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Benchmark Monotonic and Cyclic Tests of Fully-Restrained Wood Structural Panel Braced Walls

Miles E. Waltz Jr

Ned Waltz, PE, SECB
Senior Engineer, Product Evaluation

TEST LABORATORY: Weyerhaeuser Engineering Laboratory
Boise Technology Center
2910 East Amity Road
Boise, ID 83716
(208) 364-3600

TECHNICIANS: Zeb Atwood, Amber Kuhn

APPROVAL: Chris Brandt

Chris Brandt, PE
Senior Engineer
Codes, Standards, and Product Evaluation

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OBJECTIVES: To document the in-plane monotonic and cyclic shearwall performance of intermittent braced wall systems that combine wood structural panel sheathing with wood studs and full overturning restraint.

KEYWORDS: shearwall, brace, wood structural panel, sheathing, oriented strand board, OSB, panel, seismic, CUREE

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ABSTRACT:

This test program was undertaken to document the in-plane monotonic and cyclic performance of braced wall systems that combine wood structural panel shearwalls with wood studs and full overturning restraint. A total of eleven 8 ft. long by 8 ft. tall shearwalls were tested at the Weyerhaeuser Engineering Laboratory. Eight of these walls were monotonically tested in general accordance with ASTM E72 to measure their wall racking performance. Three were cyclically tested in general accordance with the "CUREE" load protocol of ASTM E2126 to provide an initial indication of their seismic attributes. As part of these tests, 3/8 in. OSB sheathing was evaluated using both Douglas-fir and spruce-pine-fir (SPF) wall framing and the minimum fastening provisions normally associated with prescriptive wall bracing. An additional set of walls with 3/8 in. OSB was monotonically tested to evaluate the wall sheathing using the wall racking test and fastening scheme employed by PS-2 for a sheathing qualification. A set of single "alternative" wall sheathing that has claimed structural equivalence to the wall racking attributes of wood structural panel wall bracing was also evaluated using matched monotonic and cyclic tests.

TABLE OF CONTENTS:

INTRODUCTION:

Recent industry discussions have focused on the expected in-plane racking shear resistance of the wood structural panel braced wall system defined as "WSP" in the *2012 International Residential Code* (IRC). As detailed by the IRC, the minimum WSP wall bracing system consists of:

- wood structural panel (WSP) wall sheathing with a minimum thickness of 3/8 in.,
- 6d common (0.113 x 2.0 in.) sheathing nails spaced 6 in. o/c at the panel edges and 12 in. in the field,
- 2x4 nominal lumber studs that typically range from spruce-pine-fir (SPF) to Douglas-fir or southern pine, and
- a wall stud spacing of 16 in. o/c.

While wood structural panel sheathing materials are monotonically qualified for racking resistance in accordance with *PS2-10: Performance Standard for Wood-based Structural-Use Panels (PS-2)*, the test details required for the PS-2 qualification of 3/8 in. thick sheathing do not correspond with the conditions outlined above. For the purpose of judging the suitability of the sheathing for the broad range of in anticipated end uses, the PS-2 qualification test targets a higher load configuration than described by the minimum IRC wall bracing provisions.

When designed in accordance with the American Wood Council's *2008 Special Design Provisions for Wind and Seismic* (SDPWS), the WSP wall bracing system described above has an engineered allowable seismic design capacity in fully-restrained applications that ranges between 185 and 200 plf depending upon the framing species. As detailed in the SDPWS commentary, ultimate monotonic capacities of a fully-restrained wood structural panel shearwall are on the order of 2.8 times the allowable seismic design strength. Despite this, in some technical task groups, questions have been raised about the expected tested performance of the baseline WSP bracing system described above.

The primary objective of this investigation was to use standardized, consensus test methods to conduct wall racking tests of the baseline WSP wall bracing system to benchmark its performance with Douglas-fir and spruce-pine-fir (SFP) framing. A secondary objective was to conduct a limited amount of cyclic testing of the same fully-restrained wall configurations to document the expected seismic performance attributes of similar wall configurations. A tertiary objective was to conduct matched tests to compare the performance of a commercially available "alternative" wall sheathing that has been recognized by some code evaluation organizations as an "equivalent" substitute for wood structural panel sheathing in IRC braced wall applications.

EXPERIMENTAL DESIGN:

Table 1 summarizes the experimental design adopted for this study. Further details regarding the specimen construction are provided in Appendices 1 and 2.

This test program consisted of in-plane monotonic wall racking tests conducted in general accordance with ASTM E72 and fully-restrained cyclic shearwall tests conducted in general accordance with ASTM E2126. The primary exceptions were that, given the scope of the test program and exploratory nature of the study, only two monotonic and one cyclic test were undertaken for each wall configuration.

Wall configuration A1 was monotonically tested as a means to judge whether the 3/8 in. oriented strand board (OSB) sheathing used for this investigation complied with the minimum wall racking requirements of PS-2. The 8d common sheathing nail selection and placement pattern reflected in Table 1 correspond with the qualification test requirements detailed by Table 5 of PS-2.

Wall configurations A2 and D1 were monotonically tested to satisfy the primary experimental objective: to investigate the wall racking performance of the baseline (code minimum) WSP bracing system using Douglas-fir and SPF framing materials. Wall configurations A3 and D2 were the similarly configured cyclic tests.

Table 1: Experimental Design – 8x8 ft. In-Plane Shearwall Tests

<table>
<tr><th>Task</th><th>n</th><th>Std.</th><th>Sheath</th><th>Fastener</th><th>Pattern
(edge/field)</th><th>Stud</th><th>Stud Space (in.)</th><th>Center Stud</th><th>Hold-down</th></tr>
<tr><td>A1</td><td>2</td><td>E72[1]</td><td rowspan="3">3/8 in. OSB</td><td>0.131 x 2.5 in.</td><td>3/12 in.</td><td rowspan="5">2x4 DF</td><td rowspan="7">16 in.</td><td rowspan="7">2x</td><td rowspan="2">E72 rods</td></tr>
<tr><td>A2</td><td>2</td><td>E72[1]</td><td rowspan="2">0.113 x 2.0 in.</td><td rowspan="2">6/12 in.</td></tr>
<tr><td>A3</td><td>1</td><td>E2126</td><td>Full restraint</td></tr>
<tr><td>C1</td><td>2</td><td>E72[1]</td><td rowspan="2">Alt. Panel</td><td rowspan="2">Staple[2]</td><td rowspan="2">-/- [2]</td><td>E72 rods</td></tr>
<tr><td>C2</td><td>1</td><td>E2126</td><td>Full restraint</td></tr>
<tr><td>D1</td><td>2</td><td>E72[1]</td><td rowspan="2">3/8 in. OSB</td><td rowspan="2">0.113 x 2.0 in.</td><td rowspan="2">6/12 in.</td><td rowspan="2">2x4 SPF</td><td>E72 rods</td></tr>
<tr><td>D2</td><td>1</td><td>E2126</td><td>Full restraint</td></tr>
</table>

Notes

[1]E72 as modified by PS-2 Section 7.3.3.

[2]The alternative sheathing product was fastened using a staple configuration and fastener pattern that complied with the manufacturer's installation instructions for braced wall applications.

Wall configurations C1 and C2 were tested to investigate the performance of a commercially available "alternative" wall sheathing sometimes specified as an equivalent substitute for wood structural panels in wall bracing applications. The sheathing fastener, placement pattern, and stud spacing for these tests were chosen to meet or exceed the manufacturer's installation instructions for braced wall applications.

A 3/8 in. minimum sheathing fastener edge distance was consistently employed for all wall assemblies to be consistent with the recommended installation instructions for both sheathing products.

As mentioned above, drawings to detail the specifics of the test wall construction are provided as Appendices 1 and 2. The specimen configurations detailed in Appendix 1 were chosen to comply with the specifications of PS-2 and ASTM E72. The cyclic shearwall specimen configurations shown in Appendix 2 were chosen to provide wall designs that were practically "minimized" in accordance with the 2008 SPDWS and the

2012 National Design Specification for Wood Construction. Some of the detailing decisions specifically made to avoid designing the wall components with excess capacity included:

- Selecting a low grade of 2x4 nominal framing material,
- Using only two 5/8 in. anchor bolts per wall,
- Selecting low-grade rod stock for the anchors,
- Always using a single 2x sill plate,
- Using a single hold-down type that had sufficient design capacity for all the walls, but varying the number of screws between the hold-down anchors and the end posts to balance the design capacity for the design shear of each configuration.
- Using only a double 2x end post to meet the hold-down manufacturer's minimum design requirements, and
- Varying the number of screws used to stitch together the double 2x studs at end posts to match the wall's lateral design capacity.

Each of these items was detailed as close as could practically be accomplished to match the assumed allowable design capacity and minimum code requirements for a given wall configuration. Detailing decisions made with finite members/parts to meet code minimum requirements for things like anchor bolt spacing and number of end post studs resulted in some degree of practical overcapacity that could not be avoided in either this test program or in application.

MATERIALS:

All of the materials used in this investigation were either purchased on the open market or obtained from on-hand stores. No materials were obtained from special mill runs or trials.

Framing

All of the framing used for this study was 2x4 nominal lumber that was high-temperature kiln-dried to a moisture content on the order of 15%.

All of the Douglas-fir framing material came from one unit of 2x4 nominal, 8 ft. long lumber produced by Idaho Forest Products and purchased from Franklin Building Supply in Boise, ID. This material was graded as "No. 2" in accordance with the Western Wood Products Association grading rules.

All of the SPF framing material came from one unit of 2x4 nominal, 8 ft. long lumber produced by Central Forest Products Association Mill No. 54. This surplus material was purchased for another project and taken from indoor storage at the Weyerhaeuser Engineering Laboratory. Stamps on this product indicate that it was graded as "Stud" grade in accordance with the Canadian National Lumber Grading Authority provisions.

Since it was anticipated that the test program would take place over several months on a time-permitting basis, both units of material were stored in a conditioning room with ambient atmospheric conditions of 20^0C and 65% RH. This was done to mitigate the potential for large moisture content differences between groups. Neither unit was fully-equilibrated to these environmental conditions at the time of testing.

Sheathing

The OSB sheathing used in this investigation was purchased on the open market specifically for the purpose of this investigation. This 3/8 in. thick commodity material was produced by Weyerhaeuser Mill No. 533 on 14 February 2012. It was square-edged material that was "sized for spacing," had a rating of "Exposure 1," and a PS-2 span rating of "24/0." It was stamped with APA as the third-party inspection agency. A full unit of this material was purchased through the Weyerhaeuser distribution yard in Boise, ID.

The "alternative" proprietary sheathing material was a commercially available product that reportedly uses a laminated "fibrous" sheathing board that is approximately 1/8 in. thick to provide structural racking resistance. The tested material was purchased on the open market in a region of the country where it is readily available and shipped to the Weyerhaeuser Engineering Laboratory for testing in a protective crate.

METHODS:

All testing outlined in this report was conducted at the Weyerhaeuser Engineering Laboratory in Boise, Idaho between April and June of 2012.

Stud Sorting

Each of the framing members that received sheathing panel nailing were pre-sorted from the available stud material based upon specific gravity. For the Douglas-fir and SPF walls, the goal of the pre-sort was to select framing material for each wall assembly that had average oven-dry specific gravities as close as practically possible to the published values 0.50 and 0.42, respectively. This pre-sort was employed as an attempt to avoid building individual test walls with critical members that were either far above or below the accepted global averages for the commercial species combinations assumed by the shearwall design tables of the 2008 SDPWS. Given the limited replications, this sort was judged necessary to avoid unrealistic skews of the test data.

For the initial sort, each stud from each source bundle was weighed on a scale, the length measured with a tape measure, and the cross-section dimensions at the center measured using calipers. The moisture content was approximated using a pin-type electrical resistance meter. This data was used to estimate the overall expected oven-dry specific gravity. Lumber with estimated specific gravities within ±0.05 of the targeted average was used to fabricate the test walls.

Specimen Fabrication

Each test specimen was fabricated by Weyerhaeuser Engineering Laboratory personnel in accordance Table 1 and the drawings summarized in Appendices 1 and 2. All walls were framed and sheathed by the same two associates. The framing for each test wall was constructed between 4 and 24 hours prior to testing. For consistency, all walls were sheathed the same workday they were tested.

Monotonic Shearwall Tests

The monotonic shearwall tests of Groups A1, A2, C1, and D1 were conducted in general accordance with the wall racking test method of ASTM E72-10. The primary exceptions to E72 were as follows:

- As discussed above, two replicates were tested for each wall configuration.
- The wall framing material was selected to target the published oven-dry specific gravity for each commercial species group.
- As described by Section 7.3.2 of PS-2, an additional deflection device was added to measure the vertical deflection of the compression post.
- The load protocol was modified to reflect the procedure outlined Section 7.3.3 of PS-2. The "test load" used to establish the load protocol was the SDPWS allowable seismic design load for the tested configuration. One exception to this was that a more aggressive cycle was inadvertently employed for the A1 walls (460 plf test load instead of 410 plf test load). This deviation should be conservative. For walls sheathed with an alternative panel, the test load for Group A2 was assumed (as equivalent to the code-minimum WSP).

Figures 1-2 illustrate the test setup. Load was applied to the top of each wall using a servo-hydraulic actuator attached to the 3.5 x 3.5 in. load head. The load head was rigidly attached to the specimen top plate using ¾ in. bolts. Each wall was similarly anchored to a 3.5 x 3.5 in. base track. The load and base tracks were aligned in a manner that ensured that the sheathing did not bear on the test fixtures and was free to rotate relative to the framing.

The in-plane loads applied to the wall were measured using an electronic load cell positioned in-line between the actuator and load head. Lateral deflections were measured at the top of the wall using a temposonic wand referenced to the top plate. A linear motion potentiometer (LMP) positioned at each end of the wall measured the uplift relative to the anchorage track. A third LMP positioned at the center of the sill plate measured the rigid body sliding of the wall. All of the devices were monitored throughout the test by the same computerized data acquisition (DAQ) system that controlled the loading.

During each test, the load cycles were generated and electronic devices monitored by the computerized DAQ/hydraulic controller system. Each wall specimen was observed to determine the failure mode that governed the peak load capacity.

Following each test, short clear wood blocks were cut from each wall stud and plate that received sheathing nails. These blocks were used to determine the stud moisture content in accordance with ASTM D4442-07 and the stud specific gravity in accordance with ASTM D2395-07.

