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Structural performance assessment of trapezoidally-corrugated and centrally-perforated steel plate shear walls

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ABSTRACT

In recent years, there has been a growing interest towards the use of corrugated infill plates as an alternative to flat infill plates in steel plate shear wall (SPSW) systems. Corrugated plates offer various advantages over flat plates including higher energy dissipation capacity, ductility, out-of-plane stiffness, and improved buckling stability. On the other hand, perforation of the web-plate can allow the utility passage through SPSW and also can alleviate the problem of large panel force over-strength due to larger web-plate thickness. Considering the structural and architectural features of corrugated- and perforated-web SPSWs further research is required in order to obtain a better understanding of the structural and seismic performances of such efficient lateral force-resisting systems. On this basis, this paper investigates the cyclic behavior and energy absorption capabilities of SPSWs with trapezoidally-corrugated and centrally-perforated infill plates. To this end, numerous finite element models with various geometrical properties are developed and analyzed under cyclic loading. Results and findings of this study are indicative of effectiveness of the web-plate thickness, corrugation angle, and opening size on the hysteretic performance of corrugated- and perforated-web steel shear wall systems. Optimal and proper selection of the aforementioned geometrical parameters can result in SPSW systems with desirable structural behavior and seismic performance.

1. Introduction

Steel plate shear walls (SPSWs) are efficient lateral force-resisting systems which are commonly used in design and retrofit of buildings. Structural and economical considerations may result in the design of SPSWs with unstiffened or stiffened as well as slender or stocky infill plates. Structural behavior and seismic performance of such systems are directly influenced by the geometrical and material characteristics of the web plates as the primary lateral force-resisting components. Among various considered configurations, SPSWs with corrugated and/or perforated infill plates have lately gained some attention and accordingly several studies have been reported in this regard.

Mo and Perng [12] reported an experimental study on framed shear walls with corrugated steel plates and demonstrated improved seismic performance of such structural systems. Stojadinovic and Tipping [16] performed an experimental study in order to develop an alternative lateral bracing system comprising corrugated sheet steel shear walls for use with light-framed cold-formed steel buildings. Moreover, a numerical study conducted by Gholizadeh and Yadollahi [9] showed that the structural behavior of a corrugated plate can be superior to that of a flat plate due to its higher loading capacity, ductility, and energy absorption capability. Emami et al. [6], also, reported an experimental research on the cyclic behavior of trapezoidally-corrugated and unstiffened steel shear walls and compared the stiffness, strength, ductility ratio, and energy dissipation capacities of steel shear walls with unstiffened, trapezoidally vertical corrugated, and trapezoidally horizontal corrugated infill plates. Recently, Tong and Guo [17] investigated the elastic buckling behavior of steel trapezoidally-corrugated shear walls with vertical stiffeners theoretically and numerically and proposed formulas for predicting the elastic buckling loads of stiffened steel trapezoidal corrugated shear walls.

Roberts and Sabouri-Ghomi [14] performed a series of cyclic loading tests on unstiffened steel shear walls with centrally-placed circular openings of varying diameters. As reported, all the tested panels exhibited stable hysteresis loops and adequate ductility for the first four loading cycles without significant loss in their load-carrying capacity. Vian and Bruneau [19] conducted an experiment to investigate the efficiency of steel infill panels with circular openings. The test specimen displayed stable S-shaped hysteresis loops with little or no pinching. Furthermore, Moghimi and Driver [13] studied the effect of regular perforation patterns on SPSW column demands. This study showed that although the perforations reduce the shear capacity of the infill plate considerably, they may not reduce the force demands on the columns. Valizadeh

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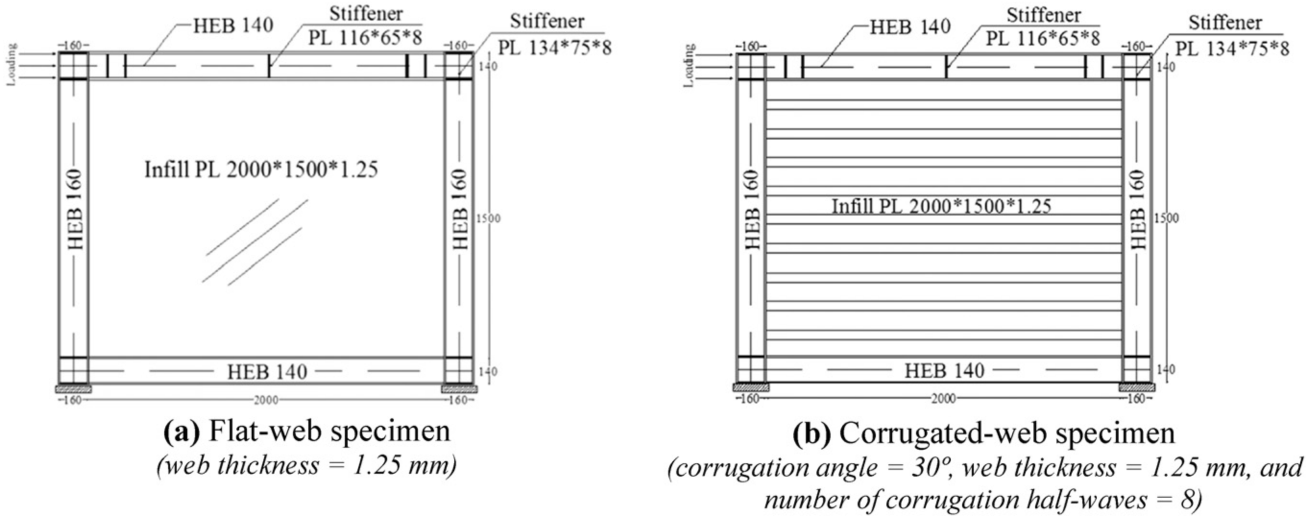

