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An Experimental Study on the Hysteric Behavior of Composite Shear Walls

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Abstract

Due to architectural and structural requirements, the use of composite shear walls becomes necessary in reinforced concrete high-rise structures subjected to earthquake loads. Composite shear walls also play an important role to limit the inter-story drift displacements during severe earthquakes in terms of load bearing system performance. Within the scope of this study, composite shear wall (CSW) with 1/3 scaled end zones, consisting of bended steel plates, were formed. The dimensions of the bended steel plates used in the shear wall end zones were 4L - 23x69x5 mm. The composite shear wall was tested under the effect of hysteric horizontal loadings in the earthquake laboratories in Selcuk University, and its behavior was examined. Measurements were taken; the load displacement curves, load displacement envelopes, inter-story drift angle were shown in graphs and evaluated; and the distribution of the cracks that formed on the plates were studied in details.

Key words: Composite shear wall, bended sheet plate, hysteric lateral load, crack distribution.

1. Introduction

For architectural and other reasons, the design of reinforced concrete shear wall with high lateral load resistance, which are used in high-rise structure that can potentially be exposed to earthquake effects, require the formation of shear wall end zones with narrow cross-section and intensive reinforcement. Placing fresh concrete in sections where the intensity of reinforcement is high is somewhat difficult. However, excessive reinforcement intensity complicates the implementation of the design project.

To solve this problem, researchers have investigated the making of composite shear walls, and the use of ready-made profiles with I and H sections at the shear wall end zones was researched in many studies [1-7]. In addition, studies were also performed on the effect of bended sheet plates on shear wall behavior [8-11].

In this study, the end zone of the composite shear wall was formed from the bended sheet plates with L sections, and the seismic behavior of the composite shear wall was studied experimentally. The main criterion in the selection of the bended sheet plate elements used in this study was ensuring that plates of any thickness used in the project could form bended steel plates.

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2. Materials and Method

The composite shear walls formed at 1:3 scale were manufactured with a height, width and length of 300cm, 10cm and 100cm, respectively (Figure 1). Four L-sectioned bended sheet plate elements with dimension of 23x69x5 mm were used and 8 mm diameter stirrups were applied at intervals of 7.50 cm in the shear wall end zones. On the body of the shear wall, 12 reinforcements with 10 mm diameter were used (Figure 2).

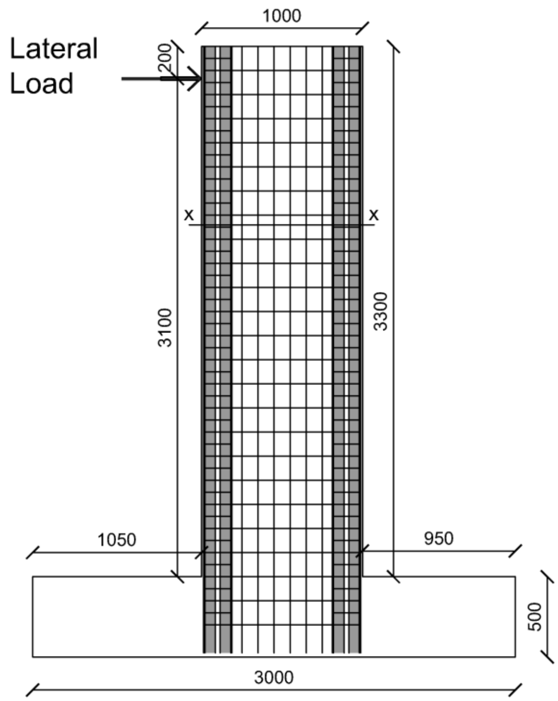

Figure 1. Size of specimen (mm)

Horizontal reinforcements were placed into the shear wall body at intervals of 15 cm. As the shear wall end zones constituted the subject and focus of the study, a rigid foundation was formed. The foundation had a dimension of 3.00 x 0.50 x 0.70 meters. The reinforcements were placed into the mold positioned parallel to ground. The preparation of the experimental element was completed by using of C25 class ready-made concrete into the mold after the reinforcements were placed. The experimental element was brought to a vertical position after it sufficiently hardened. The prepared experimental element was carried to the horizontal loading system at the earthquake laboratory in Selcuk University by using sliding crane. The shear wall was fixed onto the floor at the laboratory by means of 8 connecting elements.

