Theory and Practice of Science and Technology
2025, VOL. 6, NO. 3, 223-226
DOI: 10.47297/taposatWSP2633-456942.20250603

Research Progress and Review of Dual Seismic Resistance Structural Systems

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ABSTRACT
The research focuses on the architectural design of dual seismic structural systems, exploring how to effectively enhance seismic performance and extend the service life of modern buildings. Faced with frequent seismic events, traditional seismic design methods are facing significant challenges, especially in the application of high-rise buildings where deficiencies urgently need to be addressed. This article introduces the concept of dual seismic structural systems, systematically analyzing its design principles and performance control objectives. Through experimental research on various new seismic structures, the advantages of dual seismic structures in terms of ductility, energy dissipation, and shear resistance are revealed, and the actual performance of new structural forms such as composite shear walls and X-shaped bracing is comparatively analyzed.

KEYWORDS
Dual Seismic Resistance Structural System; Seismic Structure; Seismic Design

1 Introduction

1.1 Research Background

With the acceleration of urbanization, high-rise buildings have become a symbol of modern cities. However, frequent seismic disasters have made the seismic safety of buildings increasingly prominent. Traditional seismic design mainly relies on the ductility of the main structure, aiming to absorb and dissipate seismic energy through the deformation capacity of the structure. This method can meet certain seismic fortification goals under small and moderate earthquake scenarios, but in the event of strong earthquakes, structural damage is often irreversible, and the repair process is cumbersome and costly [1].

Studies have shown that single seismic structures face design challenges, such as the complexity of post-seismic repair and the issue of functional overlap between load-bearing components and energy-dissipating components. Therefore, architects and engineers urgently need new design concepts to achieve more efficient seismic performance. In recent years, the proposal of the dual seismic structural system has provided a new perspective for solving these problems. This system clarifies the separation of load-bearing structures and energy-dissipating structures, making the realization of seismic fortification goals more feasible [2]. The design principles of the dual seismic structure not only focus on the specific functions of each structural component but also emphasize reducing structural damage after earthquakes, laying the foundation for the safety and durability of buildings.

In recent years, experimental research on different seismic structural forms has been increasing, showing significant advantages of dual seismic structures in terms of ductility, energy dissipation, and shear resistance. By comparing and analyzing new structural forms such as composite shear walls and X-shaped bracing, related studies have confirmed the effectiveness of these structures in resisting seismic loads and their convenience in post-seismic repair [3]. In this field, continuous exploration has not only promoted theoretical progress but also brought better solutions for architectural practice. Against this backdrop, the purpose of this paper is to further optimize the practical framework of architectural seismic design by in-depth exploration of the design theory and implementation of the dual seismic structural system, providing new support for enhancing the seismic performance of modern urban buildings.

1.2 Research Purpose and Significance

In the context of an era with frequent earthquakes, the seismic resistance of buildings is not only related to the safety of people's lives and property but also has a significant impact on the development of the socioeconomy. In response to the many challenges faced by current building structures when confronted with natural disasters, it is particularly important to study the design concept of dual seismic structural systems. The purpose of this article is to explore how to effectively enhance seismic performance and extend the service life of buildings to meet the increasingly severe demands of earthquake engineering.

Traditional seismic design methods, while capable of achieving the fortification goals of no damage in small earthquakes, repairable damage in medium earthquakes, and no collapse in large earthquakes to some extent, have revealed various shortcomings in practical application. For instance, a single seismic structure often requires concentrated treatment of the damage to the main structure and load-bearing components during post-earthquake repairs, leading to design dilemmas and ambiguity in the seismic system [1]. Therefore, by adopting a dual seismic structural system, we can effectively separate the load-bearing structure from the energy-dissipating structure, not only clarifying the functional location of each component but also providing a solid guarantee for achieving seismic fortification goals.

The introduction of a dual seismic structural system has significantly improved the seismic energy dispersion and dissipation capabilities of buildings, effectively reducing structural damage caused by seismic actions, and has demonstrated tremendous application potential in the construction of large cities. Through experimental research and theoretical analysis, this paper delves into various new forms of seismic-resistant structures, providing comprehensive design principles and performance control objectives to meet the challenges of seismic resistance in modern construction [2][4]. These studies not only promote the progress of seismic design for high-rise buildings but also lay the foundation for the sustainable development of future cities, holding profound social and economic significance.

