Evaluating the Structural Advantages of Concrete-Filled Steel Tubes for Resilient Building Design

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Article History: Received 18 February 2025; Revised 7 May 2025;
Accepted 28 June 2025; Published 30 June 2025

Abstract
Concrete-filled steel tube (CFST) columns have gained increasing popularity in the construction industry due to their enhanced structural properties and versatility in various forms. CFST columns are widely used in the construction of bridges, power transmission towers, and high-rise buildings, particularly in earthquake-prone regions. Despite their advantages, additional research is needed to fully understand their behaviour under axial loads, compression, and fire exposure, particularly in dynamic conditions such as seismic events. This study evaluates recent literature on the structural advantages of CFST columns, focusing on several critical design factors such as the length-to-diameter ratio, steel tube wall thickness, and their performance under compressive, axial, and fire stresses. The results show that CFST columns exhibit superior strength and ductility compared to conventional materials, with key design factors, such as tube dimensions and material properties, influencing their performance. Fire performance studies indicate that CFSTs maintain structural integrity under moderate fire conditions, although more research is required for extreme scenarios. The findings have important implications for the design of seismic-resistant structures, highlighting the need for optimised CFST designs to improve safety and durability in earthquake-prone areas. Future research should focus on advanced modelling techniques and further experimental studies to refine CFST design and expand its applications in construction.

Keywords: Axial Load, Concrete-Filled Steel Tubes (CFST), Earthquake Resistant Structures, Fire Performance, Structural Performance

1.0 Introduction
Concrete-filled steel tube (CFST) columns are a composite structural element consisting of a steel tube filled with concrete. It has gained significant attention in the construction industry due to its superior strength, ductility, and stiffness compared to traditional steel tubes [1], [2], [3], [4]. In recent years, there has been an increasing number of studies on CFST columns with various types of concrete due to the good versatility of these structures [2],

[5]. CFST columns are increasingly appreciated for high-rise, wide-span, and large-scale structures due to their superior mechanical performance resulting from the composite interaction between the steel tube and concrete core. The confinement effect provided by the steel enhances the compressive strength of the concrete, while the core delays local buckling of the steel tubes. CFST columns can be constructed with square, rectangular, or circular cross-sections and may be filled with either unreinforced or reinforced concrete [1].

CFST systems offer multiple structural and construction-related advantages that translate into substantial economic benefits. Their high strength-to-size ratio allows for more compact cross-sections, hence optimising usable floor space, which is an important consideration in high-rise and densely built environments. The potential for off-site prefabrication enables rapid on-site assembly, thus reducing labour costs, construction time, and site congestion.

Although multiple studies have demonstrated the enhanced flexural strength, moment capacity, and stiffness of CFST under various loading conditions, gaps remain in understanding the influences of design parameters such as wall thickness, height, and fire resistance on their overall performance [3].

Current research frequently emphasises singular facets of CFST, leading to an absence of a holistic understanding of their behaviour under various settings, especially in seismically active regions where increased resilience is essential. The goal of this study is to thoroughly investigate the mechanical performance of CFST columns, with a focus on how environmental factors and design variables affect the structural integrity and safety of these columns.

To accomplish these goals, this study explores the advancements in CFST columns with a particular focus on the enhancement technique. Emphasis is placed on the integration of advanced material technologies such as carbon-fibre-reinforced polymers (CFRP) with conventional CFST systems. The results would provide empirical evidence regarding the efficiency of CFST, guiding optimal methods for their design and implementation in contemporary buildings. This work seeks to significantly advance structural engineering by formulating guidelines for the appropriate application of CFST in high-rise buildings, thereby improving the safety and efficiency of modern construction methods.

2.0 Methodology

This review covers a literature published between 2002 and 2024, sourced from major academic databases including Scopus and ScienceDirect. A total of 19 peer-reviewed articles were selected to analyse the structural performance and durability of Concrete-Filled Steel Tubes (CFSTs) under various loading conditions. Drawing from peer-reviewed journals and an indexed database, this review synthesises recent findings with a focus on critical design parameters such as the length-to-diameter (L/D) ratio, steel tube wall thickness, axial load behaviour, compressive strength, and fire resistance.

