Cyclic Testing of Fiberboard Shear Walls with Varying Aspect Ratios

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America's Housing Technology and Information Resource

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PURPOSE AND SCOPE

The purpose of this testing program is to measure the cyclic performance of light-frame wood shear walls braced using fiberboard structural panels. Shear wall segments with aspect ratios varying from 1:1 to 4:1 are tested.

METHODS AND MATERIALS

Testing was conducted at the NAHB Research Center laboratory in Upper Marlboro, MD in January 2006.

Testing was conducted in accordance with general provisions of ASTM E 2126-05 *Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Walls for Buildings* (ASTM International, 2005). Shear wall test matrix is summarized in Table 1.

Table 1 - Test Matrix

Configuration #	Specimen Width	Aspect ratio	Stud Spacing	Sheathing Fasteners	Overturning Restraint
1	96 inch	1:1	16 inch	Roofing Nails	Holddown
2	48 inch	2:1	16 inch	Roofing Nails	Holddown
3	32 inch	3:1	16 inch	Roofing Nails	Holddown
4	24 inch	4:1	12 inch	Roofing Nails	Holddown

A total of four shear wall configurations were tested with aspect ratios of 1:1, 2:1, 3:1, and 4:1, respectively. A sample size of two was used for each shear wall configuration. A total of eight specimens were tested.

Table 2 summarizes materials and construction details and Table 3 summarizes fastening schedules.

Table 2 - Materials and Wall Construction

Wall height:	8 feet
Wall width:	per test matrix (Table 1)
Openings:	None
Stud height:	91.5 inches
Framing lumber:	2x4 Southern Yellow Pine (SYP), grade not indicated 2-2x4 SYP top plates 2-2x4 SYP corner studs
Stud spacing:	per test matrix (Table 1)
Sheathing:	4'x8' ½-inch-thick fiberboard structural sheathing (ASTM C 208) cut to required width
Holddown:	Simpson HTT16 raised 1 inch from bottom plate
Anchor bolts:	½-inch diameter bolts with round cut washers spaced a maximum of 48 inches on center and located at 12 inches from corners. For 32-inch-wide walls, anchor bolts located at quarter points, i.e., 8 inches from corners. For 24-inch-wide walls, anchor bolts located at third points, i.e., 8 inches from corners.
Sheathing nails:	electro-galvanized roofing nails (D=0.120", L=1-1/2", H=7/16" – nominal)
Framing nails:	16d pneumatic nails (D=0.131", L=3.25")
Sheathing nail edge distance:	3/8" at interior panel joints (Configuration 1 only), 3/4" at all other edges
Interior sheathing:	none

Table 3 - Fastening Schedule

Connection	Fastener	Spacing
Top plate to top plate (face-nailed)	16d pneumatic	24 inches on center
Top/bottom plate to stud (end-nailed)	2-16d pneumatic	per connection
Stud to stud (face-nailed)	16d pneumatic	24 inches on center
Holddown	18-16d common	per hold-down
Sheathing panels to framing	Roofing nails	3 inches on perimeter 6 inches in field

Figure 1 shows a schematic of a typical shear wall test setup including instrumentation. Figure 2 is a photograph of a test setup with a 4-foot shear wall specimen.

