Mérnöki Szimpózium a Bánkiban
(ESB 2025)

Analytical Study on the Behavior of Circular Concrete-Filled Steel Tube Columns and Design Provisions

[1]Kamaran Mohammed Kareem, [2]Bakhtyar Saleh Ahmmad, [3]Eszter Horvath-Kalman

*[1]University of Halabja, Department of Civil Engineering, Halabja, Iraq.
kamaran.kareem@uoh.edu.iq
[2]Doctoral School of Safety and Security Science. Obuda University, Budapest, Hungary.
bakhtyar.ahmman@phd.uni-obuda.hu
[3]Faculty of Architectural and Civil Engineering, Obuda University, Budapest, Hungary.
kalman.eszter@ybl.uni-obuda.hu*

Abstract

This study examines the behavior of circular Concrete-Filled Steel Tube (CFST) columns through analytical evaluation supported by an extensive literature review. The influence of key geometric and material parameters is investigated, focusing on column configurations that fall within the application limits of the EC4 and AISC 360-10 design codes. A database of 1192 CFST column results compiled from previous studies is utilized to assess the predictive accuracy of both codes across a wide range of parameters. The comparison indicates that EC4 predictions exhibit closer agreement with observed behavior, whereas AISC 360-10 tends to provide more conservative estimates for all parameter combinations. The findings suggest that the application limits of EC4 can be extended to encompass a broader range of column properties, while the confinement effect should be addressed more comprehensively in AISC 360-10 formulations. Furthermore, the L/D ratio and relative slenderness are identified as key factors influencing column behavior, while the D/t ratio shows a less direct impact.

Keywords: CFST, EC4, AISC 360-10.

1 Introduction

Concrete-Filled Steel Tube (CFST) columns exhibit distinctive mechanical and construction-related advantages that make them well suited for demanding engineering applications. They are widely used as primary load-carrying members in high-rise buildings [1,2], deep underground tunnels [3], long-span bridges [4,5], and towers [6], where their high energy absorption capacity, stiffness, and ductility are especially valuable in earthquake-prone regions [6,7]. As modern construction requirements evolve, steel–concrete composite members—including CFSTcolumns—have gained prominence by combining the strengths of both steel and concrete to produce high-performance structural systems. In CFST columns, the steel tube confines the infilled concrete, restricting its lateral expansion and thereby enhancing its compressive strength and ductility [12–14]. Simultaneously, the concrete core delays or prevents local buckling of the steel tube, improving the composite section's overall load-bearing capacity, ductility, and energy absorption performance [5,10].

From a construction standpoint, the steel tube acts as permanent formwork, reducing construction time and cost [7–9], while the smaller cross-sectional footprint of CFST columns compared with equivalent steel or reinforced concrete sections provides additional economic benefits [1]. Among their various advantages, the confinement effect of circular steel tubes is particularly significant, as appropriate geometric and mechanical properties enable the concrete core to exhibit strength levels exceeding its nominal compressive capacity [11]. The practical relevance of these advantages is demonstrated by real-world structures employing large CFST sections for decades. For example, the SEG Plaza Tower in Shenzhen (completed in 2000) incorporates 1.6 m circular CFST columns, and the Victoria Square Tower in Dalian (completed in 2018) uses 1.5 m × 1.8 m rectangular CFST columns [15]. These applications highlight the importance of considering size effects in design, as specimen dimensions significantly influence load-carrying capacity, and neglecting them may result in unconservative structural performance [15].

Extensive research on the compressive behavior of circular concrete-filled steel tube (CFST) columns has been conducted over recent decades. The axial strength of stub CFST columns has received considerable attention in the literature [1,2,9,16–18]. From a practical engineering perspective, the structural response of slender (long) CFST columns has also been investigated in earlier studies [10,19–21]. Nevertheless, a recent study by Kang et al. [22] indicates that the number of experimental investigations on long CFST columns remains significantly lower than that on stub columns. Moreover, the same study highlights that the range of material parameters examined in existing experiments is insufficient to fully capture the underlying mechanical behavior of CFST columns. These observations were derived from a statistical assessment based on the experimental database originally established by Tao et al. [23] in 2008. Although a substantial number of studies on CFST columns have been published since the development of this database, there remains a clear need for additional experimental research on long columns with a broader range of material parameters to achieve a more comprehensive understanding of the behavior of circular CFST columns.

