Designation: D7989 – 15

Standard Practice for Demonstrating Equivalent In-Plane Lateral Seismic Performance to Wood-Frame Shear Walls Sheathed with Wood Structural Panels[1]

This standard is issued under the fixed designation D7989; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice establishes a method for alternative shear wall systems to compare seismic equivalency parameters (SEP) derived from cyclic in-plane racking tests to performance targets derived from tests of light-frame shear walls constructed with wood structural panel (WSP) sheathing attached to dimension lumber framing using nails.

1.2 This practice considers only the performance of shear walls subject to cyclic lateral loading, parallel to the plane of the shear wall. Design of walls with openings and performance for other wall functions, such as out-of-plane bending, combined shear and uplift, etc. are not considered.

1.3 This practice is applicable only to shear walls where all vertical-load-supporting elements are intact at the end of the in-plane lateral load test and remain capable of supporting gravity loads. Wall assemblies whose vertical-load-supporting elements buckle or otherwise become incapable of supporting gravity loads during the lateral load test are outside the scope of this practice. In addition, for bearing wall systems, this practice assumes that the shear wall system under evaluation has documented design procedures to ensure that vertical-load-supporting elements have adequate resistance to the combined effect of compression loads caused by overturning and gravity loads.

1.4 This practice does not address height limitations, detailing requirements, wall openings, derivation of design values for strength and stiffness, or other requirements and limitations that may be necessary for an alternative shear wall system. These requirements shall be provided elsewhere, such as by a suitable product standard for the alternative shear wall system.

1.5 This practice assumes that the stiffness or deformation of the alternative shear wall system can be estimated, and that design loads within a structure will be distributed among seismically equivalent wall systems based on their relative stiffness.

1.6 This practice is not intended to preclude other rational means of evaluating seismic performance.

1.7 This practice assumes that the alternative shear wall system may be used alone or in combination with wood-frame shear walls sheathed with wood structural panels.

1.8 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2126 Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings

F1667 Specification for Driven Fasteners: Nails, Spikes, and Staples

2.2 *Other Documents:*

PS1-09 Structural Plywood, U.S. Department of Commerce Voluntary Product Standard

PS2-10 Performance Standard for Wood-Based Structural Use Panels, U.S. Department of Commerce Voluntary Product Standard

3. Terminology

3.1 *Definitions*—The definitions in Test Methods E2126 also apply to this practice.

3.2 *Definitions Specific to this Practice:*

3.2.1 *aspect ratio, n*—ratio of a shear wall's height divided by its length.

[1] This test method is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.05 on Wood Assemblies.

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[2] 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.

3.2.2 *allowable design load, n*—maximum in-plane racking resistance assigned to a tested shear wall configuration for seismic design using an allowable stress design methodology.

3.2.3 *alternative shear wall system, n*—shear wall system seeking to establish seismic equivalence to the reference shear wall system.

3.2.3.1 *Discussion*—The alternative shear wall system may represent a range of possibilities including pre-fabricated or field-fabricated wall assemblies that do not resemble the reference shear wall system or assemblies with minor modifications to the reference system, such as the use of alternative fasteners, framing, or sheathing.

3.2.4 *component overstrength, n*—ratio of peak load divided by allowable design load.

3.2.5 *drift capacity, n*—ultimate cyclic displacement on the average envelope curve defined in Test Methods E2126 corresponding to the failure limit state.

3.2.6 *ductility, n*—ratio of drift capacity divided by the displacement on the average envelope curve defined in Test Methods E2126 corresponding to the allowable design load.

3.2.7 *peak load, n*—maximum load on the average envelope curve defined in Test Methods E2126.

3.2.8 *reference shear wall system, n*—wood-frame shear wall system used for the equivalence benchmark, consisting of wood structural panel sheathing attached to dimension lumber framing using 6d, 8d, or 10d common or box nails, with full round heads, complying with Specification F1667, Section S1, Table S1.1, and Specification F1667, Table 6 or Table 15.

3.2.8.1 *Discussion*—Table X1.1 provides summary information for the walls evaluated to represent the reference shear wall system.

3.2.9 *seismic equivalence parameters (SEP), n*—key parameters representing seismic performance of shear walls, specifically drift capacity, component overstrength, ductility, and maintenance of vertical-load-supporting capability.

3.2.10 *shear wall, n*—wall designed to resist lateral racking shear forces parallel to the plane of the wall.

3.2.11 *shear wall configuration, n*—shear wall of a specific height and length representing one possible case of a shear wall system and consisting of a specific arrangement of components, such as framing, fasteners, sheathing, and anchorage.

3.2.12 *wood structural panel (WSP)*—panel manufactured in accordance with PS1 or PS2 from veneers; wood strands or wafers; or a combination of veneer and wood strands or wafers; bonded together with waterproof resins or other suitable bonding systems.

4. Summary of Practice

4.1 Shear walls are tested in accordance with Test Methods E2126, and the average envelope curve is generated for each specimen as defined in 3.2.4 of Test Methods E2126.

4.2 SEPs are determined from the average envelope curve for each specimen, and the average SEPs for each tested shear wall configuration are compared to the benchmark parameters.

