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Experimental investigation on stiffened steel plate shear walls with two rectangular openings

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ABSTRACT

One of the most important advantages of steel plate shear wall (SPSW) is to create openings with different sizes and arbitrary locations on the infill plate depending on their application. In this research, the effects of two openings on the structural behavior of SPSWs were studied experimentally. Experimental testing was performed on three one-third scaled single-story SPSW specimens with two rectangular openings under quasi-static cyclic loading. The differences between the three perforated experimental specimens were the interval between two openings and their closeness to the frame columns. The structural parameters of perforated specimens were compared to the similar specimen without any opening. The experimental results were utilized (a) to compare the ultimate shear strength, stiffness and energy absorption of specimens; (b) to evaluate the performance of central, lateral, top and bottom panels; (c) to investigate the effect of distance between the openings and the columns on the formation of plastic hinges on the column flanges; (d) to study the behavior of stiffeners around the openings. Test results showed that the ultimate shear strength, stiffness and energy absorption were the same in all three perforated specimens and the interval between the two openings had no effect on these values. Moreover, existence of openings will lead to reduction in values of structural parameters.

1. Introduction

Steel plate shear walls (SPSWs) are an innovative lateral load resisting system capable of effectively bracing a building against both wind and earthquake forces [1]. In addition, one of the advantages of steel shear walls is the providing of openings in the infill plate, which sometimes are required for architectural reasons. The strength and ductility of steel plate shear walls make them very suitable in buildings in seismic high-risk zones [2]. The efficiency of this system was compared with other loading resisting systems such as moment frame and concrete shear wall systems. In general, SPSWs have proven to be effective and economical bracing system for buildings in the range of 15–40 stories [3–5]. During the last three decades, experimental and analytical research on SPSWs systems is mainly focused on the behavior investigation of single- and multi-story thin unstiffened SPSWs with solid infill plates (i.e. without openings). Therefore, limited researches have been conducted on the various types of openings in SPSWs.

Takahashi et al. [6] conducted the first research program on the behavior of stiffened SPSW panels with one stiffened door opening. The test result showed that the stiffness and ultimate shear strength of the steel plate with an opening was supplied well with increase of plate thickness and adequate reinforcement around it. Roberts and Sabouri [7] conducted 16 quasi-static cyclic loading tests on unstiffened slender shear steel panels with centrally placed circular opening. They concluded that the shear strength and stiffness of a perforated panel can be conservatively estimated by applying the linear reduction factor $(1-D/L)$ to the shear strength and stiffness of a similar solid panel, where D and L are the diameter of circular opening and panel depth, respectively. Vian and Bruneau [8] conducted experimental works on a pattern of multiple regularly spaced circular perforations in the infill steel. Piak [9] presented a formula to predict the ultimate shear strength of perforated steel plates under shear loading. Choi et al. [10] performed an experimental study to investigate the structural capacity of framed steel plate walls with various thin infill plates. Alinia et al. [11] performed a series of numerical analyses to inquire the influence of central and near border cracks on buckling and post-buckling behavior of shear panels. It was implied that discontinuity in tension zones can have significant influence on buckling and post-buckling behavior of SPSWs. Sabouri and Sajjadi [12, 13] tested 4 one story one span SPSWs with a central stiffened

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rectangular. They also tested a specimen with one-way stiffener without opening as well as a single frame. It was reported that both the initial stiffness and the ultimate shear strength of the SPSWs reduced with an increase of the width of the opening, compared with identical panels without an opening. Pellegrino et al. [14] studied the influence of the dimension, position and shape of one perforation on the linear buckling and the non-linear behavior of steel plates. Purba [15] proposed a formula to determine the shear strength of a perforated infill plate with the specific perforation pattern proposed by Vian and Bruneau [8].

Valizadeh et al. [16] experimentally obtained that the creation of opening reduced the initial stiffness, strength and energy absorption. Hosseinzadeh [17] investigated the behavior of SPSWs with and without stiffened large rectangular openings. Alavi [18] experimentally developed a formula and verified it for the estimation of shear strength of a perforated and diagonally stiffened SPSW. Bromwich [19] proposed a shear strength model of the infill plate with multiple circular openings based on a strip model for unstiffened SPSW.

In this research, experimental studies were performed on three one-third scaled one-bay single-story stiffened SPSW specimens with two symmetrical rectangular openings under quasi-static cyclic loading. The differences between the three perforated experimental specimens were the interval between two openings and their closeness to the frame columns. Additionally, the experimental results of the specimen without any openings given in Ref. [12] were used for the comparison of structural parameters. This specimen was similar to perforated specimens in terms of infill plate specifications and frame geometry.

