COMPARISON OF LATERAL PERFORMANCE: RESIDENTIAL LIGHT WOOD FRAMING VERSUS COLD-FORMED STEEL FRAMING

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Shear Wall Test Comparison

1.0 Monotonic Test Comparison

1.1 Introduction

Comparisons of monotonic tests of wood and CFS shear walls are presented in this chapter. The main focus will be on single fastener behavior of APA rated 7/16-in OSB sheathed shear sheathing. The overall behavior and failure modes of the walls are discussed and compared to the fastener tests. Values of average strength and effective shear stiffness of single fastener in walls are presented, and also compared to the test results of fastener tests.

The compared test results from other researchers are listed below:

APA Report 154 (Tissell, 1993) provides the historical record of wood shear wall tests conducted by APA – The Engineered Wood Association. Most walls was tested per FHA Circular 12. This test protocol can potentially result in higher ultimate loads than are reached when the wall is tested to full design load on the first cycle and to twice design load on the second cycle.

Dinehart and Shenton (1998) conducted both static and dynamic tests on wood frame shear wall to determine the wall resistance to lateral loading and compare the static and dynamic performance. The traditional ASTM E-564 test procedure was used in the static tests.

Serrette (1996) conducted tests to investigate the behavior of light gauge steel shear walls sheathed with plywood, oriented strand board, and gypsum wallboard. The first and second phases were to investigate the static behavior of shear walls.

Sponsored by USBT, Serrette (1998) also performed some tests to determine how the Snap-Cap Insulated Framing System impacted the lateral resistance of the sheathed wall to wind and seismic loads. In the tests, the screw fastener schedule, fastener size and head insulation were varied.

1.2 Specimen Description and Test Protocol

The shear wall specimens presented in this study were similar to each other, with framing type and sheathing material being the only difference. This provided an opportunity to directly compare and analyze the wood and CFS shear walls of similar configurations.

The static and cyclic tests used 8ft x 8ft or 4ft x 4ft specimens. Narrow shear walls (less than 1:3) are not considered. Figures 7.1 and 7.2 show the basic configuration of an 8ft x 8ft shear wall. The material and fasteners might be different for tests of different researchers. Instrumentation and apparatus might also be different.

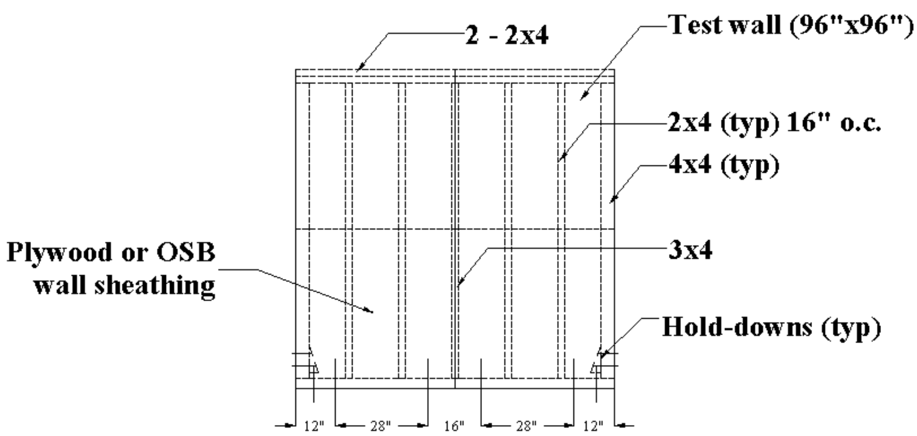


Figure 7.1. Wood Stud Test Shear Wall 8ft x 8ft (Shah, 2001)

