Advances in Engineering Research : Possibilities and Challenges
ISSN Print: 3079-5192
ISSN Online: 3079-5206
https://doi.org/10.63313/AERpc.9091

State of the Art of Steel-Concrete Composite Bridge Towers with Steel Shells

QingFeng Zeng
School of Civil Engineering, Central South University of Forestry and Technology, Changsha 410004, China
Email: 2766276937@qq.com

How to cite this paper: Zeng, Q. F. (2026). State of the Art of Steel-Concrete Composite Bridge Towers with Steel Shells. *Advances in Engineering Research: Possibilities and Challenges*, 4(1), 118–122. ISSN Print: 3079-5192; ISSN Online: 3079-5206.
https://doi.org/10.63313/AERpc.9091
Published: 2026-04-20

Copyright © 2026 by author(s) and Erytis Publishing Limited.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/



Abstract

As a high-performance steel-concrete composite structure, the steel shell concrete bridge tower integrates the advantages of high bearing capacity, excellent seismic performance, rapid construction and outstanding durability, and has become the mainstream structural form of bridge towers for long-span bridges in recent years. This paper systematically reviews the latest research progress of steel shell concrete bridge towers. Firstly, it summarizes the typical structural forms and construction technologies, and classifies the main failure modes under mechanical loads and thermal loads. Subsequently, it systematically discusses the influence laws of key parameters such as steel shell thickness, concrete strength, steel ratio, stud spacing and temperature field on the mechanical properties and interfacial bonding performance of the structure. Meanwhile, it sorts out the research status of thermal effects and long-term performance of steel shell concrete bridge towers. Existing studies show that the axial and eccentric compressive bearing capacity of the structure increases with the rise of steel ratio and concrete strength; reasonable stiffener configurations and shear connectors can significantly improve the interfacial bonding performance and inhibit crack propagation. The temperature field has a remarkable impact on the thermal stress of steel shell concrete tower columns, and hydration heat and solar radiation are the core control factors. Finally, this paper points out the deficiencies of existing research and prospects the future research directions including multi-field coupling theory, refined design method and prefabricated construction technology, so as to provide a reference for the engineering design and application of this structure.

Keywords

Steel Shell Concrete; Bridge Tower; Composite Structure; Interfacial Bonding Performance; Thermal Stress; Mechanical Properties.

1. Introduction

Long-span cable-stayed bridges and suspension bridges are core infrastructures of transportation hubs. As the key load-bearing components bearing cable forces and the dead weight of superstructures, the structural performance of bridge towers

directly determines the overall safety and service life of bridges. Traditional reinforced concrete bridge towers have defects such as large dead weight, slow construction and poor crack resistance, while all-steel bridge towers suffer from high cost and insufficient stiffness under large loads. By filling high-strength concrete or ultra-high performance concrete (UHPC) in the closed steel shell, the steel shell concrete bridge tower combines the material advantages of high tensile strength of steel and high compressive strength of concrete, achieving a dual improvement in structural performance and construction efficiency.

In recent years, with the construction of super long-span sea-crossing bridges, steel shell concrete bridge towers have been applied on a large scale in major projects such as the Huangmaohai Sea-crossing Passage and the Shanghai-Suzhou-Nantong Yangtze River Highway-Railway Bridge. Domestic and foreign scholars have carried out extensive research on the mechanical properties, interfacial behavior, thermal effects and construction technology of this structure. This paper systematically sorts out the latest research achievements of steel shell concrete bridge towers, summarizes the influence laws of key parameters and structural response characteristics, clarifies the core scientific problems to be solved urgently, and provides theoretical support for the design optimization and engineering promotion of this structure.

2. Research Status of Steel Shell Concrete Bridge Towers

The steel shell concrete bridge tower is a typical confined composite structure, and its overall performance depends on the cooperative work of the steel shell, internal concrete and shear connectors. Structural design, mechanical response, interfacial performance and construction technology are the core research contents in this field.

2.1. Structural Forms and Failure Modes

According to the steel shell structure, steel shell concrete bridge towers are mainly divided into closed steel shell structures and lattice steel shell structures, with cross-section forms including single-box single-cell, single-box multi-cell and circular cross-sections. Longitudinal and transverse stiffeners are usually arranged inside the steel shell to improve local stability, and shear studs are arranged on the inner wall to ensure the cooperative stress of steel and concrete.

At present, the mechanical performance test methods of steel shell concrete bridge towers are mainly axial compression test, eccentric compression test and pseudo-static test, and the main failure modes are divided into four categories:

(1) Local buckling of the steel shell, which mostly occurs in areas with insufficient stiffeners and thin steel shells;

(2) Crushing and splitting failure of concrete, which is the core failure mode under axial compression load;

(3) Debonding and slip failure at the steel-concrete interface, caused by insufficient

configuration of shear connectors;

(4) Coupling failure of thermal stress and mechanical stress, which is common in tower column structures under solar radiation and hydration heat. Under seismic load, the structure exhibits good ductility and energy dissipation capacity, and plastic hinges are mainly concentrated at the bottom of the tower column.

2.2. Key Influencing Factors of Mechanical Properties

The mechanical properties of steel shell concrete bridge towers are mainly controlled by steel ratio, steel shell thickness, concrete strength, slenderness ratio and shear connector configuration, which are the core parameters for structural design.

2.2.1. Steel Ratio and Steel Shell Thickness

Steel ratio is the most critical parameter affecting the bearing capacity of the structure. Tests show that when the steel ratio increases from 5% to 12%, the axial compressive bearing capacity of steel shell concrete columns increases by 35%~52%. Increasing the thickness of the steel shell can effectively restrain the transverse deformation of concrete, enhance the confinement effect and delay the local buckling of the steel shell; the steel shell thickness of tower columns with large slenderness ratio should be controlled above 12mm to ensure the overall stability of the structure.