Practical design formulations provided in international standards enable engineers to estimate the load-carrying capacity of concrete-filled steel tube (CFST) columns. Among the commonly used specifications are the American AISC 360-10 [25], European Eurocode 4 (EC4) [26], Japanese AIJ 2008 [27], Australian AS 5100.6 [28], Chinese DBJ/T13-51-2010 [29], and South African SANS 10162-1 [30]. The predictive performance of these design provisions varies in estimating the axial capacity of CFST columns. Several studies have demonstrated that, for stub columns, AISC 360-10 yields conservative predictions when compared with experimental results [1,5,9,16,18]. Based on experimental data for both short and long CFST columns, Oliveira [19] similarly reported conservative predictions by AISC 360-10.

In contrast, EC4 has been reported to provide unconservative capacity predictions for stub columns in some studies [1,19], while other experimental investigations have shown close agreement between EC4 predictions and test results for stub columns [9,16,18]. For slender CFST columns, Oliveira [19] observed that EC4 predictions are generally in good agreement with experimental results, although they remain slightly unconservative. Dundu [20], who evaluated EC4 predictions against experimental results for long columns with length-to-diameter (L/D) ratios ranging from 6 to 21.7, concluded that EC4 predictions were conservative by up to 25%. Similarly, Zeghiche [10] assessed EC4 predictions against test results of very slender CFST columns with L/D ratios exceeding 12.5 and reported that EC4 provides safe-side estimates.

The variability in these assessments underscores the need for further experimental investigations to improve understanding of the behavior of circular CFST columns. While a substantial number of tests involving average material and geometric properties within the applicability limits of existing specifications have already been reported, future experimental programs should extend beyond these limits in order to identify potential shortcomings and enhance the robustness of current design provisions.

The purpose of this study is to provide a comprehensive evaluation of the prediction methods in AISC 360-10 [25] and EC4 [26]. A dataset of 1192 CFST column tests gathered from the literature—covering a wide range of parameters—was used to ensure a reliable assessment of these design specifications. The evaluation of the 1192 CFST column experiments offers the potential to more accurately illustrate the influence of column parameters on compressive strength and the predictive performance of the specifications.

2 Assembled test database

The accuracy and reliability of design equations depend on rigorous validation against experimental data of high quality. In this regard, a comprehensive test database compiled by the authors [33] has been utilised in this study. This database encompasses results from 129 independent studies on CFST columns, conducted over the period from 1967 to 2024.

A total of 1192 data points were collected from the open literature to assemble a database for conventional carbon steel CFST circular stub columns subjected to uniaxial compression (without eccentricity). The length-to-diameter (L/D) ratios of all selected columns are less than 5, ensuring that the columns behave as stub columns during testing. After the data were collected, the authors [33] took several steps to ensure consistency across the database: (i) standardisation of concrete compressive strength. Since concrete samples used in compressive strength tests vary in shape and size, the concrete strength of all test columns in the database was converted to the equivalent strength of a 150 × 300 mm standard cylinder, as specified in AS/NZS 2327 [34], using established conversion methods [200]. This conversion process serves solely to standardise the material strength values and does not represent any structural size effect in composite columns; and (ii) adjustment of ultimate strength (Nue). The Nue value of each specimen was obtained following the definition proposed by Tao et al. [35]. According to this definition, Nue is determined as the strength at 1 % strain limit if no peak load occurs prior to this strain. Otherwise, the peak load is taken as Nue. This methodology avoids the overestimation of load capacity for CFST columns exhibiting strain-hardening behaviour. Table 1 presents the minimum (Min), maximum (Max), mean (μ), and standard deviation (σ) of some key parameters from the compiled test data as reported by [36]. In this table, D, D/t , fy, f_c', and ξc are the outer diameter, diameter-to-thickness ratio, steel yield stress, concrete compressive strength (for 150 × 300 mm cylinders), and confinement factor ($\xi_c = A_s f_y / A_c f_c'$), respectively. Here, As and Ac are the cross-sectional areas of steel and concrete, respectively. It is important to note that, where the modulus of elasticity of the steel tube (Es) was not reported, it was assumed to be 200 GPa. The elastic modulus of concrete (Ec) for all specimens was calculated using the equation provided in AS/NZS 2327. Further details on the compilation and characteristics of the database can be found in Ref. [33].

Table 1. Summary of geometric dimensions and material properties of CFST specimens in the compiled test database.