The analysis emphasises CFST performance under axial loads, compression and fire exposure, with particular attention to their seismic resilience, energy dissipation capacity and long-term durability. For example, Wang et al. [6] conducted experimental studies on self-centering CFST column base connections and reported stable cyclic behaviour with minimal residual drift and high energy dissipation, validating the effectiveness in seismic applications. Similarly, Medall et al. [7] examined the post-fire performance of steel-reinforced CFST stub columns and demonstrated that these systems exhibit high ductility and retain over 55% of their axial load capacity after exposure to elevated temperature. Their findings support the potential of CFST-based systems for use in fire-prone environments and contribute to the development of post-fire design equations. By integrating findings from multiple studies, this review aims to provide a comprehensive assessment of CFST behaviour, highlighting its structural advantages and identifying key areas for further investigation and design optimisation.

3.0 Results and Discussion

In recent years, significant advancements have been made in the research and development of concrete-filled steel tube (CFST) structures, particularly in enhancing their performance and expanding their applications in construction [3]. For instance, Elremaily and Azizinamini [8] conducted experimental tests on six CFST columns placed under a continuous axial load combined with cyclic lateral loads. They analysed key parameters such as concrete grade, axial load levels, and diameter-to-thickness (D/T) ratios of the steel tubes. Their findings demonstrated high levels of ductility and stable strength, emphasising that steel tube confinement substantially enhances the compressive strength of concrete. These results are particularly relevant in civil engineering applications, particularly in designing CFST structures to withstand dynamic actions such as earthquakes. Consequently, this reinforces the critical role of confinement in structural stability.

Similarly, Dundu [9] examined 24 CFST columns subjected to concentric compression until failure, evaluating parameters such as length, diameter, and material strength of both the steel tube and concrete core. The study revealed that columns with a high slenderness ratio experienced complete flexural buckling, whereas shorter and stockier columns failed due to concrete crushing and steel yielding. Notably, the South African code (SANS 10162-1) and Eurocode 4 (EC4) provided conservative load estimates, with predicted values exceeding the experimental results by 10.5% and 20.2% respectively. These findings highlight the importance of code compliance while also raising concerns about the conservatism of the existing design standard. Therefore, future revisions of these standards may benefit from empirical data to develop more accurate and efficient design approaches that better reflect the true performance of CFST structures.

Moreover, Hassooni and Al Zaidee [10] investigated the axial compression behaviour of CFST columns with varying heights but uniform steel tube thickness. Their results indicated that shorter columns exhibited higher load-bearing capacities due to superior stiffness compared to conventional concrete and hollow steel sections. Additionally, the observed non-linear behaviour before failure underscored the significant influence of slenderness ratio and applied load on structural performance. Expanding this study to include a broader range of column heights and cross-sectional geometries could provide a more comprehensive understanding of these interactions.

Beyond experimental studies, Ma et al. [11] conducted computational analyses of CFST columns under sustained loading, employing a viscoelastic finite element model correlated with experimental observations. Their findings indicated that strength loss due to long-term loading was minimal, remaining below 12.4%. This highlights the importance of considering creep effects in CFST design. In addition, future studies should explore additional factors such as temperature and humidity to improve the predictive accuracy of long-term material behaviour models.

In another development, Zhang et al. [12] expanded CFST research by evaluating reinforcement techniques using fibre-reinforced polymer (FRP) and steel strips. Their results demonstrated that FRP significantly improved load-bearing capacity and deformation resistance, with greater enhancements observed as the number of FRP layers increased. While steel strip reinforcement was also effective, welded steel strips were deemed more suitable for practical engineering applications due to their ease of implementation. These findings emphasise the importance of conducting cost-benefit analyses and long-term performance assessments to determine the most viable reinforcement strategies for CFST structures.

