EXPERIMENTAL RESEARCH ON CONCRETE STIFFENED STEEL PLATE SHEAR WALL

Amir AYAZI
Associated professor, Islamic Azad University, Shahr-e-Qods Branch, Tehran, Iran
A.ayazi@shahryariau.ac.ir

Farhang FARAHBOD
Associated professor, Road, Housing & Urban Development Research Center, Tehran, Iran
F.farahbod@bhrc.ac.ir

Behnoosh RASSOULI
Master student, Islamic Azad University, Eslam-Shahr Branch, Tehran, Iran
behnoosh12000@yahoo.com

Soheil SHAFAEI
Master, Islamic Azad University, Eslam-Shahr Branch, Tehran, Iran
soheil_shafaei_ch@yahoo.com

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ABSTRACT

Steel plate shear wall (SPSW) and concrete stiffened steel plate shear wall (CSPSW) are manipulated as ductile structures and appropriate lateral-load resisting systems. CSPSW consists of an infill steel plate and a reinforced concrete panel attached to one side of the infill steel plate. In CSPSW, beams and columns are considered as boundary elements which develop pure shear of the infill steel plate. Although CSPSW is known as a good solution for tall buildings in a region of high seismic hazard, limited research has been fulfilled on this kind of shear wall so far. Hence, more experimental and numerical investigations are demanded to grasp the complicated behaviour of this system.

In this study, an experimental investigation into ductile concrete stiffened steel plate shear wall is conducted at Road, Housing & Urban Development Research Center, Tehran, Iran, and the test results and observations are discussed. In accordance with experimental results, the CSPSW specimen provides a stable cyclic manner and can reach inter-story drift of 6%. By proper design of CSPSW, it can be able to show an acceptable failure mode.

INTRODUCTION

Steel plate shear wall (SPSW) is a system which resists story shear and overturning moment in high-rise buildings. The system consists of an infill steel plate and boundary elements, beams and columns. SPSW carries lateral loads by developing diagonal tension field; however, owing to compression field, the infill steel plate buckles. By buckling of the infill steel plate, stiffness of SPSW decreases markedly. For preventing buckling of diagonal compression, a reinforced concrete panel is attached to one side of the infill steel plate by shear connectors, bolts. This system is called concrete stiffened steel plate shear wall (CSPSW) (Astaneh-Asl, 2001 and 2002).

Limited research has been conducted on CSPSW, as mentioned in AISC seismic provision. In addition, comprehensive numerical and experimental investigations into CSPSW are demanded to perceive key parameter for seismic design of CSPSWs (Zhao, 2007 and AISC 341-10).

First experimental investigation was accomplished by zhao and Astaneh-Asl at university of California, Berkeley in 2002. The innovative specimen's test result shows that CSPSW provides high initial stiffness and a ductile manner; hence, it can be manipulated in tall buildings constructed in a region of high seismic hazard (Zhao, 2004). By 2010, several one-story and three-story CSPSW were tested by Arabzadeh and Ayazi at Tarbiat Modares University, Tehran, Iran. According to the obtained results, a composite action between the infill steel plate and the reinforced concrete panel is improved by the increase of bolts, shear connectors. Moreover, in design of the columns, vertical boundary elements, for multi-story, special concern must be taken into account due to shear yield of the infill steel plate.

Based on the literature survey, this field of study requires extensive research. In this study, a one-story one-bay CSPSW is experimentally studied, and the test results are discussed.

EXPERIMENTAL DESIGN AND SET UP

A one-story one-bay CSPSW with scale of 1:4 is designed according to AISC341-10. The behaviour of code designed specimen is investigated by developing finite element code. Numerical investigation illustrates that designed beams and columns cannot be able to ensure ductile manner; as a result, the boundary elements are modified. Figure 1 shows the CSPSW specimen.

