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Analytical Performance of Hybrid Columns with CFST using Ansys Workbench

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Abstract— *This study examines the performance of a new type of composite column: Rectangular CFST-shaped columns comprising concrete-filled steel tubes. The fundamental structural behaviour of the Rectangular CFST columns is discussed in this study. Rectangular CFST columns were analytically studied under axial loading, lateral loading, load acting angle 30° (with respect to horizontal) and load acting angle 60° (with respect to horizontal). The analytical results were used to assess the load-deformation relationship. ANSYS Workbench software is used for this study. Based on the finite-element model, parametric studies were conducted to investigate the effects of the slenderness ratio, steel and concrete strengths. This paper investigates nonlinear static analysis of rectangular concrete filled steel tube (long column) with vertical steel plate, perfobond steel plate and lacing bar. The CFST columns can provide high strength and fire resistance, favorable ductility and large energy absorption capacity compared with the reinforced concrete structures. High rise buildings deep underground tunnels bridges and towers are some examples of structures in which CFST columns are deployed as main load carrying member*.

Keywords— *Rectangular CFST with vertical steel plate, perfobond steel plate and lacing bar, ANSYS Workbench*.

I. INTRODUCTION

Concrete-encased concrete filled steel tube (CFST) is a type of steel concrete composite section, which consists of inner concrete filled steel tube (CFST) and outer reinforced concrete (RC). The CFST columns can provide high strength and fire resistance, favorable ductility and large energy absorption capacity compared with the reinforced concrete structures. High rise buildings deep underground tunnels bridges and towers are some examples of structures in which CFST columns are deployed as main load carrying member. 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.

The CFST column has many advantages compared with ordinary steel or reinforced concrete systems. The main advantages are listed below.

- Interaction between steel tube and concrete - Local buckling of the steel tube is delayed, and the strength deterioration after the local buckling is moderated, both due to the restraining effect of the concrete. On the other hand, the strength of the concrete is increased due to the confining effect provided by the steel tube, and the strength deterioration is not very severe, because concrete spalling is prevented by the tube.
- Drying shrinkage and creep of the concrete are much smaller than in ordinary reinforced concrete. It has a large absorption capacity.
- Cross-sectional properties - The steel ratio in the CFT cross section is much larger than in reinforced concrete and concrete-encased steel cross sections. The steel of the CFT section is well plasticized under bending because it is located outside the section.
- Construction efficiency - Labour for forms and reinforcing bars is omitted, and concrete casting is done by Tremie tube or the pump-up method. This efficiency leads to a cleaner construction site and a reduction in manpower, construction cost, and project length.
- Fire resistance - Concrete improves fire resistance so that fireproof material can be reduced or omitted.
- Cost performance - Because of the merits listed above, better cost performance is obtained by replacing a steel structure with a CFT structure.
- Ecology - The environmental burden can be reduced by omitting the formwork and by reusing steel tubes and using high-quality concrete with recycled aggregates.

II. SCOPE AND OBJECTIVES OF THE STUDY

The CFST columns can provide high strength and fire resistance, favorable ductility and large energy absorption capacity compared with the reinforced concrete structures. Rectangular concrete filled steel tube (long column) with vertical steel plate, lacing bar and perfobond steel plate.M30 grade of concrete and fe250 steel is used. The size of steel tube is 100 x 100 x 5mm. Height of column 4000mm.Ansys Workbench software is used for the modeling and analysis. The main objectives of this study are follows.

- Study of nonlinear static analysis of rectangular concrete filled steel tube (long column) with lacing, perfobond steel plate and vertical steel plate using Ansys Workbench software.
- To compare the axial capacity of rectangular CFST with vertical steel plate, perfobond steel plate and lacing bar.
- To compare strength of column under axial loading, lateral loading, load acting angle 30° (with respect to horizontal) and load acting angle 60° (with respect to horizontal).

