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Summary

The results of a series of reversed cyclic 4 ft. x 8 ft. (length x height) 15/32-in. plywood and 7/16-in. oriented strand board (OSB) shear wall tests are presented in this paper. The walls were framed with C-shaped 3-1/2 in. 20 gauge (0.036 in.) studs at 24 in. on center. Each wall was subjected to a sequential phase displacement time history at a frequency of 0.67 Hz. Performance of the wall was shown to depend on the type of sheathing material, the strength of the chord studs, and the screw fastener schedule. Although the hysteretic loops were significantly pinched (a characteristic of the light framed shear wall), the wall was shown to be capable of dissipating significant energy before failure. Based on these limited test data, recommendations for interpretation of these data for design are presented.

Introduction

Residential structural framing using light gauge steel is an option that many designers, developers, and homeowners are now considering as an alternative to wood construction. The information available for design of light gauge steel framing, however, is not as extensive as that which exists for wood. The purpose of the experimental research program presented here was to investigate the "psuedo-dynamic" behavior of light gauge steel framed shear walls sheathed with plywood and oriented strand board (OSB) and attached to the frame using No. 8 screws at different screw schedules.

Test Program and Setup

The basic steel framing for the 4 ft. x 8 ft. walls is shown in Figure 1. At the ends of the wall, double studs (back-to-back) were used to prevent local and flexural buckling in the chords. Figure 1 also shows the position of the anchor (shear) and the hold-down bolts. The shear bolts adjacent to the hold-downs were located in accordance with Section 403.1 of the 1995 CABO One & Two Family Dwelling Code (not more that 12 in. from the corner). For the shear wall to develop its full capacity based on the sheathing, the hold-down and anchor bolts were over designed. The average maximum capacity for the hold-downs used in all the tests was 21,197 lb. (based on literature provided by the hold-down manufacturer).

A total of 16 walls were tested in this program. The configurations of the walls are summarized in Table 1. The walls were designed to prevent shear failure at the base of the wall or failure due to overturning. At the ends of the wall, double studs back-to-back were used to limit failure due

to buckling in the chords. For each wall configuration evaluated, two tests were performed. This provided a minimum level of reliablility/validity of the test data.

Details of the components of the shear walls are given below:

- *Studs:* 20 gauge 3.50 in. C-stud with 1.625 in. flange and 0.375 in. lip, fabricated from ASTM A446 Grade A (33 ksi) steel--all studs were mill certified.

- *Track:* 20 gauge 3.5 in. C-track with 1.25 in. flange, fabricated from ASTM A446 Grade A (33 ksi) steel--all tracks were mill certified.

- *Framing screws:* No. 8 x 0.5 in. Wafer (Modified Truss) Head self-drill.

- *Hold-downs (tie-down) screws:* No. 10 x 1 in. Hex Washer Head self-drill (in a few cases--three tests--No. 10 x 0.625 in. Pancake Head self-drill screws were used).

- *Plywood (15/32-in.) and OSB (7/16-in.) screws:* No. 8 x 1 in. Flat Head w/counter sinking nibs under the head, type 17 point, coarse high thread.

- *Installation of plywood and OSB screws:* All screws were installed a minimum of 3/8 in. (+ 1/16 in.) from the edge of the plywood or OSB panel.

All walls were assembled in a horizontal position then lifted vertically and installed in the test frame as shown in Figure 2. Details of anchorage of the wall and attached of the loading plate at the top of the wall are illustrated in Figure 3. At the base of the wall a 3.5 in. by 0.5 in. aluminum spacer plate (the full length of the wall) was installed between the bottom track and the fixed base of the test frame. The spacer plate allowed the plywood or OSB panel to displace relative to the framing without bearing on the base of the test frame (before failure). At the top of the wall a similar spacer was used between the loading plate and the track.

The test protocol used in this research program (see Figure 4) is referred to as the sequential phase displacement protocol. This protocol has been recommended by the Ad Hoc Committee on Testing Standards for Structural Systems and Components--Structural Engineers Association of Southern California--for testing of shear wall assemblies. The walls were cycled at 1.5 seconds per cycle (0.67 Hz).

Instrumentation

The instrumentation for the tests is shown in Figure 5. Four displacements--top of wall lateral displacement (in-plane shear displacement), uplift at both ends of the wall, and slip--and three loads--applied load at top of wall, two hold-down loads--were measured and recorded electronically using a special purpose data acquisition and control system. The position of the wall was monitored 300 times a second and data was recorded at a rate of 50 times per second. Each recording included wall displacements and loads.

