Designation: E 564 – 00

An American National Standard

Standard Practice for Static Load Test for Shear Resistance of Framed Walls for Buildings[1]

This standard is issued under the fixed designation E 564; 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 describes methods for evaluating the shear capacity of a typical section of a framed wall, supported on a rigid foundation and having load applied in the plane of the wall along the edge opposite the rigid support and in a direction parallel to it. The objective is to provide a determination of the shear stiffness and strength of any structural light-frame wall configuration to be used as a shear-wall on a rigid support.

1.2 *Limitations*—This practice is not intended to be used as a basis for classifying sheathing shear capacity or as an evaluation of combined flexure and shear resulting from the wall being loaded on a flexible foundation.

1.2.1 The effect of sheathing variations is assessed by holding all other variables constant. Permitted variations in framing configuration and boundary conditions, however, require accurate documentation of the test setup to validate across-study comparisons of sheathing contribution to wall shear capacity.

NOTE 1—A wall tested on a flexible foundation is evaluated by comparing shear stiffness and strength results to those of an identical wall tested on a rigid foundation, following this practice. However, no methods are given for the measurement of wall bending displacements or assessment of stress distribution resulting from foundation flexure. Any extrapolation of wall racking behavior from the foundation conditions specified by this practice to flexible conditions shall be done with the support of a comparative test on a representative foundation.

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:*

E 4 Practices for Force Verification of Testing Machines[2]

E 72 Test Methods of Conducting Strength Tests of Panels for Building Construction[3]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[4]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *racking*—when applied to shear walls, refers to the tendency for a wall frame to distort from rectangular to rhomboid under the action of an in-plane force applied parallel to the wall length.

3.1.2 *shear wall*—structural subassembly that acts as a cantilever/diaphragm to transfer horizontal building loads to the foundation in the form of horizontal shear and an overturning moment.

3.1.3 *uplift*—the vertical displacement measured at the loaded end stud with respect to the test apparatus.

3.2 *Symbols:*

3.2.1 a—height of cantilevered shear wall, in metres (feet).

3.2.2 b—length of cantilevered shear wall, in metres (feet).

3.2.3 C—initial length of the diagonal $\sqrt{a^2 + b^2}$, in metres (feet).

3.2.4 δ—diagonal elongation, in millimetres (inches).

3.2.5 Δ—total horizontal displacement of the top of the wall measured with respect to the test apparatus, in millimetres (inches). This value includes effects due to panel rotation, translation, and shear.

3.2.6 G'—global shear stiffness of the assembly, includes rotation and translational displacements as well as diaphragm shear displacement.

3.2.7 G'_{int}—internal shear stiffness of the assembly, includes only the shear displacement of the wall in calculation.

3.2.8 P—concentrated load applied at the top edge of the wall at the selected reference displacement, in newtons (pound-force).

3.2.9 P_u—highest load level held long enough to record gage measurements, in newtons (pound-force).

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

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

[4] *Annual Book of ASTM Standards*, Vol 14.02.

3.2.10 S_u—ultimate shear strength of the assembly, in newtons per metre (pounds per foot).

4. Summary of Practice

4.1 The shear strength and stiffness of a wall assembly and its connections are determined by forcing a racking deformation. This is accomplished by anchoring the bottom edge of the wall assembly and applying a force to the top edge oriented perpendicular to the wall height dimension and parallel to the wall length dimension. Wall distortion is restricted to the plane of the unstressed wall. The forces required to rack the wall and the corresponding displacements at each load interval are measured.

5. Wall Test Assembly

5.1 *General*—A wall assembly consists of frame elements including any diagonal bracing members or other reinforcements, sheathing elements, and connections. The wall assembly tested in accordance with this practice shall represent the minimum acceptable stiffness using the targeted frame and sheathing materials.

5.2 *Connections*—The performance of the wall test assembly is influenced by the type and spacing of framing connections, sheathing-to-frame connections and the wall assembly anchorage connection to the test fixture, floor, or foundation.

5.2.1 All connections used in the test shall be representative of those used in the actual building construction.

5.2.2 Connector size and location on the frame shall correspond to specifications.

5.3 *Frame Requirements*—The frame is an integral part of the wall test assembly. The test wall shall consist of the same number, size, and grade of framing members as are intended to be used in service.

