrete core. Effects of these parameters on the axial load carrying capacity and corresponding strain have been investigated. To comment on the performance, two parameter; confinement index and concrete enhancement factor are formulated, presented, and discussed. A numerical parametric study has been carried out to study the effect of steel tube thickness (t), steel tube outer diameter (D), D/t ratio, and the grade of concrete core on the load carrying capacity of CCFST columns. It can be concluded that by increasing the thickness of steel tube, the load carrying capacity and ductility of such columns shall be significantly enhanced. An index to evaluate the effect of confinement due to the composite action between steel tube and concrete core has been formulated and investigated. It can be concluded, based on the numerical results, that the thicker tube (i.e., tubes having lower D/t ratio) will offer more confinement to the concrete core and, accordingly, will significantly enhance the properties of concrete core like compressive strength and ductility. However, for steel tubes filled with higher grade of concrete it can be concluded that the confinement will be in lower side as compared to normal strength concrete.

The strain curve obtained by the FE results fits poorly with the test data. Compares the load-longitudinal strain curves of the CFT stub columns that were obtained through FE analysis with test. The proposed FE model can imitate the load-longitudinal strain curves of the CFT stub columns with high precision. In the elastic stage, the increasing parts of the simulated load- longitudinal strain curves nearly matched the test curves. In the elastic-plastic and failure stages, the FE curves deviated from the test curves to some extent

From the literatures reviewed, the following findings were understood and were used to frame the project work methodology.

1. CFST columns under axial loads with various parameters such as length to diameter ratio, diameter to thickness, end conditions, fill material, geometrical shapes etc.,
2. The slenderness ratio influences the ultimate load carrying capacity of the column.
3. Provision of concrete in-fill increases the ultimate load carrying capacity of CFST columns.
4. Buckling load capacity is less for Hollow tubes when compared to CFST columns.
5. Load resistance is better in rectangular fluted columns as compared to the triangular fluted columns.
6. Stiffening at the ends eliminates or minimizes the influence of end conditions
7. Also since the effect of cross section has a significant role in improving the strength, extensive research need to be done according to the loading and different regions.

3. MATERIAL SPECIFICATION

The column section selected for the analysis is taken from the paper published by B.R.Nirajana and Burak Evigen . Composite column sections such as CFST columns are not available in is codal provisions. The authors were analysed the column sizes for a length of 1000mm and the different shapes of flutes. I have taken the column length of 700mm with 150 mm diameter to analyse the behavior of concrete filled rectangular fluted steel tube column.

Nomenclature	Number Of Flutes	Length X Diameter(mm)	Thickness Of Steel (Mm)	Dimension Of Fluted Inward And Outward (Mm)
Rectangular Outward Fluted Circular Steel Tube Column.(ROFCST)	4	700X150	3	40X10
	6	700X150	3	40X10
	8	700X150	3	40X10
Rectangular Inward Fluted Circular Steel Tube Column.(RIFCST)	4	700X150	3	40X10
	6	700X150	3	40X10
	8	700X150	3	40X10

Table. 1. Dimension of column

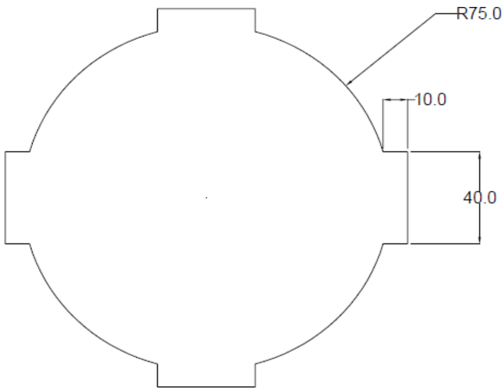


Figure.3.1 CFRFST with 4 outward rectangular flutes

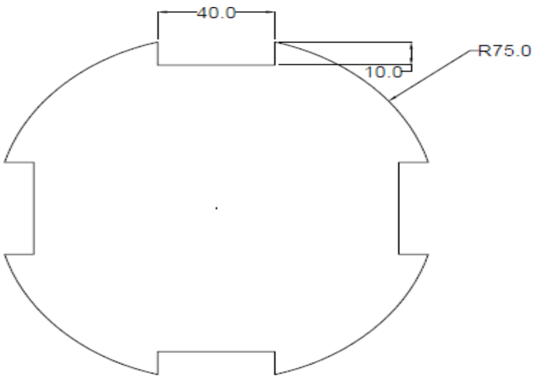


Figure.3.2 CFRFST with 4 inward rectangular flutes

4. FINITE ELEMENT MODELLING

The ANSYS Workbench environment is a user-friendly up-front finite element analysis tool for use with CAD systems and/or Design Modeler. ANSYS Workbench is a programme that allows you to perform structural, thermal, and electromagnetic analyses. The following are the steps involved in finite element analysis.[11]

1. Model discretization

2. Select element displacement function

3. Calculate element properties

4. Obtain the element load vector

5. Assemble element properties

6. Impose boundary conditions Determine the displacement .

a. GEOMETRY DOMAIN AND MATERIAL PROPERTY OF THE ELEMENTS

Use the property module to create the geometry and assign the material property Nonlinear elastic material model is used for the analysis with Young's modulus of 2 X10^5 N/mm^2 and Poisson's ratio taken as 0.3 and the density of steel taken as 7850 kg/m^3.