No. of data	Metric	*D (mm)*	*D/t*	*L/D*	$f_y(MPa)$	$f_c'(MPa)$	ξ_c
1192	Min	60.0	8.4	0.8	176.0	15.0	0.04
	Max	1100.4	319.1	5.0	1233.0	185.6	10.17
	μ_m	171.5	49.0	3.1	382.5	60.4	1.04
	σ	97.0	38.0	0.6	152.2	32.3	0.90

3 Design specifications

EC4 and AISC 360-10 standards are used in this paper. EC4 adopts limit-state design to ensure serviceability and safety by applying partial safety factors to loads and material properties. On the other hand, the AISC 360-10 procedure, which is based on structural steel design, allows the use of either the limit state or the allowable stress design. A total of 1192 CFST column test results for circular sections were collected from the literature, covering a relatively wide range of CFST column parameters, were employed in the design specification calculations.

3.1 Eurocode-4

The plastic resistance of a concrete-filled composite cross-section is determined by summing the contributions of the steel tube and the infilled concrete, as expressed in Eq. (1). Square and rectangular CFST sections provide limited confinement, since the tube walls primarily resist the lateral pressure of the concrete through plate bending rather than through the development of hoop stresses, as occurs in circular sections [37]. For circular CFST columns, Eurocode 4 (EC4) provides an explicit formulation that accounts for the confinement effect, as given in Eq. (2). In this formulation, f_y denotes the yield strength of the outer steel tube, Ac and As represent the cross-sectional areas of the concrete core and steel tube, respectively, η_a is the steel reduction factor, and η_c is the concrete enhancement factor. When the load eccentricity is less than 10% of the external diameter of the steel tube, the steel reduction and concrete enhancement factors are evaluated using Eqs. (3) and (4), respectively.

EC4 considers the confinement effect in circular CFST columns provided that the relative slenderness ratio ($\bar{\lambda}$) does not exceed 0.5. The relative slenderness is defined by Eq. (5), where $N_{pl,Rd}$ is the plastic resistance of the column calculated using Eq. (2), and N_{cr} is the Euler critical buckling load. The critical load is determined according to Eq. (6), in which $(EI)_e$ denotes the effective flexural stiffness of the composite member, as defined in Eq. (7). Here, E_s and E_c are the elastic moduli of steel and concrete, respectively, with the concrete modulus given by $E_c = 22000\left(\frac{f_c+8MPa}{10}\right)^{0.3}$. The terms I_s and I_c represent the second moments of area of the steel tube and concrete core, respectively. Finally, K_e is a correction factor taken as 0.6.

$$N_{pl,Rd} = A_s f_y + A_c f_c \tag{1}$$

$$N_{pl,Rd} = \eta_a A_s f_y + A_c f_c \left[1 + \eta_c \frac{t f_y}{D f_c}\right] \tag{2}$$

$$\eta_a = 0.25\left(3 + 2\bar{\lambda}\right) \leq 1.0 \tag{3}$$

$$\eta_c = 0.4.9 - 18.5\bar{\lambda} + 17\bar{\lambda}^2 \geq 0 \tag{4}$$

$$\bar{\lambda} = \sqrt{\frac{N_{pl,Rd}}{N_{cr}}} \tag{5}$$

$$N_{cr} = \frac{\pi^2 (EI)_e}{L^2} \tag{6}$$

$$(EI)_e = E_s I_s + K_e E_c I_c \tag{7}$$

3.2 AISC-360-10

For axially loaded CFST columns, AISC 360-10 calculates the compressive load capacity based on member slenderness, as shown in Eq. (8), where P_{no} is the nominal compressive capacity of the composite section and P_e is the Euler critical load, which is calculated using effective stiffness $(EI)_e$ as Eq. (9) where elastic modulus of concrete in AISC 360-10 is given by $E_c = 4700\sqrt{f_c}$ and C3 is the coefficient for effective rigidity of the filled composite column calculated as Eq. (10).

$$P_n = P_{no}\left[0.658^{\frac{P_{no}}{P_e}}\right] \qquad \frac{P_{no}}{P_e} \leq 2.25$$

$$P_n = 0.877P_e \qquad \frac{P_{no}}{P_e} > 2.25 \tag{8}$$

$$(EI)_e = E_s I_s + C_3 E_c I_c \tag{9}$$

$$C_3 = 0.6 + 2\left[\frac{A_s}{A_c + A_s}\right] \leq 0.9 \tag{10}$$

AISC 360-10 considers local buckling effect using three different classifications for steel tubes. A circular CFST member is considered to be compact if D/t ratio is lower than $\lambda_p = 0.15\,E_s/f_r$. The section is considered to be non-compact if D/t ratio is greater than λ_p but lower than $\lambda_r = 0.19\,E_s/f_r$. Finally, the section is considered to be slender when D/t ratio is larger than λ_r. The nominal compressive capacity of the composite section P_{no} is calculated according to these classifications of the sections. For compact sections nominal compressive capacity is equal to plastic strength of the composite section(P_P):

