Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings[1]

1. Scope

1.1 These test methods cover the evaluation of the shear stiffness, shear strength, and ductility of the vertical elements of lateral force resisting systems, including applicable shear connections and hold-down connections, under quasi-static cyclic (reversed) load conditions.

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

1.3 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.

1.4 *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]

D2395 Test Methods for Specific Gravity of Wood and Wood-Based Materials

D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials

D4444 Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters

E564 Practice for Static Load Test for Shear Resistance of Framed Walls for Buildings

E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies

E631 Terminology of Building Constructions

2.2 *ISO Standard:*[3]

ISO 16670 Timber Structures—Joints Made with Mechanical Fasteners—Quasi-static Reversed-cyclic Test Method

2.3 *Other Standards:*[4]

ANSI/AF&PA NDS National Design Specification for Wood Construction

3. Terminology

3.1 For definitions of terms used in this standard, see Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ductility ratio, cyclic (D), n*—the ratio of the ultimate displacement (Δ_u) and the yield displacement (Δ_{yield}) of a specimen observed in cyclic test.

3.2.2 *elastic shear stiffness* (K_e) (see 9.1.4, Fig. 1), *n*—the resistance to deformation of a specimen in the elastic range before the first major event (FME) is achieved, which can be expressed as a slope measured by the ratio of the resisted shear load to the corresponding displacement.

3.2.3 *envelope curve* (see Fig. 2) , *n*—the locus of extremities of the load-displacement hysteresis loops, which contains the peak loads from the first cycle of each phase of the cyclic loading and neglects points on the hysteresis loops where the absolute value of the displacement at the peak load is less than that in the previous phase.

3.2.3.1 *Discussion*—Specimen displacement in the positive direction produces a positive envelope curve; the negative specimen displacement produces a negative envelope curve. The positive direction is based on outward movement of the hydraulic actuator.

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[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] 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] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[4] Available from American Forest and Paper Association (AF&PA), 1111 19th St., NW, Suite 800, Washington, DC 20036, http://www.afandpa.org.

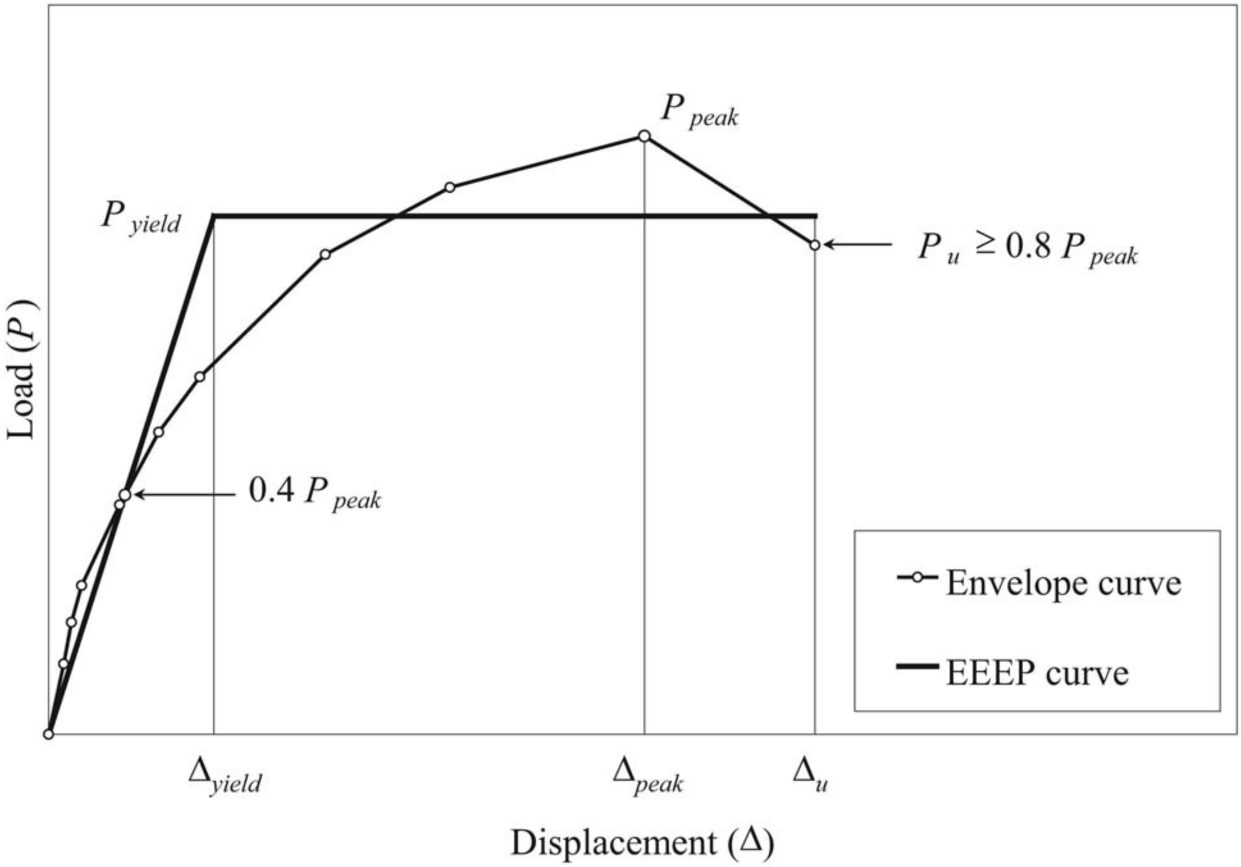

FIG. 1 Performance Parameters of Specimen: (A) Last Point at $P_u \geq 0.8\ P_{peak}$

3.2.4 *envelope curve, average*(see Fig. 3), *n*—envelope curve obtained by averaging the absolute values of load and displacement of the corresponding positive and the negative envelope points for each cycle.

3.2.5 *equivalent energy elastic-plastic (EEEP) curve* (see 9.1.4, Fig. 1), *n*—an ideal elastic-plastic curve circumscribing an area equal to the area enclosed by the envelope curve between the origin, the ultimate displacement, and the displacement axis. For monotonic tests, the observed load-displacement curve is used to calculate the EEEP curve.

3.2.6 *failure limit state, n*—the point on the envelope curve corresponding to the last data point with the absolute load equal or greater than $|0.8\ P_{peak}|$, as illustrated in Fig. 1.

3.2.7 *failure load (P_u), n*—the load corresponding to the failure limit state.

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

3.2.9 *limit state, n*—an event that demarks the two behavior states, at which time some structural behavior of the specimen is altered significantly.

3.2.10 *specimen, n*—the vertical element of the lateral force resisting system to be tested. Example of specimens are walls, structural insulated panels, portal frames, etc. A specimen can be a single element or an entire line of resistance within a lateral force resisting system.

3.2.11 *stabilized response, n*—load resistance that differs not more than 5 % between two successive cycles at the same amplitude.

3.2.12 *strength limit state* (see Fig. 1), *n*—the point on the envelope curve corresponding to the maximum absolute displacement Δ_{peak} at the maximum absolute load (P_{peak}) resisted by the specimen.

3.2.13 *ultimate displacement, cyclic (Δ_u), n*—the displacement corresponding to the failure limit state in cyclic test.

3.2.14 *ultimate displacement, monotonic (Δ_m), n*—the displacement corresponding to the failure limit state in monotonic test.

3.2.15 *yield limit state, n*—the point in the load-displacement relationship where the elastic shear stiffness of the assembly decreases 5 % or more. For specimens with nonlinear ductile elastic response, the yield point (Δ_{yield} , P_{yield}) is permitted to be determined using the EEEP curve (see 9.1.4).