Behavior and Test Results

The overall behavior of the plywood and OSB panel assemblies was practically identical. In general, racking of the wall resulted in the screw fasteners rocking (tilting) about the plane of the stud flange (as illustrated in Figure 6). Rocking resulted in the head and shank of the screw pressing into the panel and bending in the flange immediately around the screw hole. This behavior resulted in permanent lateral deflection of the wall and appears to be the main source of energy dissipation in the walls. As the lateral displacement of the wall increased, the panel pulled over the screw heads with subsequent unzipping of the wall, as shown in Figure 7. As the panel unzipped, the capacity of the wall dropped off. An examination of the walls after each test revealed that except for three screws (in the 16 walls tested) no screws pulled out of the stud flanges. It was also observed that none of the screws suffered any significant bending and none of the screws fractured from fatigue.

For all walls with screw schedules of 3 in./12 in. and 2 in./12 in., the chord studs crippled (crushed) locally either at the position of web cut-out above the hold-down or at the hold-down, as shown in Figure 8. Crippling appeared to promote the pull-over behavior of the panels. The walls with 2 in./12 in. schedules also exhibited local/distortional buckling in the flange of the studs adjacent to the compression chord.

Tabulated results from the test program are given in Table 2. Data are presented for the nominal load capacity at the last and second to last set of stable hysteretic loops, and the corresponding level of lateral displacement. The nominal load and displacement values are based on averages from the "push-pull" regimes of the time history. Typical plots of load versus total top of wall lateral displacement are given for 4 representative walls in Figures 9, 10, 11 and 12.

Discussion of Test Results

A comparison of the plywood and OSB walls with the same screw schedules indicates that the plywood walls had generally higher load capacities than corresponding OSB walls. The difference in capacities, appears to be approximately 10% (neglecting the walls with the 2 in./12 in. screw schedule):

> - plywood vs. OSB with screws at 6 in./12 in.: 1.11
> - plywood vs. OSB with screws at 4 in./12 in.: 1.08
> - plywood vs. OSB with screws at 3 in./12 in.: 1.15
> - plywood vs. OSB with screws at 2 in./12 in.: 0.96

The ratio for the walls with fasteners at 2 in./12 in. is approximately one because the failure was controlled by crushing of the chord studs (which were identical for the plywood and OSB walls). The 10% higher capacity should be viewed in perspective since the plywood is approximately 7% thicker that the OSB.

Ideally, three limit states of behavior for the wall assemblies should be considered when establishing the nominal design strength of wall: maximum strength, stiffness (displacement),

and damage. The damage limit state is difficult to interpret since there are no established procedures for doing so. Thus, in this project no attempt was made to characterized load capacity based on damage.

A detailed review of the load displacement curves for the 16 walls showed the following basic trends:

- strength degradation at a given level of displacement is initially stable
- stiffness degradation with increasing lateral displacement (characterized by a load-displacement curve which lead to severe pinching of the hysteretic loops)

The current trend in the design of light framed wood shear walls is based on static test data. Following the recommendations of the 1994 UBC, the allowable design load in a plywood wall, on wood framing, is established to provide an elastic lateral displacement of 0.5 in. (0.005H; H = wall height) at the allowable load. The wall should also be able to at least maintain its capacity up to an inelastic lateral displacement of approximately $3R_w/8$ times the elastic displacement (where Rw is a structural system coefficient).

For the cyclic tests, the following criteria are suggested for interpretation and development of design data:

- load at which pinching becomes markedly evident represents a change in wall stiffness and may be used to establish the elastic limit state for the wall--typically occurred in the region of 0.75 in.

- load at the last set of stable hysteretic loops (stable loops being defined as consecutive cycles at a given level of displacement where the strength does not change by more than 5% between consecutive cycles at that displacement)--*use the strength given by the lowest hysteretic loop*

- interpret the back-bone curve as an equivalent static curve (back-bone based on the lowest strength loop at a cycle displacement)

- compute the energy dissipated and limit the capacity based on the energy demand of the wall

Conclusion

The results from cyclic (pseudo-dynamic) in-plane shear wall tests for light gauge steel framing are presented. Based on the results from the tests, the following preliminary conclusions can be drawn:

(1) The measured maximum resistance of the plywood walls was higher (approximately 10%) than that of the OSB walls.

(2) Attention to the design of chords studs for panels with tight screws schedules (3 in./12 in. and 2 in./12 in.) is critical for the wall to develop its capacity.

(3) More research is needed to establish strength values for walls with tight screw schedules when the chord studs do not fail prematurely.