$$P_{no} = P_p \tag{11}$$

and plastic strength of the section is given by:

$$P_p = A_s f_y + C_2 A_c f_c \tag{12}$$

C2 is equal to 0.95 for circular CFST columns. By adopting this coefficient, AISC360-10 implies that the steel tube reaches its yield strength when the concrete core strength is about $0.95 f_c$. For square and rectangular composite columns the parameter C2 is equal to 0.85. AISC360-10 considers the confinement effect of circular steel sections by just incorporating C2 coefficient of 0.95, instead of 0.85, which implies an 11% constant performance increment for circular tubes.

For non-compact sections, the nominal compressive capacity is calculated as follows:

$$P_{no} = P_p - \frac{P_P - P_y}{(\lambda_r - \lambda_P)^2}(\lambda_r - \lambda_P)^2 \tag{13}$$

where, P_y is the yield strength of the composite section, and is given by:

$$P_y = A_s f_y + 0.7 A_c f_c \tag{14}$$

In Eq. (19) f_{cr} is the critical local buckling stress of the filled circular section, and is calculated as follows:

$$f_{cr} = \frac{0.72 f_y}{\left(\left(\frac{D}{t}\right)\frac{f_y}{E_s}\right)^{0.2}} \tag{15}$$

Through these AISC 360-10 equations slender sections are limited to developing critical local buckling stress f_{cr} of steel tube and $0.7 f_c$ of concrete core.

4 Performance of Design Codes Relative to Experimental Behavior

Figure 1 illustrates the relationship between the relative slenderness ($\bar{\lambda}$) and the ratio of design specification predictions to experimental axial capacities (N_{spec}/N_{exp}) for CFST columns. As shown in the figure, which covers relative slenderness values up to approximately 0.35, the predictions from EC4 and AISC 360-10 exhibit noticeable differences, particularly in the lower slenderness range. For $\bar{\lambda}$ below about 0.15–0.20, EC4 generally overestimates the axial capacity ($N_{spec}/N_{exp} > 1.0$), whereas AISC 360-10 tends to underpredict it ($N_{spec}/N_{exp} < 1.0$). This pattern is consistent with previous findings, such as those reported by Ekmekyapar and Al-Eliwi (2016), which also observed higher EC4 predictions relative to AISC for stockier columns.

As the slenderness ratio increases toward the upper limit shown in the figure ($\bar{\lambda} \approx 0.35$), the predictions of the two codes begin to converge. Although slight differences remain, AISC 360-10 predictions gradually move closer to the experimental values, while EC4 transitions from overestimating the strength to providing more conservative predictions beyond $\bar{\lambda} \approx 0.4$ in broader datasets. However, within the plotted range ($\bar{\lambda} < 0.35$), EC4 continues to produce generally higher strength predictions than AISC 360-10.

It is also crucial to specify the importance of parameters (L/D, D/t and ξ) to be able to understand the mechanics of CFST columns. Figure 2 illustrates the relationship between the L/D ratio and the strength index (SI) for the CFST columns listed in Table 1. Within the range shown in the figure (L/D values less than 6), the data indicate that the L/D ratio has a clear influence on the axial capacity of the columns. Although some scatter is present, the overall trend suggests that as the L/D ratio increases, the SI generally decreases, indicating reduced column capacity with increasing slenderness. This confirms that L/D is an important parameter influencing the strength behavior of CFST members.

It can also be shown that the relative slenderness ratio defined in EC4 formulation has the potential to be a good measure for column capacity predictions (Figure 3).

From the relationship between D/t and SI, and confinement factor (ξ) and SI, it can be observed in Figures 4 and 5, respectively, that these parameters have no direct impact on column compression behaviour.

