Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(4) (2021) 321-324
DOI: 10.22060/ceej.2020.16928.6396

Influence of Crack on the Behavior of Steel Plate Shear Wall Under Lateral Loading

A. Ghamari[1*], V. Broujerdian[2]

[1] Department of Civil Engineering, Darreh Shahr Branch, Islamic Azad University, Darreh Shahr, Iran.
[2] Department of Civil Engineering, Iran University of Science and Technology, Tehran, Iran.

ABSTRACT: Experimental and numerical studies of Steel Plate Shear Wall (SPSW) and its successful performance under past earthquakes have introduced this system as a lateral bearing system. There is a lot of unknown information about SPSW despite reported numerous studies. The effect of crack on the SPSW behavior is one of the unknown aspects of SPSW. Although crack had affected some experimental tests, its effect on the SPSW behavior has not been investigated comprehensively. Even in numerical studies, due to the complicity of the crack in modeling and analyzing especially in nonlinear studies, it has not been evaluated comprehensively. Because of the thin steel plate and inherent welding, the emerging of the crack in SPSW is deniable. Therefore, in this paper, the effect of central and edge cracks on the behavior of SPSW was studied numerically and parametrically. Numerical results indicated that the central crack is more destructive than edge cracks in case of fracture, ultimate strength, and energy absorption. Although small cracks do not have a considerable effect on the behavior of SPSW, the central crack with a long length leads the SPSW to fracture in the elastic zone. Moreover, although long edge crack reduces ultimate strength and energy absorption, it does not lead the SPSW to fracture. Due to the difficulty of crack modeling and crack analysis in SPSW, the necessary relations were proposed to obtain a pushover diagram without needing to modeling. The proposed relation estimates the pushover diagram of the system in good agreement with FE results.

Review History:

Received: Aug. 17, 2019
Revised: Dec. 13, 2019
Accepted: Dec. 28, 2019
Available Online: Mar. 02, 2020

Keywords:

Steel Shear Wall
Crack
Seismic Behavior
Stiffness
Strength

1. Introduction

Steel Plate Shear Walls (SPSWs) are capable systems against lateral loading [1]. This system enjoys high stiffness and strength as well as considerable ductility [2]. This system had shown ductile behavior in past earthquakes [3]. These advantages pursued designers to use them in their projects. Also, some strategic building has been built using SPSW. Generally, in small-scale and full-scale laboratory studies, a continuous infill steel plate is used [2-6] that is dissimilar with real projects condition. Due to the limitation of steel plates in the case of practical dimensions and SPSWs technical construction, the constructor utilizes two plates for infill plates. The two plates are welded together at mid-height of the infill plate that is susceptible to crack.

Since it is used thin plates for infill plates of SPSWs systems and due to the nature of the crack, existing of the crack in the infill plate is undeniable. Also, in some experimental studies [7,8], the emerging of crack was reported although the main feature of those studies was not to study crack in SPSW. Therefore, there is a gap in knowledge in this field. In so doing, in this study, the effect of crack on the SPSW is investigated numerically and parametrically.

*Corresponding author's email: aghamari@alumni.iust.ac.ir

2. Methodology

Numerical studies are carried out using the Finite Element (FE) method. In so doing, the capacities of ANSYS and ABAQUS software are used. The crack initiation is obtained by ABAQUS and then the crack propagation is modeled by ANSYS. This technic is because of the limitations of the mentioned software and their capabilities in modeling and analyzing.

The geometrical properties and crack location at mid-height of infill plate in FE models are shown in Fig. 1. The infill plate equals 4mm was designed for all models. The boundary frame was designed to resist the post-bucking behavior of the infill plate. For each model, a specific name was selected that contains two parts. The first part, EF or CF represents edge or central crack, respectively. The second part shows the crack length in mm. Models with the crack length of 4, 8, 16, 32, 64, 128, 256, 512, and 1024 mm were modeled.

