A Parametric study on Core shapes of a Concrete-Encased CFST Column

Akshay K V, Aswathy P

Abstract— The paper presents finite element analysis of a Concrete-Encased CFST (Concrete Filled Steel Tube) column. A Concrete-encased CFST consists of a CFST core embedded inside the reinforced concrete. The CFST core utilizes high strength concrete to provide enough axial compressive strength, while the peripheral RC encasement utilizes normal or high strength concrete to resist most of the lateral loads. In this study, different shapes of steel tubes are used to replace the inner core of the composite column and are modeled and analyzed using ANSYS 16.1. All the analytical models have been subjected to axial, lateral and eccentric loadings. Different core shapes were subjected to all the three loading conditions and their behavior in terms of total deformation and force reactions were discussed. After studying the behaviour of different models of composite columns the efficient model was suggested for its better behaviour.

Index Terms— Ansys 16.1, Axial loading, Concrete-encased CFST column, Core shapes, Eccentric loading, Finite element analysis, Force reaction, Lateral loading, Total deformation.

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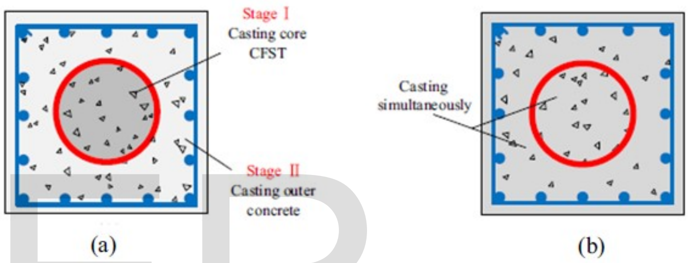
1 INTRODUCTION

Concrete-encased CFST (Concrete Filled Steel Tubes) are a kind of composite member consisting of an inner CFST core component and an outer reinforced concrete (RC) component given as an encasement. A typical CFST column has been widely used owing to their excellent composite action. However, due to their complicated joints connection, local buckling and poor fire-resistant performance of CFST columns, a novel type of composite column, named as steel tube-reinforced concrete (ST-RC) column, has gained popularity in China. Generally, the CFST core utilizes high strength concrete to provide enough axial compressive strength, while the peripheral RC encasement utilizes normal or high strength concrete to resist most of the lateral load [1].

When compared with conventional RC columns, the concrete-encased CFST (CE-CFST) columns have higher compressive strength, ductility and deformation capacity due to the presence of inner CFST. When compared with CFST columns, the CE-CFST columns have easier joints connection, better fire-resistant performance, and less quantity of steel usage. Apart from these advantages, faster construction speed is expected since the inner CFST column can be erected first to bear the construction load. In this type, the CFST core is erected first to bear the calculated load of the building structure upto the desired floor. Then the rebar and the concrete outside the steel tube are casted upward from the bottom story. Then the process is repeated until it reaches the full story height. The inner steel tube also acts as a formwork for the inner high strength concrete. This type of construction is known as staged construction process and the process where it is casted simultaneously is known as Non- staged construction process, as shown in Fig.1.



(a) (b)

Fig. 1. Typical Concrete-encased CFST column. (a) Staged construction (b) Non-staged construction

2 OBJECTIVES

- To study the behavior of CE-CFST columns with different core shapes.
- To study the behavior of inner core with respect to different loading conditions.
- Comparing the result and to suggest an efficient model for its better behaviour

3 LITERATURE REVIEW

Huang Yuan, Huan-Peng Hong, Huang Deng, Yu Bai (2018) conducted a study of “Displacement ductility of staged construction-steel tube-reinforced concrete columns”. The mechanism of two types of ST-RC columns in a 15 storey building was explained. An FE model was proposed for staged construction of ST-RC columns. The proposed FE model was able to predict the lateral stiffness, strength and deformation capacities. To improve the overall deformation capacity of the ST-RC columns, the key is to ensure the inner CFST and peripheral concrete encasement cooperate with one another to exert their respective advantages.

Lin-Hai Han, Yu-Feng An (2014) conducted a study on “Performance of concrete-encased CFST stub columns under axial compression”. A finite element analysis (FEA) modeling is developed to analyze the behavior of the composite columns. The material nonlinearity and the interaction between concrete and steel tube are considered. Full range analysis on the load versus deformation relations of the concrete-encased

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CFST stub columns is presented.

