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Providing Analytical Relationship to Calculate the Stiffness of Composite Steel Shear Walls

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ABSTRACT: The composite shear wall system is considered as one of the newest structural systems. In composite steel shear wall, reinforced concrete cover causes to increase shear capacity of steel shear wall up to in-plane shear yield limit rather than tension along the diagonal tensile field by anchoring steel plate and preventing its buckling. In innovative composite steel shear wall system, a gap is created between concrete cover and boundary beams and columns. Tests on traditional and innovative composite steel shear wall show a slight failure in innovative system compared to traditional system. In this paper, steel plate, concrete cover and frame were separated to calculate the stiffness of composite steel shear wall by their interaction (CPFI). To evaluate the effect of concrete stiffness on composite steel shear wall stiffness, the gap between concrete cover and boundary members has been discussed, and then two relationships have been proposed to calculate the stiffness of composite steel shear wall. The results show that the use of low yield stress steel plate with equivalent thickness to traditional steel plate will increase stiffness in composite steel shear wall. Also, concrete cover involvement in boundary members will increase the stiffness.

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1- Introduction

Composite steel shear wall is an innovative lateral load-carrying system and consists of a steel plate with reinforced concrete cover in which the cover has been attached to its one side or both sides by shear connectors. In steel shear wall, story shear is tolerated by steel plate tensile force after buckling under diagonal pressure. But in composite steel shear wall, reinforced concrete cover has constrained the steel plate and prevented its buckling before in-plane shear yield capacity, As a result, steel plate tolerates story shear by shear yield. The shear yield capacity of steel plate can be significantly greater than shear yield capacity by diagonal tensile field [1]. The use of these walls is increasing due to high stiffness and strength, excellent ductility and suitable behavior on seismic loads. Some tests were first performed by Astaneh Asl and colleagues at University of California, Berkeley in 1998 to 2002 [1] on composite steel shear wall where a new type of the wall behavior was examined under cyclic loads and compared to traditional composite steel shear wall. The only difference between innovative and traditional shear wall was a gap between concrete cover and the peripheral frame.

After all, research was done on composite steel shear wall by making experimental models and analyzing numerical models in which their behavior was studied by examining the influence of some design parameters such as the number of shear connectors, the number of reinforced concrete layers, thickness of steel plate, thickness of concrete cover and etc. The most important studies include research of AmirKabir University by Rahai and Hatami [2] in 2007 and laboratory and numerical studies of Tarbiat Modarres University by Arabzadeh et al. [3] in 2009.

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2- Methodology

In this paper, to validate the numerical modeling, one-story frame of composite steel shear wall related to Arabzadeh and et al. [3] was modeled in ABAQUS. Figure 1 shows dimensions details and loading of the mentioned test that plate, frame and concrete cover at one side and four shear connector bolts were exactly modeled in finite element method. The gap about 11/25 mm is considered between the concrete cover and boundary components. As it can be seen in Figure 2 use of mesh size of 30 mm for the frame, concrete cover and steel plate created best fit with the behavior of laboratory specimen in stiffness ratio, yield strength and ultimate strength, so this meshing was used for analyses.

3- Results and Discussion

In this paper, in order to calculate the stiffness of composite steel shear wall, it has been attempted to separate behavior of steel plate, frame and concrete cover by using the interaction theory of plate and frame and to calculate basic principle of design and stiffness of composite steel shear wall by considering their interaction (CPFI). In this paper, the gap between the concrete cover and peripheral members of beam and column has been taken into account as one of the effective parameters on the stiffness of composite steel shear wall.

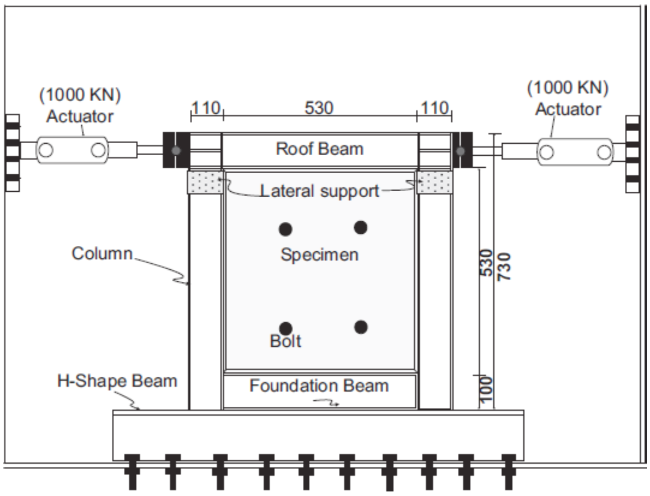

Figure 1. Dimensions details and loading of Arabzadeh and et al. test [3]