3. Results and discussion

4. Load-displacement curve

The load-displacement curves of FE models are shown in Fig. 2 Based on the figure, edge crack leads the curve down but it is not causing to sudden fracture of SPSW. Leading

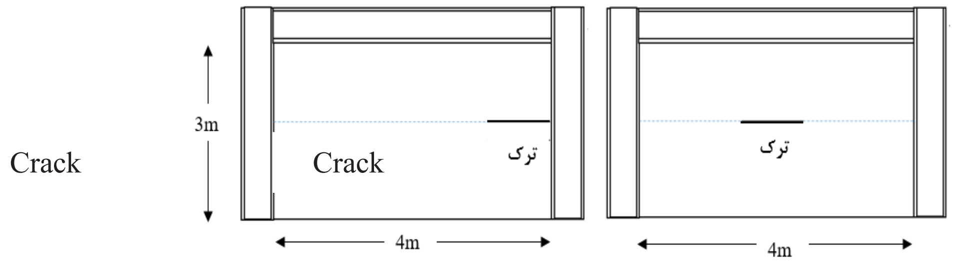

Fig. 1. Cracked SPSW

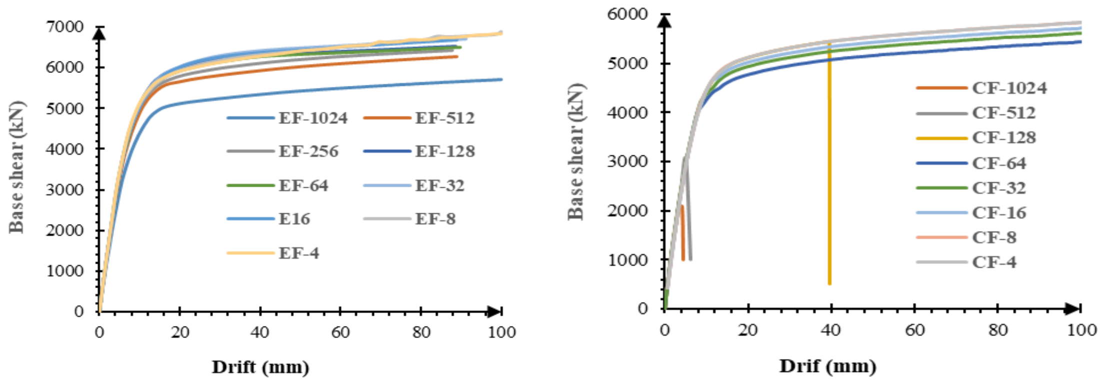

Fig. 2. Load-displacement curve of FE models

the curve down represents reducing in ultimate strength and energy absorption. But, walls with a central crack length greater than 3.2% of infill plate are fractured suddenly. Moreover, central crack length greater than 12.8% of infill plate cause fracture of the wall in the elastic zone. It is concluded that walls with a central crack length great than 12.8% should not be used as seismic zones.

4.1. Stress in SPSW

Fig. 3 shows the yielded state of SPSW for edge and central crack at ultimate drift. As shown in this figure, long crack length prevents forming of stress tension field action in the infill plate. Also, a crack with a small length does a considerable effect on the tension stress field action. Moreover, in-wall with long central crack, yielding is concentrated at two ends of the crack. In the other words, the infill plate dosed participate in energy-absorbing because of fracturing of the infill plate in the elastic zone. But, in-wall with a long central crack, a considerable area of infill plate is yielded however the tension field action is not completed.

5. Parametric model

Modeling of SPSW is complicated even without accounting cracks. Considering the crack effect, the complexity of modeling is further enhanced. To overcome this problem a parametric model is proposed for cracked SPSW. For this meaning, displacement and strength of infill plate and mainframe are calculated separately. To archive the pushover curve of cracked SPSW, the obtained curves are combined together. Shear displacement of infill plate, Δwp, without taking into account of crack effect is obtained from Eq. (1).

$$\Delta_{wp}=\frac{0.65\,\sigma_t}{E}\,\frac{3+\sin^2 2\alpha}{\sin 2\alpha}\,d \tag{1}$$

Where E is the Yang modulus, σt is the tension yield strength, d is the frame height, and α is the tension field action.

It is assumed that ultimate strength, Ff, and ultimate elastic displacement, Δf, of the mainframe are calculated when two hinges are formed at the two ends of columns.

$$\Delta_f=\frac{M_p\,d^2}{6E\,I_c} \tag{2}$$

$$F_f=\frac{4M_p}{d} \tag{3}$$

Where Ic and Mp are the moment of inertia and plastic moments of the column. The load-displacement of uncracked SPSW is drawn using the Eq. (1) to (3) inelastic zone. To tack into account of crack, the infill plate length, b, is modified. If it is assumed that b2 be cracked infill and cracked equal to, and crack propagated length be b1 therefore the modified infill plate length accounting cracking is equal to $b_2=\mathrm{b}-b_1$. Therefore, the shear strength of the cracked infill plate is calculated by Eq. (4).

