STRUCTURAL PERFORMANCE OF CORRUGATED PLATE L-SHAPED STEEL COLUMNS WITH TUBULAR CORE

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Abstract - *The increasing demand for structurally efficient and space-saving structural systems in modern construction has led to the development of special-shaped steel columns. Among these, corrugated plate L-shaped steel columns with tubular cores provide enhanced stiffness, improved buckling resistance, and efficient utilization of interior space. This study investigates the axial compression behaviour, deformation characteristics, and stability performance of corrugated plate L-shaped steel columns with internal steel tubes using finite element analysis. Numerical modelling and validation were carried out using ANSYS Workbench 2024 R1. The finite element model was validated against published experimental results, showing good agreement with only 1.33% variation in ultimate load capacity and 4.37% variation in displacement. A detailed parametric study was performed by varying corrugation width and corrugation length. The results indicate that corrugation geometry significantly influences the structural performance of the columns. Columns with a corrugation width of 10 mm exhibited the highest load carrying capacity, while corrugation lengths between 200 mm and 250 mm provided balanced ductility and stability behaviour. The study confirms that corrugated plate L-shaped steel columns with tubular cores demonstrate stable ductile behaviour, delayed local buckling, and improved structural efficiency under axial loading conditions. The proposed system can be effectively applied in high-rise buildings, industrial structures, and seismic-resistant steel construction.*

Keywords: Corrugated steel column, L-shaped column, tubular core, finite element analysis, buckling behaviour, axial compression, and structural stability.

1. INTRODUCTION

Rapid developments in modern architecture require structural systems that provide high load-carrying capacity while minimizing interference with interior space utilization. Conventional reinforced concrete and steel columns often protrude into occupied spaces, thereby reducing functional floor area and limiting architectural flexibility. To overcome these limitations, special-shaped steel columns such as L-shaped and T-shaped sections have been increasingly adopted in modern structural systems.

Corrugated steel plates are widely used in structural engineering applications due to their high out-of-plane stiffness, enhanced shear resistance, and improved buckling performance. When corrugated plates are integrated with steel tubular cores, the resulting composite system exhibits improved axial load resistance, lateral stability, and post-buckling behaviour.

Previous studies have demonstrated the effectiveness of corrugated geometries in improving the stiffness and stability of thin-walled steel members. However, limited research has been conducted on corrugated plate L-shaped steel columns with tubular cores subjected to axial compression. Therefore, the present study investigates the structural behaviour of corrugated plate L-shaped steel columns using finite element analysis.

The major objectives of the present study are:

- To investigate the axial compression behaviour of corrugated plate L-shaped steel columns.
- To evaluate the effect of corrugation geometry on deformation and load carrying capacity.
- To study the influence of corrugation width and corrugation length.
- To assess the stability and buckling behaviour of the proposed column system.
- To identify the optimum corrugation configuration for improved structural performance.

2. LITERATURE REVIEW

Several researchers have investigated the behaviour of corrugated steel systems and special-shaped columns under different loading conditions.

Xin Ning and Sergio Pellegrino (2015) investigated the buckling behaviour of axially loaded corrugated cylindrical shells and reported that corrugations significantly improve longitudinal stiffness and buckling resistance. Kueh et al. (2010) studied buckling in corrugated structures using analytical and numerical methods and observed that boundary conditions strongly influence structural stability.

Preetha V. et al. (2019) analysed the buckling behaviour of steel columns and concluded that slenderness ratio and moment of inertia significantly affect buckling resistance. Wang Zhang et al. (2018) experimentally investigated T-shaped concrete-filled steel tubular columns and demonstrated that tubular cores improve load carrying capacity and stiffness.

Amer Mohammed et al. (2023) examined the seismic behaviour of L-shaped steel tubular columns and reported improved lateral stiffness and energy dissipation characteristics. Sergey Kudryavtsev (2011) investigated triangular corrugated steel webs and found that increasing corrugation density delays local buckling and improves structural stability.

Although significant research has been conducted on corrugated steel members and tubular columns, limited studies are available on corrugated plate L-shaped steel columns with tubular cores under axial compression. Therefore, the present study aims to address this research gap through finite element analysis and parametric investigation.