Lin-Hai Han, Fei-Yu Liao, Zhong Tao, Zhe Hong (2009) conducted a study on"Performance of concrete filled steel tube reinforced concrete columns subjected to cyclic bending". This paper reports nine test results of ST-RC columns, which were tested under constant axial load and cyclically increasing flexural loading. Axial load level and cross-sections were varied. Strength, ductility, stiffness and energy dissipation was investigated ST-RC columns are found to be showing good seismic performance.

Qing-Xin Ren, Lin-Hai Han, Chao Hou, Zhong Tao, Shuai Li (2017) carried out a study on "Concrete-encased CFST columns under combined compression and torsion: Experimental investigation". The composite columns are subjected to combined compression and torsion under earthquake loads. A total of 26 tests were conducted on three types of specimens, i.e., concrete-encased CFST columns, hollow reinforced concrete (RC) columns without inner CFST components and conventional CFST columns. The tested concrete-encased CFST columns under combined compression and torsion behaved in a ductile manner owing to the existence of the inner CFST component.

D. R. Panchal, V. P. Sheta (2016) studied about "Experimental study on circular and square concrete filled steel tube columns subjected to axial compression loads". This paper investigates the behaviour of concentrically axially loaded circular and square high strength steel columns filled with different grades (M20, M30 & M40 etc.) of concrete. Performance indices such as Ductility index, Strength factor and Concrete contribution Ratio were also evaluated and compared. From the results, it has been noted that square columns have higher axial capacity. But the Ductility index for circular columns is better than square columns.

Qing-Xin Ren, Lin-Hai Han, Chao Hou, You-Xing Hua (2017) conducted a study of "Experimental behaviour of tapered CFST columns under combined compression and bending". This paper researches on the structural performance of tapered composite columns under combined compression and bending. The test parameters included sectional type, tapered angle, slenderness ratio and load eccentricity. It is found that Tapered CFST columns behaved in a ductile manner when subjected to combined compression and bending.

L. H. Hana, D. Y. Maa, K. Zhoua (2018) conducted a study on "Concrete-encased CFST structures: behaviour and application". This paper initially reviews the recent research on concrete-encased CFST Structures. The major research findings on bond performance, static performance, dynamic performance and fire resistance are presented. This paper also outlines some construction considerations, such as the utilization of materials, the fabrication of the steel tube, and the methods of casting the inner and outer concrete some typical practical projects utilizing concrete-encased CFST members are presented and reviewed.

4 FINITE ELEMENT ANALYSIS

A non-linear static analysis was done in ANSYS workbench 16.1 software for the CE-CFST columns. A column specimen of 660mm height and a width of 220mm by 200mm were taken for the modeling. The FE model mainly includes four components, namely in-filled and peripheral concrete, steel tube and reinforcement steel bars. Both in-fill and peripheral concrete were modeled by solid65. The longitudinal and transverse reinforcement bars were modeled using Beam188 element. And finally the Steel tube was modeled using solid186. A sample column specimen is given in Fig.2.

