



Standard Test Methods for End-Joints in Structural Wood Products¹

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INTRODUCTION

Adhesive bonded end-joints are used in structural glued wood products. The bond performance of these end-joints is only one of several parameters that influence the in-service performance of these products. Evaluating the performance of these end-joints require specific tests.

The testing regimen, which may consist of one or more of the test methods specified in this standard, is dependent on the type of product, the stage in the manufacturing of the product or sub-components when the testing is to be performed, and the objective of the evaluation. [Appendix X1](#) – [Appendix X7](#) provide an overview of considerations for developing a testing regimen.

1. Scope

1.1 This standard provides test methods for evaluating the structural capacity and integrity of end-joints in structural wood products.

1.2 End-joints are manufactured by adhesive bonding of machined, mated surfaces at the ends of two pieces of lumber to form a joint. Typical end-joint configurations include finger joints and scarf joints. The combination of one or more end-joints and the adjoining sections of the structural wood product within the assembly is considered to be the test specimen.

1.3 Off-line test methods include: (1) Axial Tension, (2) Bending, and (3) Cyclic Delamination.

1.4 In-line test methods include: (1) Tension Proofload and (2) Bending Proofload.

1.5 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.

1.6 *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

- [D9 Terminology Relating to Wood and Wood-Based Products](#)
- [D198 Test Methods of Static Tests of Lumber in Structural Sizes](#)
- [D1101 Test Methods for Integrity of Adhesive Joints in Structural Laminated Wood Products for Exterior Use](#)
- [D1151 Practice for Effect of Moisture and Temperature on Adhesive Bonds](#)
- [D1183 Practices for Resistance of Adhesives to Cyclic Laboratory Aging Conditions](#)
- [D2559 Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions](#)
- [D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products](#)
- [D3434 Test Method for Multiple-Cycle Accelerated Aging Test \(Automatic Boil Test\) for Exterior Wet Use Wood Adhesives](#)
- [D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials](#)
- [D5456 Specification for Evaluation of Structural Composite Lumber Products](#)
- [D4688 Test Method for Evaluating Structural Adhesives for Finger Jointing Lumber](#)
- [D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material](#)
- [D7247 Test Method for Evaluating the Shear Strength of](#)

¹ These test methods are under the jurisdiction of ASTM Committee D07 on Wood and are the direct responsibility of Subcommittee D07.01 on Fundamental Test Methods and Properties.

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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.

Adhesive Bonds in Laminated Wood Products at Elevated Temperatures

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

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 Terms used in these methods shall be as defined in Terminologies D9 and E6 and Practices E4 and E177.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *delamination*—separation of a bondline due to dimensional changes (swelling and shrinkage) of the wood around the joint caused by extreme changes in the moisture content.

3.2.2 *finger joint*—a joint formed by bonding two pieces of lumber with ends machined to a mated finger-like profile (Fig. 1).

3.2.3 *finger joint specimen*—board segments joined at one or both ends by finger joints to form an assembly and obtained from a finger joint production line for testing.

3.2.4 *finger length*—length of machined finger along the longitudinal axis of the full-size member from the finger tip to the base of the finger (Fig. 1).

3.2.5 *finger pitch*—widest width of machined finger at the base of the joint (Fig. 1).

3.2.6 *gauge length*—the clear distance between the grips for a specimen subjected to axial tensile loading.

3.2.7 *horizontal finger joint*—finger joint where the finger profile appears only on the narrow face of the lumber.

3.2.8 *in-line test*—a test that is carried out on all production from a continuous manufacturing process.

3.2.9 *joint misalignment*—non-zero slope between the longitudinal axes of two adjoining pieces in the direction of depth or thickness, or both.

3.2.10 *joint offset*—distance between joint profile surfaces of two adjoining pieces in a cross-sectional direction perpendicular to the finger or scarf joint length.

3.2.11 *off-line test*—a test that is carried out on a sample taken from a continuous manufacturing process or from inventory of the product.

3.2.12 *outer finger*—the finger at the edges of the face showing the finger profile (Fig. 1).

3.2.13 *proofload testing*—a test where a preselected load or stress level is applied to the specimen.

3.2.14 *scarf joint*—a joint formed by bonding two pieces of lumber with ends machined with a single sloping profile. The length of the specimen cross-section occupied by the scarf joint is the run of the slope (Fig. 2).