$$\mathrm{F}_{\mathrm{w2}}=(\tau_{\mathrm{cr}}+0.5\,\sigma_t\,\sin 2\alpha)\,b_2.t \tag{4}$$

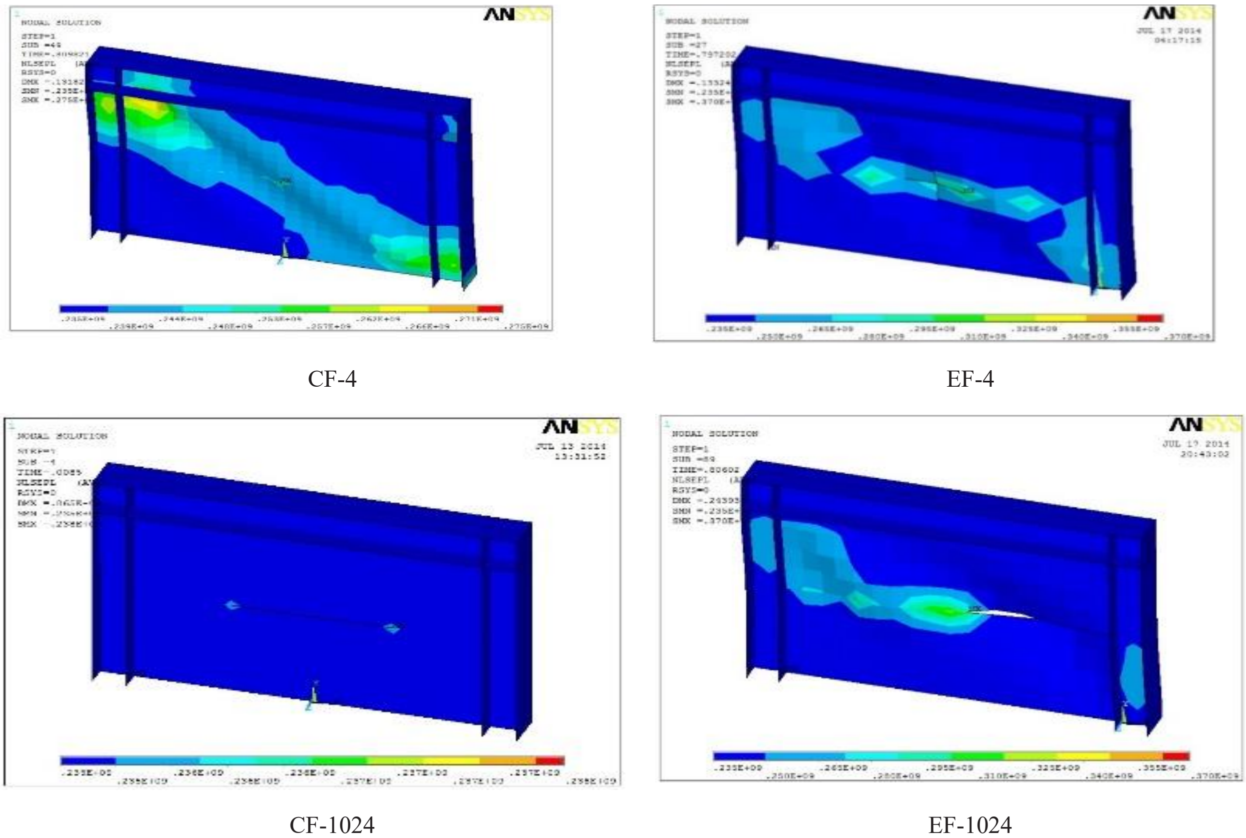

Fig. 3. Yielding of SPSW for edge and central cracks

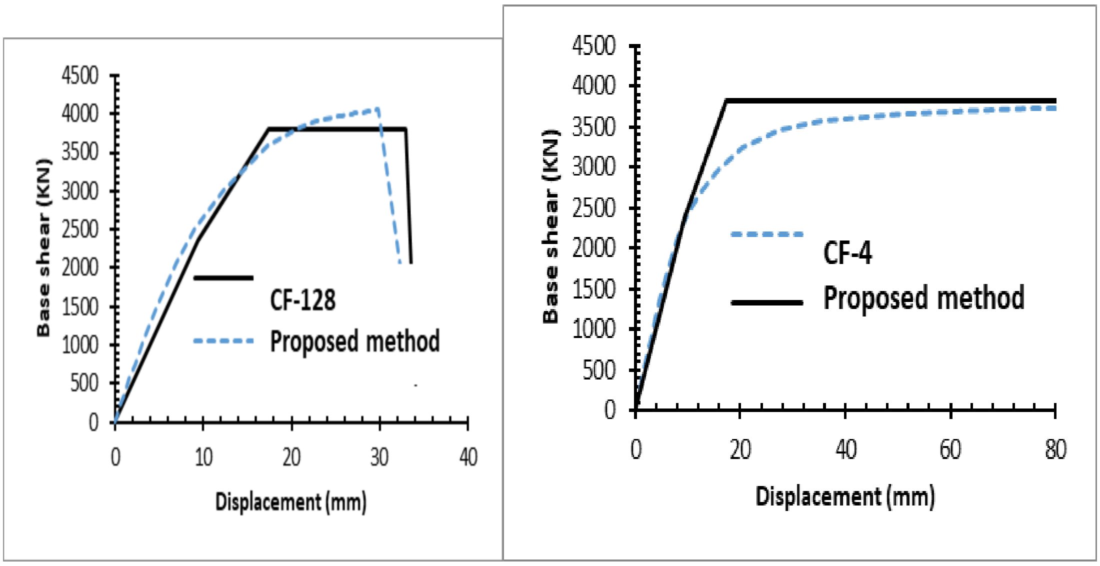

Fig. 4. Comparing of proposed method with FE results

5.1. Verification of parametric method

In Fig. 4, the FE results are compared with the proposed method to evaluate the accuracy of results. As seen in the figure, the proposed method shows a good agreement with FE results. Its error in elastic zone is around 2% in calculating stiffness. In addition, it calculates the ultimate strength 5% lower than FE results.

6. Conclusions

In this paper, the effect of crack on the behavior of SPSW was studying numerically and parametrically. The results are summarized as follows:

- Crack with small length does not considerable effect on the behavior of SPSW.

- Both long edge and central cracks in infill plate reduce the ultimate strength and energy absorption of SPSW. But, central crakes are more critical than edge crakes.

- In central crake length greater than 3.2% of infill plate length, it causes to suddenly fracture of SPSW in the inelastic zone. Moreover, the wall with central crake length greater than 3.2% of infill plate length, fractured in the elastic zone with significantly low energy absorption.

- Central long crack prevents forming the yielding of diagonal infill plate whereas edge crack does not considerably impact on it.

- The proposed parametric model is in good agreement with FE results in the case of predicting the pushover curve.

References