3. FINITE ELEMENT MODELLING

3.1 Numerical Modelling

Finite element analysis was carried out using ANSYS Workbench 2024 R1 to simulate the behaviour of corrugated plate L-shaped steel columns under axial compression.
The validated specimen consisted of:

- Corrugated steel plate limbs
- Internal square steel tube
- Flange plates forming an L-shaped configuration

The geometric parameters adopted in the study are summarized in

Table 1. Geometric Parameters of Validated Model

Parameter	Description	Value
B st	Outer ring side length	150 mm
Tst	Steel tube thickness	8 mm
bf	Flange width	200 mm
tf	Flange thickness	16 mm
Bcw1	Double limb corrugation width	150 mm
B cw2	Single limb corrugation width	200 mm
tcw1 & tcw2	Corrugated plate thickness	2 mm

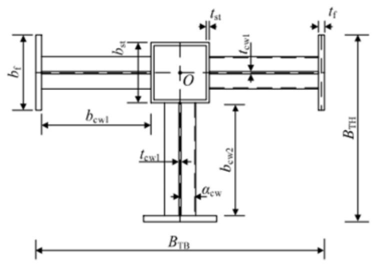

Fig 1 : Section parameters of TCSC -validation Model

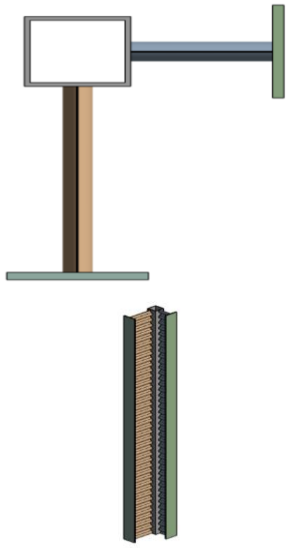

Fig 2 : Modelling of LCSC

3.2 Element Type and Meshing

The structural model was discretized using the SOLID186 element available in ANSYS. SOLID186 is a higher-order 20-node three-dimensional structural solid element suitable for nonlinear analysis and accurate stress prediction.
A structured hexahedral mesh with an element size of 100 mm was adopted. Mesh refinement studies confirmed convergence and numerical stability.

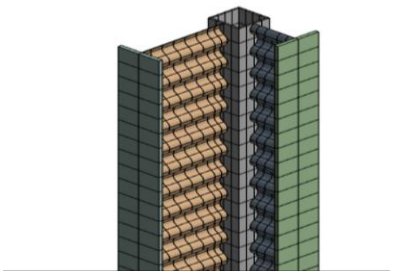

Fig 3 : Meshing of LCSC

3.3 Material Properties

The material properties used in the finite element model are listed in Table 2.

Table 2. Material Properties

Property	Value
Modulus of Elasticity	2.06×10^5 MPa
Yield Strength	355 MPa
Density	7850 kg/m^3
Poisson's Ratio	0.30

Elasto-plastic material behaviour was incorporated to simulate realistic structural response.

3.4 Boundary Conditions and Loading

Pin–pin support conditions were applied to represent practical column behaviour. Axial compressive loading was gradually applied at the top surface to capture nonlinear deformation and buckling behaviour.
The nonlinear analysis included:

- Material nonlinearity
- Geometric nonlinearity
- Large deformation effects
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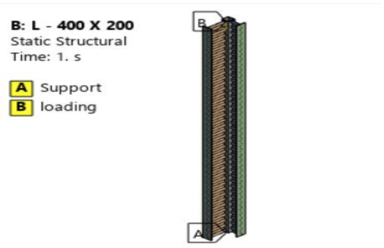


Fig 4 : Boundary condition of LCSC

4. PARAMETRIC STUDY AND RESULTS DISCUSSION

4.1 Parametric Models Considered

A comprehensive parametric study was conducted by varying corrugation width and corrugation length.

Table 4. Parametric Models

Model	Description
B-L-400×200	Reference model
C-L-300×300	Square section configuration
D-L-300×300	Corrugation width = 10 mm
E-L-300×300	Corrugation width = 15 mm
F-L-300×300	Corrugation length = 300 mm
G-L-300×300	Corrugation length = 200 mm
H-L-300×300	Corrugation length = 250 mm

4.2 Structural Behaviour under Axial Loading

All analysed models exhibited typical compression member behaviour consisting of elastic deformation, yielding, and post-buckling stages.

