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Investigation of coupled steel plate shear wall behavior under lateral loading

A. R. Rahai[1], N. Valizadeh[1,*] , A. Shokoohfar[2]

[1] Department of Civil Engineering, Amirkabir University of Technology, Tehran, Iran.
[2] Department of civil engineering, Azad University of Qazvin, Qazvin, Iran.

ABSTRACT: Coupled steel plate shear wall (CSPSW) is an efficient system to withstand lateral forces, especially in regions with a high risk of earthquakes. This system consists of two steel plate shear walls are linked together with coupling beams at the floor levels. In this article to study the CSPSW behavior, two parameters have been investigated. One is the degree of the coupling, which presents the level of interactions between the two piers and the other is the plastic strength of the coupled steel plate shear wall. Several CSPSW models have been prepared which differ in the terms of the length and the characteristics of the coupled beam and the height of the CSPSW. These models have been analyzed using the nonlinear static method. The numerical study of Borello and Fahnestock is used to verify the finite element method. The numerical results prove that the variation of the coupled beam length, by considering a constant stiffness for them, causes to change the performance of the coupling beam significantly. Moreover, increasing the coupling beam stiffness increases the coupling capability, as well as an increase of the base shear of CSPSW.

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1. INTRODUCTION

The Coupled steel plate shear wall (CSPSW) is a lateral force-resisting system that is excellent for energy dissipation purposes in the seismic regions. The efficiency of the CSPSW system highly depends on the coupling beam properties. Post-buckling resistance due to the formation of the diagonal tensile field is the main parameter of the lateral strength of the SPSW system. The limited number of researches focused on the CSPSW systems.

Li et al. studied the role of the coupling beams in the CSPSW through an especial test program. Their experiments were planned for a 40% scale C-SPSW specimen as a representative of the first two floors of a C-SPSW system in a real six stories building. Li et al presented a design method to form the plastic hinges at a predetermined point at the bottom quarter height of the column [1].

Borello and Fahnestock made too many efforts to investigate the code provision's efficiency for designing the CSPSW systems. Their research was a part of a multi-institution NEESR project on steel plate shear walls. A numerical study was carried out on a typical six-stories building to evaluate the code provisions [2].

The main reference of the current study is the Borello and Fahnestock researches at the National Science Foundation. The established the main purpose of the investigation on the determination of the degree of coupling as a representative for the percentage of the interaction of two piers of SPSW. They performed too many nonlinear analyses on thirty-two SPSW-WC structures. Their comprehensive parametric studies prove that take attention to the degree of coupling parameter can increase the material efficiency and lessen the structural member's weight impressively [3].

*Corresponding author's email: nasim_vz@yahoo.com

In the current study, several numerical models have been prepared to investigate the effects of the length and stiffness of the coupling beams on the seismic behavior of the CSPSW systems using ABAQUS software. The degree of coupling of the piers and plastic strength of steel shear wall were considered as the two main criteria for evaluation of the numerical results.

2. FINITE ELEMENT (FE) METHOD VERIFICATION

The numerical results of the Borello and Fahnestock study were utilized to validate the FE method of this study [2].

2.1. Numerical models Features

The yield strength of the steel plates by considering the interaction of the frame and steel plates was assumed to be 248 MPa; this value was considered to be less than that of strength yield for frames to complete the self-denying action of steel plates. The yield strength of the frames was assumed to be 345 MPa. The modulus of elasticity and the poisons ratio

Table 1. Members dimensions in the verification model

Element	Shape
EVBE	W14x145
IVBE	W14x132
HBE	W18x50
CB	W18x65
Web Plate	**PL3352x3557x1/6(mm)**

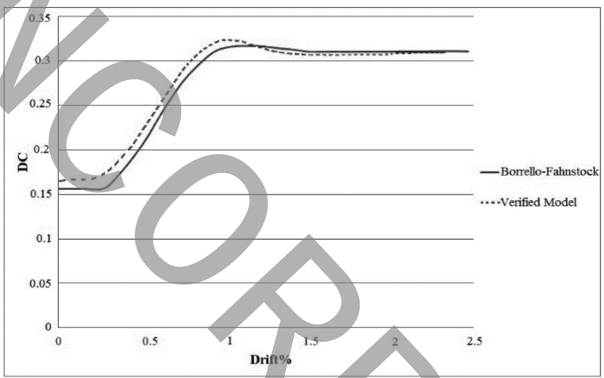

Fig. 1. The variation of the coupling degree versus roof drift of the verification model

were determined MPa and 0.3, respectively.

W14x257 and W14x283 were considered for internal and external columns, respectively. W 18x50 was utilized for horizontal boundary elements. The coupling beam sections were considered as a variable in the numerical models. W18x65, W18x97 and W18x175 were utilized for coupling beams.

3. RESULTS AND DISCUSSION

The numerical models comprised six specimens categorized in one story and four stories models. Three different coupling beam sections were utilized for each group of models.

The numerical results of the models with the W18x65 section for coupling beam show a 50% reduction in lateral drift and a 25 percent increase in base shear bearing capacity. The results are slightly different for the models comprised of the W18x97 section for coupling beams. The numerical results demonstrated a 30 percent increase in base shear bearing capacity and a 50 percent reduction for lateral drift. The later parameter variation is increased for the models with four stories height to 60 percent.

These results were improved for models with the W18x175 section of coupling beams. An average 45 percent and 60 percent increase were observed for base shear bearing capacity and lateral drifts, respectively.

The variation of the coupling degree of the CSPSW system is revealed the negative effect of increasing the coupling beam length. The length of coupling beams induces more significant effects in one-story models. An average 37 and 30 percent reduction were determined for one story and four stories models, respectively.

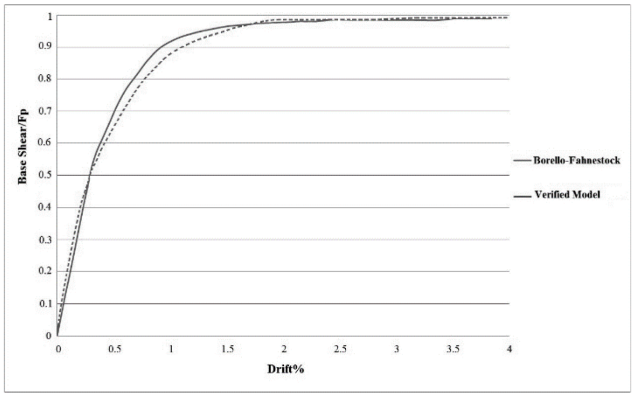

Fig. 2. The normalized base shear variations versus roof drift of the verification model

A 22.5 percent increase of base shear bearing capacity was calculated for replacing the section W18x65of the coupling beams with W18x175section.

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4. CONCLUSIONS

The present study investigated the efficiency of the CSPSW systems in the seismic regions. The main parameters of this numerical study are the plastic strength of the steel plate and the coupling degree of the coupled system. The following conclusions were drawn from this study:

The coupling beam length variation has a considerable negative effect on the coupling degree.

The coupling beam length has no significant effect on the lateral stiffness and base shear bearing capacity.

The effect of the coupling beam stiffness is more noticeable in one-story models.

Regarding the higher coupling degree and the coupling, beam stiffness leads to a considerable reduction in flexural displacements.

Adding the coupling beam to the steel plate shear wall system improves the performance criteria of the SPSW system and reduces the flexural displacements.

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