Acknowledgments

References

Serrette, R., Nguyen, H., and Hall, G. (1996). "Shear Wall Values for Light Weight Steel Framing." Report No. LGSRG-3-96, Light Gauge Steel Research Group, Santa Clara University, Santa Clara, CA

Table 1 Description of wall configurations tested

Test Specimen	Wall Description	Fastener Schedule	Wall Dimensions
AISI-OSB1 AISI-OSB2	7/16" OSB APA rated sheathing w/panels on one side--parallel to framing (framing at 24 in. o.c.)	6 in. / 12 in.	4 ft. x 8 ft.
AISI-OSB3 AISI-OSB4	same	4 in. / 12 in.	4 ft. x 8 ft.
AISI-OSB5 AISI-OSB6	same	3 in. / 12 in	4 ft. x 8 ft.
AISI-OSB7 AISI-OSB8	same	2 in. / 12 in.	4 ft. x 8 ft.
AISI-PLY1 AISI-PLY2	15/32" plywood APA rated sheathing (40ply) w/panels one side--parallel to framing (framing at 24 in. o.c.)	6 in. / 12 in.	4 ft. x 8 ft.
AISI-PLY3 AISI-PLY4	same	4 in. / 12 in.	4 ft. x 8 ft.
AISI-PLY5 AISI-PLY6	same	3 in. / 12 in.	4 ft. x 8 ft.
AISI-PLY7 AISI-PLY8	same	2 in. / 12 in.	4 ft. x 8 ft.

Notes:
Studs and track are 3-1/2 in. 20 ga.--ASTM A446 Grade A (33 ksi) steel
Studs flange: 1-5/8 in.; stud lip: 3/8 in.; Track (runner) flange: 1-1/4 in.
Framing screws: No. 8 x 1/2 in. Wafer (Modified Truss) Head self-drill.
Hold-downs screws: No. 10 x 1 in. Hex Washer Head self-drill
Plywood and OSB screws: No. 8 x 1 in. Flat Head w/counter sinking nibs under the head, type 17 point, coarse high thread
20 ga. = 0.0346 in. (design thickness)

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Table 2 Summary of test results

Test Specimen	Wall Description	Nominal load capacity at 2nd to last stable hysteretic loops[1], lb/ft.	Displacement at 2nd to last stable hysteretic loops, in.	Nominal load capacity at last stable hysteretic loops[1], lb/ft.	Displacement at last stable hysteretic loops, in.
AISI-OSB1 AISI-OSB2	7/16" OSB APA rated sheathing w/panels on one side--parallel to framing (framing at 24 in. o.c.--fasteners at 6"/12"--4'x8' wall)	700 700	1.50 1.20	700 700	1.80 1.80
AISI-OSB3 AISI-OSB4	7/16" OSB APA rated sheathing w/panels on one side--parallel to framing (framing at 24 in. o.c.--fasteners at 4"/12"--4'x8' wall)	900 710	1.20 0.90	1000 825	1.80 1.20
AISI-OSB5[2] AISI-OSB6[2]	7/16" OSB APA rated sheathing w/panels on one side--parallel to framing (framing at 24 in. o.c.--fasteners at 3"/12"--4'x8' wall)	1400 1000	1.80 0.90	1450 1100	2.30 1.20
AISI-OSB7[2] AISI-OSB8[2]	7/16" OSB APA rated sheathing w/panels on one side--parallel to framing (framing at 24 in. o.c.--fasteners at 2"/12"--4'x8' wall)	1400 1400	1.20 1.20	1650 1750	1.70 1.70
AISI-PLY1 AISI-PLY2	15/32" plywood APA rated sheathing (4-ply) w/panels one side--parallel to framing (framing at 24 in. o.c.--fasteners at 6"/12"--4'x8' wall)	750 610	1.20 1.20	785 775	1.80 1.80
AISI-PLY3 AISI-PLY4	15/32" plywood APA rated sheathing (4-ply) w/panels one side--parallel to framing (framing at 24 in. o.c.--fasteners at 4"/12"--4'x8' wall)	850 825	1.20 0.95	975 1000	1.80 1.20
AISI-PLY5[2] AISI-PLY6[2]	15/32" plywood APA rated sheathing (4-ply) w/panels one side--parallel to framing (framing at 24 in. o.c.--fasteners at 3"/12"--4'x8' wall)	1300 1350	1.75 1.75	1475 1450	2.30 2.30
AISI-PLY7[2] AISI-PLY8[2]	15/32" plywood APA rated sheathing (4-ply) w/panels one side--parallel to framing (framing at 24 in. o.c.--fasteners at 2"/12"--4'x8' wall)	1400 1425	1.15 1.15	1675 1575	2.70 1.70

[1] based on the lowest strength curve (average of the +/- values)
[2] crippling in compression stud above hold-down or at web cutout above hold-down

