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An American National Standard

Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Walls for Buildings[1]

This standard is issued under the fixed designation E 2126; 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 These test methods are designed to evaluate the shear stiffness, shear strength, and ductility of a wall assembly, including applicable shear connections and hold-down connectors, under quasi-static cyclic (reversed) load conditions.

1.2 These test methods are intended for wall assemblies constructed from wood or metal framing with solid sheathing or other bracing methods or structural insulated panels.

1.3 *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:*

D 2395 Test Methods for Specific Gravity of Wood and Wood-Based Materials[2]

D 4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials[2]

D 4444 Test Methods for Use and Calibration of Hand-Held Moisture Meters[2]

E 564 Practice for Static Load Test for Shear Resistance of Framed Walls for Buildings[3]

E 575 Practice for Reporting Data from Structural Tests of Building Constructions, Connections, and Assemblies[3]

E 631 Terminology of Building Constructions[3]

E 1803 Test Methods for Determining Structural Capacities of Insulated Panels[4]

3. Terminology

3.1 For definitions of terms used in this standard, see Terminology E 631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ductility factor (μ), n*—the ratio of the ultimate displacement (Δ_u) and the yield displacement (Δ_{yield}).

3.2.2 *envelope curve (see Fig. 1), n*—the locus of extremities of the load-displacement hysteresis loops. Initial envelope curve contains the peak loads from the first cycle of each phase of the cyclic loading. Wall displacement in the positive direction produces a positive envelope curve; the negative wall displacement produces a negative envelope curve. The positive direction is based on outward movement of the hydraulic actuator. The negative direction is based on inward movement of the actuator.

3.2.3 *equivalent energy elastic-plastic (EEEP) curve (see Fig. 2), n*—an ideal elastic-plastic curve circumscribing an area equal to the area enclosed by the observed load-displacement curve or envelope curve between the origin, the ultimate displacement, and the displacement axis. The elastic portion of the EEEP curve contains the origin and has a slope equal to the elastic stiffness, k_e. The plastic portion is a horizontal line equal to P_{yield} determined by the following equation:

$$P_{yield} = \left(\Delta_u - \sqrt{\Delta_u^2 - \frac{2A}{k_e}}\right) k_e \quad (1)$$

where:

P_{yield} = yield load (lbf or N);

A = the area (lbf·in. or N·m) under the observed load-displacement curve or envelope curve from zero to ultimate displacement (Δ_u);

k_e = elastic shear stiffness (lbf/in. or N/m) defined by the slope of the secant passing through the origin and a point on the observed load-displacement curve or envelope curve where the load equals 0.4 P_{peak}.

3.2.4 *failure limit state, n*—the point in the load-displacement relationship corresponding to the last data point with the absolute load equal or greater than 0.8 P_{peak}.

3.2.5 *failure load, n*—0.8 P_{peak}.

3.2.6 *first major event (FME), n*—the first significant limit state to occur (see *limit state*).

3.2.7 *limit state, n*—an event that marks the demarcation between two behavior states, at which time some structural behavior of the element or system is altered significantly.

[1] These test methods are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and are the direct responsibility of Subcommittee E06.11 on Horizontal and Vertical Structures/Structural Performance of Completed Structures.

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[2] *Annual Book of ASTM Standards*, Vol 04.10.

[3] *Annual Book of ASTM Standards*, Vol 04.11.

[4] *Annual Book of ASTM Standards*, Vol 04.12.

