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Evaluating the Effect of Rectangular Opening Positioning on the Seismic Behavior of Composite Shear Walls

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Abstract: Composite Shear Wall (C-PSW) is one of the efficient systems against lateral loads. About 50 years ago, steel shear walls were used as a resistor against lateral loads, however, poor buckling of these walls made researchers use reinforced concrete layer in one or both sides of the steel shear wall in order to solve this problem which led to proposing composite shear wall. This study discusses the effect of rectangular opening positioning on seismic performance of the system. To do so, different models were analyzed under cyclic load using finite element method. The results showed that, the most appropriate position for creating an opening is bottom corners of the frame.

Key words: Composite shear wall, seismic behavior, finite element method, performance, discusses, problem

INTRODUCTION

Composite shear wall is one of the lateral resistant systems in which steel has increased tensile capacity. On the other hand, given the quick buckling of steel shear wall, the concrete resolves steel weakness. Combination of steel shear wall with the reinforced concrete materials in the form of positioning the reinforced concrete on one or both sides of the steel plate is called composite shear wall. In the last two decades, several studies have been performed on modelling and investigating the seismic behavior of composite plate shear wall in America and Japan.

Astaneh-Asl (2002) in University of Berkeley studied the seismic behavior of composite shear wall systems composed of a boundary steel frame and a steel shear wall with reinforced concrete wall attached to one of its sides. In this study, the steel shear wall was welded to the boundary frame and connected to the reinforced concrete wall using screws. Moreover, two samples were made in half scale to represent composite shear wall systems with new and traditional classifications. In the traditional kind, the edge surfaces of reinforced concrete wall was in direct contact with the boundary steel frame while there was a certain spacing between the boundary steel frame and the concrete wall in the new kind.

Driver *et al*. (1998) conducted experiments to compare the buckling of the plates under study by classic theory of plates and concluded that there is no significant difference between theoretical buckling loads and the values obtained by the experiment.

Rahai and Hatami (2009) analyzed 42 samples of composite shear wall using finite element method. Then, they experimentally examined 5 samples by changing different parameters and concluded that the stiffness of composite shear wall is directly proportional with the concrete coating thickness and inversely proportional with the spacing between the cuttings. Increasing the spacing between the cuttings increases ductility and dissipated energy and decreases out-of-plane buckling of the shear wall.

Arabzadeh *et al.* (2011) conducted studies on composite shear walls, taking into account parameters such as type of connection between beam and column, positioning of reinforced concrete layer in one or both sides of the steel wall panel, creation of a seam between reinforced concrete and boundary elements and changes in the direction of positioning the rebar. They showed that the critical buckling load increases by increasing the number of screws connecting concrete panel to the steel panel, furthermore, positioning reinforced concrete panel at two sides of the steel plate increases resistance and energy dissipation and decreases ductility. Moreover, using highly resistant concrete decreases the amount of damage in reinforced concrete wall but it has no significant effect on increasing system resistance. The

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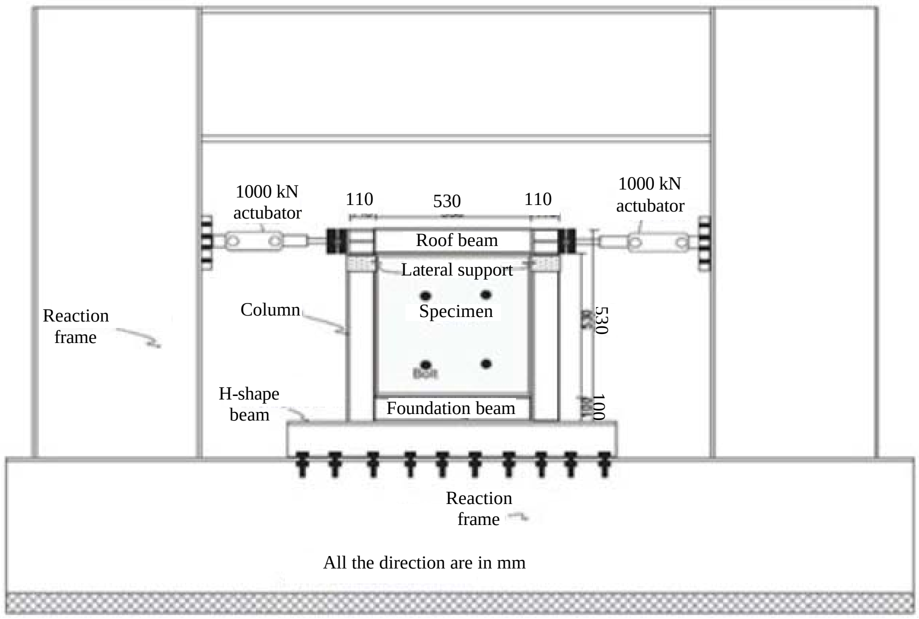