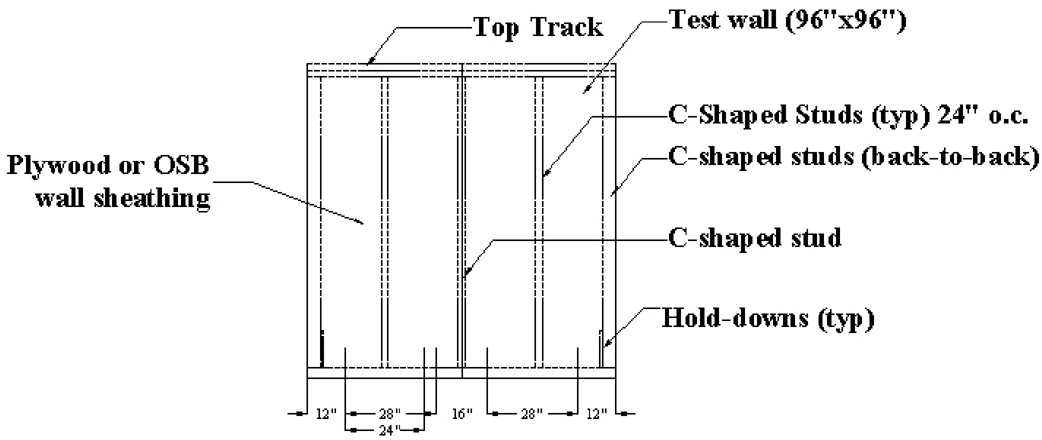


Figure 7.2. CFS Stud Test Shear Wall 8ft x 8ft (Shah, 2001)

1.3 Behavior Comparison

Dinehart and Shenton (1997) described the behavior of wood framing shear wall in the monotonic tests as following: first, sheathing tended to pull away from the frame, pulling the nails along with it. The nails were pulled out of the stud. In only a few instances were nails pulled through the sheathing. This lifting of the sheathing away from the frame occurred only along the edges of the sheathing. Second, the bottom plate spit parallel to the grain at the uplift corner. Finally, some interior studs were observed to twist along their length, and split at their top or bottom along the line of the sheathing nails in the stud.

The first-step behavior of wood framing shear wall is the same as the fastener Parallel Test of W8 and W10: the nails were pulled out or pulled through the sheathing. The behavior of shear wall implies that parallel force governed most of the fastener behaviors. Because Dinehart and Shenton (1997) built the shear walls using Spruce-Pine-Fir stud of different quality than Douglas Fir. Most nails were pulled out, while most of the nails were pulled through the panel in the fastener Parallel Test.

In Serrette (1996) CFS framed shear wall tests, racking of the wall resulted in the screw fasteners tilting about the plane of the stud flange. Tilting resulted in the head and shank of the screw pressing into the panel and bending of the flange material immediately around the screw. As the lateral displacement of the wall increased, the panel pulled over the screw heads and became unzipped. The wall responded to unzipping by a sudden drop in load carrying capacity. No screws pulled out of the stud flanges. For more dense screw schedule, the chord studs crippled, which advanced the pull-over behavior of the panels. Crippling typically initiated in the non-sheathed flange of the chord stud member.

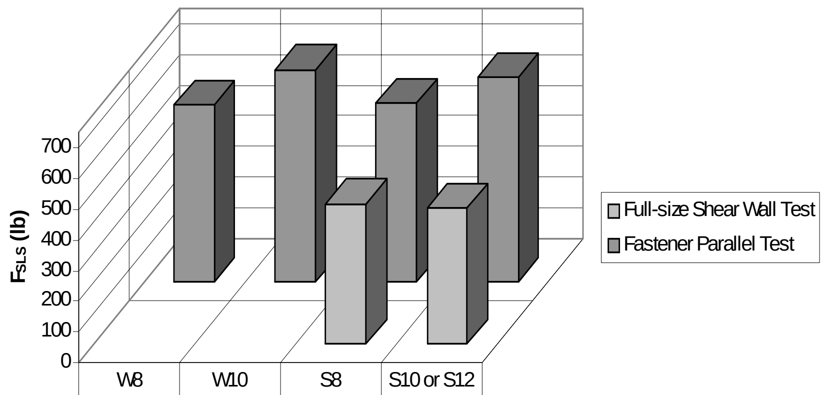
In Serrette's tests of Snap-Cap Insulated Framing System, failure was initiated by deformation of the OSB around the screw head as the head pressed into the OSB and screws tilted with respect to the plane of the stud flange. Buckling in the compression chord was the ultimate failure mode. The above descriptions of initial fastener behavior and failure mode are the same as the fastener behavior of Specimens S8 and S10 fastener Parallel Test.

