Seismic Equivalence Parameters for Engineered Woodframe Wood Structural Panel Shear Walls

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Abstract

Seismic equivalency parameters for drift capacity, component overstrength, and ductility for woodframe wood structural panel shear walls have previously been defined using a collection of 48 different walls tested with the CUREE cyclic load protocol (Waltz et al. 2008). When establishing minimum seismic performance parameters for new lateral force resisting systems to prove equivalence to woodframe wood structural panel shear walls, this initial reference database was viewed as being representative and sufficient. In the work summarized by this paper, 32 additional shear walls were tested to compare with and supplement the reference database. The new wall tests cover the practical extremes in nail diameter, panel thickness, and nail spacing for woodframe wood structural panel shear wall construction as defined by *2005 Special Design Provisions for Wind and Seismic* (*2005 Wind and Seismic*) AF&PA 2005) and the *2006 International Building Code* (*2006 IBC*) (ICC 2006). The seismic equivalency parameters developed using the new 32 wall test set aligned very well with the distributions observed in the original 48 wall database. When data from the current study and the reference database are combined, the new database consists of 80 cyclic wall tests from four different laboratories that encompass a broad range of woodframe shear wall configurations. The average drift capacity, component overstrength, and ductility performance parameters for the combined data set were within 3 percent of the original estimates. The seismic equivalency criteria that would be derived using the combined database were also within 3 percent of those originally developed.

Introduction

Woodframe shear wall drift capacity, component overstrength, and ductility have previously been summarized for 48 walls tested using the CUREE cyclic load protocol (Waltz et al. 2008). The purpose of the original analysis was to provide criteria that could be used to establish seismic equivalency parameters that define performance of wood structural panel shear walls framed with wood studs. The original 48 wall tests were collected by an independent Task Group working to provide a means for the International Code Council Evaluation Service (ICC-ES) to evaluate seismic performance of new products. When coupled with a specific allowable load derivation procedure and qualitative assessment of degradation in the wall's ability to carry gravity load, non-listed products and systems (e.g., those not defined in *Minimum Design Loads for Buildings and Other Structures, ASCE 7*) capable of meeting the target parameter performance levels established by the Task Group would be judged to be seismically equivalent. As seismically "equivalent" products, they would be assigned the same seismic design coefficients as woodframe wall systems sheathed with wood structural panels.

The original database of 48 walls covered a variety of shear wall aspect ratios, design capacities, sheathing panel thicknesses, nail sizes, and nail spacings. The database was a collection of wall tests conducted at three different labs for a variety of purposes using the CUREE cyclic test protocol (ASTM 2007) with realistic anchorage and boundary conditions. But, it did not cover the extremes of nail size, sheathing thickness, and nail spacings in shear wall design tables provided in references such as the *2005 Wind and Seismic* standard and the *2006 IBC*. In the work summarized by this paper, cyclic in-plane shear testing of two replicates of 16 different engineered shear wall configurations were completed to bracket the practical extremes of the shear wall design tables based on nail size, spacing, and sheathing thickness. The broader range of configurations in this study is compared to the 48 wall database used to develop the original equivalency targets.

The shear wall testing summarized in this paper was undertaken as part of a collaborative effort between American Forest & Paper Association, Weyerhaeuser, and APA–The Engineered Wood Association in the Spring of 2008.

Test Method

The 16 wood-frame wood structural panel shear wall configurations detailed in **Table 1** were tested to determine their in-plane shear performance in general accordance with provisions of ASTM E 2126-07 *Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Walls for Buildings* (ASTM 2007). Loading was undertaken using the Method C (CUREE) protocol as defined by the standard. A minimum of two tests were conducted for each shear wall configuration.

This test program was developed to cover the range of nail size, nail spacing, and sheathing thickness for shear wall configurations defined by the *2005 Wind and Seismic* standard and *2006 IBC*. Given that 5/16-in.-thick sheathing is not commonly available, Test Groups A–D were selected to represent the highest unit shear capacity configurations that could be constructed with a small nail (6d common) and thinnest practical square edge sheathing (3/8 in.). Test Groups I–L were chosen to represent the highest unit shear capacity configurations that could be constructed using a large nail (10d common) and thick sheathing (19/32 in.). Test Groups E–H and M–P were selected to provide some data with an intermediate unit shear capacity using relatively common choices for nail size (8d common) and sheathing thickness (3/8 in. and 7/16 in.). For each nail and sheathing thickness combination, both a 2 in. and 6 in. on center (o.c.) edge boundary nail spacing were tested. For each nail and sheathing thickness combination, two aspect ratios were tested: 1:1 and 2:1. A 1:1 aspect ratio was tested to include a vertical butted joint between adjacent sheathing panels and to correspond with standard specimen size used in wood structural panel product evaluation tests. The 2:1 aspect ratio walls represent the maximum aspect ratio for seismic design applications permitted without taking a design strength reduction.