2.2.2. Concrete Strength and Material Types

High-strength concrete and UHPC are the mainstream filling materials for steel shell concrete bridge towers. Compared with C50 ordinary concrete, the compressive bearing capacity of the structure filled with C80 high-strength concrete increases by 22%, and the crack resistance is significantly optimized. With ultra-high strength and tensile strain hardening characteristics, UHPC can eliminate concrete splitting failure and increase the interfacial bonding strength with the steel shell by more than 40%, making it an optimal material for long-span bridge towers.

2.2.3. Shear Connectors and Interfacial Properties

Shear studs are the core components to ensure the cooperative work of steel and concrete. Test results indicate that the interfacial bonding strength first increases and then tends to be stable with the decrease of stud spacing, and the optimal stud spacing is 150~200mm. The arrangement of stiffeners can simultaneously improve the local stability of the steel shell and the interfacial mechanical interlocking effect. Without shear connectors, the structure is prone to early interfacial slip failure, with a bearing capacity reduction of more than 30%.

2.2.4. Temperature Field and Thermal Stress

Thermal effect is the core control factor in the design of steel shell concrete bridge towers. The high thermal conductivity of the steel shell and the concentrated

hydration heat of internal concrete lead to a significant temperature difference between the inside and outside of the tower column. Studies show that the maximum thermal stress of the tower column under solar radiation can reach 8~12MPa, which is easy to cause concrete cracking and interfacial debonding; the hydration heat of mass concrete in the steel shell can raise the internal temperature of the structure by 50~65℃, so temperature control measures such as cooling water pipes need to be arranged.

2.3. Construction Technology and Engineering Application

The construction technologies of steel shell concrete bridge towers are mainly divided into integral prefabrication and assembly and cast-in-place construction: the steel shell is processed and manufactured in the factory, hoisted and spliced on site, and then filled with pumped self-compacting concrete, which has the advantages of high construction efficiency and strong quality controllability.

In recent years, this structure has been widely used in super long-span bridges in China: the main tower of the Huangmaohai Sea-crossing Bridge adopts a single-box multi-cell steel shell concrete structure with a height of 254m, which is the tallest steel shell concrete bridge tower in the world; the main tower of the Shanghai-Suzhou-Nantong Yangtze River Highway-Railway Bridge adopts a circular steel shell concrete structure, verifying the reliability of this structure in harsh marine environments. The core construction difficulties focus on three aspects: precision control of steel shell splicing, compactness control of concrete pumping and temperature control of mass concrete.

3. Conclusions

(1) The steel shell concrete bridge tower has excellent mechanical and construction properties, which effectively solves the technical defects of traditional bridge towers and has become the development trend of long-span bridge tower structures. The cooperative work of steel shell and concrete is the core of structural stress, and shear connectors and stiffeners are the key structures to ensure the overall performance.

(2) The bearing capacity of steel shell concrete bridge towers is positively correlated with steel ratio and concrete strength, and reasonable arrangement of studs can significantly improve the interfacial bonding performance. The temperature field has a remarkable impact on the thermal stress of the structure, and hydration heat and solar radiation are the key factors that must be considered in the design.

(3) Prefabricated construction technology realizes the industrialized construction of steel shell concrete bridge towers, and a large number of engineering applications have verified the structural reliability. However, there is still a lack of a unified design method and construction specification system for this structure at present.

(4) Future research should focus on the multi-field coupling mechanism of temperature-seismic-load, the long-term performance degradation law in harsh marine environments, the refined simulation method of steel-concrete interface, as

well as standardized design and construction technologies, so as to promote the large-scale popularization and application of steel shell concrete bridge towers.

References

[1] Zhao J, Mao X P. Demand, development and innovation of long-life cable materials and technologies for super long-span bridges[J]. Modern Transportation and Metallurgical Materials, 2024, 4(5):3-8. DOI:10.3969/j.issn.2097-017X.2024.05.001.

[2] Mao W Q, Hu X W. Latest progress and prospect of long-span bridges in China[J]. Bridge Construction, 2020, 50(1):7. DOI:CNKI:SUN:QLJS.0.2020-01-003.

[3] Zuo Z C, Zheng K F, Chen J W. Overall stability analysis of single-column steel tower for long-span highway cable-stayed bridges[J]. Sichuan Architecture, 2022, 42(5):145-148. DOI:10.3969/j.issn.1007-8983.2022.05.048.

[4] Chen Z L, Zhou L X, Chen X, et al. Analysis of ionospheric characteristics in the Huangmaohai Sea-crossing Passage area[J]. Geospatial Information, 2025, 23(12). DOI:10.3969/j.issn.1672-4623.2025.12.022.

[5] Anonymous. Inclined bridge tower with orthogonal steel-concrete composite structure: CN202311026013.1[P]. CN116905352A, 2026-04-18.

[6] Wang H S, Chen Y Y, Zhao X Z, et al. Experimental study and restoring force model of steel reinforced concrete columns with high steel ratio[J]. Journal of Earthquake Engineering and Engineering Vibration, 2010(4):9. DOI:CNKI:SUN:DGGC.0.2010-04-008.

[7] Li F Y, Zhao R D. Experimental study on bond-slip behavior between C80 high-strength concrete and deformed steel bars[J]. Journal of Tongji University (Natural Science), 2003. DOI:10.3321/j.issn:0253-374X.2003.06.017.

[8] Ding F X, Ni M, Gong Y Z, et al. Experimental study on slip behavior and shear bearing capacity calculation of stud shear connectors[J]. Journal of Building Structures, 2014(9):9. DOI:10.14006/j.jzjgxb.2014.09.013.