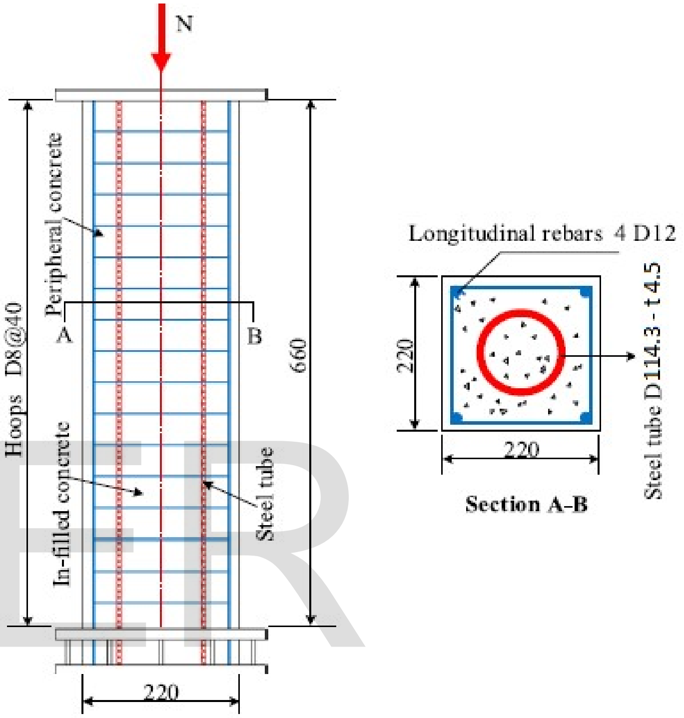

Fig. 2. A typical column specimen and section

The in-fill concrete of M100 grade was provided and a grade of M40 for peripheral concrete. The Elastic modulus of concrete, Ec, was taken as $5000\sqrt{fc}$ (fc denotes the concrete compressive strength) according to Indian Standard. The tensile strength of concrete was taken as $0.7\sqrt{fc}$. The poisson's ratio of concrete was taken as 0.15.

The Longitudinal and Transverse reinforcement bars of Fe415 were taken. The inner steel tube of yield strength 250MPa was used. The poisson's ratio and the Elastic modulus Es of the steel were assumed to be 0.3 and 206 GPa, respectively. The material properties of the same are given in Table 1. The contact was simulated by the coulomb friction model, the friction coefficient used in the analysis was 0.6. The mesh convergence studies were conducted to determine the optimal FE mesh that can provide both relatively accurate solution and low computational time, the approximate mesh is shown in Fig.3. The circular core is taken as the base specimen shown in Fig.4.

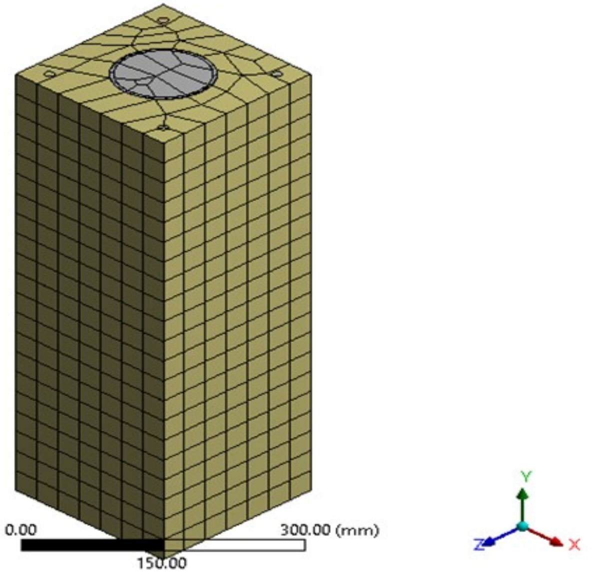

Fig. 3. A typical column meshing

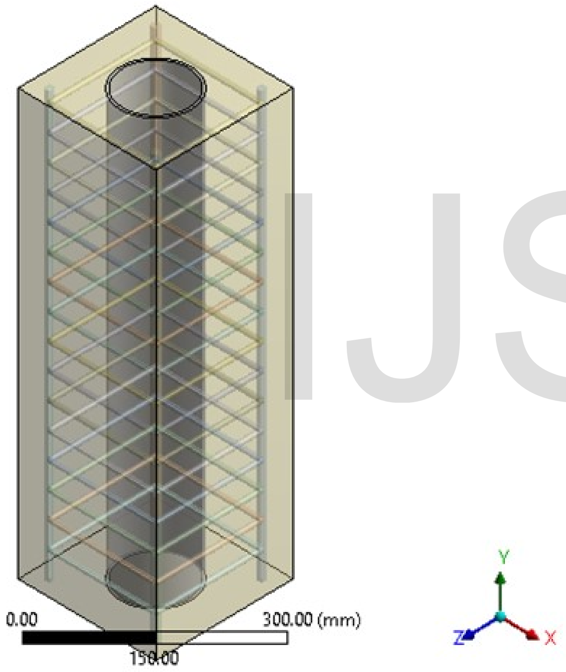

Fig. 4. A structural model of the base column

Table 1: Material properties

$f_{c,out}$ (MPa)	$f_{c,in}$ (MPa)	f_{ys} (MPa)	f_{yl} (MPa)	f_{yv} (MPa)	S (mm)
40	100	250	415	415	40

Note: $f_{c,out}$, $f_{c,in}$ denote the compressive strength of outer and inner ccrete,respectively; f_{ys}, f_{yl}, f_{yv} denote the yield strength of steel tube, longitudinal bar and transverse bar, respectively.