Overall, parallel force governed the fastener behavior at the edge of the panel. Average values of single fasteners shear wall tests will be compared to the test results of faster Parallel Tests.

1.4 Shear Wall vs. Fastener Test

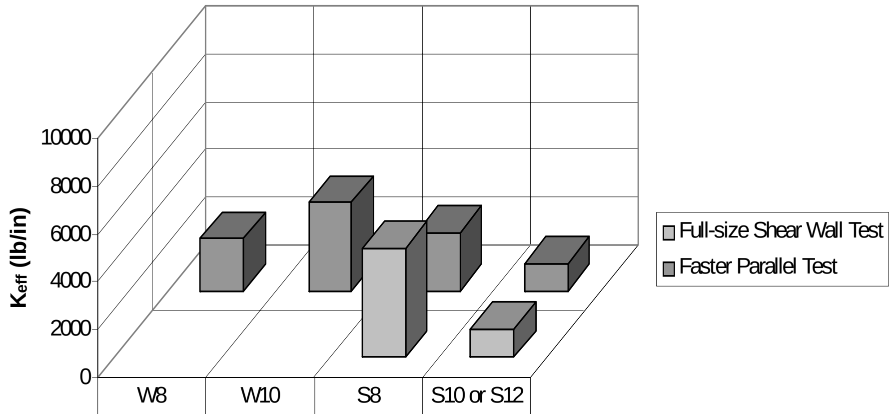
Ultimate Strength State and Effective Shear Stiffness are compared. To verify sample test, results of similar shear wall tests are compared. Since no test results are available for S10 shear walls, S12 test is compared. All sheathings are 7/16-in OSB and most of the specimens are 8ft x 8ft except for those mentioned. Fastener capacities is computed, divide shear wall capacities by number of nails at one edge. Effective shear stiffness is computed by the NAHB method.

- **6-inch Fastener Spacing (Graphs 7.1 & 7.2)**



	W8	W10	S8	S10 or S12
Full-size Shear Wall Test			456	442
Fastener Parallel Test	575	690	580	665

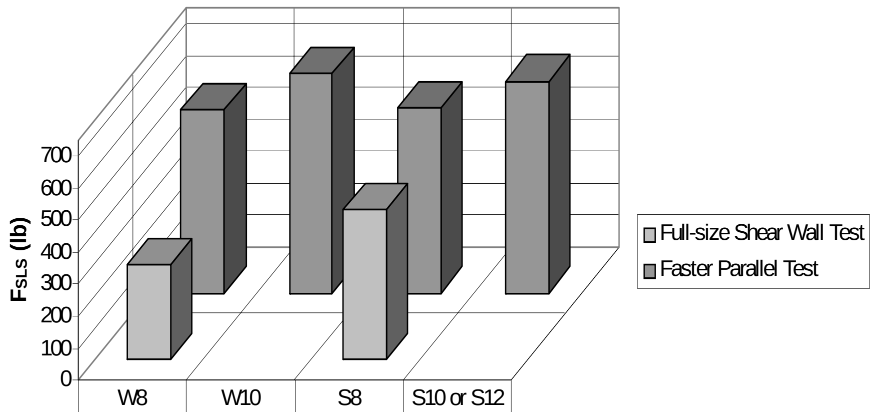
Graph 7.1. Fastener Parallel Test Strength vs. Shear Wall Strength
Shear wall S10 is 4ft x 8ft.
Shear walls S8 and S12 have similar strength.
Shear wall strengths are lower than fastener Parallel Test strengths.



