

A Comparative And Parametric Investigation Of Circular And Square CFST Columns Using Finite Element Analysis

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ABSTRACT

Concrete-filled steel tubular (CFST) columns combine the compressive resistance of a concrete core with the tensile capacity, ductility, and confinement supplied by an external steel tube. This study presents a comparative and parametric finite-element investigation of circular and square CFST columns using ANSYS Mechanical APDL. Three-dimensional nonlinear models employed SOLID65 elements for concrete and SHELL181 elements for the Fe250 steel tube. Concrete grades M25, M30, M55, M60, and M80 were defined using the material values reported in the study. The analytical programme examined cross-sectional shape, concrete grade, tube dimensions, and diameter-to-thickness or breadth-to-thickness ratios. Eurocode-based calculations produced design buckling resistances of 1,355 kN for the representative circular column and 1,675.629 kN for the representative square column. Across the parametric series, reducing D/t or B/t increased load capacity because thicker steel walls improved confinement and delayed local buckling. For the compared CFST models, circular columns exhibited lower deformation and stress than square columns at every reported load level; at 4,000 kN, deformation was 2.61 mm for the circular model and 9.89 mm for the square model. Comparison with plain concrete further demonstrated the benefit of steel confinement. The results identify cross-sectional geometry, concrete strength, and tube slenderness as the dominant parameters controlling CFST capacity and deformation.

Keywords: Concrete-filled steel tube; CFST column; Finite element analysis; ANSYS APDL; Circular column; Square column; D/t ratio; B/t ratio

I. INTRODUCTION

Concrete-filled steel tubular columns are composite members in which a hollow steel section is filled with concrete. The steel tube resists tension and bending, provides permanent formwork, and confines the concrete core. The concrete supports compressive load and restrains inward local buckling of the tube. This interaction improves stiffness, ductility, load capacity, and construction efficiency compared with the isolated use of either material.

Cross-sectional shape strongly influences composite action. A circular tube applies comparatively uniform lateral pressure around the core and can generate a triaxial compressive state. In a square tube, confinement is concentrated near the corners, while the flat faces are more susceptible to outward deformation. The resulting difference affects local buckling, stress distribution, axial shortening, and ultimate resistance.

International design approaches include Eurocode 4, AISC-LRFD, NBR 8800, and GB 50936-2014. These frameworks differ in the treatment of steel-concrete interaction and confinement. Finite-element analysis provides a complementary route for examining nonlinear material response, geometric effects, and deformation patterns before physical testing.

The present study compares circular and square CFST columns through manual code-based calculations and ANSYS APDL models. The parametric programme varies concrete grade and tube geometry to determine how D/t and B/t ratios influence load capacity, stress, and deformation.

II. OBJECTIVES

- To develop nonlinear finite-element models of circular and square CFST columns.
- To determine the ultimate load-bearing capacity and deformation response of the investigated column configurations.
- To evaluate the influence of cross-sectional dimensions, steel-tube thickness, concrete grade, D/t ratio, and B/t ratio.
- To compare ANSYS results and code-based analytical predictions for CFST columns.
- To compare CFST response with corresponding plain-concrete column behaviour.

III. LITERATURE SURVEY

Previous investigations have examined CFST columns through physical testing, finite-element simulation, and design-code comparison. Ibanez, Hernandez-Figueirido, and Piquer evaluated the effect of wall thickness across circular, square, and rectangular sections, while Adak et al. compared CFST and reinforced-concrete columns using experimental results and ABAQUS models [1], [2]. Ren et al. investigated non-standard CFST cross-sections and reported outward buckling near the middle of stub-column specimens [3].

Kurian, Paulose, and Mohan used ANSYS to compare hollow steel tubes and concrete-filled circular and rectangular columns, showing the importance of slenderness, tube thickness, and concrete grade [4]. Han et al. developed nonlinear finite-element models for combined loading, and Evirgen et al. demonstrated that lower D/t ratios improve strength and ductility [5], [6]. Subsequent studies have addressed eccentricity, high-strength materials, seismic response, elevated temperature, and the steel-concrete interface [7]-[12].

The reported research gap concerns the combined comparison of circular and square shapes across concrete strengths and tube slenderness ratios using a consistent ANSYS framework. The present analysis addresses that gap through a parametric study of load capacity, deformation, and stress.

IV. METHODOLOGY

Finite-element model

Three-dimensional nonlinear models were developed in ANSYS Mechanical APDL. The concrete core was represented using SOLID65, an eight-node solid element capable of modelling concrete cracking and crushing. The steel tube was represented using SHELL181, which captures membrane and bending actions and is suitable for thin-to-moderately-thick steel walls. The reported concrete model used the Willam-Warnke failure criterion.