3.2.15 *span*—the distance between the centerlines of end reactions on which the test specimen is supported to accommodate a transverse bending load.

3.2.16 *standard dry dimensions*—the cross-sectional size used in design for sawn lumber, this is also known as the standard dry size.

3.2.17 *tip gap*—distance between the finger tip and the base of the finger in the opposing segment (Fig. 1).

3.2.18 *tip thickness*—smallest width of machined finger (Fig. 1).

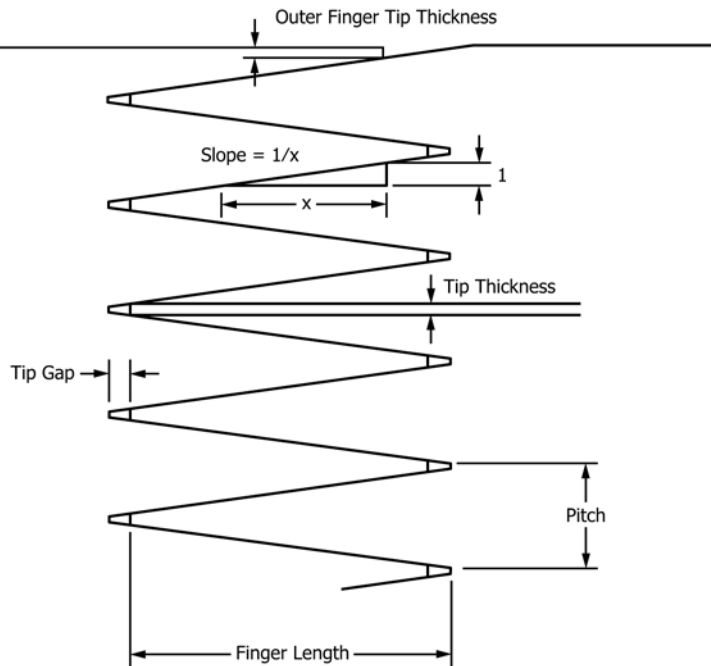


FIG. 1 Finger Joint Profile

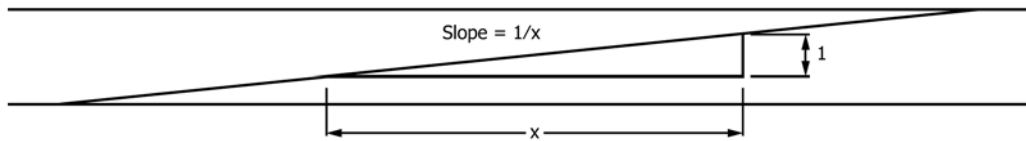


FIG. 2 Scarf Joint Profile

3.2.19 *vertical finger joint*—finger joint where the finger profile appears only on the wide face of the lumber.

4. Significance and Use

4.1 These test methods are applicable to specimens with or without specific conditioning regimens. Tests are permitted to be performed on specimens that are not at moisture equilibrium, such as under production conditions in a plant, or on specimens that have been conditioned to specified moisture content or durability conditioning prior to testing.

4.2 These test methods can be used as follows:

4.2.1 To standardize the determination of strength properties for the material and joint being tested.

4.2.2 To investigate the effect of parameters that may influence the structural capacity of the joint, such as joint profile, adhesive type, moisture content, temperature, and strength-reducing characteristics in the assembly.

4.3 These test methods do not intend to address all possible exposure or performance expectations of end-joints. The following are some performance characteristics not considered:

4.3.1 Long-term strength and permanence of the wood adhesive.

4.3.2 Time dependent mechanical properties of the joint.

4.3.3 Elevated temperature performance of the joint.

AXIAL TENSION TEST METHOD (OFF-LINE)

5. Scope

5.1 This test method provides procedures for the determination of the axial tensile capacity of full-size end-joint specimen off-line.

5.2 Applications of this test method include: end-joint qualification and daily quality control of production, and other purposes where the strength of a full-size end-joint must be verified or determined.

6. Summary of Test Method

6.1 The test specimen is subjected to an axial tensile load. The length of the specimen is short enough such that failures occur primarily at or as a result of the joint, but long enough such that the stresses around the joint are not affected by the grips.

6.2 Except as specified below, the specimens shall be tested in accordance with Test Methods [D4761](#) for Axial Strength in Tension.