	W8	W10	S8	S10 or S12
Full-size Shear Wall Test			4598	1210
Faster Parallel Test	2192	3702	2475	1162

Graph 7.2. Fastener Parallel Test Stiffness vs. Shear Wall Stiffness
Shear wall S8 stiffness is higher than shear wall S12 stiffness.
4ft x 8ft CFS shear wall stiffness is similar to fastener Parallel Test stiffness.
4ft x 8ft shear wall is more ductile than 8ft x 8ft shear wall.

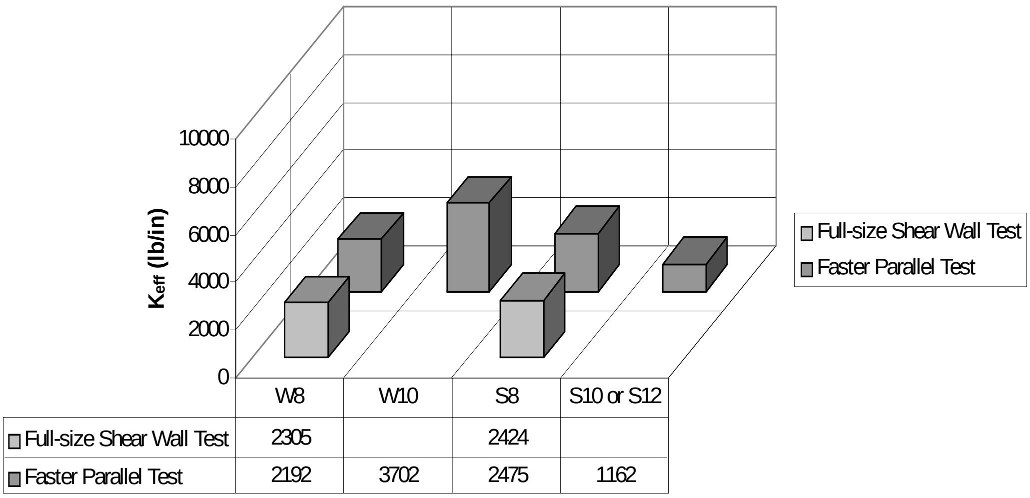
- **4-inch Fastener Spacing (Graphs 7.3 & 7.4)**



	W8	W10	S8	S10 or S12
Full-size Shear Wall Test	299		471	
Faster Parallel Test	575	690	580	665

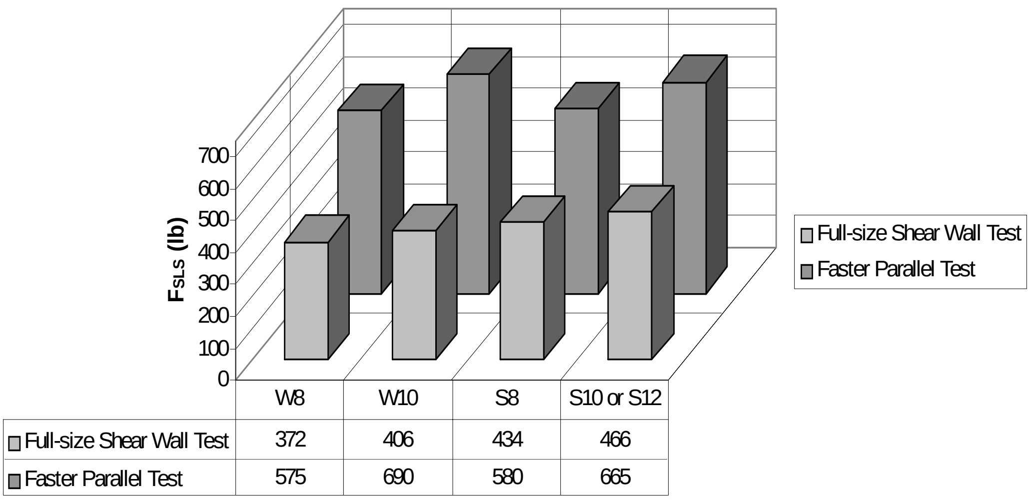
Graph 7.3. Fastener Parallel Test Strength vs. Shear Wall Strength
Shear wall W8 is 1/2-in OSB sheathing. *Shear wall S8 is 4ft x 8ft.*
Shear wall W8 strength is lower than S8 strength.

