Experimental Investigation of Light-Gauge Steel Plate Shear Walls

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ABSTRACT

Steel plate shear walls (SPSW) which are allowed to buckle in shear and form a diagonal tension field have been used as lateral load resisting systems for buildings. Research, both analytical and experimental, shows that these systems can be ductile, stiff, and have stable hysteretic energy dissipation when hot-rolled infill plates are used. However, the demands imparted on the surrounding framing in a seismic retrofit situation are substantial, and in most cases, the existing framing is likely insufficient. SPSW utilizing light-gauge cold rolled infill plates could be a more viable option for retrofit scenarios. The work presented here is an experimental investigation of the seismic adequacy of such a system.

This poster describes the prototype design, specimen design, experimental set-up and experimental results of three light-gauge steel plate shear wall concepts. Prototype light-gauge steel plate shear walls were designed as seismic retrofits for a hospital structure in an area of high seismicity and emphasis was placed on minimizing their impact on the existing framing. Three single story test specimens were designed using these prototypes as a basis, two specimens with flat infill plates (thicknesses of 1.0 mm) and a third using a corrugated infill plate (thickness of 0.75 mm). Connection of the infill plates to the boundary frames was achieved through the use of bolts in combination with industrial strength epoxy or welds, allowing for mobility of the infills if desired. Testing of the systems was done under quasi-static conditions.

BACKGROUND

Existing research on the systems described above is limited. Although, there has been extensive research on steel plate shear walls using flat hot-rolled plates as infill panels, the use of light-gage steel, corrugated or flat, has not been thoroughly studied.

Research on steel plate shear walls has produced useful models for the design and analysis of such lateral load resisting systems. Some of these have ended up in the newest version of the Canadian Institute of Steel Construction specifications (CSA, 2001). Using the results of analytical and experimental research done at the University of Alberta (Thorburn, Kulak, and Montgomery, 1983, and Timler and Kulak, 1983) the specification allows for the representation of a steel plate shear wall by a series of pin-ended tension members (known as the strip model and shown in Figure 1). These tension members are inclined at an angle calculated to be the orientation of the principle stresses of the plate.

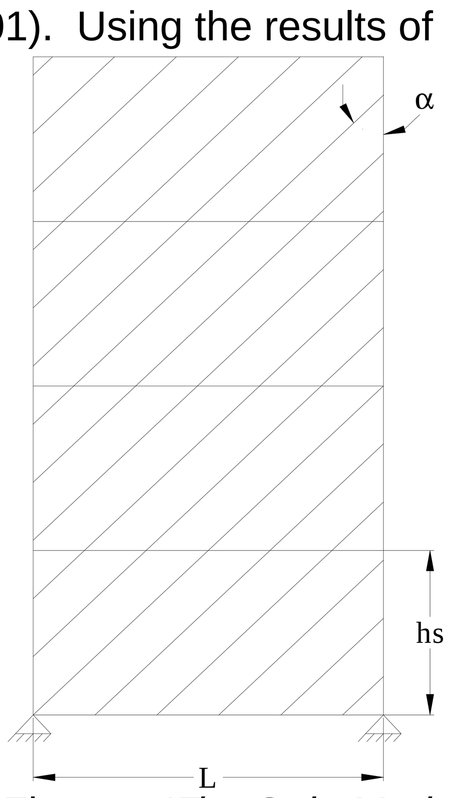

Figure 1 *The Strip Model*

OBJECTIVES

The objectives of this research are:

- Design prototype light-gauge steel plate shear wall concepts in the context of the seismic retrofit of hospitals. Three concepts are considered as part of this project.
- Based on the prototypes, design and experimentally test under quasi-static conditions, light-gauge steel plate shear wall specimens.
- Assess the hysteretic properties of those specimens and the demands from the infills on the existing framing.
- Compare the results of testing with predictions made using the strip model.

