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Limited Component Evaluation of the Effect of Regular Cavities on the Sheet Metal Element of the Steel Plate Shear Wall

Seyyed Abbas Mojtabavi, Mojtaba Fatzaneh Moghadam, Masoud Mahdavi

Abstract**—**Steel Metal Shear Wall is one of the most common and widely used energy dissipation systems in structures, which is used today as a damping system due to the increase in the construction of metal structures. In the present study, the shear wall of the steel plate with dimensions of 5×3 m and thickness of 0.024 m was modeled with 2 floors of total height from the base level with finite element method in Abaqus software. The loading is done as a concentrated load at the upper point of the shear wall on the second floor based on step type buckle. The mesh in the model is applied in two directions of length and width of the shear wall, equal to 0.02 and 0.033, respectively, and the mesh in the models is of sweep type. Finally, it was found that the steel plate shear wall with cavity (CSPSW) compared to the SPSW model, S (Mises), Smax (In-Plane Principal), Smax (In-Plane Principal-ABS), Smax (Min Principal) increased by 53%, 70%, 68% and 43%, respectively. The presence of cavities has led to an increase in the estimated stresses, but their presence has caused critical stresses and critical deformations created to be removed from the inner surface of the shear wall and transferred to the desired sections (regular cavities) which can be suggested as a solution in seismic design and improvement of the structure to transfer possible damage during the earthquake and storm to the desired and pre-designed location in the structure.

Keywords**—**Steel plate shear wall, Abacus software, finite element method, boundary element, seismic structural improvement, Von misses Stress.

I. Introduction

TODAY, the construction of structures around the world, due to various factors such as severe earthquakes and increasing the height of buildings (due to high population density in cities), requires design with the help of new elements. Elements that allow for higher depreciation when applying existing forces to the structure and have creative and innovative designs to meet the needs of architecture. The steel plate shear wall (SPSW) has been used for the first time since about forty years ago (including in North America and Asia) in the structure to dissipate incoming energy [1]. The SPSW is made of a structural frame and recessed steel plates. The beams and columns around the SPSW are referred to as boundary beams and columns. The SPSW can withstand earthquake forces (especially horizontal forces) by expanding the diagonal stress field after subsidence in shear forces. The main reason for this is the high rotational power of the plates on the steel shear wall, which destroys the energy generated because high rotational power of the plates in SPSW. Also, due to the architectural structure and the possibility of creating openings in the inner plate of the shear wall, it will be possible to make changes in this element, which will lead to general behavioral changes in the shear wall body of the steel plate [2]-[4]. SPSWs are widely used in high-rise structures, and today, due to the increasing construction of towers, the need to pay attention to new types of steel shear walls has increased [5]-[7]. Chan et al., by modeling a hollow steel shear wall and increasing the hole diameter, assessed the effect of its existence on the shear wall performance. The results showed that creating a hole in the inner plate of the steel shear wall increased the stress at the site of the hole and its entirety and reduced the demand for deformation in the surrounding elements [8]. Farzampour et al. evaluated the effect of corrugated sheets on steel shear wall. The results showed that the presence of this feature caused the overall deformity of the inner plate to decrease [9]. Ashish and Harshalata conducted a study on a 6-story steel structure with three load-bearing openings in both horizontal and vertical directions, which was improved seismically using SPSW in its central opening. The results showed that the use of SPSW increases the stiffness of the structure, reduces the axial and shear force in the columns and increases the economic efficiency of the project [10]. Sabouri et al. evaluated the effect of the distance of the holes (openings) on the performance of the steel wall shear wall in a laboratory. The experimental experiments were performed on three single-story layer SPSW samples with two rectangular openings under a quasi-static cycle loading. The experimental results showed that the shear strength, stiffness and final energy absorption are the same in all three perforated samples and the distance between the two openings has no effect on these values [11].

II. Software Modeling

A. Material Specifications

In the present study, modeling with Abacus software (version 6.12.3) was performed. For this purpose, using ST37 steel with density, modulus of elasticity and Poisson's coefficient is 0.000078 kg/m^3, 200 MPa and 0.3.

In the steel plastics section, the yield stress and plastic strain were introduced to the software in a linear manner, with points (344,0) and (449, 0.104) indicating the numerical coordinates of the input to Abaqus.

Seyyed Abbas Mojtabavi is with the Islamic Azad University of Chalous, Iran, Islamic Republic Of (e-mail: mojtaba.it49@gmail.com).