4. Summary of Test Method

4.1 The elastic shear stiffness, shear strength and ductility of specimens are determined by subjecting a specimen to full-reversal cyclic racking shear loads. This is accomplished by anchoring the bottom edge of the specimen to a test base simulating intended end-use applications and applying a force parallel to the top of the specimen. The specimen is allowed to

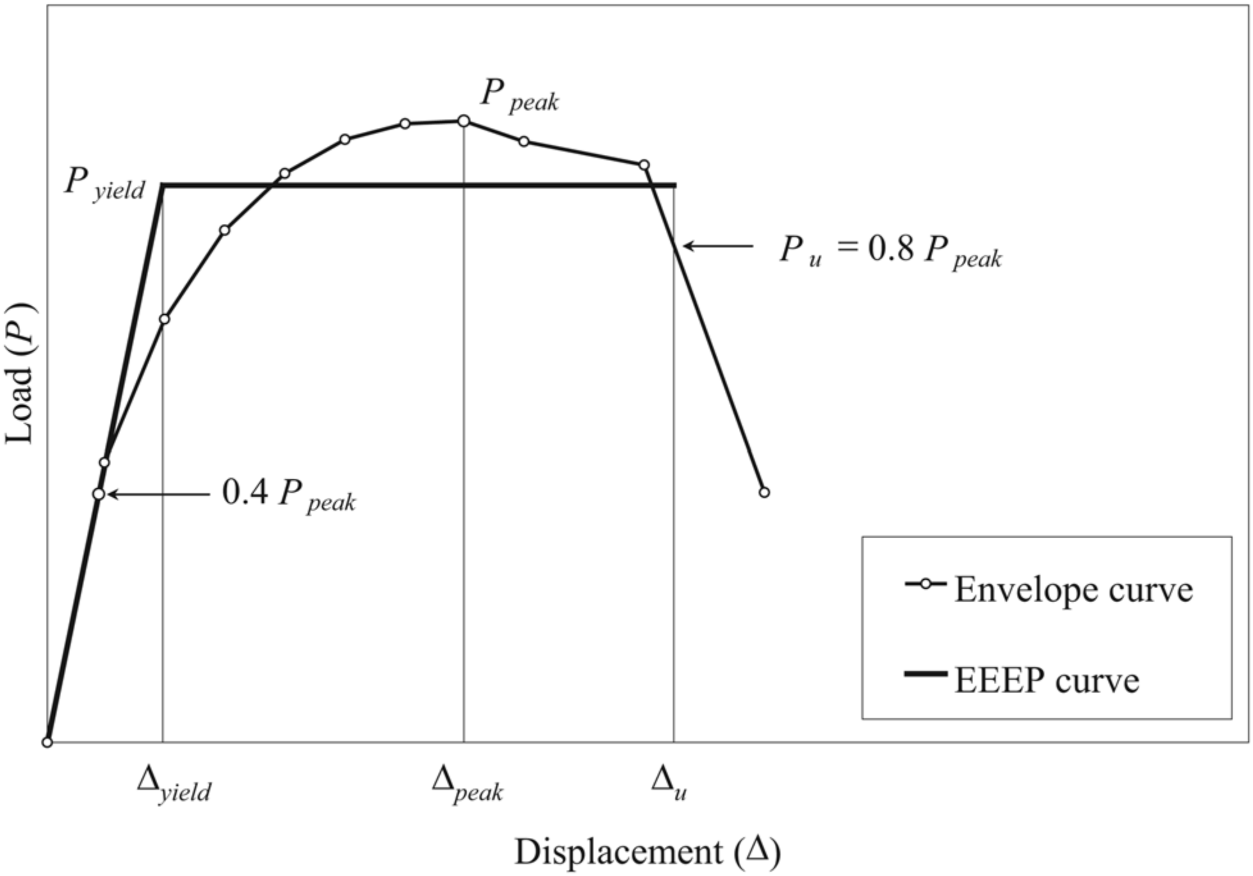

FIG. 1 Performance Parameters of Specimen: (B) Last Point at $P_u = 0.8\,P_{peak}$ *(continued)*

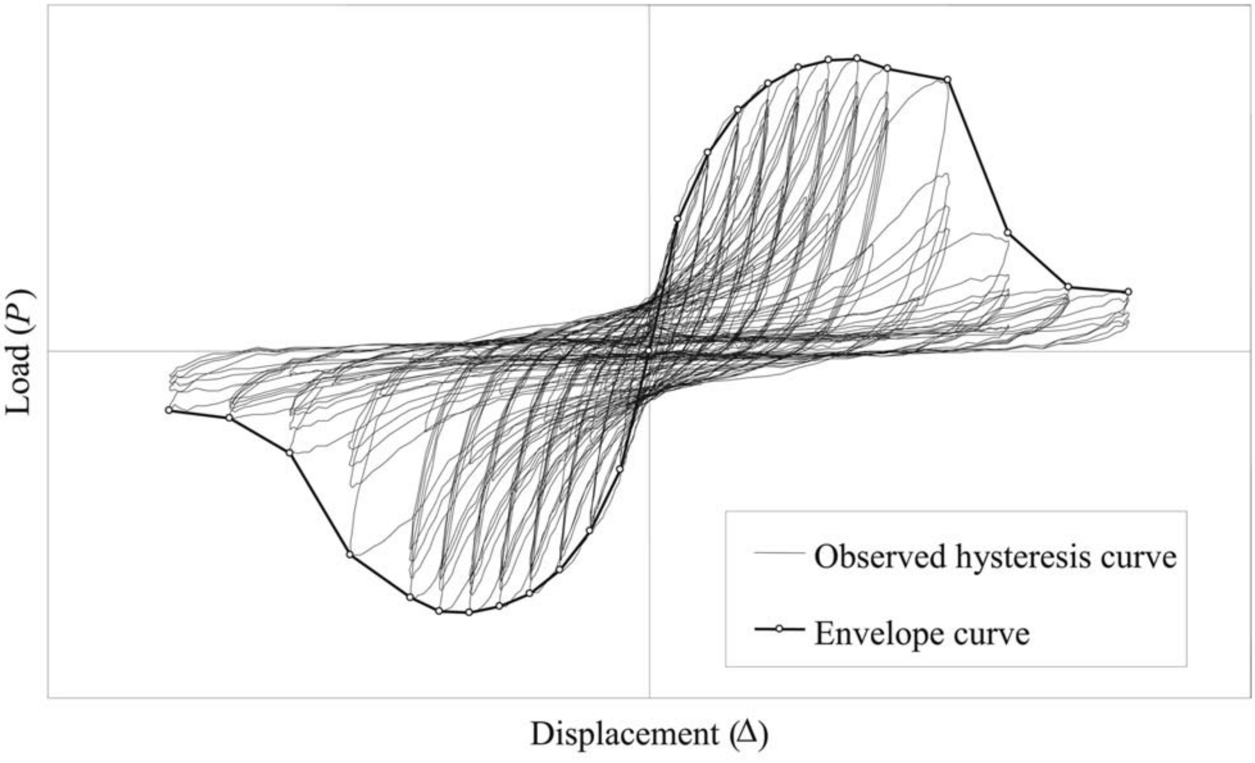

FIG. 2 Examples of Observed Hysteresis Curve and Envelope Curves for Test Method A

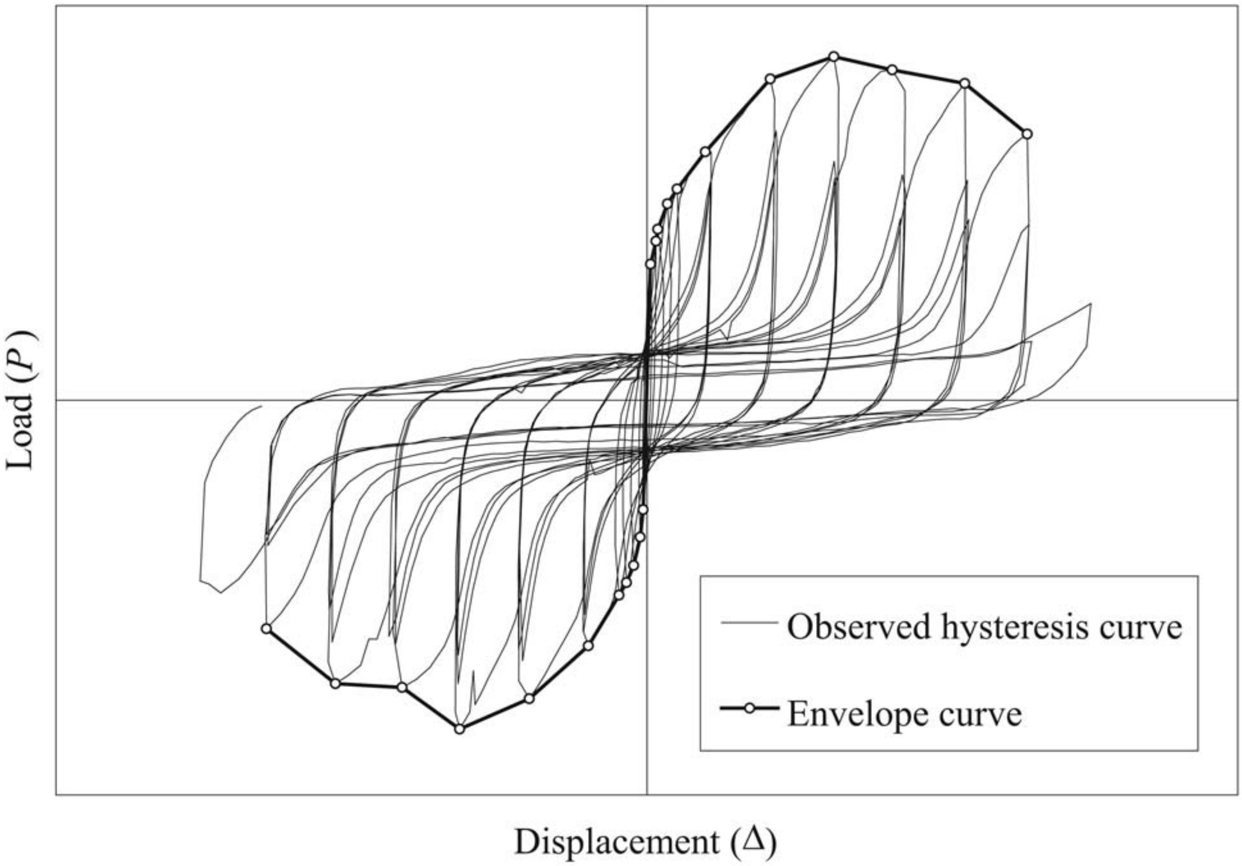

FIG. 2 Examples of Observed Hysteresis Curve and Envelope Curves for Test Method B *(continued)*

displace in its plane. Sheathing panels that are a component of a specimen shall be positioned such that they do not bear on the test frame during testing. (See Note 1.) As the specimen is racked to specified displacement increments, the racking (shear) load and displacements are continuously measured (see 8.7).