Specimens

Shear wall size, sheathing, framing, fastening, anchorage, and connections were in accordance with **Table 1** and **Figure 1**.

All framing was "standard" grade 2 by 4 nominal Douglas-fir material spaced at 24 in. o.c. Multiple plies of this same stud material were used at the end posts and adjoining panel edge framing where an increased thickness was required. Multiple plies were joined using self-drilling 1/4 in. diameter by 3 in. screws for (2) 2x framing and self-drilling 1/4 in. diameter by 4-1/2 in. screws for (3) 2x framing. A single commercial "low deformation" hold down type was used for all testing. The number of screws in the hold down varied such that the ASD design capacity of the hold down-to-post connection was only slightly greater than the calculated ASD shear wall overturning forces.

All of the wall sheathing was oriented strandboard (OSB) sheathing produced in accordance with *Performance Standard for Wood-Based Structural Use Panels* (DOC-NIST, PS2-2004). Panel edge distance for the sheathing nails was a 3/8 in. minimum for all configurations. Sheathing nailing was staggered at panel edges for 2 in. o.c. edge nail spacing in accordance with *2005 Wind and Seismic*. Per *2006 IBC* requirements for high seismic areas, 3 in. square by 0.229 in. thick plate washers were used at anchor bolts for walls having 2 in. o.c. sheathing nail spacing at panel edges. Standard round washers, 1-3/4 in. diameter by 1/8 in. thick, were used at anchor bolts for walls having 6 in. o.c. spacing at panel edges.

The test specimens were detailed to provide wall designs that were in accordance with *2005 Wind and Seismic* and the *2007 Supplements to the 2006 IBC*. The framing, fram-

Table 1.—Shear wall test specimen configurations.

			Sheathing nails			Hold down[a]	
Test group	H by L (ft.)	OSB thickness and grade	Common nail size	Spacing (edge/field)	A307 anchor bolts	No. of screws	ASD capacity (lbf)
A	8 by 8	3/8 in. Struc I	6d	6 in./6 in.	(2) 5/8 in.	8	2,286
B	8 by 4						
C	8 by 8			2 in./6 in.	(4) 5/8 in.	18	5,143
D	8 by 4				(2) 5/8 in.	20	5,715
E	8 by 8	7/16 in. Sheathing	8d	6 in./6 in.	(2) 5/8 in.	8	2,286
F	8 by 4						
G	8 by 8			2 in./6 in.	(4) 5/8 in.	14	4,000
H	8 by 4				(2) 5/8 in.	18	5,143
I	8 by 8	19/32 in. Sheathing	10d	6 in./12 in.	(2) 5/8 in.	12	3,429
J	8 by 4						
K	8 by 8			2 in./12 in.	(4) 3/4 in.	20	9,230
L	8 by 4				(2) 3/4 in.		
M	8 by 8	3/8 in. Struct I	8d	6 in./6 in.	(2) 5/8 in.	8	2,286
N	8 by 4						
O	8 by 8			2 in./6 in.	(4) 5/8 in.	20	5,715
P	8 by 4				(2) 5/8 in.		

[a] All end posts were built-up (2) 2x members except for Test Groups K and L where (3) 2x members were used to meet minimum wood thickness recommendations for the hold down device.

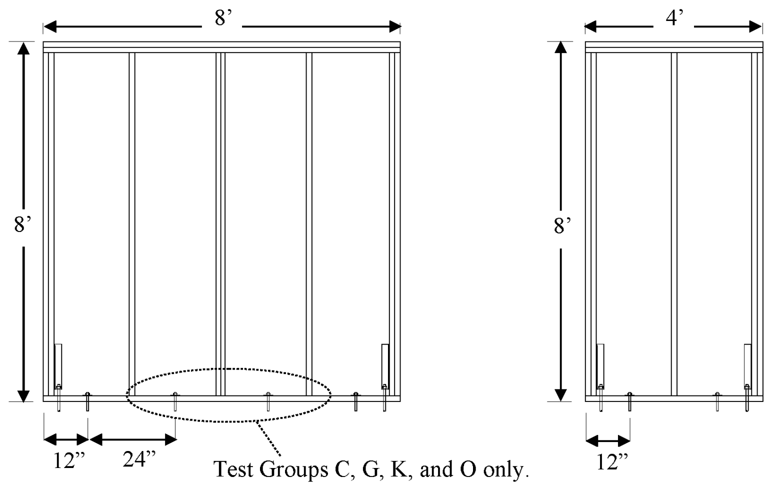

Figure 1.—Shear wall specimens.

ing connection, and anchorage details were matched as closely as could practically be accomplished to allowable in-plane design capacity and minimum code requirements for a given wall configuration in a high seismic application. Care was taken in detailing so that framing, connections, and anchorage were not over-designed.

