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Combined Effect of with and without Corrugated Concrete Filled Double Skin Tubular Sections Subjected to Axial, Biaxial, and Lateral Loading

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Abstract- *This paper deals with the static compression behaviour of concrete-filled double-skin tubular (CFDST) columns with and without corrugated plates subjected to axial, biaxial and lateral loading. These sections take advantage of the high strength of their infill concrete as well as the ductility of their steel skins. The study were proposed to compare and fix the position for corrugation of plates used. The axial, biaxial and lateral load behaviour of CFDST columns with and without corrugated plates is analysed and developed a FE model to simulate the response of CFDST columns with and without corrugated plates using ANSYS16.1 software. A worst model is then selected and it is strengthened by incorporating ultra high strength steel tubes on four corners of the selected column. The result will be analyzed and value is compared with the conventional systems.*

Keywords- *CFDST column, static loading, axial loading, biaxial loading, lateral loading, corrugation.*

I. INTRODUCTION

The structural performance of concrete-filled double-skin tubular (CFDST) sections has been the subject of a notable number of studies in recent years. Conventional CFDST sections consist of two hollow flat steel skins, and the gap between these two skins is filled with concrete. Since CFDST sections use the merits of the high compression strength of the concrete core as well as the ductility of the steel material in the surrounding skins, these sections are an astute choice in structural design. The corrugated plates have an insignificant effect on the strength of column specimens. However, the ductility and energy absorption capacity of CFDST columns are improved dramatically. A finite element modelling framework was also developed to simulate the response of CFDST columns with corrugated plates. They are widely used in high-rise and multi-storey buildings as columns and beam-columns, and as beams in low-rise industrial buildings. In composite construction, 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.

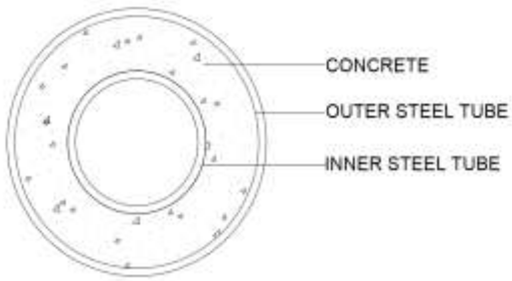

Fig. 1. Cross sectional view of hollow – steel column

II. SCOPE AND OBJECTIVES OF THE STUDY

In composite construction, 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. More complicated type of CFDST specimens with various cross sections can be tried. The work can be extended to study the behaviour of cyclically loaded CFDST columns. The main objective of the study are as follows.

- To assess the axial, biaxial and lateral load behavior of CFDST columns with and without corrugated plates
- To assess the worst model by incorporating ultra-high strength (UHS) steel tubes
- To develop a FE model to simulate the response of CFDST column by using ANSYS

III. FINITE ELEMENT MODELLING OF CFDST COLUMNS WITH DIFFERENT GEOMETRIES

A. Geometry

Three dimensional models were developed to demonstrate the behavior properly. The model includes two flat steel plates as double skin and the gap is in the filled with concrete. The dimensions and material properties considered in this thesis are fixed with reference to *Mojtaba Farahi et al.* In this thesis, total six models were developed including the conventional column. The remaining five columns are corrugated columns with corrugations provided at different positions. Fig. 2 shows the cross-section of corrugated plate. The outer steel plate is of size 247.5x 247.5 mm and the inner steel plate is of size 160x 160 mm for all models.

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TABLE I. Cross-sectional details of corrugation