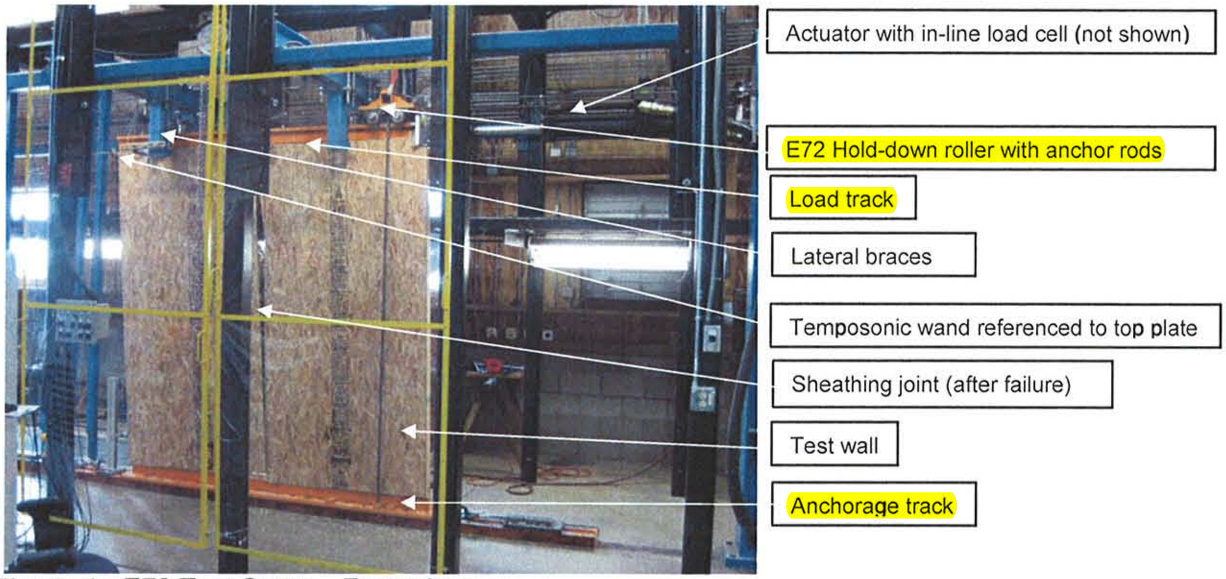

Figure 1: E72 Test Setup – Front view

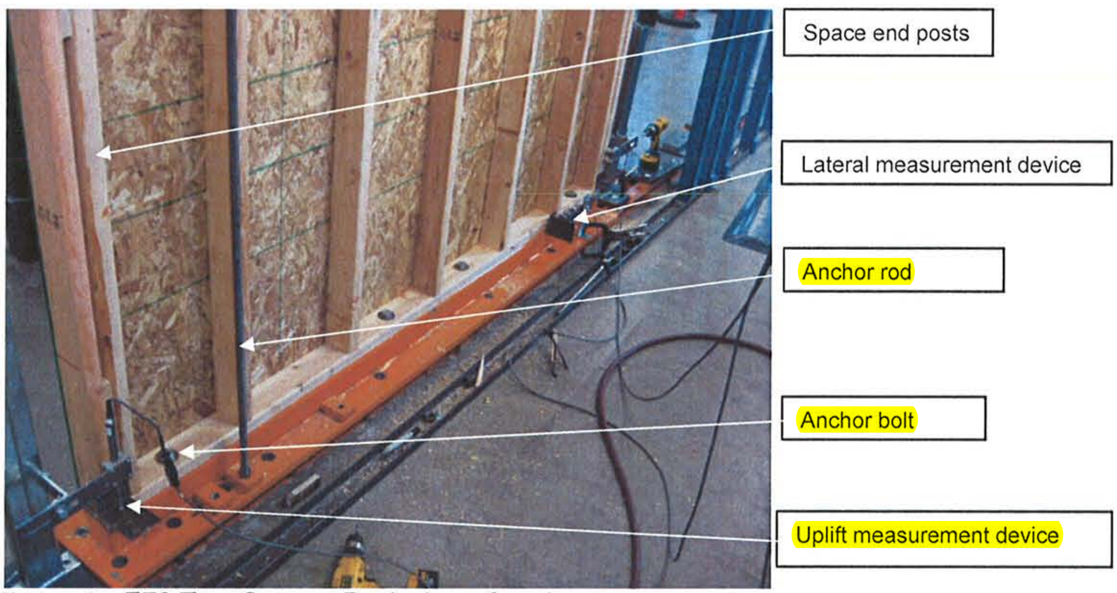

Figure 2: E72 Test Setup – Back view of anchorage

Cyclic Shearwall Tests

The cyclic "full-scale" shearwall tests were conducted in general accordance with ASTM E2126-11. The primary exception was:

- As discussed above, one replicate was tested for each wall configuration

Figures 3-5 illustrate the test setup. Load was applied to the top of each wall using a servo-hydraulic actuator attached to a load head that complied with Note 3 of ASTM E2126 Section 7.3.1. The load head was attached to the specimen top plate using enough 3 in. long SDS screws to provide rigid attachment throughout the test. Each wall was anchored down to a steel track embedded in a concrete floor. A combination of wood and steel spacer blocks were used to prevent the sheathing from bearing on the test frame at the base and the load head at the top.

The in-plane loads applied to the wall were measured using an electronic load cell positioned in-line between the actuator and load head. Lateral deflections were measured at the top of the wall using a temposonic wand referenced to the top plate. This external wand was also used to control the displacement cycles for the load protocol. An LMP positioned at each end of the wall measured the uplift relative to the anchorage track. A third LMP positioned at the center of the sill plate measured the rigid body sliding of the wall. All of the devices were monitored throughout the test by the same computerized data acquisition that controlled the loading.

Prior to testing, each wall was installed into the frame and bolted down per the project drawings. The walls were allowed to sit for at least 10 minutes prior to testing, but after the anchor bolts and hold-downs were tightened per Section 6.2.3 of ASTM E2126.

The displacement-controlled cyclic tests were conducted in accordance with the test protocol defined by Method C of ASTM E2126. Given that the test walls were expected to have drift capacities that exceeded 2.5% of the wall height based upon the monotonic tests, the parameter Δ was consistently taken as 2.5% of the wall height (2.4 in.) per the limit imposed in Section 8.5.2 of ASTM E2126. The parameter α was always defined as 0.5.

During each test, the displacement cycles were generated and electronic devices monitored by the computerized DAQ/hydraulic controller system. Each wall specimen was observed to determine the failure mode that governed the peak load capacity.

Following each test, short clear wood blocks were cut from each wall stud and plate that received sheathing nails. These blocks were used to determine the stud moisture content in accordance with ASTM D4442-07 and the stud specific gravity in accordance with ASTM D2395-07.

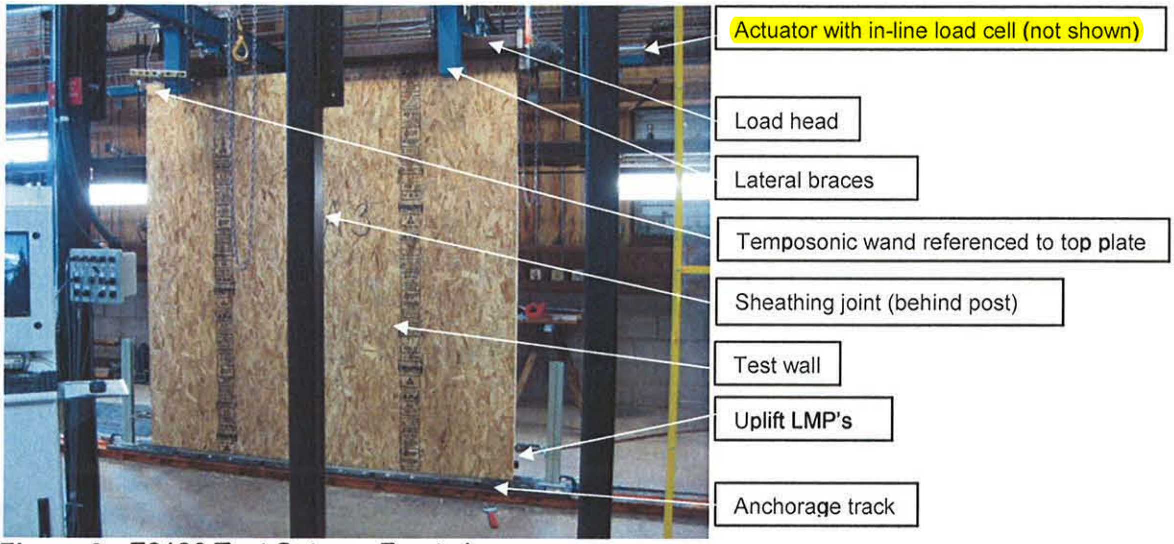

Figure 3: E2126 Test Setup – Front view

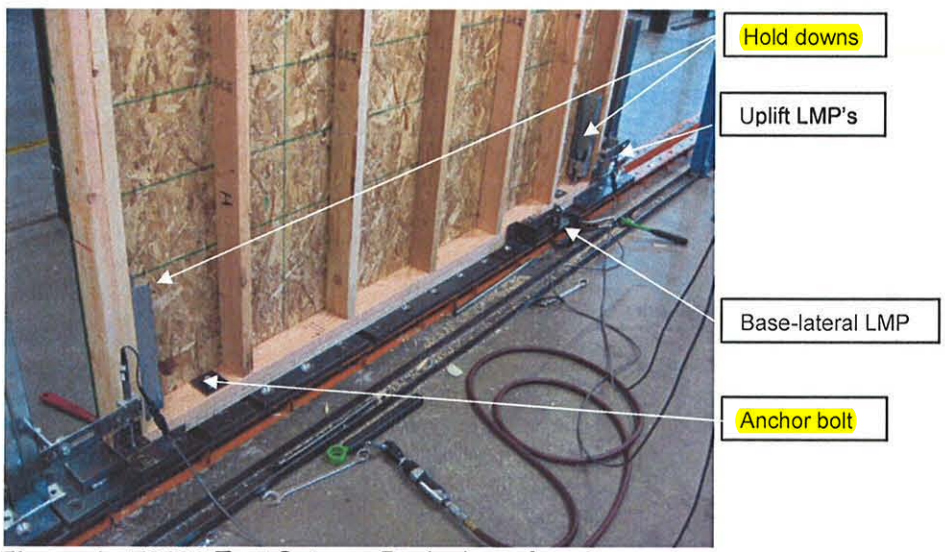

Figure 4: E2126 Test Setup – Back view of anchorage

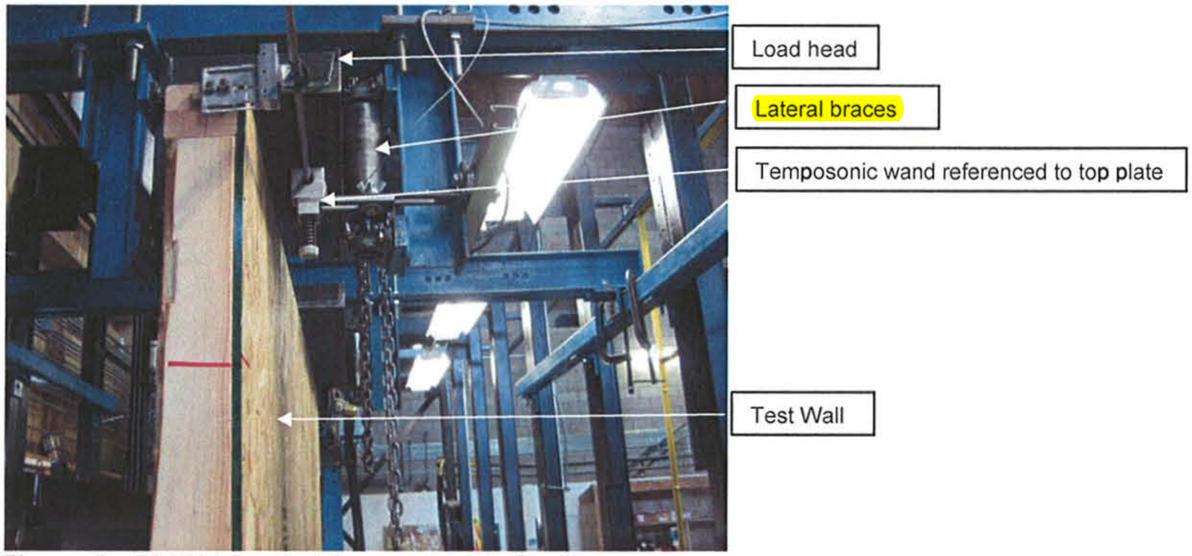

Figure 5: E2126 View looking up at end of wall

RESULTS:

Table 2, Figure 6, and Figure 7 summarize the relevant test results from this study. Detailed datasheets are provided in Appendices 3-5.

Table 2 identifies the primary failure modes observed for each test assembly. All of the shearwalls in this test program, regardless of whether they were tested monotonically or cyclically, initially behaved in a similar fashion. The vertical studs began to rotate relative to the sheathing as lateral drift was imposed. In general, the following failure modes were observed:

- All of the shearwalls sheathed with OSB consistently failed at the sheathing-to-framing connection due to some combination of sheathing nail withdrawal from the framing, nail head pull through from the sheathing, and/or sheathing edge tearout.

- When monotonically tested, the wall panels of Group C1 sheathed with the alternative panel failed primarily due to diagonal buckling of the sheathing. When the sheathing buckled, it either pulled the staple heads through the sheathing or tore them through the panel edges.

- When cyclically tested, the wall panels of Group C2 sheathed with the alternative panel failed due to a combination of staple head pull-through from the sheathing and sheathing edge tearout.

None of the cyclically tested walls experienced a hold-down, framing, or anchorage failure.