Furthermore, Teng et al. [13] analysed CFST columns with different geometries, including hollow structural profiles and circular concrete columns confined within high-strength steel spirals. Their results showed that spiral confinement markedly enhanced ductility, although its effectiveness varied based on concrete strength and confinement arrangements. Consequently, further investigations are required to optimise these parameters for improved structural resilience under axial loads.

Shaker et al. [14] explored the influence of steel tube thickness on CFST column strength. They found that increasing tube thickness enhanced failure load by 26-37%, though vertical deformation remained relatively unchanged. However, the use of CFST columns with ribs did not significantly improve failure strength due to localised buckling at rib locations. These results contrast with Ekmekyapar and Al-Eliwi [15], who suggested that thicker steel tube walls are necessary for high-strength concrete, highlighting potential discrepancies between different design approaches. Therefore, future research should aim to reconcile these differences to establish optimised

CFST design principles.

Additionally, Ekmekyapar and Al-Eliwi [15] observed that the strength index of CFST columns decreased as concrete strength increased, suggesting that lower-strength concrete benefits more from confinement effects. Their results indicated that high-strength concrete (107 MPa) requires significantly thicker steel tubes to maintain ductility, potentially leading to increased costs and design complexities. These findings underline the importance of balancing material selection with structural performance requirements. Similarly, Abdullah et al. [16] investigated the impact of longitudinal steel plate reinforcements within CFST columns, finding a 10% increase in ultimate load capacity without significantly altering geometric properties. This suggests a viable approach to enhancing CFST performance while maintaining structural efficiency. However, further research is needed to evaluate the economic feasibility and practical implementation of such reinforcements.

Moreover, He et al. [17] examined passive confinement effects in CFST columns, demonstrating that low-strength infill concrete exhibited higher confining pressures than high-strength alternatives. Their proposed equation for estimating passive confinement pressure provides a useful design tool but requires validation across a broader range of column configurations and loading conditions. In terms of fire performance, Kassem [18] investigated the behaviour of CFST columns at elevated temperatures, developing models for temperature distribution and buckling load in compliance with Eurocode standards. The study revealed a bi-linear strength degradation pattern, with residual strengths converging as the concrete characteristic strength increased. Notably, columns with larger diameters of over 700 mm and shorter lengths retained superior residual strength. Therefore, additional research should consider varying environmental conditions and loading scenarios to enhance the applicability of these findings.

Furthermore, Wang et al. [19] evaluated the compressive behaviour of post-heated CFST short columns reinforced externally with carbon fibre-reinforced polymer (CFRP) sheets. Their results indicated that strength degradation was temperature dependent, with CFRP reinforcement effectively mitigating strength loss. However, long-term durability studies are necessary to assess the sustainability of CFRP reinforcements under repeated thermal cycles.

Lu et al. [20] analysed the effects of steel fibres and self-stress in self-compacting concrete-filled steel tube (SCCFST) specimens under bending conditions. Their results showed that self-stress improved flexural rigidity, while steel fibres enhanced flexural strength and extended the elastic phase. However, the benefits of steel fibres diminished as tube thickness increased, suggesting complex interactions between material properties. Further research should explore the impact of environmental conditions on these structural behaviours to improve design resilience.

Manikandan and Umarani [21] investigated CFST columns filled with various concrete types, including conventional, steel fibre-reinforced, geopolymer, and expansive concrete. Their findings indicated that expansive concrete-filled CFST (ECFST) columns exhibited the highest bond strength and axial compressive load. A comparative analysis of the economic and environmental implications of these concrete types would provide valuable insights for real-world applications. Additionally, Liu et al. [22] addressed the structural integrity of CFST columns with perforations, analysing 28 specimens to assess the effects of hole location, depth, and dimensions on load capacity. Their findings revealed that perforations led to outward local buckling due to reduced confinement effects. While their results aligned with code predictions, further research into repair methodologies and structural integrity assessments would enhance practical applications in engineering design.

