PARAMETRIC STUDY OF CONCRETE FILLED STEEL TUBE (CFST) AND CONCRETE FILLED FIBER REINFORCED TUBE (CFFT) COLUMNS

[1]Sweta Bariya, [2]V. R. Panchal, [3] D. R. Panchal,
[1]Post Graduate (Structural Engineering) student, M. S. Patel Department of Civil Engineering, Chandubhai S. Patel Institute of Technology, Charotar University of Science and Technology, Changa, Gujarat, India
[2]Professor and Head, M. S. Patel Department of Civil Engineering, Chandubhai S. Patel Institute of Technology, Charotar University of Science and Technology, Changa, Gujarat, India
[3]Assistant Professor, Faculty of Engineering & Technology, M. S. University, Vadodara, Gujarat, India

***IndexTerms* – Concrete filled steel tube, Concrete filled fiber tube.**

***ABSTRACT* :** This paper presents a Finite Element (FE) models of concrete filled steel tube (CFST) and concrete filled fiber reinforced tube (CFFT) short columns, which are developed using ABAQUS software. Different parameters such as *L/D* ratio of column, grade of steel, and shape of column like, circular, square and rectangle are compared in this analysis. The maximum axial load resistance of CFST and CFFT columns with different *L/D* ratio are also compared. The research shows that the percentage increase in axial-load carrying capacity is much higher in case of CFST column as compared to the CFFT column. Also, the shape of the column plays an important role on its ultimate load carrying capacity. Circular column provides a greater resistance as compared to square and rectangular columns. It also shows that the CFST columns are more ductile as compared to CFFT columns. Load carrying capacity of columns are also improved by adopting a higher grades of steel.

1. INTRODUCTION

Both concrete filled steel tube (CFST) and concrete filled fiber reinforced tube (CFFT) composite column are compression members. wherein outer steel and glass fiber reinforced polymer (GFRP) tube act as a permanent formwork respectively and concrete filled inside the tubes acts as a core in columns. In CFST and CFFT columns, both materials are combined in such a manner that the maximum advantage of both the materials are used effectively. It resulted in reduction of self-weight of the column as well as reduction in its cross-section area. Due to the development of confining effect on the core concrete in CFST and CFFT columns, the concrete acts as ductile material. Due to the external confinement, the strengthening capacities of the columns are effectively increased.

A research is limited to evaluate the behavior of CFST and CFFT composite columns. Experimental and analytical work have been carried out on CFST column to investigate the load carrying capacity [1]. Experimental and analytical study have been performed to observe the buckling response of concrete filled fiber tube (CFFT) columns [2]. Brief study has been carried out on square concrete section which is reinforced with GFRP bars which is placed with pultruded GFRP structural sections under differ loading conditions. A detailed study has been conducted to analyse the axial and flexural behavior of the column and comparison has been made with the analytical results with experimental one [3]. Research has been carried out on CFST stub columns and new finite element (FE) model has been developed in ABAQUS which is compared with the existing Finite Element model. The results of new FE model were compared with the collected test data, The comparison shows that new FE model is more accurate and precise for analytical study of CFST stub columns [4]. A concrete encased concrete filled fiber reinforced polymer tube (CCFT) composite column has been proposed. In CCFT column, fiber reinforced polymer (FRP) tube is filled by the concrete inside, concrete outer face is confined with grid of polymer and concrete cover. Total 16 nos. of columns were casted and analytical models also proposed to compare the analytical and experimental results [5]. The code is silent for the design of steel concrete composite columns. Thus, more study is required for composite columns in order to improve the codal provision as far as Indian standards are concerned [6].

2. Validation

In order to carry out the validation, study conducted by Tao et al. [4] on "Finite element modelling of concrete filled short column under axial compression" is opted. They have developed a new FE modelling of CFST column and compared the results with the existing FE models as well as experimental results.

Fig 1 shows the comparison of results obtained and results obtained by Tao et al. [4].