The CSPSW Specimen experimentally investigated has an overall hight of 100 cm and an overall width of 96 cm. figure 2 depicts dimensions of the CSPSW and test set up. The thickness of the infill steel plate is 0.15 cm and a reinforced concrete panel with 4 cm thickness is attached to the infill steel plate by 25 bolts. The reinforced concrete panel is designed according to ACI 318-M11.

The specimen was attached to a base beam by 26 high-strength bolts, while the base beam was connected to the strong floor by 16 high-strength bolts. Lateral bracing restrains out-of-plane displacement of specimen as shown in figure 1. The gravity load is not applied to CSPSW; hence, pure shear behaviour of system is studied.

Lateral load were applied at roof beam level by actuators. The lateral cyclic loading procedure was based on ATC-24 (ATC 1992). The yield point of specimen (δy) is calculated by finite element code developed by the authors, in which the difference between numerical and experimental study was infinitesimal.

The infill steel plate has a yield stress of 200 MPa and the boundary elements have a yield stress of 246 MPa. The reinforced concrete panel was precast concrete, and the nominal compressive strength (f'c) was 25 MPa.

Figure 1. The one-story one-bay CSPSW specimen

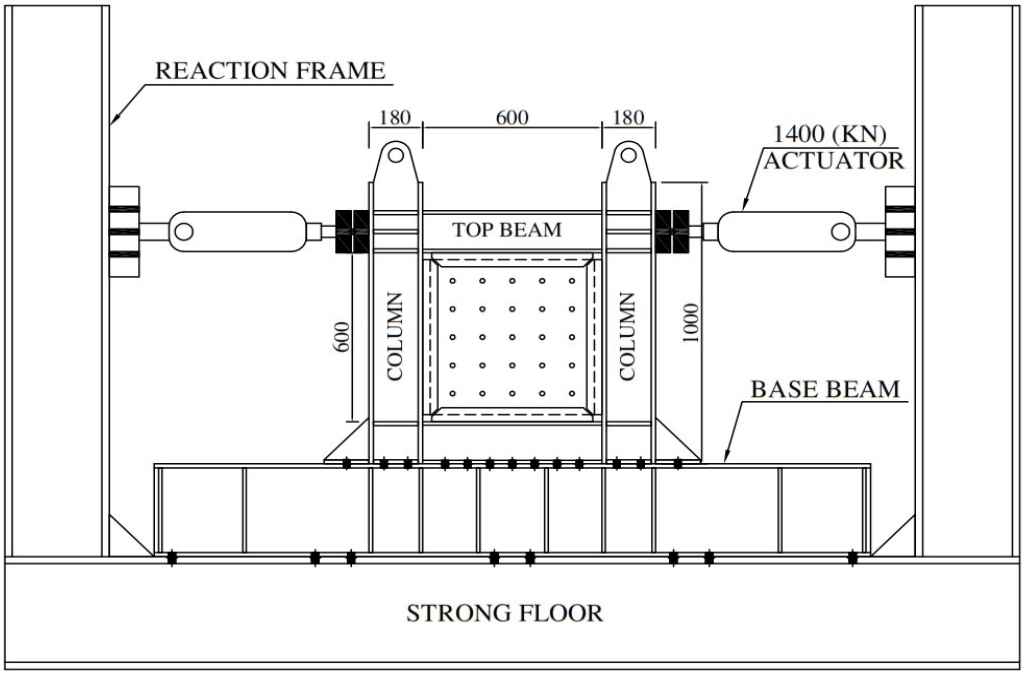

Figure 2. The dimensions of CSPSW specimen and test set up

EXPERIMENTAL PHENOMENA

The CSPSW specimen was found to be capable of tolerating 37 cycles of shear loading, in which the maximum shear load was 823.2 KN. In cycle 38, first the connection of left column and base plate, and then a bolt of base beam were fractured. At this point, finally, the test was ended.

Figure 3 illustrates shear force-displacement curve of CSPSW specimen which demonstrates an appropriate behavior and a stable cyclic post-yielding performance.