2 Performance Analysis of Dual Seismic Resistance Structural System

Among various seismic design concepts, the dual seismic structural system combines ductility with energy dissipation characteristics, effectively enhancing the seismic resistance and safety of the structure. In addressing earthquakes, the dual seismic structural system significantly reduces the impact of seismic energy on the main structure by effectively dispersing and dissipating it, ensuring the overall stability and functionality of the structure[1]. Data reveals that under the influence of minor earthquakes, the maximum inter-story drift angle of the dual seismic structural system always remains below 1/500, indicating its good compliance and adaptability within seismic design standards.

When comparing the performance of different seismic structural types, the performance of composite shear walls and frame-bracing structures is particularly outstanding. Research shows that composite shear walls not only exhibit significant advantages in shear capacity but also have a much higher energy dissipation capacity than traditional reinforced concrete shear walls. For instance, the ductility coefficient of composite shear walls can reach 1.56 to 1.76 times that of reinforced concrete shear walls, an improvement in performance that makes the structure safer and more reliable under seismic actions[2]. More crucially, the protection of the main structure is optimized by adjusting the energy dissipation characteristics of the non-load-bearing structures.

In summary, the core advantage of the dual seismic structural system lies in its exceptional energy dissipation characteristics and ductility, which not only enhance the resistance of buildings to earthquakes but also ensure the resilience and safety of the structure. Continuous research and practice will continue to promote the application of this system in building design to better cope with the increasingly severe challenges of earthquakes.

3 Comparison of New Seismic-Resistant Structures

In the current field of architectural design, the research and application of seismic-resistant structures are experiencing rapid development. New types of seismic-resistant structures, such as composite shear walls and frame-brace systems, each have their unique features to meet the stringent seismic performance requirements of modern buildings. Among them, the composite shear wall, with its distinctive component layout, demonstrates significant advantages over traditional seismic-resistant structures. Its ductility and energy dissipation capacity are notably enhanced compared to reinforced concrete shear walls, with energy dissipation coefficients reaching 1.56 to 1.76 times that of the latter. This characteristic has increasingly drawn attention in the field of seismic design [7].

The seismic performance of the frame-brace system is also considerable, as it possesses good rigidity and ductility, effectively resisting lateral forces caused by earthquakes. Through systematic comparisons of different systems, it has been found that the frame-brace structure can maintain a small inter-story drift angle under minor earthquakes, and all inter-story drift angles meet seismic design standards. This proves its feasibility from a practical application perspective [2].

Furthermore, the introduction of dual seismic-resistant structural systems has shown that the energy dissipation mechanism employed by these systems reduces the deformation of the main structure, thereby enhancing the overall seismic performance. This not only increases the ductility of the structure but also allows it to quickly recover functionality after an earthquake, providing a solid guarantee for the safety of residents and property [19]. During experiments on the actual performance of composite shear walls, it was observed that they also exhibit superior energy dissipation capabilities under heavy loads, indicating that they can maintain good structural integrity and functionality under various excitations [12].

Evaluating the effectiveness of new seismic-resistant structures relies not only on theoretical analysis but also on a wealth of experimental data to demonstrate their actual performance. For instance, post-earthquake damage detection and assessment, inter-story drift limitations, and structural stability after long-term use are all important components of research. Utilizing this data, future architectural seismic design will become more rationalized, and the concept of intelligent and efficient seismic-resistant design will be more widely applied and promoted in practice.

4 Discussion

4.1 The Advantages of Dual Seismic Structure

The dual seismic resistance structural system is a key innovation in modern seismic design, demonstrating exceptional performance and adaptability. Facing natural disasters such as earthquakes, its unique design philosophy not only enhances the seismic capacity of buildings but also effectively extends their service life. The advantages of the dual seismic resistance structural system are mainly reflected in the following aspects.

Firstly, the system possesses excellent energy dissipation capabilities. Under seismic action, the synergistic effect of the main structure and the secondary structure allows for the effective dispersion and dissipation of energy [4]. The main structure bears most of the static and dynamic loads, while the secondary structure controls the deformation of the main structure through its specific design, ensuring the stability and safety of the main structure during earthquakes. Specifically, the dual seismic resistance structural system exhibits good adaptability under different earthquake intensities, capable of optimizing the structure's performance by adjusting design parameters, maintaining high stiffness and stability during moderate earthquakes, and protecting the integrity of the main structure by consuming energy during strong earthquakes.