Fig. 1: Model geometry

capacity of steel plate increases and ductility decreases by decreasing the distance to screws center. Using finite element modeling for different samples of composite shear walls with rectangular openings in which the openings had increasing changes in length and width, the researcher showed in 2016 that generally, all seismic parameters (e.g., initial stiffness, ductility, energy dissipation and maximum resistance) decrease by increasing the surface of openings and the changes in different seismic parameters by increasing the opening length are similar in both states of elongation parallel and perpendicular to the force. Generally, opening elongation in both directions equally affect seismic parameters.

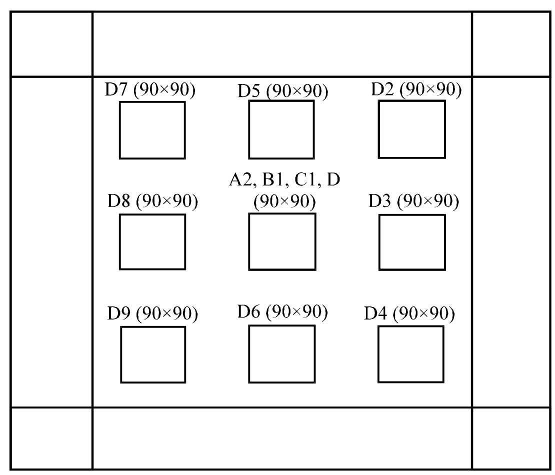

Fig. 2: Models and location of the taps in each models

MATERIALS AND METHODS

Design and analysis: The response of composite steel shear walls can be investigated using two methods, non-linear dynamic analysis and pushover. The former has a more complex procedure and is time consuming, so, it is not used extensively but the latter is simpler and quicker and is used by the analysts in most cases.

The main approach of designing these systems is based on the fact that the walls should endure meta elastic deformations during web plate yielding. Furthermore, boundary elements should be designed, so that they would remain in the elastic region during web steel plate yielding.

Modeling: According to Fig. 1 and 2, a composite shear wall composed of two columns with 730 mm height, two beams with 530 mm height, a steel plate connected to boundary elements by two backing plates with 530×530 dimensions and a reinforced concrete layer with 507.5×507.5 dimensions and 30 mm thickness positioned just in one side of the steel plate and connected to it by 6 screws is studied. In order to prevent the interaction between concrete and boundary elements, a small seam with 11.25 mm thickness is positioned between the concrete layer and boundary elements and loading is applied on the upper beam level. Furthermore, all connections are in the form of global corner welding. Load in applied on the sample in 19 cycles as per

Table 1: Model results

Changes in seismic parameters model	M1	M2	M3	M4	M5	M6	M7	M8	M9
Changes in maximum resistance									
Maximum resistance (kN)	527	525	528	527	527	527	528	526	522
Percentage of maximum resistance change relative to the model M1	0	-0.04	+0.2	0	0	0	+0.2	-0.2	-0.9
Changes in initial stiffness									
Initial stiffness (kN.mm)	95	99	105	105	97	100	101	96	101
Percentage of initial stiffness change relative to the model M1	0	+4.2	+10	+10	+2	+5	+6	+1	+6
Changes in ductility									
Ductility	4.2	4.3	4.6	4.5	4.3	4.4	4.4	3.8	4.4
Percentage of ductility change relative to the model M1	0	+2	+9	+7	+2	+5	+5	-9	+5
Changes in total dissipated energy									
Energy dissipation (kN.mm)	262	261	263	262	262	262	263	261	259
Percentage of change in total dissipated energy relative to the model M1	0	-0.4	+0.4	0	0	0	+0.4	-0.4	-1.15
Changes in maximum stress created									
Maximum stress (MPa)	463	469	460	492	498	493	510	485	480
Percentage of change in the maximum stress relative to the model M1	0	+1.3	-0.6	+6	+8	+6	+10	+4.7	+3.7