5.4 *Test Setup*—Provisions shall be made to resist rigid-body rotation in the plane of the wall where this reflects the use of the assembly in actual building constructions. This shall be done by application of relevant gravity or other loadings simultaneously with the racking loads. The bottom of the assembly shall be attached to the test base with anchorage connections simulating those that will be used in service. Load distribution along the top edge of the wall shall simulate floor or roof members that will be used in the actual building construction. When required to minimize distortion, reinforcement, such as a strong-back attached along the length of the top plate or a steel bearing plate attached to the end of the top plate shall be installed. The wall test assembly shall be laterally supported along its top with rollers or equivalent means so as to restrict assembly displacement outside the plane of loading. Lateral support rigidity shall not exceed that provided in the actual building construction.

5.5 *Wall Size*—Test wall size will vary with the study objectives. Tests conducted to assess the structural performance of actual building construction shall have dimensions commensurate with those of the shear walls being simulated.

5.6 *Curing and Conditioning*—For framed wall constructions containing elements whose structural performance is a function of age, curing conditions, moisture content, or temperature, the wall test assembly shall be conditioned prior to the test in accordance with the appropriate voluntary consensus standards, manufacturer specifications, or industry curing practices for the various products used, or as needed to meet the intent of the test. Care shall be taken to ensure that curing and conditioning are representative of that expected in the actual building construction and that all elements of the wall test assembly at the time of the test are approximately at the equilibrium conditions expected in service.

5.7 *Environmental Effect*—When required to evaluate wall assembly performance for simulated environmental conditions, preconditioned specimens shall be tested in an environmental chamber.

6. Procedure

6.1 *Number of Tests*—Test a minimum of two wall assemblies to determine the shear capacity of a given construction. For unsymmetrical shear walls, run the second test with the specimen orientation reversed with respect to the direction of the load application used in the first test. If the strength or shear stiffness of the second test is not within 15 % of the results of the first test, test a third wall assembly with the wall oriented in the same manner as the weaker of the two test values. The strength and stiffness values reported shall be the average of the two weakest specimen values if three or more tests are performed.

6.2 *Loading Procedure*:

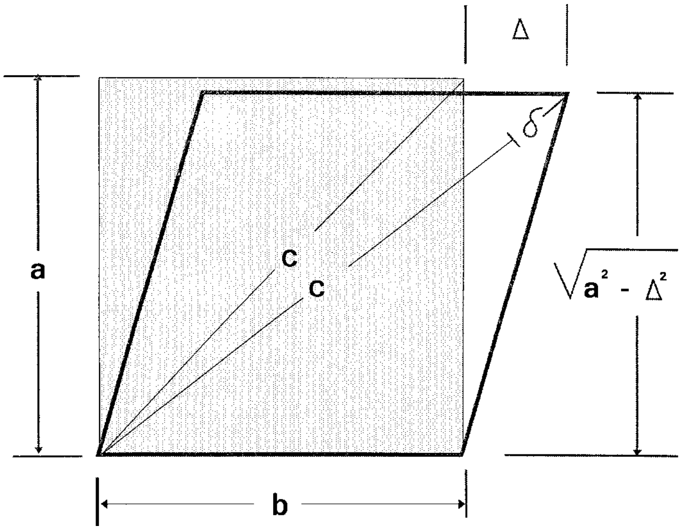
6.2.1 *General*—Racking loads shall be applied parallel to and at the top of the wall, in the central plane of the frame, using a hydraulic jack or similar loading device capable of maintaining a constant displacement rate for continuous load to failure or holding a static load in the case of incremental loading. Loads shall be applied at a constant rate of displacement to reach the target limit (that is, limiting displacement of ultimate load) in no less than 5 min.

6.2.2 Gravity loads, when required, shall be applied along the top of the wall in a manner consistent with floor or roof frame loading.

6.2.3 *Static Load Test*—Maintain the duration of load application at each increment at least 1 min before load and deflection readings are recorded. Apply preload of approximately 10 % of estimated ultimate load and hold for 5 min to seat all connections. Remove the load, wait 5 min, and read all gages as the initial readings. At load levels approximately one third and two thirds of the estimated ultimate load, remove the load and record the recovery of the wall after 5 min. Reload to the next higher load level above the backoff load. Continue loading and unloading in this manner until ultimate load is reached.