4.3 Seismic equivalency is established if each of the SEPs for the alternative shear wall system meets specified requirements and the vertical-load-supporting elements are intact and capable of supporting gravity loads.

5. Significance and Use

5.1 This practice documents cyclic performance benchmarks for shear walls constructed with wood structural panel (WSP) sheathing attached to dimension lumber framing using common or box nails as defined in 3.2.8.

5.2 Procedures described in this practice provide a method to evaluate an alternative shear wall system's SEPs to demonstrate equivalent in-plane lateral seismic performance to the reference shear wall system.

5.3 The procedures described in this practice do not address all factors to be considered for recognition of an alternative shear wall system. Such factors, as described in 1.4, vary by the end-use application and shall be addressed outside the scope of this standard through an evaluation of the acceptability of the alternative shear wall system in accordance with requirements of building codes and standards, as applicable.

6. Testing Requirements

6.1 *Test Program Design*—The test program used to evaluate the alternative shear wall system shall be based on consideration of the range of intended applications and variables that have a potential impact on the seismic performance. Variables may include, but are not limited to, allowable design loads, configuration options, material variations, fastener spacings, and aspect ratios.

6.2 *Number of Tests*—For each tested shear wall configuration, the number of replicates shall be as required in 8.1 of Test Methods E2126 or as required by the applicable product standard.

6.3 *Loading*—Cyclic lateral load tests shall be conducted using Method C from Test Methods E2126.

6.3.1 *Load Beam*—The load beam used to apply load to the test assembly shall comply with 7.3 of Test Methods E2126.

6.4 *Rigid Base*—Testing shall be conducted on a rigid base, such that the performance of the test specimens is not influenced by deformation of the base structure. The specimens shall be anchored directly to the base and shall be in full contact with the base.

6.5 *Test Specimen Construction*—Specimens shall be constructed using details consistent with the intended application. Sheathing, if present, shall not bear on any portion of the test fixture or the loading beam during the tests, except where the specified end-use installation requires the sheathing to bear on supporting elements, such as foundations or sill plates. If bearing on a wood sill plate is specified in application, a similar wood sill plate shall be included in the tested assembly.

6.5.1 *Aspect Ratios*—Aspect ratios and wall dimensions shall be consistent with the intended application.

6.5.1.1 Alternative shear wall systems that are similar to the reference system (i.e., repetitive vertical stud framing spaced at 24 in. on center or less with structural sheathing nailed to framing), except for variations in framing materials, sheathing materials, or fasteners, shall be evaluated using an aspect ratio of 1:1 and a minimum wall height of 8 ft (2.4 m).

6.5.1.2 Alternative shear wall systems that vary more significantly from the reference system described in 6.5.1.1 shall be evaluated using the range of aspect ratios for the intended application.

6.5.2 *Sheathing Joints*—Alternative shear wall systems that will include discrete sheathing panels shall include at least one vertical sheathing joint if such joints will occur in application. Test specimens may include horizontal sheathing joints as necessary, such as where specimen heights exceed panel height or where sheathing is intended to be installed with the long dimension perpendicular to the longitudinal axis of the studs.

6.5.3 *Framing*—Where applicable, the stud and plate material, species, grade, size, and spacing shall be representative of that used in application. Framing shall meet the requirements of 6.3 in Test Methods E2126.

6.5.3.1 For alternative systems described in 6.5.1.1, framing with the smallest standard stud and plate cross sections expected in application shall be used, and the smallest number of end post studs that can practically be employed in accordance with standard design provisions shall be used.

6.5.4 *Anchorage and Framing Connections*—Shear anchorage, overturning restraint, and framing connections, including connections between individual plies of built-up posts, shall be representative of connections used in application and shall be designed and detailed to balance the design resistance of the connections to the design load of the shear wall.

6.5.5 *Sheathing Connections*—Where sheathing attached to framing is used to resist lateral loads, the sheathing fasteners shall be installed using the minimum edge distance recommended by the sheathing manufacturer along all four sheathing edges. The number of fasteners installed along each edge shall be equal to the length of the sheathing edge divided by the specified fastener spacing, plus one. Spacing between the sheathing corner fastener and the next adjacent fastener is permitted to be less than the recommended spacing to accommodate the required edge distance. Sheathing fasteners placed in the field of the panel, if any, shall be positioned as required by the design. Sheathing fasteners shall be driven so that the head of the fastener contacts the surface of the sheathing, but not so deep as to crush the surface, unless specified differently by the manufacturer.

7. Evaluation of Cyclic Response

7.1 *Average Envelope Curve*—The average envelope curve shall be generated for each test specimen as defined in 3.2.4 of Test Methods E2126.

7.2 *SEP Determination*—The component overstrength, drift capacity, and ductility shall be determined for each specimen as defined in 3.2. The average values calculated for all replicates of a tested shear wall configuration shall be the SEPs for the alternative shear wall configuration. The results of multiple shear wall configurations shall not be averaged or otherwise combined for the evaluation.

7.3 *Assessment of Vertical-Load-Supporting Elements*—The condition of the vertical-load-supporting elements shall be visually assessed to qualitatively determine whether the capability to support gravity loads is retained.

