Standard Test Methods of Conducting Strength Tests of Panels for Building Construction[1]

This standard is issued under the fixed designation E72; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

Sound engineering design of structures using existing or new materials requires accurate technical data on the strength and rigidity of the basic elements employed in various construction systems. It is the purpose of these test methods to provide a systematic basis for obtaining engineering data on various construction elements and structural details of value to designers, builders, building officials, and others interested in this field. The results should closely approximate the performance in actual service.

1. Scope

1.1 These test methods cover the following procedures for determining the structural properties of segments of wall, floor, and roof constructions:

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1.2 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.

1.2.1 *Exception*—SI units are used in Fig. 6.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials

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

D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters

E4 Practices for Force Verification of Testing Machines

E73 Practice for Static Load Testing of Truss Assemblies

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

E661 Test Method for Performance of Wood and Wood-Based Floor and Roof Sheathing Under Concentrated Static and Impact Loads

[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.

E695 Test Method of Measuring Relative Resistance of Wall, Floor, and Roof Construction to Impact Loading
E2126 Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings
E2309/E2309M Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines
E2322 Test Method for Conducting Transverse and Concentrated Load Tests on Panels used in Floor and Roof Construction

2.2 *Other Document:*[3]

NIST Voluntary Product Standard PS20 American Softwood Lumber Standard

3. Test Specimens

3.1 *Size*—There shall be at least three specimens for each test. Specimens shall be constructed to represent sections of the wall, floor, or roof assembly. The specimens shall be representative as to material and workmanship and shall be of the largest practical size to predict structural performance attributes of the assembly. Unsymmetrical assemblies shall be tested in each axis for which the results may be different.

3.2 *Length or Height*—The length or height of specimen for each element shall be chosen to conform to the length or height of that element in actual use.

3.3 *Width*—The width of specimen shall be chosen, insofar as possible, to include several of the principal load-carrying members to ensure that the behavior under load will simulate that under service conditions. With the exception of specimens for the racking load test, the nominal width of wall specimens shall be 4 ft (1.2 m). The actual width of specimens shall be a whole number multiplied by the spacing of the principal load-carrying members except for prefabricated panels, for which the actual width shall be the width of panel used. If the structural properties of a particular construction are to be compared with another construction, there should not be a great difference in the actual widths of the specimens.

3.4 *Age*—Constructions, such as concrete and masonry (brick, structural clay tile, concrete block) for which the structural properties depend upon the age of the specimen, shall be tested not less than 25 days nor more than 31 days after fabrication. This age requirement applies also to plastered and stuccoed constructions.

4. Loading

4.1 *Apparatus*—The testing machine or load-measuring apparatus shall comply with the requirements prescribed in Practices E4.

4.2 *Application of Load*—Apply the load to all of the specimens in any test in increments so chosen that a sufficient number of readings will be obtained to determine definitely the load-deformation curve (see Section 6). Record the initial reading of the load and the reading of the deformation, either with no load on the specimen or under a small initial load. Increase the load to the first increment and record the deformation. Unless otherwise specified, decrease the load to the initial load and record the set (sometimes designated "permanent set"). Increase the load to two increments and record the set, when it is released to the initial load. Follow this sequence of readings for three increments, four increments, and so forth, of load. When for each specimen the behavior of the specimen under load indicates that the specimen might fail suddenly and damage the deformation-measuring apparatus, remove this apparatus from the specimen and increase the load continuously until the maximum load that can be applied to the specimen is determined.

4.3 *Duration of Load Application*—Except for racking tests, after each increment of load is applied, maintain the load level as constant as possible for a period of 5 min (see Note 1). Take deformation readings as soon as practical after load application, at the end of the 5-min period under constant load, and immediately and at the end of the 5-min period after any partial or complete load release. Plot initial and 5-min readings in the form of load-deformation curves. Maintain complete load-deformation-time records throughout the test. If application of a given load is required for a certain period, such as 24 h, take deformation readings at the beginning, at intervals during this period, and at the end of this period, to allow the satisfactory plotting of a time-deformation curve for the complete period.

NOTE 1—Reasons for the 5-min application of constant-level increment loads are as follows:

(1) To permit the assembly to come to a substantial rest prior to taking the second set of readings (Depending on the method employed for applying the test load, it may be necessary to continue, at a reduced rate, the motion of the loading device in order to maintain the constant load level during the 5-min period.)

(2) To provide sufficient time for making all observations. (Longer time intervals may be required under certain conditions.)

(3) To observe any time-dependent deformation or load redistribution, or both, and to record accurately the load level when time-dependent deformation starts, that is, at the divergence of the immediate and delayed load-deformation curves. This load level may, under certain conditions, have an important bearing on the design load.

(4) To be able to stop the test, if this should be desirable, prior to total failure, after initial failure has been anticipated as a result of the observations.

(5) To assure uniformity in test performance and consistency in test results.

5. Deformation Measurements

5.1 Measure the deformations with sufficient precision to define the load-deformation relationship, and report at least to the nearest 0.01 in. (0.25 mm). The deformation-measuring apparatus specified for any loading may be replaced by other apparatus, provided that it permits readings of deformation that are equivalent in accuracy to those from the specified apparatus.

6. Reports

6.1 Show the results of each of the tests graphically, as illustrated in Fig. 1. Plot loads as ordinates and the deformations as abscissas for all tests. There shall be at least three specimens for each test, and the results for each test shall be

[3] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

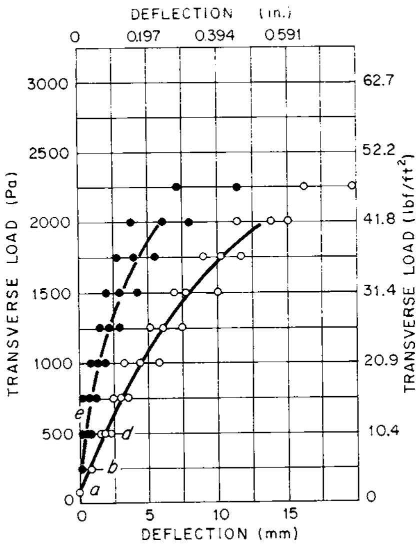

FIG. 1 Typical Graph Showing Results

shown on the same graph. Show the points for deformation under load by open circles and those for set by solid circles. Average the three values for either the deformation or the set and plot this average value in pencil on the graph. Draw a smooth curve among the average points to show the average behavior of the construction. The load-deformation curves shall be continuous lines and the load-set curves shall be dashed lines. Although the particular specimen for each point on the graph is not designated, record it on the laboratory data sheets. If readings are obtained under greater loads for some specimens than for others, plot all the values, but draw the curves only to the average values for which there are three values.

6.2 Prepare the test report in accordance with Practice E575.

7. Precision and Bias

7.1 No statement is made either on the precision or on the bias of these test methods due to the variety of materials and combinations of materials involved.

TESTING WALLS

8. Significance and Use

8.1 The procedures described are those that will test the behavior of segments of wall construction under conditions representative of those encountered in service. Performance criteria based on data from those procedures can ensure structural adequacy and service life.

