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A Study on Buckling Analysis on CFST Columns with Different Slenderness Ratio & RCC Columns using ANSYS

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Abstract: Concrete Filled Steel Tubes mainly was first established in the first half of the 90's years. However, the thesis is mainly to understand their behaviour with the aim of improving their performance in the certain corresponding conditions considered here. The anticipated study presents a study with the software to investigate the consequence on the compressive behaviour of square CFST columns. The key of interest is mainly the variation in the ratio of slenderness i.e. the length-to-dimension ratio (L/D) and the common load applied to all cases. The project is all about the buckling analysis of different cases corresponding to slenderness from 15 to 35 each case having sub-cases of different thickness from 1mm to 5mm and thus total twenty-five case models of square CFST columns sections. The material used for the concrete is M25 and the steel is of Grade Fe250. The load for which the cases are analyzed is 30000 N identifying the problem of maximum displaced columns. In this study, the software program includes model with different sizes of CFST columns corresponding to each case of L/D ratio i.e. 250 mm, 230 mm, 200 mm, 180 mm, 160 mm respectively. The different sizes of CFST columns are analyzed through software for the parameters such as Deformation, Stress & Critical Load. After the complete analysis of CFST columns, the efficient columns or the CFST which shows best results is then compared with the conventional RCC columns for the check of behaviour of CFST corresponding to the considered sections. The compressive behaviour of Concrete Filled Steel Tubes is also investigated in this study with the equivalent Stress results. For the better efficient result remedial measure can be adopted as a suggestion such as Jacketing of columns, Steel Jacketing, Fibre reinforced columns etc. The main objectives of this study are as follows-

1) ***To model the concrete filled steel tubular columns with different sizes having slenderness ratio varying from 15 to 35 and have different thickness using finite element software.***
2) ***To compare the CFST columns within cases due to vertical load by 'Eulers formula' for parameters such as Deformation, Equivalent Stress & Critical Load.***
3) ***To analyze and design the RCC column cases of different sizes for the study.***
4) ***Comparison between the efficient CFST Column sections with the respective section of RCC column sections on the parameters similar to the previous ones i.e. Deformation, Equivalent Stress & Critical Load along the tabulation results.***
5) ***To Check the practical behaviour and optimization of CFST columns with graphical representation.***

Keywords: CFST, L/D, Deformation, Critical Load, RCC

I. INTRODUCTION

A. History of Concrete Filled Steel Tubes

Pre 1960's -Revolution and requirement have been dynamism for the structural design throughout the history. As early in 1930's, the former SOVIET UNION constructed a 101m bridge by using concrete filled steel tubes. Nominal research and experience using concrete filled steel tubes formed anxiety of using CFST. In 1960's - 1980's - In 1961 Kato Naka wrote the technical journal on CFST in Japan which described circular CFST compression member used in power transmission tower. In 1980's – 1990's - In 1980, revision of standards was carried out by Architectural Institute of Japan (AIJ) to include square steel tubes and their limitations. These five contractors and that steel manufacturer along with the Building research institute (BRI) of the ministry of the construction of the Japan stared a five-year experimental research project called New Urban Housing Project. In 1993, another five-year research project on the hybrid and composite structures as the fifth phase of the U.S. – Japan Collaboration Earthquake Research Program and the investigation the CFST column system was included in the program research findings obtained from this project made the present design recommendations for the CFST column

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B. Various Types of CFST Columns

There are two types of composite columns generally used in buildings, steel section encased in concrete and steel section in-filled with concrete. A concrete filled steel tubular (CFST) structure consists of steel tube of square, rectangular or circular cross-section filled with plain or reinforced concrete. Various forms of latter type of CFST composite columns are represented in figure below. Following are the various types of CFST columns:

1) Composite column systems
2) Reinforced composite column systems
3) Concrete-filled double skin tubes (CFDST)
4) Reinforced Concrete-filled double skin tubes (CFDST)
5) Concrete-encased CFST columns
6) Stiffened CFST columns