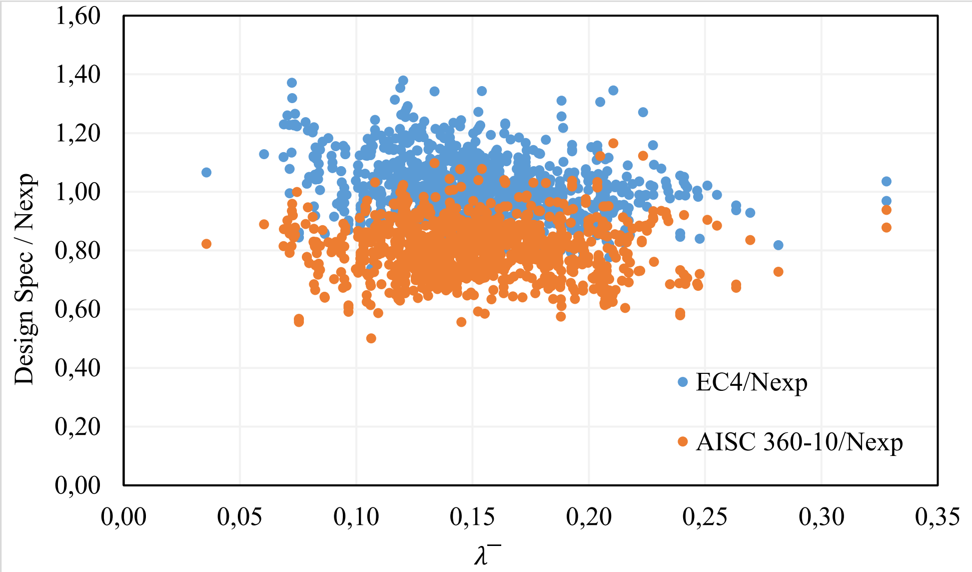

Figure 1. Relative slenderness versus ratios of EC4 and AISC360-10 predictions to test results.

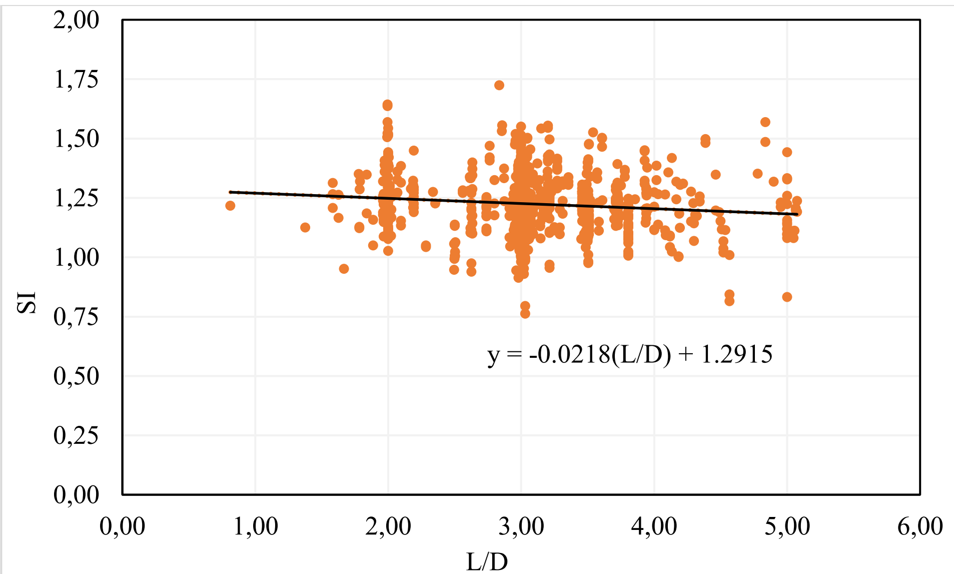

Figure 2. L/D ratio versus strength index of columns.