METHODS

The experiments were conducted in the SEESL laboratory at the University at Buffalo. Loading was quasi-static, followed the guidelines of ATC 24, and was applied with a 250 kip static actuator. Figure 2 shows a schematic of the test set-up. The thickness of the infill materials were 0.0396" (1.0 mm) and 0.0295" (0.75 mm) for the flat and corrugated specimens respectively. Boundary frames used web-angle beam-to-column connections, W12x96 columns and W18x86 beams, and were 72" (1830 mm) high by 144" (3660 mm) wide. All specimen were connected to the strong floor of the SEESL using a steel foundation beam and rocker bearings. Figures 3 and 4 show specimen F1 (flat infill with epoxy connection to boundary frame) and C1 (corrugated infill with epoxy connection to boundary frame) prior to testing. Specimen F2 was similar to F1 but had a welded infill-to-boundary frame connection.

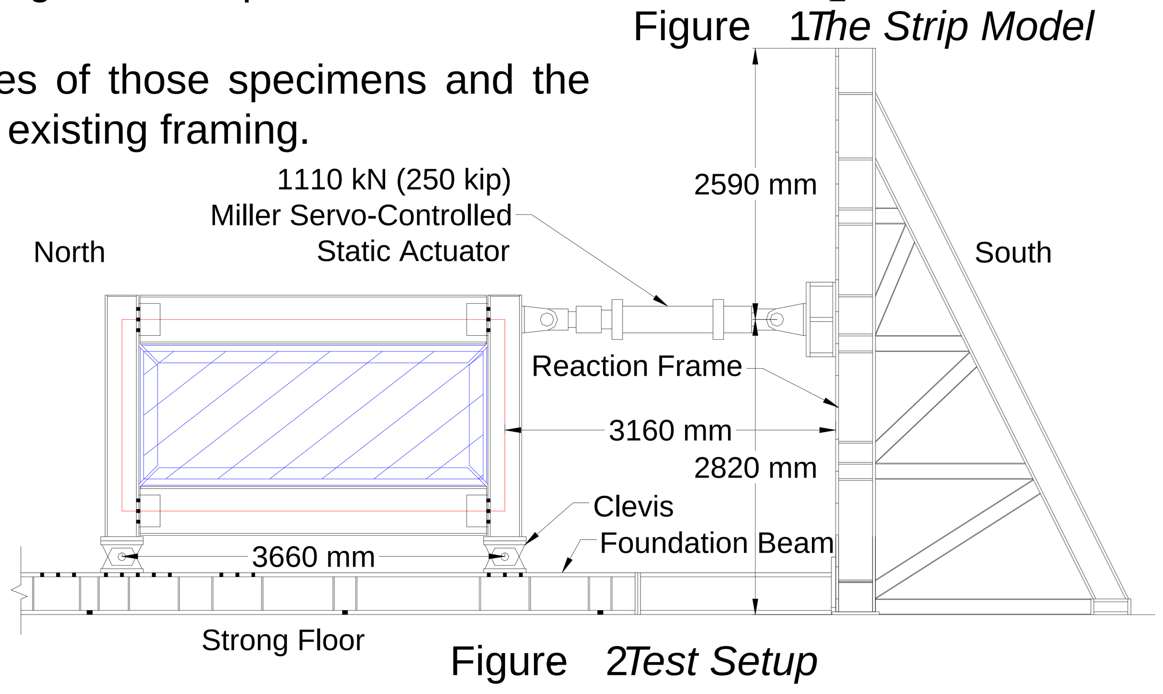

Figure 2 *Test Setup*

References and Publications

Berman, J. W., and Bruneau, M. (2003a) "Experimental Investigation of Light-Gauge Steel Plate Shear Walls for the Seismic Retrofit of Buildings", *Technical Report No. MCEER-03-0001*, MCEER, Buffalo, NY.