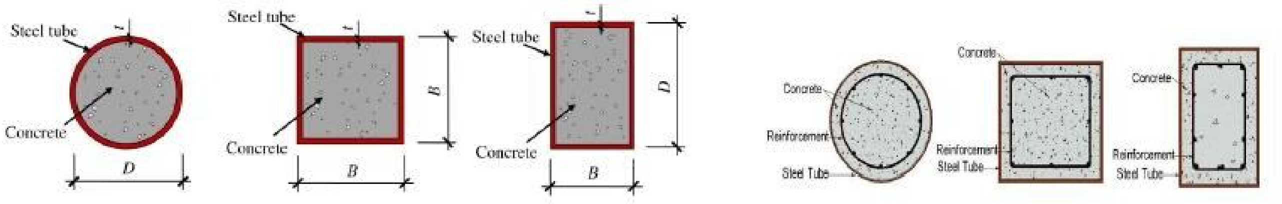

Fig. 1.1 Typical Cross-Sections of Simple Composite & RCC Columns

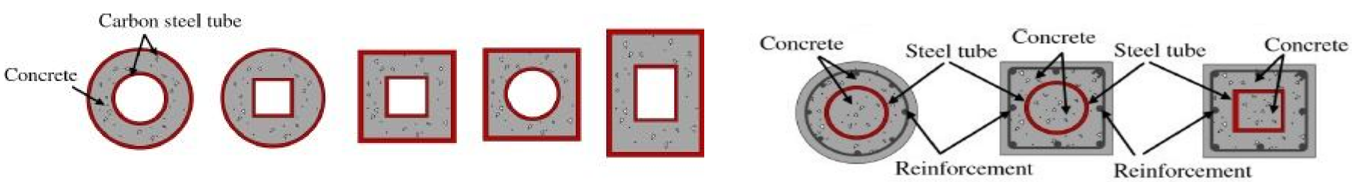

Fig. 1.2 Typical Cross-Sections of Concrete Filled & RCC Filled

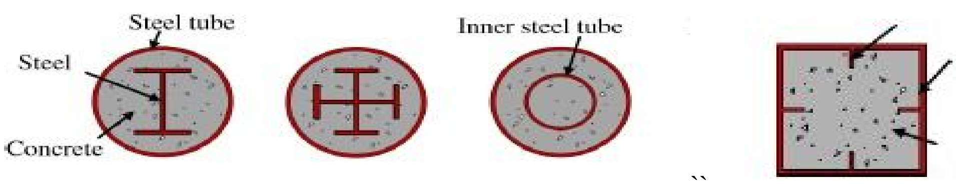

Fig. 1.3 Concrete Encased & Stiffened CFST Columns

C. Behaviour of CFST Columns Under Axial Tension

Few studies have been conducted for CFST under axial tension, one of them by Han at in 2007 and the schematic failure mode is shown in figure below. Steel tube diameter in the middle of specimen gets smaller under pure tension, while concrete failure is characterized by a transverse crack, which divides it into pieces. In CFST, concrete prevents the reduction of the steel tube diameter while the steel tube contributes to a uniform distribution of the tensile stresses in concrete, so there are more cracks with smaller width.

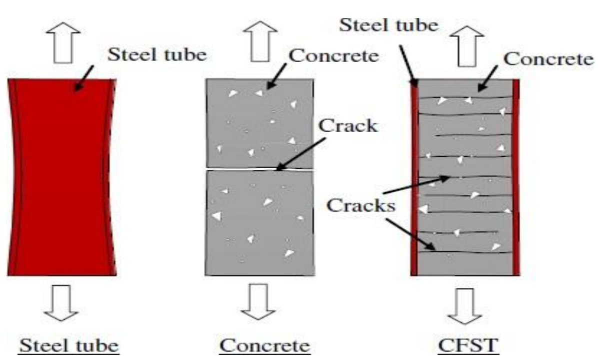

Fig. 1.4 Failure modes of steel tube, concrete & CFST under axial tension

D. Behaviour of CFST Columns Under Bending

Figure below shows the schematic failure modes of steel tube, reinforced concrete member and CFST subjected to bending. The failure of the steel tube results from inward buckling. In RC members the failure can result from concrete crushing in the compression zone while in the tension part horizontal or diagonal shear cracks can develop. In CFSTs the failure is characterized by outward buckling of the steel tube in the compression zone and concrete crushing, while in the tensile part, the crack's width and distance between cracks is smaller in comparison to RC members.

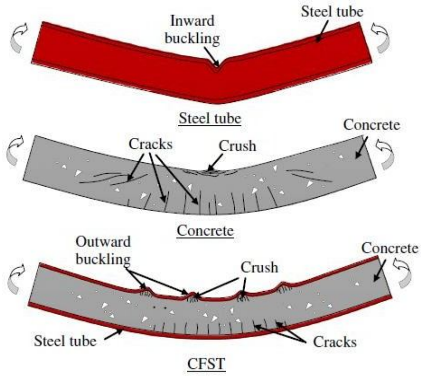

Fig. 1.5 Failure modes of steel tube, RC member & CFST under bending

II. LITERATURE REVIEW

A. Ziyad A. Khaudhair, P.K. Gupta,A.K. Ahuja (2013) in this paper studied about the aim of this parametric study is to study the load carrying capacity and post-yield characteristics of axially loaded Concrete Filled Steel Tube (CFST) columns with square cross section. The verified computational model has been used for predicting the ultimate axial load carrying capacity of CFST columns having different sizes filled with normal compressive strength concrete. The specimens were selected to simulate the cross-section sizes in actual construction practice. All specimens had length equal to three times the cross-section width to behave as short columns and neglect the effect of slenderness. The parameters of this study were cross-section width and thickness of steel tube. Effects of these parameters on enhancement the properties of concrete core, load carrying capacity and post-yield behaviour have been numerically investigated.

B. Vima Velayudhan Ithikkat, Dipu V S (2014) has studied that in recent years, as a type of hybrid system, the concrete-filled steel tubular (CFST) columns are increasingly used in buildings and bridges. In concrete-filled steel tube (CFST) columns, the steel tube provides formwork for the concrete, the concrete prolongs local buckling of the steel tube wall, the tube prohibits excessive concrete spalling, and composite columns add significant stiffness to a frame compared to more traditional steel frame construction. The design of concrete filled steel tubes is considered to be difficult since a proper formula is not present to find out the axial load carrying capacity of such CFST short columns. The main aim is to find an approximate formula for finding the ultimate axial load carrying of rectangular concrete filled steel tube short column by obtaining relations between various material properties of CFST using a finite element model developed using ANSYS software and validating it against the experimental data obtained during literature survey.