9. Compressive Load

9.1 *Test Specimens*—Tests shall be made on three like specimens, each having a height equal to the length of the element and a nominal width of 4 ft (1.2 m) (see Section 3).

9.2 *Apparatus*—The apparatus shall be assembled as shown in Fig. 2 and shall conform to the detailed requirements for component parts prescribed in 9.2.1 and 9.2.2, or the equivalent.

9.2.1 *Compressometer*—A bracket shall be attached to the specimen near the upper end, supporting a metal rod. A bracket shall also be attached to the specimen near its lower end, supporting a deflection—measuring device with the spindle up and the gage length shall be recorded. The conical end of the rod shall seat in a hole in the end of the spindle and the rod and spindle shall be held in contact by stretched rubber bands. The deflection—measuring device shall be graduated to 0.001 in. (0.025 mm) or less.

9.2.2 *Deflectometer*—A fine wire shall be attached to a clamp near the upper end of the specimen. The free end connected to stretched rubber bands shall be attached to a clamp near the lower end of the specimen. A mirror having a

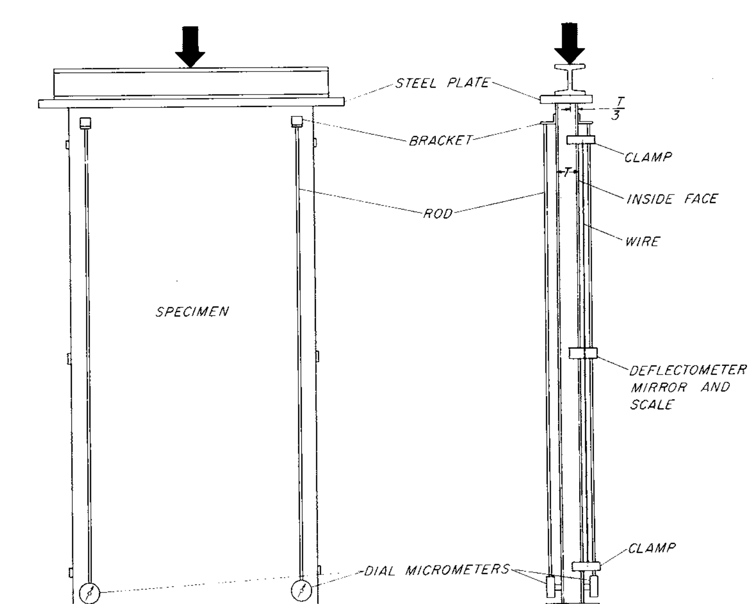

FIG. 2 Compressive Load Test on Wall Specimen

paper scale one-half the width of the mirror shall be attached horizontally to the edge of the specimen at midheight. The scale shall be graduated to 0.1 in. (2.5 mm) or less.

9.3 *Procedure:*

9.3.1 *Loading*—Test the specimen as a column having a flat end at the bottom (Fig. 2). Apply compressive loads to a steel plate covering the upper end of the specimen. Apply the load uniformly along a line parallel to the inside face, and one-third the thickness of the specimen from the inside face. For wood construction, a rate of loading corresponding to a movement of the testing machine crosshead of nominally 0.03 in./min (0.8 mm/min) has been found satisfactory.

9.3.2 *Load-Deformation Data*—Attach four compressometers to the faces of the specimen, one near each corner of the specimen as shown in Fig. 2, to measure the shortening of the specimen. Record the readings to the nearest 0.001 in. (0.025 mm).

9.3.3 *Lateral Deflection*—Attach two deflectometers, one to each edge of the specimen, as shown in Fig. 2. Record the readings, when the image of the wire coincides with the wire, to the nearest 0.01 in. (0.25 mm).

9.4 *Calculations and Report:*

9.4.1 *Deformation*—For each compressometer, calculate the shortening under each load as the difference between the reading of the compressometer when the load is applied and the initial reading. Calculate the shortening of the specimen as the average of the shortenings for each of the four compressometers multiplied by the ratio: specimen length divided by the compressometer gage length. Obtain the sets in a similar manner.

9.4.2 *Lateral Deflection*—Calculate the lateral deflection and the lateral set under each load for each deflectometer as the difference between the reading of the deflectometer when the load is applied and the initial reading. Calculate the lateral deflection and lateral set for the specimen as the average of the lateral deflection and lateral set of the two deflectometers.

9.4.3 *Data Presentation*—Record the maximum load for each specimen and report the results of load-deformation and load-deflection measurements in the form of a graph in accordance with Section 6. Report gage lengths of all deflection or deformation gages.

10. Tensile Load

10.1 *Test Specimens*—Tests shall be made on three like specimens, each having a height equal to the length of the element and a nominal width of 4 ft (1.2 m) (see Section 3).

10.2 *Apparatus*—The apparatus preferably shall be assembled in a vertical testing machine and shall conform to the detailed requirements for component parts prescribed in 9.2.1 and 9.2.2, or the equivalent, with the exception that the compressometers prescribed in 9.2.1 shall be replaced by extensometers which shall be like the compressometers but so adjusted before load is applied that the stretch of the specimen can be measured.

10.3 *Procedure:*

10.3.1 *Loading*—Test the specimen as a tension specimen by uniform application of tensile forces along the line of the fastenings at the top and the bottom of the wall in a building. The top and bottom pulling fixtures may be attached to the specimen by fastenings similar to those used in a building, provided that, under the maximum load, failure of the specimen occurs between the top and the bottom of the specimen, not in either the pulling fixtures or the fastenings. If, under the tensile load, failure occurs either in a pulling fixture or in a fastening, the results of the test determine only the properties of the fixtures or the fastenings, not of the wall construction. When the failure occurs in fastenings, the tensile load indicates the maximum tensile strength of the construction that can be realized in actual service unless improved fastenings are provided.

10.3.1.1 *Masonry Constructions*—The construction may be continued upward beyond the top of the specimen and downward below the bottom of the specimen to enclose attachments for the pulling fixtures.

10.3.1.2 *Framed Wall Constructions*—If the construction has studs (either of wood or metal) the studs may be extended upward and downward beyond the top and bottom of the specimen and attached to the pulling fixtures. If the framed wall has plates at the top and the bottom, attach the pulling fixtures to the plates in the specimen.

10.3.2 *Load-Deformation Data*—Attach four extensometers to the faces of the specimen, one near each corner, as shown in Fig. 2, to measure the stretch of the specimen. Record the readings to the nearest 0.001 in. (0.025 mm).

10.3.3 *Lateral Deflection*—Attach two deflectometers, one to each edge of the specimen, as shown in Fig. 2. Record the readings, when the image of the wire coincides with the wire, to the nearest 0.01 in. (0.25 mm). Lateral deflection (if any) may be caused by nonaxial loading of the specimen.

10.4 *Calculations and Report*—For tensile loads, the calculations and report shall be similar to those required for compressive loads (see 9.4).

11. Transverse Load—Specimen Horizontal

11.1 *Test Specimens*—Tests shall be made on three like specimens on symmetrical assemblies and six like specimens on unsymmetrical assemblies, each having a length equal to the length of the element and a nominal width of 4 ft (1.2 m) (see Section 3).

11.2 *Apparatus*—The apparatus shall be assembled as shown in Fig. 3 and shall conform to the detailed requirements for component parts prescribed in 11.2.1 – 11.2.3, or the equivalent.