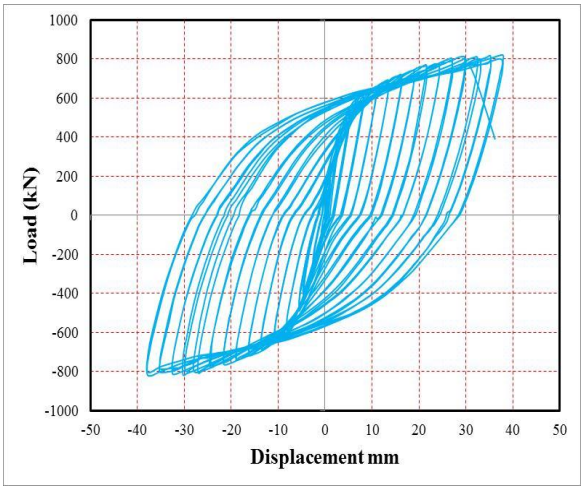

Figure 3. Shear force-displacement curve of specimen

SUMMARY OF GENERAL OBSERVATIONS DURING THE TEST

Important experiment observations in each loading group are summarized in table 1. According to test results, the specimen depicts an authentic ductile behaviour and an acceptable failure mode. The CSPSW specimen reaches inter-story drift of 6%, and by the fracture of left column, the test was terminated. Figure 4 depicts the CSPSW specimen after the test.