III. Finite Element Modelling

A. Geometry

Three-dimensional models were developed in Ansys Workbench to demonstrate the behaviour properly. The dimensions and material properties considered in this thesis are fixed with reference to Indian Standards. The models included the steel tubes, concrete core. First 4 column models included the vertical steel plate, next 4 column models included perfobond steel plate and last 4 column models included lacing bar. The size of steel tube is 100 x 100 x 5mm. Size of column 300 x300 x 4000mm. in this study 5mm thick vertical steel plate were used. The perfobond steel plate have 32 hole, and its diameter is 50mm.The center to center distance of these holes is 125mm.The lacing bar have the diameter of 24mm and distance between lacing is 200mm

B. Material Properties.

Rectangular concrete filled steel tube is modeled by using Ansys Workbench 16.1.M30 grade of concrete and Fe 250 mpa steel is used. The model developed on the basis of Slenderness ratio (L/D=13.33). Lacing bars Fe 415 mpa is used. Poisson's ratio of steel 0.3 and Poisson's ratio of concrete is 0.15.

C. Modelling and Analysis

The rectangular CFST columns are modelled using ANSYS Workbench. The material properties were assigned; support and loading conditions were provided. The analysis done in this study is structural analysis. In structural analysis the column models are analysed under axial loading, lateral loading, load acting angle 30° (with respect to horizontal) and load acting angle 60° (with respect to horizontal). Column support is fixed at bottom and free at top. There are twelve models in this study. They are shown in table I.

TABLE I. Rectangular CFST column models

Models with Vertical Steel Plate		
Model 1	SM 90°	Rectangular CFST Column With Vertical Steel Plate – Axial Loading.
Model 2	SM 0°	Rectangular CFST Column With Vertical Steel Plate– Lateral Loading
Model 3	SM 30°	Rectangular CFST Column With Vertical Steel Plate – Load Acting Angle 30°(with respect to horizontal)
Model 4	SM 60°	Rectangular CFST Column With Vertical Steel Plate - Load Acting Angle60°(with respect to horizontal).
Models with Perfobond Steel Plate		
Model 5	PM 90°	Rectangular CFST Column With Perfobond Steel Plate – Axial Loading
Model 6	PM 0°	Rectangular CFST Column With Perfobond Steel Plate – Lateral Loading.
Model 7	PM 30°	Rectangular CFST Column With Perfobond Steel Plate - Load Acting Angle 30° (with respect to horizontal).
Model 8	PM 60°	Rectangular CFST Column With Perfobond Steel Plate - Load Acting Angle 60° (with respect to horizontal).
Models with Lacing Bar		
Model 9	LM 90°	Rectangular CFST Column With Lacing Bar - Axial Loading
Model 10	LM 0°	Rectangular CFST Column With Lacing Bar- Lateral Loading.
Model 11	LM 30°	Rectangular CFST Column With Lacing Bar- Load Acting Angle 30° (with respect to horizontal).
Model 12	LM 60°	Rectangular CFST Column With Lacing Bar- Load Acting Angle 60° (with respect to horizontal).

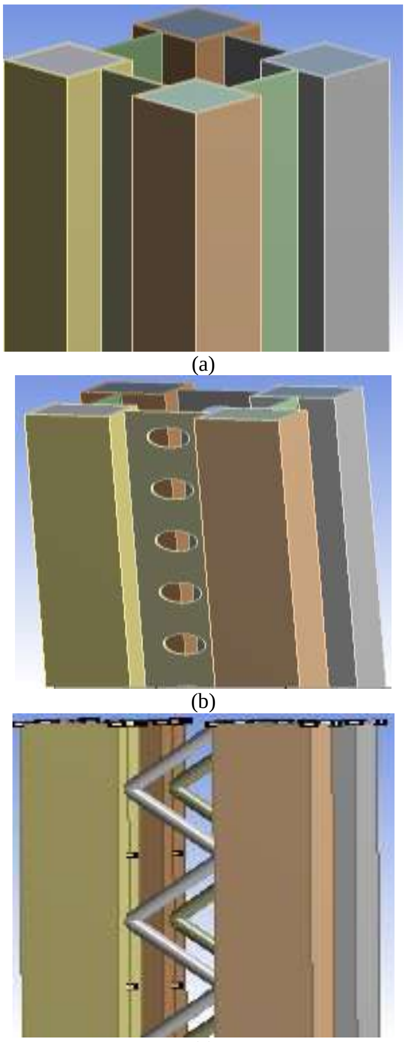

(a) (b) (c)

Fig. 1. Rectangular CFST column models with (a) vertical steel plate,(b) perfobond steel plate, (c) lacing bar.