A total of six specimens were modeled by changing the core shape of the steel tube. The models are circular core (C CORE), Square core (S CORE), Non-prismatic tapered circular core (C CORE NP), Non-prismatic tapered square core (S CORE NP), Non-prismatic barrel shaped circular core (C CORE NP2) and Non-prismatic barrel shaped square core (S CORE NP2). The volume of the inner concrete core inside the steel tube is kept constant. The size details are given on Table 2 and the figures are provided in Fig.5.

Table 2: Geometric specifications of models

Specimen Label	Steel tube Dia/Length (mm)			Thickness (mm)
	Top section	Middle section	Bottom section	
C CORE	114.3	-	114.3	4.5
S CORE	101.3	-	101.3	4
C CORE NP	80	-	128.6	4.5
S CORE NP	75	-	110.5	4
C CORE NP2	80	128.6	80	4.5
S CORE NP2	75	110.5	75	4

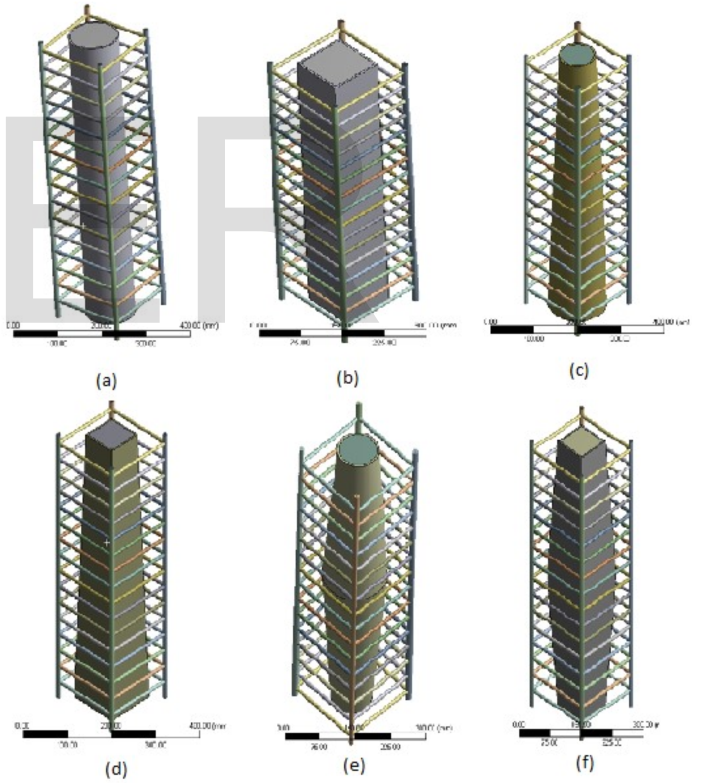

Fig. 5. (a) C CORE (b) S CORE (c) C CORE NP (d) S CORE NP (e) C CORE NP2 (f) S CORE NP2

4.1 Supports and Loading Conditions

The bottom surface of the column was restrained against all degrees of freedom. A total of three loading conditions were applied on the modeled six Concrete-encased CFST columns. The three loading conditions were Axial loading, Lateral loading and Eccentric loading.

The axial loading was applied from the top surface by restraining the bottom surface against all degrees of freedom. The lateral loading was applied from one of the side axis because of the symmetry of the structure. The eccentric loading was done similar to that of axial loading but at an eccentricity of 75% from the centre of the column (i.e from 82.5mm from the centre). All the loadings were done by a controlled displacement.

5 ANALYSIS RESULTS

5.1 Axial Loading

From the study of Axial loading on all the specimens, the S CORE showed better axial capacity. The ultimate axial load taken by the specimens are shown in Table 3.