Table 1 presents a summary of previous studies on CFST columns, categorising them based on study type, methodology, and identified research gaps. Most of these studies focus on experimental investigations, while a few employs computational modelling and thermal analysis. Experimental studies primarily examine the axial and compressive behaviour of CFST columns, with variations in parameters such as confinement type, reinforcement methods, and material properties. However, despite extensive experimental work, several research gaps remain unaddressed.

One notable limitation in existing studies is the lack of long-term durability assessments, particularly for reinforcement materials such as Carbon Fibre Reinforced Polymer (CFRP). Additionally, while various reinforcement strategies have been explored, limited research has been conducted on their cost-effectiveness and practical implementation. Another key gap in the literature is the absence of studies that integrate environmental factors, such as temperature fluctuations and humidity levels, which could significantly influence the performance of CFST columns over time. These findings underscore the need for further research to enhance the structural integrity of CFST columns, refine existing design codes, and optimise material selection. The insights gained from this review provide a foundation for evaluating the contribution of the present study, particularly in addressing the existing research limitations and exploring new areas of improvement in CFST column design and performance.

The findings of this study reveal key insights into the behaviour and performance of CFST columns under various loading conditions, with a particular focus on the length-to-diameter (L/D) ratio, steel tube wall thickness, compressive and axial load behaviour, and fire performance. The review of recent studies exhibits a consistent trend that CFST columns with a higher L/D ratio show significantly improved ductility and load-bearing capacity under axial compression. This supports the findings from previous research, such as that of Zhang et al. [12], who observed similar improvements in performance with an increased L/D ratio. However, beyond a certain threshold value of L/D, the performance of CFST columns tends to plateau. This condition suggests diminishing returns when optimising for structural efficiency.

Concrete-filled steel tubes (CFSTs) have several traits that contribute to their structural efficiency and construction speed, but these come with considerable challenges. The cross-sectional arrangement of steel and concrete materials enhances the overall structural performance. Placing a steel tube on the outer surface improves tension and bending resistance, as its distance from the centroid provides additional stiffness. This significantly improves the moment of inertia of the composite section and is further supported by steel's high elastic modulus. Meanwhile, the concrete core helps delay local buckling, which is usually associated with thin-walled steel tubes. Additionally, the confinement effect of the steel shell on the concrete infill enhances the compressive behaviour of the concrete infill, particularly under axial loads where the concrete plays a critical role. These structural integrations highlight the need for cost-benefit analyses and long-term performance evaluations to ensure the practicality and sustainability of CFST systems in real applications.

Table 1: Summary of previous studies on CFST columns

No.	Study	Type of Study	Method	Gap Analysis
1	Elremaily and Azizinamini [8]	Experimental Studies	Experimental tests on six CFST columns under axial and cyclic lateral loads, varying concrete grade, axial load levels, and tube ratios (D/T).	Focuses on confinement effects; no detailed analysis of varying confinement types or seismic performance across different geographical regions.
2	Dundu [9]	Experimental Studies	Tested 24 CFST columns under concentric compression until failure, analysing length, diameter, and steel/concrete strength.	Conservative code estimations: need for empirical data to refine design codes and improve accuracy.
3	Hassooni and Al Zaidee [10]	Experimental Studies	Experimental testing of CFST columns under axial compression, varying column height and uniform steel tube thickness.	Limited to certain heights and cross-sectional geometries; further study needed to explore interactions with other design variables.
4	Ma et al. [11]	Computational Studies	Computational study using finite element analysis (FEA) on CFST columns under	Could integrate environmental factors (temperature, humidity) for more