NOTE 1—Visual assessment of vertical-load-supporting elements relies on examination during and after the test for observation of occurrence of buckling of the vertical-load-supporting elements. For wood-frame walls that comprise the reference shear wall system, the lack of observed buckling of the studs and end posts has been used as visual confirmation of retained ability to support gravity loads.

8. Requirements for Equivalency

8.1 Table 1 provides the SEP performance targets based on tests of the reference shear wall system conducted in accordance with Method C of Test Methods E2126.

8.2 Seismic equivalency is established if the SEPs for the alternative shear wall system meet requirements specified in Table 1 and if the vertical-load-supporting elements are judged to retain capability to support gravity loads.

9. Keywords

9.1 cyclic loads; earthquake, shear wall; lateral force; seismic; wood structural panel;

TABLE 1 SEPs for Equivalency to Nailed, Wood-Frame, WSP Shear Walls

Parameter	SEP Requirement
Component Overstrength[A]	$2.5 \leq \frac{P_{peak,\ avg}}{P_{ASD}} \leq 5.0$
Drift Capacity	$\Delta_{U,\ avg} \geq 0.028h$
Ductility	$\frac{\Delta_{U,\ avg}}{\Delta_{ASD,\ avg}} \geq 11$

$P_{peak,\ avg}$ = average peak load for all replicates of the wall configuration,
P_{ASD} = allowable design load for the wall configuration,
$\Delta_{U,\ avg}$ = average ultimate displacement for all replicates of the wall configuration,
h = height of the shear wall, and
$\Delta_{ASD,\ avg}$ = average displacement corresponding to the allowable design load for all replicates of the wall configuration.

[A] The minimum value of component overstrength shall be permitted to be 2.3 where both of the following conditions are met: *(1)* test specimen construction is similar to reference shear wall construction in accordance with 6.5.1.1, and *(2)* sheathing is attached to framing with 10d common nails.

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 Introduction

X1.1.1 Shear walls constructed with wood structural panels (WSP) fastened to sawn lumber framing with common or box nails are widely used in construction. This system serves as the reference shear wall construction for this practice. When subjected to cyclic loads, this reference system demonstrates desirable ductile yield modes with significant drift capacity, ductility, and overstrength. The seismic design provisions for engineered light-frame wood construction in North America account for this beneficial behavior by assigning seismic design coefficients that account for these attributes. These coefficients are used to determine the seismic design loads on a structure and to estimate the building response to an earthquake.

X1.1.2 As new structural systems are developed or modifications to the reference system are introduced, the seismic response capabilities of the new or modified systems are often questioned. For example, will the use of a proprietary sheathing panel, fastener, or framing material fundamentally change the seismic response of the benchmark wall system? Can an entirely new wall system or product be intermixed with the benchmark system and behave in a compatible fashion? This practice provides a relatively simple, quantitative method for comparison of cyclic resistance parameters to establish seismic equivalence. However, there are many considerations beyond the results of the in-plane lateral tests performed in accordance with this practice for evaluation of SEPs that must be considered before a new system can be deemed equivalent to the reference system for all aspects of building performance in a seismic event. For this reason, it is required for the alternative shear wall system to have documentation, such as a product standard, that addresses the specific issues listed in 1.4, as well as any other relevant issues necessary to the use of the product. Assessing all aspects of seismic performance for the end use application is beyond the scope of this standard.

X1.2 Development of Equivalency Procedure

X1.2.1 In 2007, an ICC Evaluation Service task group was formed to create an approach for a new structural system to demonstrate seismic equivalence to wood-frame WSP shear walls (**1, 2**). This task group included consulting engineers, academics, trade association representatives, product manufacturers, and wood industry professionals. The initial focus of the group was to derive a procedure that could be used to judge whether high-aspect-ratio, prefabricated shear panels could be assigned the seismic design coefficients and factors associated with the WSP reference system.

X1.2.2 Several different quantitative parameters from cyclic shear wall testing were reviewed by the industry task group to represent the seismic performance of the reference system (**1, 2**). Ultimately, they selected drift capacity, component overstrength, and ductility, as defined in this practice, to represent seismic performance for the reference system.

X1.2.3 In addition, the task group observed that degradation of the sheathing and fasteners under progressive cyclic lateral loading does not typically compromise the ability of the wood studs in the reference system to support vertical loads. Therefore, it was determined that alternative systems should also demonstrate this characteristic (**1, 2**). Alternative systems that demonstrate significant degradation of the vertical-load-supporting elements during the lateral load test cannot achieve equivalence through this protocol alone.

X1.2.4 It is an underlying assumption of this procedure that an alternative shear wall system judged to be equivalent through this practice may either be used alone or in combination with wood-frame shear walls sheathed with wood structural panels. The potential for use in combination with the reference shear wall system precludes the possibility for a system to trade-off excess performance in one SEP for low performance in another (for example using excess overstrength to justify reduced drift capacity). Such tradeoffs could lead to unpredictable load distribution and performance when the combined system is subject to inelastic deformation in a seismic event. This procedure is intended to ensure compatibility between the reference and alternative systems, so that they can be used in combination.