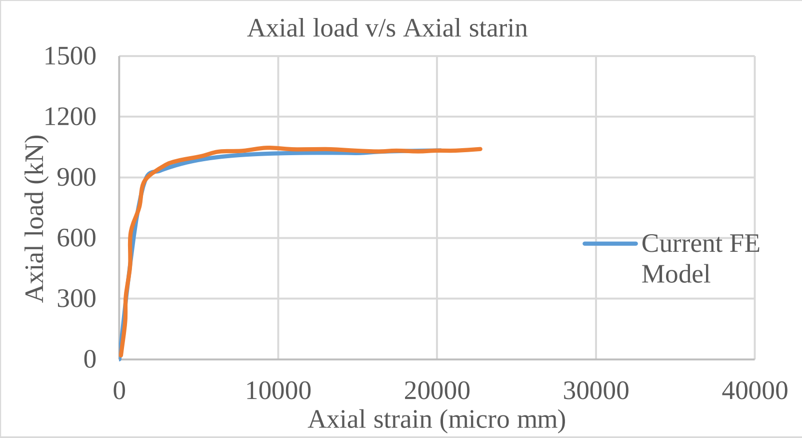


Fig 1. Axial load v/s Axial strain

3. Finite Element Modelling

3.1 General

The main objective of the study is to elaborate a FE model for CFST and CFFT short columns with different *L/D* ratio. The concrete core is modelled by using eight node brick element and the steel/FRP tubes are modelled using shell element in this analysis. For the interaction of concrete core and inner surface of steel/FRP tubes, the surface to surface connection is being taken in ABAQUS.

The Concrete and Steel tube material properties are given in Table 1.

Table 1. Material Properties

1	Concrete		
	Young's Modulus of Elasticity	25980.8	MPa
	Characteristic strength	27	MPa
	Poisson's Ratio	0.2	
2	Steel		
	Young's Modulus of Elasticity	2 x 10^5	MPa
	Yield strength	310	MPa
	Poisson's Ratio	0.3	

The FRP tube material properties are given in Table 2.

Table 2. FRP Material Properties

1	FRP Tubes		
	Young's Modulus of Elasticity (*x* direction)	13800	MPa
	Young's Modulus of Elasticity (*y* direction)	13800	MPa
	Young's Modulus of Elasticity (*z* direction)	17800	MPa
	Yield strength	63	MPa
	Poisson's Ratio	0.33	

The geometrical dimensions of CFST and CFFT columns are given in Table 3.

Table 3. Geometrical Properties of CFST and CFFT Columns

Sr. No.	Shape	Size (mm)	Thickness (mm)	*L/D* Ratio	Length (mm)
1	Circular	88.9 Dia.	4.8	3	267

				5	445
				7	623
2	Square	72 × 72	4.8	3	216
				5	360
				7	504
3	Rectangle	98 × 48	4.8	3	144
				5	240
				7	336

3.2 Boundary condition and Interaction

In a modelling part of short column, no need to include stiffener's or plate at ends for results. only bottom surface of the specimen is fixed against all degree of freedom, and displacement is allowed in vertical direction at the loaded end only. The rotational degrees of freedom for both the ends of specimen are not restrained. A friction coefficient between outer surface of concrete core and inner surface of steel/FRP tube is considered as 0.6 for this study.