Shear wall strength is lower than fastener Parallel Test strength.

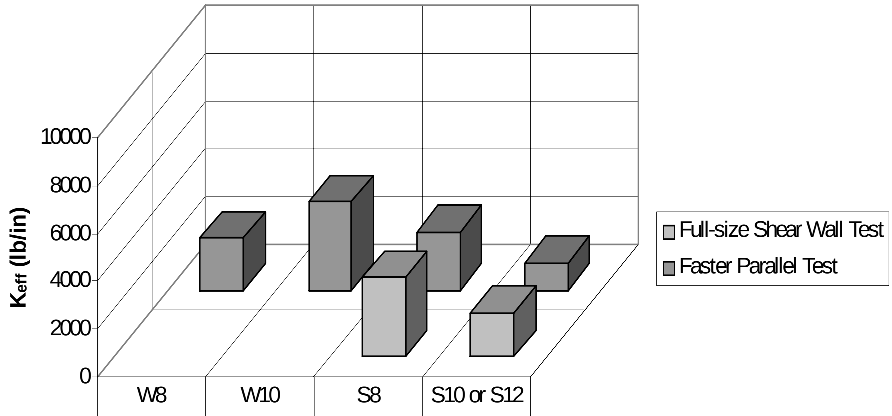


Graph 7.4. Fastener Parallel Test Stiffness vs. Shear Wall Stiffness
Shear wall W8 stiffness is similar to S8 stiffness.
8ft x 8ft wood shear wall stiffness is similar to fastener Parallel Test stiffness.
4ft x 8ft CFS shear wall stiffness is similar to fastener Parallel Test stiffness.

- **3-inch Fastener Spacing (Graphs 7.5 & 7.6)**



Graph 7.5. Fastener Parallel Test Strength vs. Shear Wall Strength
Shear wall W10 is 1/2-in OSB sheathing. *Shear walls S8 and S10 are 4ft x 8ft.*
Shear wall W8 strength is the lowest and shear wall S12 strength is the highest.



	W8	W10	S8	S10 or S12
Full-size Shear Wall Test			3338	1863
Faster Parallel Test	2192	3702	2475	1162

Graph 7.6. Fastener Parallel Test Stiffness vs. Shear Wall Stiffness
Shear wall W8 stiffness is higher than S8 stiffness.
4ft x 8ft CFS shear wall stiffness are higher than fastener Parallel Test stiffness.

1.5 Discussion

Strengths of wood shear walls are lower than CFS shear walls under monotonic tests. Shear walls W8 and S10 are more ductile than S8, which is good for life safety, but not for repair cost.

Wood shear wall strengths range only 52% to 64% of fastener Parallel Test strengths. The reason is that, in shear wall tests, fasteners had different behaviors in the corner or the middle of the panel edge when shear wall failed. Shear wall strength is the average value.

CFS shear wall strengths range 66% to 81% of fastener Parallel Tests strength, which is higher than wood framed shear wall. The reason is that some CFS shear walls failed due to stud buckling, which could absorb some energy. Effective shear wall stiffness is higher than fastener Parallel Tests stiffness.

Fastener Parallel Test is more valuable than Perpendicular Test. The test results could predict shear wall test.