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Table 2: Summary of Results

ID	Test	Sheathing	Type	Studs	Stud Space (in.)	Sheathing Fastener Size	Sheathing Fastener Space (edge/field)	Input Delta	0.4 Peak Load (plf)	0.4 Peak Disp.[2] (in.)	Seismic[1] ASD Design Load (plf)	Seismic[1] ASD Design Disp.[2] (in.)	Load at 0.2 in. Load (plf)	Load at 0.2 in. Disp.[2] (in.)	EEEP Yield Load (plf)	EEEP Yield Disp.[2] (in.)	Peak Load (plf)	Peak Disp.[2] (in.)	Ultimate Load (plf)	Ultimate Disp.[2] (in.)	Avg. Stud SG	Avg. MC (%)	Primary Failure Mode[3]	Normalized Parameter[4]: Gravity Load Capacity Intact?	Normalized Parameter[4]: *Drift at Ultimate* (%)	Normalized Parameter[4]: *Peak/ ASD Design* Load	Normalized Parameter[4]: *Ult. Drift/ ASD Drift*
PS-2/E72 Monotonic Wall Tests																											
A1	1	3/8 in. OSB	E72	DF	16	8d com. (0.131 x 2.5 in.)	3"/12"	-	580	0.153	410	0.078	648	0.200	-	-	1,449	2.315	1,159	3.139	0.48	11.9	NHP, SET, NWD	-	-	3.53	-
	2								575	0.130	410	0.068	698	0.200	-	-	1,438	2.267	1,150	2.829	0.51	9.9	NHP	-	-	3.51	-
								Avg.	**577**	**0.142**	**410**	**0.073**	**673**	**0.200**	**-**	**-**	**1,443**	**2.291**	**1,155**	**2.984**	**0.50**	**10.9**	**-**	**-**	**-**	**3.52**	**-**
A2	1	3/8 in. OSB	E72	DF	16	6d com. (0.113 x 2.0 in.)	6"/12"	-	263	0.117	200	0.059	324	0.200	-	-	659	2.368	527	4.448	0.46	9.2	NHP, NWD	-	-	3.29	-
	2								269	0.088	200	0.046	355	0.200	-	-	673	2.732	538	4.587	0.50	12.9	NHP, NWD	-	-	3.36	-
								Avg.	**266**	**0.103**	**200**	**0.053**	**340**	**0.200**	**-**	**-**	**666**	**2.550**	**533**	**4.517**	**0.48**	**11.1**	**-**	**-**	**-**	**3.33**	**-**
C1	1	Alt. Panel	E72	DF	16	Staple[5]	-/-[5]	-	181	0.125	200	0.147	242	0.200	-	-	452	0.885	361	2.475	0.48	9.9	SB, SHP	-	-	2.26	-
	2								183	0.123	200	0.135	249	0.200	-	-	457	1.624	365	2.372	0.49	11.7	SB, SHP	-	-	2.28	-
								Avg.	**182**	**0.124**	**200**	**0.141**	**245**	**0.200**	**-**	**-**	**454**	**1.255**	**363**	**2.423**	**0.49**	**10.8**	**-**	**-**	**-**	**2.27**	**-**
D1	1	3/8 in. OSB	E72	SPF	16	6d com. (0.113 x 2.0 in.)	6"/12"	-	251	0.097	184	0.045	328	0.200	-	-	628	2.320	502	4.780	0.43	10.2	NHP, SET, NWD	-	-	3.41	-
	2								258	0.113	184	0.059	324	0.200	-	-	646	2.574	517	4.356	0.43	10.3	NWD, SET, NHP	-	-	3.51	-
								Avg.	**255**	**0.105**	**184**	**0.052**	**326**	**0.200**	**-**	**-**	**637**	**2.447**	**509**	**4.568**	**0.43**	**10.3**	**-**	**-**	**-**	**3.46**	**-**
E2126 Cyclic CUREE Wall Tests																											
A3	1	3/8 in. OSB	Cyclic	DF	16	6d com. (0.113 x 2.0 in.)	6"/12"	2.40	**221**	**0.160**	**200**	**0.133**	**246**	**0.200**	**478**	**0.347**	**553**	**1.628**	**442**	**2.707**	**0.49**	**13.2**	NWD, SET	Y	**2.8%**	**2.8**	**20.3**
C2	1	Alt. Panel	Cyclic	DF	16	Staple[5]	-/-[5]	2.40	**177**	**0.152**	**200**	**0.183**	**213**	**0.200**	**404**	**0.346**	**442**	**1.595**	**354**	**1.953**	**0.49**	**13.7**	SHP	Y	**2.0%**	**2.2**	**10.7**
D2	1	3/8 in. OSB	Cyclic	DF	16	6d com. (0.113 x 2.0 in.)	6"/12"	2.40	**229**	**0.186**	**184**	**0.123**	**238**	**0.200**	**507**	**0.411**	**572**	**2.219**	**458**	**3.630**	**0.42**	**10.1**	NWD, SET, NHP	Y	**3.8%**	**3.1**	**29.5**

Notes:
1. Seismic shearwall allowable stress design load for 3/8 in. OSB panels taken from *2008 Special Design Provisions for Wind and Seismic*. For other other sheathings, 200 plf assumed.
2. The drift measurements used for the E72 test were based upon an load/drift curves that had the shearwall rigid body rotation and translation components analytically removed.
   Drift for cyclic tests is based upon the measured drift at the top of the wall and includes all movement sources.
3. Failure mode codes: NWD - sheathing nail withdrawal, SET - sheathing edge tearout, LSS - localized stud splitting, NHP - nail head pullthrough, DNF- did not fail, NS - progressive sheathing nail slip,
   SB - sheathing buckling, SHP - staple head pullthrough and edge tearout
4. Wood structural panel seismic equivalency parameter from ICC-ES Acceptance Criteria AC 130.
5. Product fastened using a staple size and placement pattern that met the manufacturer's minimum installation requirements.

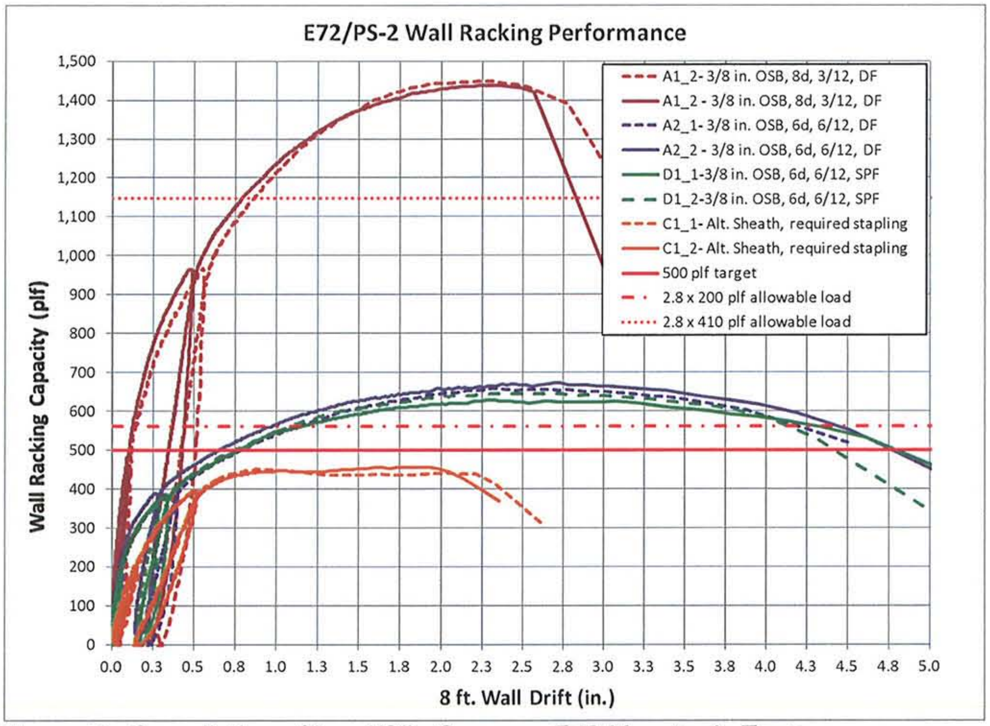


Figure 6: Compilation of Load/Slip Curves – E72 Monotonic Tests

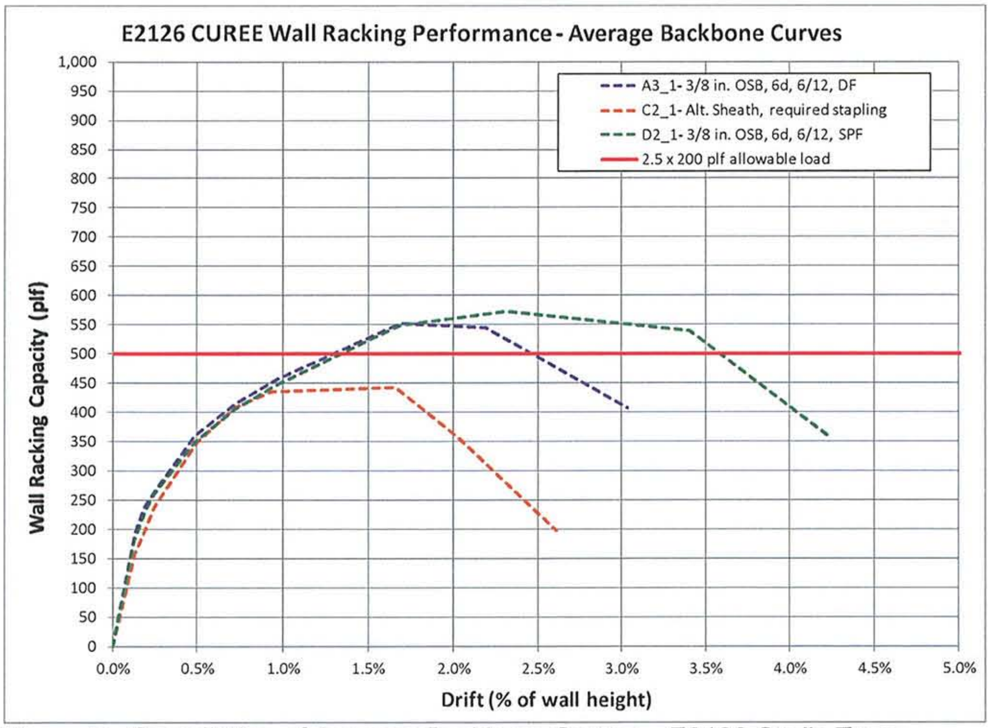


Figure 7: Compilation of Average Backbone Curves – E2126 Cyclic Tests

Figure 8: Typical OSB sheathing edge tearout

Figure 9: Typical fastener head pull-through and withdrawal for an OSB sheathed assembly

CALCULATIONS:

Table 2 includes several calculated values.

Monotonic Tests

The monotonic E72 shearwall tests were first analyzed by adjusting the measured wall drift to remove the rigid body rotation and translation as described by Section 7.3.3 of PS-2. The resulting adjusted drift curves, depicted in Appendix 3, were then used to identify the following parameters presented in Table 2:

- the load and deflection at 40% of the peak load (pre-peak),
- the load at an adjusted wall deflection of 0.2 in.,
- the deflection at the SDPWS allowable seismic design load,
- the load and deflection at the peak load, and
- the load and deflection at the "ultimate" point or "drift capacity" as defined by Section 3.2.13 of ASTM E2126,

The other calculations required by ASTM E72 were also computed. However, only those parameters of specific interest to this experiment have been reported here.

It should be noted that the allowable stress shearwall design values contained Table 2 were developed for the OSB sheathed walls using the 2008 SDPWS shearwall design provisions for seismic applications. For Group C1, it was assumed for comparison purposes that the allowable seismic design value for the "equivalent" OSB sheathed wall could also be applied to the assemblies sheathed with the alternative sheathing product.

The ratio between the measured peak capacity and the allowable seismic design load has been provided for normalized comparison purposes.

Also for comparison purposes, three different reference lines have been provided in Figure 6:

- A line at 500 plf has been added to highlight minimum E72 wall bracing strength level that has been the subject of recent industry discussions.
- A line a 560 plf has been added to highlight the strength level associated with 2.8 times the 200 plf allowable seismic design load for the baseline OSB sheathing/nail combination with Douglas-fir studs. (The comparable strength level associated with SPF framing would be 515 plf).
- A line a 1,148 plf has been added to highlight the performance level associated with 2.8 times the 410 plf allowable seismic design load for the OSB sheathing/nail combination with Douglas-fir studs used for a PS-2 qualification.

Cyclic Tests

In general, for the cyclic shearwall tests, the first step in the analysis process was to define the positive and negative "backbone" or "envelope" curves for each test as defined by Section 3.2.4 of ASTM E2126-11. The positive and negative backbone curves were then averaged to produce a single "average" backbone curve which was used for the remainder of the calculations. Averaging the curves first is also consistent with the analysis method used to analyze the wood industry benchmark shearwall database and E2126 requirements.

To be consistent with industry practice and the AC130 equivalency provisions, the average backbone curves from the cyclic test were not adjusted to remove the rigid body rotation and translation of the wall assembly.

The following parameters were determined from the cyclic test backbone curves:

- the load and deflection at 40% of the peak load (pre-peak),
- the load at a deflection of 0.2 in.,
- the deflection at the SDPWS allowable seismic design load,
- the load and deflection at the peak load,
- the load and deflection at the "ultimate" point or "drift capacity" as defined by Section 3.2.13 of ASTM E2126,
- the load and deflection at the equivalent energy elastic-plastic yield point (EEEP) as defined by Section 3.2.5 of ASTM E2126.