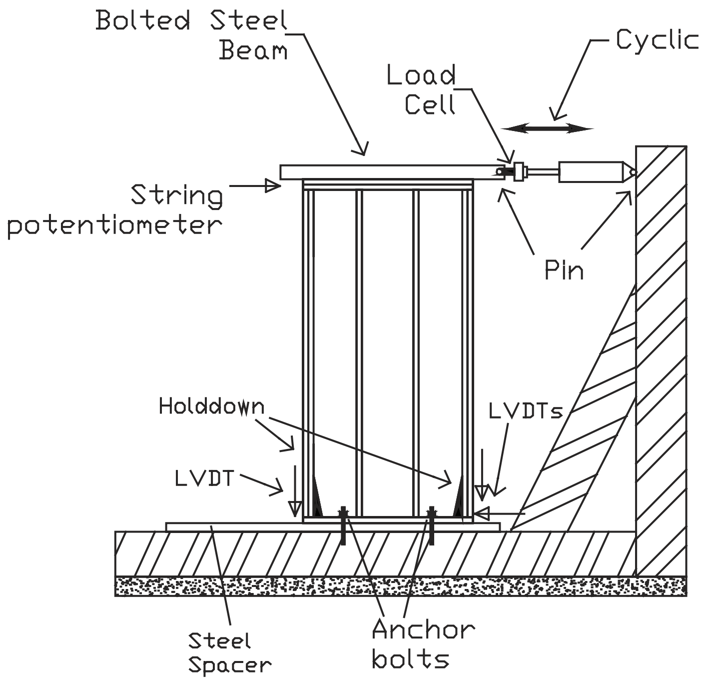


Figure 1 - Shear Wall Test Setup

Figure 2 - 4-ft Shear Wall Test Specimen

Shear walls were tested by displacing the top of the specimen in accordance with a displacement-controlled CUREE cyclic protocol (Method C, ASTM E 2126) at a constant frequency of motion of 0.2 Hz (5 seconds per cycle) (Figure 3). Hydraulic actuator motion was applied using 4-inch by 4-inch by 0.25-inch-wall steel distribution beam bolted to the top plate of the specimen. Reference deformation (Δ) of 2.4 inches was used with the CUREE displacement history. This reference deformation was selected based on review of monotonic test results of fiberboard shear walls (Dolan and Toothman, 2003) and was bound by the requirement of AC130 (ICC-ES, 2004) for delta not to exceed 2.5% of wall height. The hydraulic actuator had a total stroke of 12 inches. Therefore, a maximum excursion of 6 inches (minus a tolerance of 0.25 inches on the maximum excursion for instrument preservation purposes) was applied to the specimen. A sampling rate of 20 Hz was used such that 100 data points were recorded for each cycle.

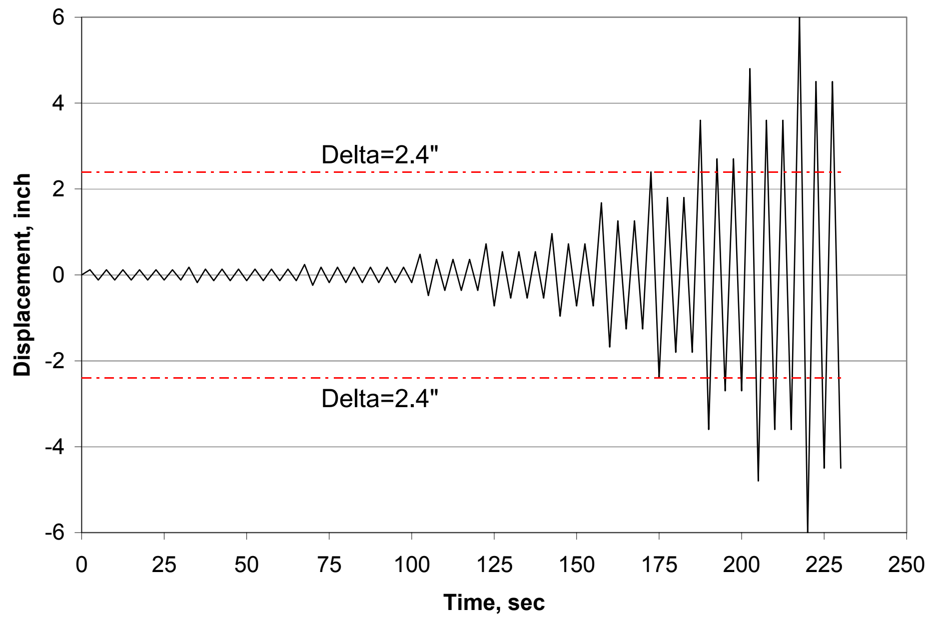


Figure 3 - CUREE Protocol

Load was measured using a 20,000 lb capacity electronic load cell located between the cylinder and the steel distribution beam. Displacement of the top of the wall was measured using a string potentiometer. Bottom plate slip and vertical wall deformations were measured using linear variable differential transformers (LVDT). Shear wall deflections reported in the Results section of the report are adjusted for the bottom plate slip.