3.3 Material modeling of concrete

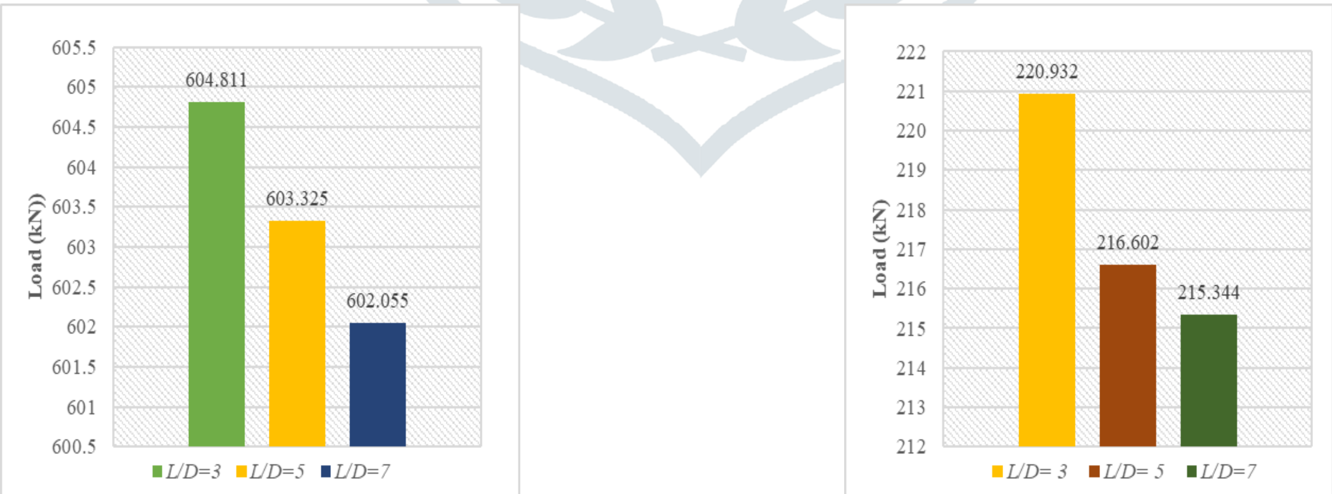
In CFST and CFFT columns the core of the concrete is confined by the steel tube and FRP tube, respectively under the axial compression. Due to the confinement effect it expands in lateral direction. This confinement helps to expand the overall durability and ductility of the column. It is presuming that due to confinement effect core concrete is in a tri-axial stress state and while steel is in biaxial state after the interaction between steel and concrete. FE analysis is a powerful and versatile technique that allows the composite action to be considered that provides an accurate and rational model accessible to analyse the behavior of concrete under passive confinement. Dilation angle for circular, square and rectangle columns are taken as 25.29, 20 and 40, respectively.

3.4 Material modelling of steel/FRP tubes

An elasto-plasticity model of steel/FRP tubes helps to achieve more accurate results on the descending side of the stress v/s strain curve. Therefore, elasto-plasticity model is used for both CFST and CFFT columns.

4. Results

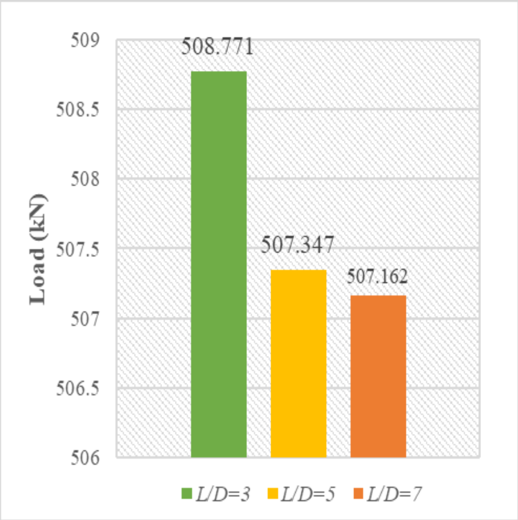
a) Comparison of Ultimate load for circular CFST and CFFT columns are shown in Fig 2.



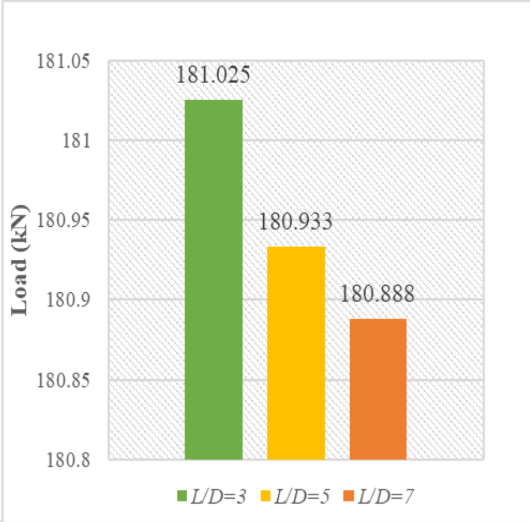
(a) Circular CFST column (b) Circular CFFT column

Fig 2. Ultimate Load of circular column with different *L/D* ratios

b) Comparison of Ultimate load for square CFST and CFFT columns are shown in Fig 3.