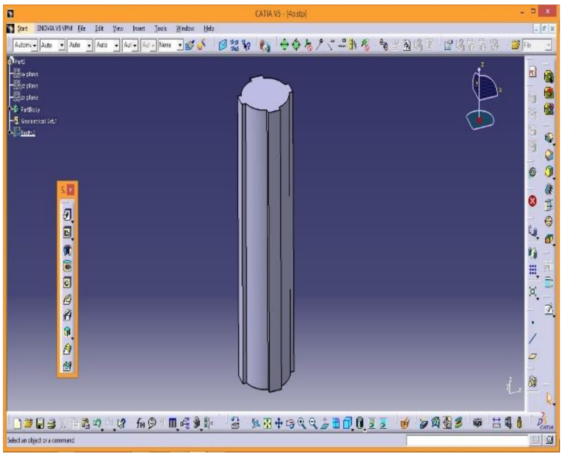


Fig.4.1 Geometry and Material Domain – ASSEMBLY

a. MESHING THE FINITE ELEMENT MODEL

The main concept in finite element modelling is to generate mesh. Mesh are used to divide a model into numerous small areas, which makes the analysis accurate. Mesh size can be changed. Here tetrahedron mesh is been provided for accurate values as shown in fig 9.

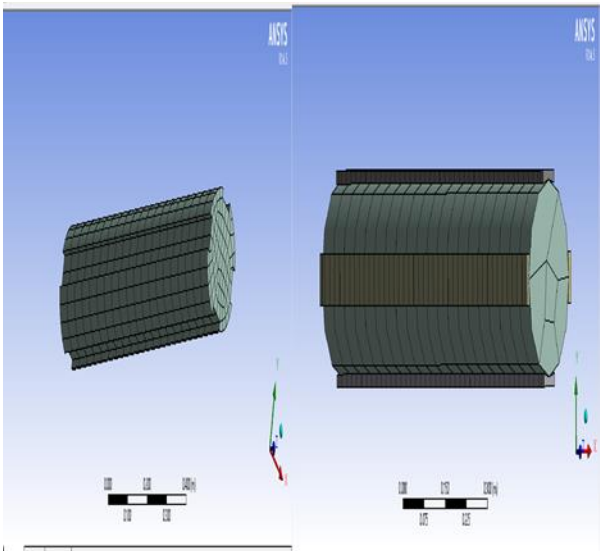


Fig. 4.2. Mesh Generation

b. ASSIGNING SUPPORT CONDITION AND LOAD

Creating boundary condition of the beam that constraints the support in the lower end. Both ends are simply supported and the load is applied creating a new plane module.

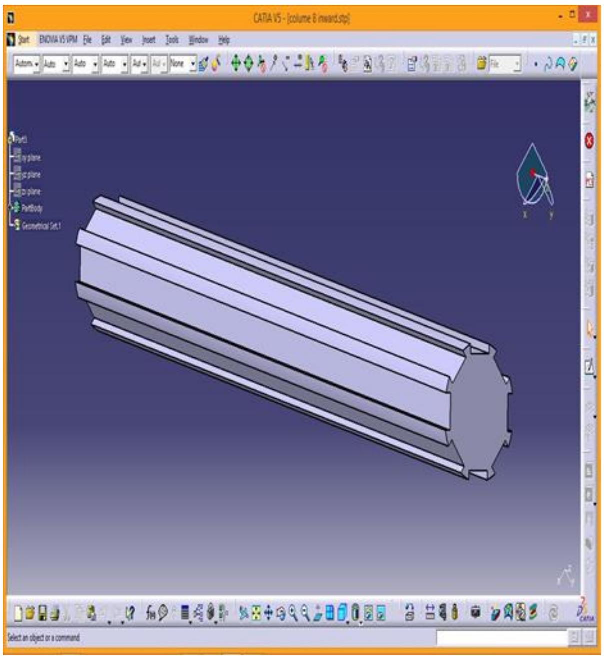
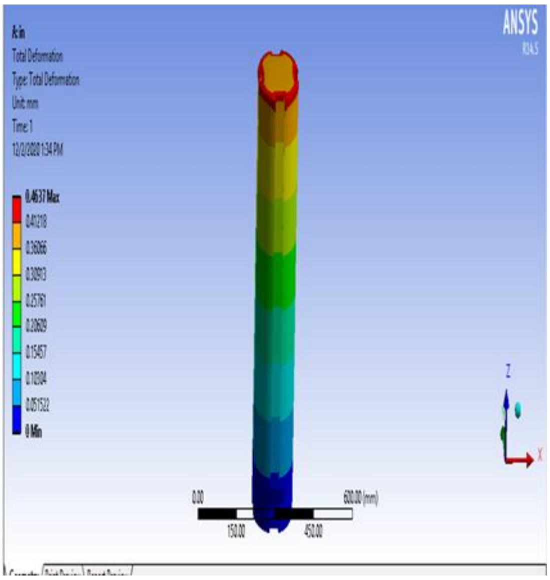


Fig. 4.3 .Boundary Condition

C. ANALYSIS VISUALIZATION

c. The model is solved under the given solution such as total deformation and equivalent von misses stress. Use the visualization module to see the results.