C. Hasan Abdulhadi Ajel , Abdulnasser M. Abbas (2015) ,has studied the structural behavior of concrete - filled steel tube (CFST) columns has been investigated using experimental and analytical studies. The effect of concrete compressive strength, thickness of steel tube, stiffeners and longitudinal reinforcement were considered. Specimens that have been studied consist of sixteen square samples with dimensions of 150 mm ×150 mm × 300 mm height, and fifteen circular samples of 150 mm diameter and height of 300 mm. The tested samples were studied analytically using three-dimensional finite element representation by ANSYS (ver. 12.1) computer program. Eight nodes brick elements SOLID 65 and SOLID 45 were used to simulate concrete and steel tube respectively. While two nodes element LINK 8 are used for steel rebar.

D. M.Pragna, Partheepan Ganesan (2016) studied about the load carrying capacities of concrete filled steel tubes (CFT) subjected to compression loading. The study on the behavior of CFT and various parameters influencing their behavior are carried out using commercially available ANSYS, FEM software. Predicting the behavior of CFT using the modeling software has become economical and this is time saving. Nonlinear finite element analysis of Concrete filled steel tube is performed by varying parameter such as grade of concrete infill, diameter to thickness ratio of the steel (D/t).

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Volume 8 Issue III Mar 2020- Available at www.ijraset.com

III. METHODOLOGY

A. *Structural Specifications of Cases*

The structural member or element to be designed & analyze here is Column filled Steel tube (CFST) i.e. a type of composite material. The column filled steel tube considered here are of five different cases i.e. Slenderness ratio (L/D = 15), Slenderness ratio (L/D = 20), Slenderness ratio (Length to least dimension ratio = 25), Slenderness ratio (L/D = 30) & Slenderness ratio (L/D = 35) under which there are again five sub-cases differ on the basis of thickness of hollow steel tube fitted along the outer side of cement concrete column wall. The following table below are the Case Study to be analyzed and designed in this thesis-

Table 3.1 Distribution of all Models for the Study Analysis

Slenderness Ratio (L/D)	Main -Cases	Thickness of Steel Tubes	Sub-Cases
15	Case 1	1 mm	Case 1A
		2 mm	Case 1B
		3 mm	Case 1C
		4 mm	Case 1D
		5 mm	Case 1E
20	Case 2	1 mm	Case 2A
		2 mm	Case 2B
		3 mm	Case 2C
		4 mm	Case 2D
		5 mm	Case 2E
25	Case 3	1 mm	Case 3A
		2 mm	Case 3B
		3 mm	Case 3C
		4 mm	Case 3D
		5 mm	Case 3E
Slenderness Ratio (L/D)	Main -Cases	Thickness of Steel Tubes	Sub-Cases
30	Case 4	1 mm	Case 4A
		2 mm	Case 4B
		3 mm	Case 4C
		4 mm	Case 4D
		5 mm	Case 4E
35	Case 5	1 mm	Case 5A
		2 mm	Case 5B
		3 mm	Case 5C
		4 mm	Case 5D
		5 mm	Case 5E

The data used in this research is shown in the form of tabulation considered for design and analysis of columns are given below-

Table 3.2 Structural Properties used for all CFST Columns

Particulars	Structural Properties
CFST-Columns Shape	Square
Total Area for all Case 1 Models	625 cm^2
Total Area for all Case 4 Models	625 cm^2
Total Area for all Case 3 Models	400 cm^2
Total Area for all Case 4 Models	324 cm^2
Total Area for all Case 5 Models	256 cm^2
Thickness of Steel tubes	1 mm to 5 mm
Slenderness Ratio to be Studied	15, 20, 25, 30, 35
Case 1 CFST- Columns Size	250 mm
Case 2 CFST- Columns Size	230 mm
Case 3 CFST- Columns Size	200 mm
Case 4 CFST- Columns Size	180 mm
Case 5 CFST- Columns Size	160 mm
Length of all CFST-Columns (Case 1)	3750 mm
Length of all CFST-Columns (Case 2)	4600 mm
Length of all CFST-Columns (Case 3)	5000 mm
Length of all CFST-Columns (Case 4)	5400 mm
Length of all CFST-Columns (Case 5)	5600 mm
Dead load	IS 875 Part-1
Live load	IS 875 Part-2

B. Case Model Plan (Slenderness Ratio =15,20,25,30,35)

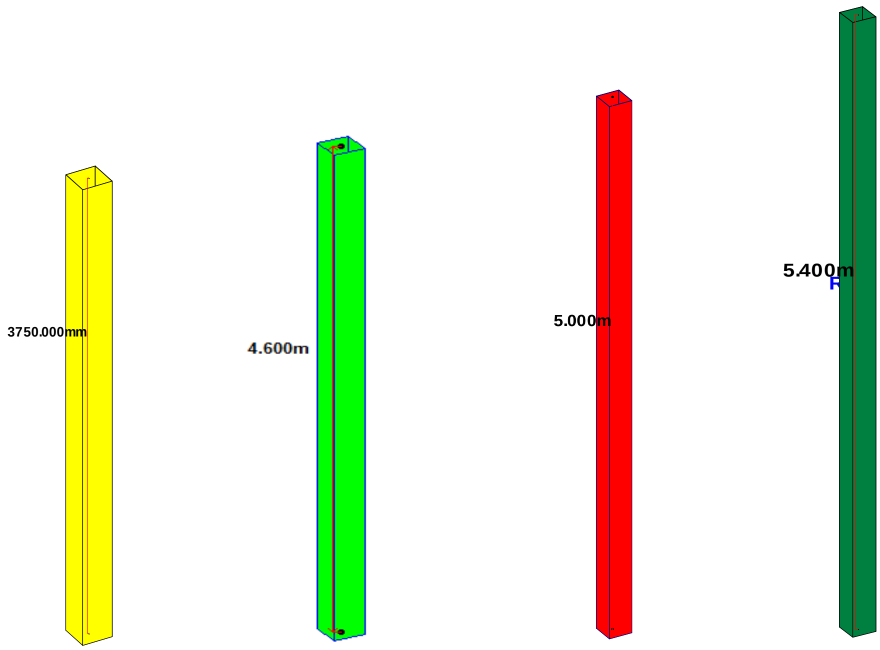

Fig. 3.1 Three Dimenisonal Rendering View of CFST Column of All Case Models (Case 1,2,3,4,5 Models)