11.2.1 *Supports*—Two steel rollers with a steel plate between each supporting roller and the specimen.

11.2.2 *Loading Assembly*—Two steel rollers with a steel plate between each loading roller and the specimen.

11.2.3 *Deflection Gage*—A frame shall be placed on the upper face of the specimen. To prevent stresses deforming the frame as the specimen deforms under load, this frame shall rest on three hardened steel balls each supported by a steel block on the face of the specimen. Two of the balls shall be placed in a line vertically above one support and the third ball vertically above the other support. Two deflection—measuring devices, one near each longitudinal edge of the specimen, shall be

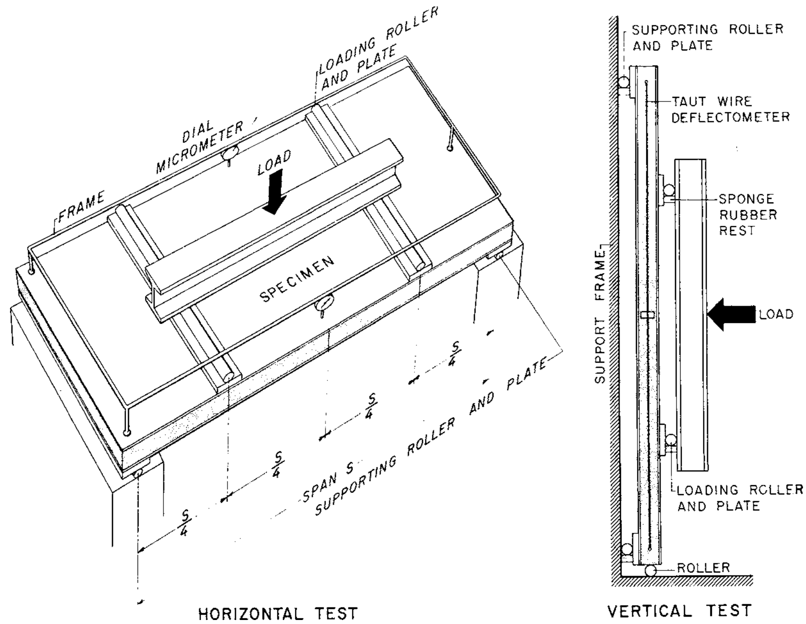

FIG. 3 Transverse Load Test on Wall Specimen

attached to the frame at midspan. The spindles shall rest on the upper face of the specimen. The devices shall be graduated to 0.001 in. (0.025 mm) or less.

11.3 *Procedure:*

11.3.1 *Loading*—Use "two-point" loading for transverse load tests. Test the specimen as a simple beam (Fig. 3) on a span approximately 6 in. (150 mm) less than the specimen length. Apply two equal loads, each at a distance of one quarter of the span from the supports, toward the middle of the span. For wall specimens tested horizontally (Fig. 3), the load on the specimen shall include the weight of specimen between the supports. Apply the transverse loads to the outside face for three of the specimens and to the inside face for three of the specimens. For symmetrical assemblies, test only three specimens.

11.3.1.1 Uniformly distributed loading may be used instead of quarter-point loading, if a satisfactory method is available. The transverse strength for any span may be greater for some constructions under uniformly distributed load than under loads applied at the quarter-points of the span. Transverse load, uniformly distributed, may be applied by air pressure, either in a bag or in a chamber having the specimen as one face. Support specimens tested under uniform loading by rollers as for quarter-point loading.

11.3.1.2 The bag method of loading is shown schematically in Fig. 4. Connect a reaction platform parallel to the face to be loaded and wider than the specimen to the supports by tie rods. Place an airtight bag of rubberized cloth as wide as the specimen and as long as the span between the specimen and the reaction platform. Apply transverse load to the specimen by increasing the air pressure in the bag. Measure the pressure by means of a manometer. Water is usually the liquid in the manometer, but the specific gravity of the liquid shall be such that the error in pressure readings does not exceed 1 %.

11.3.1.3 When the chamber method of loading is used with the specimen horizontal, place the specimen near the floor, which should be practically airtight. An airtight frame or curb shall surround the specimen closely and be about flush with the upper surface of the specimen. A rubber blanket covers the specimen, overlaps the frame, and is sealed so that it is reasonably airtight. Use a small vacuum pump or positive action exhaust blower to reduce air pressure between the

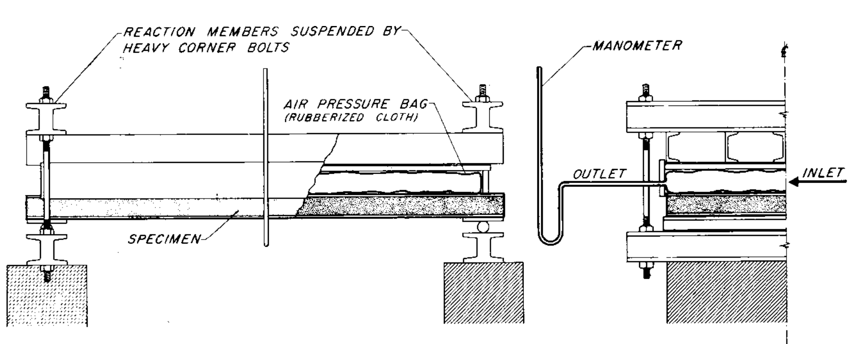

FIG. 4 Apparatus for Uniformly Distributed Transverse Load (Bag Method)

specimen and floor. Measure the difference in pressure above and below the specimen by means of a manometer.

11.3.2 *Strength on Short Span*—The transverse strength of any construction increases as the span is shortened. If the strength of the construction for a shorter span is desired, do not compute it, but test the construction on the short span.

11.4 *Calculations and Report:*

11.4.1 *Load-Deflection Data*—For each micrometer, calculate the deflection under a given load as the difference between the reading to the nearest division of the micrometer when the load is applied and the initial reading. Calculate the deflection of the specimen for the span as the average of the deflections obtained from each of the two micrometers. Calculate the sets under the initial load by using a similar method. Record the maximum load for each specimen.

11.4.2 *Data Presentation*—Report the results in the form of a graph in accordance with Section 6.

12. Transverse Load—Specimen Vertical

12.1 *Test Specimens*—Tests shall be made on three like specimens on symmetrical assemblies and six like specimens on unsymmetrical assemblies each having a length equal to the length of the element and a nominal width of 4 ft (1.2 m) (see Section 3).

12.2 *Apparatus*—The apparatus shall be assembled as shown in Fig. 3 and shall conform to the requirements for component parts prescribed in 12.2.1 – 12.2.5, or the equivalent.

12.2.1 *Steel Channel.*

12.2.2 *Rollers*—Cylindrical rollers, two supporting rollers, two loading rollers.

12.2.3 *Screw Jack.*

12.2.4 *Ring Dynamometer.*

12.2.5 *Deflectometers*—Two taut-wire mirror-scale deflectometers similar to those described in 9.2.2.