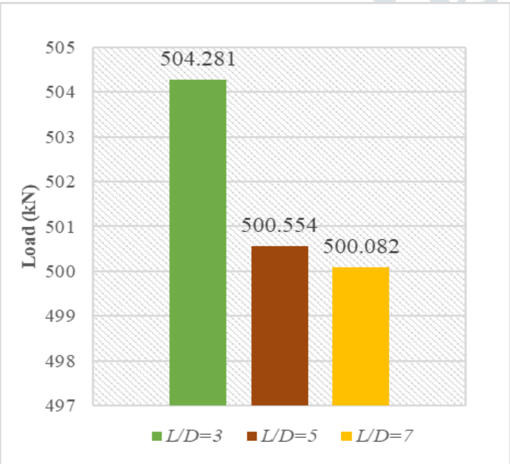
(a) Square CFST column



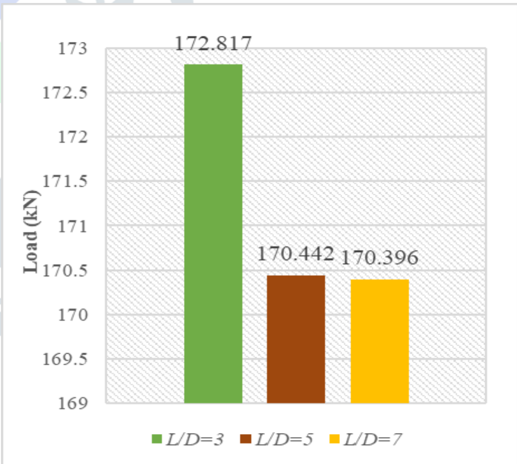
(b) Square CFFT column

Fig 3. Ultimate Load of square column with different *L/D* ratios

c) Comparison for Ultimate load for rectangle CFST and CFFT columns are shown in Fig 4.



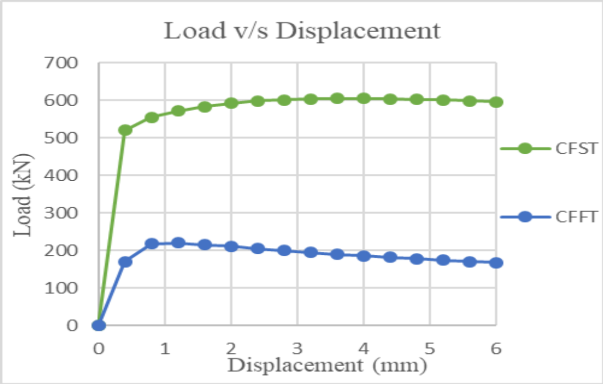
(a) Rectangle CFST column



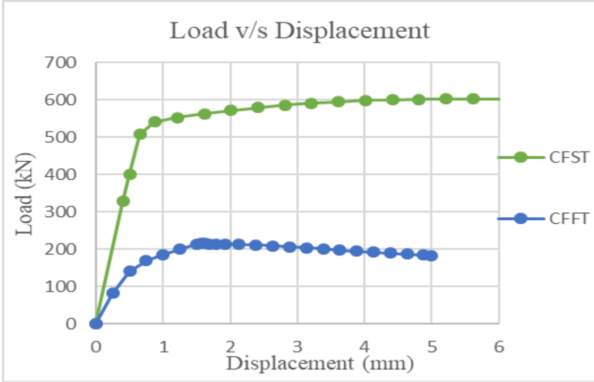
(b) Rectangle CFFT column

Fig 4. Ultimate Load of rectangle column with different *L/D* ratios

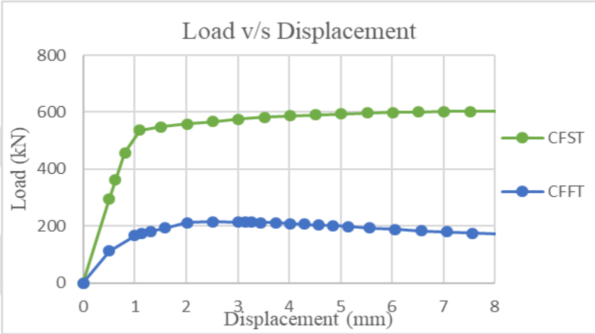
d) Load v/s Displacement results for circular CFST and CFFT columns are shown in Fig 5.