NOTE 1—If the end-use applications require sheathing panels bear directly on the sill plate, such as most structural insulated panels, the specimen may be tested with sheathing panels that bear on the sill plate.

5. Significance and Use

5.1 These test methods are intended to measure the performance of vertical elements of the lateral force resisting system subjected to earthquake loads. Since these loads are cyclic, the loading process simulates the actions and their effects on the specimens.

6. Specimen

6.1 *General*—The typical specimen consists of a frame, bracing elements, such as panel sheathing, diagonal bracing, etc., and fastenings. The bracing is attached on one side of the frame unless the purpose of the test requires bracing on both sides. The elements of the specimen shall be fastened to the frame in a manner to conform to 6.2. Elements used to construct specimens may be varied to permit anticipated failure of selected elements. All detailing shall be clearly identified in the report in accordance with Section 10.

6.2 *Connections*—The performance of specimens 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, if applicable, and the tightness of the fasteners holding the specimen to the test base.

6.2.1 *Sheathing Panel Attachments*—All panel attachments shall be consistent with the types used in actual building construction. Structural details, such as fastener schedules, fastener edge distance, and the gap between panels, shall be reported in accordance with Section 10.

6.2.2 *Attachment to the Test Base*—Specimen shall be attached to the test base with fasteners in a manner representing field conditions. For intended use requirements over a non-rigid foundation, a mock-up flexible base shall be constructed to simulate field conditions. Consideration shall be given to the orientation and type of floor joists relative to the orientation of the wall assembly. When strap connections are used, they shall be installed (that is, inside/outside the sheathing, etc.) without pre-tension in a configuration that simulates the field application. The test report shall include details regarding this attachment.

6.2.3 *Anchor and Hold-Down Bolts*—When the specimen frame is made of solid wood or wood-based composites, the anchor bolts shall be tightened to no more than finger tight plus a ⅛ turn, provided that the design value of stress perpendicular to the grain is not exceeded (see Note 2). The hold-down bolts

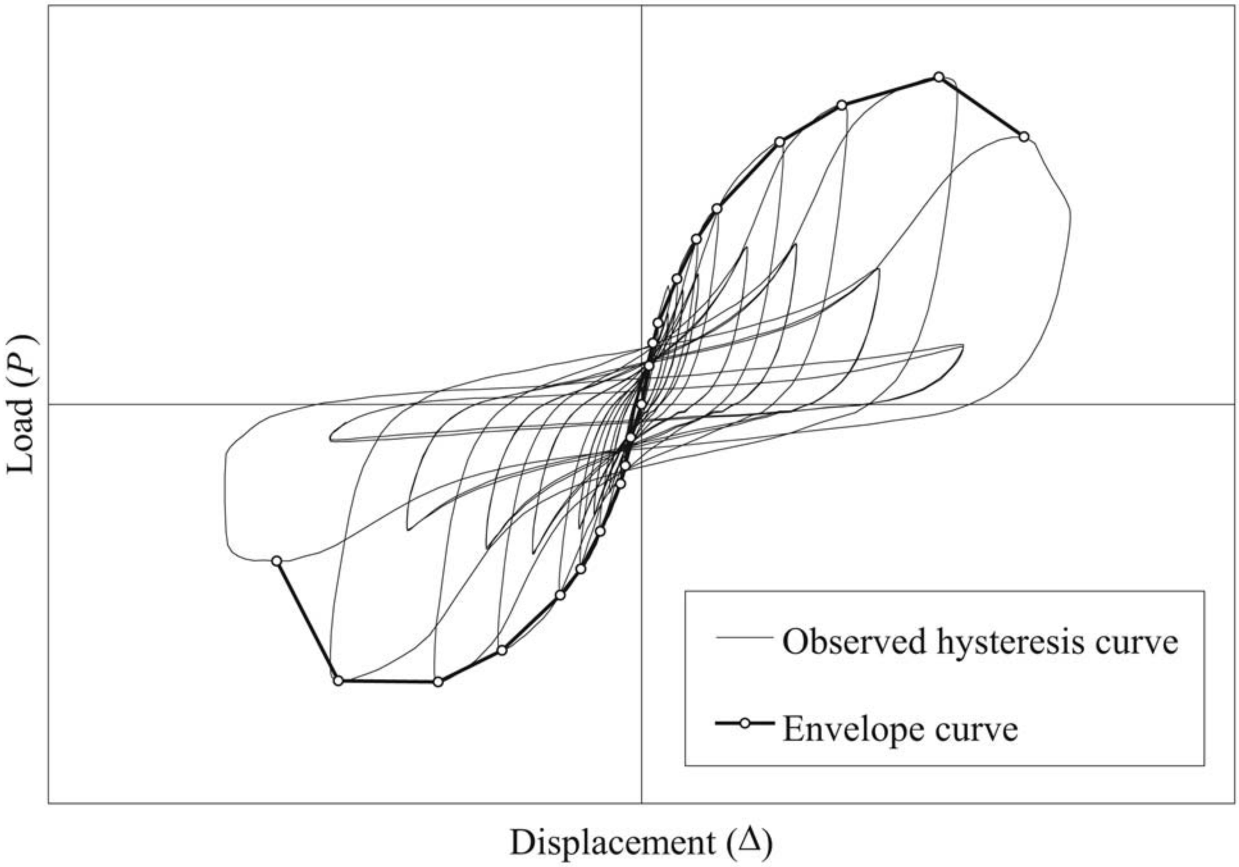

FIG. 2 Examples of Observed Hysteresis Curve and Envelope Curves for Test Method C *(continued)*

shall be tightened consistently between replicates in accordance with hold-down manufacturer's recommendation. The assembly test shall not start within 10 min of the anchor bolt tightening to allow for stress relaxation of the anchor.

NOTE 2—Since solid wood and wood-based composites relax over time as well as potentially shrink due to changing moisture content, the intent of the finger tight plus a ⅛ turn is to avoid any significant pre-tension on the anchor bolts, which may affect the test results. It is the committee judgment that the maximum bolt tension should not be more than 300 lbf (1.33 kN) for the purpose of ensuring the bolt is not caught on a thread or not seated fully. It should be noted that, however, the bolt tension depends on wood species and density, bolt thread pitch (or bolt diameter), and plate washer size. A general rule of thumb is to finger-tight plus ⅛ turn, which will result in a nut displacement of approximately 0.01 in. (0.254 mm) for ½ and ⅝-in.-diameter (12.7 and 15.9-mm-diameter) UNC bolts. A torque of about 50 lbf-in. (5.65 kN-mm) without bolt lubrication would normally produce 300 lbf (1.33 kN) of bolt tension.

6.3 *Frame Requirements*—The frame of the specimen 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 (or the relevant product identification information for structural composite lumber framing); moisture content of the framing members at the time of the specimen fabrication and testing, if more than 24 h passes between these operations (see Test Methods D4442, Test Methods A or B; or D4444, Test Methods A or B); and specific gravity of the framing members (see Test Methods D2395, Test Method A). The specific gravity of the framing members shall be representative of the published specific gravity for the product with no individual member exceeding the published value by more that 10 % (see ANSI/AF&PA NDS for example).

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

6.4 *Structural Insulated Panel*—The panel is prefabricated assembly consisting of an insulating core of 1.5 in. (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 *Specimen Size*—The specimen shall have a height and length or aspect (height/length) ratio that is consistent with intended use requirements in actual building construction (see Fig. 4).