12.3 *Procedure*—Transverse loads cannot be applied satisfactorily to some wall constructions, such as masonry, with the specimen in a horizontal position. For such constructions, apply the loads with the specimen in a vertical position, as shown in Fig. 3, thus simulating service conditions. The specimen, on a steel channel, shall rest on cylindrical rollers to prevent restrained end conditions. The axes of the rollers shall be parallel to the faces of the specimen. The two supporting rollers shall be in contact with the vertical surface of the frame and each roller shall rest horizontally on sponge rubber about 0.4 in. (10 mm) thick to prevent longitudinal restraint. Each of the two loading rollers shall also rest on sponge rubber. Apply the loads horizontally by a screw jack and measure by a ring dynamometer between the jack and the specimen. The error in the load indicated by the dynamometer shall not exceed 1 %. Attach two taut-wire mirror-scale deflectometers to the specimen, one to each vertical edge.

12.3.1 Apply the transverse load to the outside face for three of the specimens, and to the inside face for three of the specimens. For symmetrical assemblies, test only three specimens.

12.3.2 The bag method of loading is shown schematically in Fig. 4. Connect a reaction platform parallel to the face to be loaded and wider than the specimen to the supports by tie rods. Place an airtight bag as wide as the specimen and as long as the span between the specimen and the reaction platform. Apply transverse load to the specimen by increasing the air pressure in the bag. Measure the pressure by means of a manometer or other pressure measuring device. The error of the pressure reading shall not exceed 1 %.

12.3.3 When the Chamber Method of loading is used with the specimen vertical, the specimen forms one face of an airtight chamber from which the air is exhausted. If all four edges of the specimen bear on the chamber, this loading determines the strength of the specimen as a plate supported at the four edges, not the transverse strength as defined in these methods.

12.3.4 If a specimen tested by the chamber method, either horizontally or vertically, has an airtight cavity, vent each cavity to the low-pressure face by a hole in the face of the specimen not less than 0.2 in. (5 mm) in diameter, located where it will least affect the transverse strength of the specimen.

12.4 *Calculations and Report*—Calculate the results of test and report as described in 11.4, and report deflectometer readings to the nearest 0.01 in. (0.25 mm).

13. Concentrated Load

13.1 *Test Specimens*—Concentrated load tests shall be made on each transverse specimen after the transverse load tests, the concentrated load being applied to the same face to which the transverse load was applied.

13.2 *Apparatus*—The apparatus shall be assembled as shown in Fig. 5 and shall conform to the requirements for component parts prescribed in 13.2.1 – 13.2.3, or the equivalent.

13.2.1 *Steel Bar*—Steel bar having a diameter of 1 in. (25.4 mm) and the edge of the face contacting the specimen rounded to a radius of 0.05 in. (1.3 mm).

13.2.2 *Depth Gage*—The depth gage shall consist of a deflection—measuring device graduated to 0.001 in. (0.025

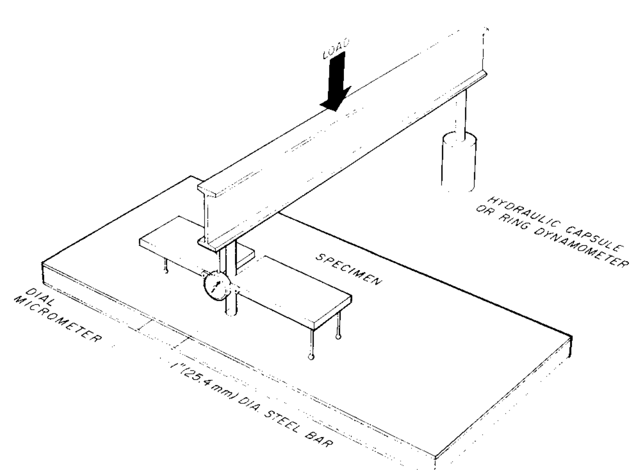

FIG. 5 Concentrated Load Test

mm) or less mounted on a three-legged support. The support shall be notched to permit placing the device directly adjacent to the bar and shall be long enough to permit placing the supporting legs on undisturbed areas of the face of the specimen.

13.2.3 *Loading Device*—Any convenient means for applying a compressive load up to 1100 lbf (5 kN) and means for measuring the load within 1 %.

13.3 *Procedure:*

13.3.1 *Loading*—Place the entire specimen or portion of the specimen on a horizontal support and properly level. Place the steel bar on the face of the specimen at what is judged to be the weakest place and, also, at what is judged to be the strongest place. Apply a load vertically downward to the upper surface of the bar. Continue loading until maximum load or 1000 lbf (4.45 kN) is attained.

13.3.2 *Depth of Indentation*—Measure the depth of indentation, by means of the depth gage, and record the reading of the micrometer to the nearest 0.001 in. (0.025 mm).

13.4 *Calculations and Report:*

13.4.1 *Depth of Indentation*—Calculate the depth of indentation (set) after a given load has been applied and the bar removed to the nearest 0.001 in. (0.025 mm) as the difference between the depth for that load and the initial reading of the micrometer before a load has been applied to the specimen.

13.4.2 *Data Presentation*—Report the results in the form of a graph in accordance with Section 6.

14. Racking Load—Evaluation of Sheathing Materials on a Standard Wood Frame

NOTE 2—These test methods have been used to evaluate design shear resistance of wall assemblies without the involvement of anchorage details. If the test objective is to measure the performance of the complete wall, Practice E564 is recommended.

14.1 *Scope*—This test method measures the resistance of panels, having a wood frame, and sheathed with sheet materials such as structural insulating board, plywood, gypsum board, transite, and so forth, to a racking load such as would be imposed by winds blowing on a wall oriented at 90° to the panel. It is intended to provide a reliable, uniform procedure for determining the resistance to racking load provided by these sheet materials as commonly employed in building construction. Since a standard frame is employed, the relative performance of the sheathing is the test objective.

14.1.1 This test is conducted with standardized framing, loading procedures, and method of measuring deflection, as detailed in the method to ensure reproducibility. Provision is made for following the sheathing manufacturers' recommendations for attaching the sheathing to the frame, and for reporting the behavior of the specimen over its entire range of use.

14.1.2 In applying the results, due allowance shall be made for any variation in construction details or test conditions from those in actual service.

14.2 *Test Specimens:*

14.2.1 *Size and Number*—The test specimen shall be 8 by 8 ft (2.4 by 2.4 m) and the framing shall be constructed as shown in Fig. 6 and a minimum of three panels of each construction shall be tested.

14.2.2 *Framing*—Frames shall be newly constructed for each test. All individual framing members shall be continuous.

14.2.2.1 *Sheathing Material Evaluation*—The frame shall be constructed as nearly like the frames shown in Fig. 6 as possible. No. 1 Douglas-fir Larch or Southern Pine lumber conforming to NIST Voluntary Product Standard PS20 shall be used. The stud spacing and size of the stud at the vertical panel joint shall be permitted to vary as necessary to reflect the manufacturer's specified test condition or standardized requirements. Any deviations from the framing scheme depicted in Fig. 6 shall be reported.

NOTE 3—A common situation where the 14.2.2.1 framing provisions apply would be for product qualification and evaluation of sheathing products where design values have already been established. In those instances, the sheathing performance and variation is the primary interest.