Notations	Values (mm)
α (°)	45
a	20
h	15
t	3
l	70
d	15
c	21.21

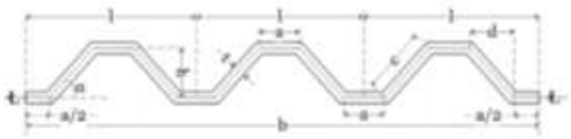


Fig. 2. Typical geometry of the cross-section of corrugated plate

B. *Material Properties*

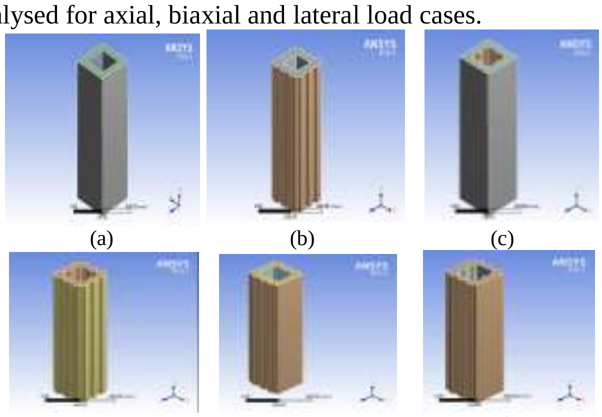
The material properties used for the concrete and reinforcing steel of all models are given in Table II.

TABLE II. Material properties of concrete and reinforcing steel

MATERIAL PROPERTY	VALUE
Structural Steel	
Density	7850 Kg/m^3
Poisson's ratio	0.3
Young's modulus	$2x10^{11}$ N/mm^2
Shear modulus	7.692 $x10^{10}$ N/mm^2
	1.667 $x10^{11}$ N/mm^2
Concrete	
f_{ck}	42 N/mm^2
Young's modulus	32403 N/mm^2
Poisson's ratio	0.15
Shear modulus	1.408 $x10^{10}$ N/mm^2
Bulk modulus	1.543 $x10^{10}$ N/mm^2

C. *Modelling and Analysis*

The different CFDST sections are modelled using ANSYS Workbench 16.1. Frictional contact was used to explain the interaction. A frictional coeffeicient of 0.2 was used to resemble a sliding surface. The material properties were assigned, support and loading conditions were provided. Each model is analysed for axial, biaxial and lateral loading conditions. To stimulate the real conditions, the column is analysed by one end with fixed support and other end is free. The bilinear isotropic hardening rule was used for the finite element analysis. Fig. 3 shows the cross-sections of different models used for the study. Each model shown below is analysed for axial, biaxial and lateral load cases.



(a) (b) (c) (d) (e) (f)

Fig. 3. Cross sections of all CFDST columns – (a) Conventional column (b) Outer corrugated and inner plate column (c) Outer plate and inner corrugated column (d) Outer and inner corrugated column (e) Outer and inner parallally corrugated column (f) Outer and inner perpendicularly

D. *Results and Discussions*

After the analysis of the structures, the results are noted and summarized as follows. The fig. 5 shows the load – deformation curve of the different columns for different load cases.

- Maximum axial load capacity is obtained for outer plate and inner corrugated column.
- Maximum biaxial load capacity is for doubly corrugated column having corrugations provided parallel and perpendicular directions.
- Maximum lateral load capacity is for outer plate and inner corrugated column and for doubly corrugated column having corrugations provided in perpendicular direction.
- All the corrugated models show excellent load-deformation behavior for the loading conditions except the lateral loading case
- In biaxial load case, the parallel and perpendicularly placed corrugated column shows more ductile behavior than other ones.

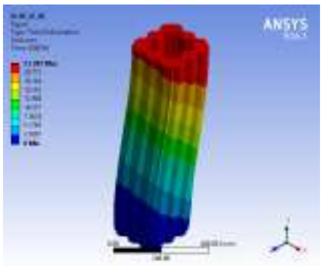
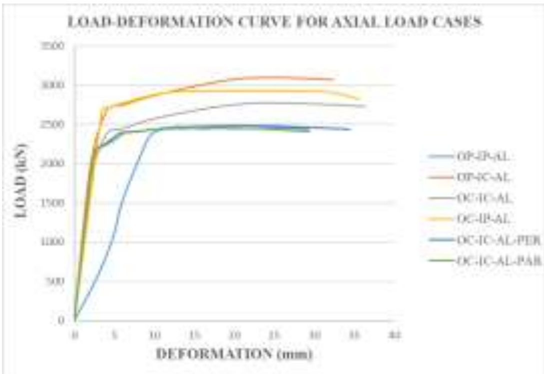
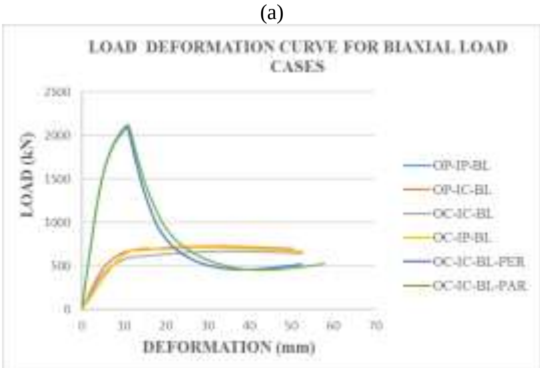


