Designation: D7989 – 21

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, and so forth 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 Structural Plywood, U.S. Department of Commerce Voluntary Product Standard [3]

PS2 Performance Standard for Wood-Based Structural Use

[1] This practice 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] Online, Available: https://www.nist.gov/system/files/documents/2019/12/16/PS%201%2019%20final%20WERB-approved%20%28NIST%20vers%2011-18-2019%29%2B.pdf

Panels, U.S. Department of Commerce Voluntary Product Standard[4]

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.

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

3.2.3 *alternative shear wall system, n*—shear wall system for which seismic equivalence to the reference shear wall system is sought.

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 (Specification F1667, Table 14, Type 1, Style 9) or galvanized box (Specification F1667, Table 5, Type 1, Style 3A) nails, with full round heads, complying with F1667.

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 galvanized 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, overturning restraint types, 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 7.3.1 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.

[4] Online, Available: https://www.nist.gov/system/files/documents/2019/05/09/ps_2-18_final_apr_2019_dfa_reviewed.pdf

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 (that is, 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 typical connections used in application and shall be designed and detailed to optimize to the extent practical the design resistance of the connections to the design load of the shear wall.

6.5.4.1 Alternative systems described in 6.5.1.1 shall be tested with bolts for shear anchorage and eccentric-type hold downs positioned inside the wall for overturning restraint unless use of an alternative shear anchorage or hold down system, or both, will be required in application. Where either an alternative shear anchorage or overturning restraint is required in application, the specified alternative shall be permitted for the evaluation.

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 failure modes, such as buckling, that compromise the wall assembly's ability to carry vertical load. For wood-frame walls that comprise the reference shear wall system, the lack of observed buckling or other significant vertical load limiting failure modes for 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;