X1.2.5 The resulting procedure, which serves as the basis of this practice, has been subsequently employed as a practical method to judge whether new shear wall products behave in a manner similar to the reference shear wall system or if modifications to the reference system affect its seismic performance. Systems that are demonstrated to be similar to and compatible with the reference system are assigned the ASCE 7 (**3**) seismic design coefficients and factors for light-frame wood shear walls sheathed with wood structural panels.

X1.2.6 Prior to the compilation of the reference database and development of this procedure, proponents of an alternative system had to create their own reference database for the WSP reference system, either through literature review or testing. Small sample sizes, variations between laboratories, and use of different load protocols served to create inconsistent performance benchmarks that were not necessarily representative of the performance of the reference system as a whole or of its most frequently constructed configurations. In addition, there were no standardized parameters by which to judge equivalence. For these reasons, the SEP targets in this practice were developed from a large reference database representing the full range of typical reference shear wall configurations based on tests conducted at multiple laboratories.

X1.3 Reference Database

X1.3.1 *Number of Wall Tests*—The seismic equivalency parameters of Table 1 were originally derived from a reference database including tests of 48 blocked wood-frame WSP shear walls (**1, 2**). The database was subsequently expanded to include 80 wall tests, which bracketed the practical range of sheathing thickness, nail size, and nail spacing (**4**). Most walls were tested with aspect ratios of 2:1 or less.

X1.3.2 *Load Protocol*—The shear walls in the reference database were tested at four independent laboratories using the CUREE protocol (Method C of Test Methods E2126). This load protocol was chosen because it is commonly used by the wood products industry in the United States, and because the failure modes observed with this loading protocol are consistent with failures observed due to real earthquakes. Because the results of cyclic tests can vary depending on the load protocol, this practice has adopted Method C from Test Methods E2126 as the default procedure. However, it is recognized that a large amount of data has been generated using Method A from Test Methods E2126, and that Method A typically produces conservative SEPs relative to Method C. Therefore, a conservative application of this standard would permit the use of this procedure to evaluate systems previously tested using Method A from Test Methods E2126, provided that the results of the two methods are not mixed. It is also not permissible to adjust the results from Method A to try and predict Method C performance. Several different failure modes are possible for each of the two protocols, making a simple conversion impractical for a consistent evaluation. While it is recognized that Method B (ISO 16670 Protocol) from Test Methods E2126 is also a legitimate method for cyclic loading, a suitable database has not been compiled based on that method to enable establishment of seismic equivalence parameters for the reference shear wall system, so that method is not included in this practice.

X1.3.3 *Test Configuration*—The walls in the reference database were tested on a rigid base and constructed with properly designed anchorage and uplift connections, consistent with use in typical applications. With the exception of one shear wall configuration that was tested with an 8.5 ft wall height, the walls in the reference database were constructed with an 8 ft wall height.

X1.4 Derivation of SEP Targets

X1.4.1 *Envelope Curve*—Each wall specimen in the reference database was evaluated using its established allowable design value and the average envelope curve currently defined in Test Methods E2126. At the time that the reference database was compiled, Test Methods E2126 did not include the concept of an average envelope curve. It was common practice to calculate cyclic test parameters separately for the positive and negative envelopes for each specimen then average the results. During compilation and evaluation of the reference database, it was noted that this practice tended to artificially inflate the drift capacity and ductility for walls with asymmetric response such that the reported parameters could significantly exceed those of the least ductile direction. To correct this problem, the concept of the average envelope curve was developed and used to analyze the benchmark database. It has subsequently been added to Test Methods E2126. The average envelope curve serves to quantitatively limit the response parameters for a wall with asymmetric response to values closer to those achieved by the least ductile direction of the hysteresis curve.

X1.4.2 *Statistical Basis:*

X1.4.2.1 There was considerable discussion by the original task group about how to establish reasonable targets for alternative shear wall systems. The mean SEP values calculated from the reference database were considered overly conservative, because half of the reference database itself would not meet that performance level. Conversely, minimum SEP values from the reference database were rejected, because the resulting average performance of the alternative system could be substantially lower than that of the reference shear wall system. Another approach considered was to require the global average SEPs of the alternative shear wall system to meet or exceed a confidence bound of the average performance of the reference database. However, this approach was rejected, because it could result in poor performance of some alternative wall configurations being masked by good performance of other wall configurations. Ultimately, to account for statistical variability in both the reference database and alternative shear walls that may be evaluated following this practice, the minimum performance parameters were chosen to be approximately one standard deviation below the mean for the reference database, and the appropriate SEP estimate for the alternative shear walls was chosen as the average value for all replicates of a given shear wall configuration. It is not intended that each replicate meet the target values from the reference database; however, it is intended that the average SEPs for each tested alternative shear wall configuration meet the target values. The summary statistics considered in the development of SEP targets are shown in the reference papers (**1, 2, 4**). It should be noted that while the database includes two stapled-wall tests, exclusion of the stapled-wall data does not change the results.

X1.4.3 *Upper and Lower Limits*—The SEP targets of Table 1 include minimum permitted values for drift capacity and ductility. In general, increased values for these parameters are assumed to provide improved seismic response, so there is no upper limit. However, an upper limit on component overstrength was imposed, because excessive overstrength of a component can overload surrounding structural elements and attachments in an actual earthquake.