C. Material Specification for all Main and Sub - Cases

These Concrete filled steel tubes columns slope are basically made up of two basic materials i.e. concrete and steel. The table given below shows the properties of materials considered for design and analysis of all CFST Columns.

Table 3.3 Material Properties Applied in Cases

Particular	Details
Grade of Concrete	M25
Grade of Steel Tubes	Mild Steel (Fe250)
Young's Modulus of Concrete	2.5 X 10^{10} Pa
Young's Modulus of Steel	2 X 10^{11} Pa
Bulk Modulus	1.67 X 10^{11} Pa
Poisson's Ratio for Concrete	0.18
Poisson's Ratio for Steel	0.30
Density of Concrete	2400 Kg/m^3
Density of Steel	7850 Kg/m^3

D. Loading Specification Common for All Models Used in Software

The load which is to be studied in the project is discussed under following clauses below such as Primary load which is applied in the local minus Y-Direction i.e. Taking 30000 N as primary load for all the cases and sub-cases for the required buckling analysis on the free side of the CFST columns.

E. RCC Columns Specification Used as Comparative Element

The conventional columns or RCC is here been used as a comparison product with the best efficient CFST Column model within the above cases so as to conclude that whether the CFST columns can be used as normal construction element as like Reinforced cement concrete in load bearing structure or CFST columns will remain as non-load bearing structural element. Hence, at last the Comparative Analysis is been done with the RCC and best analyzed CFST Column Models. The following are the details of Reinforced cement concrete to be analyzed here for the comparison are as follows-

1) According to above cases of CFST columns to compare these materials, the RCC analysis is done on the following sizes of 250 mm, 230 mm, 200 mm, 180 mm & 160 mm. The length of each columns is 3.75 m, 4.6 m ,5 m ,5.4 m ,5.6 m.
2) Here, in RCC the point load of 30000 N is applied in the vertical minus -y direction and after this design analysis of columns is done and the result are carried out manually.
3) The Modelled RCC columns are analyzed and their deformation, critical load & stresses are found out.

F. Step Sequence for Buckling Analysis Applied in Software for CFST Columns Model

1) Firstly, the workbench software i.e. ANSYS 15.0 Software is opened. From tool customization box from the side portion Static Structural is dragged from the ANSYS 15.0 software. After Dragging, Right click on the "Geometry", then new window is opened i.e. DM Mechanical, then click New Geometry & Units, the axis plane is selected i.e. Z-X Plane.
2) Next Sketching is done with by clicking in the lower portion of Geometry. Draw the required shape of Column i.e. through rectangle & give dimension to it from this tool only. Select Line from the above tool (H1 & V1), after that Modelling is done by extruding the following given diagram with the help of "Model" tool along ZX Plane. Hence, Sketch 1 is done by applying the above steps. Enter Specific Length according to the following cases (i.e. 3.75 m, 4.6 m, 5 m, 5.4, 5.6 m) respectively.
3) Now, Click on the Engineering Data edit. New window opens named "Contents of different material" from their select concrete material. Feed the properties details as per requirement and assign to the existing column. Similarly select steel from the material defining box and assign steel properties to the column. Generated Modelled Column appears on the screens then closed and then by right click on "Model Tool" click on the update so that the model which we have generated an be updated.
4) Next the support is added by clicking the "SETUP TOOL" and click on the edit, then add fixed support on the face side according to the following cases. Again, select load or force present in the side box from the setup tool and define the following load value according to the cases discussed above along downward Y -Direction.

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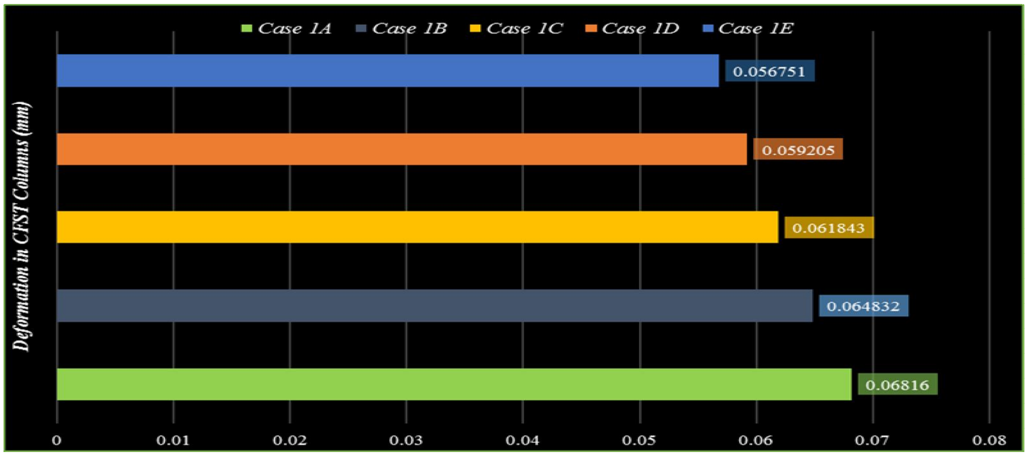
Volume 8 Issue III Mar 2020- Available at www.ijraset.com