6.3 The specimen is loaded so that failure occurs or a preselected load is reached within the prescribed amount of time.

NOTE 1—It is preferred to apply load at a constant rate of increase.

Either load or displacement control is acceptable. Apply load at a rate that is as close to constant as is practical. Sudden increases in load should be avoided.

7. Apparatus

7.1 *Test Machine*—As specified in Test Methods [D4761](#).

7.2 *Grips or Clamping Devices*—As specified in Test Methods [D4761](#).

NOTE 2—Grip designs that do not minimize damage from clamping may result in a high frequency of failure at the edge of the grips. Generally, if a specimen fails at the edge of the grips, the result should be disregarded unless the load level attains a load level that is sufficient to demonstrate a minimum end-joint capacity. When a high frequency of grip related failure occurs at or below the load levels of interest, the grips should be redesigned as excessive culling of specimens for this reason may impact the representativeness of the tensile strength for the sample tested.

7.3 *Distance Between Grips*—The gauge length for finger-joint testing shall be selected such that the edges of the grips are 2 ft (610 mm) apart. The gauge length for scarf joint testing shall be set to the nearest 1 ft (305 mm) increment greater than the length of the joint plus 2 ft (610 mm). With either joint type, the tolerance for gauge length shall be ± 2 in. (51mm).

NOTE 3—The gauge length used for the test is intended to be long enough to result in uniform tensile stress across the joint and short enough to minimize the number of failures that occur away from the joint. The specification outlined in 7.3 has proven reasonable for testing commonly fingerjointed dimension lumber sizes. Larger cross-sections may require longer gauge lengths.

7.4 *Accuracy*—As specified in Test Methods [D4761](#).

8. Test Specimens and Conditioning

8.1 *Cross-Section*—The specimen shall be tested without modifying the dimensions of the commercial cross-section. The use of reduced cross-section test specimens is permissible according to considerations and guidelines for developing test procedures provided in [Appendix X5](#).

8.2 *Length*—The minimum specimen length shall be the gauge length, determined in accordance with 7.3, plus any required length to achieve contact along the full length of the grips.

8.3 *Conditioning*—Specimens are permitted to be tested as produced or following a specified conditioning regimen depending on the purpose of the test program. The specimen conditions and details of the conditioning regimen, if applicable, shall be reported.

9. Procedure

9.1 *Specimen Measurements:*

9.1.1 *Cross-Sectional Dimensions*—The cross-sectional dimensions of each specimen for which the tensile strength is to be determined shall be measured to the nearest 0.01 in. (0.25

mm) and recorded. Where the cross-sectional dimensions differ on either side of the joint, such as when testing samples before they are planed to a standard size, the cross-sectional dimensions used to calculate the tensile strength shall be reported. The width and thickness should be measured at the least dimensional plane of the adjoining segment.

NOTE 4—When testing for end-joint quality control at a production facility, it may be acceptable to determine the tensile strength using the standard dry cross-sectional dimensions.

9.1.2 Moisture Content—Unless otherwise specified by a durability conditioning protocol or product standard, measure and record the moisture content of the specimens following a test on each side of the joint and as close to the failure zone as practical in accordance with the procedures outlined in Test Methods **D4442** or using a calibrated moisture meter according to Practice **D7438** guidelines. For specimens tested as produced from a manufacturing process in which lumber moisture content is controlled or where all specimens are pre-conditioned to a uniform moisture content prior to mechanical testing, moisture content measurements for each specimen are not required. In those instances, the reduced number of specimens from the sample shall be determined in accordance with the guidelines in Practice **D2915**.

9.2 Test Setup—The end-joint shall be centered between the two grips. The specimen shall also be centered in the grips so that the longitudinal axis of the specimen coincides with the direction of the load application. Load shall be applied to the specimen at a rate determined in accordance with **9.3**.

NOTE 5—Centering the joint in the grip span minimizes the bias between joint tests due to bending moments induced by grip head balance. It is recognized that bending moments caused by non-homogeneity in the specimen's mechanical properties cannot be eliminated.

9.3 Speed of Testing—A constant test rate shall be selected for testing the sample such that the specimen failure load is achieved between 1 and 10 min.

9.4 Maximum Load—The maximum load attained in the test shall be recorded.

9.5 Record of Test Rate—A description of the rate of loading and method of application shall be recorded.

9.6 Record of Failure—For all specimens tested to failure, a description of the failure mode in accordance with **Annex A1** shall be recorded. Any specimen irregularities or the presence of strength reducing defects within the joint shall also be recorded.