14.2.2.2 *Sheathing and Sheathing-to-Framing Attachment Design Shear Evaluation without the Involvement of Anchorage*—The framing shall be constructed in accordance with Fig. 6 except that the framing materials (size and specific gravity), stud spacing, and sheathing fastener size and spacing shall conservatively represent the range of applications that use the same design shear or racking resistance. The oven-dry specific gravity of the framing materials that receive perimeter sheathing fasteners at the panel boundaries and center stud shall be determined in accordance with Test Methods D2395 and reported. The average framing specific gravity for any test assembly shall not exceed the targeted average by more than 0.03.

NOTE 4—The framing details of 14.2.2.2 apply in instances where the racking test is used to evaluate the racking resistance of the sheathing and sheathing-to-framing attachment for the establishment of design values. This may include evaluation for sheathing, fastener, or framing products to be used in engineered or braced wall applications. In these instances, the goal is to ensure that the interaction between the framing, sheathing fastener, and sheathing is representative of the end use condition.

14.2.3 *Moisture Content*—The average moisture content of framing material shall be between 6 and 15 % at the time of testing. Immediately after the racking test, the moisture content of all framing members that receive sheathing perimeter fasteners shall be determined using Test Methods D4442 or Practice D7438 and reported. Racking tests shall be conducted within 72 h of fabrication unless the moisture content was determined at the time of fabrication. The average moisture content for each test frame at the time of fabrication, if applicable, and at the time of testing shall be reported. The elapsed time between fabrication and testing shall be reported.

14.2.4 *Application of Sheathing*—The method of applying the sheathing shall be as specified by the manufacturer and include at least one centered vertical sheathing joint. Sheathing fasteners shall be installed using the minimum edge distance recommended by the 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

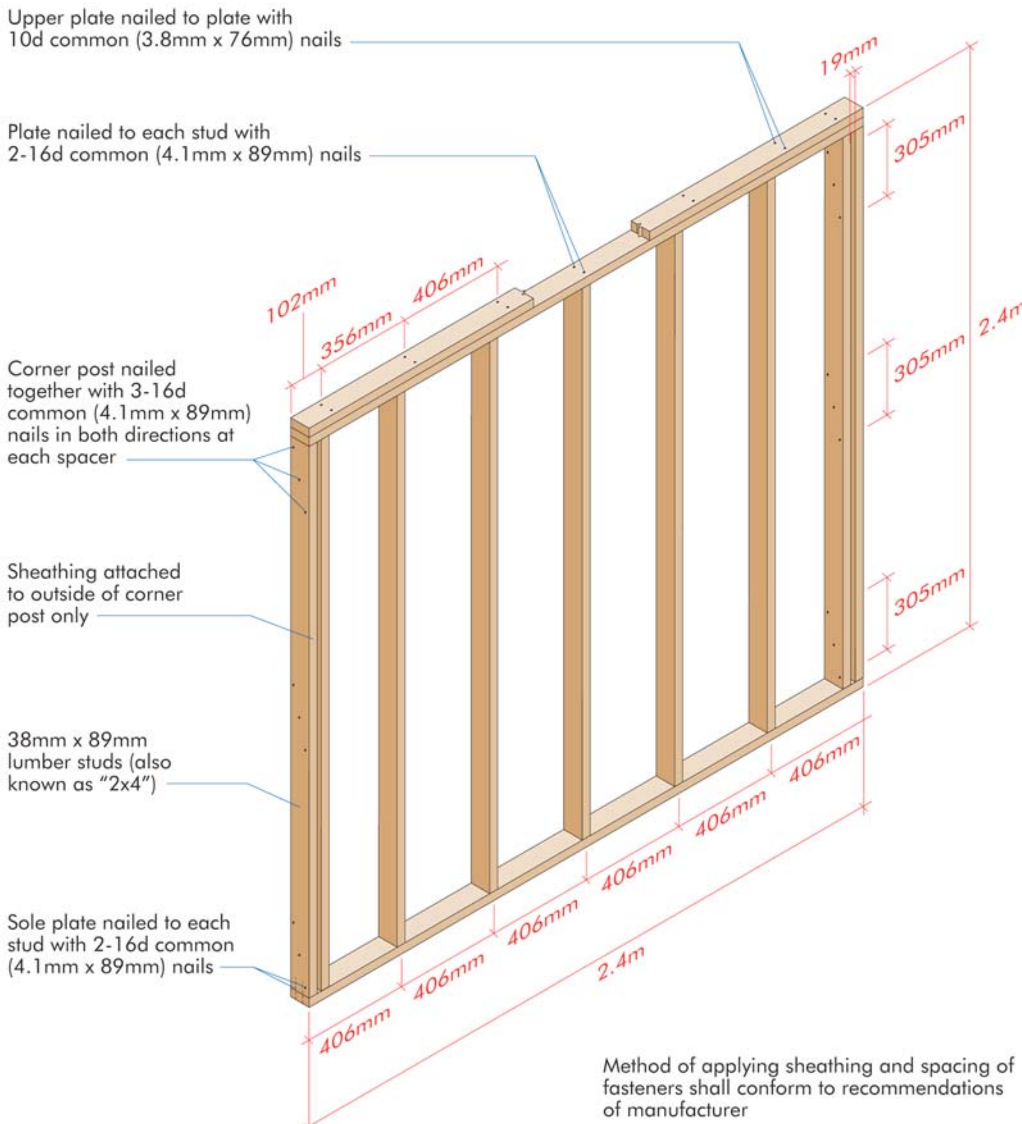

FIG. 6 Standard Wood Frame

permitted to be less than the recommended spacing to accommodate the required edge distance. Sheathing fasteners shall be driven through the sheathing into only the outside stud of each corner post shown in Fig. 6. Unless otherwise specified, fasteners shall be driven perpendicular to the surface of the sheathing. 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 manufacturers.

NOTE 5—Differences in edge distance, angle of fastener, and amount of fastener head penetration into the sheathing may impact the results of the tests and should be consistently installed in accordance with the manufacturer's installation instructions.

14.3 *Apparatus*—The apparatus shall be assembled as shown in Fig. 7. In-plane lateral load shall be applied and measured by any suitable means capable of the precision specified by Practices E4. The essential parts of the testing apparatus, exclusive of the loading apparatus, are as described in 14.3.1 – 14.3.5. The test report shall include a detailed diagram of the test setup.

14.3.1 *Base and Loading Fixtures*—The test panel shall be attached to timber or steel base and loading fixtures. The base fixture is in turn attached rigidly to the base of the test frame. When the panel is racked, the sheathing shall freely rotate without bearing on the base fixture, loading fixture, or any other portion of the test frame. The base and loading fixtures shall be of any convenient cross section, but shall be at least as long as the panel and not wider than the width of the framing lumber used to construct the wood frame. Means shall be provided to bolt or otherwise attach the top and bottom plates of the test panel firmly to the base and loading fixtures. For illustrative purposes, two bolts are shown in Fig. 7. More shall be permitted. The attachment between the test panel and the loading fixtures shall be reported.

NOTE 6—Typical framing lumber widths may be 3½ in. (89 mm) for 2 by 4, 5½ in. (140 mm) for 2 by 6..., etc.

