

# Steel Tubular Members: Performance, Design, and Applications

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## Introduction

Steel tubular members are pivotal components in modern construction, offering a unique combination of strength, efficiency, and aesthetic appeal. Their inherent structural advantages, such as high stiffness-to-weight ratios and excellent resistance to torsional forces, have led to their widespread adoption across diverse engineering applications, from high-rise buildings and bridges to industrial structures and offshore platforms. The versatility of steel tubes, encompassing circular, square, and rectangular cross-sections, allows for tailored solutions to complex structural challenges. However, the performance of these members is intricately linked to several critical factors, including their seismic behavior, susceptibility to buckling, and durability under various environmental and loading conditions. Understanding these aspects is paramount for ensuring the safety, reliability, and longevity of steel structures. The seismic performance of steel tubular connections, specifically their ductility and energy dissipation capabilities, is a crucial area of investigation for designing resilient infrastructure in earthquake-prone regions. Geometric parameters and welding details significantly influence the overall structural integrity under cyclic loading, providing vital data for safer designs [1].

The inherent stability of steel hollow sections is a fundamental consideration in their application. A comprehensive review of buckling behaviors in circular and rectangular steel hollow sections under various loading conditions synthesizes existing research on local, distortional, and global buckling modes and their interaction. This insight is essential for engineers to accurately predict the stability limits of steel tubular members and prevent premature failure [2]. The advancement of material science has introduced high-strength steel, offering potential benefits for structural applications. Research exploring the application of high-strength steel in tubular members for bridges, analyzing its behavior under fatigue and extreme loads, compares its performance with traditional steel and demonstrates its potential for lighter and more durable bridge designs, addressing both challenges and benefits [3].

Beyond static and seismic loads, the fire resistance of steel structures is a critical design parameter, particularly for tubular members. Examining the fire resistance of steel tubular members, specifically the effectiveness of intumescent coatings and concrete-filled sections, provides insights into thermal performance and residual strength under elevated temperatures, offering guidance for fire protection strategies in steel structures [4]. In the realm of cold-formed steel, which is increasingly utilized for its cost-effectiveness and ease of fabrication, advanced design methodologies are being developed. A novel design approach for cold-formed steel tubular members considering local buckling effects integrates advanced computational methods to predict load-carrying capacity, offering a more efficient and accurate design framework compared to traditional methods and contributing to

more reliable and optimized use of cold-formed steel [5].

The fundamental load-carrying capacity of steel tubular members, particularly under compression, is a subject of ongoing research. Investigations into the ultimate strength of steel tubular compression members with various cross-sectional shapes analyze the influence of material properties, slenderness ratios, and end restraint conditions on buckling strength, providing valuable data for optimal selection and design of these members [6]. Welded hollow section joints represent critical connection points in steel structures, and their behavior under combined loading is vital for overall structural integrity. Examining the stress distribution, deformation patterns, and failure mechanisms of various joint configurations offers insights into improving the structural integrity and load-carrying capacity of these critical connections in steel structures [7].

The use of advanced computational tools has become indispensable in modern structural engineering for predicting the behavior of steel members. The application of finite element analysis (FEA) for predicting the behavior of steel tubular members subjected to axial and bending loads, validated against experimental data, demonstrates the accuracy of the numerical approach for design optimization and parametric studies, providing a reliable tool for structural engineers [8]. Environmental factors can significantly impact the long-term performance of steel structures, especially in aggressive conditions. Research examining the structural integrity of steel tubular members in marine environments, focusing on corrosion resistance and fatigue life, evaluates the performance of different protective coatings and material grades under harsh conditions, providing crucial findings for the design of offshore structures and coastal infrastructure [9].

Composite structural systems, such as concrete-filled steel tubular (CFST) members, offer enhanced structural performance. An experimental and numerical study on the behavior of concrete-filled steel tubular columns under eccentric loading investigates their load-carrying capacity, ductility, and failure modes, providing essential data for the efficient design of CFST columns in various structural applications [10]. The development and application of steel tubular members continue to evolve, driven by the need for greater efficiency, sustainability, and performance. From enhancing seismic resilience to optimizing material usage and ensuring durability in challenging environments, research in this domain contributes significantly to the advancement of civil engineering practices. The interplay between material properties, geometric configurations, loading conditions, and environmental factors presents a complex yet fascinating area of study. The ongoing pursuit of innovative solutions and robust design methodologies underscores the importance of steel tubular members in shaping the built environment of the future. This collection of research highlights the multifaceted nature of steel tubular member engineering, addressing key performance aspects critical for modern structural design. The continuous exploration of new materials, construction techniques, and

analytical tools promises further advancements in the field, enabling the creation of safer, more efficient, and more sustainable structures. The insights gained from these studies are instrumental in pushing the boundaries of what is possible in steel construction. The collective knowledge presented here serves as a foundation for future research and development, addressing emerging challenges and opportunities in structural engineering.