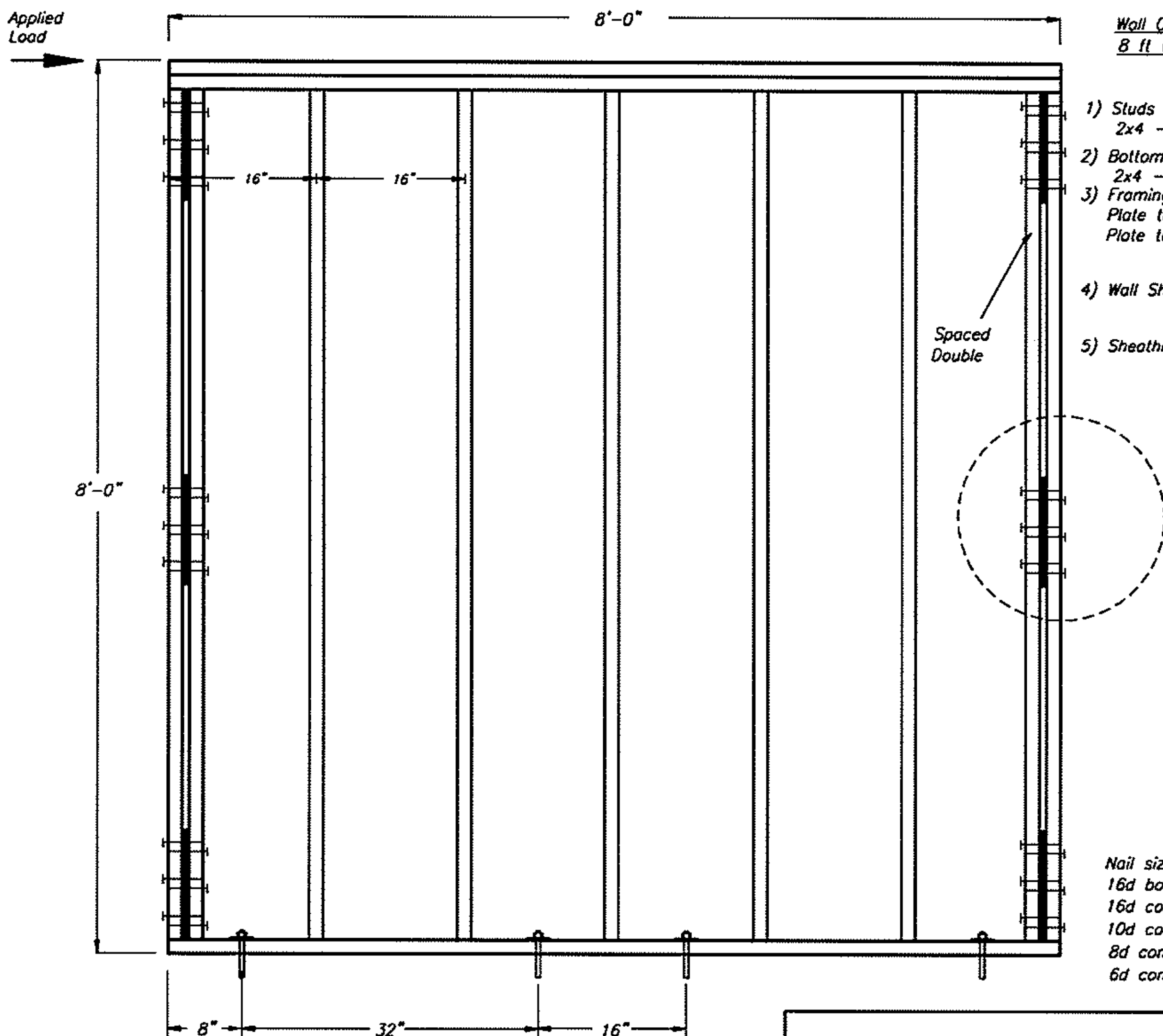
Where necessary, interpolation was used to estimate points that fell between discrete positions on the average backbone curve. The other calculations required by Section 9 of ASTM E2126 were also computed. However, only those parameters of specific interest to this experiment have been reported here.

The last four columns of Table 2 are the wood frame wood structural panel "equivalency" parameters as defined by ICC-ES AC130. The drift at the ASTM E2126 "ultimate" point, also known as "drift capacity," is reported as a percentage of the wall height. The component overstrength is reported as the peak load the wall resisted divided by the published allowable design capacity. The "ductility ratio" was computed by dividing the "drift capacity" by the deflection measured at the published allowable design strength of the wall.

The allowable stress shearwall design values contained Table 2 were developed for the OSB sheathed walls using the 2008 SDPWS shearwall design provisions for seismic applications. For Group C2, it was assumed for comparison purposes that the allowable seismic design value for the "equivalent" OSB sheathed wall could also be applied to the assemblies sheathed with the alternative sheathing product.

For comparison purposes, a reference line for 500 plf has been added to Figure 7. This line represents 2.5 times the 200 plf allowable seismic design load for the baseline OSB sheathing/nail combination with Douglas-fir studs. This minimum strength benchmark represents one of the four cyclic test parameters used to judge seismic equivalency to light-frame wood structural panel shearwalls.

APPENDIX 1: TEST SPECIMEN DETAILS – E72 MONOTONIC TESTS



Wall Construction:
8 ft wall lengths 16 in. o/c Spacing

1) Studs and top plates:
   2x4 – See Table 1
2) Bottom plate:
   2x4 – See Table 1
3) Framing attachment:
   Plate to plate–(2) 10d common at 16 in. o/c
   Plate to stud–(2) 16d common each end

4) Wall Sheathing – see Table 1

5) Sheathing to frame attachment – see Table 1

3/4 x 3.5 x 12 in. OSB Spacer
Fastened with 6 16d common
(3 each direction)

Nail size:
16d box: 0.131" dia. x 3 1/2" long
16d common: 0.162" dia. x 3 1/2" long
10d common: 0.148" dia. x 3" long
8d common: 0.131" dia. x 2-1/2" long
6d common: 0.113" dia. x 2" long

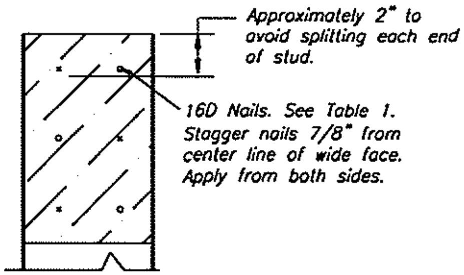
Weyerhaesuer Engineering Laboratory
Ned Waltz, PE, SECB

Title: Exp. 2379 – E72
Date: 11 April 2012
Drawing Number: 1 of 2

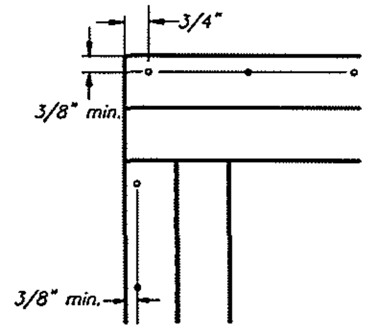
Table 1.

Test ID	Size	Panel	Fastener	Edge/Field Spacing	Stud Spacing	Washer Size	Anchor Bolts	End Post 16D Stitch Nails	Stud Framing at all Edges	Replicates	Fasteners at Panel Edge	Fasteners at Panel End
A1	8'x8'	3/8" OSB	0.131 x 2.5 in. nail	3"oc/12"oc	16" o/c	STD RND	(4)3/4"	(18)	2x4 DF	2	33	17
A2	8'x8'	3/8" OSB	0.113 x 2 in. nail	6"oc/12"oc	16" o/c	STD RND	(4)3/4"	(18)	2x4 DF	2	17	9
C1	8'x8'	Alt. Panel	staple (see note 1)	-/-	16" o/c	STD RND	(4)3/4"	(18)	2x4 DF	2	-	-
D1	8'x8'	3/8" OSB	0.113 x 2 in. nail	6"oc/12"oc	16" o/c	STD RND	(4)3/4"	(18)	2x4 SPF	2	17	9

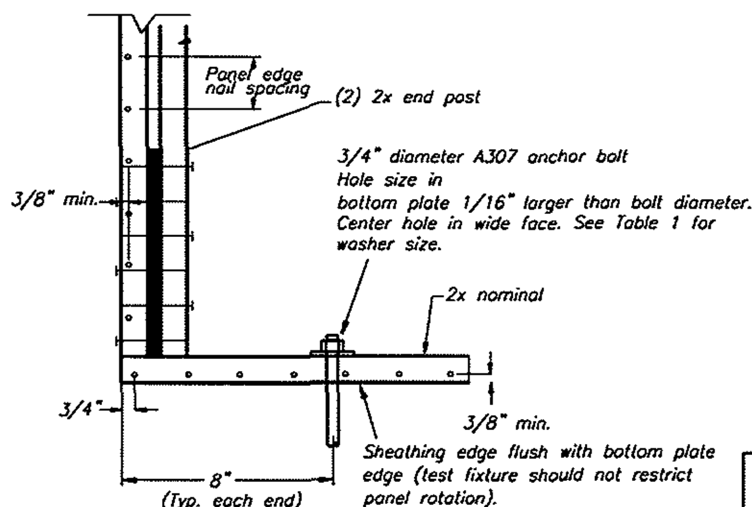
Note 1 - Alternative panel staple size and placement pattern to meet manufacturer's minimum installation requirements.



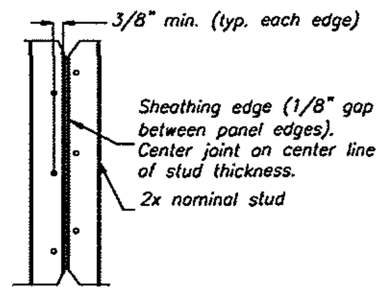
Stud to Stud at End Post (typical)



Panel Corner Detail - Top of Wall



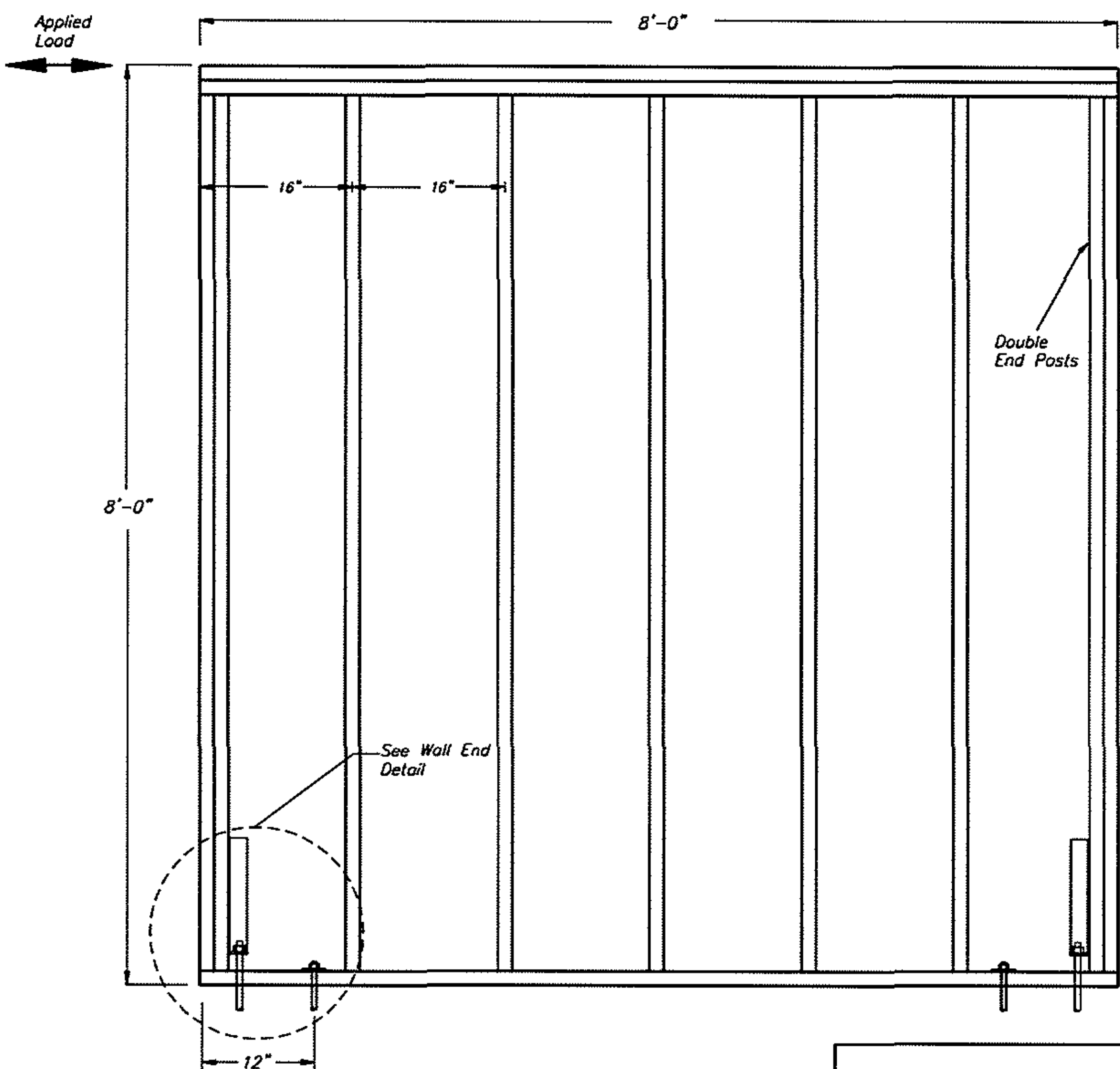
Wall End Detail (2x bottom plate)



Adjoining Panel Edge Detail (stagger nailing)

Weyerhaesuer Engineering Laboratory Ned Waltz, PE, SECB	Title Exp. 2379 - E72 Date 11 April 2012 Drawing Number 2 of 2

APPENDIX 2: TEST SPECIMEN DETAILS – E2126 CYCLIC TESTS



Wall Construction:
8 ft wall lengths 16 in. o/c Spacing

1) Studs and top plates:
2x4 - See Table 1

2) Bottom plate:
2x4 - See Table 1

3) Framing attachment:
Plate to plate-(2) 16d common per foot
Plate to stud-(2) 16d box each end
Stud to stud - see Table 1

4) Wall Sheathing - see Table 1

5) Sheathing to frame attachment - see Table 1

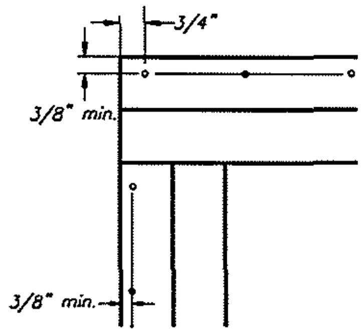
Nail size:
16d box: 0.131" dia. x 3 1/2" long
16d common: 0.162" dia. x 3 1/2" long
10d common: 0.148" dia. x 3" long
8d common: 0.131" dia. x 2-1/2" long
6d common: 0.113" dia. x 2" long

Weyerhaesuer Engineering Laboratory Ned Waltz, PE, SECB	Title: Exp. 2274 - Cyclic
	Date: 11 April 2012
	Drawing Number: 1 of 2

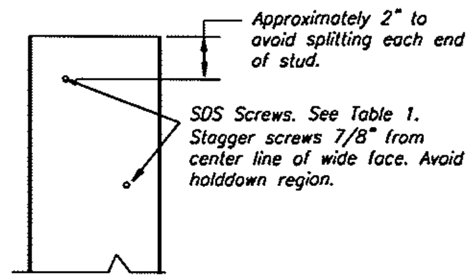
Table 1.