5) Go to "Solution Tool", by opening the edit potion in solution again new window appear on the screen, showing the solution content in the side portion of the current window. Click on the Stress linked with the solution tool and after that Equivalent stress result & Deformation result and lastly Total result of it. Click on solve for the analysis print of the above result through this software and Deformation, Critical Load & Equivalent Stress results are found out.
6) Now, Drag Linear Buckling form the tool customization box to the solution of Static Structural and link it with Static Structural box.

IV. RESULTS & DISCUSSIONS

A. Deformation in Case 1 CFST Columns

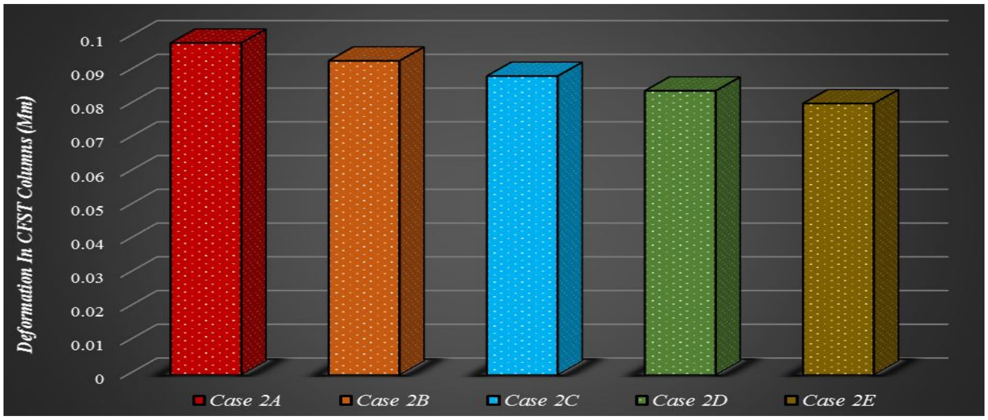
The descriptive detail of report is shown in Graph 4.1. According to the report the values of deformation is due to vertical loading assigned along X & Z directions. It is concluded from the reports that at 3.75 m height for each subcases of Case 1, there is maximum increase in deformation due to load applied is at top portion. The results are of Square CFST columns of CASE 1 of size 250 mm i.e. based on slenderness ratio equal to 15 where the value of deformation is such as 0.0681 mm (for Case 1A) > 0.0648 mm (for Case 1B) > 0.0618 mm (for Case 1C) > 0.0592 mm (for Case 1D) > 0.0567 mm (for Case 1E). Therefore, deformation is maximum in the Case 1A of thickness 1 mm which is vulnerable when compared to Case 1E of thickness 5 mm which is best in terms of deformation (in Case 1 models). Hence, more the thickness of column increases, the deformation decreases**.**



Graph 4.1 Deformation Report for Case 1 (L/D = 15)

B. Deformation in Case 2 CFST Columns

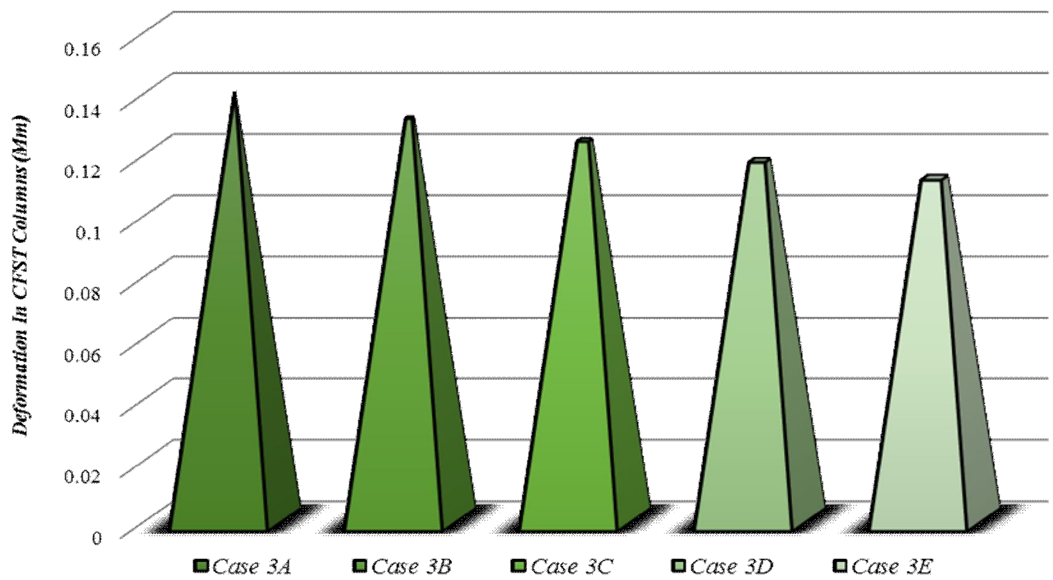
The descriptive detail of report is shown in Graph 4.2.The results are of Square CFST columns of CASE 2 of size 230 mm i.e. based on slenderness ratio equal to 20 where the value of deformation is such as 0.0984 mm (Case 2A) > 0.0931 mm (Case 2B) > 0.0886 mm (Case 2C) > 0.0842 mm (Case 2D) > 0.0804 mm (Case 2E). Therefore, deformation is maximum in the Case 2A of thickness 1 mm which is vulnerable when compared to Case 2E of thickness 5 mm which is best in terms of deformation (in Case 1 models). Hence, more the thickness of column increases, the deformation decreases.



