Journal of Steel Structures & Construction

Zirakian and Boyajian, J Steel Struct Constr 2016, 2:1
DOI: 10.4172/2472-0437.1000e104

Editorial Open Access

Recent Studies on Steel Plate Shear Wall Systems

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Abstract

Steel plate shear walls (SPSWs) have been used as the primary or part of the primary lateral force-resisting system in design and retrofit of buildings. Development and use of low yield point (LYP) steel with considerably low yield stress and high elongation capacity nowadays provides the possibility to design SPSW systems with improved serviceability, structural performance, and enhanced energy absorption characteristics. This paper provides a review of recent studies performed by the first author on the seismic design and retrofit of SPSW systems using LYP steel material. The results and findings of these studies form the groundwork for future research in the design and detailing of cost-effective high-performing SPSW systems.

Keywords: Steel plate shear wall; Low yield point steel; Design; Retrofit; Recent studies

Introduction

SPSWs are considered as efficient lateral force-resisting systems which have been in use since the 1970s and offer many advantages over other systems, e.g., rigid and braced frames as well as reinforced concrete shear walls, in terms of cost, performance, and ease of design. A proliferation of research work has been undertaken on the structural behavior and seismic performance of these systems and the results of these studies have been incorporated into design codes and specifications.

The application of SPSWs has been based on two different design philosophies and detailing strategies. Stiffened and/or stocky-web SPSWs with improved buckling stability and high seismic performance features, as mostly used in Japan, and unstiffened and slender-web SPSWs with relatively lower buckling and energy dissipation capacities, as widely used in the United States and Canada.

Presently the development and use of LYP steel with considerably low yield stress (80-120 MPa) and high elongation capacity provides the possibility to combine the merits of the two aforementioned design strategies resulting in high-performing SPSW systems which are cost-effective. Although some reported studies have demonstrated the advantages of LYP steel shear walls, various aspects of structural and seismic characteristics of these systems have not been fully investigated. In particular, the linkage between structural specifications and seismic performance and pathways to performance-based designs of these systems are largely undeveloped.

Considering the various advantages and capabilities of LYP steel shear walls, systematic and comprehensive investigations have been conducted by the first author in order to facilitate the seismic design and prevalent application of such promising lateral force-resisting and energy dissipating systems. A summary of the findings is presented herein with suggested directions to consider for future research.

Element-, Component-, and System-level Investigations

Element-level investigations were initially performed by Zirakian and Zhang on the buckling and yielding behavior of LYP steel plates as the primary lateral force-resisting and energy dissipating elements in SPSW systems [1]. Considering the early yielding of LYP steel plates, accurate determination of limiting plate thickness corresponding to simultaneous buckling and yielding can play an important role in efficient seismic design of LYP steel shear wall systems. In fact, early yielding of the LYP steel infill plate results in more energy absorption of the plate, which in turn decreases the amount of the energy absorbed by the frame members of the system. On this basis, detailed theoretical and numerical investigations were made to accurately determine limiting plate thickness criterion as an effective design parameter. It was shown that application of LYP steel material desirably decreases the limiting plate thickness; contrastingly, increasing the plate length-to-height ratio unfavorably results in larger plate thicknesses to initiate concurrent buckling and yielding of these systems (Figure 1).

For the component-level investigations, the stiffness, strength, and hysteretic performances of LYP steel shear wall panels (Figure 2) were investigated through detailed numerical simulations [2,3]. The effects of using LYP steel infill plates on the interaction between the frame and plate elements were also studied. It was shown that employment of LYP steel infill plate's results in desirable structural behavior and plate-frame interactions. Based on such findings together with a detailed

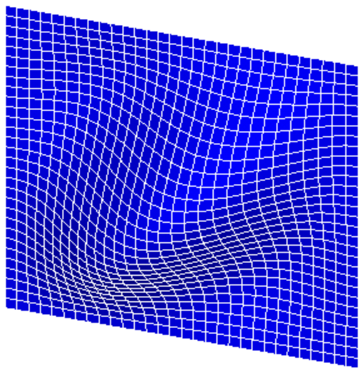

Figure 1: Plate element.

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Received January 11, 2016; **Accepted** January 13, 2016; **Published** January 20, 2016

Citation: Zirakian T, Boyajian D (2016) Recent Studies on Steel Plate Shear Wall Systems. J Steel Struct Constr 2: e104. doi:10.4172/2472-0437.1000e104

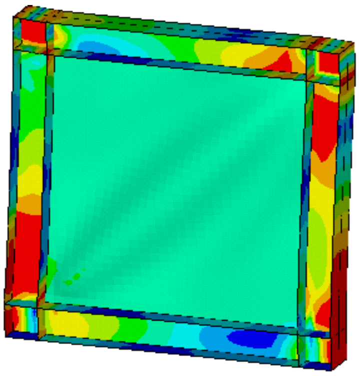

Figure 2: SPSW panel.