Test ID	Size	Panel	Fastener	Edge/Field Spacing	Stud Spacing	Washer Size	Anchor Bolts	SDS3.0" End Post Stitch Screws	Stud Framing at all Edges	Replicates	Holddown SDS3.0" Screws	Fasteners at Panel Edge	Fasteners at Panel End
A3	8'x8'	3/8" OSB	0.113 x 2 in. nail	6"oc/12"oc	16" o/c	3x3	(2)5/8"	4	2x4 DF	1	6	17	9
C2	8'x8'	Alt. Panel	staple	–/–	16" o/c	3x3	(2)5/8"	4	2x4 DF	1	7	–	–
D2	8'x8'	3/8" OSB	0.113 x 2 in. nail	6"oc/12"oc	16" o/c	3x3	(2)5/8"	4	2x4 SPF	1	6	17	9

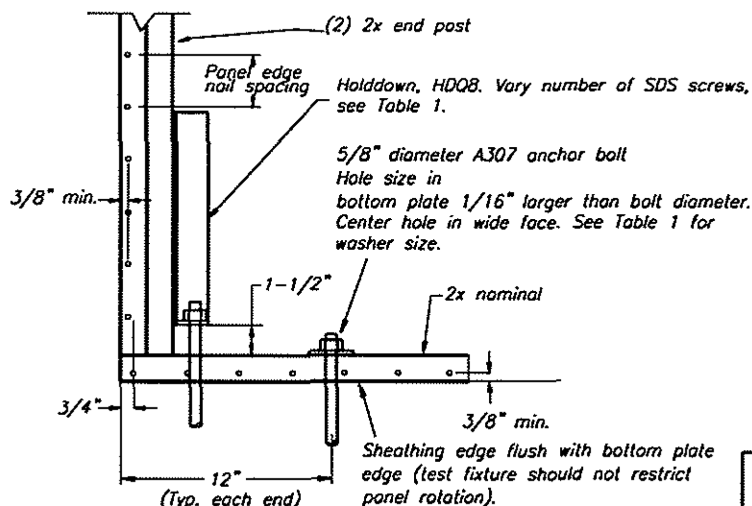
Note 1 – Alternative panel staple size and placement pattern to meet manufacturer's minimum installation requirements.



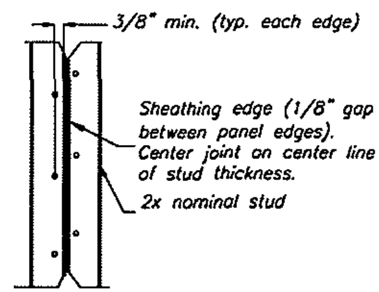
Panel Corner Detail – Top of Wall



Stud to Stud at End Posts



Wall End Detail (2x bottom plate)



Adjoining Panel Edge Detail (stagger nailing)

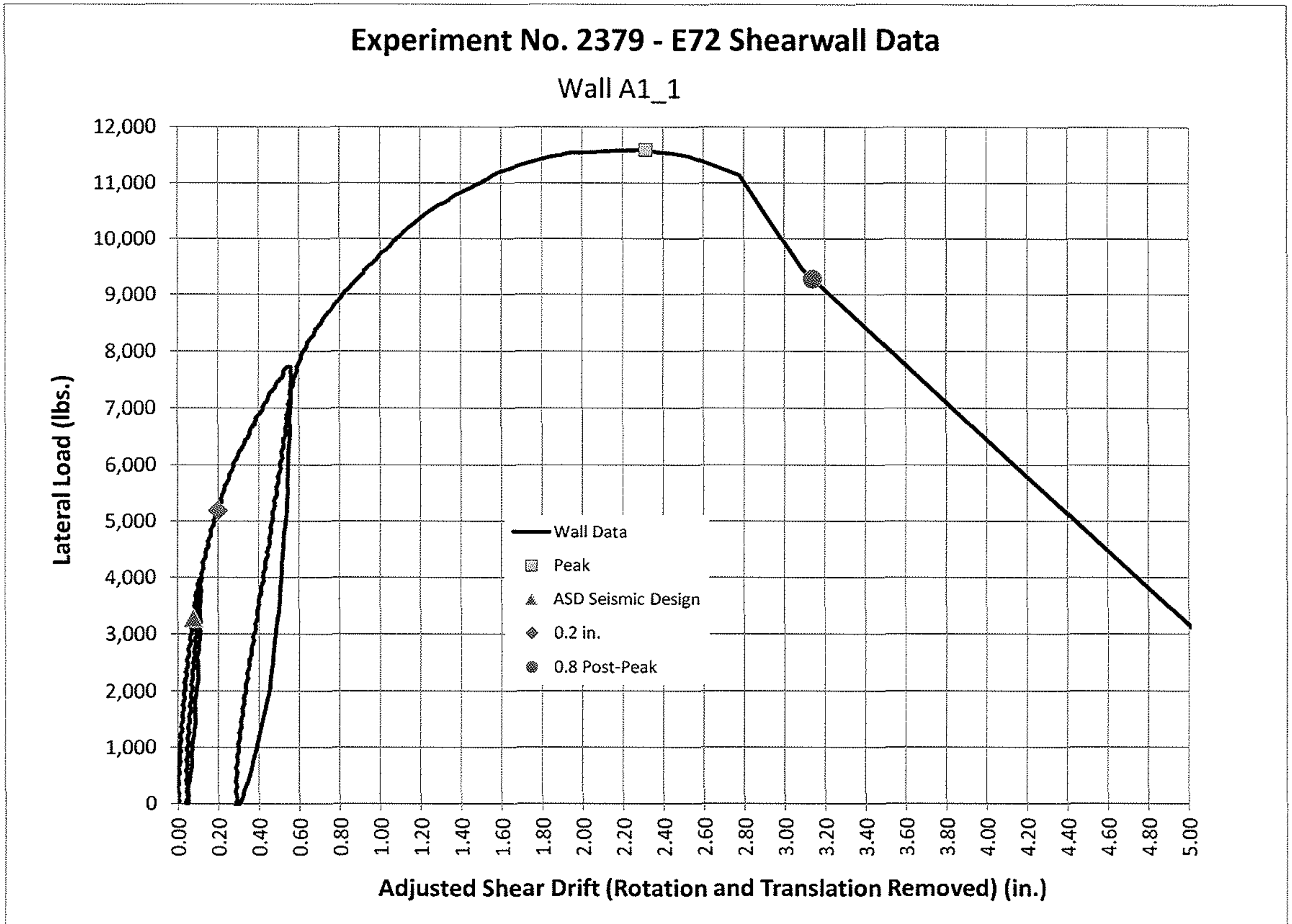
Weyerhaesuer Engineering Laboratory
Ned Waltz, PE, SECB