Graph 4.2 Deformation Report for Case 2 (L/D = 20)

C. Deformation in Case 3 CFST Columns

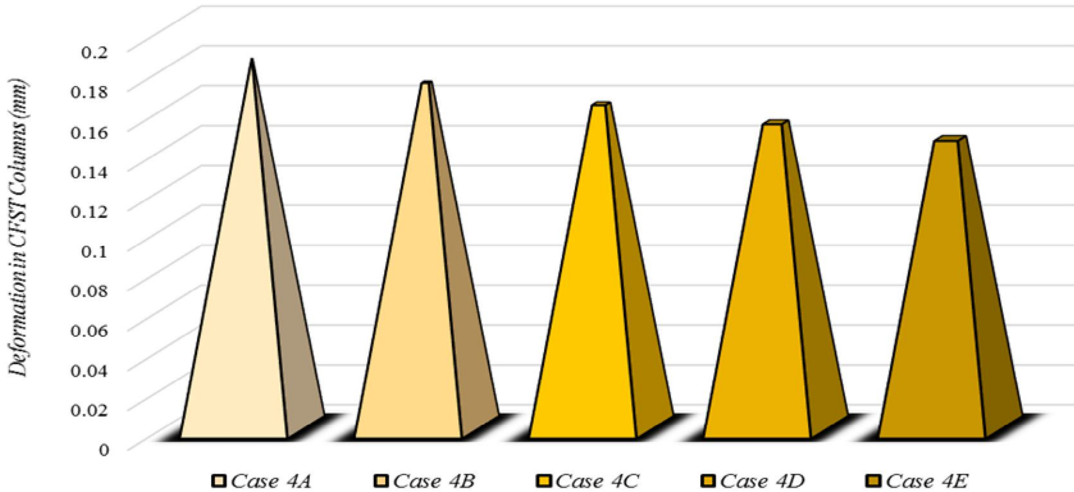
The output report is shown in Graph 4.3. According to the report the values of deformation is due to vertical loading assigned along X & Z directions. The results are of Square CFST columns of CASE 3 of size 200 mm i.e. based on slenderness ratio equal to 25 where the value of deformation is such as 0.14 mm (Case 3A) > 0.1315 mm (Case 3B) > 0.1241 mm (Case 3C) > 0.1175 mm (Case 3D) > 0.111 mm (Case 3E). Therefore, deformation is maximum in the Case 3A of thickness 1 mm which is vulnerable when compared to Case 3E of thickness 5 mm which is best in terms of deformation (in Case 2 models). Hence, Hence, more the thickness of column increases, the deformation decreases.



Graph 4.3 Deformation Report for Case 3 (L/D = 25)

D. Deformation in Case 4 CFST Columns

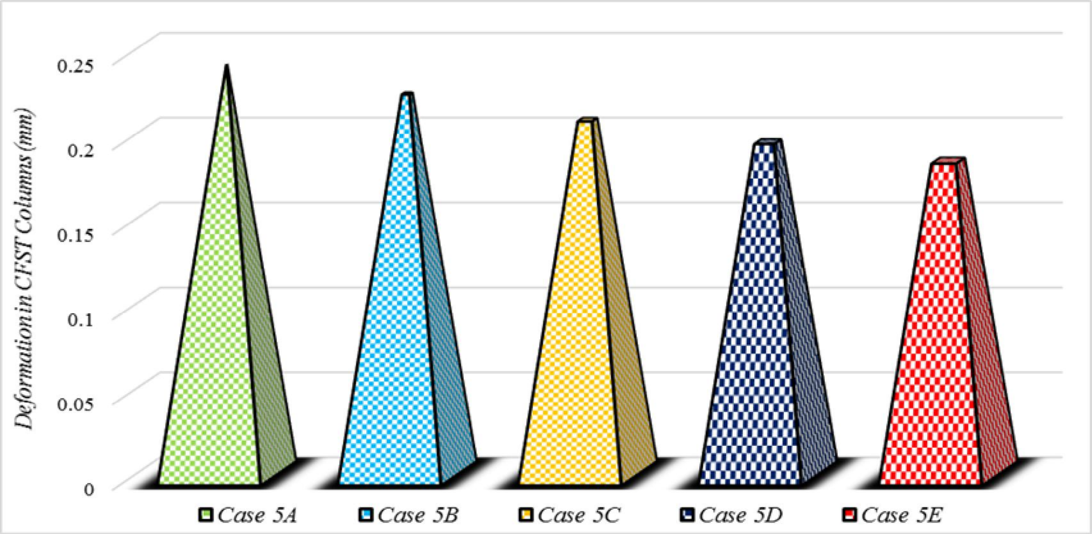
The output report is shown in Graph 4.4. According to the report the values of deformation is due to vertical loading assigned along X & Z directions. The results are of Square CFST columns of CASE 4 of size 180 mm i.e. based on slenderness ratio equal to 30 where the value of deformation is such as 0.1853 mm (Case 4A) > 0.173 mm (Case 4B) > 0.1623 mm (Case 4C) > 0.153 mm (Case 4D) > 0.145 mm (Case 4E). Therefore, deformation is maximum in the Case 4A of thickness 1 mm which is vulnerable when compared to Case 4E of thickness 5 mm which is best in terms of deformation (in Case 4 models). Hence, more the thickness of column increases, the deformation decreases.