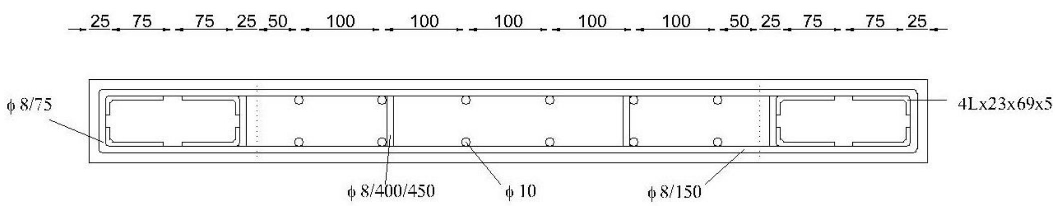

Figure 2. Cross section of composite shear wall at section x-x (mm)

3. Loading Protocol and Measuring Mechanism

In order to better monitor the progress of the cracks, the samples were fully painted with white after they were placed into the loading mechanism. By applying a horizontal load with a 500 kN capacity hydraulic load transmitting mechanism attached to the hydraulic control unit in the laboratory, the experiments were performed by first using force-controlled, and then (beyond yielding) displacement-controlled loading protocols. The loads applied in the experiment and the displacement pasts are given in Figure 3.

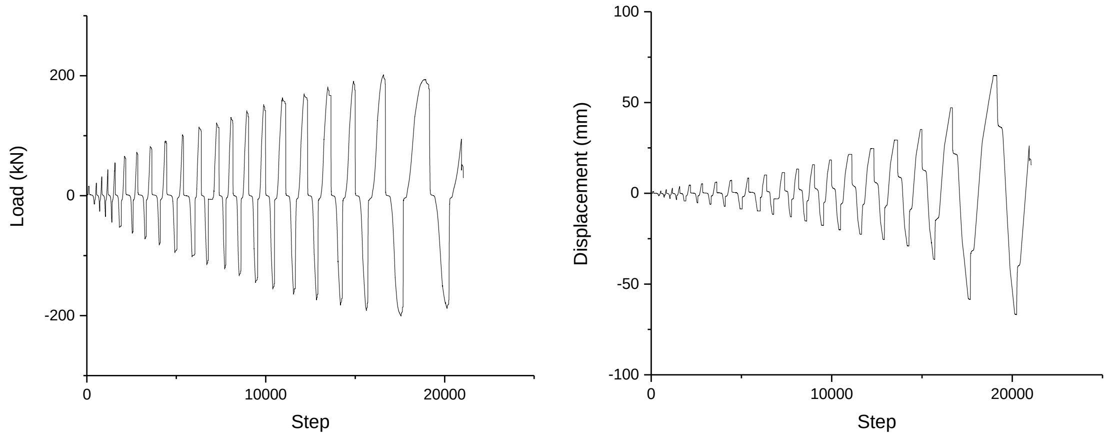

Figure 3. Load and displacement history.

To measure the level of load applied to the shear wall, readings were taken from the ≈500 kN capacity load cell. The load applied during the experiment was monitored with the data taken from the load cell. Vertical displacement measurements were performed by means of the potentiometric rulers placed onto the sample at heights of 101 cm, 203 cm and 283 cm (Figure 4).