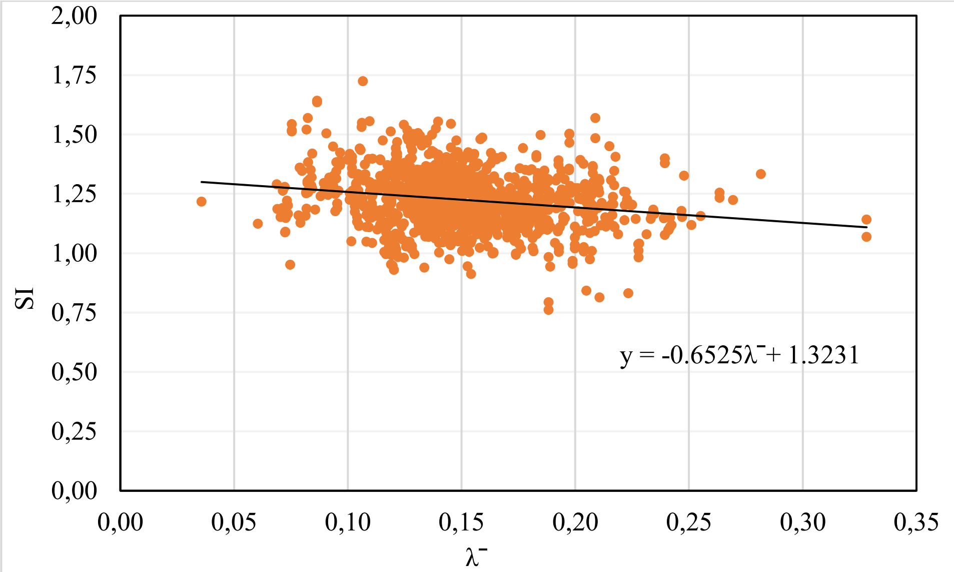

Figure 3. Relative slenderness versus strength index of columns

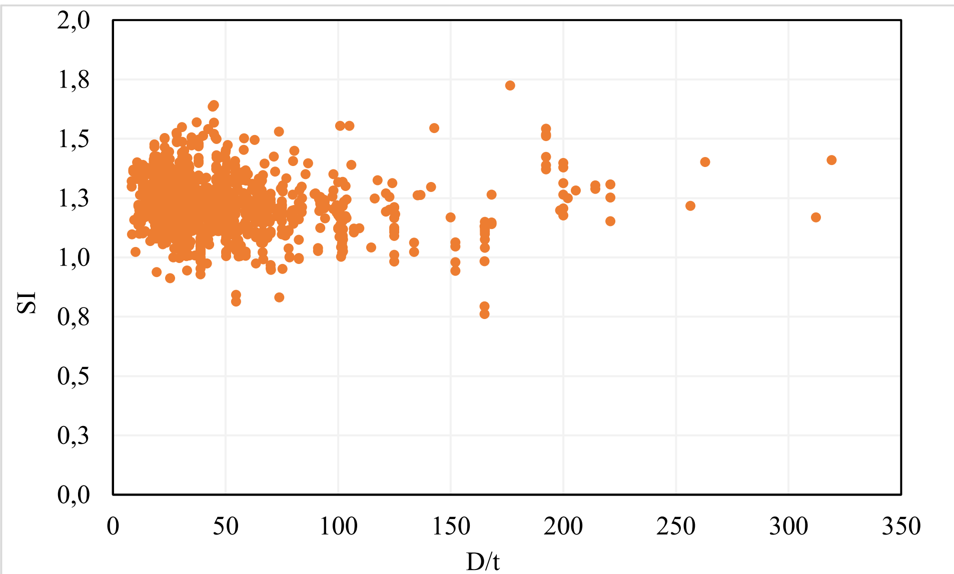

Figure 4. D/t ratio versus strength index of columns.

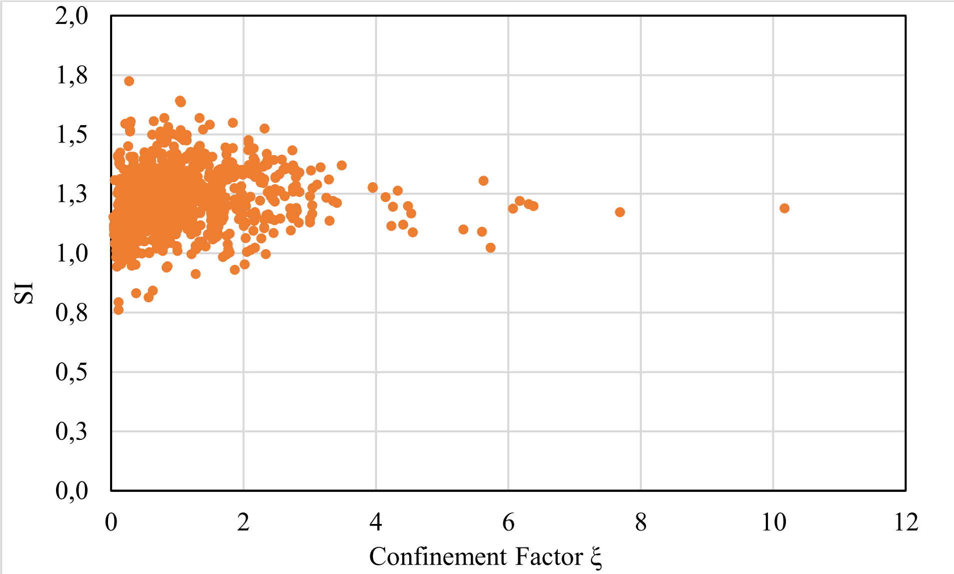

Figure 5. Confinement factor (ξ) versus strength index of columns.