The deformation plots showed that maximum displacement occurred near the mid-height of the columns. Corrugated plates effectively delayed local buckling, while the internal tubular core improved load transfer efficiency and confinement.

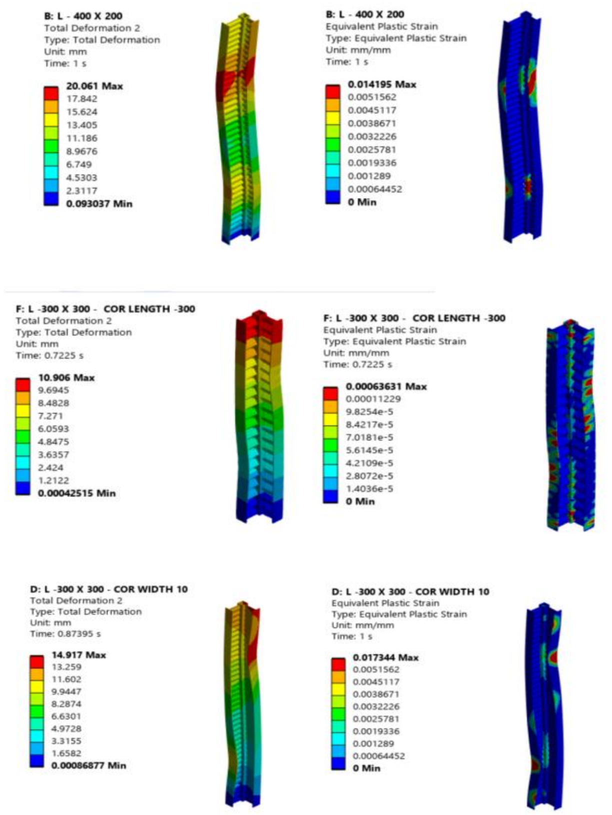


Fig 5 : Results Of Each Parametric Case

The load–deflection response demonstrated three distinct behavioural stages:

- **Elastic Region**

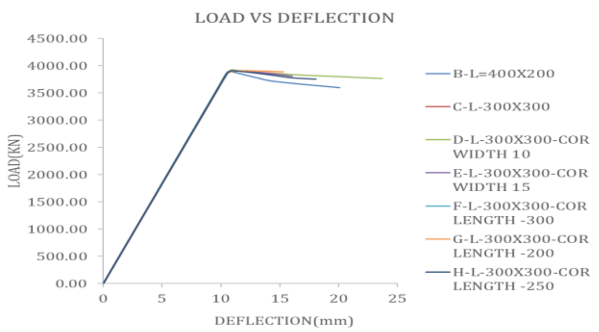
At initial loading stages, the relationship between load and displacement remained linear. Structural stiffness was nearly constant and no permanent deformation occurred.

- **Yielding Region**

As the applied load increased, plastic strains initiated near the corrugated folds and flange–tube junctions. Gradual reduction in stiffness was observed without sudden strength degradation.

- **Post-Peak Behaviour**

After reaching ultimate load, buckling became the dominant failure mode. The columns exhibited stable post-buckling response and gradual reduction in load carrying capacity, indicating ductile behaviour.



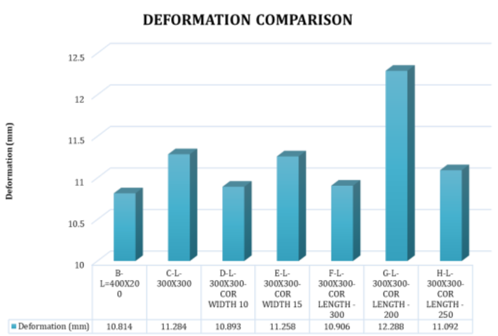
4.3 Deformation Behaviour

The deformation values obtained from numerical analysis are summarized in Table 5.