When concidering the C CORE as the base model, the S CORE showed an increase of 0.51 percentage, whereas all other models showed a decrease of 4.66%, 3.30%, 3.00% and 2.81% of C CORE NP, S CORE NP, C CORE NP2 and S CORE NP2 respectively.

Table 3: Axial loading

Loading	Models	Load(KN)
Axial	C CORE	3073.5
	S CORE	3089.1
	C CORE NP	2930.4
	S CORE NP	2972
	C CORE NP2	2981
	S CORE NP2	2987

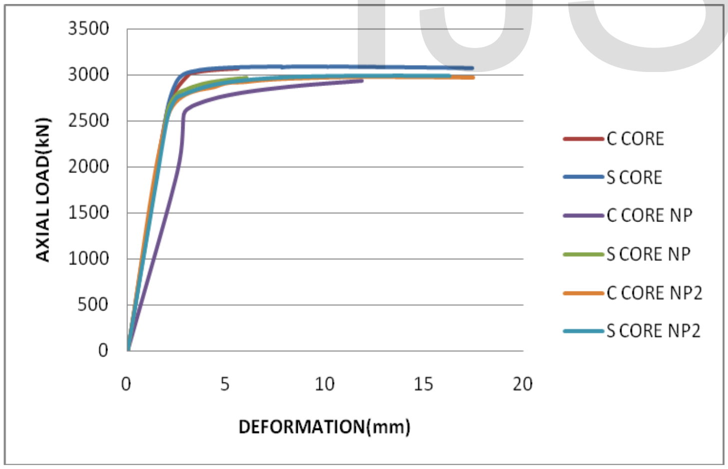

Fig. 6. The Axial load versus Deformation graph

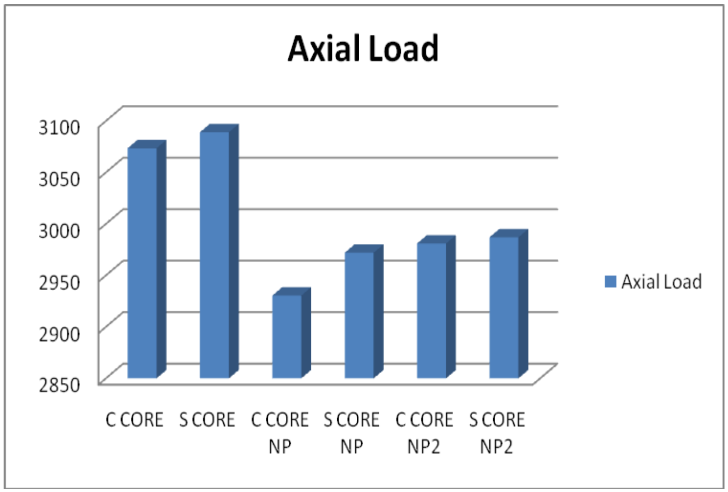

Fig. 7. The Axial load comparison diagram

5.2 Lateral Loading

From the study of Lateral loading on all the specimens, the S CORE showed much higher lateral resistance than the other models. The ultimate lateral load taken by the specimens are shown in Table 4.

The S CORE showed an increase of 49.05 percentage, whereas all other models showed 5.46%, 18.36%, 1.22% and -9.57% of C CORE NP, S CORE NP, C CORE NP2 and S CORE NP2 respectively when compared with the C CORE.

Table 4: Lateral loading

Loading	Models	Load(KN)
Lateral	C CORE	293.35
	S CORE	437.24
	C CORE NP	309.37
	S CORE NP	347.23
	C CORE NP2	296.93
	S CORE NP2	265.28