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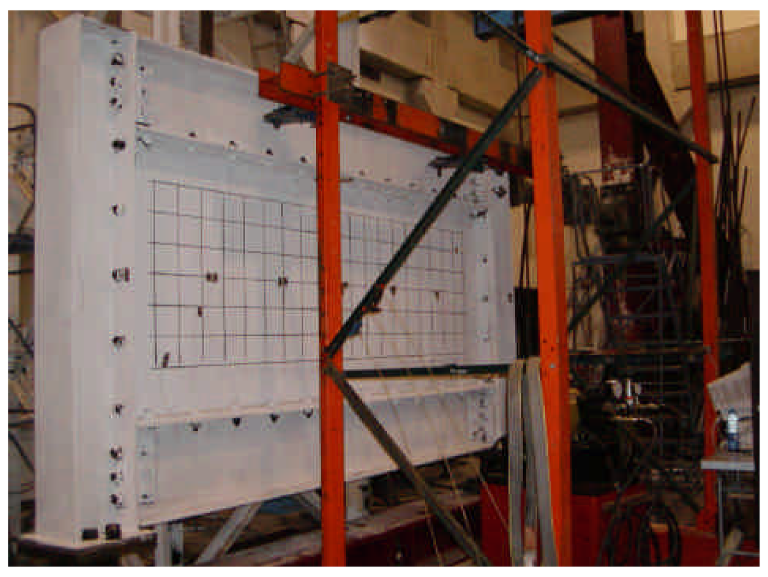
Figure 3 *Specimen F1*

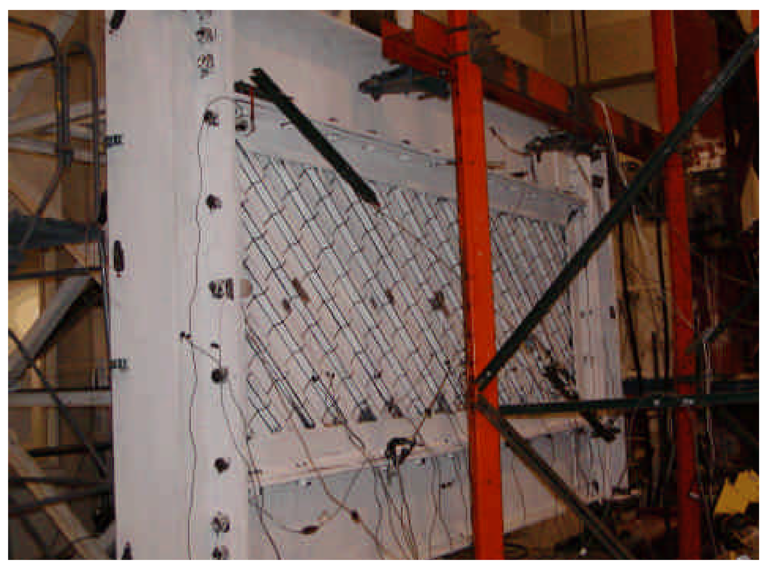
Figure 4 *Specimen C1*

RESULTS

Figures 5 and 6 show the hysteretic force-drift loops for specimens C1 and F2 respectively, with those predicted for the boundary frame and the monotonic pushover results superimposed. These specimen were pushed to $3\delta_y$ and $12\delta_y$ prior to significant strength loss. Figures 7 and 8 show infill buckling of specimens C1 and F2. Note the difference between the local plastic buckling of specimen C1 and the local elastic buckling of specimen F2. The failure mode for specimen F1 was a fracture in the epoxy connection prior to any significant energy dissipation. Specimen C1 failed as a result of fractures in the infill at locations of repeated local buckling as shown in Figure 9. Specimen F2 failed as a result of fractures in the infill that propagated from the end of the infill plate to boundary frame connection. An example of these fractures is shown in Figure 10.