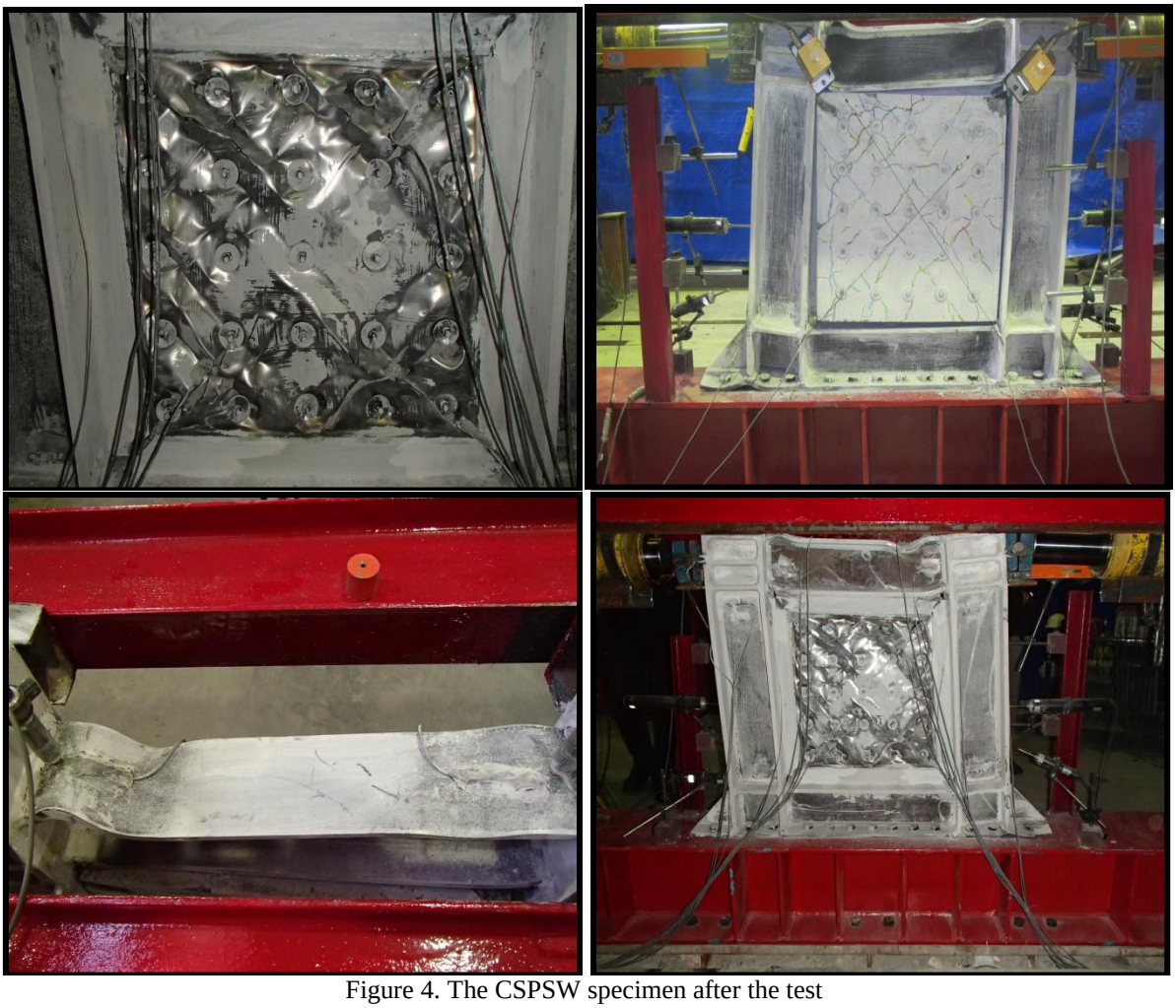

Figure 4. The CSPSW specimen after the test

Table 1. Important experimental observations in each loading group

Cycle No.	Load (KN)	Displacement (mm)	Test Summery
Cycles 1-3	129.4	-	The CSPSW remained elastic. Linear behavior was observed.
Cycles 4-6	258.7	-	The CSPSW remained elastic. Friction sound between the infill steel plate and reinforced concrete panel was barely heard.
Cycles 7-9	404.7	-	Shear yield of the infill steel plate took place. Boundary elements remained Elastic.
Cycles 10-12		5.4	Pure shear yield of the infill steel plate was propagated. Inelastic buckling of the infill steel plate was captured.
Cycles 13-15		8.1	Yield of the upper beam web was observed. Friction sound between the infill steel plate and the reinforced concrete panel became louder.
Cycles 16-17		10.8	Yield of the upper beam web was evidently seen.
Cycles 18-19		13.5	Yield of the bottom beam web was seen. Hairy crack was observed on the reinforced concrete panel.
Cycles 20-21		16.2	Yield of the upper beam flange was captured. The infill steel plate was torn between outer bolts.
Cycles 22-23		18.9	The infill steel plate was torn at four places. More hairy cracks were spread out on the reinforced concrete panel. Yield of the left column web was seen at bottom.
Cycles 24-25		21.6	Yield of the right column web and flanges were observed at bottom. Tears of the infill steel plate widened.
Cycles 26-27		24.3	Plastic hinge at upper beam was formed. Yield of both columns happened.
Cycles 28-29		27	Several tears were observed in the infill steel plate.
Cycles 30-31		29.7	Plastic hinge at column was formed.
Cycles 32-33		32.4	A crack took place at connection of left column and left base plate.
Cycles 34-35		35.1	The gap between the infill steel plate and the columns was closed.
Cycles 36-37		37.8	The infill steel plate was torn diagonally. Sever damage to the reinforced concrete panel was observed.
Cycle 38		40.5	Left column was fractured at the base. A bolt of base beam was fractured. The test was finished.

CONCLUSIONS

A one-story one-bay CSPSW specimen was experimentally investigated at Road, Housing & Urban Development Research Center, Tehran, Iran. In accordance with the experimental results, the following conclusions are obtained:

- CSPSW is an appropriate lateral-load resisting system which carries remarkable shear forces.
- If CSPSWs are designed reasonably and efficiently, they are able to tolerate lateral loads up to inter-story drift of 6 %.
- Failure mode of CSPSW is acceptable for seismic design.

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