Test Results

Table 2 summarizes the test results. The cyclic test data was analyzed consistent with methods used to analyze the reference database (Waltz et al. 2008). The positive and negative backbone curves for each dataset were obtained as described in ASTM E2126. The positive and negative curves were then combined to produce an average backbone curve that was used to determine the test results summarized in **Table 2**. An example load displacement hysterisis curve is shown in **Figure 2**. An example averaged backbone curve is shown in **Figure 3**. Each line of **Table 2** represents the average of two test replicates.

The reported drift capacity, component overstrength, and ductility contained within Table 2 are defined as follows:

- Drift Capacity: The “ultimate” displacement defined by Section 3.2.12 of ASTM E2126. This parameter is expressed as a percentage of the wall height.

Table 2.—Shear wall test results – Averages of two replicates.

		ASD		EEEP yield		Peak		Ultimate						
Test group	n	Load (lbf)	Disp. (in.)	Load (lbf)	Disp. (in.)	Load (lbf)	Disp. (in.)	Load (lbf)	Disp. (in.)	Drift capacity (%h)	Component over-strength	Ductility	Gravity load intact	Primary failure mode[a]
A		1,780	0.107	3,897	0.241	4,427	1.670	3,542	2.683	2.8	2.5	25.0	Yes	W
B		890	0.114	2,240	0.300	2,485	2.359	1,988	3.552	3.7	2.8	31.2	Yes	W, P
C		4,530	0.202	11,237	0.537	12,779	2.379	10,223	3.117	3.2	2.8	17.0	Yes	W
D		2,265	0.252	5,591	0.657	6,317	2.945	5,054	3.896	4.1	2.8	16.3	Yes	W, P
E		1,920	0.088	5,364	0.242	6,012	1.655	4,809	2.660	2.8	3.1	30.4	Yes	W, P, T
F		960	0.138	2,674	0.435	3,097	2.358	2,370	3.714	3.9	3.2	27.8	Yes	W
G		4,680	0.180	14,049	0.661	16,202	2.361	12,962	2.653	2.8	3.5	15.1	Yes	W, O[b]
H	2	2,340	0.306	6,329	0.842	7,087	2.786	5,670	3.051	3.2	3.0	10.0	Yes	W, P, O[c]
I		2,720	0.142	5,916	0.316	6,714	2.018	5,371	2.970	3.1	2.5	21.2	Yes	P
J		1,360	0.213	2,936	0.450	3,320	2.325	2,656	3.612	3.8	2.4	17.0	Yes	W, P
K		6,960	0.257	14,890	0.533	16,909	2.301	13,528	3.317	3.5	2.4	12.9	Yes	W, P
L		3,480	0.410	6,627	0.735	7,433	2.342	5,947	3.537	3.7	2.1	8.7	Yes	W, O[d]
M		1,840	0.086	4,994	0.233	5,630	1.648	4,504	2.543	2.6	3.1	29.9	Yes	P, T
N		920	0.106	2,469	0.309	2,803	1.642	2,243	2.787	2.9	3.0	26.1	Yes	W, P
O		4,880	0.198	13,506	0.614	15,250	2.337	12,199	2.980	3.1	3.1	15.2	Yes	W, P
P		2,440	0.248	6,350	0.690	7,027	2.379	5,622	3.388	3.5	2.9	13.8	Yes	P

[a] Failure codes: W – sheathing nail withdrawal; P – sheathing nail head pull-through at panel; T – sheathing nail edge tearout of panel; and O – other.
[b] One replicate failed when the screws used to stitch the center stud failed in fatigue.
[c] One out of two plies in one chord of one replicate failed in tension during the later stages of the test.
[d] One chord of one replicate failed in tension during the later stages of the test.

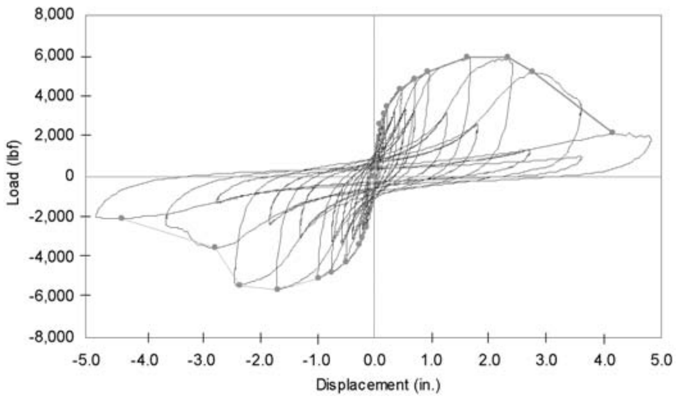

Figure 2.—Example hysterisis curve (Specimen E1).