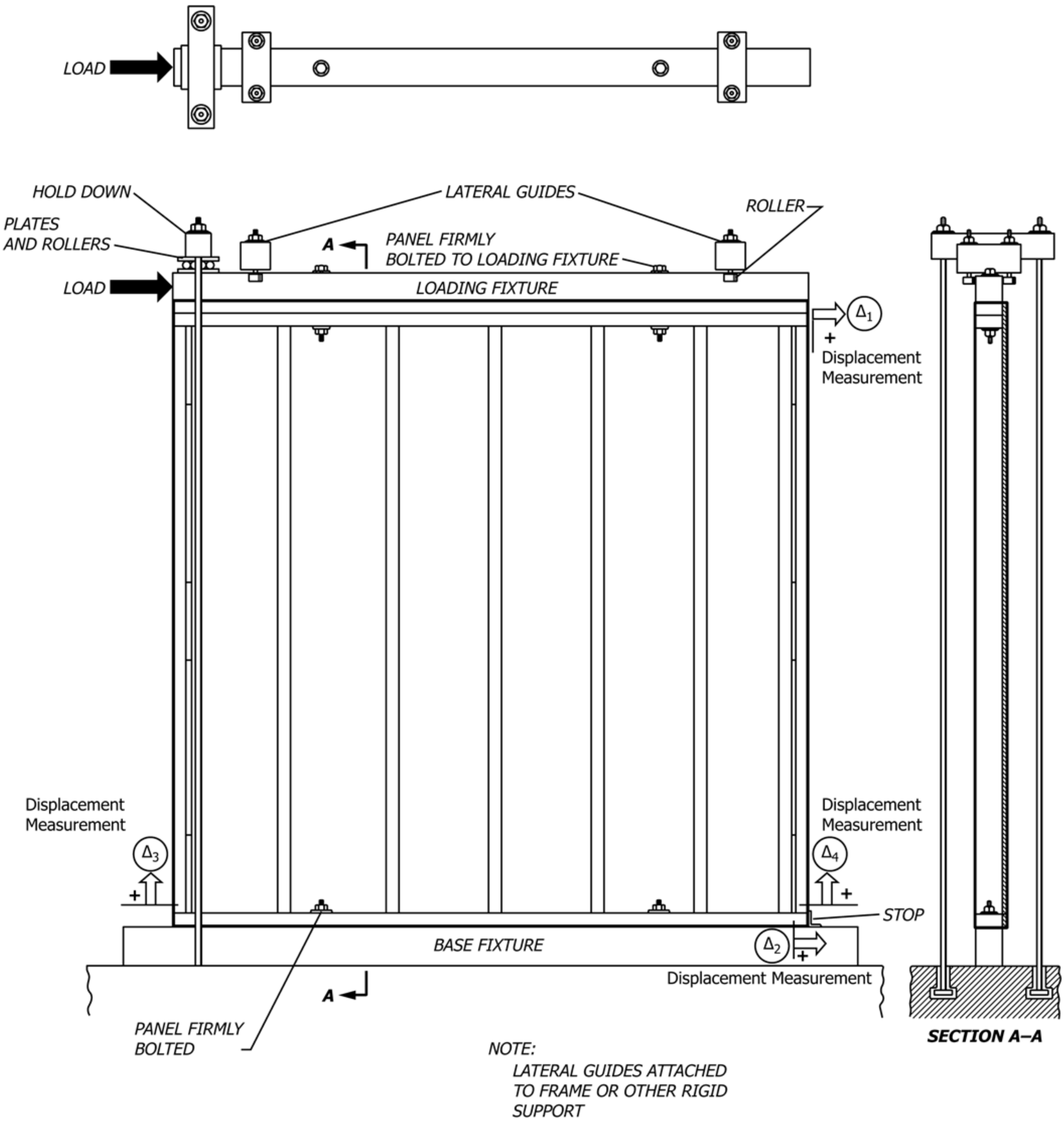

FIG. 7 Racking Load Assembly

14.3.2 *Hold-Down*—A hold-down shall be provided as shown in Fig. 7 to rigidly overcome the tendency of one end of the panel to rise as the racking load is applied. Plates and rollers shall be provided between the loading fixture and the hold-down so that the top of the specimen can deflect horizontally with respect to the bottom without interference from the hold-down. Because the amount of tension in the rods of the hold-down may have an effect on the results of the test, nuts on the hold-down rods shall be tightened prior to load application so that the total force in each rod does not exceed 20 lbf (90 N) at the beginning of test as determined by previous calibration.

14.3.3 *Loading Apparatus*—Load shall be applied to the specimen in shear through a horizontal compressive force applied to the loading fixture parallel to the top plate.

14.3.4 *Lateral Guides*—Lateral guides shall be provided so that the specimen will deflect in a plane. The rollers should be bearing-supported to reduce friction to a minimum. The lateral guides shall be firmly attached to the loading frame. Plates for the rollers shall be provided.

14.3.5 *Displacement Measuring Devices*—linear displacement measuring devices shall be provided to measure the displacement of the different parts of the panel during test. The deflection measurement devices shall be Class "B" or higher when evaluated in accordance with Practices E2309/E2309M. The locations and sign conventions of the displacement measuring devices shall be as shown in Fig. 7. The devices are used to measure: the lateral displacement of the centerline of the top plate (Δ_1) and the bottom plate (Δ_2), and the vertical displacement at the center of the tension stud (Δ_3) and the compression stud (Δ_4).

NOTE 7—Δ_1 provides a gross horizontal displacement measurement for the racking test specimen that includes lateral movement from specimen shear deformation, rigid body rotation, and rigid body translation. Δ_2, Δ_3, and Δ_4 provide displacement measurements used to analytically determine the assembly deformation that excludes movement from rigid body rotation and translation.

14.4 *Procedure*—The racking load shall be applied using a series of stages that are a function of the expected maximum load. The panel shall be loaded at a constant rate using a minimum of three stages, with the final stage loading the panel to failure. Loads and displacements are measured and recorded through all stages at a frequency of not less than once every 10 s.

NOTE 8—The expected maximum load may be determined based upon preliminary tests, experience, calculation, or standardized product requirements.

14.4.1 *Loading Rate*—Load shall be applied continuously throughout test at a uniform rate of racking load or fixture displacement. The loading rate shall be such that the peak load in the first stage shall be achieved in not less than 2 min. The same load or displacement rate shall be used for subsequent stages. Report the loading rate used and the time from load initiation to maximum load for each test specimen. The average time to the maximum load, excluding relaxation time, for a series of specimens shall not be less than 10 min.

14.4.2 *Loading Procedure*—Load the specimen using a minimum of the three mandatory stages outlined below. Additional preliminary stages shall be permitted.

14.4.2.1 *First Stage*—Load the specimen to a load level not less than 30 % of the expected maximum load. Unload the specimen in 30 s or less and record the set.

NOTE 9—Some performance standards that use this test method may require a minimum relaxation time between loading stages. For example, a 5 min recovery period between loading stages is typically required when testing wood structural panels.

14.4.2.2 *Second Stage*—Load the specimen to not less than 60 % of the expected maximum load. Unload the specimen in 30 s or less and record the set.