2.0 Cyclic Test Comparison (Previous Tests)

2.1 Introduction

Cyclic tests of wood and CFS shear walls are presented in this chapter, based on shear walls of APA rated 7/16-in OSB sheathing. Overall behavior and failure modes of the walls are discussed and compared to the fastener tests. Ultimate strength and effective shear stiffness of walls are presented and compared fastener test results. Test results of the following three researchers, using SPD protocol, are compared:

Rose (1998) tested eight specimens dynamically, sponsored by APA – The Engineered Wood Association. The tests were conducted at the Structural Laboratory , Department of Civil , University of California – Irvine.

In COLA-UCI (City of Los Angeles – University of California, Irvine) project, Pardoen investigated 36 groups of 8’ x 8’ shear walls using cyclic testing under displacement control, of which, six groups are CFS framing while the rest groups are wood framing (2000).

Serrette (1996) as phase three of his testing program conducted cyclic testing using OSB and plywood sheathing (one side of the wall sheathed

2.2 Behavior Comparison

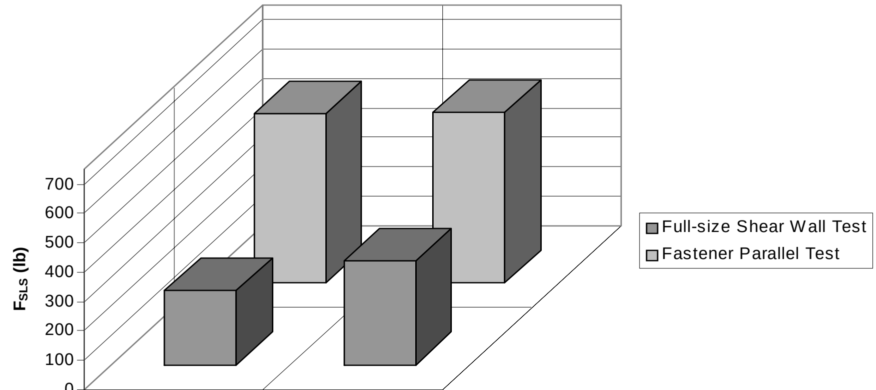
In the cyclic tests by Rose (1998), the observed failure mode was fastener fatigue, with nails breaking within the lumber framing about 3/8-in to 1/2-in below the framing surface. Fastener fatigue failures occurred near the corners of the panels after near-maximum shear loads were reached, and progressed further along the top and bottom and vertical edges of the panels, away from the corners, as the load-displacement cycles continued. The wood framed tests in COLA-UCI project had the similar failure mode. Unlike the monotonic test, the fastener behavior in the cyclic tests of wood framed shear walls had some different behavior from the faster Parallel Test and Perpendicular Test presented in this thesis. However, the test results from Parallel Test are still comparable.

For CFS shear walls the bottom of the compression chord buckled due to high compressive stresses from the racking effect. In general, racking of the wall resulted in the screw fasteners rocking (tilting) about the plane of the stud flange. Rocking resulted in the head and shank of the screw pressing into the panel and bending of the flange material immediately around the screw. The screws along the edge of the wall had no damage or failure. Like the monotonic test, the fastener behavior in the cyclic tests of CFS shear walls had similar behavior as the Parallel Test of this thesis, although the tests in this thesis are monotonic.