The steel tube was assigned Fe250 properties with a Young's modulus of 200,000 MPa and Poisson's ratio of 0.30. The representative design calculations used a column height and effective length of 2,000 mm. The base was fully restrained, while the top was guided to prevent lateral drift and receive axial loading. Geometry creation, material assignment, meshing, load application, solution, and post-processing were performed sequentially.

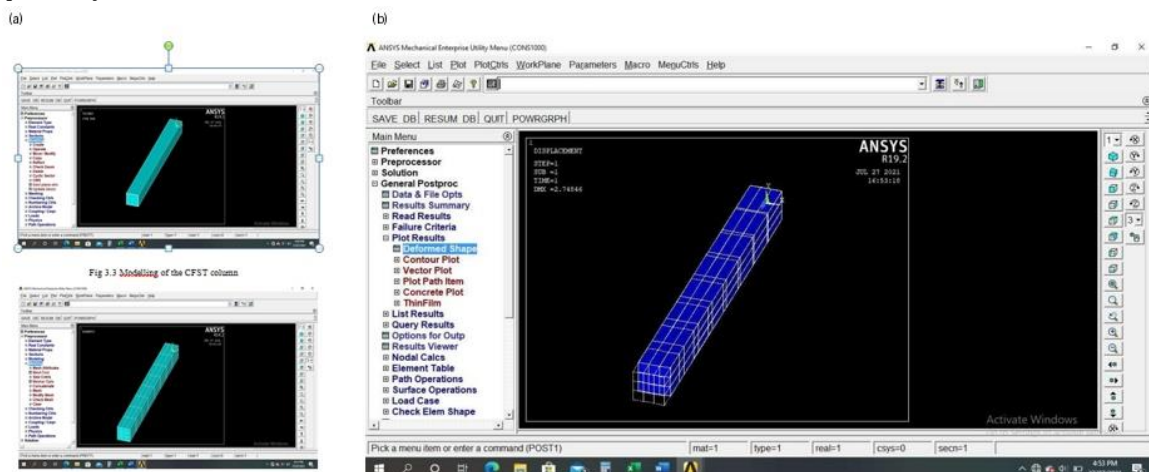


Fig. 1. ANSYS geometry, mesh, and deformed configuration of the CFST column.

Table 1. Concrete material properties used in the numerical models

Property	M25	M30	M55	M60	M80
Elastic modulus (MPa)	25,000	27,385	37,079.9	38,730.8	44,721.46
Density (kg/m ³)	2,400	2,400	2,400	2,400	2,400
Poisson's ratio	0.16	0.16	0.16	0.16	0.161
Compressive strength (MPa)	25	30	55	60	80

Analytical and parametric assessment

Manual calculations considered material design strengths, cross-sectional areas, second moments of area, local slenderness, creep effects, effective flexural rigidity, Euler buckling load, plastic resistance, non-dimensional slenderness, confinement, and buckling reduction factors. The representative circular calculation produced an axial buckling resistance of 1,355 kN, while the representative square calculation produced 1,675.629 kN.

The parametric analysis varied circular diameter and tube thickness to produce decreasing and increasing D/t series. Square breadth and tube thickness were varied similarly to produce decreasing and increasing B/t series.

Load capacities were calculated for M25, M30, M55, and M60 concrete. Separate ANSYS comparisons evaluated deformation and stress for circular and square CFST columns and for corresponding plain-concrete columns.

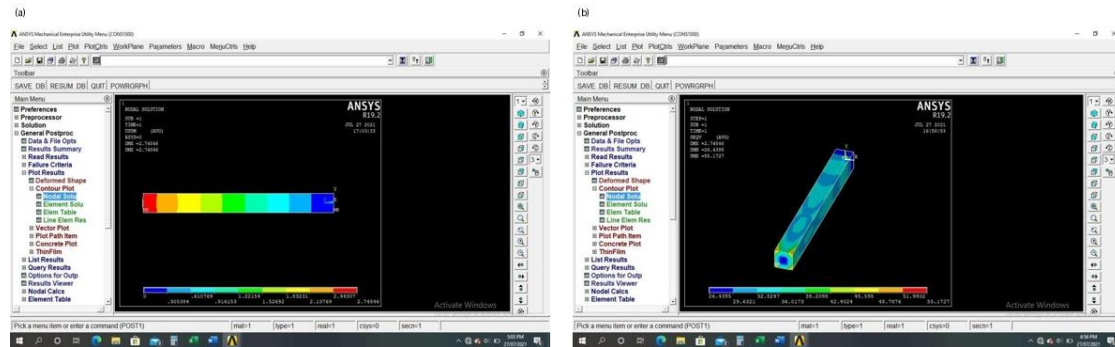


Fig. 2. ANSYS deformation and stress contours for a CFST column.