Fig. 4. Total deformation



(a)



(b)

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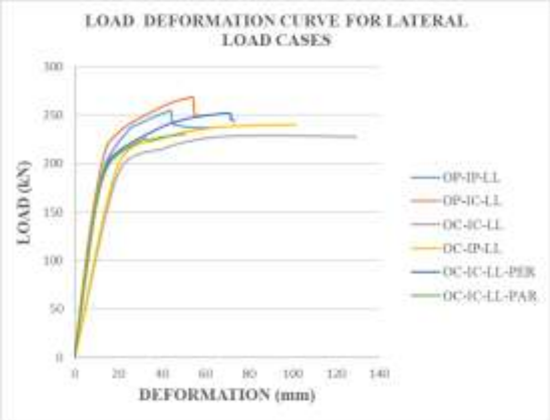


(c)
Fig. 5. Load – Deformation curve for different load cases

IV. FINITE ELEMENT MODELLING AND ANALYSIS OF STRENGTHENED BEAM

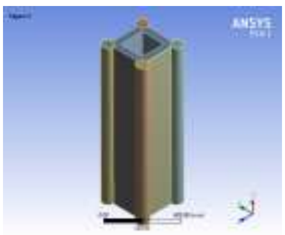
From all previous model, outer and inner plate corrugated column is chosen for strengthening and compared with conventional column. The column is strengthened with ultra-high strength steel tubes. A finite element model is developed and the analysis is carried out. The superior performance of the proposed column under compressive loading is investigated in the present work. UHS tubes used at the corners have yield stress of 1250 MPa. An advanced finite element model is developed for predicting the behaviour of proposed columns on the four corners of the column and compared with the conventional column.

A. *Geometry and Material properties*

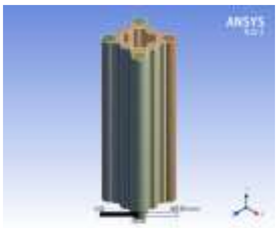
The conventional column and outer and inner corrugated column is strengthened with ultra-high strength steel tubes with yield strength 1250 N/mm^{2}.Three dimensional models were developed to demonstrate the behavior properly.

B. *Modelling and Analysis*

The sections are modelled using ANSYS Workbench 16.1. The material properties were assigned, support and loading conditions were provided. The bilinear isotropic hardening rule was used for the finite element analysis. To stimulate the real conditions, the column is analysed by one end with fixed support and other end is free. Fig. 6 shows the cross sections of strengthened CFDST columns.



(a)



(b)

Fig. 6. Cross sections of strengthened CFDST columns – (a) Conventional column (b) Outer and inner corrugated column

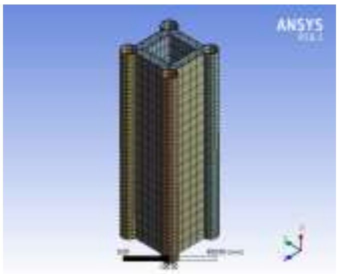
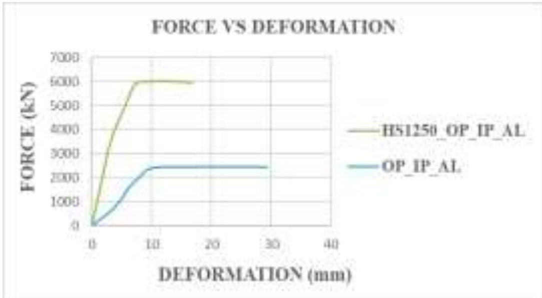