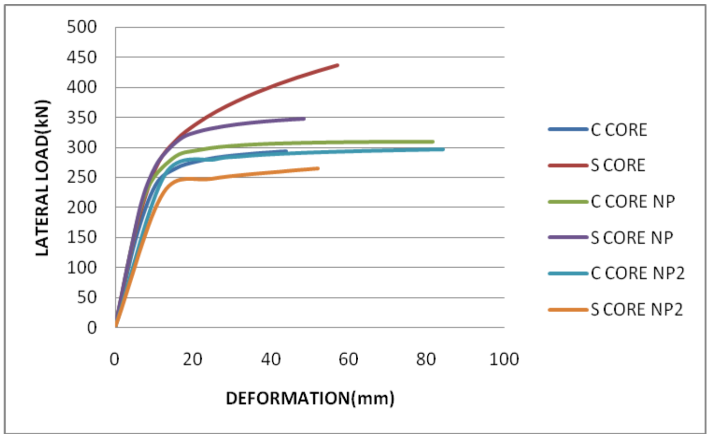

Fig. 8. The Lateral load versus Deformation graph

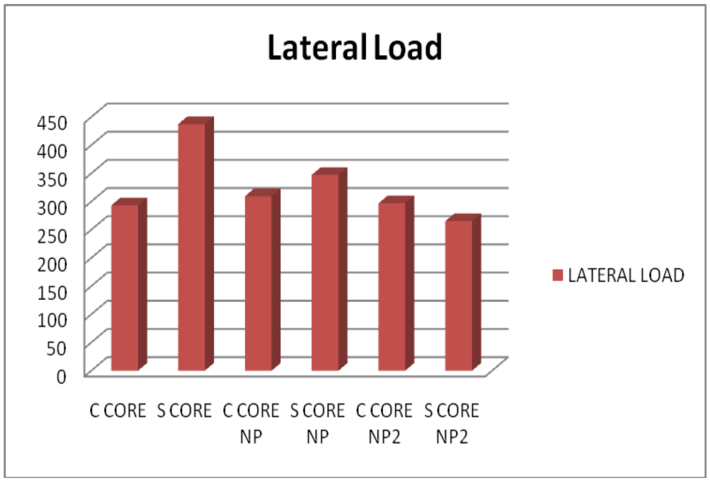

Fig. 9. The Lateral load comparison diagram

5.3 Eccentric Loading

From the study of Eccentric loading at 75% from the centre on all the specimens, the S CORE NP showed higher load carrying capacity than the other models. The ultimate load taken by the specimens are shown in Table 5.

The S CORE NP showed an increase of 275.3 percentage, whereas all other models showed 3.16%, 270.08%, 255.99% and 254.18% of S CORE, C CORE NP, C CORE NP2 and S CORE NP2 respectively when compared with the C CORE.

Table 5: Eccentric loading

Loading	Models	Load(KN)
Eccentric	C CORE	341.3
	S CORE	352.09
	C CORE NP	1263.1
	S CORE NP	1280.9
	C CORE NP2	1215
	S CORE NP2	1208.8