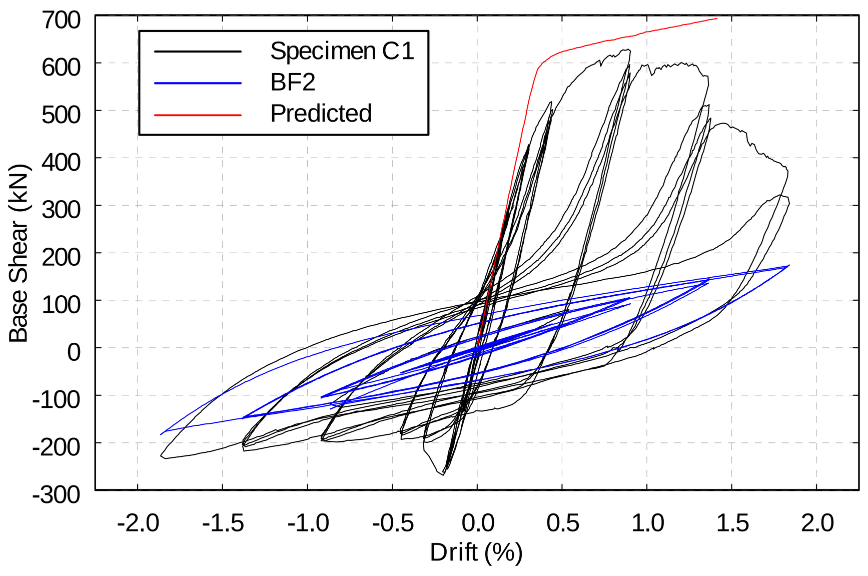

Figure 5 *Specimen C1 Hysteresis*

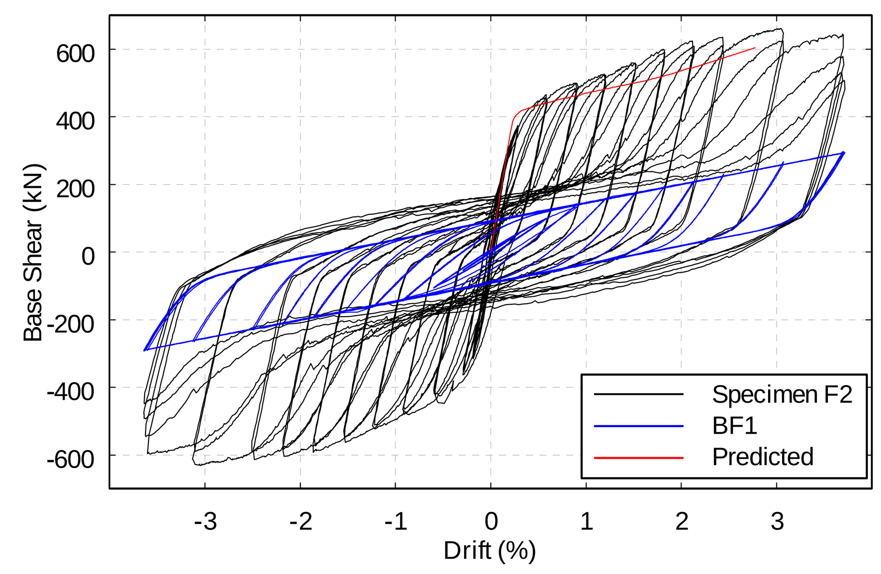

Figure 6 *Specimen F2 Hysteresis*

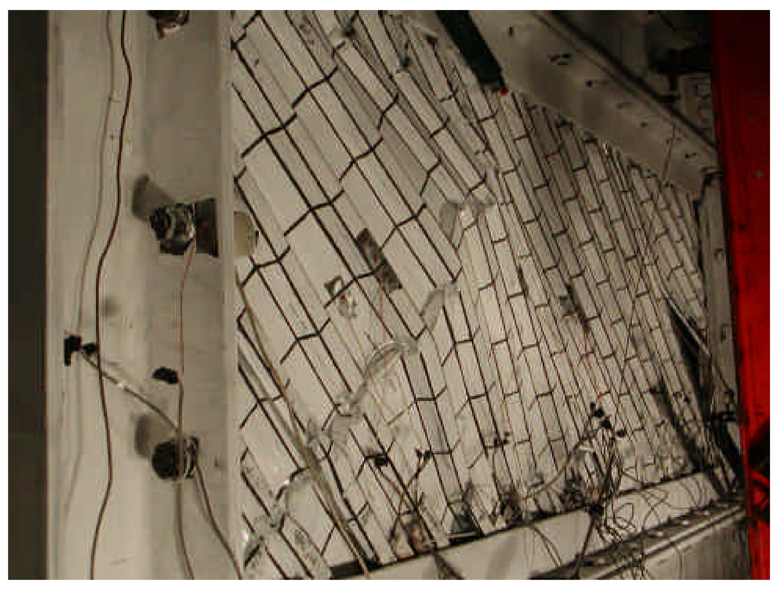
Figure 7 *Specimen C1 Infill Buckling* $3d_y$