BENDING TEST METHOD (OFF-LINE)

10. Scope

10.1 This test method provides off-line test procedures for the determination of the capacity of the end-joint in bending on short spans when subjected to either three-point or four-point loading.

10.2 Applications of this test method include: end-joint qualification and daily quality control, and other purposes where the strength of a full-size end-joint are to be verified or determined.

11. Summary of Test Method

11.1 The test specimen is simply supported and transversely loaded in bending. Depending upon the test objectives and end-joint type, the test specimen may be loaded by two equal, concentrated forces spaced equidistant from the center of the supports (four-point load configuration) or by a single concentrated force centered within the test span (three-point load configuration). The specimen is loaded so that failure occurs or a preselected load is reached within the prescribed amount of time.

NOTE 6—It is preferred to apply load at a constant rate of increase. Either load or displacement control is acceptable. Apply load at a rate that is as close to constant as is practical. Sudden increases in load should be avoided.

11.2 Except as specified below, the specimens shall either be tested in accordance with Test Methods **D4761** for Bending Edge-Wise or Bending Flat-Wise. The test method used shall be reported.

12. Apparatus

12.1 Test Machine—As specified in Test Methods **D4761**.

12.2 Load and Support Apparatus—As specified in Test Methods **D4761**, with the exception that finger jointed specimens may also be tested using a single concentrated point load (three-point load configuration) for both the edgewise and flatwise bending test methods.

12.3 Load Configuration:

12.3.1 The standard span for this test shall be 21 times the specimen depth, however other spans shall be permitted. If another span is used, it shall be reported.

12.3.2 The specimen is permitted to be placed in either the flat-wise or edge-wise orientation according to the requirements of the test program. The test orientation and the direction of the applied load relative to the joint profile shall be reported. In the case of square cross-sections, the applied load shall be described as being applied either parallel or perpendicular to the face showing the joint profile.

12.3.3 Four-Point Load Configuration—The four-point load configuration may be used for finger or scarf jointed materials. In both cases, the simple-span test specimen shall be subjected to two equal transverse concentrated loads equidistant from the center of supports. The centerline of action of the applied loads shall not be closer than 2.0 in. (51 mm) from the joint area, and the edges of bearing plates under the loads shall not impinge on the cross-section of the specimen occupied by the end-joint. Test specimens shall be prepared such that the end-joint is placed within and, whenever possible, centered in the maximum moment zone.

12.3.4 Three-Point Load Configuration—The three-point load configuration shall be permitted to test finger jointed materials. The simple-span test specimen shall be subjected to a single concentrated load centered between the supports. The finger joint shall be centered beneath the load point and the load shall be applied through a curved surface with a radius sufficient to avoid a localized crushing failure.

NOTE 7—To minimize the number of failures occurring away from the joint regardless of load configuration selected, the overall span should be selected to be as short as possible but sufficiently long to avoid shear and

bearing failures before the end-joint bending capacity is reached. The shear span (as defined in Test Methods [D198](#)) should be selected to be as long as possible to minimize failure at strength-reducing characteristics close to the end-joint.

NOTE 8—Experience has shown that a curved load head with a radius between two and four times the member depth is typically sufficient to avoid a localized crushing failure with a three-point load configuration.

12.4 *Accuracy*—As specified in Test Methods [D4761](#).

13. Test Specimens and Conditioning

13.1 *Cross-Section*—The specimen shall be tested without modifying the dimensions of the commercial cross-section. The use of reduced cross-section test specimens is permissible according to considerations and guidelines for developing test procedures provided in [Appendix X5](#).

13.2 *Conditioning*—Specimens are permitted to be tested as produced or following a specified conditioning regimen depending on the purpose of the test program. The specimen conditions and details of the conditioning regimen, if applicable, shall be reported.

14. Procedure

14.1 *Specimen Measurements:*

14.1.1 *Cross-Sectional Dimensions*—The cross-sectional dimensions of each specimen for which the bending strength is to be determined shall be measured to the nearest 0.01 in. (0.25 mm) and recorded. Where the cross-sectional dimensions differ on either side of the joint, such as when testing samples before they are planed to a standard size, the cross-sectional dimensions used to calculate the flexural strength shall be reported. The use of reduced cross-section test specimens is permissible according to considerations and guidelines for developing test procedures provided in [Appendix X5](#).