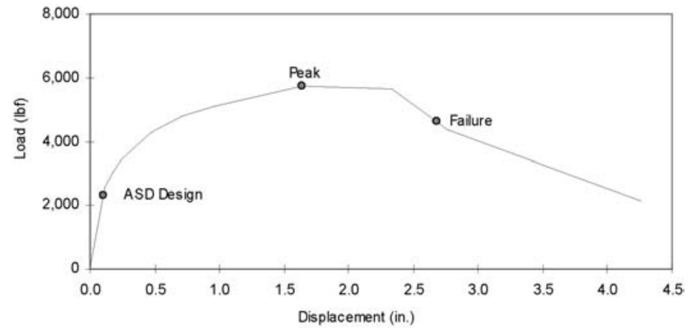

Figure 3.—Example averaged backbone curve (Specimen E1).

Table 3.—Comparison of reported data and reference data.

Test groups	Statistic[a]	Data from this experiment			Reference data			Ratio of current data to reference data		
		Drift capacity (%h)	Component over-strength	Ductility	Drift capacity (%h)	Component over-strength	Ductility	Drift capacity (%h)	Component over-strength	Ductility
All walls	n	32			48			32/48		
	Maximum	4.2	3.5	33.3	5.5	5.4	43.4	0.76	0.65	0.77
	Minimum	2.5	2.1	7.9	2.3	2.3	6.4	1.06	0.92	1.23
	Average	**3.3**	**2.8**	**19.8**	**3.6**	**3.1**	**20.3**	**0.92**	**0.92**	**0.98**
	COV	0.151	0.130	0.402	0.213	0.261	0.449	0.71	0.50	0.90
	Avg + 1 STD	3.8	3.2	27.8	4.3	3.9	29.4	0.88	0.82	0.95
	Avg – 1 STD	**2.8**	**2.5**	**11.9**	**2.8**	**2.3**	**11.2**	**1.00**	**1.08**	**1.06**

[a] COV = coefficient of variation; Avg + 1 STD = average plus 1 standard deviation; Avg – 1 STD = average minus 1 standard deviation.

- Component Overstrength: The peak load capacity of the wall divided by the allowable stress design load. This parameter is unitless.
- Ductility: The "ultimate" displacement divided by the displacement at the allowable stress design load. This parameter is unitless.

The primary failure modes observed in these wall tests were nail withdrawal from the framing, the nail head pulling through the thickness of the sheathing (commonly referred to as "nail head pull through"), and sheathing edge tear-out. Observed failures often involved a combination of modes that led to loss of shear capacity in the test specimens. In some cases, splitting of framing or partial tension rupture of the end post framing was observed as noted in **Table 2**. For one specimen only, wall G1, the failure was at least partially attributed to fatigue of the "stitch" screws that laminated together the two-ply stud at the adjoining panel edge. In 30 out of 32 tests, all of the stud framing members were judged to be intact at the conclusion of the test. In 2 out of 32 tests, one or two plies of one end post within the wall experienced a tension failure. Overall, the wall studs that carry gravity loads in this test program were judged to be intact at the conclusion of these lateral load tests.

Comparison to Reference Data

Summary statistics for the three quantitative equivalency parameters for all of the walls in the current study are shown in **Table 3**. (The assessment of the fourth parameter, the ability to support gravity loads, is qualitative when based upon a standard shear wall test without an applied vertical load). **Table 3** also includes a comparison to the previous 48 wall database developed by the Task Group and used to set equivalency parameters in the ICC-ES arena (Waltz et al. 2008). This previous data is identified in the table as "reference data."

Overall, **Table 3** suggests a high degree of overlap for each of the three parameter distributions between the reported and reference databases. On average, **Table 3** shows that average values from the current study result in slightly different estimates of drift capacity (–8%), component overstrength (–8%), and ductility (–2%) when compared with the reference data. At the average minus 1 standard deviation level, shown as "Avg – 1 STD," used by the Task group to select equivalency targets, **Table 3** suggests differences that are similar in magnitude.

Where all three of the quantitative equivalency parameters are relatively variable properties with high coefficients of variation, it seems reasonable to question whether the observed differences between the new and reference data-

Table 4.—Comparison of combined data and reference data.