2.3 Shear Wall vs. Fastener Test

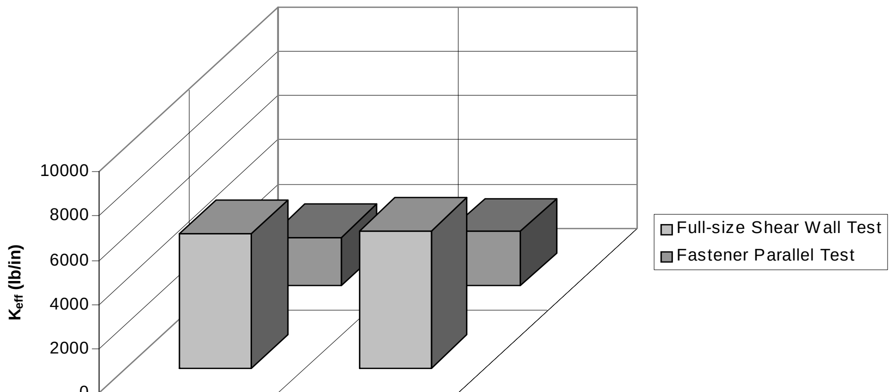
Ultimate Strength State and Effective Shear Stiffness are compared. To verify sample test, results of similar shear wall tests are compared. Data of shear wall cyclic tests is very limited. Some test data of two distinct framing types and fasteners, Specimens W8 and S8 will be discussed. All sheathings are 7/16-in OSB and most of the specimens are 8ft x 8ft except for those mentioned. Fastener strength is computed, divided shear wall strength by number of nails at one edge. Effective shear stiffness was calculated by the NAHB method.

- **4-inch Fastener Spacing (Graphs 8.1 & 8.2)**



	W8	S8
Full-size Shear Wall Test	253	355
Fastener Parallel Test	575	580

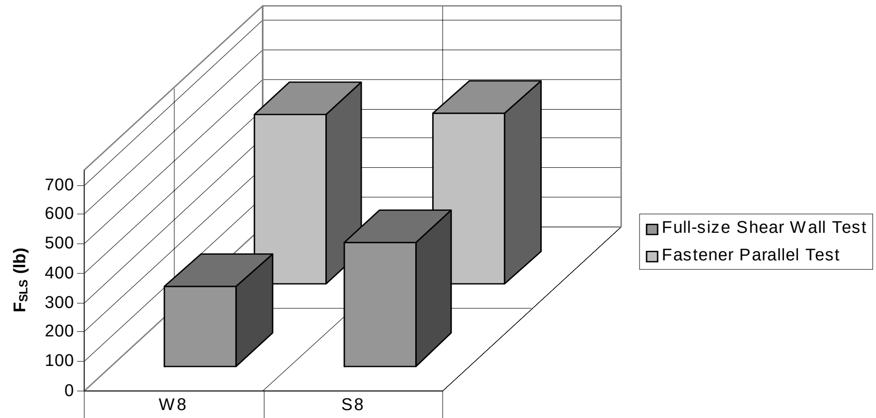
Graph 8.1. Fastener Parallel Test Strength vs. Shear Wall Strength
Shear wall S8 strength is higher than shear wall W8.
Shear wall strengths are lower than fastener Parallel Tests.



	W8	S8
Full-size Shear Wall Test	6093	6229
Fastener Parallel Test	2192	2475

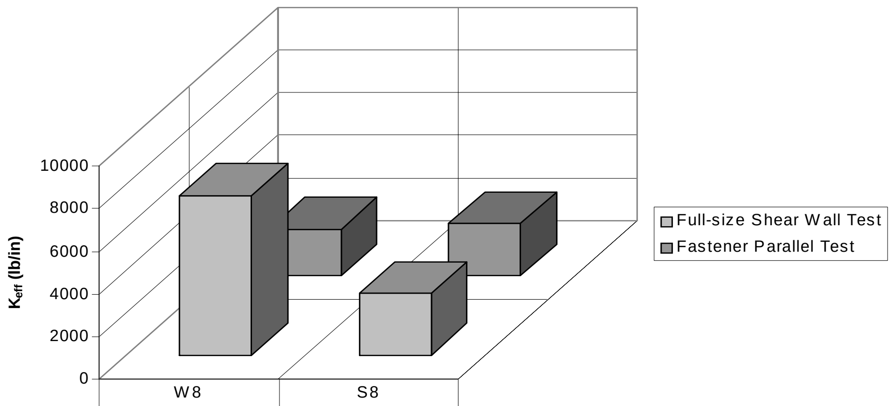
Graph 8.2. Fastener Parallel Test Stiffness vs. Shear Wall Stiffness
Shear walls W8 and S8 have similar stiffness.
Shear wall stiffness are much higher than fastener Parallel Tests.

