Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(2) (2020) 115-118
DOI: 10.22060/ceej.2019.14450.5657

Investigating the Opening Dimensions, the Stiffness of the Boundary Elements and the Type of the Infill Plate on the Behavior of Steel Plate Shear Wall

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ABSTRACT: The steel plate shear wall (SPSW) has always been of interest to designers and researchers as an efficient lateral loading system over the past few decades. Different plate conditions and boundary elements each affect the behavior of steel shear walls somehow. In this paper, the behavior of this system has been investigated in cases such as an infill plate with a central opening of different diameter, an infill plate made of a different kind of steel and increased stiffness in boundary elements. In this study, three objectives were followed using the finite element method (FEM): a) investigating the effect of a circular opening on the behavior of steel shear walls and presenting the relationship between the ratio of the diameter of the hole to the height and the ultimate strength of the wall, b) the effect of increasing the stiffness of the beam and column elements on the behavior of steel shear walls and presenting the relationship between the effect of each increase on the ultimate strength of the wall, c) the effect of the infill plate made of different steel on the behavior of steel shear walls. For this purpose, several numerical models were designed using the finite element software that differ in the dimensions of the opening, the stiffness of the boundary elements and the type of the infill plate. The results of all models were extracted in terms of the ultimate strength, ductility, stiffness, and energy absorption and compared with each other. Also, the relationships related to the effect of increasing the diameter and the stiffness of the boundary element on the ultimate strength of the steel shear wall were presented.

Review History:

Received: 2018-05-14
Revised: 2018-11-10
Accepted: 2019-01-08
Available Online: 2019-01-08

Keywords:

Steel Plate Shear Wall
Opening
Boundary Elements
Ductility
Energy Absorption
Infill Plate

1. INTRODUCTION

Steel plate shear walls exhibit a more suitable behavior in the face of lateral forces, especially earthquakes than other similar systems due to their more stiffness, energy absorption and ductility. Among the studies conducted in this area are Robert and Sabouri-Ghomi [1], Schumacher and et al [2], Astaneh-Asl [3], Alavi and Nateghi [4], Nazifi and Shariatmadar [5], Hoseinzadeh Asl and Safarkhani [6], Gholhaki et al [7], Shekastehband et al [8], Kazemi and Arabzade [9], Behzadinia and Rahai [10]. In this paper, it is attempted to determine the effect of the opening, the material of the infill plate and stiffness of the boundary elements on the behavior of steel plate shear walls. Therefore, several finite element models were developed that differed in terms of the diameter ratio of the opening to the panel height, material of the infill plate and stiffness of the boundary elements. The studied parameters included ultimate strength, ductility, energy absorption and stiffness that were considered for each model relative to other models. The ductility parameter was calculated according to the Code 360 and FEMA 356 [11-13]. Also, relations were proposed for the effect of increasing the diameter of the opening and stiffness of the boundary element on the final strength.

2. EXPERIMENTAL MODEL

In this study, the S2 experimental sample (single bay

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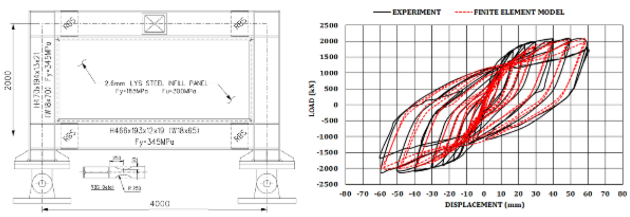

Fig. 1. Experimental model (a), FE and Experimental Hysteresis

- single story) of Vian et al. [14] was used. The sample specification is shown in Figure 1a.

3. VALIDATION

For the modeling of the sample, ABAQUS software limited version 6.14-2 was used. The S4R model was applied for modeling with a mesh size of 100mm. The ATC-24 cyclic loading protocol was also available. Figure 1b shows the comparison between the experimental hysteresis and finite element model that the results indicate a proper approximation and modeling accuracy.

4. DEFINITION OF MODELS

The finite element models are in accordance with Table 1. It should be noted that the models were prepared based on the specification of the S2 model, whose variations are shown

Table 1. FE ModelsResults and analysis of models

Models	Opening (D/d)	Infill plate	Increasing in elements Stiffness (%)	
			Columns	Beams
SPSW-WO	0	LYS 165	––	––
SPSW-O10%	0.1	LYS 165	––	––
SPSW-O20%	0.2	LYS 165	––	––
SPSW-O30%	0.3	LYS 165	––	––
SPSW-O40%	0.4	LYS 165	––	––
SPSW-O50%	0.5	LYS 165	––	––
SPSW-C50%	0	LYS 165	50%	––
SPSW-C100%	0	LYS 165	100%	––
SPSW-B50%	0	LYS 165	––	50%
SPSW-B100%	0	LYS 165	––	100%
SPSW-I572	0	A572	––	––
SPSW-I37	0	ST 37	––	––

in Table 1 below. Material specifications were according to the Vian et al. [14], Sabouri-Ghomi and Ziaei [15].