6.3 *Data Acquisition*—The objectives of a study determine the data required from this test. These generally include quantification of the shear strength and stiffness of the wall diaphragm. Shear strength is denoted as the maximum load per unit length of the wall. Shear stiffness requires measurement of the racking load and corresponding shear displacement. Shear strain is determined as the angular displacement (Δ/a Fig. 1).

6.3.1 Racking load shall be monitored using either the line pressure to a calibrated loading ram or a load cell mounted in series with the loading device. When load measurement is accomplished by monitoring hydraulic line pressure, the load versus pressure calibration shall have been developed at the



NOTE 1—Horizontal shear displacement calculated on the basis of the diagonal elongation simplifies the test by eliminating the need to measure rigid body rotation and horizontal translation of the wall.

$$(C + \delta)^2 = (b + \Delta)^2 + (a^2 - \Delta^2)$$

substituting:

$$a^2 + b^2 = c^2$$

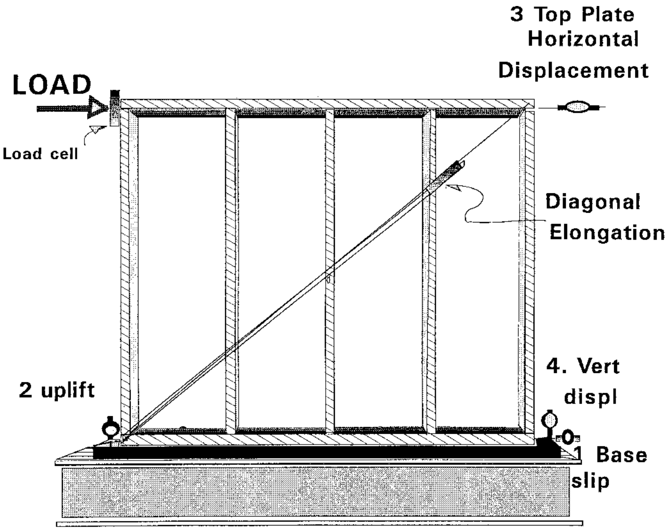
gives:

$$2c\delta + \delta^2 - 2b\Delta = 0$$

and:

$$\Delta = \frac{(2c\delta + \delta^2)}{2b}$$

FIG. 1 Horizontal Measurement



NOTE 1—The horizontal load is measured using a load cell in series with the loading ram. Wall shear displacement is determined using either four gages to separate shear from uplift, rotation, and horizontal slip of the wall or by measuring diagonal elongation to measure wall racking deformation directly. To restrain rigid-body rotation, apply boundary conditions to simulate those that control wall performance in service.

FIG. 2 Test Wall Configuration

same, or greater, hydraulic flow rate as occurs in the test to reduce chances of overestimating load due to drag effects. The loading measurement shall be accurate to ± 1% of the maximum measured load. The load measuring instrumentation shall be calibrated in accordance with Practices E 4.

6.3.2 *Displacement Measurements*—Shear displacement measurement of a wall frame shall be accurate to 0.25 mm (0.01 in.). Two approaches to estimating the shear stiffness are provided in this practice: direct measurement and that estimated by measuring the diagonal elongation of the frame.

6.3.3 *Direct Measurement*—Four (numbered in Fig. 2) displacement measurements are used to evaluate shear deformation by the direct measurement. The measurement is complicated by the fact that the assembly tends to rotate and translate as a rigid body, as the frame is deformed from a rectangle to a skewed parallelogram. In addition, the individual elements of the shear diaphragm rotate with respect to the frame as the shear load is applied.

6.3.3.1 *Slip at the Base*—For this reading, the displacement is measured at the centroid of the bottom plate with respect to the test machine in a direction parallel to the length of the wall.

6.3.3.2 *Uplift of the Stud at the Loaded End*—The distance which the bottom of the stud at the loaded end of the wall is lifted off the base of the test machine indicates the degree of rigid body rotation. This displacement divided by the horizontal distance along the base from the vertical-displacement-measurement reference point to the opposite end of the bottom plate is the tangent of the angle of rotation of the wall. As the end stud is rotating as well as being lifted, it is important to take the uplift reading as close as possible to the centerline of the stud.

