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Research on Seismic Performance of Prefabricated Shear Wall Structures

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ABSTRACT

With the construction industry's increasing demands for energy saving, emission reduction, and seismic safety, prefabricated shear wall structures are gaining attention for their high industrialization, rapid construction, and significant environmental benefits. This article systematically reviews the research progress on the seismic performance of prefabricated shear wall structures. By analyzing the literature on the design and analysis of prefabricated shear wall structures, it outlines the design philosophy and its application in residential building design. Extensive studies on the seismic performance of assembled structures indicate that innovative connection node designs, composite materials, and optimized structural configurations can effectively enhance the seismic capacity of the structures. The article also discusses construction technologies and optimization issues for high-rise shear wall structures, proposing relevant techniques and measures for addressing crack issues in prefabricated components. Finally, the role and potential of assembled structures in environmental benefits and achieving carbon neutrality targets are analyzed. Overall, research in this field provides an abundant theoretical basis and practical guidance for improving the performance of assembled shear wall structures.

KEYWORDS

Prefabricated Shear Wall; Seismic Performance; Prefabricated Components; Construction Technology; Environmental Benefit.

1 Introduction

Prefabricated steel plate shear walls have lateral resistance characteristics, can effectively resist horizontal loads, and can tightly integrate vertical and horizontal elements to form a complete structural system. Its connection method mainly uses connecting components and bolts, which can ensure the stability of the structure under load [1].

With the advancement of technology, traditional steel plate shear walls are no longer suitable because they cannot withstand bending pressure, thereby limiting their maximum effectiveness [1]. To this end, scientists have begun to explore in depth, emphasizing the impact of steel plate buckling on structural stability and seismic performance, thereby improving the service life and safety of steel plate shear walls. Due to the excellent seismic characteristics of prefabricated steel plate shear walls, in order to better resist the damage of earthquakes, especially in extreme environments, if we want to strengthen their defense function, we must double our attention to their use and minimize the possible losses they may cause. In order to reduce the uneven tensile reaction of steel plate tension field on columns during earthquakes, Guo Yanlin et al. proposed anti buckling steel plate shear walls, which constrain the out of plane buckling of steel plates through precast concrete cover plates to prevent or reduce the additional bending moment effect of steel plate buckling tension field on the columns on both sides [2].

Given the above background, the reason for writing this literature review is to summarize and analyze existing research results, explore the shortcomings of seismic performance research on prefabricated shear wall structures, and propose future research directions and priorities. The purpose is to provide comprehensive and in-depth theoretical basis for researchers, engineers, and decision-makers, and to promote the practical application and optimized design of prefabricated shear wall structures in seismic safety.

2 Seismic Performance Analysis of Prefabricated Concrete Structures

In the seismic performance analysis of prefabricated concrete structures, scholars have adopted different structural systems and connection methods to improve their seismic performance.

When used as a connector between concrete wall panels in vertical joints, glass fiber reinforced polymer (GFRP) composite laminates have several advantages over welded steel plates. These advantages include enhanced corrosion resistance, higher tensile strength, the ability to apply connections externally to structures, and the ability to adapt to uneven surfaces. Traditional loose steel connectors are used to generate shear transfer and composite effects between precast concrete walls by welding steel plates to angle steels embedded in each wall [13].

In addition, damage related to grouted steel casing is limited to the column foundation, making post earthquake column repair easier compared to traditional connections. Compared with modern mechanical splicing devices, another advantage of grouted steel sleeve connections is the ability to include non bonded parts in the steel bars inside the sleeve [10]; Many researchers have demonstrated the different advantages of prefabricated PcaC structures. Taking Tam et

al. as an example, the basic advantages of this structure were summarized, such as freezing design in early design to better utilize prefabricated components [11]; When the connection behavior between concrete panels and steel bars in prefabricated concrete structures is more similar to that of cast-in-place connections, the system exhibits better performance in terms of continuity and integrity [12].

In summary, prefabricated concrete structures have shown positive effects in improving seismic performance after being applied in different designs and connection methods. Structural detail design, connection methods, and material selection have become key factors in improving the seismic resistance of prefabricated structures.