X1.4.3.1 *Component Overstrength*—While the value of 2.5 is considered broadly applicable as the minimum value for component overstrength and used in other references including ICC-ES (**5, 6, 7**) where design values are being established, it is also recognized that for specific applications where the test specimen is similar to the reference system and uses 10d common nails for sheathing attachment that a minimum target value of 2.3 is appropriate. This reduced target value coincides with the calculated mean minus one standard deviation value for component overstrength from the entire reference database (**4**) and also accounts for the lower component overstrength observed for shear walls constructed with 10d common sheathing nails.

X1.4.4 *Performance of Reference Database*—All of the shear wall configurations in the reference database that were tested as prescribed in 6.5 with 1:1 aspect ratio in accordance with 6.5.1.1 meet or exceed the SEP targets of this practice, with the exception of one tested shear wall configuration represented by walls 73 and 74. The average drift capacity of walls 73 and 74 was 2.7 % of the wall height, slightly below the target of 2.8 %. The average ductility and overstrength for these walls exceeded the SEP targets.

X1.5 Design Stiffness

X1.5.1 The protocol requires the design procedure for the alternative shear wall to have a means to estimate wall deflections, which will be used to assign load to each shear wall in a structure based on its relative stiffness (see 1.5). The original task group recognized that the reference shear wall system provides a wide range of stiffness depending upon the wall type (i.e., sheathing and fastening schedule), aspect ratio, length, perforations, etc. Varying stiffness is accounted for through the design process, which assigns load to each shear wall based on relative stiffness. The task group determined that the stiffness of alternative shear wall systems could be treated the same way. This approach also provides a practical means to intermix an equivalent alternative system into a structure with the reference shear wall system.

X1.6 Test Configuration

X1.6.1 *Applicability*—This practice includes requirements for boundary conditions and shear wall construction consistent with test methods and procedures used in development of the reference data base. These reference conditions are intended to provide a direct comparison to the standardized conditions used for the testing of the reference shear wall system and are not intended to limit the application of alternative components or shear panel construction. For example, the requirement to test modifications to the reference shear wall system with an 8 ft minimum wall height on a rigid base is intended to ensure comparability between results for the tested assembly and the reference database. It is not intended to limit the applicability of this practice to walls of a single story or only of the height tested. Likewise, it not the intent of this practice to limit the systems only to installations that occur on a rigid foundation. If the product has special attributes that may limit its appropriateness for use with other boundary conditions, such as very high aspect ratio shear wall systems installed on a flexible base, then the appropriate product standard should address any additional requirements.

X1.6.2 *Shear Wall Configurations*—Section 6.1 requires the user to apply engineering judgment to select the appropriate wall configurations to test. It is not intended that every shear wall configuration be tested; however, enough configurations must be tested to bracket the effects of the key variables on performance. More direction is not provided, because the bracketing requirements will be product-specific. For example, one common use of the procedure has been to qualify high-aspect prefabricated shear walls. In those applications, bracketing has been completed by testing across the full range of aspect ratios for the product. In some cases, the narrowest and widest panels of each height have been tested. Another common use is to evaluate modifications to the reference shear wall system such as substitution of a framing material, sheathing, or fastener. The goal of such a program is to verify that the changes do not detrimentally affect the cyclic performance. In these cases, it is possible to have a wide variation of shear wall configurations (i.e., sheathing thicknesses, fastener spacings, etc.), wall heights, wall lengths, boundary conditions, and aspect ratios. The intent of 6.5.1.1 is to limit the review in these cases to shear wall configurations similar to those that were tested to evaluate the reference shear wall system.