- **3-inch Fastener Spacing (Graphs 8.3 & 8.4)**



	W8	S8
Full-size Shear Wall Test	272	419
Fastener Parallel Test	575	580

Graph 8.3. Fastener Parallel Test Strength vs. Shear Wall Strength
Shear wall S8 is 4ft x 8ft.
Shear wall S8 strength is higher than shear wall W8.
Shear wall strengths are lower than fastener Parallel Tests.



	W8	S8
Full-size Shear Wall Test	7500	2908
Fastener Parallel Test	2192	2475

Graph 8.4. Fastener Parallel Test Stiffness vs. Shear Wall Stiffness
Shear walls W8 stiffness is higher than S8 stiffness.
Wood shear wall stiffness is higher than fastener Parallel Test stiffness.
4ft x 8ft CFS shear wall stiffness is similar to fastener Parallel Test stiffness.

2.4 Discussion

Wood shear wall strengths of cyclic tests are lower than CFS shear wall strengths. Both 8ft x 8ft shear walls have the similar stiffness. Narrower shear wall has more ductility, which is good for life safety, but not good for repair cost.

Wood shear wall strengths range 44% to 47% of fastener Parallel Tests strengths. The reason is that, in shear wall tests, fasteners had different behaviors in the corner or the middle of the panel edge when shear wall failed. Shear wall strength is the average value.

CFS shear wall strengths range 61% to 72% of fastener Parallel Tests strength, which is higher than wood framed shear wall. The reason is that some CFS shear walls failed due to stud buckling, which could absorb some energy. Effective shear wall stiffness is higher than fastener Parallel Tests stiffness.

3.0 Conclusion and Recommendation

3.1 Conclusions

The results of the testing program described in this thesis provide several important behavioral characteristics of fasteners in Parallel and Perpendicular Tests. Some fundamental parameters used to characterize the lateral behavior of these fasteners include the data for the Yield Limit State, Strength Limit State, Effective Shear Stiffness, and Initial Shear Stiffness. Another significant behavioral characteristic observed and recorded during the testing procedure was the different failure mechanisms. General observations obtained in this study are as follows:

- Strengths under parallel loads are higher than that under perpendicular load.
- Stiffness under parallel loads is higher than under perpendicular load.
- The variability of wood and OSB sheathing strength requires attention. Strong-Wall™ Shearwall developed by Simpson Strong-Tie Co., Inc. uses steel strips at the edge of OSB sheathing to prevent the nails pulling through sheathing, which got higher strength in the cyclic tests.
- Fastener tests alone provided no answer if wood or CFS walls are better.
- Quality control is very important during construction (Schierle, 1993). Pre-fabricated shearwall like Simpson Strong-Wall™ Shearwall might be a good solution.

- Life safety and earthquake repair costs should be balanced in design. UBS 1997 deals only with life safety.
- CFS is more labor intensive, because screws are driven individually.
- The Parallel Test is more valuable than the Perpendicular Test, because studs subject to bending are not effective to resist perpendicular load.
- CFS shear walls have higher strength than wood shear walls.
- Narrower shear walls are more ductile than long shear walls.
- Stud buckling of CFS shear walls critically affects strength and stiffness.

3.2 Recommendation

- Fastener performance should be based on parallel rather than perpendicular test, both in monotonic and cyclic mode.
- A realistic protocol should be developed for dynamic tests of CFS shear walls.
- More tests are needed on Snap-Cap system to improve their performance.
- New means should be developed to solve the thermal bridge problem of CFS framing, such as adding insulation outside the sheathing.
- Considering the constant quality of steel, a lower safety factor could be considered for CFS framing.
- Stud buckling of CFS shear walls, requires more research.
- Dynamic tests should be conducted on CFS shear walls, because screws tend to tilt and dynamic test may result in three-dimensional tilting.