Test groups	Statistic[a]	Combined data (reported and reference)			Ratio of combined data to reference data		
		Drift capacity (% h)	Component over-strength	Ductility	Drift capacity (% h)	Component over-strength	Ductility
All walls	n	80			80/48		
	Maximum	5.5	5.4	43.4	1.00	1.00	1.00
	Minimum	2.3	2.1	6.4	1.00	0.92	1.00
	Average	**3.4**	**3.0**	**20.1**	**0.97**	**0.97**	**0.99**
	COV	0.196	0.226	0.429	0.92	0.87	0.96
	Avg + 1 STD	4.1	3.7	28.8	0.96	0.94	0.98
	Avg – 1 STD	**2.8**	**2.3**	**11.5**	**0.99**	**1.01**	**1.03**

[a] COV = coefficient of variation; Avg + 1 STD = average plus 1 standard deviation; Avg – 1 STD = average minus 1 standard deviation.

base are statistically significant. Since a single parametric distribution could not be used to define all of the matched distributions to be paired, a non-parametric Mann-Whitney test was consistently used to check for statistical differences between databases for each of the three parameters. With resulting p-values in excess of 0.15 in all three cases, the statistical analysis did not suggest a meaningful difference between the matched new and reference populations. Overall, this suggests that the best estimate for all three of these parameters can likely be achieved by combining databases.

Combined Data

Summary statistics from the combined data, representing 80 wood structural panel/stud shear walls tested using the CUREE cyclic load protocol, are shown in **Table 4**. An itemized listing of the 80 wall tests forming the combined data is provided in **Appendix Table A.1**.

Table 4 also provides a comparison between the newly combined database and the original "reference" database used by the Task Group. The combined data results in drift capacity, component overstrength, and ductility estimates that are similar to the values defined by the reference data used to develop performance targets for woodframe wood structural panel shear walls in the ICC-ES product evaluation process. At the average minus 1 standard deviation level, used in the ICC-ES process to define minimum performance targets for equivalency, the combined data results in a maximum 3 percent change compared to the reference data. In other words, combining the new 32 wall database that encompassed a broad range of shear wall configurations with the original 48 wall reference database resulted in no significant change to the target performance levels developed by the Task Group.

Summary

Performance parameters for woodframe shear walls tested using the CUREE Protocol have previously been defined. While the original data included 48 wall tests, additional test data were added to the existing data to better represent the extremes in nail diameter, panel thickness, and nail spacing addressed in the *2005 Wind and Seismic* standard and the *2006 IBC*. The combined data consists of 80 walls total and addresses a broader range of wood frame shear wall configurations. While representing approximately 40 percent of all walls in the combined data, the new data had only a minor effect on drift capacity, shear strength ratio, and ductility. Average values of these parameters decreased a maximum of 3 percent. Values of these parameters at the average minus 1 standard deviation level, used for establishing minimum performance targets for seismic equivalency in some evaluation criteria, changed by 3 percent maximum.

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Table A.1.—Combined data set summary.