B. Geometry and Structural Loading

The shear wall of the steel plate on two floors according to the shape (Fig. 1) with the same floor height and loading opening is equal to 5000 and 3000 millimeter. In structural modeling, IPE400 and HE1000 sections have been used as the boundary elements for the construction of beams (horizontal elements) and columns (vertical elements). The inner plates are modeled on 24 millimeter thick floors. In a hollow shear wall, the diameter of the four holes (R) is equal to 300 millimeter (Fig. 2). The non-perforated and hollow SPSW is introduced with SPSW and CSPSW titles.

The support corresponding to the ground is of the catchment type and in the roofs of the first and second floors; the catchment type is also selected in the vertical direction. In modeling, the analysis step is Buckle type. Also, the number of eigenvalues requested and maximum number of iteration values are 50 and 100, respectively. The loading of the structure is of the concentrated force type, which is applied at the upper point of the roof of the second floor.

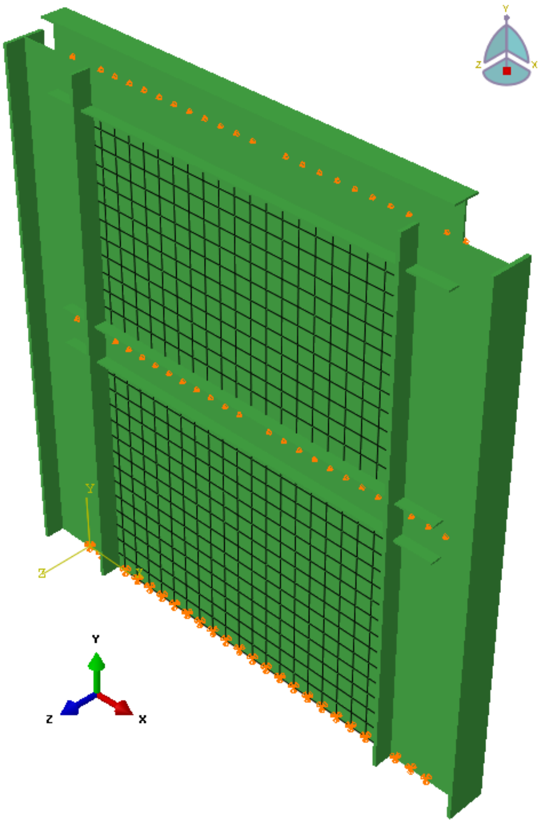

Fig. 1 SPSW designed in Abaqus software

III. Software Outputs

A. Von Mises Tension

Assessing Fig. 3, it can be seen that the maximum stress of the von misses SPSW and CSPSW models is 3.8 and 5.815 MPa. Assessing the stress at the surface of the inner plate indicates that the creation of a hole in the surface has caused the shear stress in the wall to be transferred from the entire surface to the areas around the hole.