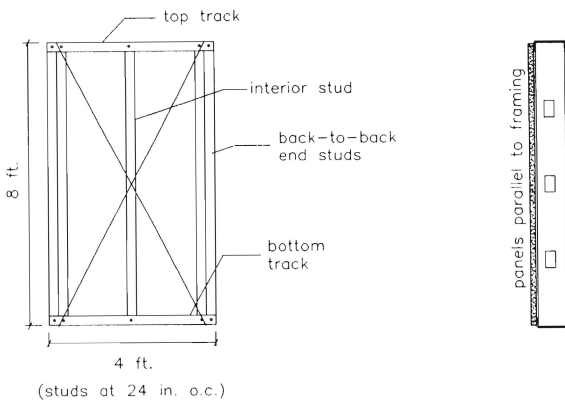Light Gauge Steel Research Group, Santa Clara University, Santa Clara, CA 95053
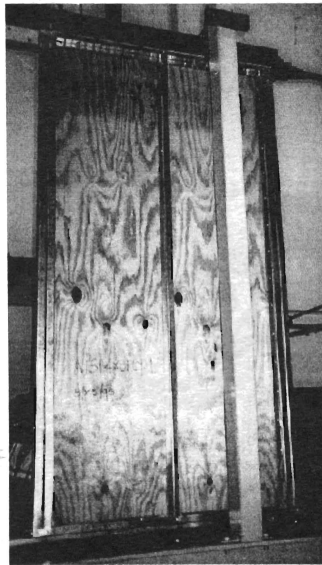
Figure 1 Basic wall frame

Figure 2 Overall test setup
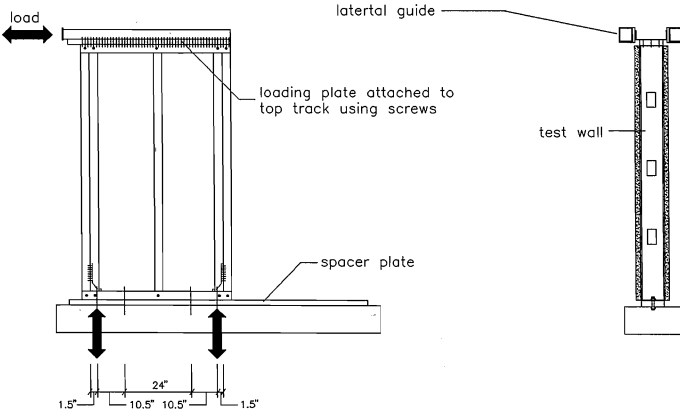
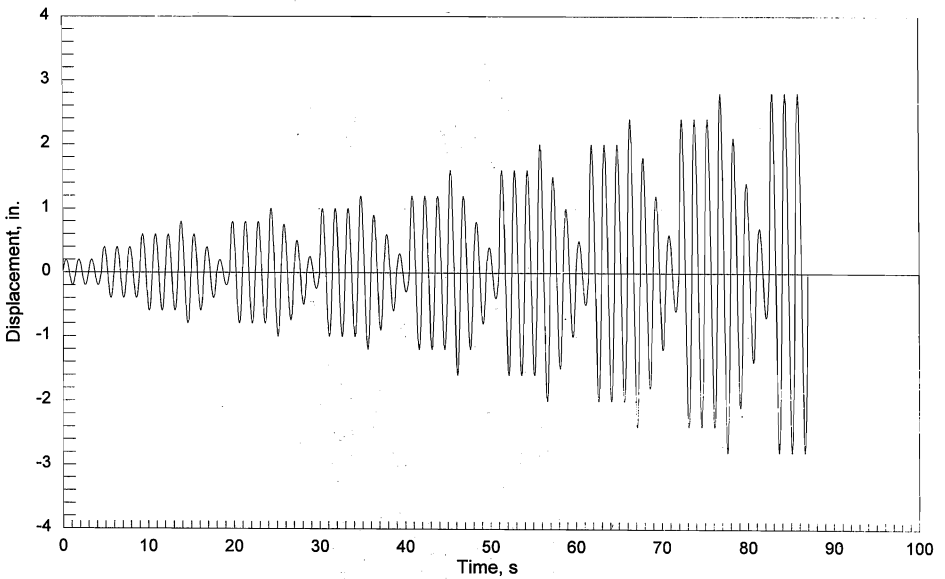Figure 3 Wall anchorage detail