Title: Exp. 2274 – Cyclic

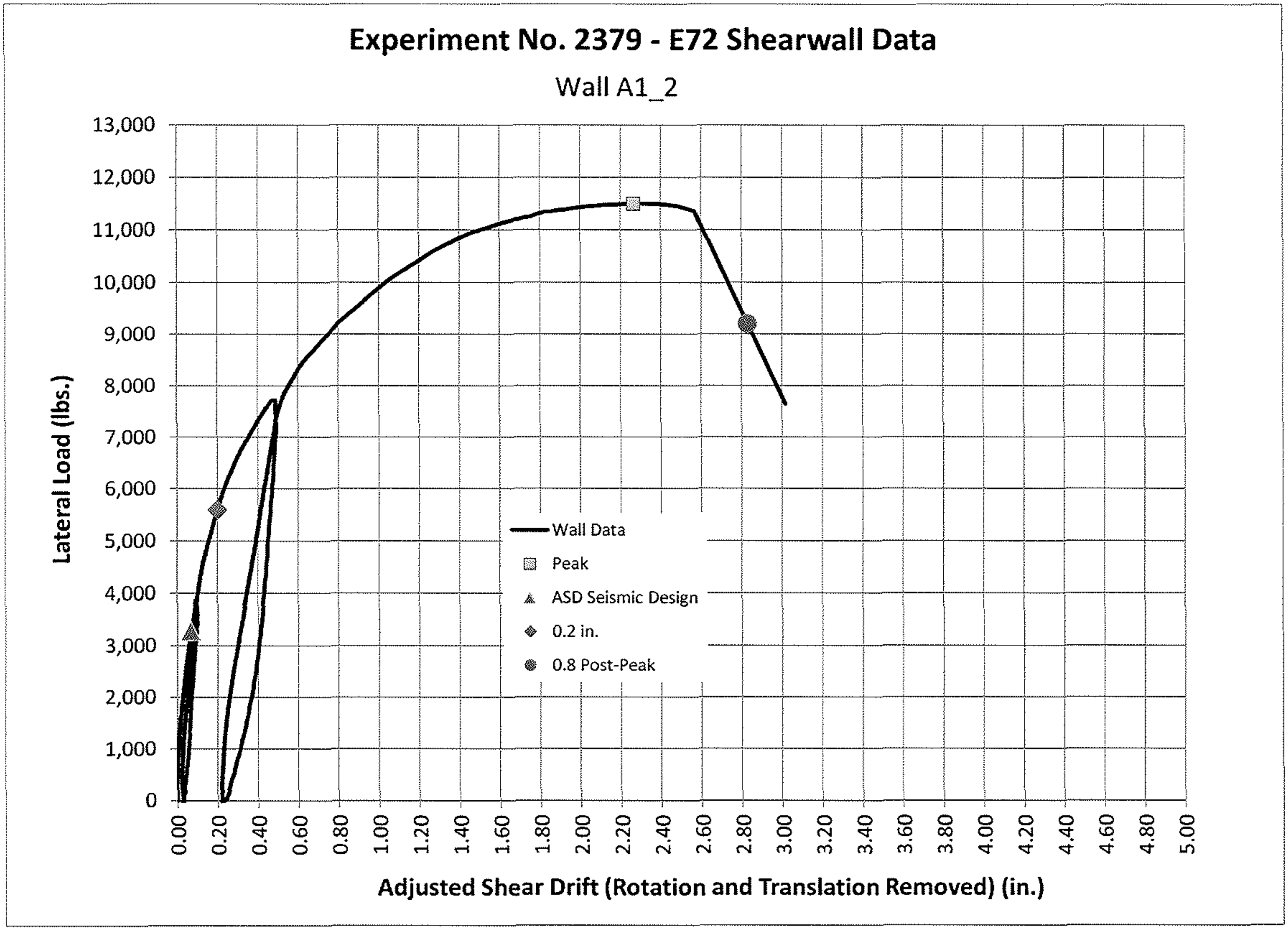
Date: 11 April 2012

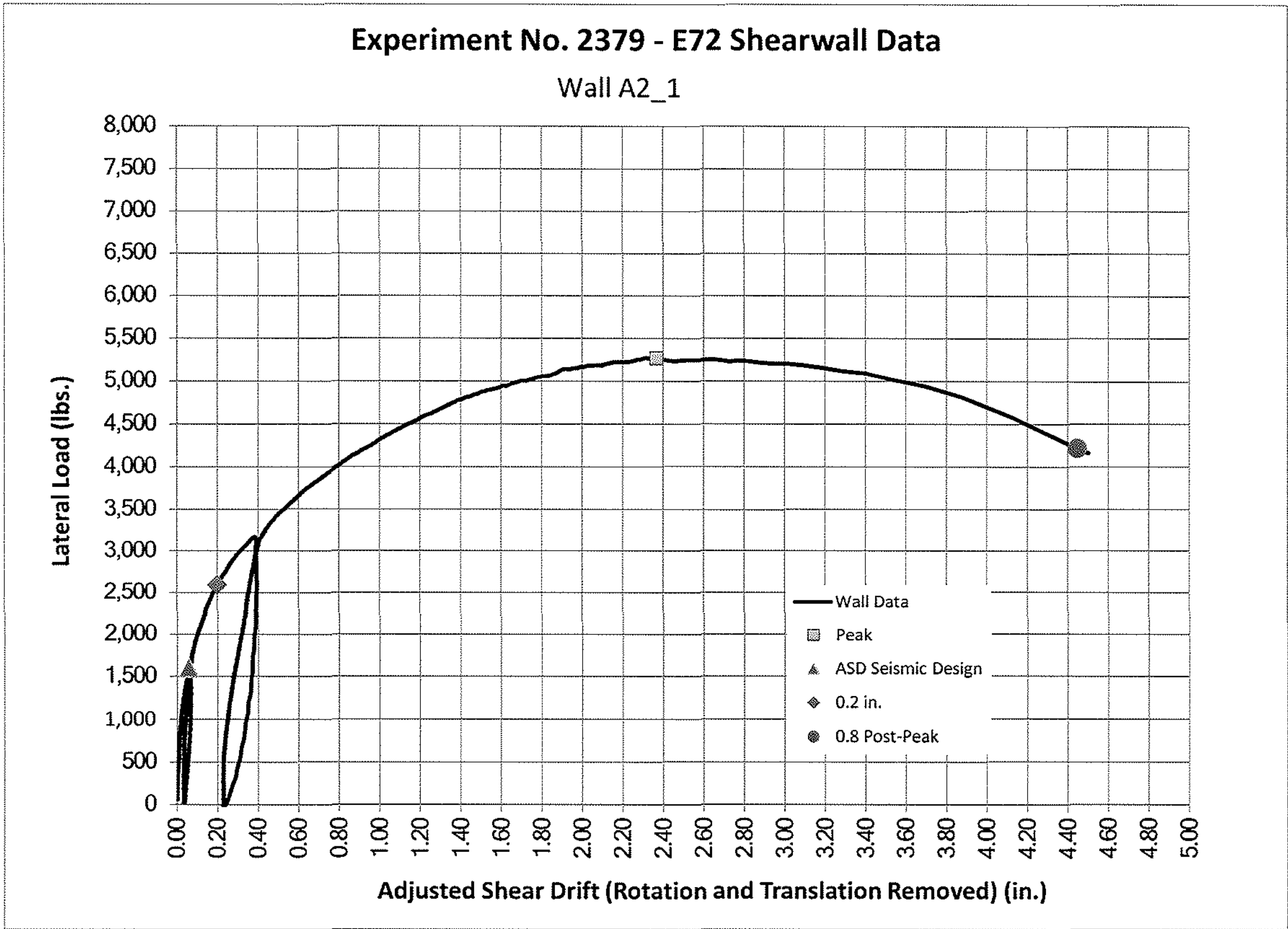
Drawing Number: 2 of 2

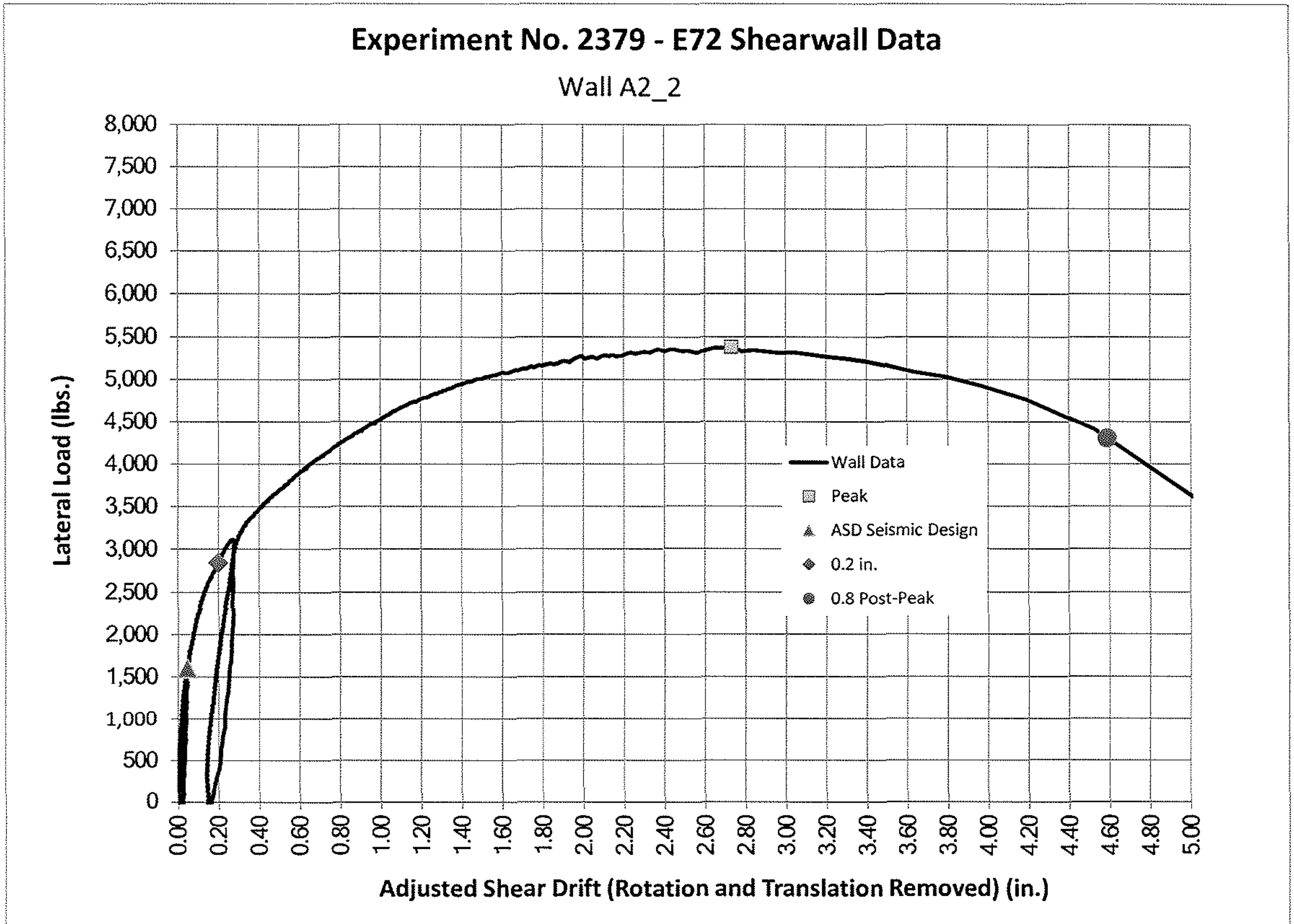
APPENDIX 3: MONOTONIC E72 WALL RACKING DATA



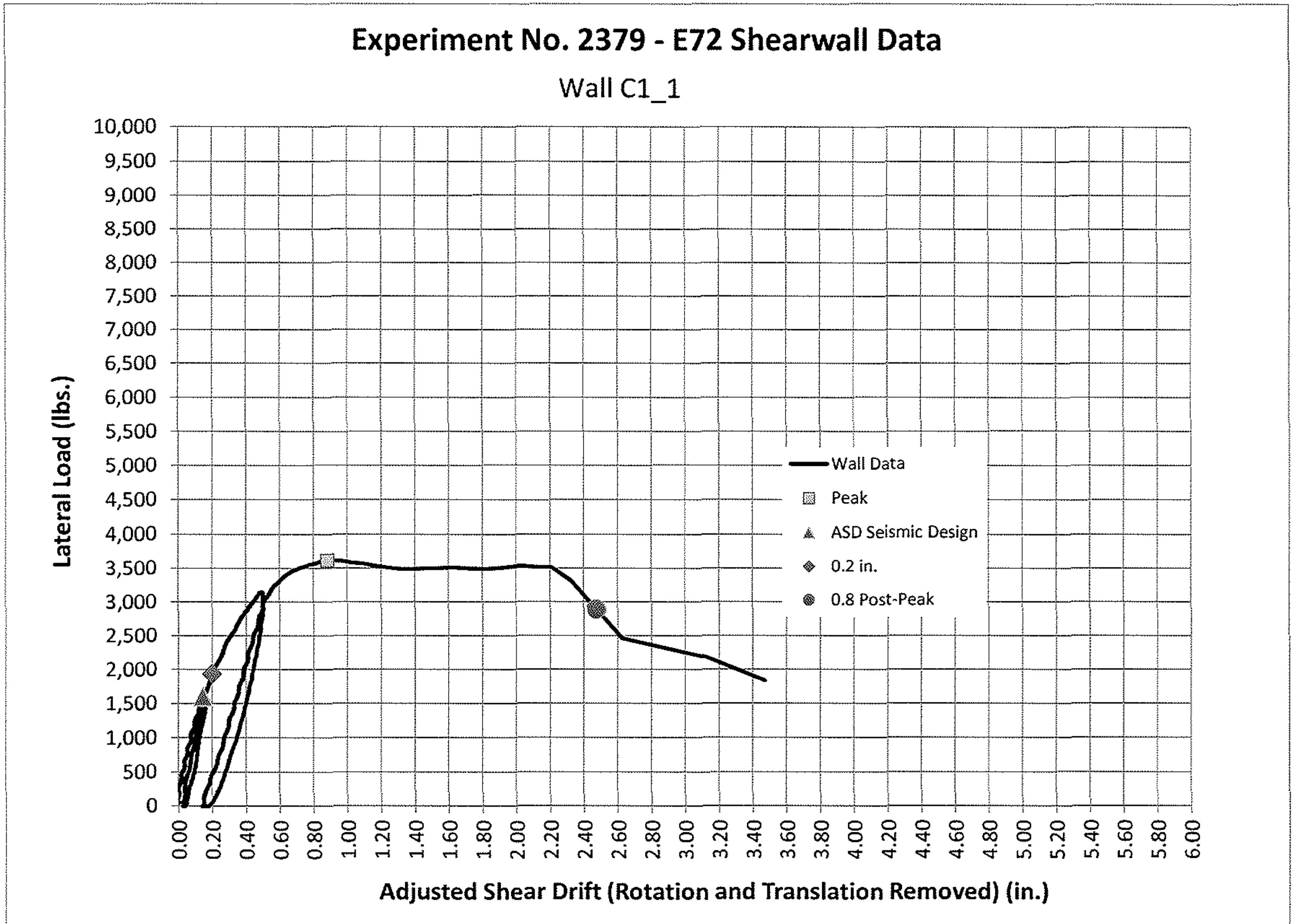
Experiment No. 2379 - E72 Shearwall Data
Wall A1_1
Lateral Load (lbs.)
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak


Experiment No. 2379 - E72 Shearwall Data
Wall A1_2
Lateral Load (lbs.)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak

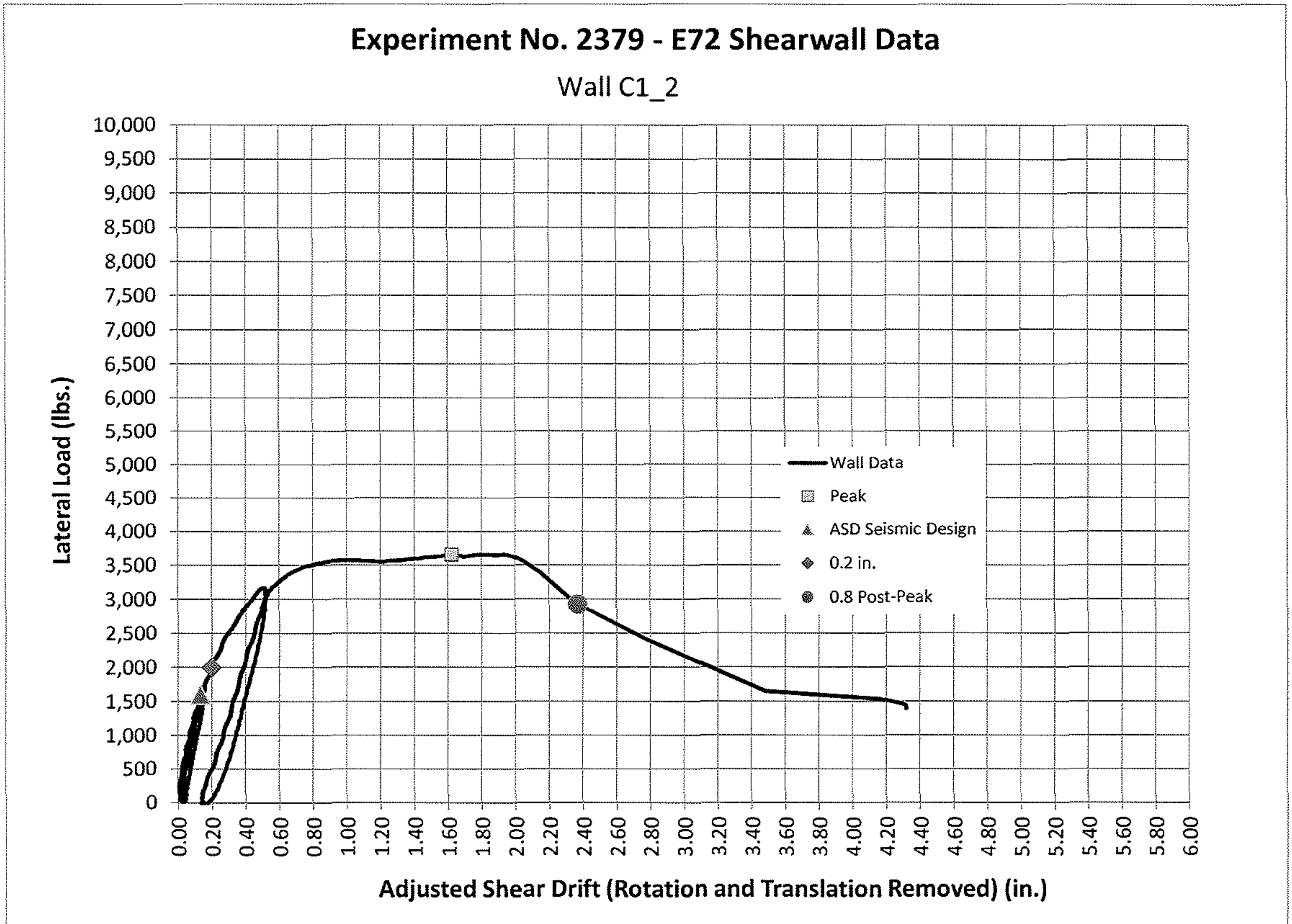

Experiment No. 2379 - E72 Shearwall Data
Wall A2_1
Lateral Load (lbs.)
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak



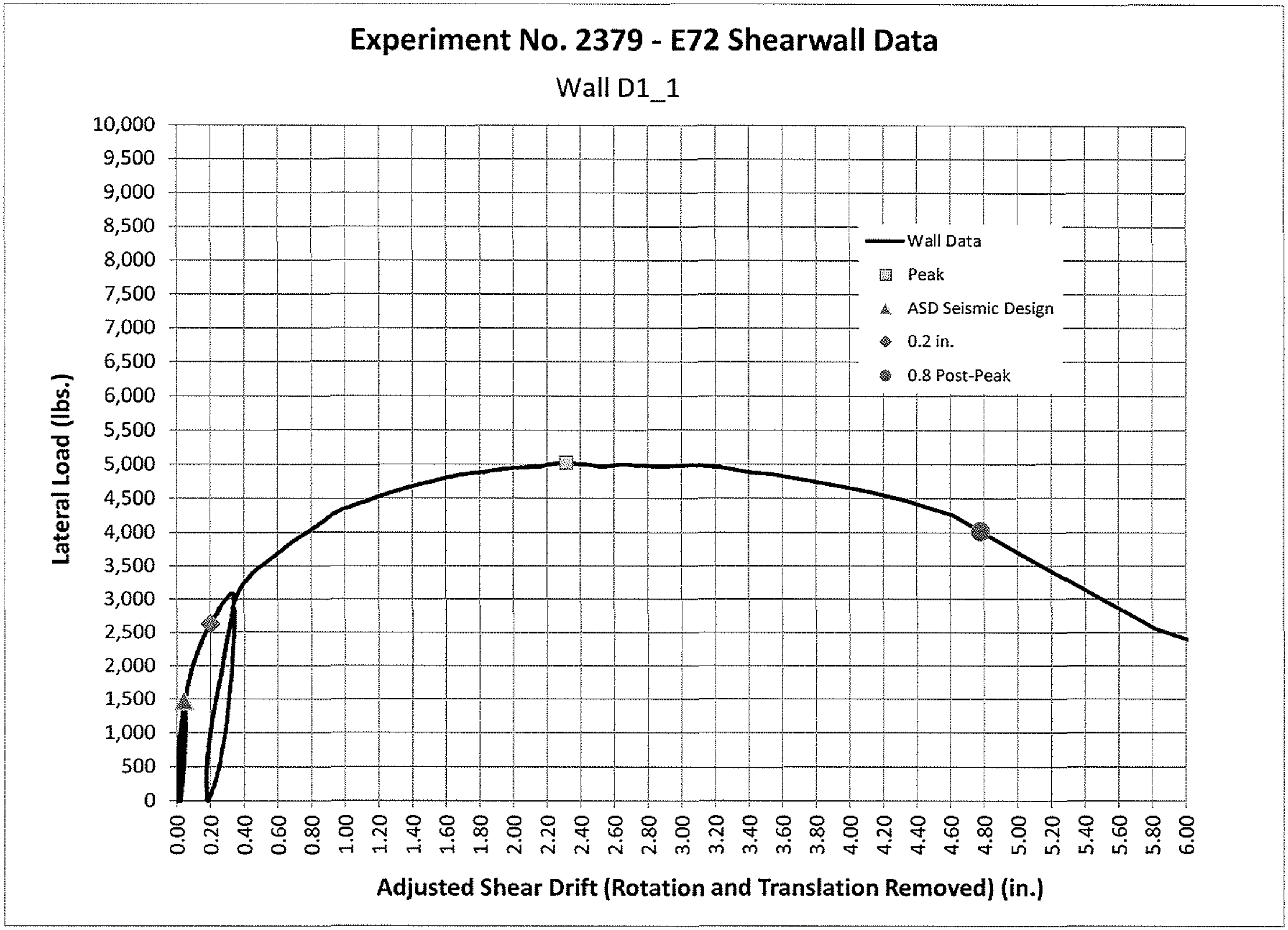
Experiment No. 2379 - E72 Shearwall Data
Wall A2_2
Lateral Load (lbs.)
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak

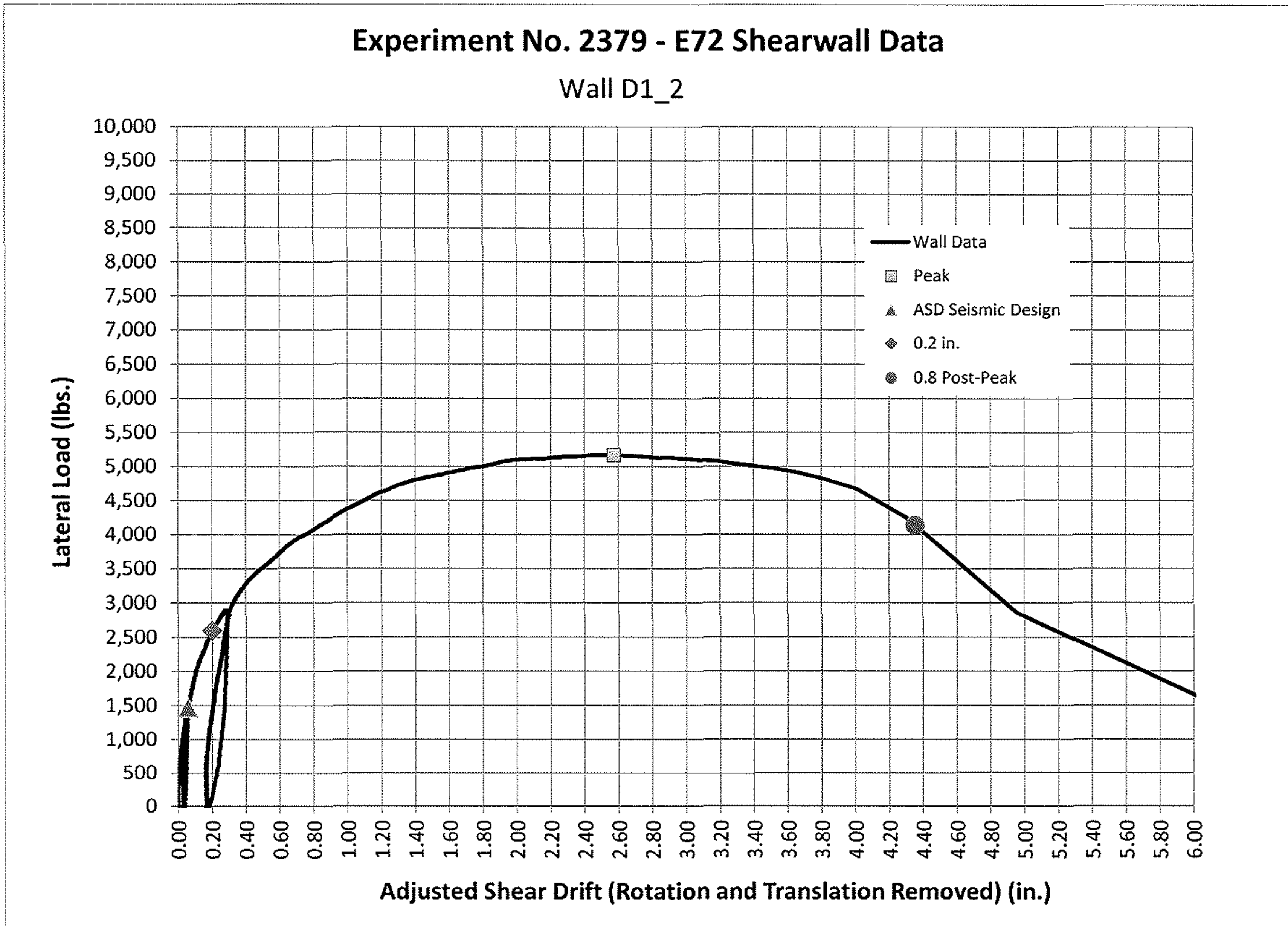


Experiment No. 2379 - E72 Shearwall Data
Wall C1_1
Lateral Load (lbs.)
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
5.40
5.60
5.80
6.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak



Experiment No. 2379 - E72 Shearwall Data
Wall C1_2
Lateral Load (lbs.)
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
5.40
5.60
5.80
6.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak


Experiment No. 2379 - E72 Shearwall Data
Wall D1_1
Lateral Load (lbs.)
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
5.40
5.60
5.80
6.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)


Experiment No. 2379 - E72 Shearwall Data
Wall D1_2
Lateral Load (lbs.)
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
5.40
5.60
5.80
6.00
Adjusted Shear Drift (Rotation and Translation Removed) (in.)
Wall Data
Peak
ASD Seismic Design
0.2 in.
0.8 Post-Peak

APPENDIX 4: CYCLIC E2126 SHEARWALL DATA

Cyclic Load Test for Shear Resistance of Framed Walls

Test Method: AC130 - "CUREE"

Date:	5/29/2012	Sample Description:	8X8 DF frame, 3/8 OSB sheath, nail 6 / 12 6d com
Experiment No:	2379	Hold Down:	Sipmson HDQ8 w/ 6 screws
File Name:	A3_1 cyclic	Height (in):	96
Technician:	Atwood	Length (in):	96
Input Delta (in.):	2.4	Devices:	10khz - LC S/N 660578(16), CH32 LMP S/N 2.004, CH33 LMP S/N 4.011, CH35 LMP S/N 4.010, CH48 Wand S/N 90088036(3)
Setup Configuration:	Single Wall		

Zeb Atwood

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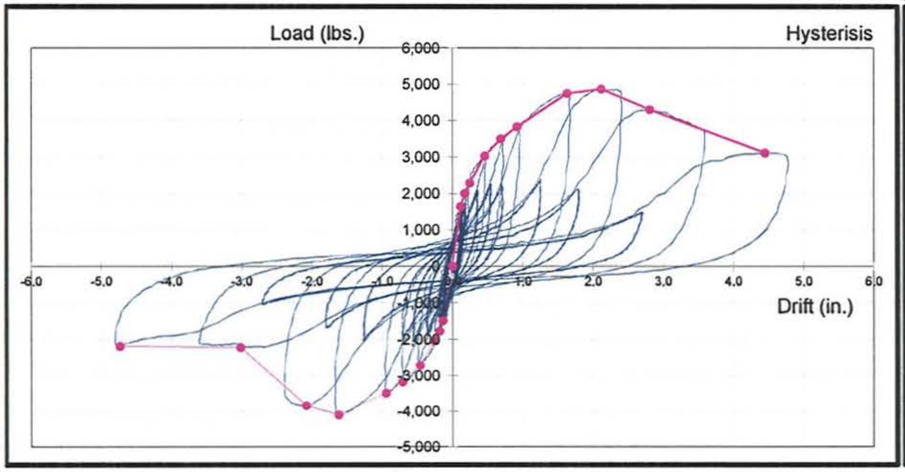
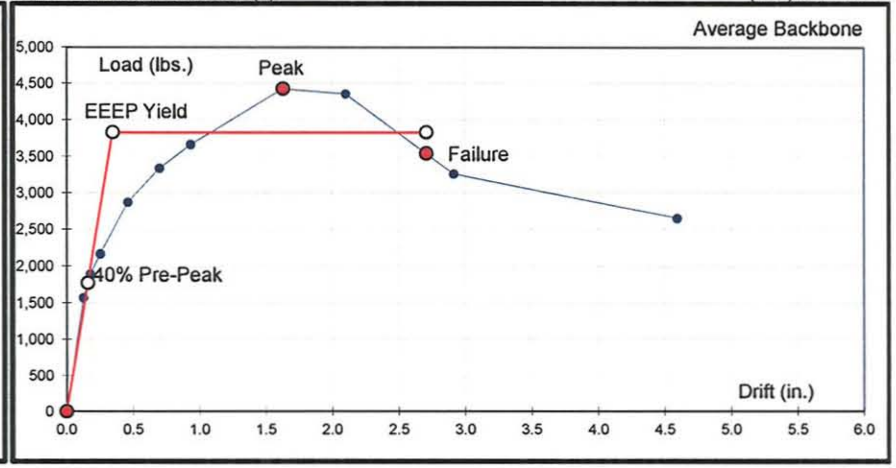
2910 E. Amity Road, Boise, ID
(208) 364-3600





General/EEEP Parameters:

	Load		Drift		Stiffness
	(lbs.)	(lbs./ft.)	(in.)	(%)	(lbs./in)
0.4 Pre-Peak:	**1,770**	221	**0.160**	0.17	11,034
Yield:	**3,827**	478	**0.347**	0.36	11,035
Peak:	**4,425**	553	**1.628**	1.70	2,719
Failure:	**3,540**	442	**2.707**	2.82	1,308

Template revision: Waltz, December 2007

Ductility: 7.80

Notes:
Combination of sheathing edge tearout along plates and nail withdrawal from center stud. No framing failures.

Cyclic Load Test for Shear Resistance of Framed Walls

Test Method: AC130 - "CUREE"

Date: 5/31/2012
Experiment No: 2379
File Name: C2_1
Technician: Atwood
Input Delta (in.): 2.4
Setup Configuration: Single Wall

Zeb Atwood

Sample Description: 8X8 DF framiing, Alt sheath, stapled per manufacturer
Hold Down: HDQ8 w/ 7 SDS screws
Height (in): 96
Length (in): 96
Devices: 10khz - LC S/N 660578(16), CH32 LMP S/N 2.004, CH33 LMP S/N 4.011, CH35 LMP S/N 4.010, CH48 Wand S/N 90088036(3)

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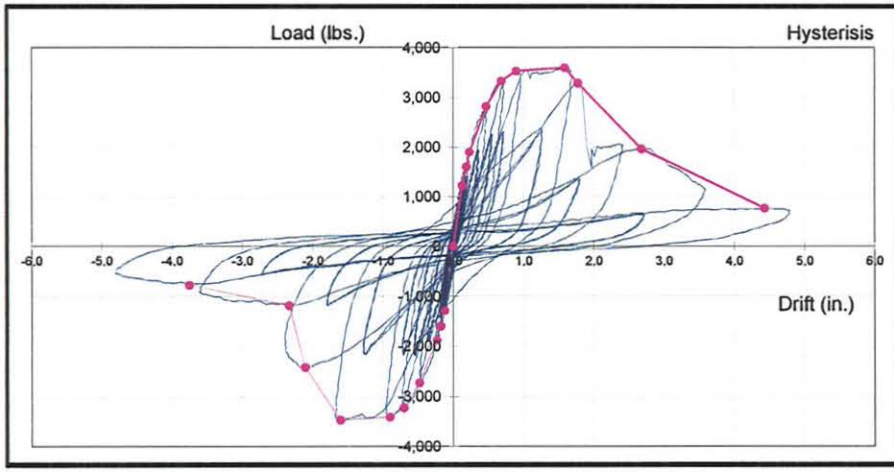

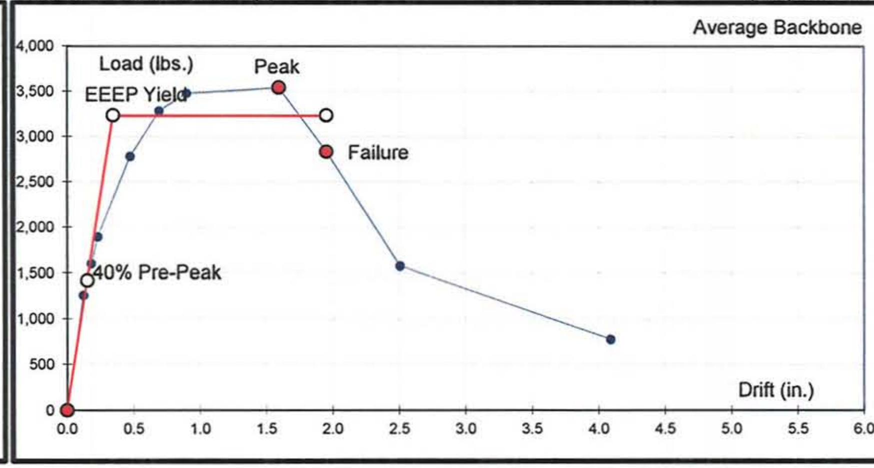

General/EEEP Parameters:

	Load		Drift		Stiffness
	(lbs.)	(lbs./ft.)	(in.)	(%)	(lbs./in)
0.4 Pre-Peak:	**1,416**	177	**0.152**	0.16	9,332
Yield:	**3,232**	404	**0.346**	0.36	9,331
Peak:	**3,539**	442	**1.595**	1.66	2,219
Failure:	**2,831**	354	**1.953**	2.03	1,449

Template revision: Waltz, December 2007

Ductility: 5.64

Notes:
Staple pullthrough and edge tearout around nearly all panel edges. Very little panel buckling observed at that point in the test. Framing entirely intact.