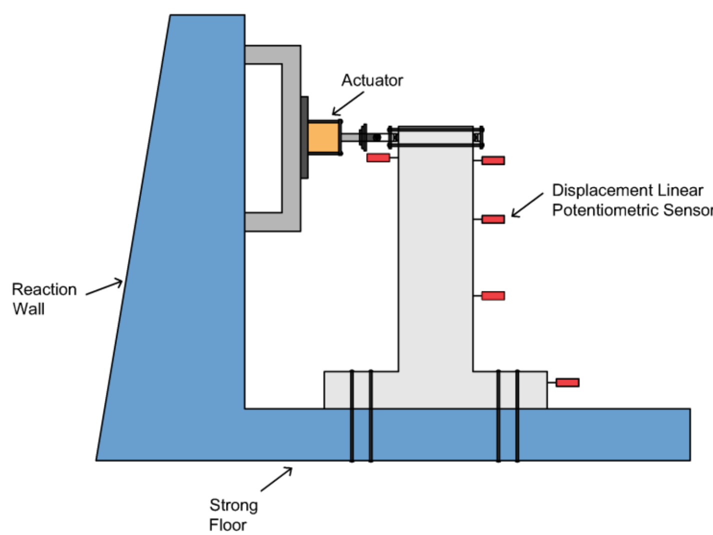

Figure 4. The testing set-up.

For sliding movements, measurements were taken with a potentiometric ruler placed 34 cm high from the bottom of the foundation in order to monitor sliding displacement. During the experiment, data coming from a total 5 potentiometric rulers and the load cell were collected through a TDG-Ai8b data collector. The collected data were transferred to a computer environment using a TDG device gateway. The transferred data were digitized using a TDG Coda software. By performing the necessary analyses on the digitized data with the help of Microsoft Excel Program, they were transformed into meaningful results.

4. Results

During the force-controlled protocol experiments, small cracks extending up to a level of 1.5 m appeared in the shear wall end zones when a force of ±50 kN was applied (Figure 5). A thin crack line, with the appearance of a bending crack, occurred in both the foundation and the shear wall when a 60 kN load level was applied (Figure 6).

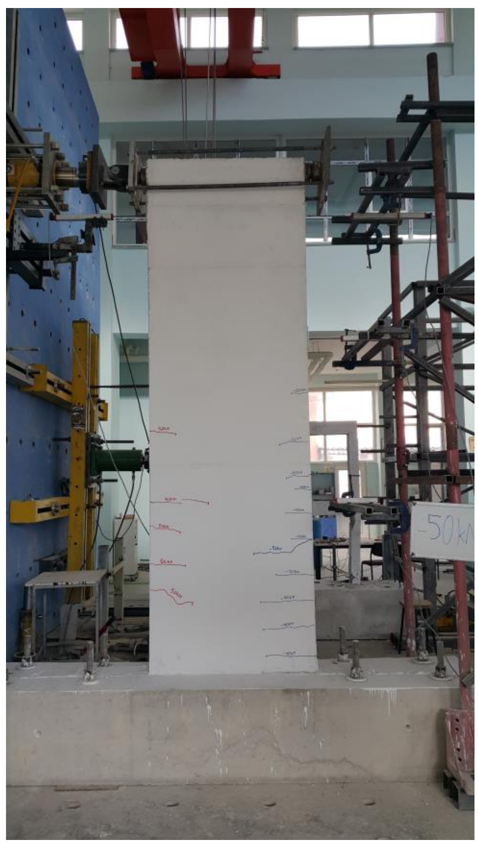

Figure 5. Crack distribution under the -50 kN.

These cracks parallel to the horizontal plane indicated that the structure exhibited ductile behavior at small displacement levels. In this case, the top displacement was measured as 5 mm. The fact that the cracks started to form at the shear wall end zones indicated that the strains in the cross section of the shear wall particularly concentrated in this zone. Long, 45 degree shear cracks formed under -110 kN load at the height of 230 cm. Top displacement was measured as 11 mm. Under a 120 kN load, a secondary crack formed in reverse direction to the cross crack formed in the previous cycle (Figure 7).

Figure 6. A thin crack line under a 60 kN.