TABLE X1.1 Reference Database – Wood-Framed Wood Structural Panel Shearwalls

Item	(Ref.)/ Ref. ID	Wall size H by L	OSB Sheathing	Fasteners	Fastener Spacing (edge/field)	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
1	(A)/24-1	8.5' by 4.5'	15/32" Str.1	10d com	2"/12"	none	3,915	0.51	9,047	1.19	10,239	3.31	9,748	4.15	4.1	2.6	8.2	Yes	Not reported
2	(A)/24-2							0.52	9,125	1.21	10,461	3.22	8,369	3.42	3.4	2.7	6.6		
3	(B)/1-8dc	8' by 8'	7/16"	8d com	4"/6"	none	2,800	0.12	6,646	0.31	7,480	2.32	5,984	3.22	3.4	2.7	26.1	Yes	Not reported
4	(B)/2-8dgb			8d galv box				0.16	6,856	0.44	7,794	2.26	6,235	3.32	3.5	2.8	20.3		
5	(B)/3-8db			8d box				0.11	7,315	0.4	8,205	2.25	6,564	3.65	3.8	3.4	34.3		
6	(C)/2	8' by 8'	7/16"	8d com	4"/6"	none	2,800	0.13	6,209	0.29	7,019	1.61	5,615	2.37	2.5	2.5	18.0	Yes	Not reported
7	(C)/3							0.15	6,303	0.34	6,965	2.32	5,572	3.59	3.7	2.5	23.6		
8	(C)/4							0.15	6,099	0.31	6,701	2.32	5,361	3.7	3.9	2.4	24.8		
9	(C)/5	8' by 8'	19/32"	10d com	2"/12"	none	6,960	0.25	14,185	0.46	15,947	3.2	12,757	3.38	3.5	2.3	13.8	Yes	Not reported
10	(C)/6							0.28	14,035	0.53	15,953	2.31	12,762	3.43	3.6	2.3	12.2		End Post
11	(C)/7							0.28	15,793	0.65	17,856	3.33	15,107	4.38	4.6	2.6	15.6		Not reported
12	(C)/8							0.28	15,393	0.62	17,421	3.4	14,537	4.38	4.6	2.5	15.7		Not reported
13	(D)/1	8' by 8'	7/16"	8d com	4"/6"	none	2,800	0.39	6,229	0.89	7,184	2.57	5,747	2.75	2.9	2.6	7.1	Yes	Not reported
14	(D)/3							0.43	6,618	1.03	7,454	2.53	5,963	2.76	2.9	2.7	6.4		
15	(D)/5							0.24	6,071	0.51	6,906	2.56	5,525	2.98	3.1	2.5	12.6		
16	(D)/6							0.24	6,217	0.54	7,136	2.55	5,709	2.87	3.0	2.5	12.0		
17	(D)/7							0.09	6,867	0.24	7,631	1.7	6,105	2.25	2.3	2.7	23.9		
18	(D)/8							0.1	6,760	0.24	7,478	1.16	6,309	2.27	2.4	2.7	23.8		
19	(E)/A-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.3	9,273	0.73	10,208	3.37	10,208	3.37	3.5	2.6	11.1	Yes	Fastener
20	(E)/A-2							0.18	9,174	0.44	10,613	3.01	8,588	3.76	3.9	2.7	20.9		
21	(E)/A-3							0.22	9,754	0.61	11,151	2.98	9,268	3.69	3.8	2.8	16.8		
22	(E)/B-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.21	9,618	0.52	10,877	2.91	8,702	3.31	3.4	2.8	16.1	Yes	Fastener
23	(E)/B-2							0.17	10,209	0.46	11,554	2.99	9,243	3.75	3.9	2.9	22.7		
24	(E)/B-3							0.16	9,976	0.46	11,396	2.83	9,691	3.79	3.9	2.9	23.3		
25	(E)/C-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.32	9,240	0.82	10,952	2.74	10,952	2.74	2.9	2.8	8.5	Yes	Sill splitting
26	(E)/C-2							0.23	9,387	0.59	10,574	2.78	8,775	3.76	3.9	2.7	16.2		
27	(E)/C-3							0.26	9,756	0.67	11,156	2.84	8,925	3.03	3.2	2.8	11.8		
28	(E)/D-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.19	9,583	0.47	10,863	2.84	9,815	3.83	4.0	2.8	20.1	Yes	Fastener
29	(E)/D-2							0.18	9,481	0.44	10,771	2.83	9,844	3.95	4.1	2.7	21.6		
30	(E)/D-3							0.28	9,179	0.69	10,265	2.83	9,441	4.04	4.2	2.6	14.3		
31	(E)/E-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.21	9,555	0.5	10,794	2.22	10,386	3.24	3.4	2.8	15.8	Yes	Fastener
32	(E)/E-2							0.2	9,744	0.51	10,923	2.26	10,068	3.28	3.4	2.8	16.1		
33	(E)/E-3							0.19	9,556	0.47	10,920	2.28	9,290	3.09	3.2	2.8	16.0		
34	(E)/F-1	8' by 8'	7/16"	8d com	3"/12"	none	3,920	0.21	8,828	0.47	10,113	2.25	8,083	2.92	3.0	2.6	13.8	Yes	Sill splitting
35	(E)/F-2							0.2	9,635	0.48	10,831	2.32	9,838	3.2	3.3	2.8	16.4		Fastener
36	(E)/F-3							0.2	9,973	0.52	11,079	2.3	10,460	3.34	3.5	2.8	16.5		Fastener
37	(F)/4A	8' by 16'	3/8"	8d box	6"/12"	none	3,200	0.13	10,523	0.5	11,663	1.94	10,183	2.78	2.9	3.6	22.0	Yes	Fastener
38	(F)/4B							0.09	10,778	0.37	11,929	2.02	10,042	3.07	3.2	3.7	35.3		
39	(F)/6A	8' by 16'	3/8"	8d box	6"/12"	pedestrian door	2,600	0.1	10,156	0.4	11,363	1.9	9,090	2.51	2.6	4.4	24.8	Yes	Fastener
40	(F)/6B							0.11	8,897	0.41	10,081	2.02	8,065	2.89	3.0	3.9	25.6		