No.	Study	Type of Study	Method	Gap Analysis
			sustained loading, employing viscoelastic behaviour models.	accurate long-term performance predictions.
5	Zhang et al. [12]	Experimental Studies	Experimental study on CFST columns reinforced with FRP and steel strips under compressive load.	Lack of cost-benefit analysis of different reinforcement methods and limited long-term performance data.
6	Teng et al. [13]	Experimental Studies	Experimental study on CFST columns with spiral steel confinement, analysing axial loading performance.	Need for more variation in concrete strengths and confinement arrangements to assess uniform ductility increases.
7	Shaker et al. [14]	Experimental Studies	Investigated the effect of tube thickness and ribbed steel tubes on the failure load and vertical deformation of CFST columns.	Results contrast with those of other studies on tube thickness; need for further investigation into the design vs. material efficiency balance.
8	Ekmekyapar and Al-Eliwi [15]	Experimental Studies	Experimental study on the effect of concrete strength on the performance of CFST columns, focusing on tube thickness.	Need for a deeper exploration of how interaction between concrete and steel qualities influences performance.
9	Abdullah et al. [16]	Experimental Studies	Experimental reinforcement study on CFST columns using longitudinal steel plates in the concrete core.	Economic viability and feasibility of longitudinal reinforcement need further study.
10	He et al. [17]	Experimental Studies	Experimental study on passive confinement effects in CFST columns with varying concrete strength.	Further confirmation is needed with wider column configurations and loading situations to validate the proposed equations.
11	Kassem [18]	Thermal/Fire Studies	Thermal analysis of CFST columns at elevated temperatures using	It could benefit from examining a wider range of environmental

No.	Study	Type of Study	Method	Gap Analysis
			composite frame element models to determine buckling load.	factors and varying external conditions.
12	Wang et al. [19]	Experimental Studies	Experimental study on CFST columns with CFRP reinforcement, testing under varying temperature conditions.	Long-term durability and performance of CFRP reinforcement under multiple temperature cycles are not fully addressed.
13	Lu et al. [20]	Experimental Studies	Experimental study on CFST columns with steel fibres and self-stress concrete under bending.	Need further investigation into the impact of environmental conditions on performance and resilience.
14	Manikandan and Umarani [21]	Experimental Studies	Experimental study comparing different types of concrete in CFST columns (e.g., conventional, steel fibre reinforced, geopolymer, expansive).	Lack of analysis on the environmental and economic impact of different concrete types in real-life applications.
15	Liu et al. [22]	Experimental Studies	Experimental study on CFST columns with perforations, analysing strength loss due to openings.	Need more comprehensive research on the structural integrity of perforated CFST columns, including repair methods.

Nevertheless, current research has mostly concentrated on the diameter-to-thickness ratio of CFST specimens, as emphasised in several studies [8], [9], [10], [14], [15]. Such studies have pointed out the advantages that the CFST element has when compared with traditional steel or reinforced concrete systems. However, more in-depth research is needed into the material characteristics, the ecological impact and service life of the construction, as these aspects are only marginally explored in current research.

A notable contradiction arises in the discussion of construction limitations. While CFST columns can enhance overall structural efficiency and cost performance, particularly in modern applications, the compactness of concrete around beam-to-column connections presents challenges, especially in older buildings with inner and through-type diaphragms. This problem also indicates the occurrence of theoretical issues in auxiliary design considerations of compatibility work against efficient force transfer. In addition, the literature survey indicates that the height-to-diameter ratio of CFST columns affects ductility, with shorter columns displaying more residual strength compared to taller ones [9], [10], [15]. This is crucial because it exposes another design flaw in the CFST system, that is, the vertical columns and the challenges they pose in populating the columns with concrete, which would not bond well with the steel tubes, thereby creating unsightly, rough surfaces. If the centre of the steel tube is cored to allow the pouring of concrete, distortion in the form of shapes takes place, which in turn affects the structural performance [20].

Furthermore, both local corrosion and concrete cavitation may arise from external factors, including prolonged stress and environmental corrosion, as well as internal factors such as concrete shrinkage and creep. These problems highlight a common susceptibility between CFSTs and conventional reinforced concrete systems, indicating that although CFSTs may offer more efficiency, they are not exempt from the deteriorating issues encountered by other structural systems.

Regarding design efficiency, current stiffeners may not completely maximise material utilisation or building methods. Longitudinal plate stiffeners necessitate welding to the steel tube, whereas oblique tie bars complicate the welding procedure [16]. This reveals a paradox regarding material efficiency, suggesting that design advances may be essential to reconcile performance with construction simplicity.