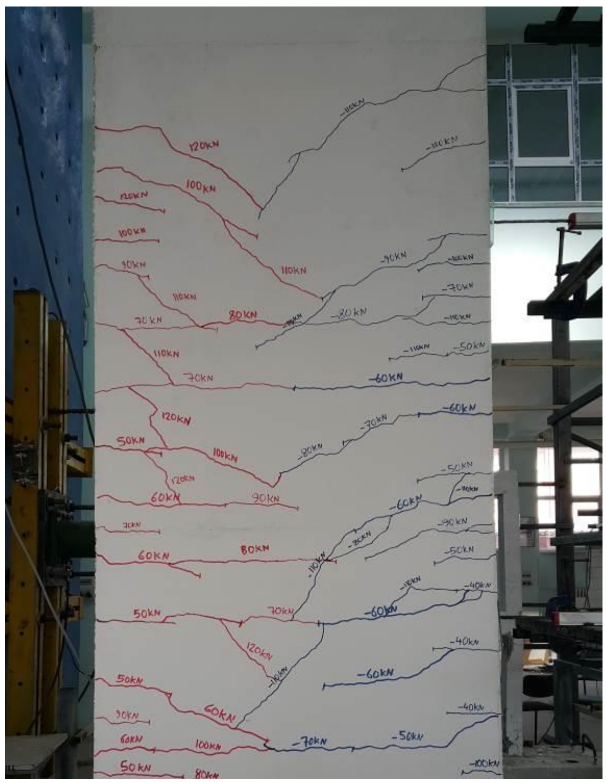

Figure 7. Shear cracks under a 120 kN.

After this phase, the bending behavior observed in the structure was gradually replaced by a shear behavior. In the ensuing cycles, the sample was displaced by 28 mm under a -180 kN load. The crushing effects in the pressure zone at the junction between the shear wall and the foundation, as well as the crack widths in the tensile zone, gradually increased (Figure 8). The shear wall was displaced by 45 mm under ±200 kN load. When concrete covers in both end zones went into pieces, the bended sheet plate became visible (Figure 9).The shear wall reached maximum load level at approximately 202 kN, and made a 47 mm displacement. After this load level, cracks tended to expand rather than progress. Since the load on the element could not be increased any further beyond this stage, the experiment was continued with the displacement controlled protocol. Buckling occurred in the bended sheet plates at the right end of the shear wall (Figure 10).

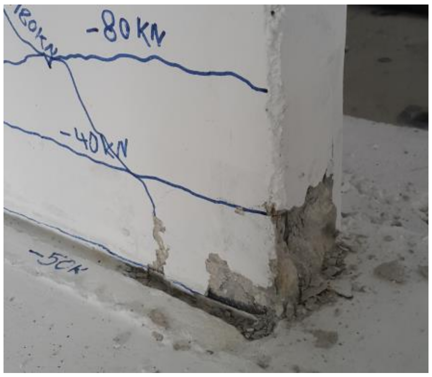

Figure 8. Crushing effects in the pressure zone.

Figure 9. Bended sheet plate becoming visible in the shear wall end zones.

Figure 10. Buckling occurring in the bended sheet plates at the right end of the shear wall under 202 kN.

Following the buckling of the plate, it could no longer carry further loads. The target displacement was then determined as -65 mm, and the shear wall was forced up to that point. The experiment was ended after the plate lost its load bearing capacity due to the bending and full buckling of the sheet plate at the left end of the shear wall, just below the tack weld connecting the bended sheet plates to one another. The final crack distribution of the experimental specimen at the end of the loading procedures is shown in Figure 11.

The graph of the load-top displacements obtained based on the measurements is given in Figure 12, while the load-displacement envelope formed by connecting the extremum points is given in Figure 13. As can be understood from this graph, the composite shear wall with L-section end zones exhibited a ductile behavior. Hence, sudden load losses were not experienced. Values for the angle of inter-story drift, obtained by dividing the top displacement with the shear wall height starting from the top level of the foundation, are presented in Figure 14.