TABLE X1.1 *(continued)*

41	(F)/8A	8' by 16'	3/8"	8d box	3"/12"	garage	1,904	0.13	8,675	0.67	9,692	3.74	9,222	5.31	5.5	5.1	40.5	Yes	Fastener
42	(F)/8B					door		0.13	9,010	0.6	10,205	3.74	9,010	4.97	5.2	5.4	37.1		
43	(F)/10A	8' by 16'	3/8"	8d com	3"/12"	garage	2,393	0.14	9,166	0.57	10,399	3.74	8,813	4.91	5.1	4.3	34.1	Yes	Fastener
44	(F)/10B					door		0.15	9,116	0.56	10,145	3.78	9,323	5.17	5.4	4.2	35.6		
45	(F)/11A	8' by 16'	3/8"	1-3/8",16ga	6"/12"	none	2,240	0.07	9,639	0.39	11,123	1.4	8,898	2.38	2.5	5.0	33.6	Yes	Fastener
46	(F)/11B			Staple				0.06	10,213	0.37	11,627	2.03	9,302	2.52	2.6	5.2	43.4		
47	(F)/26A	8' by 16'	3/8"	8d box	6"/12"	pedestrian	2,600	0.16	7,721	0.56	9,208	2.01	7,367	3.36	3.5	3.5	21.5	Yes	Fastener
48	(F)/26B					door		0.18	7,168	0.56	8,303	2.03	6,643	3.28	3.4	3.2	18.3		
49	(G)/A1	8' by 8'	3/8" Str.1	6d com	6"/6"	none	1,780	0.11	4,037	0.25	4,573	1.67	3,659	2.85	3.0	2.6	26.8	Yes	Fastener
50	(G)/A2							0.11	3,757	0.23	4,280	1.67	3,424	2.52	2.6	2.4	23.3		
51	(G)/B1	8' by 4'	3/8" Str.1	6d com	6"/6"	none	890	0.11	2,244	0.28	2,502	2.34	2,002	3.2	3.3	2.8	29.1	Yes	Fastener
52	(G)/B2							0.12	2,236	0.32	2,467	2.38	1,974	3.9	4.1	2.8	33.3		
53	(G)/C1	8' by 8'	3/8" Str.1	6d com	2"/6"	none	4,530	0.15	11,220	0.4	12,753	2.39	10,202	3.31	3.4	2.8	22.5	Yes	Fastener
54	(G)/C2							0.26	11,254	0.67	12,805	2.37	10,244	2.92	3.0	2.8	11.4		
55	(G)/D1	8' by 4'	3/8" Str.1	6d com	2"/6"	none	2,265	0.31	5,887	0.83	6,746	3.51	5,397	3.78	3.9	3.0	12.4	Yes	Fastener
56	(G)/D2							0.2	5,295	0.48	5,888	2.38	4,710	4.01	4.2	2.6	20.2		
57	(G)/E1	8' by 8'	7/16"	8d com	6"/6"	none	1,920	0.09	5,130	0.24	5,750	1.64	4,600	2.68	2.8	3.0	29.8	Yes	Fastener
58	(G)/E2							0.09	5,561	0.25	6,273	1.67	5,018	2.64	2.7	3.3	31.0		
59	(G)/F1	8' by 4'	7/16"	8d com	6"/6"	none	960	0.16	2,605	0.47	2,889	2.35	2,311	3.57	3.7	3.0	22.6	Yes	Fastener
60	(G)/F2							0.12	2,743	0.4	3,305	2.37	2,428	3.86	4.0	3.4	33.0		
61	(G)/G1	8' by 8'	7/16"	8d com	2"/6"	none	4,680	0.16	13,860	0.59	16,058	2.4	12,847	2.76	2.9	3.4	17.7	Yes	Fastener
62	(G)/G2							0.2	14,237	0.73	16,345	2.32	13,076	2.55	2.7	3.5	12.5		
63	(G)/H1	8' by 4'	7/16"	8d com	2"/6"	none	2,340	0.31	6,834	0.92	7,584	3.19	6,067	3.25	3.4	3.2	10.4	Yes	End Post
64	(G)/H2							0.3	5,823	0.77	6,590	2.38	5,272	2.85	3.0	2.8	9.5		Fastener
65	(G)/I3	8' by 8'	19/32"	10d com	6"/12"	none	2,720	0.15	5,766	0.31	6,577	1.66	5,261	2.59	2.7	2.4	17.0	Yes	Fastener
66	(G)/I5							0.13	6,066	0.32	6,851	2.37	5,481	3.35	3.5	2.5	25.5		
67	(G)/J2	8' by 4'	19/32"	10d com	6"/12"	none	1,360	0.21	2,978	0.45	3,345	2.32	2,676	3.61	3.8	2.5	17.2	Yes	Fastener
68	(G)/J3							0.22	2,894	0.45	3,296	2.33	2,636	3.61	3.8	2.4	16.7		
69	(G)/K1	8' by 8'	19/32"	10d com	2"/12"	none	6,960	0.26	14,679	0.52	16,826	2.29	13,460	3.21	3.3	2.4	12.6	Yes	Fastener
70	(G)/K2							0.26	15,101	0.55	16,992	2.31	13,596	3.43	3.6	2.4	13.3		
71	(G)/L1	8' by 4'	19/32"	10d com	2"/12"	none	3,480	0.42	6,625	0.77	7,504	2.34	6,003	3.33	3.5	2.2	7.9	Yes	Fastener/Post
72	(G)/L2							0.4	6,629	0.7	7,363	2.34	5,890	3.75	3.9	2.1	9.4		Fastener
73	(G)/M1	8' by 8'	3/8" Str.1	8d com	6"/6"	none	1,840	0.08	5,037	0.23	5,614	1.66	4,491	2.7	2.8	3.1	33.0	Yes	Fastener
74	(G)/M2							0.09	4,951	0.24	5,646	1.63	4,517	2.38	2.5	3.1	26.8		
75	(G)/N1	8' by 4'	3/8" Str.1	8d com	6"/6"	none	920	0.1	2,439	0.29	2,757	1.64	2,206	2.41	2.5	3.0	23.2	Yes	Fastener
76	(G)/N2							0.11	2,498	0.33	2,849	1.64	2,279	3.16	3.3	3.1	29.0		
77	(G)/O1	8' by 8'	3/8" Str.1	8d com	2"/6"	none	4,880	0.21	13,837	0.66	15,695	2.31	12,556	2.62	2.7	3.2	12.6	Yes	Fastener
78	(G)/O2							0.19	13,174	0.57	14,804	2.37	11,843	3.34	3.5	3.0	17.8		
79	(G)/P1	8' by 4'	3/8" Str.1	8d com	2"/6"	none	2,440	0.26	6,263	0.7	6,838	2.38	5,470	3.35	3.5	2.8	12.7	Yes	Fastener
80	(G)/P2							0.23	6,438	0.68	7,216	2.38	5,773	3.43	3.6	3.0	14.8		