Specimens were fabricated using kiln-dried southern yellow pine (SYP) lumber. Moisture content of lumber was measured using an electric moisture meter (Method A, ASTM D 4444) at fabrication and testing and ranged from 6 to 9 percent. The average specific gravity of lumber was at 0.57 with a coefficient of variation of 10% (Method A, ASTM D 2395). Each specimen was fabricated a minimum of 24 hours before testing.

Specimens were set on a 3.0-inch-wide steel channel spacer that allowed for sheathing panel rotation without interference with the setup. The loading beam was also installed such that it did not interfere with the panel rotation. Anchor bolts and holddown anchors were pretensioned by not more than ½ turn beyond finger-tight fit or not more than 500 lb where load cells were installed (an experiment showed that ½ turn approximately corresponded to 500 lb of pretension load).

Fiberboard panels and lumber were supplied by the American Fiberboard Association (IAS AA697). Fasteners and hardware were purchased from a local supplier.

RESULTS

Test results including peak load, unit shear, wall deflection at peak load, uplift at peak load are summarized in Table 4 for each specimen. Performance parameters are reported for each direction of motion (push and pull). Average value is calculated as an arithmetic average of the parameter in positive and negative directions. This average represents the test value for each performance parameter for a specimen. Average unit shear values, average deflection at peak load values, and average uplift at peak load values are also provided for each configuration.

Figure 4 shows the change in the average unit shear as a function of the aspect ratio. Figure 5 shows the change in the average value of deflection at peak load as a function of the aspect ratio. Figures 6-9 show load-deflection relationships for each specimen. All load-deflection charts have the same deflection range of ±6 inches and unit shear range of ±800 lb/ft. This graphical presentation of the results allows for direct comparison of the performance between different configurations.

Peak loads agree within 10% for replicates in each configuration. Calculation of cyclic stiffness is outside of the scope of this report. Visual evaluation of load-deformation relationships indicated good repeatability in the overall response between replicates in each configuration.

Results indicate that increase in shear wall aspect ratio from 1:1 to 4:1 is associated with a decrease in unit shear (Figure 4) and an increase in deflection at peak load (Figure 5). The relative affect of aspect ratio is greater on deflection at peak load than on unit shear. The evaluation of the significance of the observed effect of aspect ratio on unit shear and stiffness is outside of the scope of this report.

The average uplift at peak load for all configurations is within a narrow range of 0.35-0.39 inches. This observation indicates that uplift forces at corners are not sensitive to the aspect ratio and the increase in the wall deflection is caused by other factors including the difference in geometric amplification of the uplift deformations and an increased contribution of the bending component.

Failure mode for all specimens was primarily associated with a degradation of the sheathing nail connections. Sheathing nails bent, pulled out of framing, and tore through the edges of fiberboard panels. Figure 10 depicts typical failure modes for all four test configurations.

Table 4 - Summary of Test Results[1]