Figure 4 Cyclic test protocol

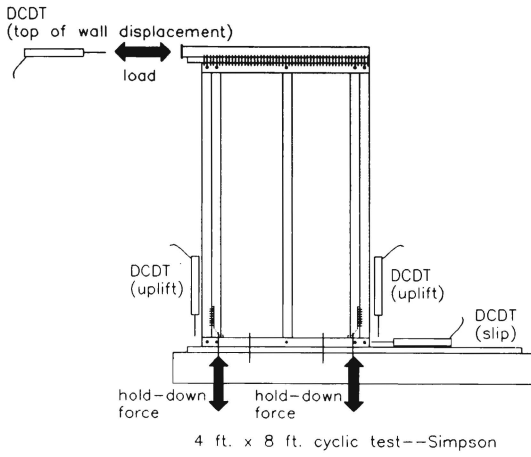4 ft. x 8 ft. cyclic test--Simpson
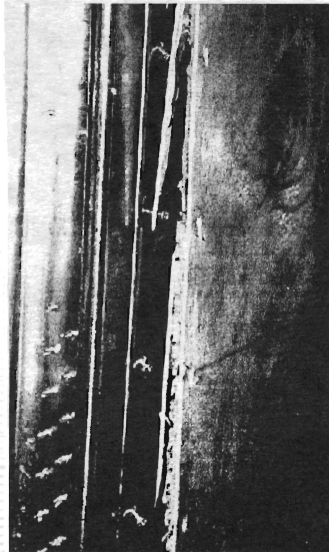
Figure 5 Instrumentation

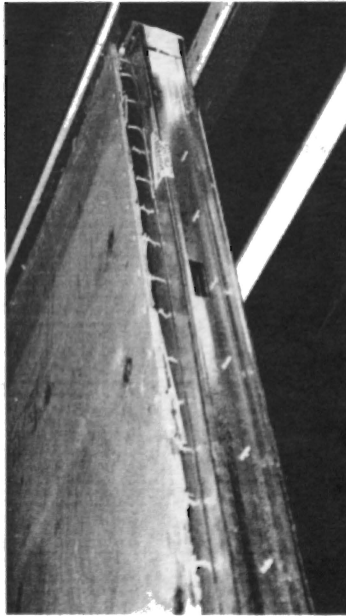Figure 6 Behavior of screws

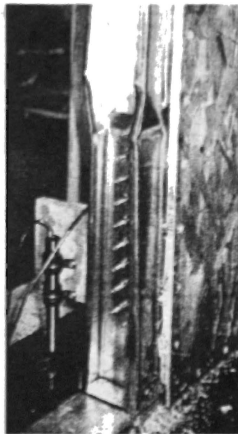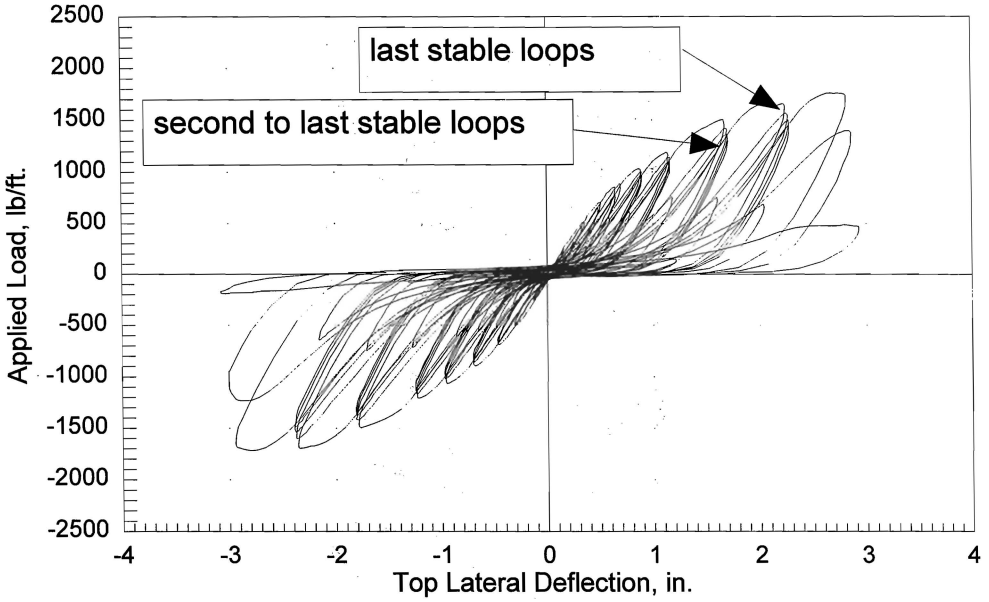Figure 7 Unzipping of panels

Figure 8 Crippling in chord stud

Figure 9 Typical hysteretic loops for cyclically tested wall