Fig. 1. Details of the modeled experimental specimens tested by Emami et al. [6].

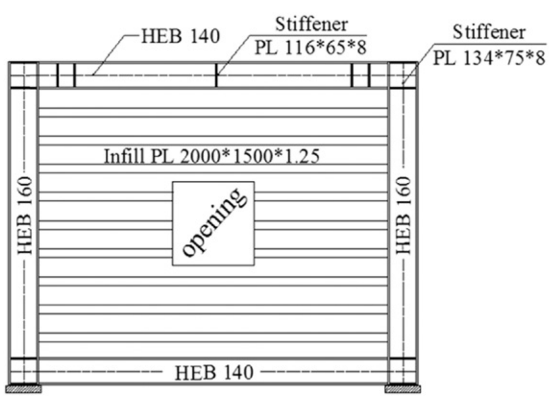

Fig. 2. Details of a typical trapezoidally-corrugated and centrally-perforated SPSW model.

et al. [18], also, conducted an experimental investigation on cyclic behavior of steel shear walls with centrally-placed circular opening. The effects of existence of the central perforation and the opening size on some structural parameters, i.e. initial stiffness, strength, and energy absorption, were evaluated in this study. Lately, Barkhordari et al. [3] reported a numerical study on the behavior of SPSWs with stiffened full-height rectangular openings and evaluated the stiffness, strength, and ductility performances of such perforated steel shear walls. In addition, Sabouri-Ghomi and Mamazizi [15] investigated the structural behavior of stiffened SPSWs with two rectangular openings experimentally. It was shown that the interval between the two openings had no effect on the ultimate shear strength, stiffness, and energy absorption, while the existence of openings led to reduction in values of the aforementioned parameters.

The stiffness, strength, and energy absorption performances of corrugated and perforated SPSWs were investigated numerically by Farzampour et al. [8]. Some of the advantages and disadvantages of employment of corrugated and perforated infill plates in terms of structural performance of SPSW systems were demonstrated. This research intends to focus on the cyclic performance and energy dissipation capability of corrugated and perforated SPSWs in order to gain a better understanding of seismic performance of such lateral force-resisting systems. To this end, non-perforated SPSW specimens tested and documented by Emami et al. [6] and Emami and Mofid [5] were selected and numerical parametric studies were performed by varying some geometrical and corrugation parameters including the web-plate thickness, corrugation angle, and opening size.

2. Characteristics of SPSW models

In order to investigate the performance of SPSWs with corrugated and perforated infill plates, parametric studies are performed on two SPSW specimens tested by Emami et al. [6] whose details are illustrated in Fig. 1. Infill plate thickness (t_w) and corrugation angle (θ) as well as centrally-placed square opening size (O) are considered as the varying parameters in this study. Details of a typical corrugated and perforated steel shear wall model are shown in Fig. 2.

Table 1
Characteristics of the SPSW models.

Web-plate form	Label	θ (deg.)	t_w (mm)	O (%)	No. of models
Trapezoidal	T-θ-t_w-O	30	1.25, 2, 3, 4	0, 5, 15, 30	16
		45	1.25, 2, 3, 4	0, 5, 15, 30	16
		60	1.25, 2, 3, 4	0, 5, 15, 30	16
		90	1.25, 2, 3, 4	0, 5, 15, 30	16

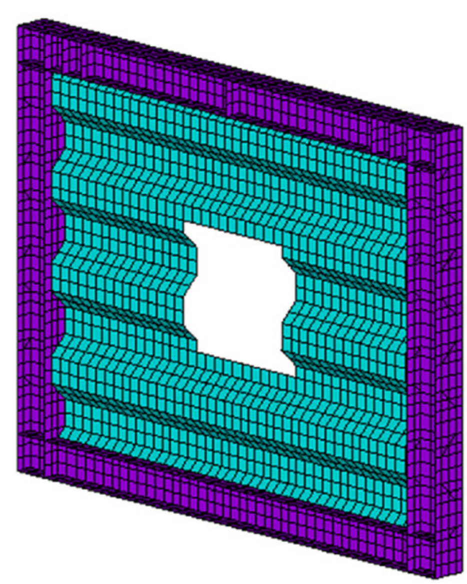

Fig. 3. A typical finite element model.