[1] M. Gholipour, M.M. Alinia, Behavior of multi-story code-designed steel plate shear wall structures regarding bay width. Journal of Constructional Steel Research, 122 (2016) pp. 40–56.

[2] R.G. Driver, G.L. Kulak, D.J.L. Kennedy, A.E. Elwi, Cyclic tests of four-story steel plate shear wall. Journal of Structural Engineering. 124 (1998) pp.112-20.

[3] S. Sabouri. C. Ventura. M. Kharrazi, Shear Analysis and Design of Ductile Steel Plate Walls. Journal of Structural Engineering-ASCE, 12 (2005) pp. 878-889.

[4] J. Jonah J. Shishkin. Robert Driver. Gilbert Driver. Analysis of Steel Plate Shear Walls Using the Modified Strip Model. Structural Engineering Report No. 261. University of Alberta, (2013).

[5] A.R. Rahai. M. Alipour, Behavior and Characteristics of Innovative Composite Plate Shear Walls. The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction. Procedia Engineering, 14 (2011) pp. 3205–3212

[6] D. Dubina, F. Dinu, Experimental evaluation of dual frame structures with thin-walled steel panels. Thin-Walled Structures, 78 (2014) pp. 57–69.

[7] C. Lin. K. Tsai, Y. Lin. K. Wang, B. Qu. M. Bruneau, Full Scale Steel Plate Shear Wall: NCREE/MCEER Phase I Tests, Proceeding of the 9th Canadian Conference on Earthquake Engineering. Ottawa. Canada. (2007).

[8] M. Guendel. B. Hoffmeister, M. Feldmann, Experimental and numerical investigations on Steel Shear Walls for seismic Retrofitting”. Proceedings of the 8th International Conference on Structural Dynamics. EURODYN. (2011).

HOW TO CITE THIS ARTICLE:

A. Ghamari, V. Broujerdian, Influence of Crack on the Behavior of Steel Plate Shear Wall Under Lateral Loading, Amirkabir J. Civil Eng., 53(4) (2021): 321-324.

DOI: 10.22060/ceej.2020.16928.6396