5 Conclusion

This study provided a comprehensive assessment of the predictive performance of the EC4 and AISC 360-10 design specifications using a large database of 1192 CFST column test results compiled from the literature. The analytical evaluation demonstrated that EC4 generally offers closer agreement with experimental axial capacities, particularly for stockier columns with lower relative slenderness ratios. In contrast, AISC 360-10 consistently produced more conservative estimates across all parameter ranges examined. The trends observed in the relative slenderness analysis confirm that EC4 tends to overpredict capacity at very low slenderness levels, whereas AISC 360-10 underpredicts it; however, the predictions of the two codes converge as slenderness increases.

The parametric investigation highlights the significance of the L/D ratio as a primary factor governing the compressive strength of CFST columns. Within the examined range ($L/D < 6$), an increase in the L/D ratio corresponds to a gradual reduction in the strength index, underscoring the need to account for slenderness effects when evaluating column behavior. Conversely, the D/t ratio and confinement factor (ξ) exhibited no direct or consistent influence on axial strength within the bounds of the database, suggesting that their effects are secondary compared to global slenderness measures. Moreover, the findings indicate that the relative slenderness formulation adopted in EC4 serves as a reliable indicator of column capacity.

Overall, the results suggest that the applicability limits of EC4 could be safely extended to a broader range of CFST column geometries, whereas AISC 360-10 would benefit from a more refined incorporation of confinement effects. By clarifying the roles of key geometric and material parameters, this study contributes to a deeper understanding of CFST column behavior and provides a foundation for improving future design provisions for composite compression members.

6 References

[1] G. Giakoumelis, D. Lam, Axial capacity of circular concrete-filled tube columns, J. Constr. Steel Res. 60 (2004) 1049–1068.

[2] F. Abed, M. AlHamaydeh, S. Abdalla, Experimental and numerical investigations of the compressive behavior of concrete filled steel tubes (CFSTs), J. Constr. Steel Res. 80 (2013) 429–439.

[3] X. Chang, X. Luo, C. Zhu, C. Tang, Analysis of circular concrete-filled steel tube (CFT) support in high ground stress conditions, Tunn. Undergr. Space Technol. 43 (2014) 41–48.

[4] N.K. Brown, M.J. Kowalsky, J.M. Nau, Impact of D/t on seismic behavior of reinforced concrete filled steel tubes, J. Constr. Steel Res. 107 (2015) 111–123.

[5] L.H. Han, W. Li, R. Bjorhovde, Developments and advanced applications of concrete-filled steel tubular (CFST) structures: Members, J. Constr. Steel Res. 100 (2014) 211–228.

[6] F. Xu, J. Chen, W.L. Jin, Experimental investigation of thin-walled concrete-filled steel tube columns with reinforced lattice angle, Thin-Walled Struct. 84 (2014) 59–67.

[7] M.H. Lai, J.C.M. Ho, Confinement effect of ring-confined concrete-filled-steel-tube columns under uni-axial load, Eng. Struct. 67 (2014) 123–141.

[8] N. Ferhoune, Experimental behaviour of cold-formed steel welded tube filled with concrete made of crushed crystallized slag subjected to eccentric load, Thin-Walled Struct. 80 (2014) 159–166.

[9] Z.W. Yu, F.X. Ding, C.S. Cai, Experimental behavior of circular concrete-filled steel tube stub columns, J. Constr. Steel Res. 63 (2007) 165–174.

[10] J. Zeghiche, K. Chaoui, An experimental behaviour of concrete-filled steel tubular columns, J. Constr. Steel Res. 61 (2005) 53–66.

[11] M.V. Chitawadagi, M.C. Narasimhan, S.M. Kulkarni, Axial strength of circular concrete-filled steel tube columns DOE approach, J. Constr. Steel Res. 66 (2010) 1248–1260.

[12] Z. Tao, L.H. Han, D.Y. Wang, Strength and ductility of stiffened thin-walled hollow steel structural stub columns filled with concrete, Thin-Walled Struct. 46 (10) (2008) 1113–1128.

[13] W.L.A. de Oliveira, S. De Nardin, A.L.H. de Cresce El Debs, M.K. El Debs, Influence of concrete strength and length/diameter on the axial capacity of CFT columns, Journal of Constructional Steel Research 65 (12) (2009) 2103–2110.

[14] L.H. Han, W. Li, R. Bjorhovde, Developments and advanced applications of concrete-filled steel tubular (CFST) structures: members, Journal of Constructional Steel Research 100 (2014) 211–228.