Item	(Ref.)/Ref. ID	Wall size H by L (ft)	OSB sheathing	Fasteners	Fastener spacing (edge/field) (in./in.)	Openings	ASD Load (lbf)	ASD Disp. (in.)	EEEP yield Load (lbf)	EEEP yield Disp. (in.)	Peak Load (lbf)	Peak Disp. (in.)	Ultimate Load (lbf)	Ultimate Disp. (in.)	Drift capacity (%h)	Component over-strength	Ductility	Gravity load intact	Primary failure mode[a]
1	(A)/24-1	8.5 by 4.5	15/32 in. Str.1	10d com	2/12	none	3,915	0.507	9,047	1.191	10,239	3.314	9,748	4.147	4.1	2.6	8.2	Yes	NR
2	(A)/24-2							0.516	9,125	1.213	10,461	3.224	8,369	3.422	3.4	2.7	6.6		
3	(B)/1-8dc	8 by 8	7/16	8d com	4/6	none	2,800	0.124	6,646	0.308	7,480	2.316	5,984	3.223	3.4	2.7	26.1	Yes	NR
4	(B)/2-8dgb			8d galv box				0.164	6,856	0.444	7,794	2.259	6,235	3.319	3.5	2.8	20.3		
5	(B)/3-8db			8d box				0.106	7,315	0.397	8,205	2.245	6,564	3.646	3.8	3.4	34.3		
6	(C)/2	8 by 8	7/16	8d com	4/6	none	2,800	0.132	6,209	0.293	7,019	1.614	5,615	2.372	2.5	2.5	18.0	Yes	NR
7	(C)/3							0.152	6,303	0.341	6,965	2.322	5,572	3.585	3.7	2.5	23.6		
8	(C)/4							0.149	6,099	0.313	6,701	2.316	5,361	3.697	3.9	2.4	24.8		
9	(C)/5	8 by 8	19/32	10d com	2/12	none	6,960	0.245	14,185	0.458	15,947	3.203	12,757	3.380	3.5	2.3	13.8	Yes	NR
10	(C)/6							0.282	14,035	0.525	15,953	2.305	12,762	3.431	3.6	2.3	12.2		End post
11	(C)/7							0.281	15,793	0.652	17,856	3.326	15,107	4.380	4.6	2.6	15.6		NR
12	(C)/8							0.279	15,393	0.618	17,421	3.398	14,537	4.380	4.6	2.5	15.7		NR
13	(D)/1	8 by 8	7/16	8d com	4/6	none	2,800	0.387	6,229	0.889	7,148	2.573	5,747	2.751	2.9	2.6	7.1	Yes	NR
14	(D)/3							0.429	6,618	1.029	7,454	2.533	5,963	2.758	2.9	2.7	6.4		
15	(D)/5							0.237	6,071	0.505	6,906	2.557	5,525	2.977	3.1	2.5	12.6		
16	(D)/6							0.240	6,217	0.540	7,136	2.548	5,709	2.874	3.0	2.5	12.0		
17	(D)/7							0.094	6,867	0.242	7,631	1.700	6,105	2.251	2.3	2.7	23.9		
18	(D)/8							0.096	6,760	0.238	7,478	1.160	6,309	2.270	2.4	2.7	23.8		
19	(E)/A-1	8 by 8	7/16	8d com	3/12	none	3,920	0.303	9,273	0.729	10,208	3.373	10,208	3.373	3.5	2.6	11.1	Yes	Fastener
20	(E)/A-2							0.180	9,174	0.442	10,613	3.006	8,588	3.763	3.9	2.7	20.9		
21	(E)/A-3							0.220	9,754	0.610	11,151	2.980	9,268	3.690	3.8	2.8	16.8		
22	(E)/B-1	8 by 8	7/16	8d com	3/12	none	3,920	0.205	9,618	0.516	10,877	2.913	8,702	3.308	3.4	2.8	16.1	Yes	Fastener
23	(E)/B-2							0.165	10,209	0.459	11,554	2.987	9,243	3.747	3.9	2.9	22.7		
24	(E)/B-3							0.163	9,976	0.456	11,396	2.833	9,691	3.790	3.9	2.9	23.3		