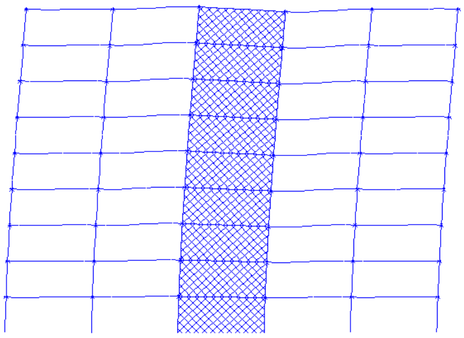

Figure 3: Multi-story SPSW frame.

consideration of code-based seismic retrofits using conventional steel shear wall systems, it was discovered that replacing SPSW infill plates made of A36 steel with LYP100 steel plates of double-the-thickness can serve as an enhanced retrofitting strategy, improving both the structural behavior and seismic performances of such systems. In addition, a modified plate-frame interaction (PFI) model was introduced and successfully applied for predicting the response of LYP steel shear wall systems with relatively low yielding and high buckling capacities.

For the system-level investigations, the structural and seismic performances of several code-designed multi-story SPSW frame retrofits (Figure 3) were considered for both conventional and LYP steel infill plates through detailed modal and nonlinear time-history analyses [4]. The SPSWs were modeled using the strip model which was shown to adequately represent the behavior of single- and multi-story SPSWs with different geometrical-material bifurcation characteristics. The multi-story models were subjected to earthquake excitations with wide ranges of peak ground velocity and acceleration values within different hazard levels. The evaluation of various seismic response parameters including drift, acceleration, base shear and moment, column axial load, and web-plate ductility demands, all attested of the advantages of using LYP steel infill material in the seismic design and retrofit of SPSW systems.

Based on the lessons learned from the past and recent catastrophic seismic events alongside major advances made in the fields of structural and earthquake engineering, design methodologies are gradually moving from formerly prescriptive to more performance-based design philosophies. Development of fragility functions for

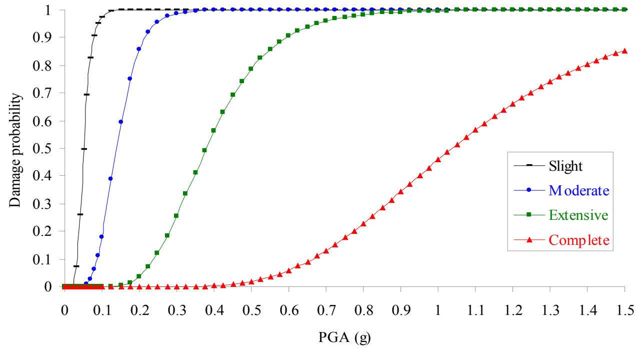

Figure 4: Typical SPSW fragility curves.

structural systems is a key component in this latter approach. On this basis and through consideration of the various sources of randomness and uncertainties involved in the areas of design and retrofit, adoption of a probabilistic methodology may result in a more robust seismic performance assessment of the structural systems. Zhang and Zirakian performed a study on the seismic performance and vulnerability of structures employing SPSW systems and LYP steel infill material based on a probabilistic seismic demand analysis [5]. Appropriate seismic response and ground motion intensity parameters along with damage-and-repair states were selected, and structural and nonstructural drift and acceleration fragility functions (Figure 4) were developed using nonlinear time-history data. Through such efforts, the effectiveness of SPSW systems using LYP steel infill material to enhance the overall seismic performance while diminishing the vulnerability of buildings has been successfully demonstrated.

Concluding Remarks

In this paper, a summary of recent studies performed by the first author on the seismic design and retrofit of SPSW systems using LYP steel material was presented. Comprehensive and systematic studies were performed through element-level investigations on steel plates, component-level investigations on SPSW panels, and system-level investigations on multi-story steel frame-shear wall structures. The fragility methodology was also utilized by developing appropriate fragility functions for probabilistic seismic performance and vulnerability assessments of SPSW systems designed and retrofitted with both conventional as well as LYP steel infill plates. These recently-published studies indicate that LYP steel infill plates offer an excellent means toward the seismic design and retrofit of shear walls by rendering an overall high-performing, cost-effective system with excellent energy dissipation and serviceability characteristics. Further research is required to augment the existing state of knowledge and to eventually introduce effective design rules and recommendations into code particularly from a performance-based standpoint.

Acknowledgement

The authors would like to express their profound appreciation for the excellent guidance and support that they received from: Dr. Jian Zhang from the University of California - Los Angeles, Dr. Carlos Estuardo Ventura from The University of British Columbia, Dr. Sheng-Jin Chen from the National Taiwan University of Science and Technology, and Dr. Chyuan Jhang of Sinotech Engineering Consultants in Taiwan.

References

1. Zirakian T, Zhang J (2015) Buckling and Yielding Behavior of Unstiffened Slender, Moderate, and Stocky Low Yield Point Steel Plates. Thin-Walled Structures 88: 105-118.

2. Zirakian T, Zhang J (2015) Structural Performance of Unstiffened Low Yield Point Steel Plate Shear Walls. Journal of Constructional Steel Research 112: 40-53.
3. Zirakian T, Zhang J (2015) Seismic Design and Behavior of Low Yield Point Steel Plate Shear Walls. International Journal of Steel Structures 15: 135-151.
4. Zirakian T, Zhang J (2016) Study on Seismic Retrofit of Structures Using SPSW Systems and LYP Steel Material. Earthquakes and Structures, An International Journal 10: 1-23.
5. Zhang J, Zirakian T (2015) Probabilistic Assessment of Structures with SPSW Systems and LYP Steel Infill Plates Using Fragility Function Method. Engineering Structures 85: 195-205.