V. RESULTS AND DISCUSSION

Circular CFST parametric capacity

Table 2. Circular CFST capacity for decreasing D/t ratio

D (mm)	t (mm)	D/t	M25 (kN)	M30 (kN)	M55 (kN)	M60 (kN)
210	5.0	42.000	1228	1318	1727	1783
212	5.6	37.857	1338	1423	1876	1899
214	7.0	30.571	1554	1643	2068	2129
215	7.5	28.667	1637	1726	2150	2211
218	9.0	24.222	1889	1977	2399	2460

Table 3. Circular CFST capacity for increasing D/t ratio

D (mm)	t (mm)	D/t	M25 (kN)	M30 (kN)	M55 (kN)	M60 (kN)
210	5.0	42.00	1228	1318	1727	1783
209	4.5	46.43	1148	1238	1641	1697
207	3.5	59.14	989	1080	1469	1524
205	3.0	68.32	901	984	1368	1421
203	2.81	72.45	857	938	1312	1363
201	2.4	83.76	783	863	1222	1270

The circular-column results show an inverse relationship between D/t and axial capacity. For M30 concrete, capacity increased from 1,318 kN at D/t = 42 to 1,977 kN at D/t = 24.222. In the increasing-slenderness series, the M30 capacity decreased to 863 kN at D/t = 83.76. Higher concrete grades increased capacity at every geometric condition.

Square CFST parametric capacity

Table 4. Square CFST capacity for decreasing B/t ratio

B (mm)	t (mm)	B/t	M25 (kN)	M30 (kN)	M55 (kN)	M60 (kN)
185	7.5	24.60	1675	1764	2184	2245
184	8.0	23.00	1736	1823	2233	2292
183	8.5	21.52	1795	1880	2281	2338
182	9.0	20.23	1853	1936	2327	2383
181	9.5	19.06	1910	1991	2372	2427
180	10.0	18.00	1965	2044	2416	2470

Table 5. Square CFST capacity for increasing B/t ratio

B (mm)	t (mm)	B/t	M25 (kN)	M30 (kN)	M55 (kN)	M60 (kN)
185	7.5	24.67	1675	1764	2184	2245
186	7.0	26.57	1613	1704	2135	2197

188	6.0	31.34	1486	1581	2032	2097
189	5.5	34.36	1420	1581	1979	2045
190	5.0	38.00	1354	1453	1925	1992

Square-column capacity followed the same slenderness trend. For M30 concrete, reducing B/t from approximately 24.6 to 18 increased capacity from 1,764 to 2,044 kN. Increasing B/t to 38 reduced the M30 capacity to 1,453 kN. The results confirm that thicker steel walls improve core confinement and delay local plate buckling.

Shape-dependent deformation and stress

Table 6. Deformation of circular and square CFST columns

Load (kN)	Circular (mm)	Square (mm)
1000	0.650	2.47
1500	0.981	3.70
2000	1.300	4.98
3000	1.960	7.50
4000	2.610	9.89

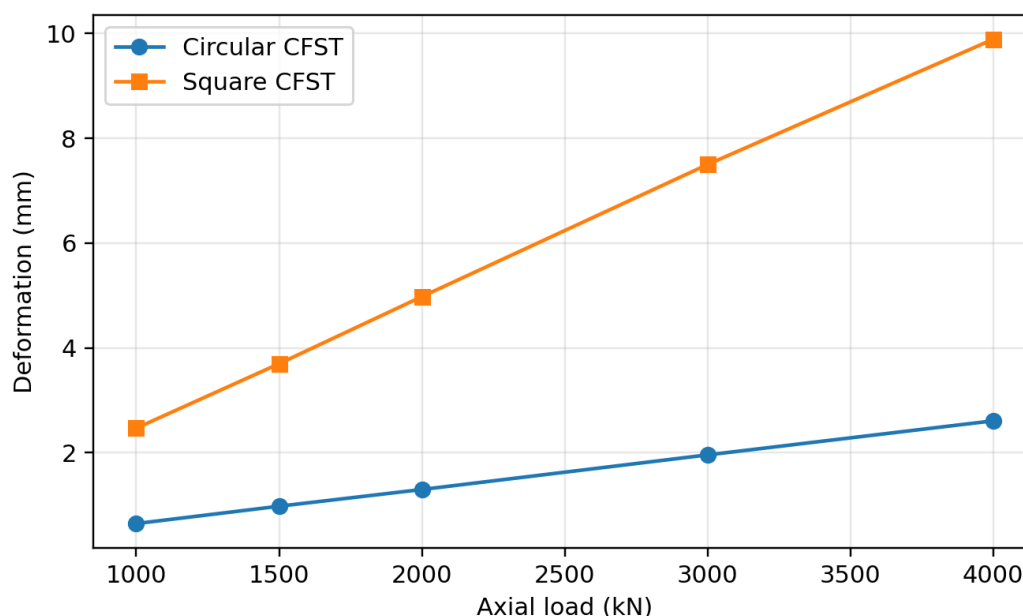


Fig. 3. Load-deformation response of circular and square CFST columns.