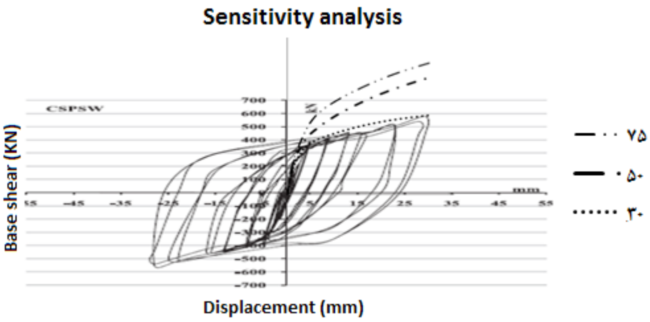

Figure 2. Meshing sensitivity analysis of composite steel shear wall

In a thin plate steel shear wall, the equation provided by Sabouri and Roberts [4] can be used to calculate the elastic stiffness of thin steel plate, according to Equation 1.

$$K_{Pl\_Spsw}=Ebt/4d \qquad (1)$$

We try to obtain an Equation 2 for measuring the plate stiffness at in-plane shear yield state by reviewing stress state in the steel plate before buckling.

$$K_{pl\_Cspsw}=\alpha\ Ebt/(2.6\ d) \qquad (2)$$

To determine the α coefficient, the results of finite element analysis model are used and the value of 0.8 was calculated for α coefficient.

In analytical method in which there is gap between concrete cover and boundary members, the stiffness of composite steel shear is obtained by considering frame interaction, plate and concrete cover effect as follows:

$$K_{Cspsw}=(6EI_C)/H_c^3\ ((6+a)/(1.5+a))+0.8\ Ebt/(2.6\ d) \qquad (3)$$

Stiffness of a concrete shear wall [5], with a length L and height H is obtained from Equation 4:

$$K_w=3EI/(H^3\ [1+0.6(1+\nu)(L/H)^2\ ]\ ) \qquad (4)$$

Since the concrete cover in traditional composite steel shear walls (no gap) has been confined by boundary elements, it was attempted that the share of concrete cover in composite steel shear wall stiffness is calculated by Equation 4 by considering β modification factor for Equation 5:

$$K_c=\beta\ 3EI/(H^3\ [1+0.6(1+\nu)(L/H)^2\ ]\ ) \qquad (5)$$

To determine the β coefficient, the results of finite element analysis model are used and the value of (1/7) was calculated for β coefficient.

Thus, to calculate the stiffness of traditional composite steel shear wall (no gap), Equation 4 can be used:

$$K_{CSPSW(no\ gap)}=(6EI_C)/H_c^3\ ((6+a)/(1.5+a))+0.8\ Ebt/(2.6\ d)+(1/7)3EI/(H^3\ [1+0.6(1+\nu)(L/H)^2\ ]\ ) \qquad (6)$$

The Equation 6 is suitable for both traditional and innovative composite steel shear walls by considering or not considering the third term (concrete cover shear stiffness), based on the assumption of existence of thickness and strength concrete cover, but more studies are needed on different sizes openings and high thickness and strength concretes.

4- Conclusions

In this paper, two analytical relationships were provided to calculate the lateral stiffness of the composite steel shear wall system in both states of gap and no gap between the concrete cover and peripheral frame. Philosophy of concrete cover in these walls was to prevent thin steel plate buckling and to change load-carrying mode of plate from post-buckling strength (diagonal tensile field) to in-plane shear strength; thereby lateral strength of system is increased.

If there is gap between concrete cover and peripheral frame, it will be as constraining steel plate, thus, in practice it has no effect on lateral load tolerance and system stiffness. But when the concrete cover is attached to the peripheral frame, it involves in lateral stiffness of system and increases system stiffness.

The results showed that the use of low yield stress steel plate as compared to traditional steel increases stiffness of system.

Due to the fact that these relations have been extracted based on a limited number of numerical models, so more studies must be done on other different sizes specimens.

References

[1] A. Astaneh-Asl, Seismic Behavior and Design of Composite Steel Plate Shear Walls, Steel Tips, Structural Steel Educational Council, Technical Information & Product Service, 2002.

[2] A. Rahai, F. Hatami, Evaluation of Composite Shear Wall Behavior under Cyclic Loadings, Journal of Constructional Steel Reaearch, 65 (2009) 1528-1537.

[3] A. Arabzadeh, M. Soltani, A. Ayazi, Experimental Investigation of Composite Shear Walls under Shear Loadings, Journal of Thin-Walled structures, 49 (2011) 842-854.

[4] S. Sabouri, Lateral Load Resisting Systems An Introduction To Steel Shear Walls, Anguizeh Poblishing Co, 1th Edn, (2001) 220-227.

[5] N. Siahpolo, Principles of Applied Earthquake Engineering, Publishing Padideh, First Edition, 2009.

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