7. Test Setup

7.1 The specimen shall be tested such that all elements and sheathing surfaces are observable. For specimens such as framed walls with sheathing on both faces of framing or frameless structural insulated panels, the specimens are dismantled after tests to permit observation of all elements.

7.2 The bottom of the specimen shall be attached to a test base as specified in 6.2. The test apparatus shall support the

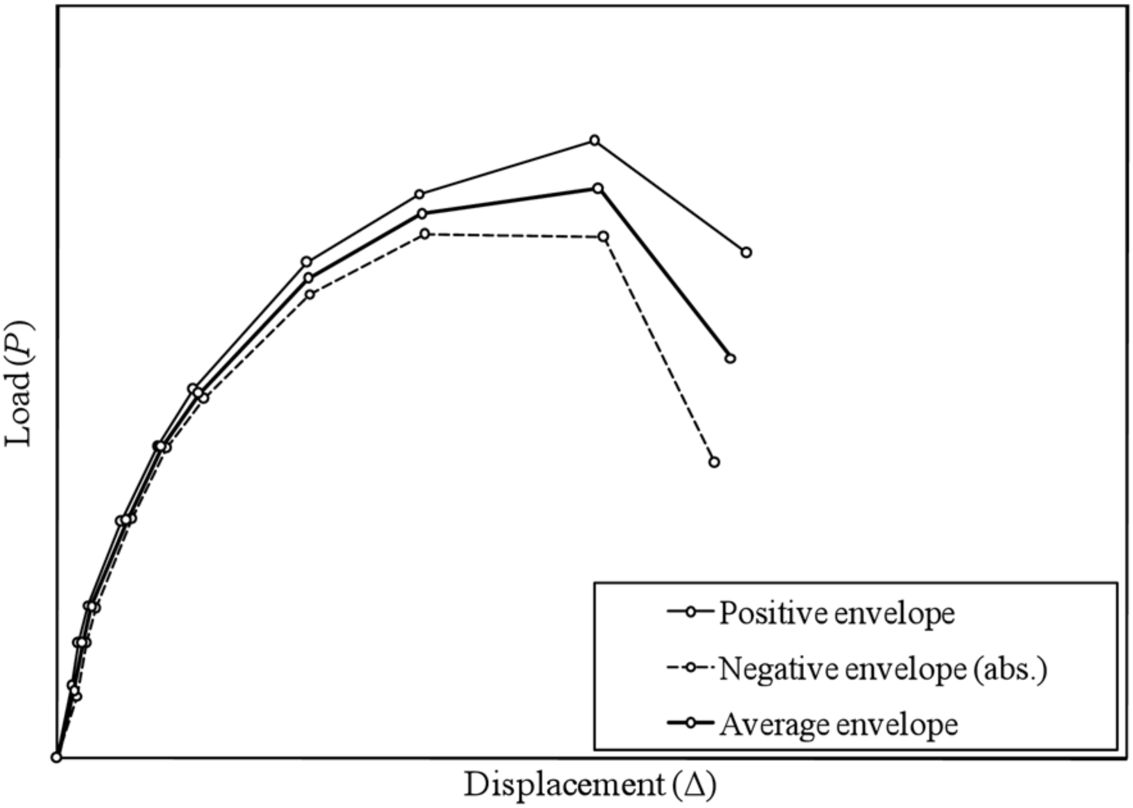

FIG. 3 Example of Average Envelope Curve (see Fig. 2, Test Method C)