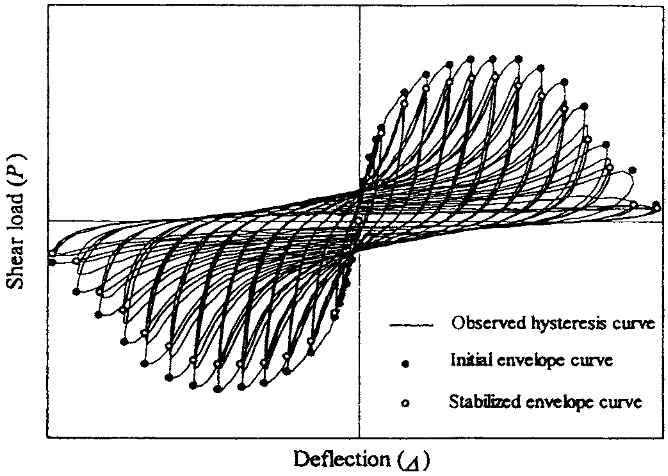

FIG. 1 Observed Hysteresis Curve and Envelope Curves

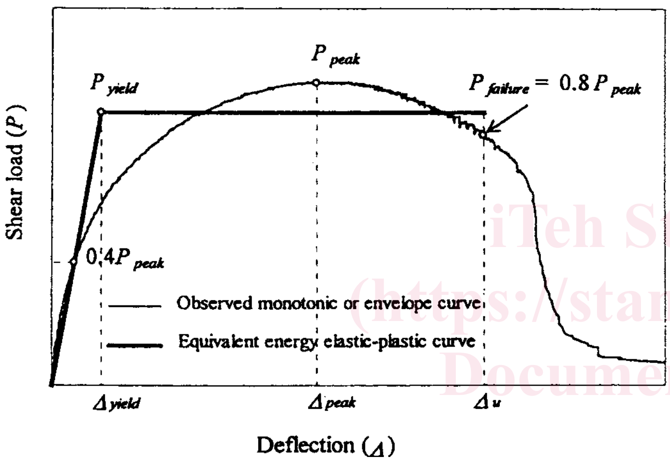

FIG. 2 Performance Parameters of Shear-Wall Assembly

3.2.8 *strength limit state*, *n*—the point in the force-displacement relationship corresponding to the maximum absolute displacement at Δ_{peak} for the maximum absolute load (P_{peak}) resisted by the assembly.

3.2.9 *ultimate displacement* (Δ_u), *n*—the displacement corresponding to the failure limit state.

3.2.10 *yield limit state*, *n*—the point in the load-displacement relationship where the elastic shear stiffness of the assembly decreases 5 % or more. For assemblies with nonlinear ductile elastic response, the yield point (Δ_{yield}, P_{yield}) is permitted to be determined using the equivalent energy elastic-plastic curve (see 3.2.3).

4. Summary of Test Method

4.1 The cyclic shear stiffness, shear strength and ductility of walls are determined by subjecting a wall assembly to full-reversal cyclic racking shear loads. This is accomplished by anchoring the bottom edge of the wall assembly to a rigid base and applying a force parallel to the top of the wall. The test assembly is allowed to displace in its own plane. As the wall assembly is racked to specified displacement increments, the racking (shear) force and displacements are continuously measured (see 8.6).

5. Significance and Use

5.1 These test methods are intended to measure the performance of walls subjected to earthquake loads. Since these loads are cyclic, the loading process simulates the actions and their effects on the walls.

6. Wall Assembly

6.1 *General*—The typical wall assembly consists of a frame on which the elements comprising the wall, including the sheathing (or diagonal bracing members, if applicable) are placed. The elements shall be fastened to the frame in a manner to conform with 6.2. Elements used to construct wall assemblies may be varied to permit anticipated failure of selected elements.

6.2 *Connections*—The performance of framed walls is influenced by the type, spacing and edge distance of fasteners attaching sheathing to framing and spacing of the shear connections and hold-down connectors to the rigid base. All of these connections shall be consistent with the types used in actual building connections.

6.3 *Frame Requirements*—The frame of the wall assembly shall consist of materials representative of those to be used in the actual building construction. The connections of these members shall be consistent with those intended in actual building construction.

6.3.1 For wood framing members, record the species and grade of lumber used; moisture content of lumber at the time of fabrication and testing, if more than 24 h passes between these operations (see Test Methods D 4442, Method A or B; or D 4444, Method A or B); and specific gravity of the lumber (see Test Methods D 2395, Method A).