The models that are analysed in this study are shown in fig. 1. Every model was meshed using a 20 noded Hexahedron element [Solid 186] to achieve better accuracy in nonlinear analysis as shown in fig. 2.


(a) (b) (c)

Fig. 2. mesh of rectangular CFST column with (a) vertical steel plate, (b) perfobond steel plate and(c), lacing bar.

D. Results and Discussions

In nonlinear static analysis of rectangular concrete filled steel tube (long column) with lacing, perfobond steel plate and vertical steel plate of 12 models are analyzed. The table II shows the maximum load and deformations of columns with vertical steel plate, perfobond steel plate and lacing bar by axial compression. The combined load-deformation graph is also plotted as shown in fig. 5. Axial deformation and lateral deformation of all models are shown fig. 3 and fig. 4

- Comparing these models, perfobond steel plates has maximum load in axial compression that is 4380.9 KN, and maximum lateral deformation is 99.66mm.
- The maximum axial deformation 7.05mm is obtained for vertical steel plate model.

The table III shows the maximum load and deformations of column with (lateral) vertical steel plate, perfobond steel plate and lacing bar by load acting lateral. The companied load-deformation graph is also plotted as shown in fig. 6.

- Comparing these models vertical steel plates have maximum load in lateral that is 214.39 KN, and perfobond steel plate have maximum lateral deformation of 849.76mm.

The table IV shows the maximum load and deformations (load acting angle 30°) of column with vertical steel plate, perfobond steel plate and lacing bar by load acting angle 30°. The companied load-deformation graph is also plotted as shown in fig. 7.

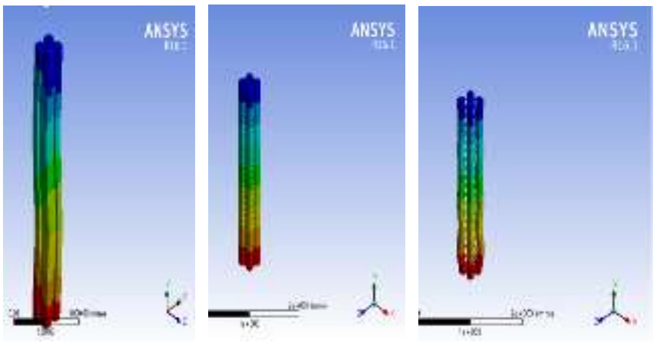
- Comparing these models vertical steel plates has maximum load in load acting angle 30° that is 231.26 KN, and perfobond steel plate model has maximum lateral deformation and axial deformation of 537.57mm and 55.95mm.

The table V shows the maximum load and deformations (load acting angle 60°) of column with vertical steel plate, perfobond steel plate and lacing bar by load acting angle 60°. The companied load-deformation graph is also plotted as shown in fig. 8.

- Comparing these models vertical steel plates has maximum load in load acting angle 60° that is 359.24 KN, and lacing bar model has maximum lateral deformation and axial deformation of 421.82mm and 35.75mm.

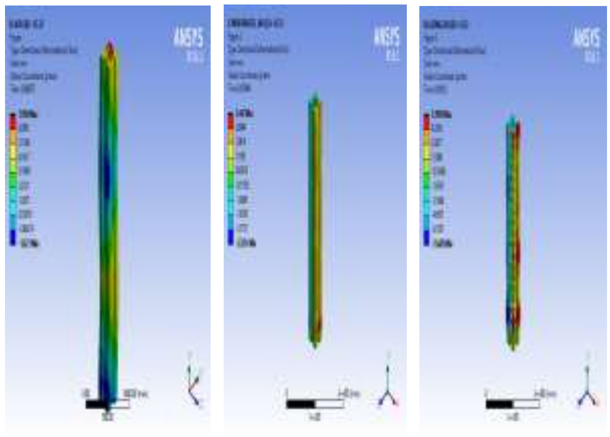
The table VI shows the strength performance of vertical steel plate model, perfobond steel plate model and lacing bar model by axial compression. The table VII Shows the strength performance of vertical steel plate model, perfobond steel plate model and lacing bar model by lateral loading. The table VIII Shows the strength performance of vertical steel plate model , perfobond steel plate model and lacing bar model by load acting angle 30°. The table IX .Shows the strength performance of vertical steel plate model , perfobond steel plate model and lacing bar model by load acting angle 60°. The combined strength performance of rectangular CFST column graph is also plotted as shown is fig. 9.