When the values were evaluated, it was observed that the shear wall element was able to carry loads of up to a maximum 2.2% inter-story drift angle. It is believed that further tightening the weld steps of the welding areas used for connecting the bended sheet plates at the buckling zones (for the purpose of forming a sufficiently thick bending sheet plate section) would help shortened the length of buckling, and that the structure would consequently exhibit a more ductile behavior.

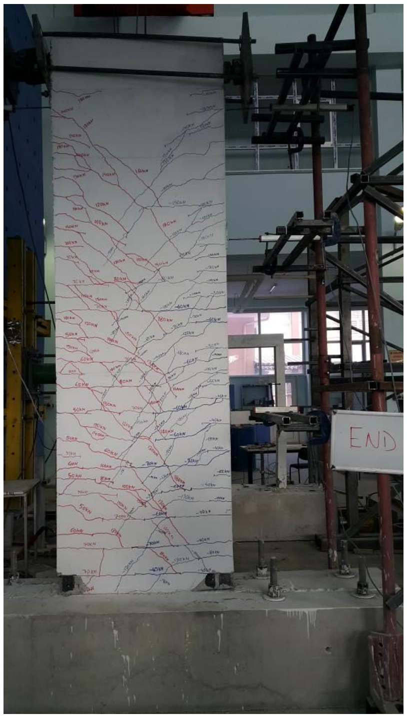

Figure 11. The final crack distribution of the experimental specimen at the end of the loading procedures.

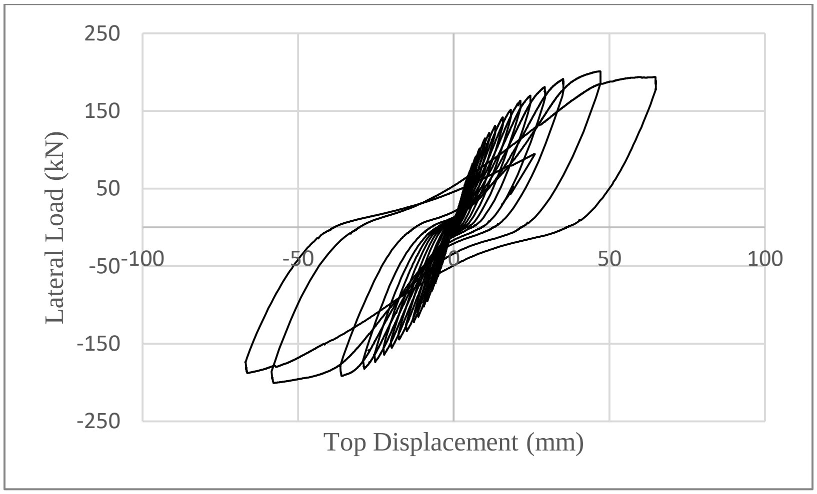

Figure 12. Lateral load versus top displacement curves.

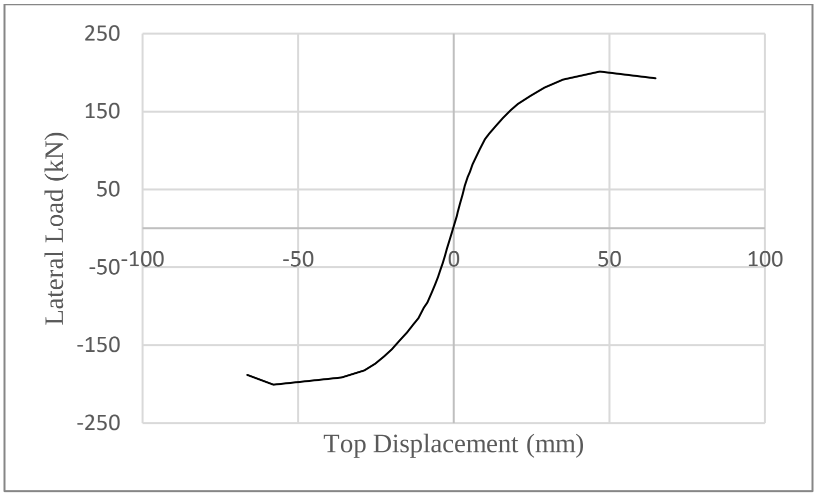

Figure 13. Lateral load versus top displacement envelopes.