Secondly, the dual seismic resistance structure shows significant advantages in terms of repair. Since the secondary structure undertakes the main deformation and energy dissipation tasks during seismic events, the degree of damage to the main structure is reduced, resulting in a significant decrease in the time and cost required for post-earthquake repairs [3]. This is particularly important for the architectural design of modern cities, as rapid recovery of building functions can not only reduce economic losses but also provide residents with a safe and stable living environment. In areas prone to natural disasters, the structural stability and seismic performance of buildings are particularly important.

It is worth mentioning that the design flexibility of the dual seismic resistance structure makes it easier to meet the requirements of different building types and functions. During the design process, the separate design of the main structure and the secondary structure avoids problems with insufficient structural stiffness that could lead to poor seismic performance. Designers can independently optimize the performance of each structural part according to specific functional requirements and usage conditions.

Through the above analysis, we can clearly recognize the many advantages of the dual seismic resistance structural system in seismic applications, bringing new perspectives and endless possibilities to modern architectural design. Relevant studies indicate that when the dual seismic resistance structure is applied reasonably, its superiority will effectively promote the advancement of architectural seismic design, ensuring the safety and functionality of buildings during earthquakes and other emergencies [1].

4.2 Application and Current Status of Dual Seismic Resistance Structural System

In future research directions, with the rapid development of the field of architectural seismic design, the application and optimization of dual seismic structural systems urgently need in-depth exploration. Based on the preliminary results of this study, it is recommended to further explore the adaptability of dual seismic structural systems under different environments and seismic conditions. For example, how to conduct personalized design of the structural system for specific geological conditions and climatic environments will be one of the key focuses of future research. This not only requires a detailed analysis of design parameters but also necessitates comprehensive research in conjunction with regional seismic data to ensure the reliability and effectiveness of the design [1].

Furthermore, the introduction of intelligent monitoring systems in design can provide real-time performance feedback for dual seismic structural systems, thereby achieving intelligent design and management. The integration of this technology can provide more guarantees for the safety of buildings and support for accurately assessing the seismic performance of structures [2].

Future research can consider how to combine modern computing technology with data analysis methods to achieve precise prediction and optimization of complex structural behavior.

Additionally, considering the importance of non-load-bearing parts in the dual seismic structural system for overall seismic performance, exploring the impact of different materials, construction forms, and their effects on energy dissipation mechanisms is also an important research direction. Through in-depth analysis of material properties and performance evaluation in practical applications, future research can provide more cutting-edge theoretical support and practical guidance for seismic design [3]. Such research not only helps to improve the reliability of structures but also provides a reference for innovation in seismic design.

5 Conclusion

In the process of exploring the architectural design of dual seismic structural systems, we have comprehensively analyzed the potential of this system in enhancing seismic performance and extending the service life of buildings. The frequent occurrence of earthquakes has exposed the limitations of traditional seismic design, especially in the field of high-rise buildings. Therefore, seeking more efficient design concepts has become extremely urgent. The dual seismic structure not only effectively enhances the seismic resistance characteristics of buildings but also demonstrates significant advantages in structural ductility, energy dissipation, and shear resistance through its unique design philosophy[1].

Through experimental research on different new seismic structures, we have delved into their performance in practical applications, particularly in structural forms such as composite shear walls and X-shaped bracing, where the dual seismic structure exhibits energy dissipation characteristics and post-earthquake recovery capabilities. These have become the new key to enhancing building seismic design. The core of this design method lies in the rational allocation of the functions of non-load-bearing structures, which not only protects the load-bearing structures but also helps to mitigate the impact of earthquakes on the main structure by controlling the energy dissipation mechanism[2]. This innovative approach provides a new path for the theory and practice of building seismic design, making the seismic design concept of high-rise buildings tend towards greater intelligence and systematization.

The final research results indicate that the dual seismic structural system possesses good applicability, especially in high-rise and multi-story buildings in our country. The improvement in seismic capacity has significant practical implications, opening up new prospects for enhancing the design level of urban building seismic systems. This study has not only promoted the industry's attention to dual seismic structures but also provided strong theoretical support for subsequent seismic design practices, marking a further evolution and development in building structural design[3].

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