- Comparing these models perfobond steel plates have maximum load in axial compression that is 4380.9 KN.
- Vertical steel plate models have maximum load in lateral loading(that is 214.39KN), have maximum load in load acting angle 30°(that is 213.26KN) and also have maximum load in load acting angle 60° (that is 359.24KN).



(a) (b) (c)

Fig. 3. Axial deformation of rectangular CFST column with (a) vertical steel plate, (b) perfobond steel and (c) lacing bar.



(a) (b) (c)

Fig. 4. Lateral deformation of rectangular CFST column with (a) vertical steel plate, (b) perfobond steel and (c) lacing bar.

TABLE II. Comparison of load and deformations on rectangular CFST column by axial loading

Model	Axial Deformation (mm)	Lateral Deformation (mm)	Load (KN)
SM 90°	69.5	7.05	4307.40
PM 90°	99.66	3.44	4380.90
LM 90°	65.53	5.78	367720

TABLE III. Comparison of load and deformations on rectangular CFST column by lateral loading

Model	Lateral Deformation (mm)	Load (KN)
SM 0°	545.32	214.39
PM 0°	849.76	112.09
LM 0°	550	94.93

TABLE IV. Comparison of load and deformations on rectangular CFST column by load acting angle 30°

Model	Axial Deformation (mm)	Lateral Deformation (mm)	Load (KN)
SM 30°	41.61	451.81	231.26
PM 30°	55.95	537.57	125.06
LM 30°	45.441	439.92	104.63

TABLE V. Comparison of load and deformations on rectangular CFST column by load acting angle 60°

Model	Axial Deformation (mm)	Lateral Deformation (mm)	Load (KN)
SM 60°	35.04	388.13	359.24
PM 60°	32.83	391.61	237.30
LM 60°	35.75	421.82	209.23

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TABLE VI. Strength performance of rectangular CFST column by axial loading

Model	Load (KN)
SM 90°	4307.40
PM 90°	4380.90
LM 90°	367720

TABLE VII. Strength performance of rectangular CFST column by lateral loading

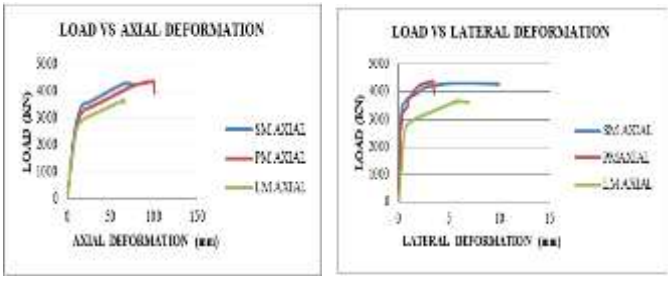
Model	Load (KN)
SM 0°	214.39
PM 0°	112.09
LM 0°	94.93

TABLE VIII. Strength performance of rectangular CFST column by load acting angle 30°

Model	Load (KN)
SM 30°	231.26
PM 30°	125.06
LM 30°	104.63

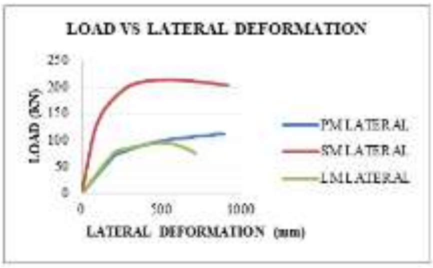
TABLE IX . Strength performance of rectangular CFST column by load acting angle 60°.