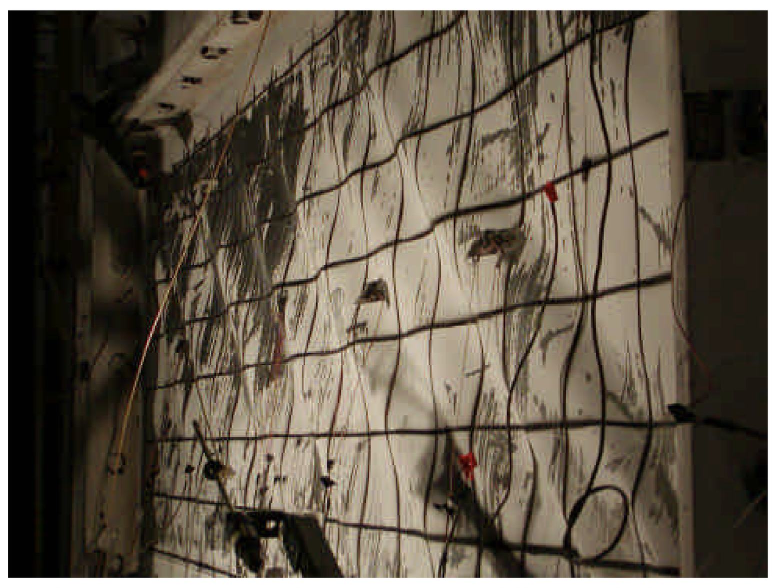
Figure 8 *Specimen F2 Infill Buckling* $6d_y$

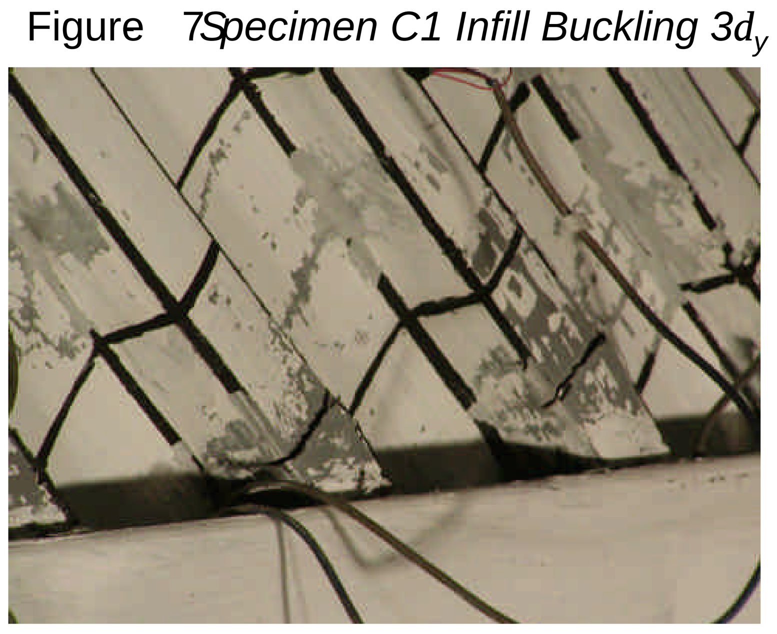
Figure 9 *Specimen C1 Infill Fractures* $3d_y$


Figure 10 *Specimen F2 Infill Fractures* $10d_y$

CONCLUSIONS

It was shown that one of the flat infill plate specimens, as well as the specimen utilizing a corrugated infill plate, achieve significant ductility and energy dissipation while minimizing the demands placed on the surrounding framing. The major difference between the corrugated and flat infill plates was found to be the failure mode. The corrugated infill specimen failed due to fractures that developed in regions of severe local buckling, while the flat infill failed due to fractures that developed along the welded connection. Experimental results were compared to monotonic pushover predictions from computer analysis using a simple model and reasonable agreement is observed.

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