25	(E)/C-1	8 by 8	7/16	8d com	3/12	none	3,920	0.321	9,240	0.815	10,952	2.743	10,952	2.743	2.9	2.8	8.5	Yes	Sill split
26	(E)/C-2							0.233	9,387	0.590	10,574	2.784	8,775	3.763	3.9	2.7	16.2		
27	(E)/C-3							0.257	9,756	0.668	11,156	2.835	8,925	3.032	3.2	2.8	11.8		
28	(E)/D-1	8 by 8	7/16	8d com	3/12	none	3,920	0.191	9,583	0.467	10,863	2.840	9,815	3.831	4.0	2.8	20.1	Yes	Fastener
29	(E)/D-2							0.183	9,481	0.442	10,771	2.827	9,844	3.964	4.1	2.7	21.6		
30	(E)/D-3							0.282	9,179	0.686	10,265	2.833	9,441	4.044	4.2	2.6	14.3		
31	(E)/E-1	8 by 8	7/16	8d com	3/12	none	3,920	0.205	9,555	0.500	10,794	2.221	10,386	3.240	3.4	2.8	15.8	Yes	Fastener
32	(E)/E-2							0.204	9,744	0.508	10,923	2.256	10,068	3.278	3.4	2.8	16.1		
33	(E)/E-3							0.193	9,556	0.471	10,920	2.278	9,290	3.089	3.2	2.8	16.0		
34	(E)/F-1	8 by 8	7/16	8d com	3/12	none	3,920	0.211	8,828	0.474	10,113	2.246	8,083	2.916	3.0	2.6	13.8	Yes	Sill split
35	(E)/F-2							0.195	9,635	0.479	10,831	2.318	9,838	3.203	3.3	2.8	16.4		Fastener
36	(E)/F-3							0.203	9,973	0.516	11,079	2.302	10,460	3.343	3.5	2.8	16.5		Fastener
37	(F)/4A	8 by 16	3/8	8d box	6/12	none	3,200	0.126	10,523	0.496	11,663	1.944	10,183	2.776	2.9	3.6	22.0	Yes	Fastener
38	(F)/4B							0.087	10,778	0.366	11,929	2.018	10,042	3.073	3.2	3.7	35.3		
39	(F)/6A	8 by 16	3/8	8d box	6/12	pedestrian door	2,600	0.101	10,156	0.398	11,363	1.895	9,090	2.505	2.6	4.4	24.8	Yes	Fastener
40	(F)/6B							0.113	8,897	0.406	10,081	2.020	8,065	2.890	3.0	3.9	25.6		
41	(F)/8A	8 by 16	3/8	8d box	3/12	garage door	1,904	0.131	8,675	0.670	9,692	3.740	9,222	5.311	5.5	5.1	40.5	Yes	Fastener
42	(F)/8B							0.134	9,010	0.598	10,205	3.739	9,010	4.968	5.2	5.4	37.1		
43	(F)/10A	8 by 16	3/8	8d com	3/12	garage door	2,393	0.144	9,166	0.571	10,399	3.736	8,813	4.907	5.1	4.3	34.1	Yes	Fastener
44	(F)/10B							0.145	9,116	0.559	10,145	3.775	9,323	5.169	5.4	4.2	35.6		
45	(F)/11A	8 by 16	3/8	1-3/8, 16 ga staple	6/12	none	2240	0.071	9,639	0.385	11,123	1.402	8,898	2.383	2.5	5.0	33.6	Yes	Fastener
46	(F)/11B							0.058	10,213	0.369	11,627	2.027	9,302	2.519	2.6	5.2	43.4		
47	(F)/26A	8 by 16	3/8	8d box	6/12	pedestrian door	2,600	0.156	7,721	0.556	9,208	2.007	7,367	3.356	3.5	3.5	21.5	Yes	Fastener
48	(F)/26B							0.179	7,168	0.559	8,303	2.034	6,643	3.278	3.4	3.2	18.3		
49	(G)/A1	8 by 8	3/8 Str. 1	6d com	6/6	none	1,780	0.106	4,037	0.252	4,573	1.667	3,659	2.848	3.0	2.6	26.8	Yes	Fastener
50	(G)/A2							0.108	3,757	0.229	4,280	1.672	3,424	2.518	2.6	2.4	23.3		