Config. #	Aspect ratio	Spec. #	Peak Load, lb			Average Unit Shear, lb/ft	Deflection @ Peak Load, inch			Uplift @ Peak Load, inch		
			Pos. Dir.	Neg. Dir.	Average		Pos. Dir.	Neg. Dir.	Average	Pos. Dir.	Neg. Dir.	Average
1	1:1	1	6,000	-5,290	(5,650)	710	3.0	-3.5[2]	(3.3)	0.38	0.35	0.37
		2	5,720	-5,320	(5,520)	690	2.8	-2.3[2]	(2.6)	0.39	0.28	0.34
					Average	**700**		**Average**	**2.9**		**Average**	0.35
2	2:1	3	2,780	-2,720	(2,750)	690	3.5	-3.5	(3.5)	0.36	0.34	0.35
		4	2,580	-2,490	(2,530)	630	3.4	-3.6	(3.5)	0.37	0.34	0.36
					Average	**660**		**Average**	**3.5**		**Average**	0.35
3	3:1	5	1,580	-1,550	(1,560)	590	4.3	-4.2	(4.3)	0.43	0.29	0.36
		6	1,410	-1,630	(1,520)	570	4.4	-4.2	(4.3)	0.42	0.42	0.42
					Average	**580**		**Average**	**4.3**		**Average**	0.39
4	4:1	7	1,080	-1,110	(1,100)	550	4.4	-5.1	(4.8)	0.37	0.4	0.39
		8	1,070	-1,090	(1,080)	540	5.3	-5.2	(5.2)	0.42	0.37	0.40
					Average	**540**		**Average**	**5.0**		**Average**	0.39

1. Positive direction – push excursion, negative direction– pull excursion.
2. Note that the apparent difference in displacement between Specimens 1 and 2 in negative direction is observed because the peak loads occurred at two successive excursions. However, the load deformation chart for Configuration 1 specimens shows that peak loads are nearly identical at both excursions and for practical purposes either one can be considered the peak load.