Cyclic Load Test for Shear Resistance of Framed Walls

Test Method: AC130 - "CUREE"

Date: 5/30/2012
Experiment No: 2379
File Name: D2_1
Technician: Atwood
Input Delta (in.): 2.4
Setup Configuration: Single Wall

Zeb Atwood

Sample Description: 8X8 wall, 3/8 in. OSB Sheath, SPF Frame, 6d com nails 6/12
Hold Down: HDQ8 w/ 6 SDS screws
Height (in): 96
Length (in): 96
Devices: 10khz - LC S/N 660578(16), CH32 LMP S/N 2.004, CH33 LMP S/N 4.011, CH35 LMP S/N 4.010, CH48 Wand S/N 90088036(3)

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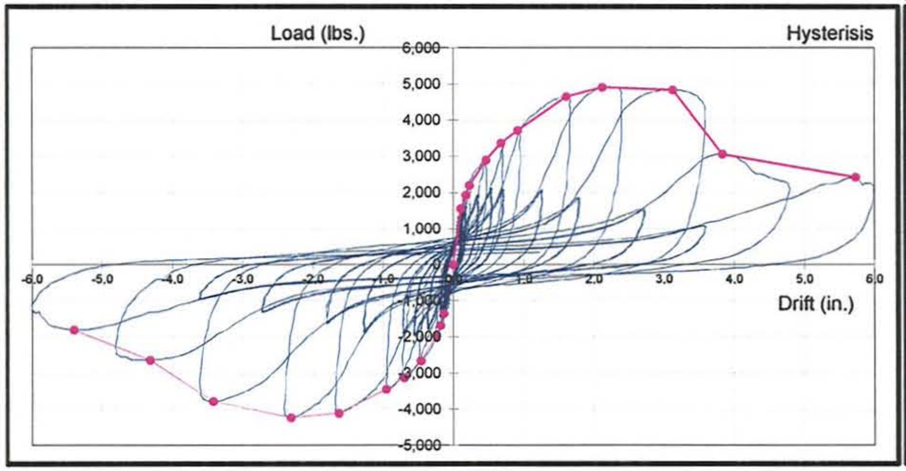
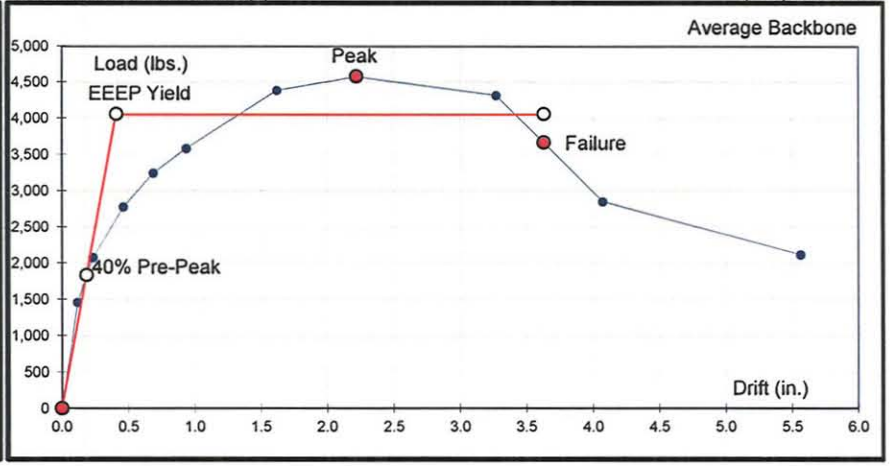
Weyerhaeuser Engineering Laboratory
2910 E. Amity Road, Boise, ID
(208) 364-3600





General/EEEP Parameters:

	Load		Drift		Stiffness
	(lbs.)	(lbs./ft.)	(in.)	(%)	(lbs./in)
0.4 Pre-Peak:	**1,831**	229	**0.186**	0.19	9,868
Yield:	**4,053**	507	**0.411**	0.43	9,866
Peak:	**4,576**	572	**2.219**	2.31	2,063
Failure:	**3,661**	458	**3.630**	3.78	1,008

Template revision: Waltz, December 2007

Ductility: 8.84

Notes:
Nail withdrawal, sheathing edge tearout, and nail head pull-through around panel edges. No framing failures observed.

APPENDIX 5: STUD SPECIFIC GRAVITY AND MOISTURE CONTENT DATA

Weyerhaeuser

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Boise Technology Center
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Experiment No: 2379
Technician: Zeb Atwood
Signature: Zeb Atwood

Date: 4-Jun-12
Test Type: **Specific Gravity and Moisture Content**
Material: Doublas-fir
Source: Purchased from Franklin Building Supply as 8 ft. long 2x4's
Conditioning: Received and tested under ambient atmospheric conditions
Nominal Size: 2 x 4

Sample	**Wet Weight** (lbs.)	**Dry Weight** (lbs.)	Oven-Dry Dimensions: Length 1 (in)	Length 2 (in.)	Width 1 (in.)	Width 2 (in.)	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick 4 (in.)	**Density** (lbs/ft^3)	**SG**	**MC** (%)
A1_1 Top	0.688	0.625	7.366	7.444	3.411	3.326	1.434	1.453	1.455	1.473	29.8	0.48	10.0
A1_1 Bottom	0.722	0.640	7.470	7.650	3.396	3.421	1.467	1.459	1.470	1.475	29.2	0.47	12.9
A1_1 Left	0.777	0.705	7.512	7.428	3.451	3.444	1.471	1.467	1.473	1.448	32.3	0.52	10.3
A1_1 Right	0.723	0.649	7.464	7.449	3.416	3.423	1.464	1.460	1.469	1.483	29.9	0.48	11.4
A1_1 Center	0.669	0.608	7.544	7.609	3.395	3.422	1.490	1.472	1.468	1.476	27.6	0.44	10.1
											29.8	**0.48**	**11.0**
A1_2 Top	0.653	0.562	6.382	6.376	3.275	3.294	1.437	1.433	1.453	1.458	32.1	0.51	16.2
A1_2 Botom	0.641	0.576	6.380	6.360	3.383	3.355	1.454	1.474	1.460	1.456	31.7	0.51	11.4
A1_2 Left	0.587	0.536	6.364	6.387	3.419	3.436	1.481	1.475	1.462	1.461	28.8	0.46	9.4
A1_2 Right	0.616	0.546	6.411	6.404	3.361	3.367	1.459	1.461	1.473	1.473	29.8	0.48	12.9
A1_2 Center	0.560	0.511	6.398	6.424	3.447	3.469	1.488	1.489	1.507	1.502	26.6	0.43	9.4
											29.8	**0.48**	**11.9**
A1_3 Top	0.493	0.443	4.981	4.999	3.374	3.382	1.465	1.474	1.459	1.458	31.0	0.50	11.5
A1_3 Bottom	0.508	0.470	4.859	4.890	3.465	3.466	1.478	1.482	1.481	1.484	32.4	0.52	8.1
A1_3 Left	0.396	0.364	3.958	3.963	3.448	3.466	1.471	1.471	1.474	1.473	31.2	0.50	8.9
A1_3 Right	0.490	0.447	4.982	4.977	3.423	3.401	1.470	1.472	1.479	1.483	30.8	0.49	9.6
A1_3 Center	0.621	0.556	5.972	5.983	3.378	3.391	1.467	1.463	1.472	1.480	32.3	0.52	11.6
											31.5	**0.51**	**9.9**
A2_1 Top	0.581	0.525	5.961	5.979	3.443	3.404	1.459	1.471	1.473	1.479	30.2	0.48	10.7
A2_1 Bottom	0.546	0.508	6.013	5.993	3.461	3.460	1.489	1.489	1.491	1.491	28.4	0.45	7.4
A2_1 Left	0.547	0.504	5.897	5.928	3.454	3.435	1.482	1.488	1.467	1.469	29.0	0.46	8.5
A2_1 Right	0.530	0.483	5.940	5.932	3.456	3.462	1.483	1.475	1.476	1.474	27.5	0.44	9.7
A2_1 Center	0.550	0.502	6.023	6.028	3.434	3.449	1.479	1.476	1.472	1.475	28.3	0.45	9.7
											28.7	**0.46**	**9.2**
A2_2 Top	0.698	0.614	6.382	6.388	3.405	3.396	1.461	1.453	1.462	1.470	33.5	0.54	13.5
A2_2 Bottom	0.620	0.549	6.450	6.450	3.390	3.360	1.477	1.481	1.466	1.470	29.6	0.47	12.9
A2_2 Left	0.615	0.548	6.440	6.447	3.408	3.411	1.463	1.460	1.479	1.469	29.4	0.47	12.2
A2_2 Right	0.658	0.582	6.450	6.447	3.434	3.385	1.449	1.466	1.467	1.471	31.3	0.50	13.0
A2_2 Center	0.667	0.590	6.381	6.390	3.386	3.356	1.465	1.466	1.472	1.480	32.2	0.52	13.0
											31.2	**0.50**	**12.9**
C1_1 Top	0.502	0.455	5.942	5.912	2.920	2.900	1.459	1.457	1.478	1.479	31.0	0.50	10.4
C1_1 Bottom	0.541	0.498	5.930	5.948	3.471	3.477	1.479	1.482	1.487	1.486	28.1	0.45	8.5
C1_1 Left	0.573	0.516	5.888	5.914	3.392	3.387	1.469	1.468	1.474	1.471	30.3	0.49	10.9
C1_1 Right	0.513	0.471	5.937	5.924	3.413	3.424	1.432	1.437	1.452	1.452	27.8	0.45	8.9
C1_1 Center	0.633	0.570	5.927	5.952	3.430	3.404	1.485	1.470	1.464	1.459	33.1	0.53	11.0
											30.1	**0.48**	**9.9**
C1_2 Top	0.510	0.458	4.914	4.929	3.417	3.410	1.459	1.464	1.466	1.482	32.1	0.51	11.3
C1_2 Bottom	0.526	0.481	5.964	5.976	3.429	3.458	1.485	1.493	1.483	1.490	27.2	0.44	9.4
C1_2 Left	0.584	0.511	5.939	5.931	3.388	3.358	1.460	1.458	1.454	1.459	30.2	0.48	14.3
C1_2 Right	0.508	0.454	5.999	6.009	2.905	2.880	1.446	1.435	1.482	1.483	30.9	0.50	11.9
C1_2 Center	0.627	0.563	6.021	5.939	3.404	3.414	1.452	1.440	1.465	1.471	32.8	0.53	11.3
											30.6	0.5	11.7
D1_1 Top	0.396	0.358	4.356	4.366	3.454	3.465	1.485	1.495	1.477	1.480	27.7	0.44	10.6
D1_1 Bottom	0.361	0.328	4.594	4.580	3.207	3.219	1.471	1.476	1.467	1.449	26.3	0.42	10.0
D1_1 Left	0.327	0.297	4.318	4.320	3.172	3.185	1.459	1.452	1.467	1.476	25.6	0.41	10.0
D1_1 Right	0.351	0.319	4.588	4.586	3.214	3.222	1.466	1.480	1.455	1.460	25.5	0.41	10.0
D1_1 Center	0.346	0.313	4.180	4.172	3.195	3.192	1.446	1.466	1.482	1.467	27.7	0.44	10.6
											26.5	**0.43**	**10.2**
D1_2 Top	0.494	0.449	6.015	6.027	3.410	3.401	1.477	1.480	1.461	1.481	25.7	0.41	10.1
D1_2 Bottom	0.510	0.463	5.786	5.809	3.431	3.438	1.472	1.481	1.472	1.480	27.2	0.44	10.2
D1_2 Left	0.490	0.442	5.648	5.648	3.401	3.396	1.448	1.442	1.437	1.435	27.6	0.44	10.9
D1_2 Right	0.571	0.517	6.665	6.651	3.361	3.376	1.454	1.485	1.465	1.476	27.1	0.43	10.4
D1_2 Center	0.391	0.355	4.793	4.765	3.411	3.419	1.464	1.481	1.472	1.465	25.6	0.41	10.2
											26.6	**0.43**	**10.3**
D2_1 Top	0.368	0.333	4.162	4.148	3.405	3.399	1.472	1.478	1.483	1.472	27.6	0.44	10.5
D2_1 Bottom	0.412	0.377	5.008	5.012	3.423	3.426	1.485	1.467	1.464	1.460	25.9	0.41	9.3
D2_1 Left	0.396	0.359	4.814	4.809	3.421	3.421	1.431	1.422	1.462	1.460	26.1	0.42	10.2
D2_1 Right	0.325	0.296	3.919	3.913	3.396	3.416	1.483	1.472	1.456	1.462	26.1	0.42	9.8
D2_1 Center	0.382	0.346	4.476	4.490	3.403	3.391	1.471	1.463	1.479	1.478	26.7	0.43	10.5
											26.5	**0.42**	**10.1**
A3_1 Top	0.470	0.424	4.634	4.631	3.214	3.215	1.469	1.470	1.472	1.470	33.5	0.54	10.8
A3_1 Bottom	0.421	0.372	4.783	4.778	3.222	3.209	1.457	1.463	1.463	1.467	28.6	0.46	13.3
A3_1 Left	0.419	0.363	4.669	4.672	3.206	3.212	1.421	1.456	1.419	1.451	29.1	0.47	15.4
A3_1 Right	0.429	0.373	4.749	4.747	3.205	3.214	1.441	1.433	1.448	1.464	29.3	0.47	14.9
A3_1 Center	0.479	0.429	4.678	4.697	3.198	3.200	1.463	1.463	1.469	1.464	33.8	0.54	11.6
											30.8	**0.49**	**13.2**
C2_1 Top	0.525	0.474	4.766	4.769	3.299	3.308	1.476	1.469	1.478	1.470	35.3	0.57	10.8
C2_1 Bottom	0.428	0.377	4.730	4.723	3.272	3.273	1.437	1.440	1.443	1.443	29.2	0.47	13.6
C2_1 Left	0.434	0.380	4.781	4.779	3.294	3.283	1.438	1.449	1.438	1.442	28.9	0.46	14.4
C2_1 Right	0.479	0.415	4.825	4.821	3.279	3.272	1.455	1.453	1.447	1.462	31.2	0.50	15.4
C2_1 Center	**0.421**	**0.368**	**4.785**	**4.778**	**3.253**	**3.249**	**1.449**	**1.440**	**1.443**	**1.440**	28.4	0.45	14.3
									n	71	71	71
									Average	**29.4**	**0.47**	**11.1**
									min	25.5	0.41	7.4
									COV	8.0%	8.0%	16.7%

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Report Distribution List

Experiment No:	2379A
Project Lead:	Ned Waltz
Project Approver:	Chris Brandt

Distributed to:	**Date**
Ned Waltz	8 June 2012
Chris Brandt	"
Phil Line (AWC)	"
BJ Yeh (APA)	"
File	"