6.3.3.3 *Top Plate Horizontal Displacement*— This measurement, taken at the centroid of the top plate, gives total horizontal displacement at Point 3, as shown in Fig. 2, due to a combination of rigid body rotation, horizontal translation of the entire wall, and shear deformation. Subtracting the displacement at Point 1 from the measured horizontal displacement of Point 3 and dividing by the stud length plus one plate thickness approximates the angle of rotation of the end stud.

6.3.3.4 *Vertical Displacement at the Toe of the Wall With Reference to the Base*—Subtracting this value from displacement Number 2 and dividing by the distance between the reference points of the two displacements gives another method for estimating the wall's rigid body displacement.

(1) The diagonal elongation approach to estimating shear deformation requires only one measurement as labeled in Fig. 2 and the calculation shown in Fig. 1.

(2) Record the load-deformation curve either continuously or incrementally. Instead of the availability of continuous deformation measuring devices, choose load increments such that at least fie sets of readings (equal increments of displacement or load) are taken for each load cycle to establish the load-deflection curve.

(3) For shear walls with openings, measurements of the change in lengths of the opening diagonals will also provide measurement of shear deformation helpful in verifying the accuracy of the racking measurements for the full length wall.

7. Calculation

7.1 Data collected from this test permit evaluation of racking stiffness, strength at defined limit-state displacements, and ultimate load capacity. If fewer than 10 tests of a single wall configuration are conducted, base the evaluation of these wall performance characteristics on the mean values.

7.2 When shear stiffness is evaluated as a global value (G') it includes rotation or translation of the wall, or both. This evaluation is of value if the test boundary conditions are identical to those used in construction and the objective is to provide an overall evaluation of wall performance within the final assembly. The global shear stiffness G' is computed as:

$$G' = \frac{P}{\Delta} \times \frac{a}{b} \tag{1}$$

This expression implies linearity. However, wall racking tests, especially those where nailed connections control stiffness and strength, are almost totally nonlinear. Therefore, values for Δ or P shall be selected at a reference load or deflection that is within acceptable performance levels. One reference load is $0.33 \times P_u$. Other reference load levels or net wall deflections may be used. If the initially selected reference load level produced deformations beyond acceptable levels, select a reduced reference load level to yield the accepted deflection limit.

7.3 *Internal Shear Stiffness (G'_{int})*—This is the actual shear stiffness of the wall assembly due only to the wall shear displacement. It is calculated using the same expression used for G' except that Δ has been adjusted to remove effects of rotation and translation.

$$G_{int} = \frac{P}{\Delta_{int}} \times \frac{a}{b} \tag{2}$$

7.4 *Internal Shear Displacement Using Horizontal and Vertical Displacement Measurements,* Δ_{int}— This displacement shall be determined as a function of Measured Displacements 1 through 4 shown in Fig. 2 using Eq 3:

$$\Delta_{int} = \Delta_3 - \Delta_1 - (\Delta_2 - \Delta_4) \times \frac{a}{b} \tag{3}$$

assuming displacements to be positive when up and to the right, or as a function of the diagonal elongation indicated in Fig. 1:

$$\Delta_{int} = \frac{(2\,C\,\delta + \delta^2)}{2\,b} \tag{4}$$

7.5 *Internal Shear Displacement Using Diagonal Displacement Measurements*—Fig. 2 shows a diagonal measurement taken to facilitate the analysis of panel racking deformation. This measurement is intended to be used to evaluate a wall shear stiffness without the necessity of accounting for small rotation and translation. Although the shear stiffness exhibited by a wall is influenced by its boundary conditions, the shear load and shear displacement will characterize the net affect.

7.6 *Ultimate Shear Strength*—Determine the ultimate shear strength, S_u, in load per unit length of wall tested as follows:

$$S_u = \frac{P_u}{b} \tag{5}$$

8. Report

8.1 The report shall conform to the provisions of Practice E 575.

8.2 *Load Deflection Curves*—Plot the load deflection curves for all assemblies tested and note the gravity or other vertical loads acting on the wall during the test.

8.3 In addition to the provisions of Practice E 575 the report shall include the rate of loading and the duration of load at each load level.

9. Precision and Bias

9.1 A statement cannot be made on the precision or bias due to the many individual elements which could comprise the wall and the small number of replicate specimens that are tested. A generally accepted method for determining precision and bias is not currently available.

10. Keywords

10.1 framed walls; racking loads; rigid support; shear displacement; shear stiffness; shear strength