(a) CFST & CFFT (length 267 mm)



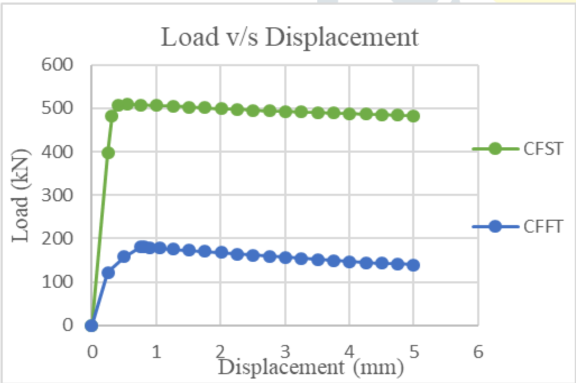
(b) CFST & CFFT (length 445 mm)



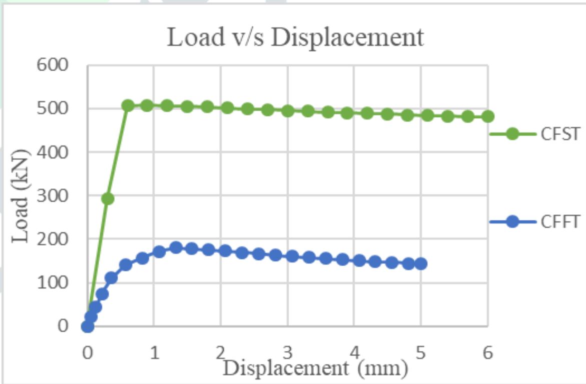
(c) CFST & CFFT (length 623 mm)

Fig 5. Load v/s Displacement for circular column

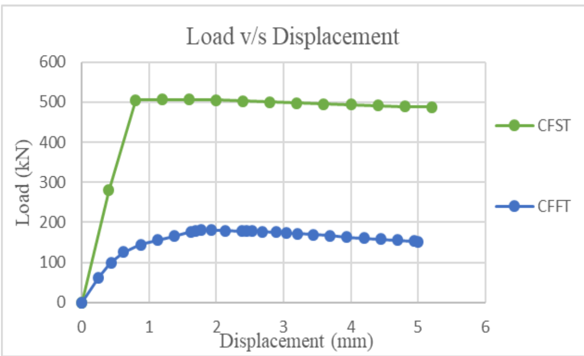
e) Load v/s Displacement results for square CFST and CFFT columns are shown in Fig 6.



(a) CFST & CFFT (length 216 mm)



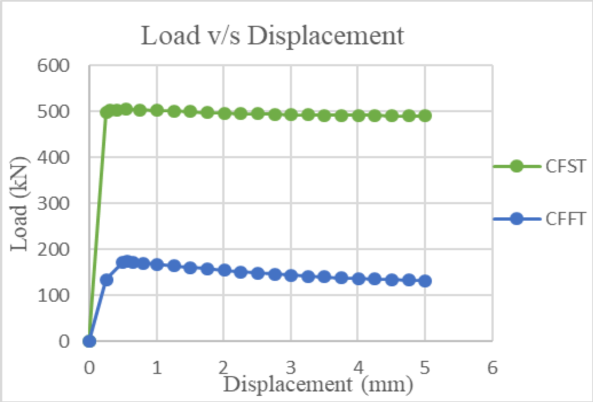
(b) CFST & CFFT (length 360 mm)



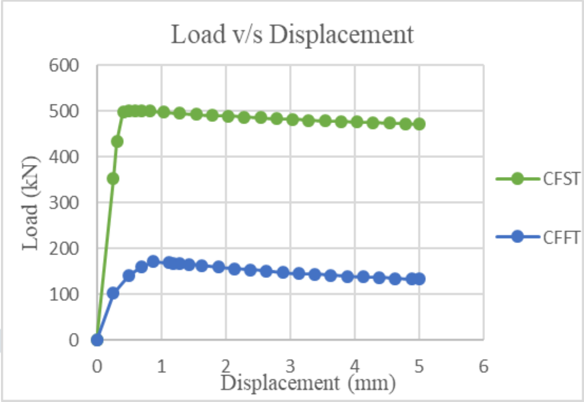
(c) CFST & CFFT (length 504 mm)

