DOI: 10.5075/epfl-ICSS12-2018-149-151

EXPERIMENTAL INVESTIGATION ON THE BEHAVIOR OF FIBER REINFORCED LIGHTWEIGHT CONCRETE FILLED DOUBLE STEEL PLATE SHEAR WALL

Ghazaleh. Eslami[1] and Alireza Rahai[2]
[1] PhD candidate, Department of civil engineering, Amirkabir University of Technology, Iran. gh_eslami@aut.ac.ir
[2] Professor, Department of civil engineering, Amirkabir University of Technology, Iran. rahai@aut.ac.ir

1. INTRODUCTION

The behavior of tall buildings during earthquakes has been a significant concern in the recent decades. Different lateral load resisting systems can be used in steel structures, namely the braced frames, shear walls, and the moment resisting frames. In the past several years, Reinforced concrete (RC) shear walls have been used to resist earthquake loads. Later, steel plate shear walls were employed as a more economical system leading to the overall weight reduction of structure. Nowadays, concrete filled double-steel-plate (CFDSP) shear walls are introduced as a significantly efficient lateral load resisting system in which the steel faceplates delay the cracking of concrete panel while the concrete panel prevent the premature buckling of steel faceplates. Steel faceplates are connected to the concrete panel using shear connectors such as shear studs, bolts, and other profiles resulting in composite behavior. Zhang et al. [1] found that a 75 to 90% partial composite action can be expected if the stud spacing is designed to achieve target development lengths of three times the wall thickness or less. This would allow the steel faceplates to develop yielding before local buckling and will lead to wall's composite action. The plane composite truss model was investigated by Nie et al. [2] to evaluate the effective shear stiffness of the composite shear walls. Moreover, they observed that the failure mode will be flexural failure in walls with a shear span ratio of 2.0 and 1.5, whereas with a shear span ratio of 1.0, the failure mode will be a mixed failure of flexure and shear. To investigate the local buckling of steel plates in composite shear walls subjected to uniform axial compression, Qin et al. [3] proposed a methodology to predict the strength of steel plates considering restraint of both concrete and shear studs. Yang et al. [4] developed three-dimensional finite element (FE) models to simulate the behavior of double skin composite (DSC) panels subjected to compression, and found the FE results to be in good agreement with the observed buckling behavior during tests. The experimental and parametric studies conducted by Kurt et al. [5], investigating the effects of wall aspect ratio, reinforcement ratio, and wall thickness, showed that lateral load bearing capacity of steel-concrete composite (SC) wall piers with aspect ratios greater than or equal to 0.6 is governed by the flexural yielding of the steel faceplates in tension, and by local buckling of the steel faceplates and crushing of the concrete infill in compression. After all, the post cracking behavior of macro synthetic polypropylene fiber reinforced concrete was investigated by Amin et al. [6].

In this study, a fiber reinforced lightweight concrete filled double steel plate shear wall and -as a reference specimen- a plain concrete filled double steel plate shear wall were fabricated and tested under monotonic lateral loading. The effects of using fiber reinforced lightweight concrete on lateral load bearing capacity, stiffness, ductility, and failure characteristics of the composite shear walls were analyzed.

2. SPECIMEN DETAILS AND TEST SET-UP

The experimental program was developed at Amirkabir University of Technology, Tehran, Iran, with the purpose of studying the effects of adding "Fibercem P50" synthetic fiber to concrete mixture in concrete filled double-steel-plate (CFDSP) shear walls subjected to monotonic lateral load.

Experimental Specimens

In this study, monotonic tests were carried out on four 1:4 scaled elements. Two specimens were fiber reinforced lightweight concrete filled double-steel-plate shear walls and another two specimens were ordinary concrete filled double-steel-plate shear walls. The variables of the experimental program were related to the fiber contribution ratio while being designed using the guidelines provided by Astaneh Asl [7]. The efficient synthetic fiber contribution ratio was obtained from previous tests to be equal to 1 kg/m^3. The details of the two types of CFDSP are presented in Table 1.