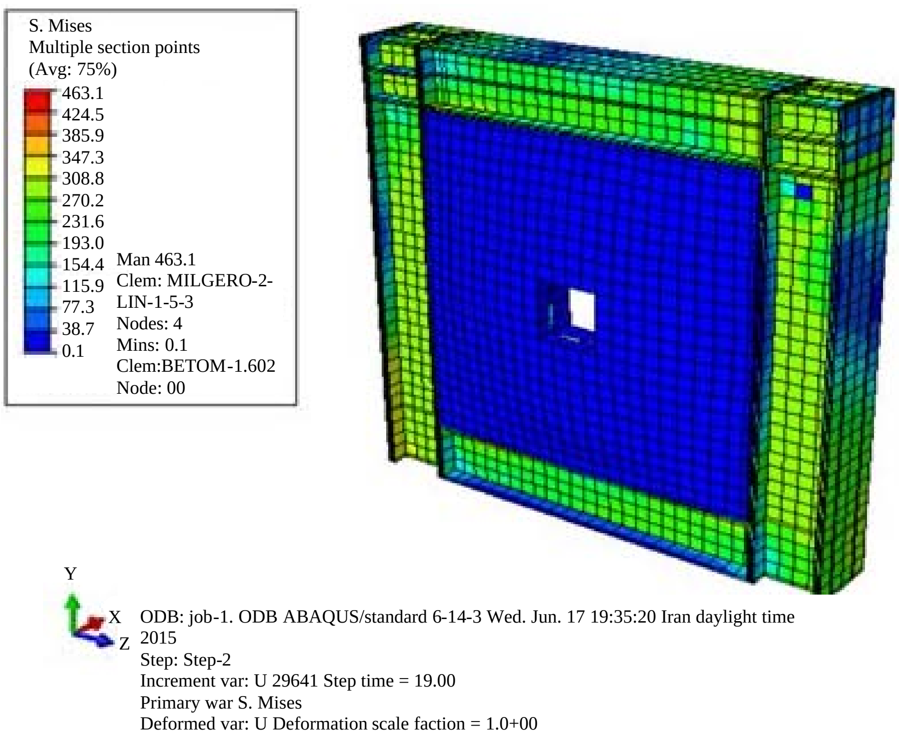

Fig. 3: Von Mises stresses for model M_1

ATC 24 regulations. The following models were also considered to investigate rectangular opening positioning. These models included nine models in which the dimensions of all openings were similar but their positioning in composite shear wall was considered to be different. According to Fig. 3, the shortest distance between opening sides and the beam or column from the steel wall is 40 mm, except for M_1. Furthermore, the models M_1, M_5 and M_6 are symmetrical relative to the vertical axis of the structure, while the models M_1, M_3 and M_8 are symmetrical relative to the horizontal axis of the structure (Table 1).

RESULTS AND DISCUSSION

Models analysis: This study presents the results of analyzing the models. Von Mises stresses for model M_1 are shown in Fig. 3 and 4 as an example. The hysteresis