NOTE 9—When testing for end-joint quality control at a production facility, it may be acceptable to determine the flexural strength using the standard dry cross-sectional dimensions.

14.1.2 *Moisture Content*—The moisture content of the test specimens shall be determined as described in [9.1.2](#).

14.2 *Test Setup*—As specified in Test Methods [D4761](#), with the exception that it is permissible to apply a single concentrated load in both the flatwise and edgewise bending test methods when testing finger jointed material.

14.3 *Speed of Testing*—A constant test rate shall be selected for testing the sample such that the specimen target failure load is achieved between 1 and 10 min.

14.4 *Maximum Load*—The maximum load attained in the test shall be recorded.

14.5 *Record of Test Rate*—A description of the rate of loading and method of application shall be recorded.

14.6 *Record of Failure*—For all specimens tested to failure, a description of the failure mode in accordance with [Annex A1](#) shall be recorded. Any specimen irregularities or the presence of strength reducing defects within the joint shall also be recorded.

CYCLIC DELAMINATION TEST METHOD (OFF-LINE)

15. Scope

15.1 This test method provides procedures for assessing the ability of the bond to resist separation after repeated exposure to moisture and drying. This test method is for end-joints in products requiring evaluation of durability, and also provides an indication of the overall consistency of the end-joint manufacturing process.

NOTE 10—This is adopted from Test Methods [D1101](#), Test Method B, for finger joints.

16. Summary of Test Method

16.1 The end-grain surfaces of a bonded wood cross-section are exposed to a vacuum-pressure soak treatment in room temperature water to saturate the specimen. The specimen is then dried under mild conditions to within 15 % above its original weight. The vacuum-pressure soaking and drying constitute one cycle. The total length of bondlines on the exposed end-grain that separated or delaminated as a result of the treatment is measured and expressed as a percentage of the original length prior to the exposure. One or multiple cycles are conducted according to the requirements of the test program or product specifications.

16.2 When the delamination exceeds a predetermined level, the population represented by the sample shall be deemed to be non-compliant, and the end-joint manufacturing process, if applicable, shall be evaluated to determine the reasons for the adverse test results.

17. Apparatus

17.1 *Autoclave*—An autoclave or similar pressure vessel designed to safely withstand pressures of at least 75 psi (520 kPa) is required for impregnating the specimens with water. The pressure vessel shall be equipped with a vacuum pump or similar device capable of drawing a vacuum of at least 25 in. (635 mm) mercury (Hg) (at sea level) in the vessel, and a pump or similar device for obtaining a pressure of at least 75 psi (520 kPa).

17.2 *Drying Oven*—The drying oven shall be capable of maintaining the conditions necessary to dry specimens in 10 to 15 h to within 15 % above its original weight.

NOTE 11—Suitable drying conditions may be obtained from cross-flow, laboratory type ovens of the circulating type. They can also be obtained using a non-circulating configuration in which air heated by a space heater is passed over the specimens and vented.

NOTE 12—Conditions that affect the drying rate include cross-flow air velocity; humidity; air temperature; and the arrangement, size, and number of specimens in the oven.

NOTE 13—Circulating type ovens that provide a cross-flow air velocity of 250 ± 50 fpm (75 ± 15 m/min) in the center of the drying chamber and maintain an air temperature of $160 \pm 5^\circ\text{F}$ ($70 \pm 3^\circ\text{C}$) should be capable of achieving the specified drying rate.

18. Test Specimens and Conditioning

18.1 *Specimen Dimensions*—The test specimen shall be prepared from a full cross-section piece, measuring approximately 6 in. (152 mm) long, and containing the joint in the center of the length.

18.2 *Pre-Conditioning*—Unless the conditioning is part of the adhesive curing process, specimens shall be tested as sampled.

18.3 *Specimen Preparation*—The specimen shall be cross-cut through the center of the joint to expose the bondlines on the end-grain and yielding two test specimens, 3 in. (76 mm) long.

18.3.1 The cut surface shall be smooth and perpendicular to the longitudinal axis of the end-jointed member.

18.4 At least 0.25 in. (6 mm) of the joint (measured from the tips of the finger or end of the scarf to the cut face) shall remain on each test specimen. If the length of the joint does not permit this to be met by cutting at the center of the joint, the joint shall be cut at the tips of the fingers or end of the scarf to yield one test specimen, and such that the full length of the joint is retained.

