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Experimental Seismic Performance of Steel Plate Shear Walls

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Introduction

Steel plate shear walls (SPSWs) have emerged as a vital structural system for seismic resistance in modern construction, offering a compelling combination of strength, stiffness, and energy dissipation capabilities. Their effectiveness in mitigating seismic forces has been a subject of extensive research and experimental investigation. One key area of exploration has been the influence of various stiffener configurations on the seismic performance of SPSWs. Studies have focused on understanding how different arrangements of stiffeners impact failure mechanisms, energy dissipation, and load-displacement relationships, revealing significant effects on ductility and ultimate strength [1]. Furthermore, the design of boundary elements in SPSWs plays a crucial role in their overall behavior. Research has delved into the influence of these elements on post-buckling behavior and overall seismic resilience, emphasizing their importance in achieving high ductility and preventing premature failure modes [2]. Innovations in SPSW design have also led to the development of reduced-thickness steel plate shear walls (RTSPSWs). Experimental evaluations of these systems have shown their potential for weight and cost savings without compromising seismic resistance, provided that connections and boundary elements are carefully detailed [3]. The exploration of novel panel zone configurations within SPSWs has also contributed to enhanced seismic performance. Investigations into designs aimed at improving energy dissipation have demonstrated superior ductility and more stable hysteretic responses compared to conventional designs [4]. Composite steel plate shear walls, which integrate steel plates with concrete infill, represent another significant advancement. Experimental studies have highlighted their superior stiffness, strength, ductility, and energy dissipation capabilities compared to steel-only SPSWs [5]. The slenderness ratio of infill plates in single-story SPSWs is another critical parameter investigated experimentally. Research in this area has examined how plate slenderness affects buckling modes, ultimate load capacity, and energy dissipation, providing data for optimizing plate dimensions [6]. The detailing of connections between the steel plate and the boundary frame is also a focus of experimental research. Studies on varying connection details have revealed their profound influence on load transfer, local buckling, and the overall hysteretic behavior of SPSWs [7]. In architectural contexts, the presence of openings in steel plate shear walls is common. Experimental studies have investigated the impact of opening size, shape, and location on the shear wall's strength, stiffness, and ductility, offering insights for mitigating potential weaknesses [8]. Finally, the integration of diagonal bracing with steel plate shear walls has been explored experimentally to enhance post-buckling resistance and ductility. Findings suggest that bracing can significantly improve stiffness, ultimate strength, and energy dissipation mechanisms [9].

Description

The experimental investigation of steel plate shear walls (SPSWs) has been a cornerstone in understanding their seismic performance. For instance, studies on SPSWs with various stiffener configurations have illuminated how differing arrangements influence critical performance indicators such as failure mechanisms, energy dissipation, and load-displacement characteristics. These investigations have demonstrated that the judicious selection of stiffener types and thicknesses can profoundly impact the ductility and ultimate load-carrying capacity of the system, providing essential data for the validation of numerical models used in seismic-resistant design [1]. Similarly, research into the seismic behavior of steel plate shear walls, distinguishing between unstiffened and stiffened configurations, has underscored the pivotal role of boundary element design. Experimental studies focusing on the post-buckling behavior of steel plates have confirmed that well-designed boundary elements are indispensable for achieving high levels of ductility and averting premature failure modes, thereby bolstering the seismic resilience of structures. These studies quantify hysteretic energy dissipation and stiffness degradation, offering valuable insights [2]. An innovative approach explored through experimentation is the application of reduced-thickness steel plate shear walls (RTSPSWs). Evaluations of these systems in mid-rise buildings have indicated that a reduction in plate thickness, when coupled with meticulous detailing of connections and boundary elements to ensure proper load transfer and prevent local buckling, can lead to substantial weight and cost savings without compromising seismic resistance [3]. Further advancements in SPSW technology have involved the introduction of novel panel zone configurations. Experimental testing of full-scale specimens under simulated seismic loads has revealed that these innovative designs can significantly enhance energy dissipation. The observed superior ductility and more stable hysteretic response compared to conventional designs highlight their potential for high-performance seismic applications in seismically active regions [4]. The exploration of composite steel plate shear walls, by integrating steel plates with concrete infill, has yielded compelling results. Experimental investigations into the influence of concrete strength and reinforcement have shown that these composite systems exhibit substantially higher stiffness and strength, along with improved ductility and energy dissipation, surpassing their steel-only counterparts and offering a pathway to high-performance seismic resisting systems [5]. The influence of infill plate slenderness ratios on the seismic behavior of single-story SPSWs has been another area of experimental focus. Research has detailed how variations in slenderness impact buckling modes, ultimate load capacity, and energy dissipation. While increased slenderness can lead to earlier buckling and reduced ductility, it may also result in higher initial stiffness, providing crucial data for optimizing plate dimensions in seismic design [6]. Experimental work has also scrutinized the critical details of connections between the steel plate and the boundary frame in SPSWs. By examining different connection types, researchers have clarified their influence on load transfer mechanisms, local buckling phenomena, and the overall hysteretic behavior. The findings consistently emphasize the necessity of robust connections for preventing premature failure and maximizing the energy dissipation effectiveness of the shear wall system [7]. The seismic performance of steel plate shear walls with integrated openings, a common architectural feature, has been thoroughly explored through experimental testing. This research provides critical data by investigating the impact of opening size, shape, and location on the shear wall's strength, stiffness, and ductility, offering practical guidance for engineers designing buildings with such features [8]. The addition of diagonal bracing to steel plate shear walls has been another subject of experimental inquiry. Studies have focused on how bracing affects post-buckling resistance and ductility, revealing that its incorporation can significantly enhance overall stiffness and ultimate strength, leading to improved seismic performance and a more stable energy dissipation mechanism compared to unbraced systems [9]. Finally, experimental studies on lightweight steel plate shear walls, often employed in modular construction, have examined their behavior under cyclic loading. These investigations have highlighted that while these systems can offer adequate seismic resistance for specific applications, careful consideration of buckling and connection rigidity is paramount for ensuring efficient and cost-effective seismic solutions [10].

Conclusion

This collection of research extensively explores the seismic performance of steel plate shear walls (SPSWs) through experimental investigations. Studies cover a range of modifications and configurations, including varying stiffener arrangements, boundary element designs, reduced plate thicknesses, novel panel zones, and composite materials (steel with concrete infill). The research consistently highlights the importance of connection details, plate slenderness ratios, and the presence of openings on the structural integrity, ductility, and energy dissipation capabilities of SPSWs. Specific findings indicate that optimized stiffeners, robust boundary elements, and well-designed connections enhance seismic resistance. Composite SPSWs offer superior performance, while innovations like novel panel zones and diagonal bracing further improve energy dissipation and strength. The research also addresses practical applications such as lightweight SPSWs for modular construction and those with architectural openings, providing valuable data for optimizing seismic design strategies and developing high-performance structural systems.

Acknowledgement

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Conflict of Interest

None.

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