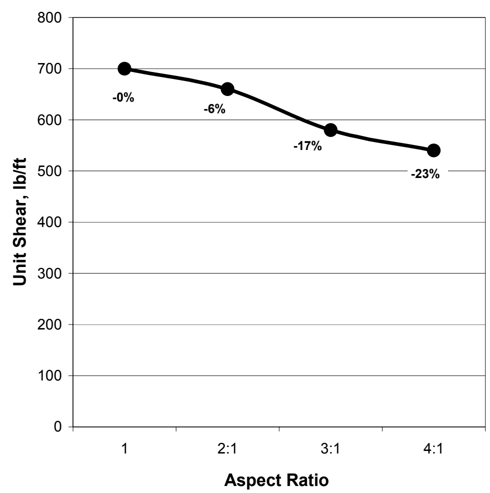


Figure 4 - Unit Shear vs. Aspect Ratio

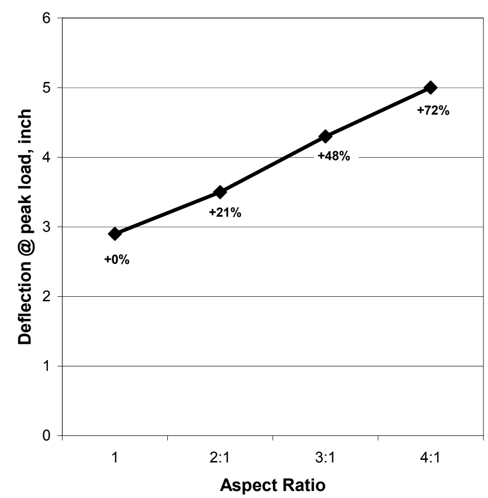


Figure 5 - Deflection @ Peak Load vs. Aspect Ratio