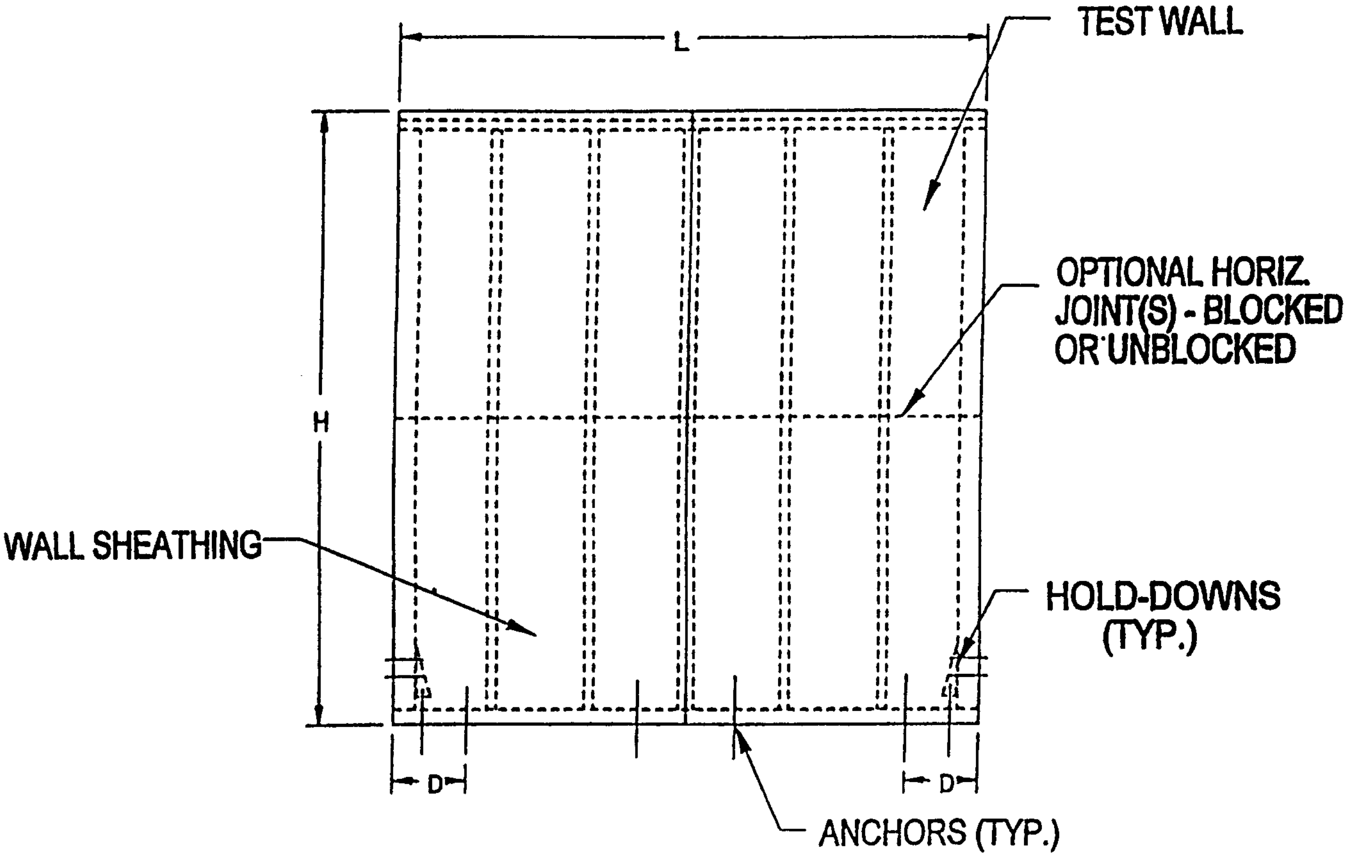

FIG. 4 An Example of Shear Wall Specimen

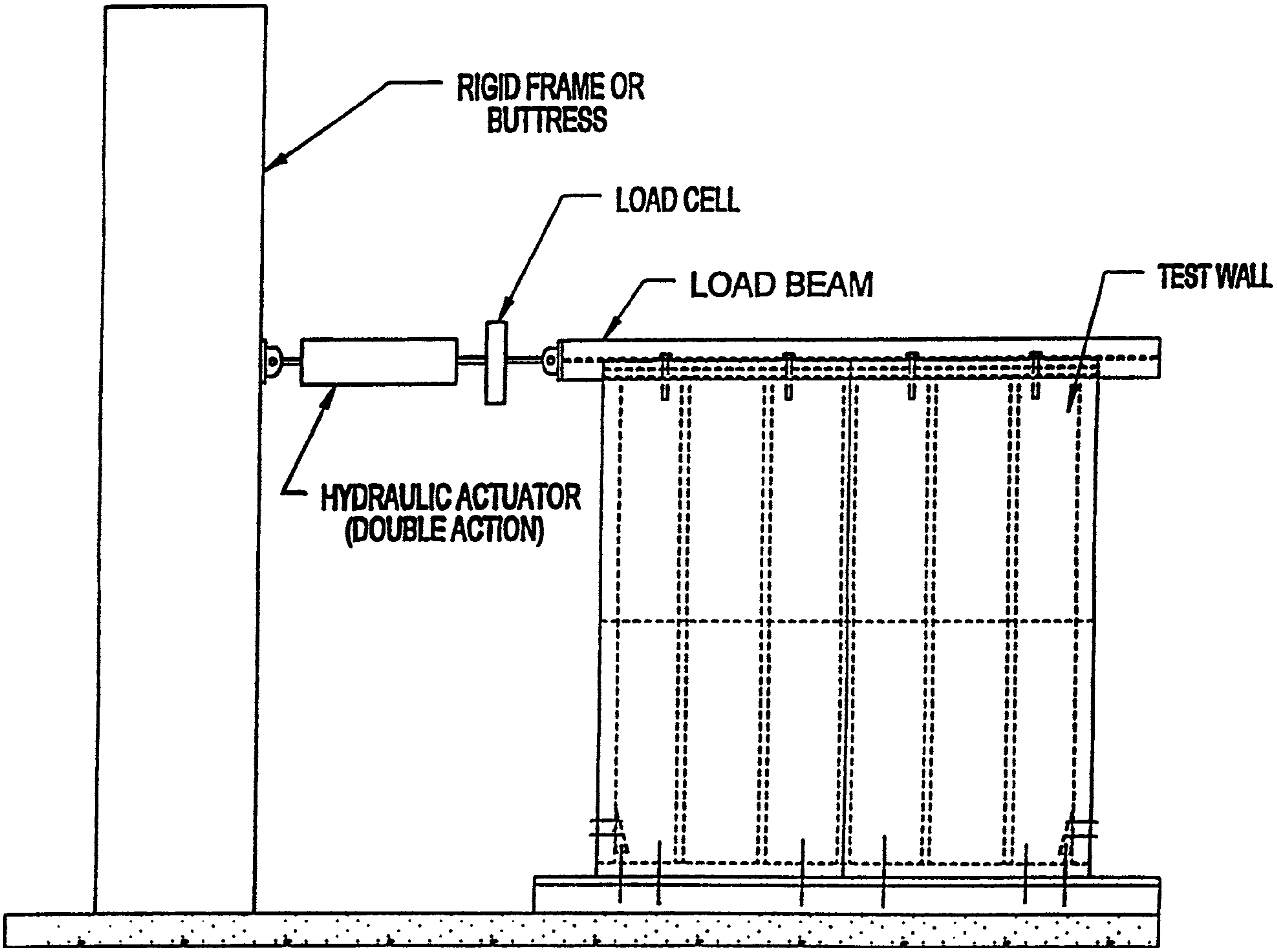

FIG. 5 An Example of Test Setup for Shear Wall Specimen

specimen as necessary to prevent displacement from the plane of the specimen, but in-plane displacement shall not be restricted.

7.3 Racking load shall be applied horizontally along the plane of the specimen using a double-acting hydraulic actuator with a load cell. The load shall be distributed along the top of the specimen by means of a loading beam or other adequate devices. The beam used to transfer loads between the hydraulic cylinder and the test specimen shall be selected so that it does not contribute to the measured racking strength and stiffness.

7.3.1 If applied to the top of the specimen directly, for example, as is shown in Fig. 5, the maximum stiffness of load beam permitted is 330 000 kips-in.^{2} (947 kN-m^2) (see Note 3).

NOTE 3—The selected stiffness corresponds with an HSS 5 × 3 × ¼-in. (127 × 76 × 6.4-mm) steel section. Other sections with equal or less stiffness have been successfully employed.

7.3.2 The load beam selected shall not be continuous over discontinuities in the test specimen (see Note 4).

NOTE 4—Examples of discontinuities include portal frame openings, wall perforations, transitions between differential bracing types, etc. Continuation of a rigid load beam over these discontinuities can add to the measured in-plane rigidity of the system. However, the use of continuous load beam over discontinuities may be considered provided that the added in-plane rigidity can be justified by the end-use applications.

7.3.3 The combined gravity load applied to the specimen by the load beam and actuator shall be less than 350 lbf (1.56 kN), unless the purpose of the test includes the influence of vertical loads on the system performance (see Appendix X3).

7.4 Test setup shall be designed and installed so that vertical (gravity) loads from test equipment applied to the specimen are negligible. Other vertical loads shall not be added to the specimen unless justified by analysis of actual building construction or the objective of the testing. When vertical loads are applied, the magnitude and test setup for the vertical load shall be reported along with the justification.

NOTE 5—The neglect of vertical loads in this standard may result in inaccurate estimates of the capacity of the specimen as an element of the lateral force resisting system in actual building construction. For example, the neglect of uplift forces in testing may overestimate the racking capacity of the element, while the neglect of dead weight of the story above may underestimate the racking capacity of the element unless buckling is the predominant failure mode.

8. Procedure

8.1 *Number of Tests*—A minimum of two specimens of a given construction shall be tested if the shear strength (v_{peak}) values of each specimen calculated according to 9.1.1 are within 10 % of each other. The lower of the two test values shall be used to calculate the 10 % allowance. Otherwise, at least three specimens of a given construction shall be tested.

8.2 The cyclic displacement of the actuator shall be controlled to follow a cyclic displacement procedure described in either 8.3 (Test Method A), 8.4 (Test Method B), or 8.5 (Test Method C).

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

8.3.1 *Sequential Phased Displacement (SPD) Loading Protocol*—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. 6. 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. 7. Each phase is associated with a respective displacement level and contains one initial cycle, three decay cycles, and a number of stabilization cycles. For nailed wood-frame 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 determined from the static monotonic load test on an identical specimen in accordance with Practice E564. To determine Δ_{yield}, it is permitted to compute EEEP curves, as shown in Fig. 1 based on monotonic test data, in accordance with 9.1.4.

8.4 *Test Method B (ISO 16670 Protocol):*

8.4.1 *ISO Displacement Schedule*—Displacement-controlled loading procedure that involves displacement cycles grouped in phases at incrementally increasing displacement levels. The ISO loading schedule consists of two displacement patterns and is illustrated in Fig. 8. The first displacement pattern consists of five single fully reversed cycles at displacements of 1.25 %, 2.5 %, 5 %, 7.5 %, and 10 % of the ultimate displacement Δ_m. The second displacement pattern consists of phases, each containing three fully reversed cycles of equal amplitude, at displacements of 20 %, 40 %, 60 %, 80 %, 100 %, and 120 % of the ultimate displacement Δ_m.

8.4.2 The sequence of amplitudes, which is given in Table 2, are a function of the mean value (where applicable) of the ultimate displacement (Δ_m) obtained from matched specimens in the monotonic tests in accordance with Practice E564.

8.5 *Test Method C (CUREE Basic Loading Protocol):*

8.5.1 *CUREE Basic Loading Protocol*—Displacement-controlled loading procedure that involves displacement cycles grouped in phases at incrementally increasing displacement levels. The loading history starts with a series of (six) initiation cycles at small amplitudes (of equal amplitude). Further, each phase of the loading history consists of a primary cycle with amplitude expressed as a fraction (percent) of the reference deformation, Δ, and subsequent trailing cycles with amplitude of 75 % of the primary one.

NOTE 6—The initiation cycles serve to check loading equipment, measurement devices, and the force-deformation response at small amplitudes.

8.5.2 The schedule of amplitude increments is given in Table 3 and is illustrated in Fig. 9. The reference deformation Δ shall be an estimate of the maximum displacement at which the load in a primary cycle has not yet dropped below 0.8 P_{peak}.

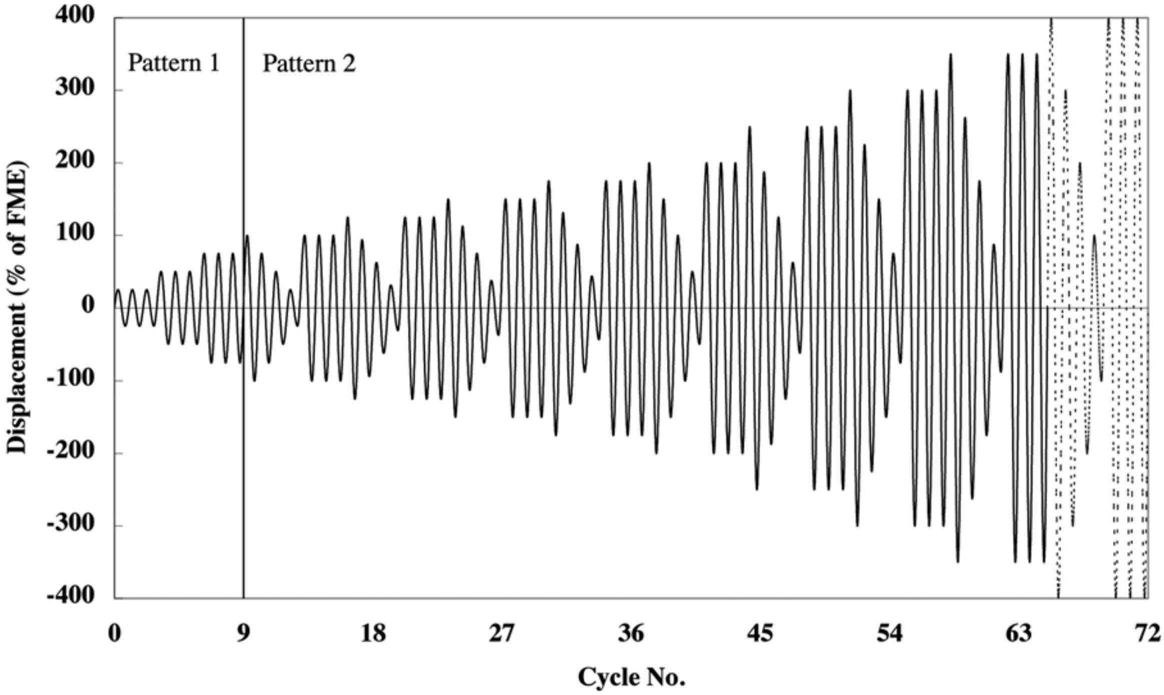

FIG. 6 Cyclic Displacement Schedule (Test Method A)