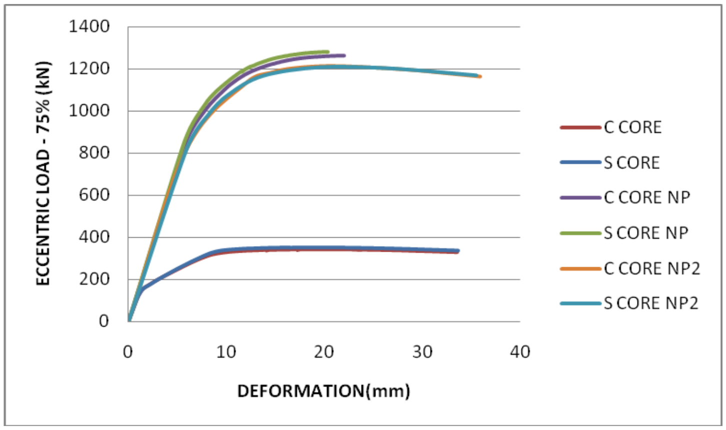

Fig. 10. The Eccentric load versus Deformation graph

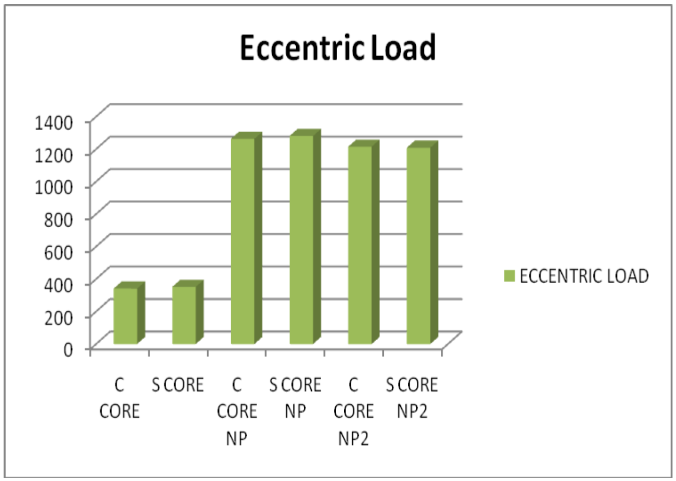

Fig. 11. The Eccentric load comparison diagram

6 CONCLUSIONS

By providing Concrete-encased CFST column instead of regular RC column or CFST column, the compressive strength, ductility and deformation capacity is increased. The main advantages are faster erection, easier joints connection, better fire-resistant performance and less wuantity of steel usage. Maintaining the same volume of inner concrete, the following conclusions are made according to the different loading conditions.

- Columns are a compression member. When applying an axial load on the different specimens, it was found that the S CORE showed an increase of 0.51% ultimate load capacity when compared with the base model of circular core section. In cases where only axial loading is the major factor, the S CORE can be used.
- The application of lateral load on the specimens showed that the S CORE has an increased loading capacity of 49.05% when compared to the base model. The lateral resisting capacity indirectly shows the seismic performance of the column, Thus the S CORE has much bewtter seismic performance when compared with the other 5 models.
- Sometimes the columns are faced with eccentric loading when the transfer of load is not uniform like in the case of a cantilever beam connected to the column end. In such cases the columns has to be designed with respect to the eccentric loading condition. Here, the S CORE NP showed 275.3% increase in ultimate loading.This is due to the fact that the tapered section distributes the load to a much higher area.

REFERENCES

[1] Huang Yuan, Huan-Peng Hong, Huang Deng, Yu Bai, "Displacement ductility of staged construction-steel tube-reinforced concrete columns", Construction and Building Materials 188 ,1137–1148, 2018

[2] L. H. Han, D. Y. Ma, K. Zhou, "Concrete-encased CFST structures: behaviour and application", Universitat Politècnica de València, València, Spain, June 27-29, 2018

[3] Lin-Hai Han , Yu-Feng An, Charles Roeder, "Performance of concrete-encased CFST stub columns under axial compression", Structures 3 ,211–226, 2015

[4] Yu-Feng An, Lin-Hai Han, "Behaviour of concrete-encased CFST columns under combined compression and bending", Journal of Constructional Steel Research 101,314–330, 2014

[5] Xiaodong Ji, Hongzhen Kang, Xingchen Chen, Jiaru Qian, "Seismic behavior and strength capacity of steel tube-reinforced concrete composite columns", Earthquake Engng Struct. Dyn, 2013

[6] Xiaodong Ji, Mingliang Zhang, Hongzhen Kang, Jiaru Qian, Hongsong Hu, "Effect of cumulative seismic damage to steel tube-reinforced concrete composite columns", Earthquakes and Structures, Vol. 7, No. 2 ,179-199, 2014

[7] Qing-Xin Ren a, Lin-Hai Han b, Chao Houc, You-Xing Hua, "Experimental behaviour of tapered CFST columns under combined compression and bending", Journal of Constructional Steel Research 128 (2017) 39–52, 2017

[8] D. R. Pancha, V. P. Sheta, "Experimental study on circular and square concrete filled steel tube columns subjected to axial compression loads", International Journal of Research in Engineering and Technology, Volume: 05 Issue: 05, 2016

[9] Mojtaba Farahi, Amin Heidarpour , Xiao-Ling Zhao , Riadh Al-Mahaidi, "Compressive behaviour of concrete-filled double-skin sections consisting of corrugated plates", Engineering Structures 111 ,467–477, 2016

[10] Lin-Hai Han, Fei-Yu Liao, Zhong Tao, Zhe Hong, "Performance of concrete filled steel tube reinforced concrete columns subjected to cyclic bending", Journal of Constructional Steel Research 65 ,1607–1616, 2009

[11] Bhushan H. Patil, P. M. Mohite, "Parametric Study of Square Concrete Filled Steel Tube Columns Subjected To Concentric Loading", Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 8(Version 1), pp.109-112, 2014