ASPECT RATIO: 1:1

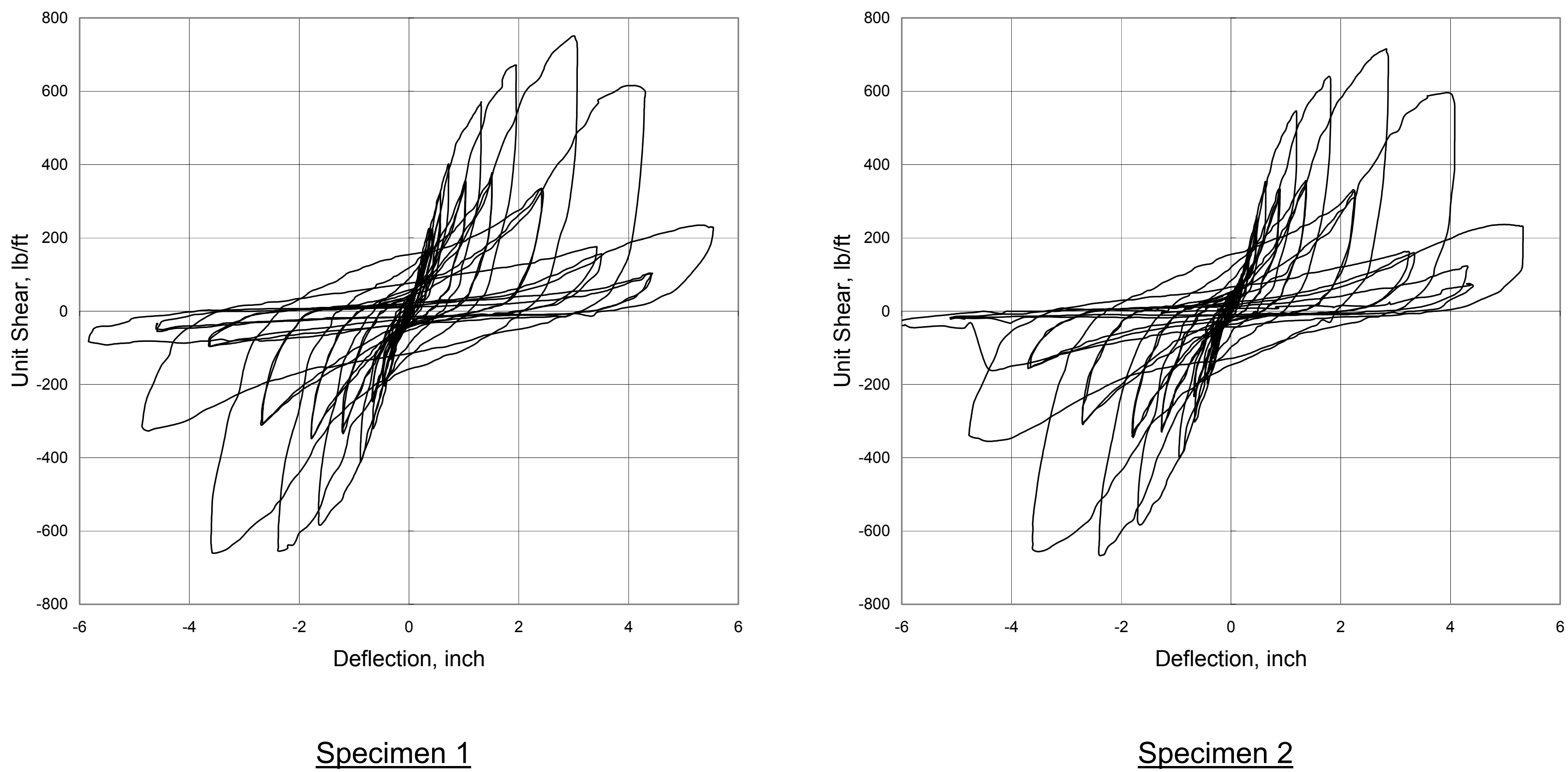
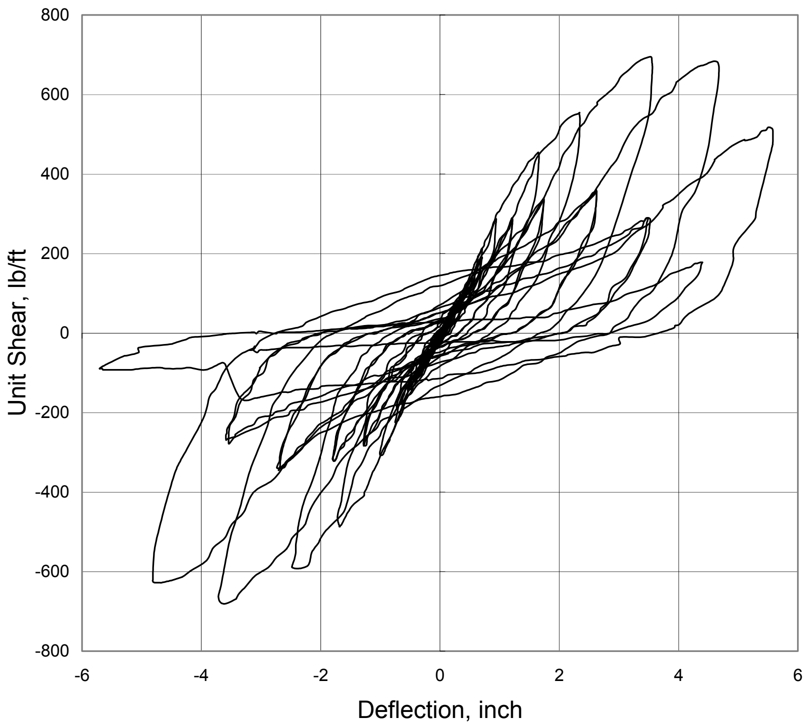
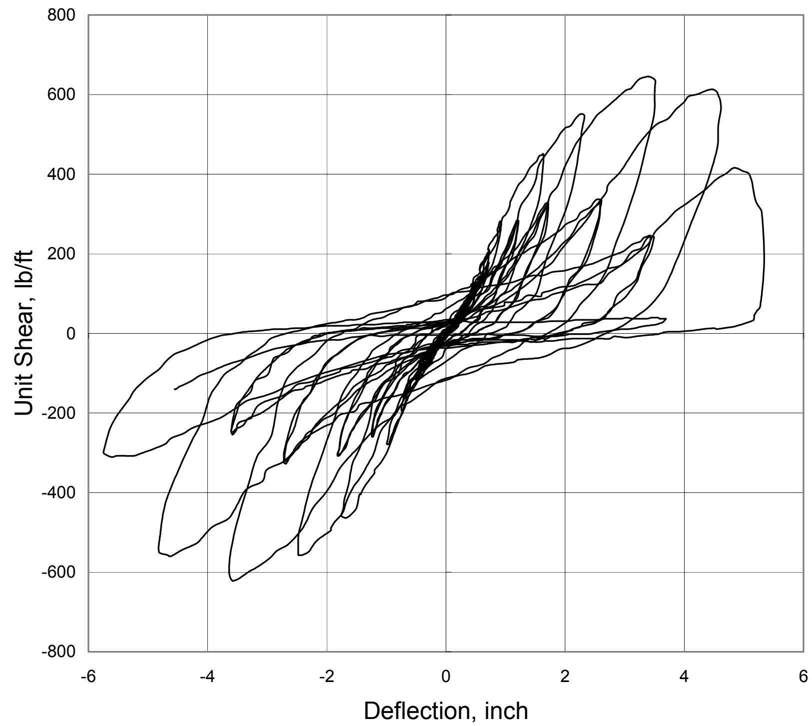