[15] Daei, A., Ahmed, B., Katwal, U., Hassan, M.K., Kang, W.H., Khan, M., Uy, B. and Tao, Z., 2025. Strength design of steel-concrete composite columns considering size effects and concrete cover spalling. Journal of Building Engineering, p.114448.

[16] F.X. Ding, Z.W. Yu, Y. Bai, Y.Z. Gong, Elasto-plastic analysis of circular concrete-filled steel tube stub columns, J. Constr. Steel Res. 67 (2011) 1567–1577.

[17] K. Sakino, H. Nakahara, S. Morino, I. Nishiyama, Behavior of centrally loaded concrete-filled steel-tube short columns, J. Struct. Eng. 130 (2004) 180–188.

[18] Y. Wang, J. Chen, Y. Geng, Testing and analysis of axially loaded normal-strength recycled aggregate concrete filled steel tubular stub columns, Eng. Struct. 86 (2015) 192–212.

[19] W.L.A. de Oliveira, S. De Nardin, A.L.H. de Cresce El Debs, M.K. El Debs, Influence of concrete strength and length/diameter on the axial capacity of CFT columns, J. Constr. Steel Res. 65 (2009) 2103–2110.

[20] M. Dundu, Compressive strength of circular concrete filled steel tube columns, Thin-Walled Struct.

56 (2012) 62–70.

[21] M. Yu, X. Zha, J. Ye, C. She, A unified formulation for hollow and solid concrete-filled steel tube columns under axial compression, Eng. Struct. 32 (2010) 1046–1053.

[22] W.H. Kang, B. Uy, Z. Tao, S.J. Hicks, Design Strength of Concrete-Filled Steel Columns, Adv. Steel Constr. 11 (2015) 165–184.

[23] Z. Tao, B. Uy, L.H. Han, S.H. He, Design of concrete-filled steel tubular members according to australian standard AS5100 model and calibration, Aust. J. Struct. Eng. 8 (2008) 197–214.

[24] Commentary on the Specification for Structural Steel Buildings AISC-360-10, in: AISC, Chicago, Illinois, 2010.

[25] AISC 360-10. Specification for Structural Steel Buildings, in: AISC, Chicago, Illinois, 2010.

[26] EN 1994-1-1 Eurocode 4. Design of Composite Steel and Concrete Structures – Part 1-1: General Rules and Rules for Buildings, in: CEN, Brussels, 2004.

[27] AIJ 2008. Recommendations for Design and Construction of Concrete Filled Steel Tubular Structures, in: AIJ, Tokyo, 2008.

[28] AS 5100.6-2004 Bridge Design Part 6: Steel and Composite Construction, in: AS, Sydney, 2004.

[29] DBJ/T13-51-2010. Technical Specifications for Concrete-Filled Steel Tubular Structures, in: DBJ, Fuzhou, 2010 (in Chinese).

[30] SANS 10162-1. The Structural Use of Steel Part 1: Limit-State Design of Hot-Rolled Steelwork, in, South Africa National Standards, Pretoria, South Africa, 2005.

[31] L.H. Han, G.H. Yao, X.L. Zhao, Tests and calculations for hollow structural steel (HSS) stub columns filled with self-consolidating concrete (SCC), J. Constr. Steel Res. 61 (2005) 1241–1269.

[32] B. Uy, Z. Tao, L.H. Han, Behaviour of short and slender concrete-filled stainless steel tubular columns, J. Constr. Steel Res. 67 (2011) 360–378.

[33] A. Daei, B. Ahmed, U. Katwal, M.K. Hassan, Z. Tao, Short concrete-filled and Concrete Encased Steel Columns Under Axial Compression: a Comprehensive Test Database, Research Report R2, Centre for Infrastructure Engineering, Western Sydney University, 2024, https://doi.org/10.13140/RG.2.2.31438.27206.

[34] Standards Australia (AS/NZS 2327:2017), Composite Structures – Composite steel-concrete Construction in Buildings, 2017. Sydney, Australia.

[35] Z. Tao, Z.B. Wang, Q. Yu, Finite element modelling of concrete-filled steel stub columns under axial compression, Journal of Constructional Steel Research 89 (2013) 12

[36] Daei, A., Ahmed, B., Katwal, U., Hassan, M.K., Kang, W.H., Khan, M., Uy, B. and Tao, Z., 2025. Strength design of steel-concrete composite columns considering size effects and concrete cover spalling. Journal of Building Engineering, p.114448.

[37] Y.M. Alostaz, S.P. Schneider, Connections to Cocrete-Filled Steel Tubes, De- partment of Civil Engineering, University of Illinois, Urbana Champaign, 1996.