14.4.2.3 *Third Stage*—Load the specimen beyond the maximum load to failure or to the point where the measured post-peak racking resistance represents 80 % of the maximum load, whichever occurs first.

14.5 *Calculations and Report:*

14.5.1 *Deformation*—For each measuring device, calculate the movement under each racking load as the difference between the readings when load is applied and the initial readings at the start of the test. Calculate set readings as the difference between the readings when the load is removed and the initial readings. Calculate and report the horizontal deformation of the test specimen as:

$$\Delta_h = \Delta_1 - \Delta_2 - (\Delta_3 - \Delta_4) \quad (1)$$

where:

Δ_h = horizontal deformation of the assembly that excludes movement from rigid body rotation and translation, in. (mm)
Δ_1 = horizontal displacement of the top plate, in. (mm)
Δ_2 = horizontal displacement of the bottom plate, in. (mm)
Δ_3 = vertical displacement of the tension stud, in. (mm)
Δ_4 = vertical displacement of the compression stud, in. (mm)

14.5.2 *Data Presentation*—Report the targeted load levels for each stage, peak loads, and corresponding deformations measured during each load stage. Report the set after loading to these amounts. Present the load-deflection curves obtained in the form of a graph. Include maximum load, the interpolated load corresponding to horizontal deformations of interest (see Note 10), the post-peak deflection at 80 % of the maximum load and any observations on the behavior of the panel during test and at failure. Express residual deflections (sets) as percentages of the deflections that produced the sets in millimetres or inches. Describe the visible failures. If the specimen has been subjected to any special conditioning prior to test, describe this treatment in detail. Describe in the report the sheathing used, the method of applying the sheathing, the type and spacing of fasteners, and the method and loading rate employed.

NOTE 10—The load at a horizontal deformation of 0.2 in. (5 mm) is often used by performance standards that reference E72.

15. Racking Load—Evaluation of Sheathing Materials (Wet) on a Standard Wood Frame

15.1 *Scope*—This test has been developed to simulate the degree of wetting possible during construction of a structure when, because of rain, the framing and sheathing may be wetted on one or both sides. Both sides of the wall panel are wetted because this represents the maximum exposure possible during the stage of construction before the structure is roofed.

15.2 *Test Specimens*—The test specimens shall conform in size and fabrication details to the requirements of 14.2.

15.3 *Specimen Conditioning*—Mount the fabricated test specimens or suspend them in a vertical position in such a manner as to prevent continuous immersion of the bottom edge of the specimen. Expose both sides of the test specimen to a water spray applied at or near the top along the entire length to ensure that the top of the specimen is being wetted. The spray shall have no jet action that cuts into the sheathing material, and the spray areas shall overlay sufficiently so that a continuous sheet of water flows down both surfaces of the specimen. Maintain the temperature of the water in the line to the spray nozzle at 75 ± 5°F (24 ± 3°C). Wet the specimens for a period of 6 h and then allow to dry for a period of 18 h. Dry in laboratory air, preferably at a temperature of 75 ± 5°F (24 ± 3°C). Make no attempt to increase the air movement over the specimens by fans or blowers. Subject the test specimens to two complete wetting and drying cycles and then a third wetting cycle.

15.3.1 No more than 2 h shall elapse between the completion of the third wetting cycle and the start of the racking test.

15.4 *Procedure*—Test the specimens in accordance with the procedure described in 14.4.

15.5 *Moisture Content Determination*—After the racking test is completed, cut moisture samples from the sheathing material, and determine moisture content on a weight basis with the moisture content expressed as a percentage of the oven dry weight in accordance with 15.5.1. Preferably, take five moisture content samples at least 4 by 6 in. (100 by 150 mm) in size from each 4 by 8-ft (1.2 by 2.4-m) sheathing panel of the test specimen: one from the center of each sheathing panel at the top and bottom edges, one from midlength on each side, and one from the panel center. Weigh the moisture content samples immediately upon being cut from the test specimen to an accuracy of not less than ±0.2 %. Carefully remove all loose particles from the sample before weighing. Then dry the samples to constant weight in an oven at (217 ± 4°F (103 ± 2°C). If large amounts of volatile matter or substances other than free water are removed from the sheathing material by drying at 103 ± 2°C, the sheathing material may be dried to constant weight at a lower temperature and the drying time and temperature given in the report.

15.5.1 *Calculation*—Calculate the moisture content as follows:

$$M = 100\left[(W - F)/F\right] \quad (2)$$

where:

M = moisture content, %,
W = initial weight, and
F = final weight when oven dry.

15.6 *Calculations and Report*—The report shall include the racking test data as specified in 14.5. It shall also include the line temperature of the water sprayed on the test specimens; the air temperature and relative humidity during the drying portion of the cycle; and the location of the moisture content samples and the moisture content of each.

TESTING FLOORS

16. Significance and Use

16.1 The procedures outlined will serve to evaluate the performance of floor segments under conditions representative of those sustained in service. Performance criteria based on data from these procedures can ensure structural adequacy and effective service.

17. Transverse Load

17.1 Test in accordance with Test Method E2322, Section 10.

18. Concentrated Load

18.1 Test in accordance with Test Method E2322, Section 11.

TESTING ROOFS

19. Significance and Use

19.1 These procedures will serve to evaluate performance of roof segments under simulated service conditions. Roof trusses shall be evaluated under Practice E73.

20. Transverse Load

20.1 Test in accordance with Test Method E2322, Section 12.

21. Concentrated Load

21.1 Test in accordance with Test Method E2322, Section 13.

22. Keywords

22.1 compressive load; concentrated loads; deformation; floors; load duration; racking load; roofs; sheathing; strength tests; tensile load; transverse load; walls

APPENDIXES

(Nonmandatory Information)

X1. TECHNICAL INTERPRETATION

X1.1 It is the purpose of these test methods to provide a systematic basis for obtaining comparable engineering data on various construction elements and structural details of value to designers, builders, building officials, and others interested in this field.

X1.2 Subjecting complete structures to known loads is very expensive and requires much time; therefore, that method of carrying out investigations to establish structural properties is not likely to be used to any great extent. Such tests have the further disadvantage that only the strength of the weakest elements of a particular structure could be measured.

X1.3 For these reasons, it seems more practicable to apply loads to specimens that accurately reproduce a structural portion of a finished building. These portions of a building have been designated as "elements;" for example, floor, wall, roof, and so forth. For the procedure described in these test methods, the elements have been restricted to those most important structurally. For each element, methods of loading are described that simulate the loads to which the element would be subjected under service conditions. It is believed that the results of these measurements on the structural elements will be more useful to architects and engineers than the results of tests on specimens of the materials from which the structure was fabricated, or the results of tests of the individual structural members. Although it may be impracticable to determine all of the structural properties of each element of a building, it is believed that the more important properties may be determined by tests described in these test methods.

X1.4 The test method, involving the application of the loads in increments and the concurrent measurement of deformation and set, simulates, to some extent, the conditions of repeated loading under service conditions. Therefore, results by such a method of loading may be more useful than those obtained by increasing the load continuously throughout the test. The results from increment loading tests may show whether different portions of a construction act as a unit under load, whether the fastenings or bonds have adequate strength, or whether they rupture under repeated loads. For any engineering structure, including small houses, it is necessary not only that the strength be adequate, but also that the deformation under load shall not appreciably decrease the usefulness of the structure. If the working load and the allowable deformation for an element for a structure are known, constructions complying with these requirements may be selected by inspection of the graphs from tests of such constructions.