Table References:

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

[B] Martin Z., "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, USA, 2004, 14 pp.

[C] Martin Z. and Skaggs T., "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, USA, 2003, 20 pp.

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

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

[F] Pardoen G.C., Waltman R.P., Kazanjy E., Freund E., Hamilton C.H., "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, USA, 2003, 271 pp.

[G] Waltz, Ned. "Benchmark Cyclic Tests of Site-Built Engineered Wood-Frame Shear Walls," *iLevel Engineering Laboratory Report No. 2215.* Weyerhaeuser, Boise, Idaho. 2008.

X1.6.3 *Modifications to Reference WSP Walls*—Section 6.5.1.1 requires that modifications to the reference shear walls be tested with an aspect ratio of 1:1 and an 8 ft minimum wall height. The reference database includes tests of matched shear wall specimens with 2:1 and 1:1 aspect ratios. The results indicate no significant difference in performance for the reference shear wall system at these aspect ratios. Testing fully sheathed walls in this range also minimizes the potential for the load head used by the test laboratory to influence the test results. Testing with an aspect ratio of 1:1 with an 8 ft minimum height and a centered panel joint is judged to be representative of modified reference shear walls with aspect ratios of 2:1 or less.

X1.6.3.1 *Vertical Panel Joint*—WSP shear walls typically contain joints at 4-8 ft intervals. Vertical joints between panels often limit the shear wall capacity and must be included in the testing if they will occur in application. Where sheathing is installed with the long axis perpendicular to the studs with staggered joints, a half-height vertical joint is acceptable.

X1.6.3.2 *Framing and Boundary Element*—The provisions of 6.5.3 and 6.5.4 are intended to ensure that the construction is reasonably representative of walls that will be used in application. As such, framing must meet the requirements of 6.3 in Test Methods E2126, and end posts and anchorage must be detailed to avoid significant excess design capacity. For example, if normal construction practice and design require two end posts, only two should be used. Hold-downs should be sized so their design capacity is as close as practical to the design load of the wall. Similar optimization of framing and anchorage was used in the construction of the benchmark wall assemblies (**2**, **4**).

X1.7 Other Approaches

X1.7.1 This practice provides a simple, quantitative approach with standardized performance targets to determine seismic equivalency for shear wall systems that respond similarly to wood structural panel shear walls when subjected to cyclic lateral loading. For systems that do not meet the performance requirements of this practice, other options exist to determine appropriate seismic design coefficients and factors. For example, FEMA P795 (**8**) provides another equivalency approach for substitution of components in a structure and FEMA P695 (**9**) provides a rational approach to establish design coefficients and factors for a lateral-force-resisting system.

REFERENCES

(1) Waltz, N., Skaggs, T., Line, P., and Gromala, D., "Establishing Seismic Equivalency to Code-Listed Light-Frame Wood Wall Systems," *World Conference on Timber Engineering*, Miyazaki, Japan, 2008.

(2) Waltz, N. and Hamburger, R., "New Rules for Evaluating the Performance of Pre-Fabricated Shear Panels," *Structure*, August 2008.

(3) ASCE, *ASCE 7-10*, "Minimum Design Loads for Buildings and Other Structures."

(4) Line, P, Waltz, N., and Skaggs, T., "Seismic Equivalence Parameters for Engineered Wood-Frame Wood Structural Panel Shearwalls," *Wood Design Focus*, July 2008.

(5) ICC-ES, *AC130*, "Acceptance Criteria for Prefabricated Wood Shear Panels."

(6) ICC-ES, *AC322*, "Acceptance Criteria for Prefabricated, Cold-Formed, Steel Lateral-Force-Resisting Vertical Assemblies."

(7) ICC-ES, *AC436*, "Acceptance Criteria for Establishing Seismic Equivalency to Code-prescribed Light-frame Shear Walls Sheathed with Wood Structural Panels Rated for Shear Resistance or Steel Sheets."

(8) FEMA, "Quantification of Building Seismic Performance Factors: Component Equivalence Methodology," P-795, 2011.

(9) FEMA, "Quantification of Building Seismic Performance Factors," P-695, 2009.