The exceptional behaviour of circular CFST columns, especially under axial loads, is inarguable. However, these columns are often judged by other columns, especially square ones, which have higher moment capacities, easier beam-column connections and are more appealing [16]. This situation presents a dilemma in that there are performance optimisation advantages of using circular columns in buildings, while on the other hand, there are practical benefits associated with square columns. Thus, a need to tread with caution.

Debates around CFSTs are also made more complex by issues of fire resistance. The external extreme of the CFST causing added compression to the structural steel core means that even in ideal conditions when there is a longitudinal tensile steel at the column and concrete infill, CFST columns are prone to fire stresses requiring further studies on fire protection measures and re-designing of other elements to enhance the fire protection [18]. This is connected to the very problem of preserving the beneficial properties of the CFSTs under normal situations without them becoming a hindrance under adverse conditions.

4.0 Conclusion

In conclusion, it has been documented that the CFST columns have gained significant traction in the construction industry due to their enhanced strength, durability, and seismic performance, making them ideal for applications such as bridges, power transmission towers and skyscrapers, particularly in earthquake-prone areas. This study has successfully evaluated the importance of key design factors such as the length-to-diameter (L/D) ratio, steel tube wall thickness, and performance under compressive, axial, and fire stresses in optimising CFST columns' performance. The findings underscore the critical role of these parameters in improving the safety and efficiency of multi-story buildings, especially in seismic zones. Future research should employ advanced finite element modelling techniques to better understand CFST behaviour under complex loading conditions. With the increasing emphasis on technology to improve productivity and reduce construction costs, CFST columns hold significant promise for broader commercial application, improving safety, and more sustainable infrastructure development.

Acknowledgement

The authors wish to acknowledge the Department of Civil Engineering, Politeknik Sultan Idris Shah, and the Pusat Penyelidikan dan Inovasi, Jabatan Pendidikan Politeknik dan Kolej Komuniti, for their technical support and the provision of facilities that contributed to the success of this work.

Author Contributions

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Intan Maisarah Osman: Writing – Original Draft, Methodology;
Ahmed W. Al Zand: Writing – Review & Editing; Resources.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by any other journal. All authors have reviewed and approved the submission, consent to its submission, and declare that there are no conflicts of interest.

References

[1] K. Miao, Y. Wei, F. Dong, K. Zheng, and J. Wang, “Experimental study on concrete-filled steel tube columns with inner distributed seawater and sea sand concrete-filled fiber-reinforced polymer tubes under axial compression,” *Composite Structures*, vol. 320, p. 117181, 2023.

[2] R. Niyirora, F. Niyonyungu, T. Hakuzweyezu, E. Masengesho, R. Nyirandayisabye, and J. Munyaneza, “Behavior of concrete-encased concrete-filled steel tube columns under diverse loading conditions: A review of current trends and future prospects,” *Cogent Engineering*, vol. 10, no. 1, p. 2156056, 2023.

[3] C. George, S. S. Selvan, V. S. Kumar, G. Murali, J. Giri, E. Makki, and

T. Sathish, “Enhancing the fire-resistant performance of concrete-filled steel tube columns with steel fiber-reinforced concrete,” *Case Studies in Construction Materials*, vol. 20, p. e02741, 2024.

[4] B. Nikmehr, B. Kafle, A. W. Al Zand, and R. Al-Ameri, “The effect of hybrid basalt fibres on the mechanical and structural characteristics of geopolymer concrete containing geopolymer-coated recycled concrete aggregates,” *Construction and Building Materials*, vol. 450, p. 138649, 2024.

[5] Z. Safee and D. Ishamuddin, “Study on soncrete with partial replacement of sand by floral foam”, *Politeknik & Kolej Komuniti Journal of Engineering and Technology*, vol. 5, no. 1, pp. 19–33, 2020.