Table 5. Deformation Comparison of Models

Model	Maximum Deformation (mm)
B-L-400×200	10.814
C-L-300×300	11.284
D-L-300×300 (Width = 10 mm)	10.893
E-L-300×300 (Width = 15 mm)	11.258
F-L-300×300 (Length = 300 mm)	10.906
G-L-300×300 (Length = 200 mm)	12.288
H-L-300×300 (Length = 250 mm)	11.092

The results indicate that corrugation geometry strongly influences deformation response. Moderate corrugation dimensions provided balanced stiffness and ductility characteristics.



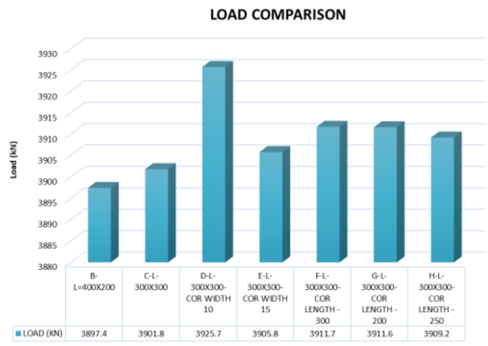
4.4 Ultimate Load Carrying Capacity

The ultimate load capacities obtained for different models are presented in Table 6.

Table 6. Ultimate Load Capacity of Models

Model	Ultimate Load (kN)
B-L-400×200	3897.4
C-L-300×300	3901.8
D-L-300×300 (Width = 10 mm)	3925.7
E-L-300×300 (Width = 15 mm)	3905.8
F-L-300×300 (Length = 300 mm)	3911.7
G-L-300×300 (Length = 200 mm)	3911.6
H-L-300×300 (Length = 250 mm)	3909.2

The highest load carrying capacity was achieved for the model with corrugation width of 10 mm. Increasing corrugation width beyond the optimum value slightly reduced stiffness and strength.



4.5 Influence of Corrugation Width

Corrugation width significantly affected the structural behaviour of the columns.
The study revealed that:

- Corrugation width of 10 mm provided the maximum load carrying capacity.
- Smaller corrugation widths improved local stiffness and delayed buckling.
- Larger corrugation widths increased flexibility and deformation.

Therefore, an optimum corrugation width is essential for balancing strength and ductility.

4.6 Influence of Corrugation Length

The variation of corrugation length showed only minor influence on ultimate load capacity. However, corrugation length strongly affected deformation behaviour and ductility. The 200 mm corrugation length exhibited maximum deformation capacity and improved post-buckling behaviour.

4.7 Failure Behaviour

All models exhibited progressive local buckling followed by gradual global instability. No sudden brittle failure was observed.
The corrugated plates acted as continuous stiffeners, distributing stresses uniformly and delaying local plate instability. The tubular core enhanced confinement and improved post-buckling resistance.

4.8 Structural Efficiency

The proposed corrugated plate L-shaped steel column system demonstrated:

- Improved axial load resistance
- Enhanced buckling stability
- Better deformation control
- Stable ductile behaviour
- High strength-to-weight ratio

These characteristics make the system suitable for modern structural applications such as high-rise buildings, industrial structures, and seismic-resistant frames.

5. CONCLUSIONS

The present study investigated the structural performance of corrugated plate L-shaped steel columns with tubular cores using finite element analysis.

The following conclusions are drawn from the investigation:

1. All analysed columns exhibited stable and ductile behaviour under axial compression.
2. Corrugated plates significantly improved structural stiffness and delayed local buckling.
3. The finite element model developed in ANSYS showed good agreement with experimental results, confirming the reliability of the numerical approach.
4. Corrugation width strongly influenced the load carrying capacity and stability behaviour of the columns.
5. The model with corrugation width of 10 mm exhibited the highest ultimate load carrying capacity.
6. Corrugation length had minor influence on strength but significantly affected deformation and ductility behaviour.
7. Corrugation lengths between 200 mm and 250 mm provided balanced structural performance.
8. The tubular core improved confinement, stiffness, and post-buckling resistance.
9. The proposed column system demonstrated high structural efficiency and improved buckling resistance compared to conventional steel sections.

The study confirms that corrugated plate L-shaped steel columns with tubular cores are promising structural systems for modern engineering applications requiring high strength, lightweight construction, and improved stability.

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