Graph 4.4 Deformation Report for Case 4 (L/D = 30)

E. Deformation in Case 5 CFST Columns

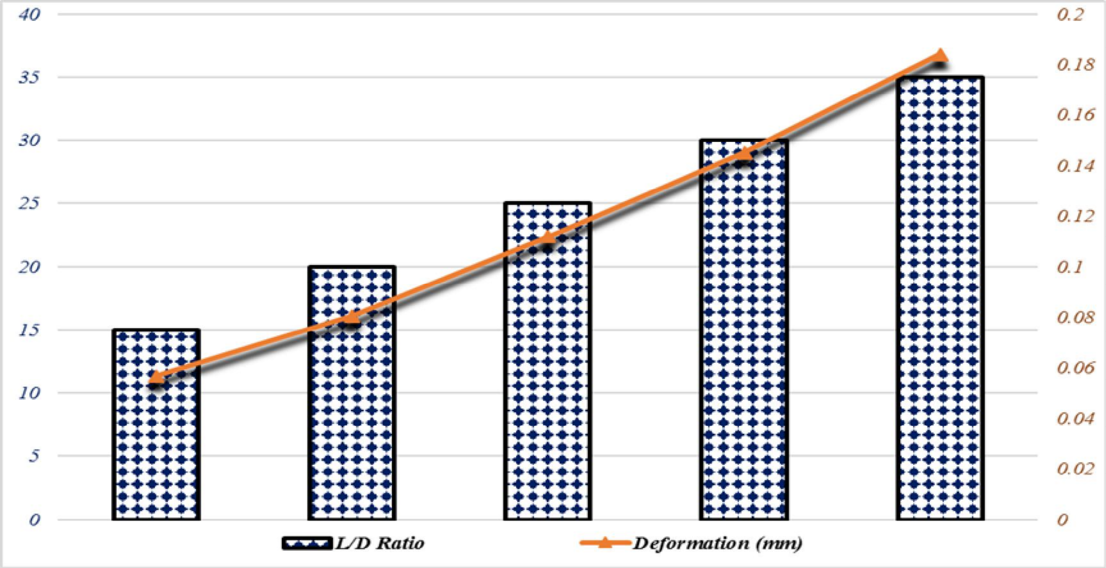
The output report is shown in Graph 4.5. The results are of CFST columns of CASE 5 of size 160 mm i.e. based on slenderness ratio equal to 35 where the value of deformation is such as 0.241 mm (Case 5A) > 0.2233 mm (Case 5B) > 0.2081 mm (Case 5C) > 0.195 mm (Case 5D) > 0.183 mm (Case 5E). Therefore, deformation is maximum in the Case 5A of thickness 1 mm which is vulnerable when compared to Case 5E of thickness 5 mm which is best in terms of deformation (in Case 5 models). Hence, more the thickness of column increases, the deformation decreases.



Graph 4.5 Deformation Report for Case 5 (L/D = 35)

F. Comparison Reports of Deformation Within CFST Column Cases

The comparison of deformation concludes that the efficient value of deformation for slenderness ratio (i.e. L/D =15) is been settled in Case 1E of thickness 5mm , minimum value for deformation for L/D =20 is in Case 2E, minimum value for deformation for L/D =25 is in Case 3E, minimum value for deformation for L/D =30 is in Case 4E & minimum value for deformation for L/D =35 is in Case 5E. Hence, its concluded that the thickness of CFST plays a major factor in deformation. The Efficient Values of Deform are as follows – 0.056 mm (Case 1E) < 0.080481 mm (Case 2E) < 0.11179 mm (Case 3E) < 0.145 mm (Case 4E) < 0.18397 mm (Case 5E) respectively. Hence, concluded that Greater the Slenderness ratio, Greater the Deformation in CFST Columns. Greater the Size of CFST column, Lesser the Deformation in steel tubes columns. The CFST Column Model of size 250 mm of thickness 5 mm at L/D = 15 is the best efficient & practically applicable column.



Graph 4.6 Comparison Report of Deformation Within Cases

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Volume 8 Issue III Mar 2020- Available at www.ijraset.com

G. Individual Reports of RCC Columns of Different Sizes

The RCC column is been designed according to the IS 456:2000 in which the total load is defined as full dead load and external or live load is same as considered for the previous CFST cases i.e. 30000 N. Thus, the RCC column is designed for all the section. Below are the following results of parameters such as Deformation due to Live load, Stress developed in the column and the Critical load of the columns calculated manually.