Table 7. Stress response of circular and square CFST columns

Load (kN)	Circular (N/mm ²)	Square (N/mm ²)
1000	23.05	47
1500	34.60	71
2000	46.118	95
3000	70.10	130
4000	92.23	189

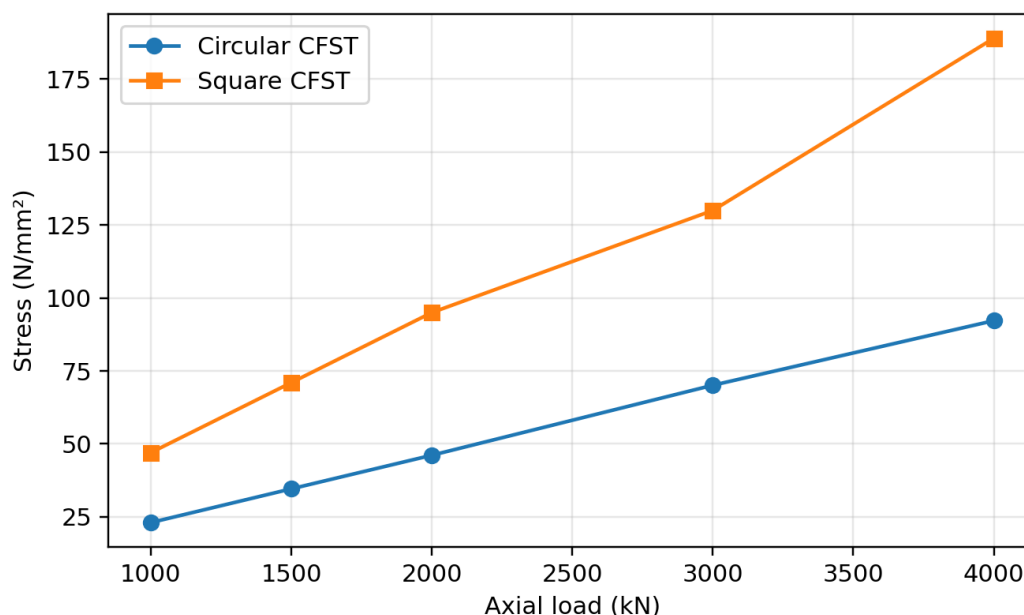


Fig. 4. Load-stress response of circular and square CFST columns.

Circular CFST columns showed lower deformation and lower reported stress at every load level. At 4,000 kN, the square column deformed 9.89 mm compared with 2.61 mm for the circular column, and the reported stresses were 189 and 92.23 N/mm², respectively. This difference was attributed to uniform confinement in the circular tube and corner-dominated, non-uniform confinement in the square tube.

Comparison with plain concrete and concrete-grade effect

Table 8. Plain-concrete column deformation

Load (kN)	Circular (mm)	Square (mm)
1000	0.719	2.75
1500	1.23	4.14
2000	1.35	5.51
3000	2.05	8.20
4000	2.74	10.10

Table 9. Plain-concrete column stress

Load (kN)	Circular (N/mm ²)	Square (N/mm ²)
1000	15.24	55.20
1500	22.88	82.71
2000	33.14	110.31
3000	49.29	165.53
4000	66.40	220.10

Table 10. CFST deformation with concrete grade

Concrete grade (MPa)	Circular (mm)	Square (mm)
25	1.38	4.98
30	1.21	4.50
55	0.88	3.30
60	0.83	2.83

The plain-concrete comparison shows larger deformation than the corresponding CFST models under the same loads, demonstrating the restraining effect of the steel tube. Increasing concrete strength also reduced deformation in both shapes. The associated graph in the study additionally plots M80 values, while the detailed deformation table reports M25, M30, M55, and M60.

VI. CONCLUSION

- The ANSYS APDL models captured the nonlinear axial response of circular and square CFST columns using SOLID65 concrete and SHELL181 steel elements.
- Circular CFST columns exhibited lower deformation and stress than square columns because their geometry provided more uniform confinement.
- Lower D/t and B/t ratios increased load-bearing capacity by increasing relative wall thickness, strengthening confinement, and delaying local buckling.
- Higher concrete grades increased axial capacity and reduced deformation for both circular and square sections.
- The representative Eurocode-based design calculations produced buckling resistances of 1,355 kN for the circular column and 1,675.629 kN for the square column.
- CFST columns deformed less than corresponding plain-concrete columns, confirming the structural benefit of the external steel tube.
- Cross-sectional shape, concrete strength, and tube slenderness are the principal variables for optimizing CFST column performance.

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