19. Procedure

19.1 The test specimens shall be placed in the pressure vessel and weighted down. Sufficient water shall be admitted at a temperature of 65 to 85°F (18 to 30°C), so that the test specimens are completely submerged.

19.2 Sticker, wire screens, or other means shall be used to separate the test specimens so that all end grain surfaces are freely exposed to water.

19.3 A vacuum of 20 to 25 in. (510 to 640 mm) Hg shall be drawn and held for 30 min then released.

19.4 A pressure of 75 ± 5 psi (520 ± 34 kPa) shall be applied for a period of 2 h.

NOTE 14—For scarf joints and finger joints longer than about 1 in. (25.4 mm), two additional vacuum-pressure cycles as described in 19.3 and 19.4 may be necessary to fully saturate the specimens.

19.5 The test specimens shall be dried using air at a temperature of $160 \pm 5^\circ\text{F}$ ($71 \pm 3^\circ\text{C}$). The air circulation and number of specimens in the oven at any time shall be selected such that the specimens are dried to within 15 % above their original weight in 10 to 15 h.

NOTE 15—Experience from the U.S. structural glued laminated timber industry indicates that bondline delamination in specimens with original average moisture content of approximately 12 % become most evident when the specimens are dried to within 110 to 115 % of their original weight. Further drying tends to reduce the moisture gradient in the specimens and allows bondline separations to close, masking the delamination. Products bonded at higher initial moisture contents, especially at 19 % or more, may require further drying to ensure that a similar moisture gradient is created and the outer fibers are significantly below the fiber saturation point. The final moisture condition in which bondline delamination is most evident and measurable should be determined for each product and specified in the applicable product standard.

19.6 During drying, the specimens shall be placed at least 2 in. (50 mm) apart, with the exposed bondlines on the end-grain surfaces parallel to the direction of the airflow.

19.7 After drying, the delamination shall be measured and recorded immediately following the procedures set forth in Section 20. The percentage delamination shall be calculated in accordance with Section 20.

19.8 For multiple-cycle delamination testing, steps 19.1 to 19.7 shall be repeated the required number of times based on

the test program or product specification. The percentage delamination after each cycle shall be determined and recorded after each cycle.

20. Measurements and Calculation

20.1 At the end of the drying period, the crosscut surface of the specimens shall be examined immediately for delamination (separation of the bondlines), and indeterminate areas shall be probed with a 0.004-in. (0.102-mm) feeler gauge.

NOTE 16—If the delamination specimens are removed from the oven and allowed to reabsorb moisture from the atmosphere, the delaminations in the bondlines will tend to close up.

NOTE 17—Care should be exercised to limit the applied pressure to the feeler gauge so as not to lengthen or widen the bondline separation beyond that observed immediately after drying.

20.2 The length of the delaminated portions shall be measured to the nearest $\frac{1}{16}$ in. (1 mm), and the delamination lengths shall be summed. This result shall be divided by the total length of exposed bondlines on the end-grain surfaces, excluding those lengths of delamination permitted to be ignored by section 20.3.

20.3 In finger joints, it is permissible to ignore the following:

20.3.1 Any delamination in the bondlines adjacent to the outer fingers;

20.3.2 Any delamination less than 0.1 in. (2.5 mm) long; and

20.3.3 Any delamination within knot boundaries visible in the crosscut surface.

PROOFLOADING (IN-LINE)

21. Scope

21.1 This test method provides an in-line quality assurance procedure for end-joint strength.

21.2 This method does not provide sufficient means to fully characterize the strength parameters of a population or sample of end-joints, and is not intended to be a substitute for off-line process qualification and on-going quality control testing.

21.3 This method reduces the variability of the lower end of strength distribution by culling low-strength end-joints.

NOTE 18—Although this method improves the structural reliability, it does not necessarily provide absolute assurance those end-joints proofloaded to a specified test level will not fail when reloaded to the same tension stress level.

NOTE 19—In a continuous end joining process, end-joints may occasionally appear in the grips. Provided this is a random occurrence, the application is still considered to meet the requirements of this method.

22. Summary of Test Method

22.1 End-joints are either tested in axial tension or in bending with a 3 or 4-point loading configuration.

22.1.1 Load is applied to the test specimen until a preselected load is reached or the specimen fails under load or exceeds a predefined deflection.