Model	Load (KN)
SM 60°	359.24
PM 60°	237.30
LM 60°	209.23



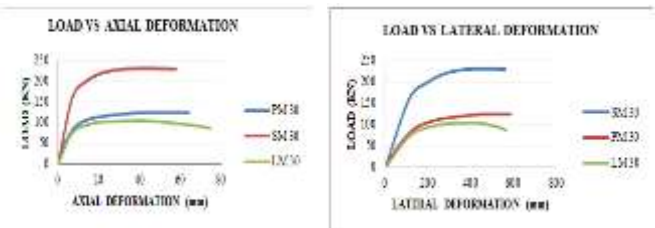
(a) (b)

Fig. 5. (a) Axial deformation and (b)Lateral deformation of rectangular CFST column with vertical steel plate, perfobond steel and lacing bar under axial loading.



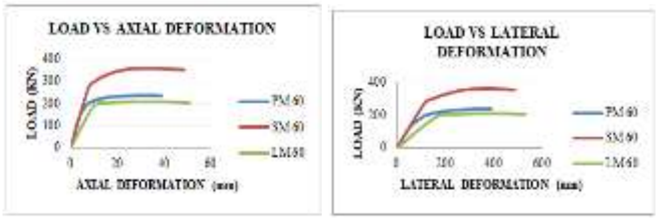
(a)

Fig. 6. (a) Lateral deformation of rectangular CFST column with vertical steel plate, perfobond steel and lacing bar under lateral loading.



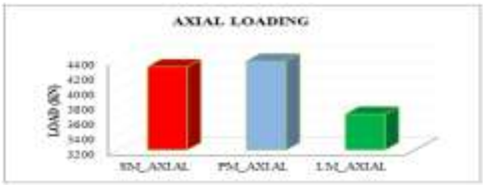
(a) (b)

Fig. 7. (a)Axial deformation and (b)Lateral deformation of rectangular CFST column with vertical steel plate, perfobond steel and lacing bar under load acting angle 30°.

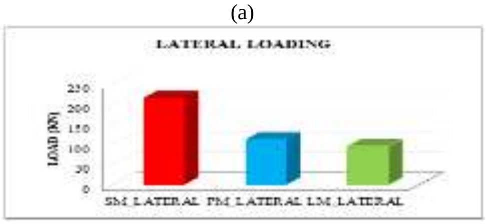


(a) (b)

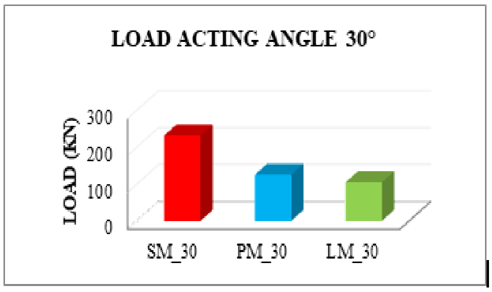
Fig. 8. (a)Axial deformation and (b)Lateral deformation of rectangular CFST column with vertical steel plate, perfobond steel and lacing bar under load acting angle 60°.



(a)



(b)



(c)

(d)

Fig. 9. Strength performance of rectangular CFST column with vertical steel plate, perfobond steel and lacing bar under (a) axial loading ,(b) lateral loading , (c)load acting angle 30° and (d) load acting angle 60°.

IV. CONCLUSIONS

- The circular concrete filled steel tube (CFST) showed maximum load 937.47 KN under axial compression.
- Comparing these models perfobond steel plate have maximum load in axial compression that is 4380.9 KN.

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- Comparing other models lateral, 30° and 60° directions the maximum load is obtained for vertical steel plates.
- The maximum load obtained for lateral, 30° and 60° directions are 214.39KN, 231.26KN & 359.24KN respectively.
- Models with lacing bar have less load carrying capacity than other models.
- By comparing with lacing bar models, CFST column with vertical steel plates and perfobond steel plates have better load carrying capacity.
- Comparing these models perfobond steel plates has maximum axial deformation and vertical steel plate has maximum lateral deformation in axial compression.
- Perfobond steel plate model has maximum lateral deformation in load acting lateral and it also have maximum axial and lateral deformation in load acting 30°.
- Lacing bar model has maximum axial and lateral deformation in load acting 60°.
- The percentage difference in maximum load between vertical steel plates and perfobond steel plates is 1% by axial compression.
- The percentage difference in maximum load between vertical steel plate and perfobond steel plate is 47%, 45% & 33% for lateral , 30°& 60° respectively
- So we can conclude that the vertical steel plate has better load carrying capacity than perfobond steel plates and lacing bar.

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