X1.5 A structure is elastic if, after a load has been applied and then removed, the set is inappreciable. If the set is small for an element of a building, it may be assumed that the construction has neither been damaged nor appreciably deformed by the load. The set, therefore, is another property that may be used when comparing different constructions and may be useful when selecting a construction for a particular purpose.

X1.6 The variations in the properties of a construction as used commercially for buildings, in all probability, will be greater than the variations for the three specimens tested as directed in these test methods because these specimens will be all fabricated at the same time by the same workmen and from the same lot of material. This fact should be clearly indicated in any general report based on these test procedures.

X2. HISTORICAL

X2.1 This standard has been a compilation of test methods for testing building panels and has included test methods for the testing of both wall panels and floor and roof panels. due to the numerous test methods and difficulty in updating all methods on a regular basis, a new Test Method E2322 was written to address only the floor and roof test methods. Results obtained from Test Method E2322 should be considered as equivalent to results from products tested by the floor and roof sections of this test method.

X2.2 The sections in this test method that addressed testing of floor and roof panels were maintained, but only with a reference to other standards for testing.

X3. RACKING TESTS

X3.1 General Conditions

X3.1.1 The racking load (that is, lateral load resistance) assembly testing of Section 14 is often used for the evaluation of sheathing products and sheathing-to-framing attachment schemes. While it is recognized that a wide range of wall configurations and anchorage conditions exist in application, for the purpose of sheathing and sheathing-to-framing attachment review, this historic test method purposefully combines a 1:1 aspect ratio wall specimen with a vertical panel joint, rigid anchorage, and full overturning restraint to provide a consistent method upon which to focus failure modes onto the sheathing and sheathing-to-framing attachment system.

X3.1.1.1 *Vertical Sheathing Joint*—A continuous vertical sheathing joint is included in a racking test specimen because such joints often exist in application and may represent weak links in an assembly. The experience of some test facilities with the test method suggests that these joints can serve as the trigger that ultimately precipitates the specimen failure. Panel joints normally require the smallest sheathing fastener edge distances to occur at a location where the shear load must be transferred between sheathing panels and through the framing attachment. Since this joint may limit the capacity of the sheathing and sheathing-to-framing attachment, it is included as part of the test assembly. Tests of assemblies without this joint may have the potential to overestimate the sheathing or sheathing-to-framing attachment's capabilities, or both. When recording the specimen failure modes, it may be useful to provide special emphasis on the impact that continuous vertical sheathing joints have upon the performance of the sheathing and sheathing-to-framing attachment system.

X3.1.1.2 *Anchorage and Overturning Restraint*—It is acknowledged that a wide range of in-plane wall racking anchorage (that is, foundation, floor, etc.) conditions exist in application. These applications may range from a lightly-anchored prescriptive braced wall panel that does not support gravity loads to a similar prescriptive wall assembly that supports significant gravity loads that provide overturning restraint, or even an engineered shearwall designed with rigid anchorage (that is, hold-down restraints designed to counteract the full overturning force). However, it is not the intent of this racking test method to replicate any specific application condition.

X3.1.1.3 The goal is to provide a consistent basis where the capacity of the sheathing and sheathing-to-framing attachment is evaluated without the confounding influence of an anchorage or framing failure. The fully-restrained boundary condition selected for the racking test ensures that the full potential of the sheathing and sheathing-to-framing attachment is the focus of this test method and is consistently evaluated. Using a lesser degree of anchorage would serve to introduce anchorage or framing-related failure modes, or both, that limit the usefulness of the assessment of the sheathing or sheathing-to-framing attachment performance, or both. For example, a racking test comparison made between sheathing or sheathing-to-framing attachment alternatives, or both, using a lightly-restrained condition may result in anchorage failure for both products. Such a review would not necessarily address the relative performance of the sheathing or sheathing-to-framing attachment, or both, in other applications where more restraint is provided and higher loads governed by the sheathing or sheathing attachment may be achieved. For these reasons, this test method uses one type of fully-restrained condition, which has been historically used to make sheathing or sheathing-to-framing attachment comparisons, or both.

X3.1.1.4 If the goal of the test program is to include other anchorage or framing conditions that are representative of a specific application, then consider using wall assembly test methods such as Practice E564 or Test Methods E2126.

X3.2 Overturning Restraint Measurement

X3.2.1 Although not required by the mandatory text, it is recognized that it may be useful for the test laboratory to measure the anchorage restraining force as part of the test. Measurement of this force can help to ensure compliance with the maximum pre-tension requirements of 14.3.2 and may provide information that is useful for the extension and interpretation of Test Methods E72 racking test data for some end-use applications.

X3.2.2 As mentioned above, applications may range from a lightly-anchored prescriptive braced wall panel which does not support gravity loads to a similar prescriptive wall assembly that supports significant gravity loads which provides overturning restraint, or an engineered shearwall that is provided with full overturning anchorage. Knowing the applied vertical load can be an aid in understanding the effect of gravity loads, for example, on the sheathing or sheathing-to-framing attachment performance, or both. However, the user should recognize that the Test Methods E72 test boundary conditions and test frame are specifically intended to evaluate the sheathing and sheathing-to-framing attachment failure modes. The anchorage force measured is a function of the test boundary conditions and may not necessarily be applicable to any specific application or used for design purposes.

X3.3 Framing Specific Gravity

X3.3.1 For those situations where the purpose of the test is to evaluate a design value for the racking resistance of the sheathing or sheathing-to-framing attachment, 14.2.2.2 requires the average oven-dry specific gravity of the framing materials that receive sheathing perimeter fasteners to be within 0.03 of that associated with the targeted framing species. Since some of the attachment related failure modes are stud specific gravity related (for example, fastener withdrawal and dowel bearing), it was judged that the framing properties should be controlled to improve the reliability of the test method and to avoid a non-conservative result when establishing a design value for the sheathing or sheathing-to-framing attachment, or both.

X3.3.2 The limit is applied only to those framing members that receive perimeter nailing because it is judged that they have the most significant influence upon racking performance. The 0.03 average specific gravity tolerance was judged to represent a practical level of variation that could be reasonably achieved with pre-sorting the framing lumber. It represents a calculated nail withdrawal or dowel bearing deviation on the order of ±10 to 20 %. Given that the racking test typically results in complex failure modes that also include modes that are not framing specific gravity dependent (for example, sheathing buckling, sheathing edge tearout, fastener deformation or fastener pull-through); the actual deviation in wall racking results associated with this tolerance is expected to be lower than implied by a simple nail withdrawal or dowel bearing assessment.

X3.3.3 The specific gravity limit does not apply to those situations where the purpose of the test is to provide a 14.2.2.1 evaluation of a specific sheathing material. In those situations, dense framing material is typically used to limit the framing related failure modes and focus the review upon the lateral load resistance attributes of the sheathing product (for example, sheathing buckling, sheathing edge tearout, etc.).