Figure 6 - Load vs. Deflection – Configuration 1

ASPECT RATIO: 2:1



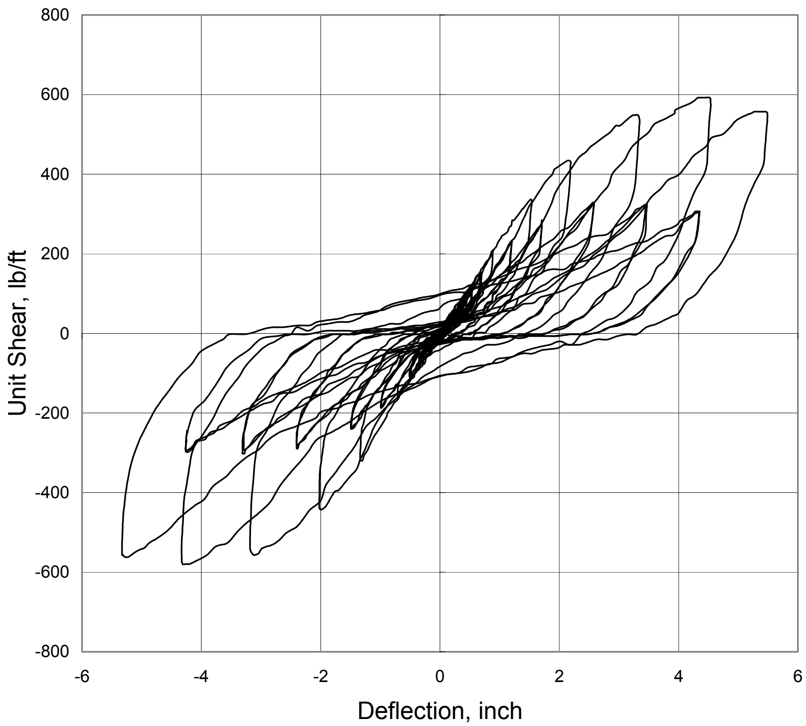
Specimen 3



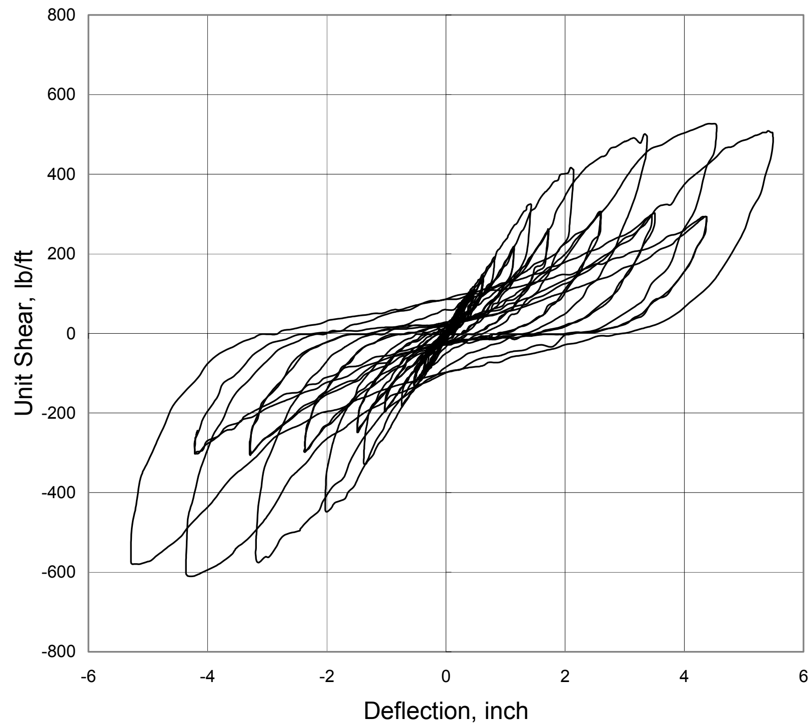
Specimen 4

Figure 7 - Load vs. Deflection – Configuration 2

ASPECT RATIO: 3:1



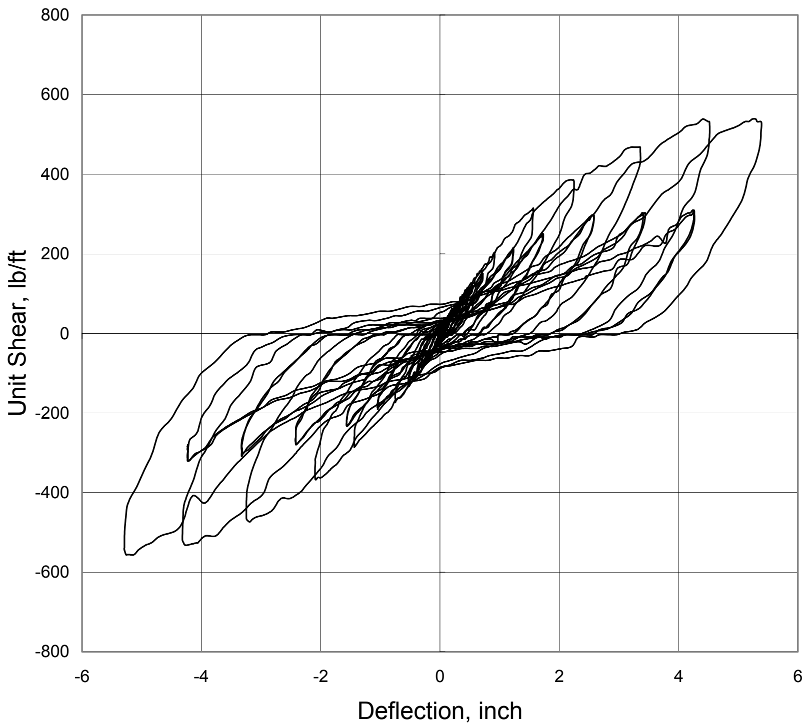
Specimen 5



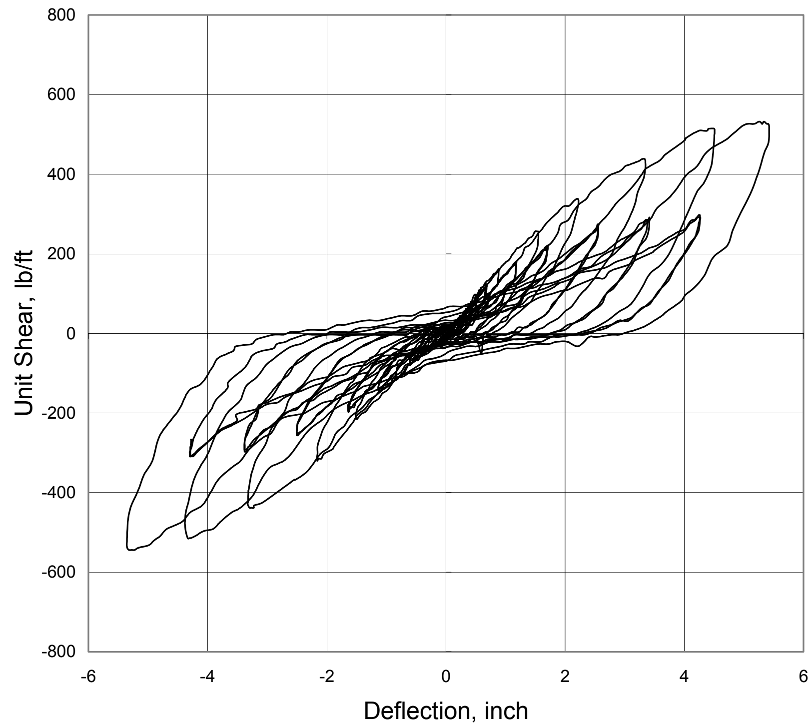
Specimen 6

Figure 8 - Load vs. Deflection – Configuration 3

ASPECT RATIO: 4:1



Specimen 7



Specimen 8

Figure 9 - Load vs. Deflection – Configuration 4

Configuration 1 (8'x8')

Configuration 1 (8'x8')

Configuration 2 (4'x8')

Configuration 2 (4'x8')

Configuration 3 (2.67'x8')

Configuration 4 (2'x8')

Figure 10 –Typical Failure Modes

SUMMARY

Fiberboard shear walls were tested using a cyclic protocol to measure the effect of aspect ratio on the shear wall performance. Results indicate a decreasing trend in unit shear and increasing trend in deflection at peak load with increasing aspect ratio. Evaluation of the significance of these trends including selection of appropriate triggers for the aspect ratio is outside of the scope of this test report.

REFERENCES

ASTM International. ASTM Standard E 2126-05 "Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Walls for Buildings". For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

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