6.3.2 For steel or other metal framing members, record the material specifications and thickness.

6.4 *Structural Insulated Panel*—The panel is a prefabricated assembly consisting of an insulating core of 1.5 inches (38 mm) minimum sandwiched between two facings. The assembly is constructed by attaching panels together and to top and bottom plates or tracks.

6.5 *Wall Size*—The wall assembly shall have a height and length or aspect (height/length) ratio that is consistent with intended use requirements in actual building construction (see Fig. 3).

7. Test Setup

7.1 The wall assembly shall be tested such that all elements and sheathing surfaces are observable. For assemblies such as framed walls with sheathing on both faces of framing or frameless structural insulated panels, the assemblies are dismantled after tests to permit observation of all elements. The bottom of the wall shall be attached to a rigid base with shear connections as specified in 6.2. The test apparatus shall support the wall assembly as necessary to prevent displacement from the plane of the wall, but in-plane displacement shall not be restricted.

8. Procedure

8.1 *Number of Tests*—A minimum of two identical wall assemblies shall be tested to determine the maximum shear

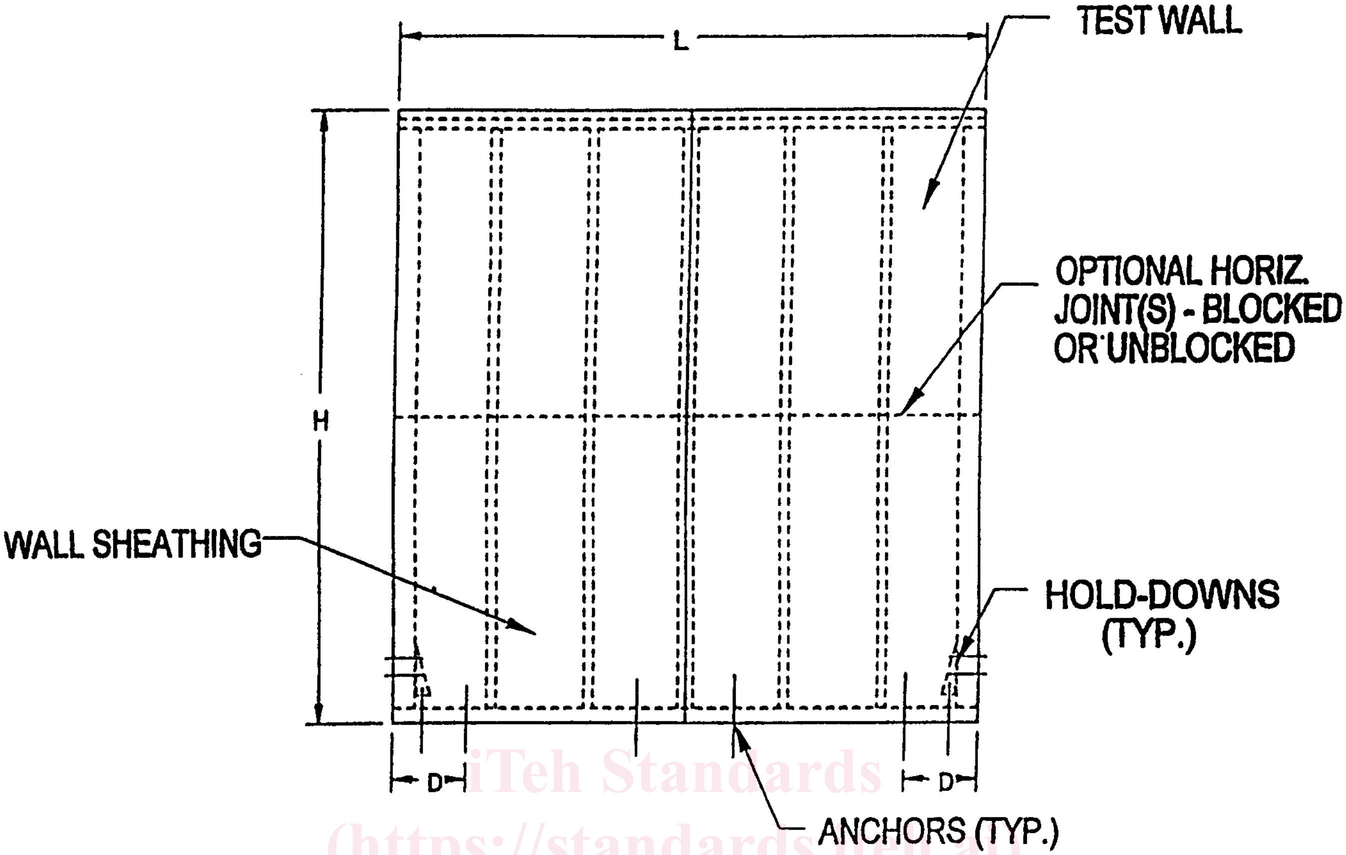

FIG. 3 Cyclic Load Shear Wall Test Specimen

stiffness and maximum shear strength of a given construction. These values shall be calculated in accordance with Section 9. If these force-displacement relationships do not agree within 10 % of the lower value, test a third identical wall assembly, and compute the mean value based on the number of walls tested.

8.2 Apply racking shear load horizontally in the plane of the wall to the top of the wall assembly (along the axis) (Fig. 4) using a programmable double-acting hydraulic actuator with load cell. The cyclic displacement of the actuator shall be controlled to follow a cyclic displacement procedure described in either 8.3 (Method A) or 8.4 (Method B).

8.2.1 The first major event (FME) and the ultimate displacement (Δ_u) shall be determined from a preliminary monotonic load test on an identical wall assembly in accordance with Practice E 564.