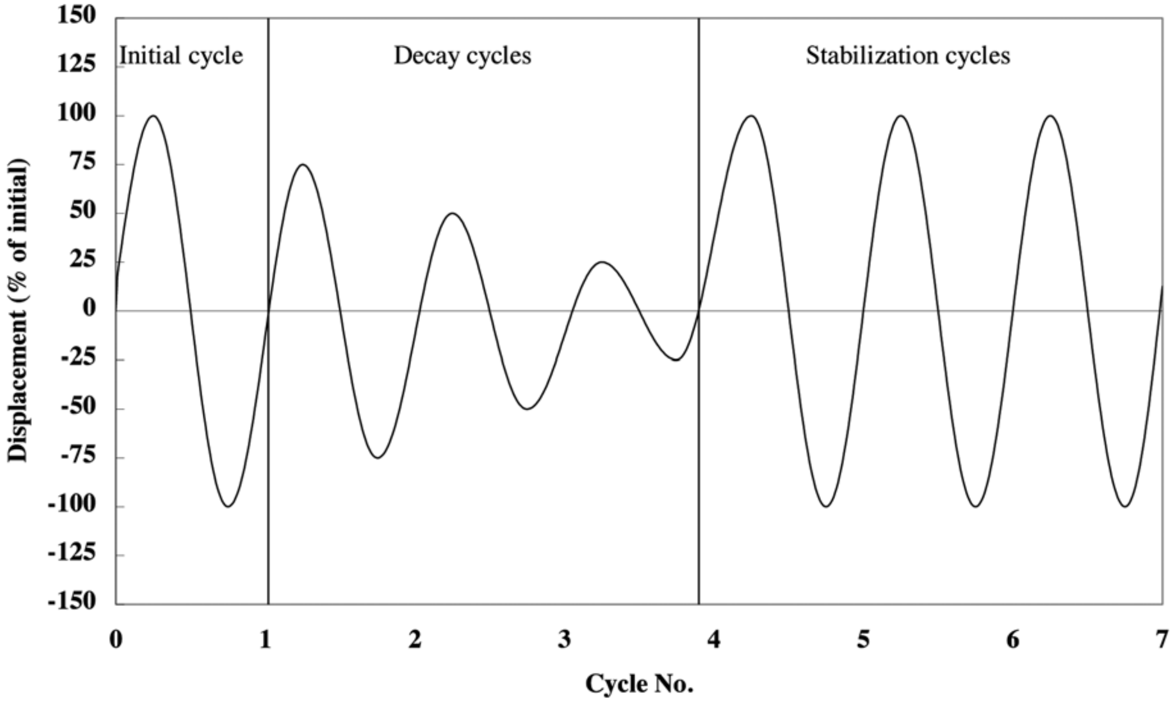

FIG. 7 Single Phase of Pattern 2 (Test Method A)

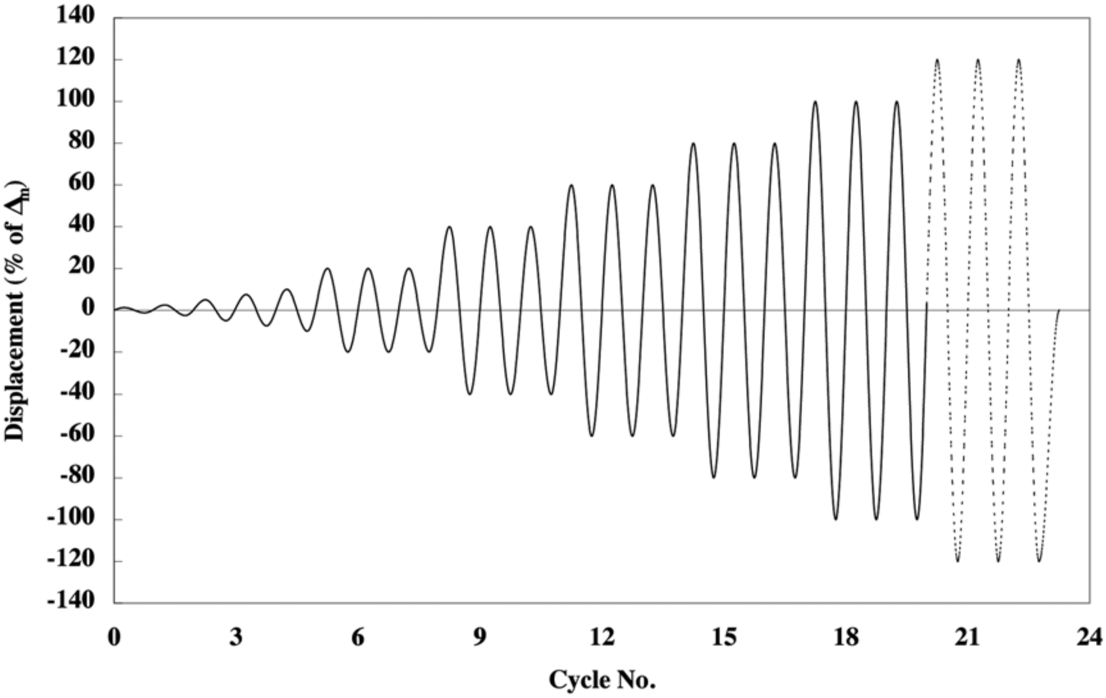

FIG. 8 Cyclic Displacement Schedule (Test Method B)

The value of Δ shall not exceed 0.025 times the wall height. If the panel has not failed at the end of Phase 8 of Table 3, then additional phases shall be added. Each subsequent phase shall consist of a primary cycle with an increase in amplitude of α (α ≤ 0.5) over the previous primary cycle, and followed by two trailing cycles with amplitude of 75 % of the primary one.

8.6 The actuator displacement in Test Methods A, B, or C 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 2.5 in./s (1.0 and 63.5 mm/s). The cyclic frequency shall range from 0.2 to 0.5 Hz to avoid inertial effects of the mass of the wall and test fixture hardware during

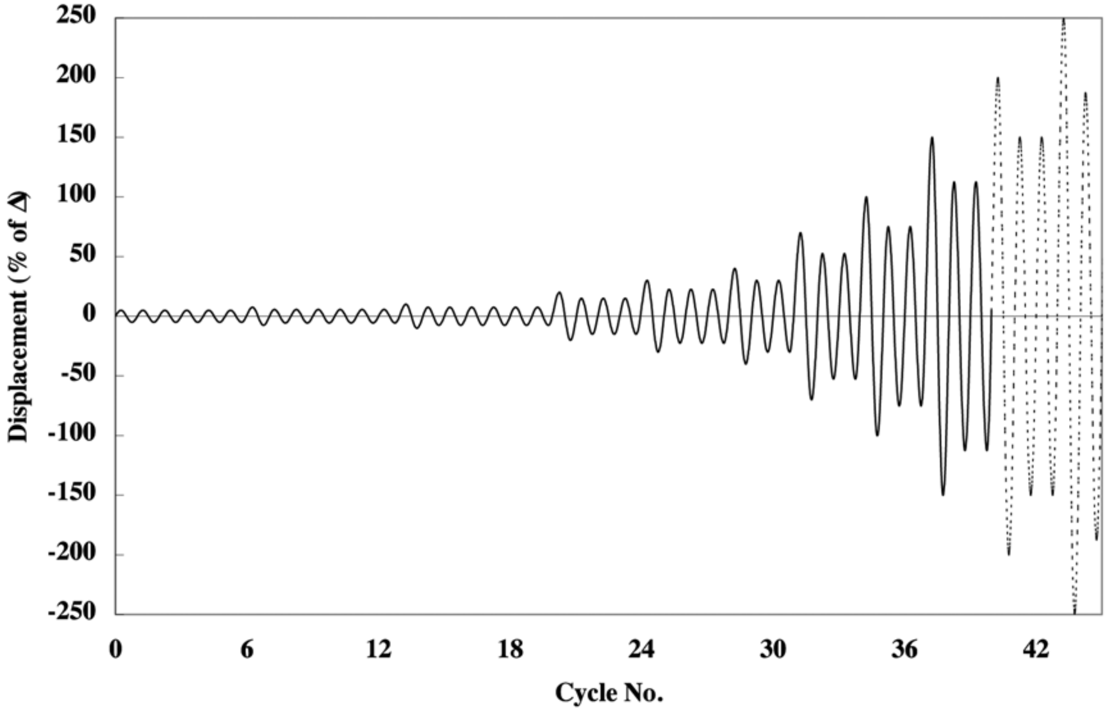

FIG. 9 Cyclic Displacement Pattern (Test Method C)