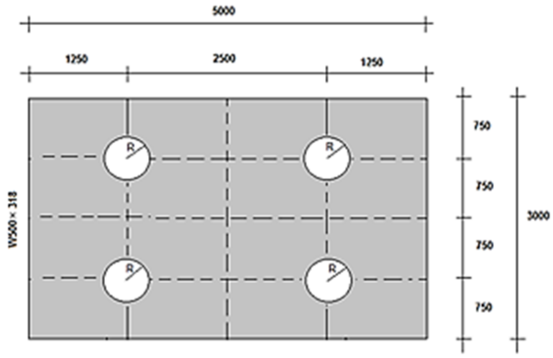

Fig. 2 Schematic design of the inner plate in the steel wall shear wall

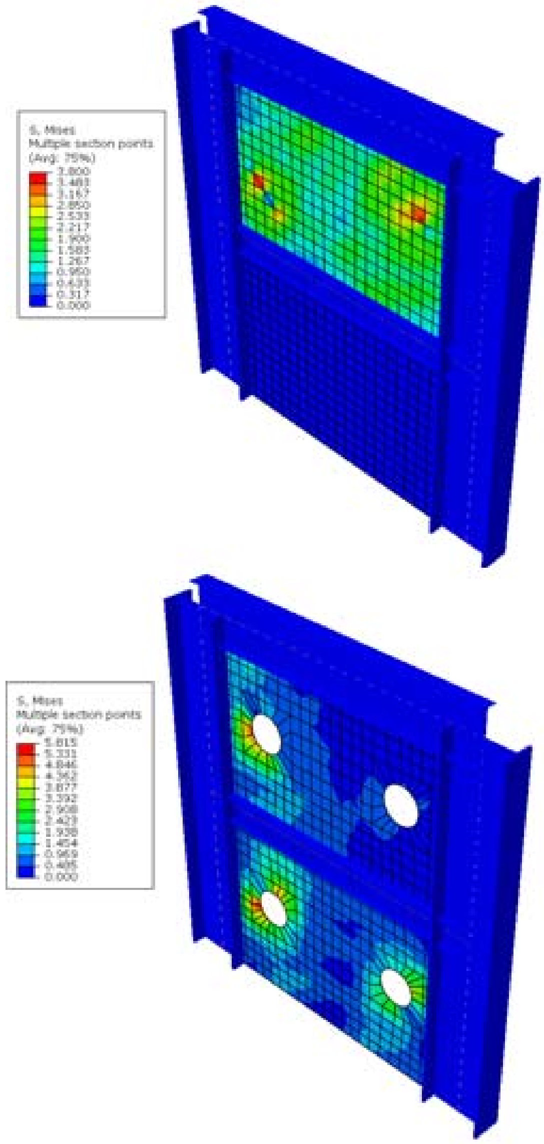

Fig. 3 Von Mises tension In SPSW and CSPSW models

Structural engineers try to minimize potential damage during design. In case of high probability of damage to the structure, reducing the level of failure (increasing the level of performance of structural elements) and transferring the damage caused to less important parts of the structure, is one of the solutions of engineers in safe design.

B. Von Mises Max in-Plane Principal Tension

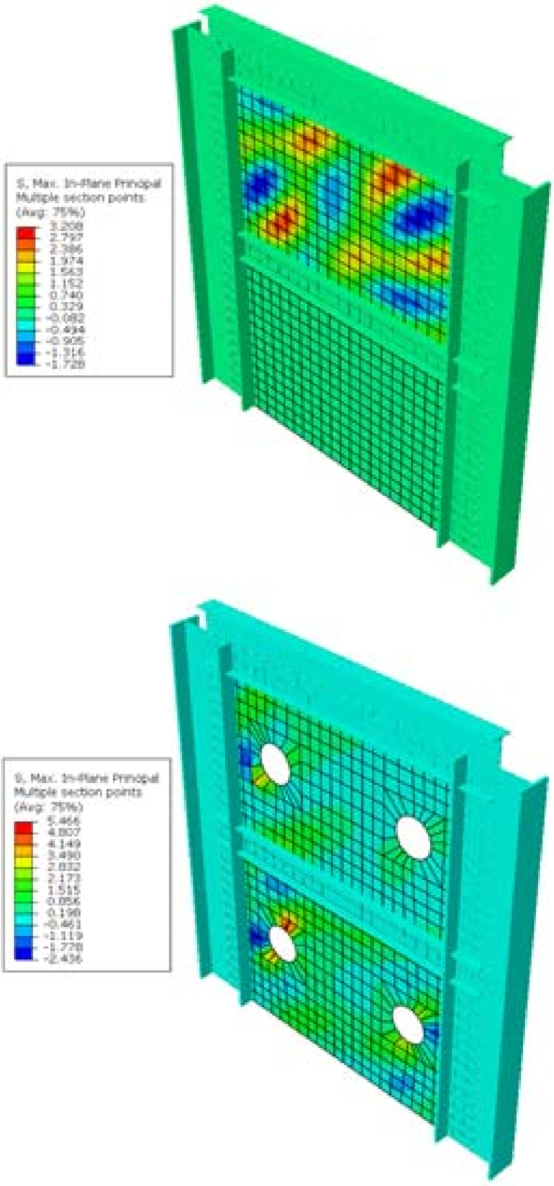

Fig. 4 Von Mises Max in –Plane Principal Tension in SPSW and CSPSW models

Assessing Fig. 4, it can be seen that the maximum stress of the main table faucet in SPSW and CSPSW models is 3.208 and 5.466 MPa, respectively, which has increased by 70%. However, the creation of a hole in the recessed inner surface has caused the critical points of this index in the SPSW model, which has been created in some parts of the inner plate of the upper floor, to be removed and transferred to the areas near the hole. When designing and seismically improving the structure, this solution can be a suitable suggestion for transferring the maximum stresses created in the structure to the desired points.