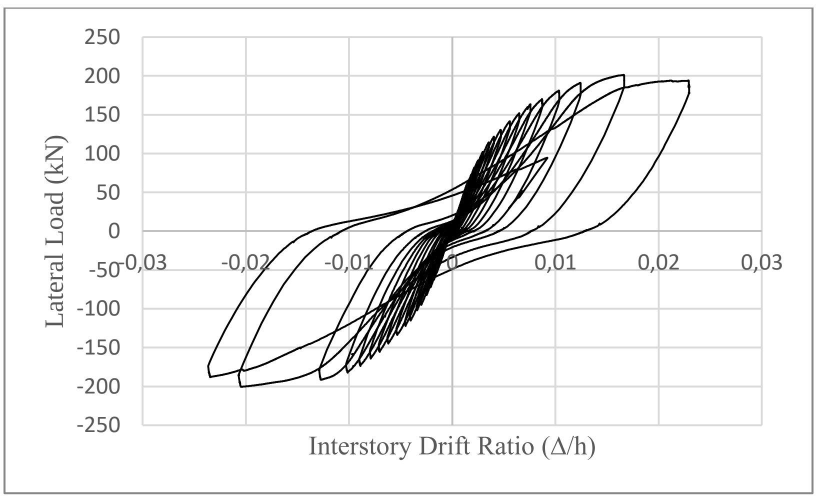

Figure 14. Lateral load vs interstorey drift ratio.

References

[1] Arabzadeh A, Soltani M, Ayazi A. Experimental investigation of composite shear walls under shear loadings. Thin-Walled Structures 2011;49:842-854.

[2] Cho SH, Tupper B, Cook WD, Mitchell D, M.ASCE. Structural steel boundary elements for ductile concrete walls. Journal of Structural Engineering 2004;130:762-768.

[3] Dan D, Fabian A, Stoian V. Theoretical and experimental study on composite steel-concrete shear walls with vertical steel encased profiles. Journal of Constructional Steel Research 2011;67:800-813.

[4] Dan D, Fabian A, Stoian V. Nonlinear behavior of composite shear walls with vertical steel encased profiles. Engineering Structures 2011;33:2794-2804.

[5] Liao FY, Han LH, Tao Z. Performance of reinforced concrete shear walls with steel reinforced

concrete boundary columns. Engineering Structures 2012;44:186-209.
[6] Qian J, Jiang Z, Ji X. Behavior of steel tube-reinforced concrete composite walls subjected to high axial force and cyclic loading. Engineering Structures 2012;36:173-184.
[7] Zhou Y, Lu X, Dong Y. Seismic behaviour of composite shear walls with multi-embedded steel sections. Part I: Experiment. The Structural Design of Tall and Special Buildings 2010;19:618-636.
[8] Yüksel SB. Structural behavior of lightly reinforced shear walls of tunnel form buildings. 2013 IACSIT Spain Conferences. 10-11 August 2013, Barcelona, Spain. IACSIT International Journal of Engineering and Technology. Volume 6, Number 1, pp. 34-37, February 2014.
[9] Yüksel SB. Experimental behavior of the repaired reinforced concrete shear walls having mesh reinforcements. ICESA 2014 International Civil Engineering & Architecture Symposium for Academicians 2014, 17-20 May 2014, Side, Antalya, Turkey.
[10] Yüksel SB, Ünal A. Experimental behavior of the 1/3 scaled composite shear wall having L shape steel made-up sections as longitudinal reinforcement in boundary regions. International Conference on Civil and Environmental Engineering 2015; 1270-1275.
[11] Yüksel SB. Uç donatıları L kesitli yapısal çelik elemanlardan oluşan kompozit perdelerin sismik davranışı. Bap Proje No: 14101011.