3 Seismic performance of prefabricated steel structures and shear walls

The seismic performance of prefabricated steel structures and shear walls has shown significant positive characteristics in recent studies. Especially, researchers have shown a strong interest in how to improve its seismic performance by optimizing the design of connection nodes and walls. Through extensive practical testing, we have found that prefabricated composite shear walls connected by T-shaped plates have good seismic resistance characteristics [3]. Through parameter analysis, the influence of external frame section form and layout, corrugated steel plate thickness and shear span ratio on the seismic performance of NFSC-CSSW system is studied [4]. After multiple experiments, we conducted in-depth research on the damage mechanism and hysteresis performance of vertical segmentation on wall panels, in order to obtain better seismic performance [5]. A numerical analysis model of anti buckling steel plate shear walls was created using the finite element software ABAQUS, and the performance degradation of anti buckling steel plate shear walls with different height to thickness ratios after earthquakes was studied [2]. A series of experimental studies and simulation analyses have further demonstrated the excellent performance of the prefabricated shear wall system under earthquake action. However, prefabricated structures still face many challenges in practical applications, including the reliability and durability of nodes, as well as precision control during the assembly process. Therefore, the research on seismic performance of prefabricated steel structures and shear walls is still an active and challenging field.

4 The influence of connection methods on the seismic performance of prefabricated structures

In prefabricated shear wall structures, the quality of the connection method directly affects its overall seismic performance. As is well known, traditional cast-in-place concrete shear walls exhibit excellent seismic performance due to their good overall integrity, while prefabricated shear walls require research on seismic performance due to the diversity of their nodes and connection methods. However, the fatigue failure phenomenon that may occur under repeated earthquake action in this connection method has a certain impact on the seismic performance. The seismic performance of a prefabricated shear wall structure using a new type of wet dry mixed horizontal joint connection method was studied by combining quasi-static testing and numerical simulation analysis [6]. Research has shown that prefabricated shear walls using fully dry combination have high durability and stability. Therefore, a comparative analysis of the failure mode, load characteristics, and other related indicators of the specimens is needed [7]. By conducting finite element analysis on the shear wall model, the aim is to analyze the influence of different horizontal joint construction methods and bolts on the seismic performance of shear walls [8]. Feasibility analysis of steel frame connected prefabricated shear wall structure; Establish an equivalent prefabricated overall structural model for seismic performance research [9]. In summary, through continuous innovation and improvement of prefabricated structural nodes and connecting components, the seismic performance of prefabricated shear walls has been significantly improved. However, further research is still needed in this field, especially in terms of the long-term performance stability of various connection methods, post earthquake repair capabilities, and overall performance evaluation of structural and non structural components working together.

5 Summary of Research Status

In the past few years, significant progress has been made in the seismic performance research of prefabricated shear wall structures. The research focuses on multiple aspects. The following are the main achievements and findings of current research: In terms of seismic performance, existing research mainly focuses on different connection methods of prefabricated structures, such as bolted connections, T-shaped plate connections, fully dry connections, etc., and their impact on the seismic performance of the structure. The research results show that these connection methods can simulate the integrity of cast-in-place structures to a certain extent, thereby improving the seismic resistance of the structure. They maintain the stress performance of shear walls, enhance energy dissipation capacity, deformation capacity, and node resistance to damage, and also improve seismic performance [6] [8] [9]. At the same time, different forms of steel plates, such as bolted joints, NFSC-CSSW systems, and T-plate connections, have a certain impact on the stiffness

and bearing capacity of shear walls, but maintain ductility, improve energy dissipation capacity and plastic deformation capacity, thereby enhancing seismic performance [3] [4] [5]. In addition, the hysteresis curves of anti buckling steel plate shear wall models with different height to thickness ratios are shuttle shaped, indicating good plastic deformation ability. The thicker the embedded steel plate, the more energy it can absorb during an earthquake. Overall, although there have been numerous studies on the seismic performance of prefabricated shear wall structures, there is still room for further deepening and refinement in both theory and practice. In the future, by studying the above aspects, it is expected to comprehensively construct a prefabricated shear wall with good mechanical performance, ductility performance, energy dissipation capacity, and deformation capacity, in order to enhance the seismic resistance of the structure.

6 Research Trends and Prospects

Prefabricated shear wall structures have become an important research direction in the field of modern architecture due to their efficient construction speed and excellent seismic performance. In terms of future development, research trends and prospects can be summarized as follows: Application of new materials and technologies: With the continuous emergence of new materials and technologies, the material properties and structural performance of prefabricated shear wall structures will be further improved. For example, the use of high-performance concrete and fiber-reinforced composite materials can improve the strength and ductility of components, thereby enhancing the seismic resistance of structures.