Fig 6. Load v/s Displacement for square column

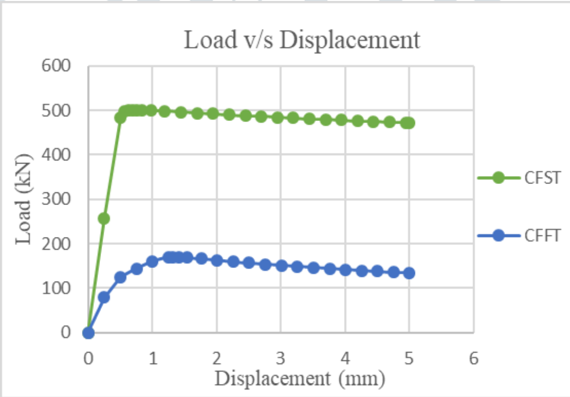
f) Load v/s Displacement results for rectangle CFST and CFFT columns are shown in Fig 7.



(a) CFST & CFST (length 144 mm)



(b) CFST & CFFT (length 240 mm)



(c) CFST & CFST (length 336 mm)

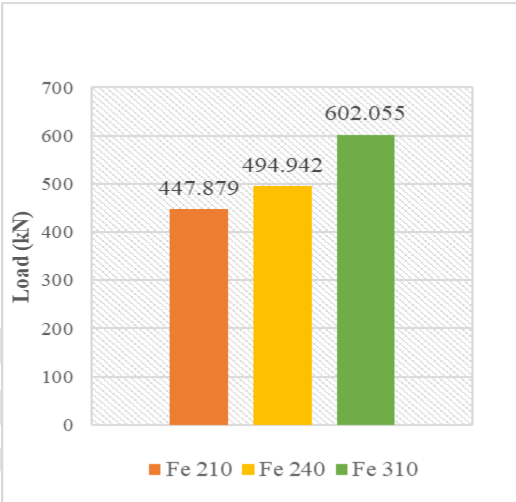
Fig 7. Load v/s Displacement for Rectangle column

Circular CFST and CFFT columns shows the highest load carrying capacity compared to square and rectangle columns. The reason being, the stress distribution in circular columns are even in all directions. Due to inertial effect, circular columns shows the excellent confinement of concrete. There is no stress concentration in circular column.

g) Ultimate Load results for circular CFST and CFFT columns with different steel grades shown in Fig 8.

(a) CFST column (length 267 mm)

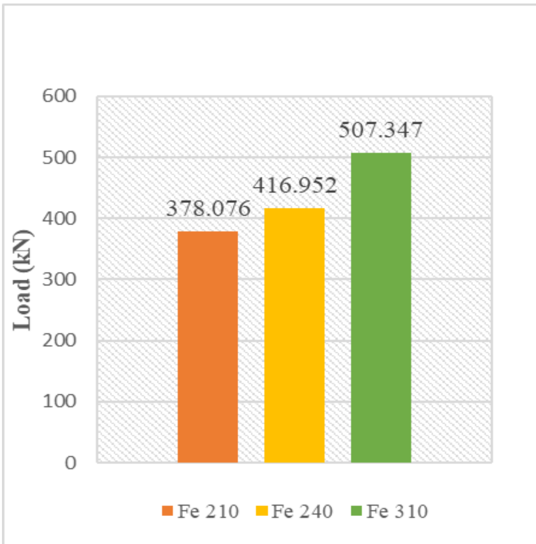
(b) CFST column (length 445 mm)



(c) CFST column (length 623 mm)

Fig 8. CFST circular column results of different steel grades

h) Ultimate Load results for square CFST columns with different steel grades shown in Fig 9.