Primary concern was paid to experimental performance of specimens in terms of infill plate buckling, yielding of plates in panels and columns, hysteretic observations. The failure of the different members was investigated according to existence of two same openings with varying locations and different aspect ratios of middle and lateral panels. Moreover the initial stiffness, ultimate shear strength and energy absorption of three experimental specimens was compared together and also with another same specimen without opening [12].

2. Characteristics of the specimens

In this paper three one-third scaled one-bay single-story stiffened SPSWs with two symmetrical stiffened rectangular openings under cyclic loading were examined and experimental results of a same specimen without any openings were used. The perforated specimens were coded as SSW2O1, SSW2O2 and SSW2O3 as shown in Fig. 1. The other SPSW specimen was called DS-SPSW-0% which its infill plate specifications and frame geometry were similar to other specimens except it was without openings as shown in Fig. 2. Stiffeners were installed on the infill steel plate divided it to some sub panels. Sub panel that was

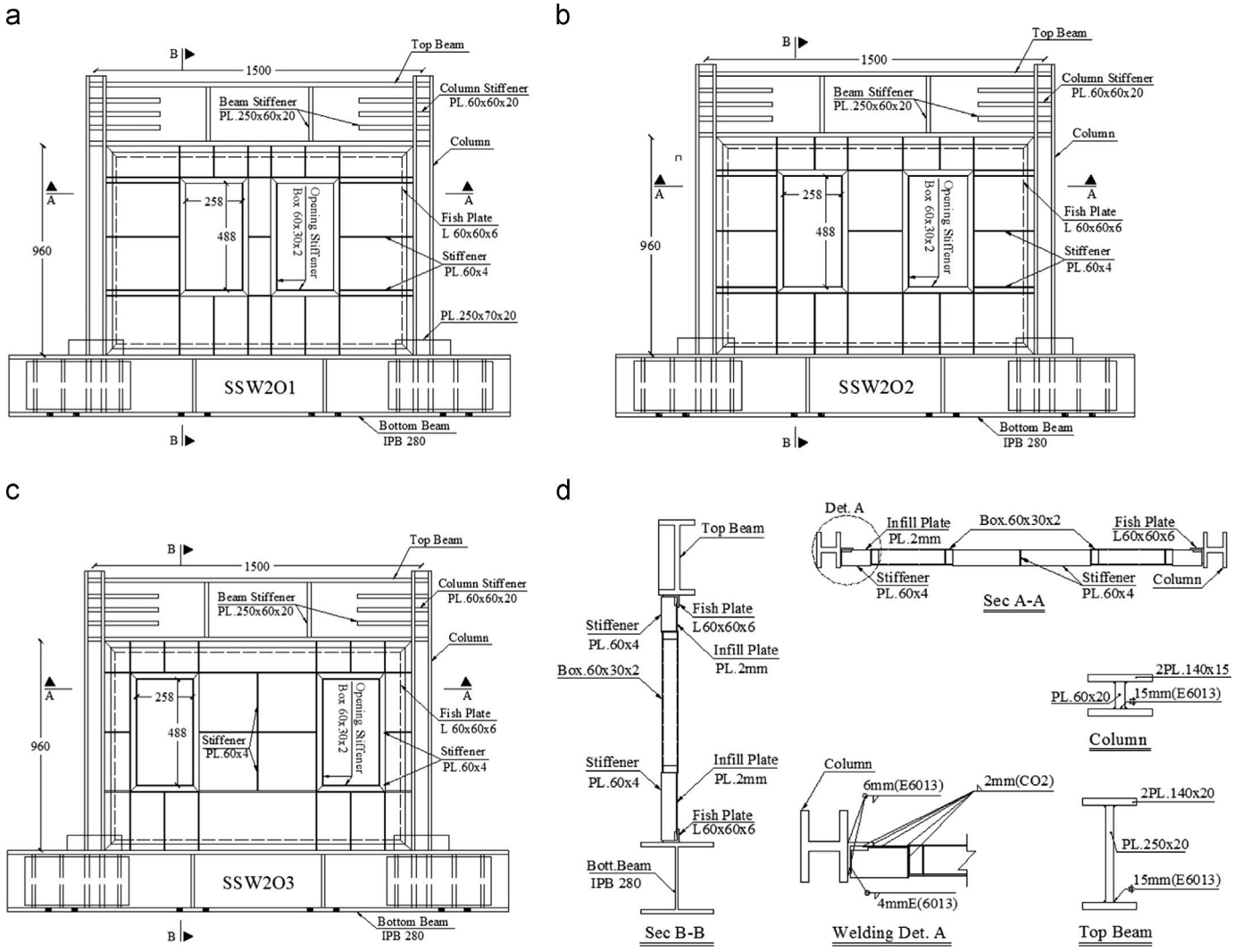

Fig. 1. Specifications and details of perforated specimens. (a) SSW201, (b) SSW202, (c) SSW202 and (d) vertical and horizontal cross sections and welding details.