C. Von Mises Max in-Plane Principal (ABS) Tension

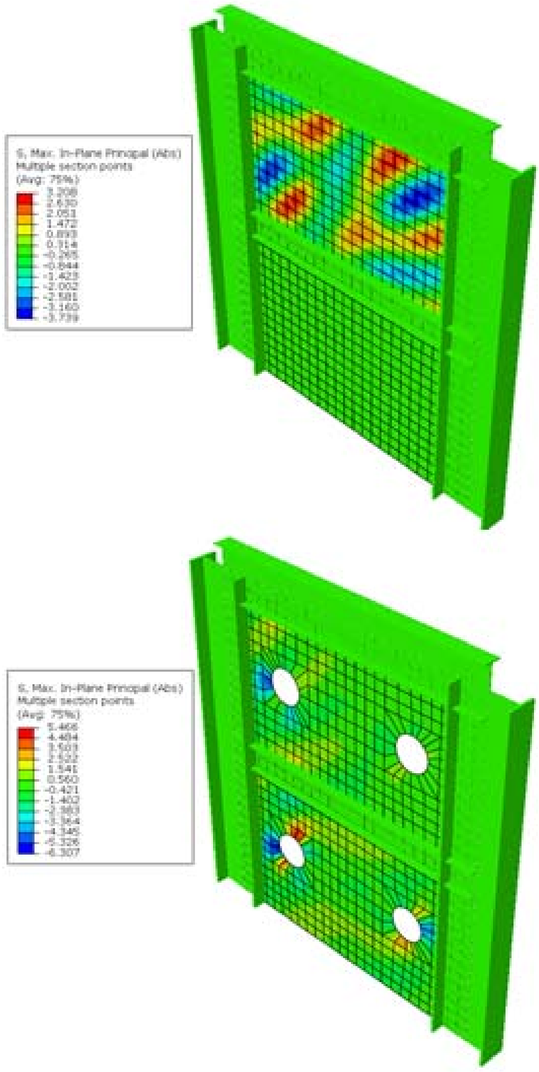

Fig. 5 Von Mises Max in-Plane Principal (ABS) Tension in SPSW and CSPSW models

Examining Fig. 5, it is found that the maximum stress of the main screen is numerically on the shear wall of the steel plate in two models, SPSW and CSPSW, equal to 3.739 and 6.307, respectively which increased by 68%.

Complete prevention of damage to energy dissipation elements will cause other members of the structure to be subjected to large loads and reduced performance from the structure. As a result, the transfer of potential faults to predetermined points is an engineering issue that will double the function of the steel shear wall element. Around the hole, it is possible to increase the hardness and reduce the critical stress using conventional methods. This suggests that creating a hole in the wall will help increase its strength and load-bearing capacity.