8.3 *Method A (Sequential-Phased Displacement Procedure)*:

8.3.1 *Sequential Phased Displacement (SPD) Loading Procedure*—Displacement-controlled loading procedure that involves displacement cycles grouped in phases at incrementally increasing displacement levels. The cycles shall form either a sinusoidal wave or a triangular wave. The SPD loading consists of two displacement patterns and is illustrated in Fig. 5. The first displacement pattern consists of three phases, each containing three fully-reversing cycles of equal amplitude, at displacements representing 25 %, 50 % and 75 % of anticipated FME. The second displacement pattern is illustrated in Fig. 6. Each phase is associated with a respective displacement level and contains one initial cycle, three decay cycles and a number of stabilization cycles. Stabilized response is defined as a decrease in load between two successive cycles of not more than 5 %. For nailed wood-frame shear walls, three stabilization cycles are sufficient to obtain a stabilized response. The amplitude of each consecutive decay cycle decreases by 25 % of the initial displacement.

8.3.2 The schedule of amplitude increments between the sequential phases is given in Table 1. The amplitude increments selected for the SPD procedure are based on the FME and the ductility factor, μ, determined from the preliminary cyclic monotonic load test.

8.4 *Method B*:

8.4.1 The sequence of amplitudes (see Table 2) of the reversed cycles in Method B is a function of the ultimate displacement (Δ_u) obtained from the preliminary static test.

8.4.2 The test loading procedure is given in Fig. 7 and Table 2. The schedule includes two displacement patterns of gradually increasing displacement amplitudes. During the first pattern, the amplitude is increased with each cycle until 0.2 Δ_u is reached. During the second pattern, a minimum of three cycles are applied at each amplitude to achieve the stabilized response at each step (see 8.3.1).

8.5 The actuator displacement in either Method A or B shall be controlled at either constant cyclic frequency or at a constant rate of displacement. The rate of displacement shall be between 0.04 and 5.0 in. (1.0 and 127 mm)/s. The cyclic