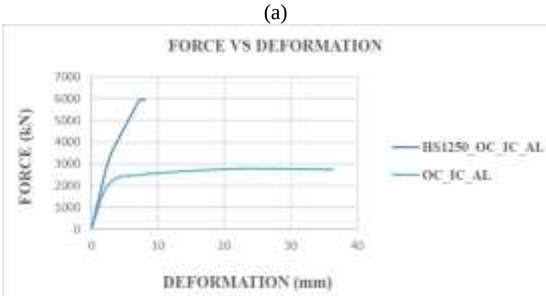
Fig. 7. Finite element modelling

C. *Results and Discussions*

The Nonlinear static analysis is carried out. Fig. 8 shows the load deformation curve for the strengthened column with respect to the un-strengthened column for different load cases.



(a)



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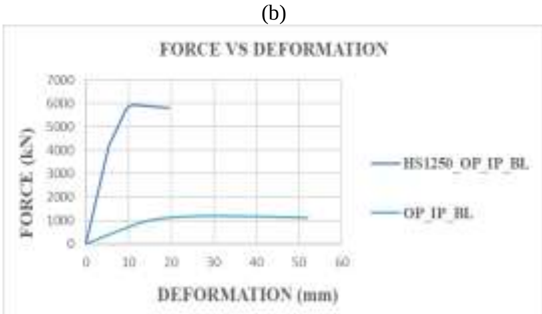
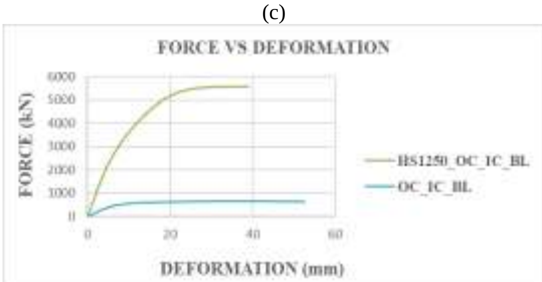


(c)



(d)

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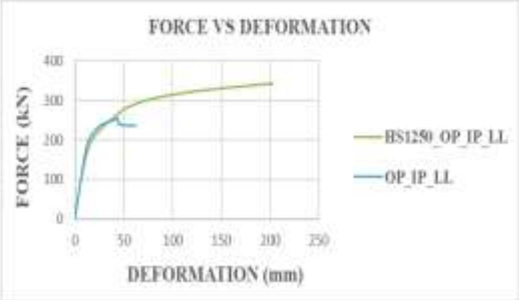
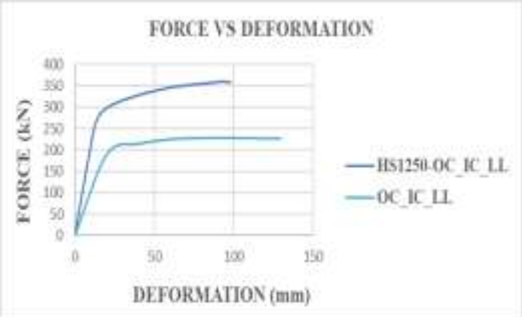


(e)



(f)

Fig. 8. Load – Deformation curves of each strengthened column for different load cases

V. CONCLUSIONS

- The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column.
- All the different corrugated column showed improvement in both strength and ductility than the conventional column except outer and inner plate corrugated column.
- Maximum axial load capacity is obtained for outer plate and inner corrugated column.
- Maximum biaxial load capacity is for doubly corrugated column having corrugations provided parallel and perpendicular directions.
- Maximum lateral load capacity is for outer plated and inner corrugated column and for doubly corrugated column having corrugations provided in perpendicular direction.
- All the corrugated models show excellent load-deformation behavior for the loading conditions except the lateral loading case.
- In biaxial load case, the parallel and perpendicularly placed corrugated column shows more ductile behavior than other ones.
- Strengthening with ultra-high strength steel tubes gives a higher load capacity.
- The strengthened corrugated column exhibits better load carrying capacity than the conventional column for axial and lateral load cases

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