22.2 Intact specimens supporting the preselected load are accepted and continue to the next step in the production process, while failed specimens are rejected and removed from the production process.

22.3 This process identifies low-strength specimens primarily by destroying them.

NOTE 20—Means should be provided to monitor production during proofloading to eliminate specimens that provide visual or audible evidence of excessive damage from the test.

22.4 This method is permitted to be applied to single end-joints or to long lengths of joined lumber containing one or multiple end-joints.

NOTE 21—Proofloading may be applied to production before or after the point where samples are drawn for off-line qualification and quality control testing. Where this method is used and no formal feedback exists between the frequency of specimens failing the proofload test level and the manufacturing process controls, it is recommended that proofloading be applied to production after the point where samples are drawn for off-line tests.

23. Apparatus

23.1 *Test Machine*—A device combining (1) a mechanism transmitting the load to the test specimen; (2) a mechanism for applying a load up to a preselected value; (3) a device or mechanism for measuring the applied load and ending the test when a preselected load is reached; (4) the necessary controls, gauges, etc., to ensure consistent application of the preselected load; and (5) a mechanism or device to ensure that specimens failing to achieve the preselected load are removed or marked for subsequent removal from production.

NOTE 22—When bending proofload testing is adopted, the bending stiffness can also be used as criterion for rejecting end-joints. Because of the non-uniform bending within the test span, the set-up will need to include a mechanism for noting the position of the joint relative to the applied loads.

NOTE 23—When proofloading in tension is used, grips or clamping devices shall be designed and used such that damage to the specimen by the grips during the proofloading process is minimized. The textured surfaces left by steel grip plates are generally inconsequential for members used in most structural applications, but may be an issue if a smooth surface is required for face bonding. Other damage should be assessed and confirmed to be insignificant to the desired end use.

23.2 Test Span:

23.2.1 When proofloading in tension, the clear distance between grips shall be selected such that the edges of the grips are at least 2 ft (610 mm) apart for finger joints and at least 2 ft (610 mm) longer than the length of the joint for scarf joints.

NOTE 24—It is recommended that the tension test span be the maximum span possible so that the number of joints positioned near or within the grips during the test is kept to a minimum.

23.2.2 When testing in bending, the test span shall be selected which will permit a predetermined bending moment to be applied to the end-joint, either from two equal transverse concentrated loads equidistant from the supports or a single concentrated load at mid-span.

NOTE 25—Simple end supports are recommended. Other types of end fixity may be used if it is taken into account when selecting the appropriate proofload. The standard span range is 15 to 30 times the specimen depth.

23.3 *Gauges and Controls*—The necessary controls and gauges shall be capable of being calibrated to consistently measure and control the required proofload for all grades, width and thickness intended to be proofloaded.

23.4 *Accuracy*—The force-measuring apparatus shall be such as to permit load measurements with an error not to exceed 2.0 % of the load.

NOTE 26—Consideration should be given to dynamic effects of the loading apparatus on the accuracy of the measured loads. It is recommended that the apparatus be designed and maintained such that it can be demonstrated that 95 % of the time, the applied load level is between 100 and 110 % of the specified proofload level.

24. Test Specimens and Conditioning

24.1 *Cross-Section*—The specimens shall be tested as produced, without modification of the cross-section.

24.2 *Length*—The minimum specimen length shall be the clear distance between grips or supports plus any required length to achieve full contact along the length of the grips or supports.

24.3 *Moisture Content*—Specimens shall be tested as produced without further moisture conditioning.

24.4 *Temperature and Adhesive Cure*—Proofload testing of end-joints with partially cured adhesive bonds shall only be performed after it has been established that the performance of the end-joint when the adhesive has reached full cure is not affected. If a lower proofload level is used for partially cured adhesive bonds in place of a proofload level that has been established for end-joints with fully cured bonds, the method for establishing the lower proofload level shall be documented.

NOTE 27—The lower proofload level should consider the variability in degree of cure between specimens and how this may change with the lumber or ambient environmental conditions.

NOTE 28—Aside from the adhesive bond, some end use applications specify and rely on the tension proofload testing to also assess the joint fabrication quality and wood quality. Use of a proofload level lower than that specified in the applicable product standard should be discussed with the end user.