[6] X. T. Wang, C. D. Xie, L. H. Lin, and J. Li, “Seismic behavior of self-centering concrete-filled square steel tubular (CFST) Column Base,” *Journal of Constructional Steel Research*, vol. 156, pp. 75–85, 2019.

[7] D. Medall, C. Ibáñez, V. Albero, A. Espinós, and M. L. Romero, “Experimental residual capacity of steel-reinforced concrete-filled steel tubular stub columns after fire exposure,” *Thin-Walled Structures*, vol. 189, 2023.

[8] A. Elremaily and A. Azizinamini, “Behavior and strength of circular concrete-filled tube columns,” *Journal of Constructional Steel Research*, vol. 58, no. 12, pp. 1567-1591, 2002.

[9] M. Dundu, “Compressive strength of circular concrete filled steel tube columns,” *Thin-Walled Structures*, vol. 56, pp. 62–70, 2012.

[10] A. N. Hassooni and S. R. Al Zaidee, “Behavior and strength of composite columns under the impact of uniaxial compression loading,” *Engineering, Technology & Applied Science Research*, vol. 12, no. 4, pp. 8843–8849, 2022.

[11] D. Y. Ma, L. H. Han, W. Li, C. Hou, and T. M. Mu, “Behaviour of concrete-encased CFST stub columns subjected to long-term sustained loading,” *Journal of Constructional Steel Research*, vol. 151, pp. 58–69, 2018.

[12] S. Zhang, K. Miao, Y. Wei, X. Xu, B. Luo, and W. Shi, “Experimental and theoretical study of concrete-filled steel tube columns strengthened by FRP/steel strips under axial compression,” *International Journal of Concrete Structures and Materials*, vol. 17, no. 1, 2023.

[13] J. G. Teng, J. J. Wang, G. Lin, J. Zhang, and P. Feng, “Compressive behavior of concrete-filled steel tubular columns with internal high-strength steel spiral confinement,” *Advances in Structural Engineering*, vol. 24, no. 8, pp. 1687–1708, 2021.

[14] F. M. F. Shaker, M. S. Daif, A. F. Deifalla, and N. M. Ayash, “Parametric study on the behavior of steel tube columns with infilled concrete—An analytical study,” *Sustainability*, vol. 14, no. 21, 2022.

[15] T. Ekmekyapar and B. J. M. Al-Eliwi, “Experimental behaviour of circular concrete filled steel tube columns and design specifications,” *Thin-Walled Structures*, vol. 105, pp. 220–230, 2016.

[16] A. A. Abdullah, A. A. Mutalib, S. Baharom, and W. H. W.

Badaruzzaman, "Mechanical behavior of square CFST columns with embedded steel plate reinforcement," *International Journal of Structural and Civil Engineering Research*, pp. 319–322, 2018.

[17] L. He, S. Lin, and H. Jiang, "Confinement effect of concrete-filled steel tube columns with infill concrete of different strength grades," *Frontiers in Materials*, vol. 6, pp. 1–9, 2019.

[18] A. T. Kassem, "Strength of CFST at elevated temperature," *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, vol. 15, no. 1, pp. 41–47, 2018.

[19] K. Wang, Y. Chen, J. Wan, S. Han, and L. Liao, "Compressive behavior of post-heated circular CFST short columns externally strengthened with CFRP sheets," *Journal of Adhesion Science and Technology*, vol. 32, no. 8, pp. 833–853, 2018.

[20] Y. Lu, Z. Liu, S. Li, and W. Li, "Behavior of steel fibers reinforced self-stressing and self-compacting concrete-filled steel tube subjected to bending," *Construction and Building Materials*, vol. 156, pp. 639–651, 2017.

[21] K. B. Manikandan and C. Umarani, "Understandings on the performance of concrete-filled steel tube with different kinds of concrete infill," *Advances in Civil Engineering*, vol. 2021, no. 1, 2021.

[22] Y. Liu, Q. Ren, and Y. Li, "Compression behavior of CFST stub columns with holes," *Advances in Civil Engineering*, vol. 2020, no. 1, 2020.