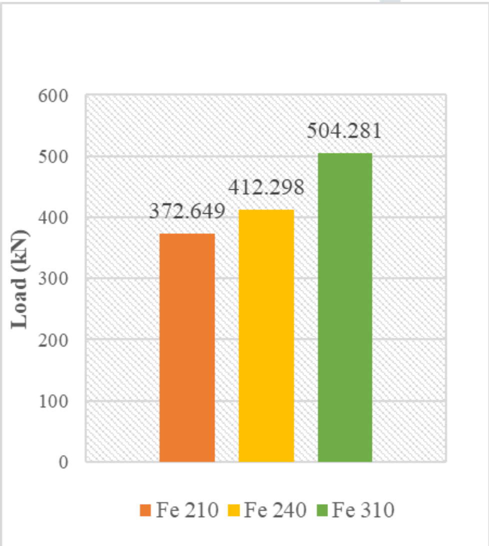


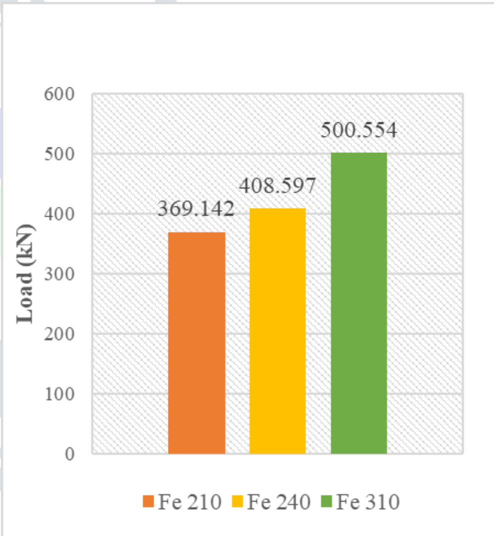
(a) CFST column (length 216 mm) (b) CFST column (length 360 mm)

(c) CFST column (length 504 mm)

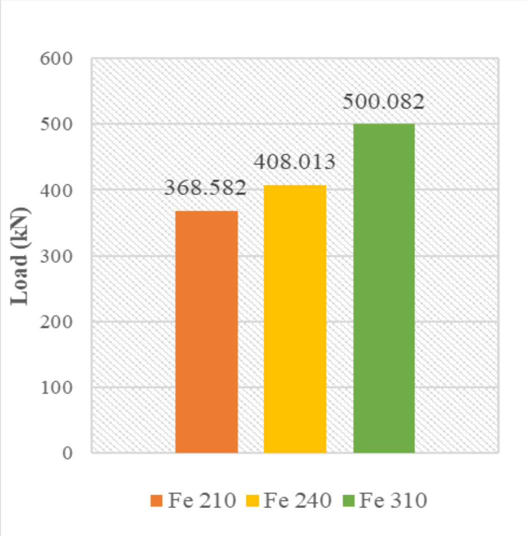
Fig 9. CFST square column results of different steel grades

i) Ultimate Load results for rectangle CFST and CFFT columns with different steel grades shown in Fig 10.





(a) CFST column (length 144 mm) (b) CFST column (length 240 mm)



(c) CFST column (length 336 mm)

Fig 10. CFST rectangle column results of different steel grades

5. Ductility Index

From the load-displacement relationship, Ductility Index can be determined. The ductility index is the ratio of deflection at the ultimate state of column to the deflection at the yielding point of the column.

The ductility index results of CFST and CFFT columns are given in Table 4.

Table 4 Ductility Index of CFST and CFFT Columns

Sr. No.	Shape	Material	Size (mm)	*L/D* Ratio	Ductility Index
1	Circular	CFST	88.9 Dia.	3	9
				5	8.63
				7	7.84
2	Circular	CFFT	88.9 Dia.	3	1.33
				5	1.25
				7	1.16
3	Square	CFST	72 × 72	3	1.52
				5	1.46
				7	1.45
4	Square	CFFT	72 × 72	3	1.5
				5	1.06
				7	1.05
5	Rectangle	CFST	98 × 48	3	1.75
				5	1.46
				7	1.22
6	Rectangle	CFFT	98 × 48	3	1.13
				5	1.04
				7	1

6. Conclusions

The load carrying capacity of different shapes of CFST and CFFT columns are investigated. The effect of different *L/D* ratios, different steel grades and different shapes on load carrying capacity of the columns is studied in detail.

Based on the results obtained in the present study, the following conclusions can be drawn:

- Circular CFST and CFFT column shows the highest load carrying capacity compared to square and rectangular column for all *L/D* ratios. Rectangular CFST column has the lowest result as compared to square and circular.
- The maximum displacement of columns increases with increase in *L/D* ratio for both CFST and CFFT columns.
- CFST columns are more ductile as compared to CFFT columns.
- CFST column provides 175% more strength then the CFFT columns due to its high elasticity and yield strength.
- The yield of confined concrete in case of CFFT column occur earlier than CFST column. The reason being FRP tubes show brittle behavior and steel tubes are itself a ductile in nature.
- Also, load carrying capacity of CFST columns can be enhanced by using higher grades of steel tubes.

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