## Description

The seismic performance of steel tubular member connections has been rigorously investigated, focusing on their ductility and energy dissipation capabilities under cyclic loading. The influence of geometric parameters and welding details on the overall structural integrity is highlighted, providing crucial data for designing safer and more resilient steel tubular structures in seismic zones [1].

Buckling is a critical failure mode for steel hollow sections. A comprehensive review synthesizes existing research on local, distortional, and global buckling modes in circular and rectangular steel hollow sections under various loading conditions, offering insights into their interaction and enabling engineers to accurately predict stability limits and prevent premature failure [2].

High-strength steel is being explored for its potential in bridge construction using tubular members. This research analyzes the behavior of high-strength steel tubulars under fatigue and extreme loads, comparing their performance with traditional structural steel and demonstrating their suitability for lighter and more durable bridge designs, while also addressing associated challenges and benefits [3].

Fire resistance is a key consideration for steel structures. The fire performance of steel tubular members, specifically the effectiveness of intumescent coatings and concrete-filled sections, is examined. The study provides insights into thermal performance and residual strength under elevated temperatures, offering guidance for fire protection strategies in steel structures [4].

For cold-formed steel tubular members, advanced design approaches are being developed to account for local buckling effects. Integrating advanced computational methods, this research predicts the load-carrying capacity more accurately and efficiently than traditional methods, contributing to more reliable and optimized use of cold-formed steel [5].

The ultimate strength of steel tubular compression members with various cross-sectional shapes, including circular, square, and rectangular, is analyzed. The study examines the influence of material properties, slenderness ratios, and end restraint conditions on buckling strength, offering valuable data for optimal member selection and design [6].

Welded hollow section joints are critical connection elements. This paper investigates the behavior of these joints under combined loading, examining stress distribution, deformation patterns, and failure mechanisms to improve structural integrity and load-carrying capacity [7].

Finite element analysis (FEA) is utilized for predicting the behavior of steel tubular members under axial and bending loads. The FEA models are validated against experimental data, demonstrating the accuracy of the numerical approach for design optimization and parametric studies, thus providing a reliable tool for structural engineers [8].

In marine environments, the structural integrity of steel tubular members is threatened by corrosion and fatigue. This research evaluates the performance of different protective coatings and material grades under harsh conditions, providing crucial findings for the design of offshore structures and coastal infrastructure [9].

Concrete-filled steel tubular (CFST) columns are investigated under eccentric loading. An experimental and numerical study examines their load-carrying capacity, ductility, and failure modes, providing essential data for the efficient design of CFST columns in various structural applications [10].

Each of these studies contributes to a deeper understanding of steel tubular members, addressing distinct performance aspects critical for structural design and safety. The collective research spans from fundamental material behavior and stability under extreme conditions to the practical application of advanced computational tools and the consideration of environmental factors. The detailed analyses provided in these papers offer engineers valuable insights and data to optimize the design and enhance the reliability of steel structures across a wide spectrum of applications. The continuous advancements in material science, analytical techniques, and understanding of failure mechanisms underscore the dynamic nature of research in this field. The insights presented are vital for ensuring the integrity, durability, and safety of steel structures in an ever-evolving built environment. The findings collectively support the development of more efficient, sustainable, and resilient steel structures for future construction needs.

## Conclusion

This collection of research explores various critical aspects of steel tubular members. Investigations cover seismic performance of connections, buckling behaviors, and the application of high-strength steel. Fire resistance, advanced design approaches for cold-formed steel, and ultimate strength under compression are also examined. The behavior of welded joints under combined loading and the use of finite element analysis for predicting member behavior are detailed. Furthermore, the corrosion and fatigue performance of steel tubular members in marine environments and the behavior of concrete-filled steel tubular columns under eccentric loading are analyzed. These studies collectively provide essential data and insights for optimizing the design and enhancing the safety and durability of steel structures.

## Acknowledgement

None.

## Conflict of Interest

None.

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**How to cite this article:** Al-Sabah, Khalid. "Steel Tubular Members: Performance, Design, and Applications." *J Steel Struct Constr* 11 (2025):328.

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**Received:** 01-Dec-2025, Manuscript No. jssc-26-188325; **Editor assigned:** 03-Dec-2025, PreQC No. P-188325; **Reviewed:** 17-Dec-2025, QC No. Q-188325; **Revised:** 22-Dec-2025, Manuscript No. R-188325; **Published:** 29-Dec-2025, DOI: 10.37421/2472-0437.2025.11.328

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