TABLE 1 Test Method A—Amplitudes of Initial Cycles

Pattern	Step	Minimum Number of Cycles[A]	Amplitude of Initial Cycle % FME
1	1	3	25
	2	3	50
	3	3	75
2	4	7	100
	5	7	125
	6	7	150
	7	7	175
	8	7	200
	9	7	250
	10	7	300
	11	7	350
	12		Additional increments of 50 (until specimen failure)

[A] See 8.3.1 for details.

cyclic loading. The loading shall follow the corresponding procedure until the applied load diminishes more than 0.2 P_{peak}, that is, until the failure limit state occurs.

8.7 Displacements shall be measured with displacement measuring devices with a resolution of 0.005 in. (0.13 mm) or other suitable devices for continuously measuring displacement under cyclic loading conditions, at a minimum sampling rate of 100 readings per cycle. The following instrumentation shall be provided for measuring displacements, and hold-down connector forces when required:

8.7.1 Horizontal displacement of the specimen at the top plate.

8.7.2 Vertical (upward and downward) displacement of both end posts (or equivalent) relative to the rigid base. The reference point for this measurement shall be on or immediately adjacent to the outside face of the end post.

8.7.3 Horizontal displacement of the bottom plate relative to the rigid base (lateral in-plane sliding).

8.7.4 Vertical displacement of the hold-down connectors relative to the end posts (deformation of the connectors and fastener slip), as applicable.

8.7.5 When specified, loads on the bolts fastening the hold-down connectors to the rigid base.

9. Calculation

9.1 Based on the observed hysteresis response curves, the envelope (positive and negative) curves are generated for each tested specimen. If the laboratory chooses to report the positive and negative performances individually, then both envelopes (positive and negative) shall be analyzed separately in accordance with Section 9. If the laboratory chooses to report one set of performance parameters that characterizes both envelopes,

TABLE 2 Test Method B—Amplitudes of the Reversed Cycles

Pattern	Step	Minimum Number of Cycles	Amplitude, % Δ_m
1	1	1	1.25
	2	1	2.5
	3	1	5
	4	1	7.5
	5	1	10
2	6	3	20
	7	3	40
	8	3	60
	9	3	80
	10	3	100
	11	3	Additional increments of 20 (until specimen failure)

TABLE 3 Test Method C—Amplitude of Primary Cycles

Pattern	Step	Minimum Number of Cycles	Amplitude of Primary Cycle, % Δ
1	1	6	5
2	2	7	7.5
	3	7	10
3	4	4	20
	5	4	30
4	6	3	40
	7	3	70
	8	3	100
	9	3	100 + 100α[A]
	10	3	Additional increments of 100α (until specimen failure)

[A] $\alpha \leq 0.5$.

then the positive and negative envelope curves shall be averaged to produce an average envelope curve according to 3.2.4 and the calculations outlined in Section 9 shall be conducted for each specimen based up the average envelope curve.

NOTE 7—If the specimen behavior in the positive and negative quadrants is similar (major events occur in the same phases on the negative and positive sides), a reasonable approximation of the average performance can be achieved by determining the parameters from positive and negative envelopes individually and then averaging them (see Appendix X4).

9.1.1 *Shear Strength (v_{peak}) lbf/ft (N/m)*—The maximum load per unit specimen length resisted by the specimen in the given envelope shall be calculated as follows:

$$\nu_{peak} = \frac{P_{peak}}{L} \tag{1}$$

where:

P_{peak} = maximum load resisted by the specimen in the given envelope, lbf (N); and

L = length of specimen, ft (m).

9.1.2 Secant shear modulus, G', at 0.4 P_{peak} and at P_{peak} shall be calculated as follows:

$$G' = \frac{P}{\Delta} \times \frac{H}{L} \tag{2}$$

where:

G' = shear modulus of the specimen obtained from test (includes shear and uplift deformation for the connection system), lbf/in. (N/m); represents the secant shear stiffness at specified specimen displacements times the aspect ratio;

P = applied load measured at the top edge of the specimen, lbf (N);

Δ = displacement of the top edge of the specimen based on test, in. (m). This includes both the shear deflection of the sheathing material and its connections, and the contribution of the shear and hold-down connection systems;

H = height of specimen, ft (m); and

L = length of specimen, ft (m).

9.1.3 Cyclic ductility ratio, *D*, as described in 3.2.1, shall be calculated. If the shear stiffness (shear modulus) at 0.4 P_{peak} is greater than that at P_{peak}, generate the EEEP curve as described in 9.1.4. Otherwise, the FME and the ultimate displacement shall be determined directly from the envelope curve. Calculate values of displacement, shear forces, and shear modulus at the yield limit state and strength limit state.

9.1.4 When specified by 9.1.3, develop an EEEP curve to represent the envelope curve. Fig. 1 illustrates typical EEEP curve. The elastic portion of the EEEP curve contains the origin and has a slope equal to the elastic shear stiffness, K_e. The plastic portion is a horizontal line equal to P_{yield} determined by the following equation:

$$P_{yield} = \left(\Delta_u - \sqrt{\Delta_u^2 - \frac{2A}{K_e}} \right) K_e \qquad (3)$$

If $\Delta_u^2 < \frac{2A}{K_e}$, it is permitted to assume $P_{yield} = 0.85\ P_{peak}$

where:

P_{yield} = yield load, lbf (N);
A = the area under envelope curve from zero to ultimate displacement (Δ_u) of the specimen, lbf·in. (N·m);
P_{peak} = maximum absolute load resisted by the specimen in the given envelope, lbf (N);
Δ_e = displacement of the top edge of the specimen at 0.4 P_{peak}, in. (mm); and
K_e = 0.4 P_{peak}/Δ_e.

9.1.4.1 To generate an EEEP curve as described in 8.3.2 based on monotonic test results, the procedures in this section are permitted, with Δ_m substituting for Δ_u.

9.1.5 If the envelope curve contains data points at loads less than $|0.8\ P_{peak}|$ (past strength limit state), the failure limit state shall be determined at 0.8 P_{peak} using linear interpolation, as illustrated in Fig. 1.

10. Report

10.1 The report shall include the following information:

10.1.1 Date of the test and of report.

10.1.2 Names of the test sponsors and test agency and their locations.

10.1.3 Identification of the specimen (test number, and so forth).

10.1.4 Detailed description of the specimen and the test setup, including the following:

10.1.4.1 Dimensions of the specimen.

10.1.4.2 Details of the physical characteristics or structural design, or both, of the specimen, including, if applicable, the type, spacing, and edge distance of fasteners attaching sheathing to framing.

10.1.4.3 Details of attachment of the specimen in the test fixture, including a description of the test base and whether sheathing panels are directly bearing on the sill plate during testing.

10.1.4.4 Location of load application and load cell, strain gauges, deflection gauges, and other items for test as applicable.

10.1.4.5 Description of construction materials (for example, material type and grade, thickness, yield point, tensile strength, compressive strength, density, moisture content, manufacturer of components used, source of supply, dimensions, model, type, and other pertinent information, and so forth, as appropriate for materials used).

10.1.4.6 Drawing showing plan, elevation, principal cross section, and other details as needed for description of the specimen and the test setup (see 10.1.4.1-10.1.4.5).

10.1.4.7 Description of general ambient conditions including the following:

(1) At construction;

(2) During curing or seasoning, if applicable (including elapsed time from construction to test); and

(3) At test.

10.1.4.8 Modifications made on the specimen during testing.

10.1.4.9 Description of any noted defects existing in the specimen prior to test.

10.1.5 Description of the test, including a statement that the test or tests were conducted in accordance with this test method or otherwise describing any deviations from the test method.