Material Properties

To characterize the compressive strength and density of concrete, 6 concrete cube samples were made for either of synthetic fiber concrete or ordinary concrete. The sample test results with age of 28 days revealed the 25% compressive strength increase by adding synthetic fiber. The properties of synthetic fiber are presented in Table 2.

Test Setup

Four 1:4 scaled one-bay one-story specimens were fabricated and tested under monotonic lateral load. Designed walls were assumed as the first floor wall of a high rise building, so the specimens were designed as a cantilever wall fixed to a rigid column which was connected to the strong floor of the laboratory (Fig. 1). To eliminate the lateral load resistance contributed by the wall peripheral frame, beam-to-column joints were designed to be pin-jointed as shown in Fig. 1.

According to the AISC 341-10 [8], the stiffness of the boundary elements (IPE 14 and Box 12) shall be designed to allow the full yield zone to be developed across the diagonal area of the steel faceplates. Test specimens were rotated and the lateral loading was applied as a gravity point load at the top of the specimens by a servo controlled actuator. The rigid column was designed to have no lateral displacement during the test. All elements of the test setup (rigid column, connection to the rigid column), were analyzed and designed for the maximum probable moment value factored by 1.5.

Instrumentation

A load cell was mounted on the hydraulic actuator to monitor the lateral loads applied to the specimen. One linear variable differential transducer (LVDT) was used to measure the displacements along the lateral load. The location of LVDT is shown in Fig. 1. Several strain-gauges were used to measure the deformations of the steel plate and their locations are shown in Fig. 1.

Table 1: The experimental specimens details.

Model	Composite shear wall dimensions (mm^2)	Concrete panel thickness (mm)	Concrete cubic compressive strength (MPa)	Concrete density (kg/m^3)	Steel plates thickness (mm)	Steel yield strength (MPa)	Metal international code	Fiber contribution (kg/m^3)	Shear connector distance (mm)
CFDSP 1 CFDSP 2	750*750	50	27	1500	1.2	240	A36	0	150
CFDSP 3 CFDSP 4	750*750	50	35	1500	1.2	240	A36	1	150

Table 2: Synthetic fiber properties.

Length (mm)	Diameter (mm)	Tensile Strength (MPa)	Melting point (°C)	Modulus of elasticity (MPa)	Water absorption (%)	Compaction factor
50	0.07	600	230	3500	0.01-0.02	0.91

Fig. 1: Specimen configuration and test set-up.

3. RESULTS AND CONCLUSION

Results

The main objective of this research project was to investigate the effects of adding synthetic fiber to plain concrete in improvement of steel faceplate and concrete panel composite action and how the lateral load bearing capacity of CFDSP shear wall is affected by it. A comparison can be made regarding the strength of the specimens by analyzing the failure load and local buckling of steel faceplates (Figs. 2-3). Fig. 2 illustrates that increasing the concrete compressive strength has a positive effect on load-displacement response and failure load of the CFDSP walls. The first collapse mode of the CFDSP wall was cracking and spalling of the concrete panel, so by using fiber reinforced concrete, the cracking of the concrete panel happened with a delay indicated from the initial stiffness of load-displacement curves. Based on the results of strain gauges, both kinds of CFDSP shear walls had the same buckling mode, but the local buckling of steel faceplates was lagged by using fiber reinforced concrete with the same values of out of plane deformations. The CFDSP shear wall maintains its composite action with the delay in local buckling of steel faceplates due to the continuous presence of concrete panel out of plane support resulted from increase in lateral capacity of the concrete panel using fiber reinforced concrete. The more the CFDSP shear wall preserves its composite action, the higher the lateral load bearing capacity is.