The end loading of the models was carried out in accordance with the experimental sample and up to a drift of 3% (60 mm).

5.1. The effect of opening diameter

In Figure 2, the pushover diagram of the models with openings is presented.

As shown in Figure 2, an increase in the opening diameter decreases the initial gradient of the pushover diagram, which indicates stiffness and the final strength has decreased

5.2. The effect of increased stiffness of the boundary elements

In Figure 3, the push over diagram of models with increasing stiffness in boundary elements is observed.

By comparing the models in Figure 3, it is observed that increasing the stiffness of the boundary elements enhances the stiffness of the system, but the final strength of the system is not elevated significantly.

5.3. The effect of changing infill plate's steel material

Figure 4 represents the push over diagram of models with changing infill plate's material.

6. CONCLUSION

1. Increasing D/d ratio reduces the final strength, ductility, energy absorption, and stiffness parameters. Moreover, reducing the final strength of the steel plate shear by increasing D/d is calculated by 22.82 (D/d) ^{2}+12.93(D/d) + 0.34

2. Increasing the stiffness of the boundary element enhances the final strength, ductility, energy absorption, and stiffness. The ratio of this increase in the model with increasing stiffness in the columns is less significant than the model with increasing stiffness in the beams because the reduced sections are predominant on the design. The increase in final strength is calculated by increasing the stiffness of the columns with the equation $\frac{0.192C_{Si}^2+23.8C_{Si}}{10000}$ and increasing the final strength by enhancing the stiffness of the beams is achieved by $\frac{4.9B_{Si}^2-149B_{Si}}{10000}$.

3. Replacing the infill sheet's steel material with low yield stress with the steel material with higher yield stress increased the parameters of ultimate strength, ductility, energy absorption, and stiffness. However, the stresses imposed on the boundary elements also increased significantly.

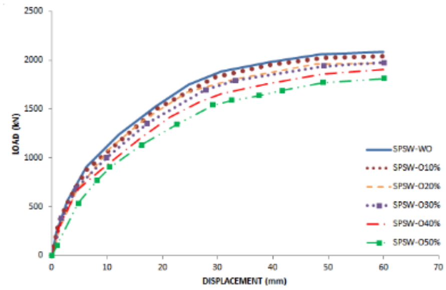

Fig. 2. Pushover of the models with openings

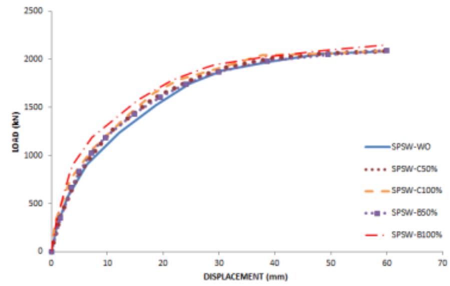

Fig. 3. push over diagram of models with increasing stiffness in boundary elements

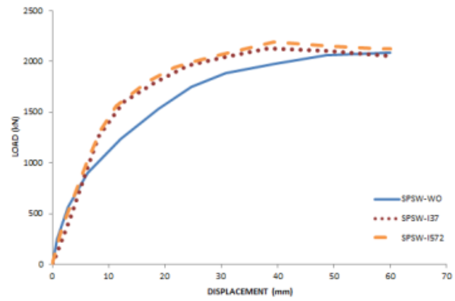

Fig. 4. Pushover diagram of models with changing infill sheet's material

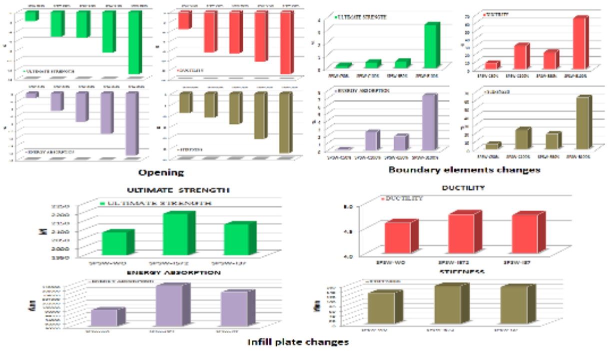

Fig. 5. Results of models

4. The material used in the infill sheet can be as effective as the stiffness of the boundary elements in the final strength and energy absorption; however, the effect of the stiffness of the boundary elements on the ductility and stiffness is much higher.

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HOW TO CITE THIS ARTICLE

F. Hatami, N. Paslar, Investigating the Opening Dimensions, the Stiffness of the Boundary Elements and the Type of the Infill Plate on the Behavior of Steel Plate Shear Wall, Amirkabir J. Civil Eng., 52(2) (2020) 115-118.

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