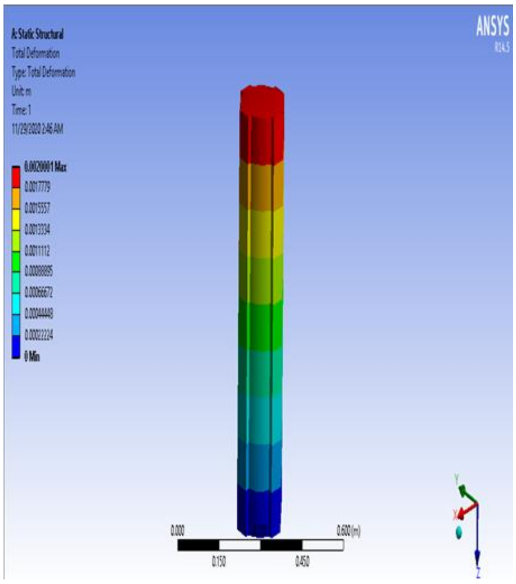


Fig. 4.4 Total Deformation for 4 fluted CFRFST column outward

Fig . .4.5 Total Deformation for 4 fluted CFRFST column outward

5. RESULT AND DISCUSSION

No of Flutes	Direction Of Fluted Column		Total Deformation (Mm)	Von Mises Stress (Mpa)	Von Mises Strain (Mm/Mm)
4	INWARD	MIN	0	5.5727	0.00005
		MAX	0.4637	63.365	0.0056
	OUTWARD	MIN	0	1.0656	0.00009
		MAX	0.002	66.586	0.0014
6	INWARD	MIN	0	5.57	0
		MAX	0.32	63.65	0.0000525
	OUTWARD	MIN	0	7.079	0.0003
		MAX	0.00049417	6.199	0.00354
8	INWARD	MIN	0	63.55	0
		MAX	0.2527	14.144	0.00049
	OUTWARD	MIN	0	19.0828	0.0009
		MAX	0.14417	56.057	0.0002

Table 5.1 Results Obtained Through Ansys

From the above table it Six specimens are taken for analysis part as they varying number of flutes and also a make a differenece in the inward and outward rectangular fluted column. From The above graph it can be concluded that ,the stress strain curve are observed that the rectangular inward fluted column increases the load carrying capacity when compared to outward

rectangular fluted steel column. The load deflection curve for the analytical study is plotted below, The presence of inward fluted column reduced the deflection At the ultimate load , when compared to outward fluted column , inward fluted column shows less deflection behavior.

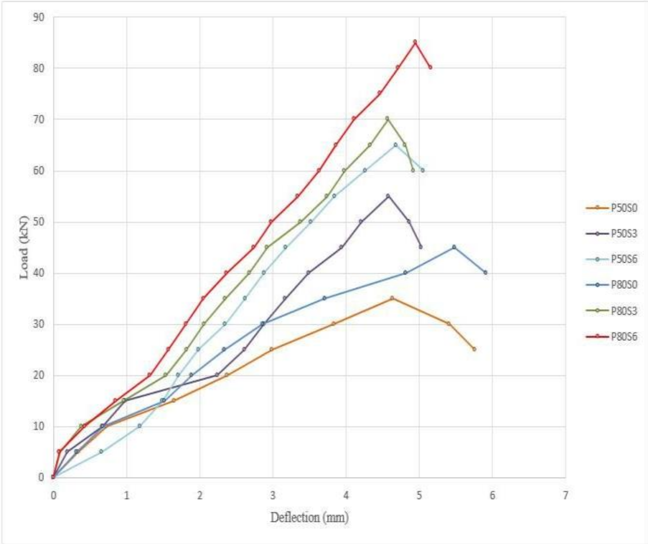


Fig. 5.1 Load deflection of Specimen

6. CONCLUSION

An Analytical study was conducted to examine the six specimens of outward and inward rectangular fluted column have been done under axial loading . They were analyzed for the significant behaviors like Total deformation, Equivalent stress and Equivalent strain. From table 6.3 the maximum deformation is seen in rectangular outward fluted circular steel tube (ROFCST). The maximum load carrying capacity is also higher for rectangular inward fluted circular steel tube (RIFCST). The Maximum deformation obtained for the rectangular inward 4 fluted column is 0.04637mm and for 6 fluted column is 0.32mm and for 8 fluted column is 0.2527 respectively. Hence it is found that among the 6 specimen of concrete filled rectangular fluted column (CFRFST) with Inner Fluted section is giving the Favorable results than the Outward fluted section. As compared to that of theoretical results the ultimate load carrying capacity of rectangular inward fluted steel column is higher as compared to rectangular outward fluted steel columns.

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