10.1.6 Summary of results, including:

10.1.6.1 Hysteresis loops (applied load versus displacement at the top of the specimen) for every specimen tested.

10.1.6.2 Complete record (table or plot) of individual displacements required to be measured in 8.7.

10.1.6.3 Shear strength (v_{peak}) from tests of identical specimens (9.1.1).

10.1.6.4 As-tested and mean values of P, Δ and G' at yield limit state and strength limit state in accordance with Section 9.

10.1.6.5 EEEP curve developed from the mean loads and displacements at yield limit state and failure limit state, if applicable (see 9.1.3 and 9.1.4).

10.1.7 Description of failure modes and any behavior change and significant events, for each test.

10.1.8 Photographs of the specimen, particularly those depicting conditions that cannot otherwise be easily described in the report text, such as failure modes and crack patterns.

10.1.9 Appendix (if needed) that includes all data not specifically required by test results. Include special observations for building code approvals.

10.1.10 Signatures of responsible persons are in accordance with Practice E575.

11. Precision and Bias

11.1 No statement on the precision and bias is offered due to the numerous individual elements that comprise the specimen and the small number of replicate specimens tested. A generally accepted method for determining precision and bias is currently unavailable.

12. Keywords

12.1 cyclic loads; earthquake; framed walls; lateral-force resisting systems; portal frames; racking loads; rigid support; shear displacement; shear stiffness; shear strength; structural insulated panels

APPENDIXES

(Nonmandatory Information)

X1. DETERMINATION OF FIRST MAJOR EVENT

X1.1 The FME is the first significant limit state that occurs during the test. The limit state in turn denotes an event marking phase change between two behavior states. As noted in 8.3.2, the FME can be determined from monotonic load tests on an identical specimen. If the first estimate is inappropriate, the data obtained can be revised for the subsequent tests. The following estimates offer guidance for a typical 8-ft (2.4-mm) wall.

X1.1.1 *Wood-Framed Walls with Wood Structural Panel Sheathing*—Aspect ratios of 2:1 or less, FME = 0.8 in. (20 mm); aspect ratio of 4:1, FME = 1.2 in. (31 mm).

X1.1.2 *Wood-Framed Walls with Gypsum Sheathing*—Aspect ratios of 2:1 or less, FME = 0.25 in. (6.4 mm).

X2. SELECTION OF CYCLING METHOD

X2.1 Test Method A Versus Test Method B

X2.1.1 *Test Method A:*

X2.1.1.1 Test Method A is a sequential phased displacement pattern that exhibits decay cycles between the steps in the loading pattern. These decay cycles provide information on whether there is a lower bound in displacement required to produce hysteretic energy dissipation (**1**).[5] An example where a lower bound displacement causing hysteretic energy dissipation may occur would be a bolted connection through an over-drilled hole.

X2.1.1.2 Test Method A is based on Ref (**2**), which was developed by the Structural Engineers Association of Southern California (SEAOSC) to test wood or steel framed shear walls for earthquake resistance. The Ref (**2**) is currently not being maintained. There is a considerable breadth of information and vast databases on walls tested under Ref (**2**). For the purposes of acceptance testing it would be permissible to correlate the results of the two test methods.

X2.1.2 *Test Method B:*

X2.1.2.1 The cyclic protocol for Test Method B was developed for ISO 16670, a method for testing mechanically fastened timber joints. The background for this standard is given in Ref (**3-6**), which indicates that a unique cyclic displacement or loading history will always be a compromise, but one that is conservative for most practical cases should be selected. The Test Method B test protocol is intended to produce data that sufficiently describe elastic and inelastic cyclic properties; and typical failure mode that is expected in earthquake loading.

X2.1.3 *Selection of Test Method A Versus Test Method B:*

X2.1.3.1 Test Method A may be applicable to systems when FME is the yield limit state or for testing slack systems to determine a lower bound displacement causing hysteretic energy dissipation. Test Method B is a ramped displacement phase that bases the cycles on the percentage of an ultimate displacement determined through static tests. Test Method B may be more applicable to systems that exhibit linear elastic behavior where FME is the strength limit state. If the ratio of Δ_m and FME is less than three, Test Method B may be preferable. Both test methods are intended to generate similar displacement amplitudes in order to obtain similar number of points in the envelope curves. The difference is the number of cycles in each phase (step).

X2.2 Test Method C

X2.2.1 Test Method C (CUREE protocol) is the latest addition to the family of cyclic test protocols. It was developed based on the statistical analysis of seismic demands on light-frame buildings representative of California (in particular Los Angeles) conditions. The CUREE basic loading history is a realistic and conservative representation of the cyclic deformation history to which a component of a wood structure likely is subjected in earthquakes (**7, 8**). At relatively large deformations (primary cycles exceeding an amplitude of 0.4 Δ), the amplitude of the primary cycles increases by large steps. These large steps are based on statistics of inelastic time history responses. If the purpose of the experiment is acceptance testing, then it is permissible to reduce the step size of the primary cycles with large amplitudes. Smaller step sizes close to failure may result in a larger capacity (largest amplitude at which the acceptance criteria are met), even though they will result in larger cumulative damage. The reason is that the large step sizes of the basic loading history permit evaluation of acceptance only at discrete and large amplitude intervals. This standard permits a reduction in step size only for phases in which the amplitude of the primary cycle exceeds Δ. In that regime the amplitude the primary cycle may be increased by $\alpha\Delta$, with α to be chosen by the user, but $\alpha \leq 0.5$.

X2.2.2 The reference deformation, Δ, is a measure of the deformation capacity (Δ_u) of the specimen when subjected to the cyclic loading history. It is used to control the loading history, and therefore needs to be estimated prior to the test. The estimate can be based on previous experience, the results of a monotonic test, or a consensus value that may prove to be useful for comparing tests of different details or configurations. In CUREE Project (**7**), the following guidelines were used:

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[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

X2.2.2.1 Perform a monotonic test, which provides data on the monotonic deformation capacity, Δ_m . This capacity is defined as the deformation at which the applied load drops, for the first time, below 80 % of the maximum load that was applied to the specimen.

X2.2.2.2 Use a specific fraction of Δ_m, that is, $\gamma\Delta_m$, as the reference deformation for the basic cyclic load test. At this time, a value of $\Delta = 0.6\ \Delta_m$ is suggested. The factor γ should account for the difference in deformation capacity between monotonic test and a cyclic test in which cumulative damage will lead to earlier deterioration in strength.

X3. TEST SETUP

X3.1 CUREE recommendations (**9**) suggest that top of wall boundary conditions may influence wall test results. The weight of the load beam and actuator on a test specimen can reduce the anchorage demand in a specimen tested in a vertical orientation. The inertia from a heavy load beam during a cyclic test will exaggerate the measured response in test frames that test a wall either vertically or horizontally. For these reasons, the mass of the load beam and any hydraulics supported by the specimen shall be minimized to the extent practical. In test setups where vertical load from the actuator is carried by the test setup, the impact of the actuator mass may be evidenced by the difference in the positive and negative response from a symmetrical system. Test frames have been constructed that do not impose any vertical load on the specimen. The 350-lbf (1.56-kN) load limit is based on committee judgment that considered a range of test frames that are successfully employed.

X4. COMMENTARY

X4.1 *Performance Parameters*—It is always permissible to analyze the positive and negative envelope curves for a specimen individually and report the corresponding response parameters without averaging. However, the method for computing average performance parameters that characterize both envelopes (positive and negative) can make a difference when a specimen shows an asymmetrical response. In laboratory practices, the responses from most wall tests are asymmetrical to some degree as damage created with an initial positive excursion tends to weaken the response from the subsequent negative excursion within the same cycle. Determining the average response parameters for a specimen with dissimilar positive and negative envelope curves by analyzing each envelope (positive and negative) individually and then averaging can result in non-conservative estimates of the performance. Therefore, it is the committee judgment that when one set of parameters is used to summarize the specimen response for structural design purposes, the parameters should be calculated from the average envelope as the primary method of analysis. Using this approach reduces the non-conservatism for a moderately asymmetric wall. Calculation of average parameters individually from the negative and the positive envelopes will provide a practical approximation of the average parameters for reasonably symmetric envelopes; that is, if major events occur in the same phases on the negative and the positive sides. Caution and judgment should be used in estimating any form of average response to characterize a system that is grossly asymmetric. In these instances, the positive and negative envelopes should always be analyzed and reported individually without averaging.

X4.2 *Number of Tests*—Depending on the purpose of a testing program, the minimum number of tests required in 8.1 may require an adjustment. For example, if the test program is intended for an exploratory study, the number of tests (two) specified in 8.1 may be sufficient. On the other hand, if the test program is intended for code acceptance, three to five replications are typically required by the code evaluation agencies for a specific specimen configuration.

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