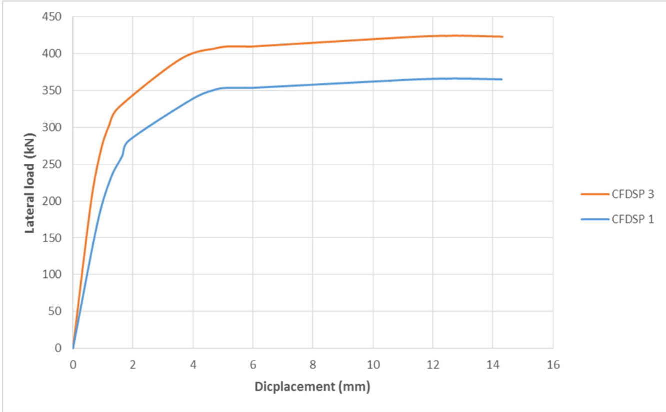

Fig. 2: Load-displacement curve of the two type specimens.

(a) (b)

Fig. 3: Buckling of the specimen after the test.

Conclusion

Composite shear walls consist of steel face plate and concrete panel that are connected in one or two sides of steel face plate. Compared to reinforced concrete shear walls, Composite shear walls of the same shear capacity, have smaller thickness and less weight. Moreover, in a composite shear wall, the concrete wall restrains the steel plate and prevents its before-yield premature buckling resulted by composite action between steel face plate and concrete panel [7]. The CFDSP shear wall was examined using various characteristics and subjected to various types of loading (axial, cyclic, impact, thermal, and combined) in some recent researches. In this research, monotonic lateral behavior of the CFDSP shear walls were investigated experimentally to study the effects of adding synthetic fiber to concrete mixture for better composite action. It was observed that:

1- Fiber reinforced concrete increase the initial stiffness of the CFDSP wall in lateral loading.

2- Utilizing fiber reinforced concrete delays the cracking and spalling of the concrete in panel. Therefore, the concrete panel continues the out of plane support of faceplates and the CFDSP shear wall maintains its composite action which leads to a 16% increase in lateral load bearing capacity.

3- Adding fiber in concrete mixture doesn't have any effects on failure mode or ultimate displacement of the wall while the local buckling of steel faceplates was lagged.

REFERENCES

[1] K. Zhang, A. H. Varma, S. R. Malushte, and S. Gallocher, "Effect of shear connectors on local buckling and composite action in steel concrete composite walls," *Nucl. Eng. Des.*, vol. 269, pp. 231–239, 2014.
[2] J. G. Nie, X. W. Ma, M. X. Tao, J. S. Fan, and F. M. Bu, "Effective stiffness of composite shear wall with double plates and filled concrete," *J. Constr. Steel Res.*, vol. 99, pp. 140–148, 2014.
[3] Y. Qin, G. P. Shu, S. G. Fan, J. Y. Lu, S. Cao, and J. H. Han, "Strength of double skin steel-concrete composite walls," *Int. J. Steel Struct.*, vol. 17, no. 2, pp. 535–541, 2017.
[4] Y. Yang, J. Liu, and J. Fan, "Buckling behavior of double-skin composite walls: An experimental and modeling study," *J. Constr. Steel Res.*, vol. 121, pp. 126–135, 2016.
[5] E. G. Kurt, A. H. Varma, P. Booth, and A. S. Whittaker, "In-Plane Behavior and Design of Rectangular SC Wall Piers without Boundary Elements," *J. Struct. Eng.*, vol. 142, no. 6, p. 4016026, 2016.
[6] A. Amin, S. J. Foster, R. I. Gilbert, and W. Kaufmann, "Material characterisation of macro synthetic fibre reinforced concrete," *Cem. Concr. Compos.*, vol. 84, pp. 124–133, 2017.
[7] A. Astaneh-asl, "Seismic Behavior and Design of Composite Steel Plate Shear Walls," 2002.
[8] American Institute of Steel Construction, "Seismic Provisions for Structural Steel Buildings," *Seism. Provisions Struct. Steel Build.*, no. 1, p. 402, 2010.