Table A.1 *(continued)*.—Combined data set summary.

Item	(Ref.)/Ref. ID	Wall size H by L (ft)	OSB sheathing	Fasteners	Fastener spacing (edge/field) (in./in.)	Openings	ASD Load (lbf)	ASD Disp. (in.)	EEEP yield Load (lbf)	EEEP yield Disp. (in.)	Peak Load (lbf)	Peak Disp. (in.)	Ultimate Load (lbf)	Ultimate Disp. (in.)	Drift capacity (%h)	Component over-strength	Ductility	Gravity load intact	Primary failure mode[a]
51	(G)/B1	8 by 4	3/8 Str. 1	6d com	6/6	none	890	0.110	2,244	0.283	2,502	2.336	2,002	3.204	3.3	2.8	29.1	Yes	Fastener
52	(G)/B2							0.117	2,236	0.316	2,467	2.381	1,974	3.900	4.1	2.8	33.3		
53	(G)/C1	8 by 8	3/8 Str. 1	6d com	2/6	none	4,530	0.147	11,220	0.401	12,753	2.385	10,202	3.311	3.4	2.8	22.5	Yes	Fastener
54	(G)/C2							0.256	11,254	0.673	12,805	2.373	10,244	2.922	3.0	2.8	11.4		
55	(G)/D1	8 by 4	3/8 Str. 1	6d com	2/6	none	2,265	0.305	5,887	0.832	6,746	3.508	5,397	3.777	3.9	3.0	12.4	Yes	Fastener
56	(G)/D2							0.199	5,295	0.482	5,888	2.382	4,710	4.014	4.2	2.6	20.2		
57	(G)/E1	8 by 8	7/16	8d com	6/6	none	1,920	0.090	5,130	0.239	5,750	1.643	4,600	2.682	2.8	3.0	29.8	Yes	Fastener
58	(G)/E2							0.085	5,561	0.245	6,273	1.667	5,018	2.637	2.7	3.3	31.0		
59	(G)/F1	8 by 4	7/16	8d com	6/6	none	960	0.158	2,605	0.469	2,889	2.346	2,311	3.568	3.7	3.0	22.6	Yes	Fastener
60	(G)/F2							0.117	2,743	0.401	3,305	2.369	2,428	3.859	4.0	3.4	33.0		
61	(G)/G1	8 by 8	7/16	8d com	2/6	none	4,680	0.156	13,860	0.590	16,058	2.400	12,847	2.760	2.9	3.4	17.7	Yes	Fastener
62	(G)/G2							0.204	14,237	0.731	16,345	2.322	13,076	2.546	2.7	3.5	12.5		
63	(G)/H1	8 by 4	7/16	8d com	2/6	none	2,340	0.313	6,834	0.918	7,584	3.193	6,067	3.254	3.4	3.2	10.4	Yes	End post
64	(G)/H2							0.300	5,823	0.766	6,590	2.378	5,272	2.848	3.0	2.8	9.5		Fastener
65	(G)/I3	8 by 8	19/32	10d com	6/12	none	2,720	0.153	5,766	0.312	6,577	1.664	5,261	2.589	2.7	2.4	17.0	Yes	Fastener
66	(G)/I5							0.131	6,066	0.321	6,851	2.372	5,481	3.351	3.5	2.5	25.5		
67	(G)/J2	8 by 4	19/32	10d com	6/12	none	1,360	0.210	2,978	0.453	3,345	2.317	2,676	3.614	3.8	2.5	17.2	Yes	Fastener
68	(G)/J3							0.216	2,894	0.447	3,296	2.334	2,636	3.611	3.8	2.4	16.7		
69	(G)/K1	8 by 8	19/32	10d com	2/12	none	6,960	0.255	14,679	0.519	16,826	2.289	13,460	3.208	3.3	2.4	12.6	Yes	Fastener
70	(G)/K2							0.258	15,101	0.547	16,992	2.313	13,596	3.425	3.6	2.4	13.3		
71	(G)/L1	8 by 4	19/32	10d com	2/12	none	3,480	0.420	6,625	0.768	7,504	2.341	6,003	3.327	3.5	2.2	7.9	Yes	Fastener/ post
72	(G)/L2							0.399	6,629	0.702	7,363	2.344	5,890	3.747	3.9	2.1	9.4		Fastener
73	(G)/M1	8 by 8	3/8 Str. 1	8d com	6/6	none	1,840	0.082	5,037	0.226	5,614	1.663	4,491	2.704	2.8	3.1	33.0	Yes	Fastener
74	(G)/M2							0.089	4,951	0.240	5,646	1.632	4,517	2.382	2.5	3.1	26.8		
75	(G)/N1	8 by 4	3/8 Str. 1	8d com	6/6	none	920	0.104	2,439	0.288	2,757	1.642	2,206	2.411	2.5	3.0	23.2	Yes	Fastener
76	(G)/N2							0.109	2,498	0.330	2,849	1.642	2,279	3.163	3.3	3.1	29.0		
77	(G)/O1	8 by 8	3/8 Str. 1	8d com	2/6	none	4,880	0.208	13,837	0.663	15,695	2.307	12,556	2.624	2.7	3.2	12.6	Yes	Fastener
78	(G)/O2							0.187	13,174	0.565	14,804	2.367	11,843	3.337	3.5	3.0	17.8		
79	(G)/P1	8 by 4	3/8 Str. 1	8d com	2/6	none	2,440	0.263	6,263	0.703	6,838	2.377	5,470	3.349	3.5	2.8	12.7	Yes	Fastener
80	(G)/P2							0.232	6,438	0.677	7,216	2.381	5,773	3.427	3.6	2.96	14.8		
													Average		3.4	3.0	20.1		
													Average minus 1 STD		2.8	2.3	11.5		

[a] NR = not reported.

Appendix Table References:

[A] Martin, Z., T. Skaggs, and E. Keith E. 2005. Using Narrow Pieces of Wood Structural Panel Sheathing in Wood Shear Walls. APA Report No. T2005-08, APA-The Engineered Wood Association, Tacoma, WA. 18 pp.

[B] Martin Z. 2004. Wood Structural Panel and Shear Wall Connections with Common, Galvanized Box, and Box Nails. APA Report No. T2004-14, APA-The Engineered Wood Association, Tacoma, WA. 14 pp.

[C] Martin, Z. and T. Skaggs. 2003. Shear Wall Lumber Framing: Double 2x's vs. Single 3x's at Adjoining Panel Edges. APA Report No. T2003-22, APA-The Engineered Wood Association, Tacoma, WA. 20 pp.

[D] Martin, Z. 2002. Effect of Green Lumber on Wood Structural Panel Shear Wall Performance. APA Report No. T2002-53, APA–The Engineered Wood Association, Tacoma, WA. 19 pp.

[E] Rosowsky, D., L. Elkins, and C. Carrol. 2004. Cyclic Tests of Engineered Shear Walls Considering Different Plate Washers. Oregon State Univ. Report for the American Forest & Paper Association, Corvallis, OR. 27 pp.

[F] Pardoen, G.C., R.P. Waltman, E. Kazanjy, E. Freund, and C.H. Hamilton. 2003. Testing and Analysis of One-Story and Two-Story Shear Walls Under Cyclic Loading. Report W-25, Consortium of Universities for Research in Earthquake Engineering, Richmond, CA. 271 pp.

[G] Data collected as part of the main body of this article.