Optimization design of connection nodes: The seismic performance of prefabricated shear wall structures largely depends on the design of connection nodes. Future research will focus on developing nodes that are high-strength, easy to install, and have good energy dissipation capabilities, such as using prestressing technology to enhance the seismic performance of nodes. Quantitative evaluation of seismic performance: The research will focus on developing more accurate mathematical models and simulation tools to quantitatively evaluate the seismic performance of prefabricated shear wall structures. The corresponding mathematical formulas and calculation models will be continuously improved based on the principles of structural dynamics and research results in earthquake engineering. By comprehensively applying the above trends, the research on seismic performance of prefabricated shear wall structures will continue to deepen, promoting the development of building structure design and construction technology to a higher level.

References

[1] Wang Yiduo, Wang Fenghui(2023). Research on seismic performance of prefabricated steel plate shear wall structure [J]. Value Engineering, 42 (1):146-148. DOI:10.3969/j.issn.1006-4311.2023.01.047.

[2] Wang Zhongqiang, Liu Xiaoqian(2024). Research on seismic damage of anti buckling steel plate shear walls [J]. Sichuan Building Materials, 50 (5):31-33. DOI:10.3969/j.issn.1672-4011.2024.05.012.

[3] Wang Yi, You Peibo, Qu Zhengzhao, etc.(2023). Research on Seismic Performance of T-shaped Plate Connected Prefabricated Composite Shear Wall [J]. Building Structures, 53(2):92-99. DOI:10.19701/j.jzjg.LS210357.

[4] Peng Xiaotong, Liu Xiaohui, Gao Yiyuan, etc.(2024). Seismic performance of narrow wing shaped column corrugated steel plate shear wall system [J]. Journal of Jinan University (Natural Science Edition), 38(3):320-330. DOI:10.13349/j.cnki.jdxbn.20231212.001.

[5] Yu Jinguang, Zhao Chu, Wang Xiaojun, etc.(2023). Research on seismic performance of prefabricated block connected steel plate shear walls [J]. Journal of Tianjin University, 56(5):542-552. DOI:10.11784/tdxbz202204034.

[6] Xu Zhong(2021). Research on Seismic Performance of Prefabricated Shear Wall Structures with Mixed Dry and Wet Connections [D]. China University of Mining and Technology.

[7] Gong Yongzhi, Ke Fulong, Tan Tao, etc.(2022). Research on seismic performance of fully dry connection assembled sandwich shear wall structure [J]. Journal of Tianjin University, 55(5):451-461. DOI:10.11784/tdxbz202105021.

[8] Tian Xiaowei, Liu Yuanzhen, Yang Heng, etc.(2022). Simulation analysis of seismic performance of assembled shear walls with bolted connections [J]. Chinese Journal of Science and Technology, 17(8):865-871,886. DOI:10.3969/j.issn.2095-2783.2022.08.006.

[9] Xie Rengui(2022).Research on Seismic Performance of Steel Reinforced Assembled Shear Wall Structures [D]. Jiangxi: Nanchang University.

[10] Belleri, Andrea & Riva, Paolo(2012). Seismic performance and retrofit of precast concrete grouted sleeve connections. PCI JOURNAL, 57:97-109. DOI:10.15554/pcij.01012012.97.109.

[11] Prafulla M, Feng Xiong, Gaochuang Cai, Yong Xu, Amir Si Larbi, Wen Chen(2021). Numerical study on the behaviour of vertical bolted joints for precast concrete wall-based low-rise buildings. Journal of Building Engineering. DOI:10.1016/j.jobe.2020.101529.

[12] Taheri, Hafez & Hejazi, Farzad & Vaghei, Ramin & Jaafar, Mohd & Ali, Abang(2016). New Precast Wall Connection Subjected to Rotational Loading. DOI:10.3311/PPci.8545.

[13] Trevor K. Nye, Chris P. Pantelides, Clayton A. Burningham(2018). Unidirectional GFRP composite connections between precast concrete wall panels under simulated seismic loads. Composite Structures, 203:624-635. DOI:10.1016/j.compstruct.2018.07.042.