Table 4.1 Complete Parameter Report for all RCC Column Sections

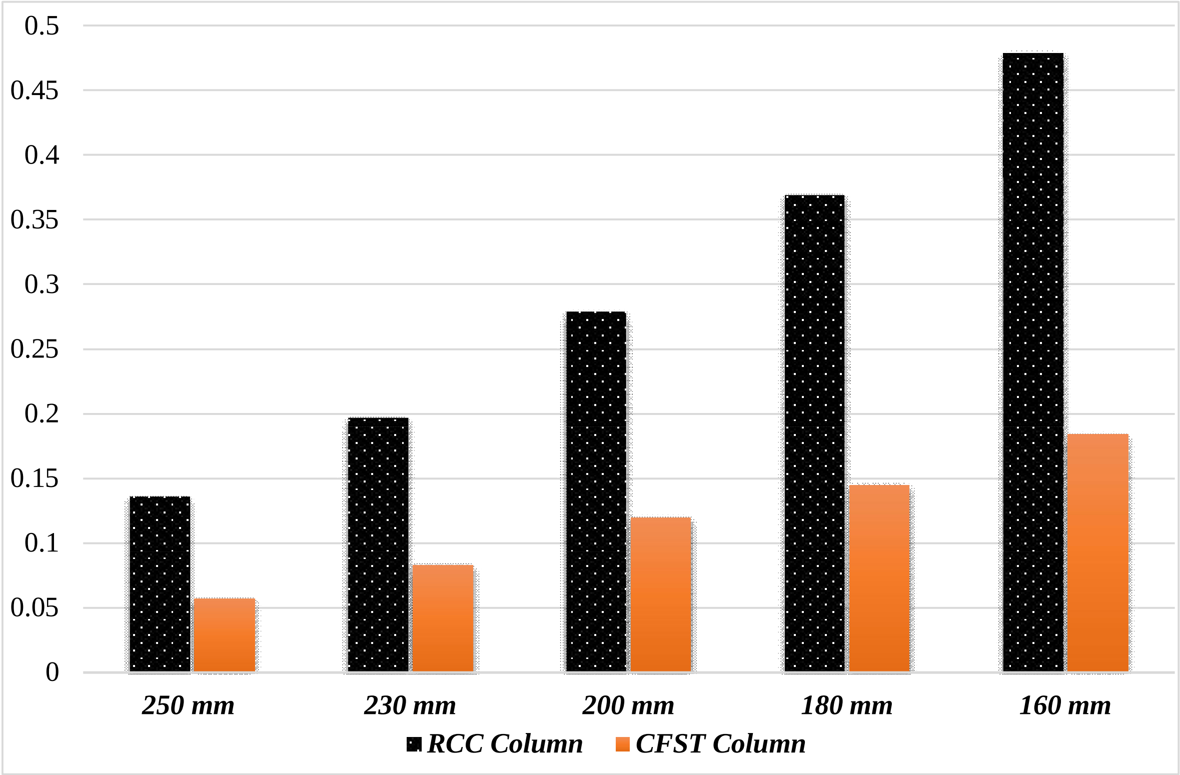
Different Sizes of RCC Column	Length (mm)	Deformation Report (mm)
250 mm	3750	0.136 mm
230 mm	4600	0.197 mm
200 mm	5000	0.279 mm
180 mm	5400	0.369 mm
160 mm	5600	0.479 mm

H. Comparison of Deformation Report Between RCC & CFST Columns

The comparison between the best cases of CFST columns in terms of deformation with the RCC columns results will definitely give the conclusion about the behavior of CFTS columns whether it can be used as product for the construction industry or which one is the efficient as per the considered sections. The output results show that the CFST columns is showing less deform in each particular size which are considered here, when compared to RCC column section which clearly shows that the CFST columns can be used for load bearing structure and are better than the conventional RCC Columns.

Table 4.2 Comparison of Deformation Result Between RCC & CFST Columns

Section Sizes	RCC Column Deformation Report (mm)	CFST Column Deformation Report (mm)
250 mm	0.136 mm	0.056751
230 mm	0.197 mm	0.080481
200 mm	0.279 mm	0.11179
180 mm	0.369 mm	0.1450
160 mm	0.479 mm	0.18397



Graph 4.7 Comparison of Deformation Result Between RCC & CFST Columns

V. CONCLUSIONS

A. It has been observed that Concrete Filled Steel Tubes of different thickness i.e. 1 to 5 mm of different sizes in which the steel tubes having thickness 1 mm shows much higher displacement or deformation and the CFST having thickness 5 mm shows lesser deform in columns. It is been concluded that the CFST columns having size 250 mm having deformation 0.056 mm is approximately 30 % more than 160mm having deformation value 0.080 mm. Making the conclusions that *Greater the Slenderness ratio, Lesser the Deformation in CFST Columns. Greater the Size of CFST column, Lesser the Deformation in steel tubes columns.*

B. Finally, above results indicate that, the best suitable or efficient CFST columns need to be checked with the conventional RCC columns of similar sizes to optimize whether the CFST can be treated as the regular product in place of RCC Columns. Later, After the CFST analysis then RCC columns report established to be compared with the steel tubes.

C. From reference Table 5.19, the RCC columns is analyzed in terms of parameters such as maximum deformation in 250 mm size i.e. 0.136 mm and minimum deform in 160 mm size i.e. 1.956 mm. Hence, here 160 mm size more vulnerable with comparison to 250 mm.

D. After the complete analysis on CFST, the efficient CFST columns sections is compared with RCC columns. The comparison of deformation here shows that the CFST columns are performing better in terms of deformation due to outside steel shell present in CFST. The result demonstrates that the deformation in RCC column of size 250 mm i.e. 0.136 mm is approximately 0.58 times more than the considered section in CFST columns 250 mm at 5 mm thickness i.e. 0.056 mm.

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