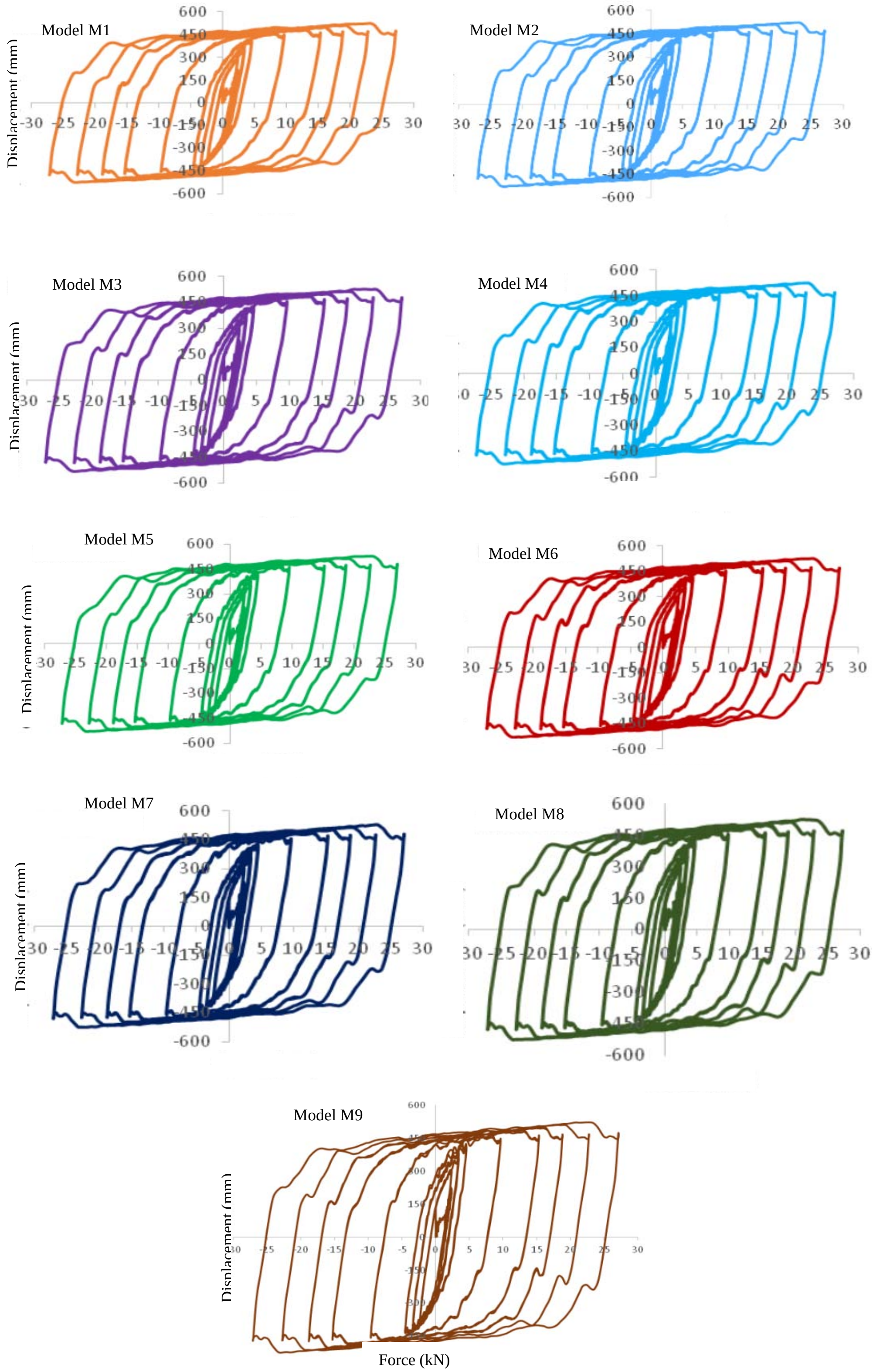

Fig. 4: Hysteresis curves of the models

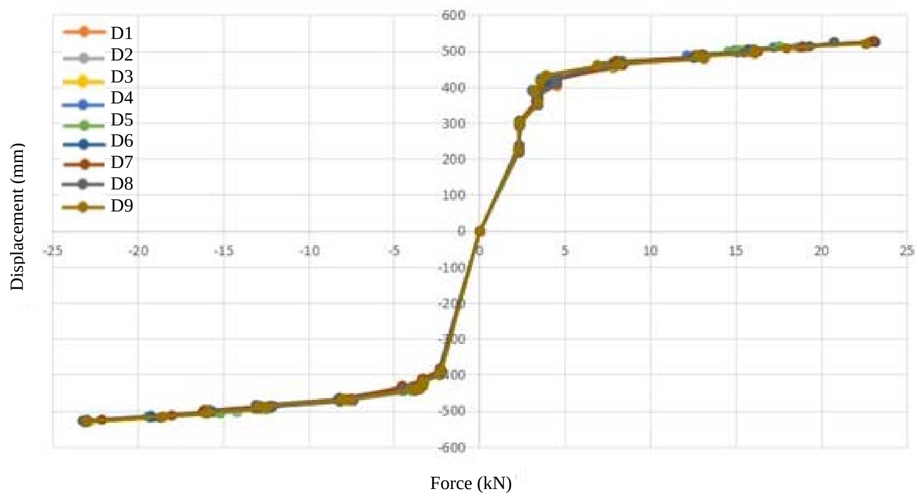

Fig. 5: Envelope of hysteresis curve of the models

curves resulted by analyzing the models are shown in Fig. 4. The seismic parameters for these models are also given in Table 1. The envelope of hysteresis curves is also shown in Fig. 5.

CONCLUSION

Ductility in tapped sample changes from minimum 7% in M_3 to maximum 24% in M_8. Maximum resistance in tapped samples decreases about 3%. The energy dissipated in tapped samples decreases about 4%. Maximum initial stiffness in samples M_3 and M_5 increases by 5% and minimum initial stiffness in the sample M_1 decreases by 5%. Positioning of the opening has no effect on the maximum resistance and energy dissipation of the composite shear wall but affects the initial stiffness up to 5% and reduces ductility up to 24%. Since, M_4 (or M_9, given the periodic nature of the earthquake) has 5% greater initial stiffness and 10% minimum decrease in ductility, it can be concluded that the best position to create an opening is bottom corners of the frame.

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