D. Von Mises Min-Principal Principal Tension

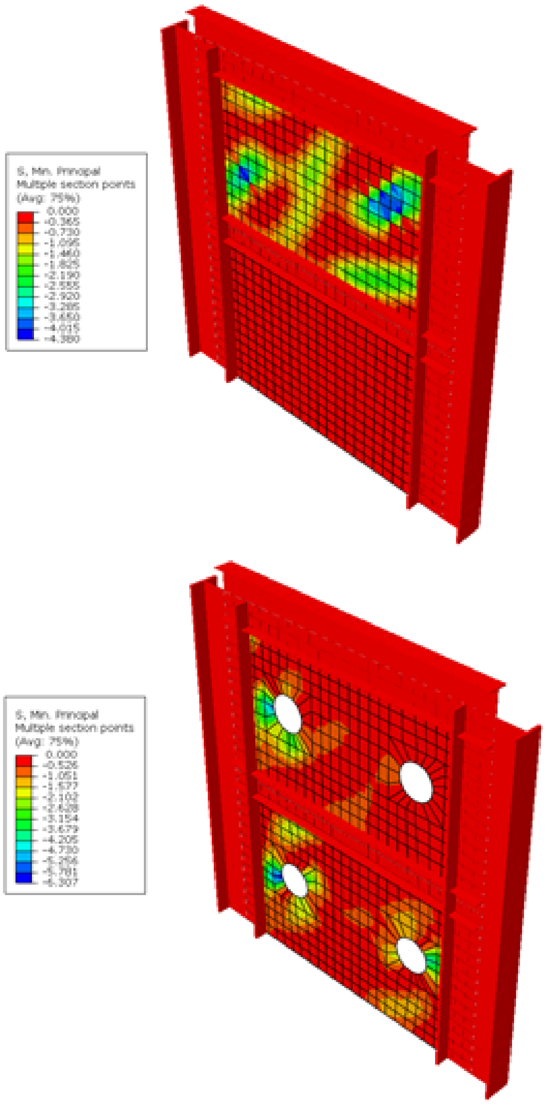

Fig. 6 Von Mises Min-Principal tension In SPSW and CSPSW models

Evaluating Fig. 6, it was found that the minimum stress on the main screen of the Monsoon Phone in terms of SPSW and CSPSW models was 4.38 and 6.307 MPa, respectively, which increased by 43%.

E. Displacement

By evaluating the results in Fig. 7, it can be seen that the deformation in the SPSW and CSPSW models has many differences in terms of width and distribution at the surface of the die element sheet. The creation of a hole in the inner plate of the shear wall caused large and critical deformations in the desired and predetermined areas (cavities). This will allow large nonlinear forces in the structure, such as high-magnitude earthquakes or severe storms, to allow potential faults to be transferred to designated and predetermined points (four holes in this study). This achievement will be considered as an effective solution in the field of seismic improvement of the structure, which has been presented as the golden proposal of this research.

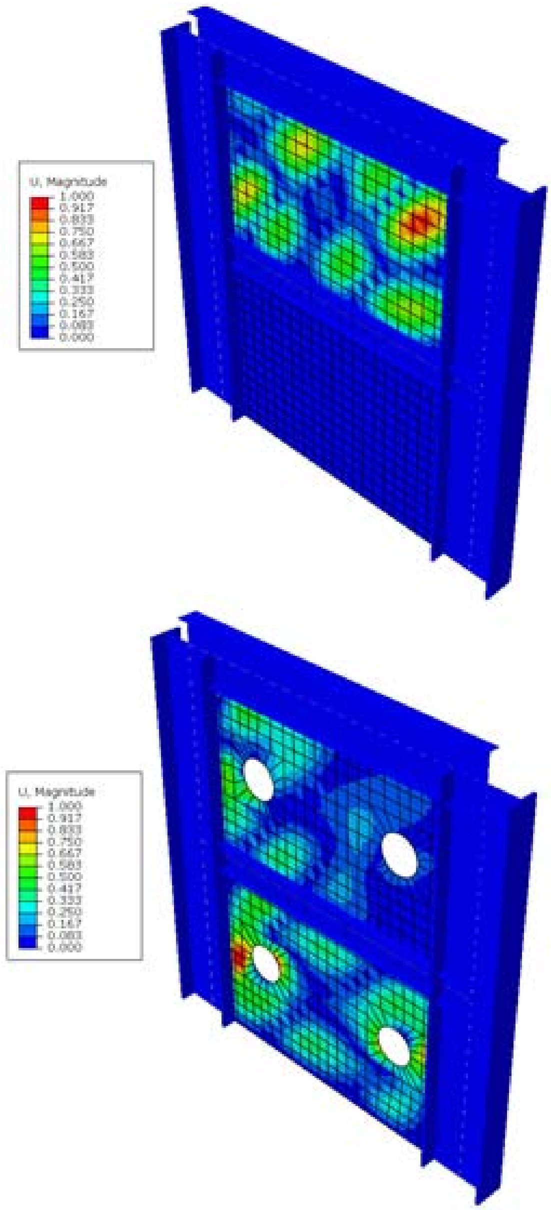

Fig. 7 Displacement in SPSW and CSPSW models

IV. Conclusion

By creating four regular holes in the die sheet on the shear wall of the steel plate (SPSW model), the stress of the von Mises is 53%. Also, the change in the location of the critical stress and the maximum from the surface of the inner plate of the shear wall to the areas around the four cavities has been one of the results of creating these cavities.

Comparing the SPSW and CSPSW models, it was found that the maximum stress of the main screen and the maximum (absolute) stress and the minimum stress of the main screen increased by 70%, 68% and 43%, respectively.

By evaluating the SPSW and CSPSW models, it was found that the maximum and critical deformation in the two models changed with the creation of the cavity and the mentioned areas were transferred from the inner plate surface on the second floor of the element to the areas around the four holes.

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