25. Procedure

25.1 *Test Setup*—When proofloading in tension, the specimen shall be centered in the grips with the long axis of the specimen coinciding with the direction of load application. When testing in bending, the specimen shall be placed with an end-joint located within the maximum moment zone.

25.2 *Speed of Testing*—The load rate shall be consistent for all end-joints within a production run.

NOTE 29—Typical line speeds result in the proofload being reached in less than three seconds.

25.3 *Proofload*—The applied proofload shall be selected in accordance with the objectives of the quality control program.

NOTE 30—The applied proofload level should be sufficiently high to reject mismanufactured or low-strength specimens, but low enough to minimize failure of acceptable specimens. Because the degree of damage to a specimen is a function of the test load level and the actual but unknown strength of the specimen, the few pieces that marginally pass the proofload test will likely encounter some damage. Therefore, it is advised that the proofload level be set higher than that to be encountered by the product when in service. For example, SPS-1 for structural fingerjoined lumber requires a minimum proofload level of 1.33 times the design capacity, while some manufacturers of I-joists have specified 1.5 times the design capacity for their fingerjoined flange components.

NOTE 31—For partially cured joints, the proofload levels may need to be reduced to account for the degree of cure and temperature of the specimen at the time of test. Guidelines on acceptable proofload level reductions should be developed for the specific adhesive and manufacturing conditions. Labeling or reporting of the actual proofload level used may be required.

25.4 If required, Practice D2915 and these methods shall be used to assess the effect of the proofloading program on the end-joint strength distribution.

JOINT OFFSET AND MISALIGNMENT

26. Scope

26.1 This test method defines procedures used to measure end-joint offset or misalignment, or both. These test methods may be used to characterize the installation tolerances of an end-joint for comparison against an applicable performance specification for these parameters.

27. Summary of Test Method

27.1 *End-Joint Offset*—Specified measurement techniques are provided to measure the relative offset of two adjoining pieces in a cross-sectional direction perpendicular to the finger or scarf joint length.

27.2 *End-Joint Misalignment*—Specified measurement techniques are provided to measure and characterize the relative misalignment of the joined pieces about the axes parallel to the member depth or thickness, or both.

28. Apparatus

28.1 Calipers or any other device suitable for measuring the distances and cross-sectional dimensions to the nearest 0.01 in. (0.2 mm).

29. Procedure

29.1 *End-Joint Offset*—The procedure used to measure end-joint offset corresponds with the diagram illustrated in Fig. 3 and includes the following steps:

29.1.1 Remove adhesive squeeze-out, torn fibers, or any surface defects prior to measuring.

29.1.2 For both sides of the end-joint, measure and report the end-joint offset as the distance between the protruding edge of the end-joint and the nearest point on the adjoining piece. Take the offset measurement at a position not impacted by edge tearout.

29.1.3 Measure and report the cross-sectional dimensions for each piece of wood adjacent to the end-joint.

29.2 *End-Joint Misalignment*—The procedure to measure the end-joint misalignment corresponds with diagram illustrated in Fig. 4 and includes the following steps:

29.2.1 Identify the side of the end-joint where the two pieces form an angle of less than 180°.

29.2.2 From the side of the joint identified in 29.2.1, use a straight-edge to draw a set of intersecting lines parallel to the member edges as depicted in Fig. 2.

29.2.3 Measure and report the end-joint misalignment as the vertical leg of the slope depicted in Fig. 4. Whenever possible, report the end-joint misalignment as the slope that occurs along 12 in. (30.5 cm) of the member length. Alternatively, the slope measurements shall be permitted to be taken over longer or shorter distances and mathematically converted to the slope that occurs along 12 in. (30.5 cm) of member length.

29.2.4 Measure and report the end-joint misalignment independently for both axes defined by the member depth and thickness, taking at least one measurement in each direction. If more than one measurement is taken in one direction, it is permitted to report their average.

29.2.5 Measure and report the cross-sectional dimensions for each piece of wood adjacent to the end-joint.

30. Report

30.1 The report content depends on the purpose of the test program. The report should include, at the minimum, the information specified in the section above and the following:

30.1.1 Description of the test machine, including detailed drawings of the test setup, the span or gauge length, and the location of the force-measuring device.

30.1.2 Description of calibration procedures, frequency, and records.

30.1.3 Method used for the measurement of the moisture content of specimens, if applicable. If Practice D7438 is used, report the basis and nature of any corrections or adjustments to the moisture content readings. If no moisture measurements are

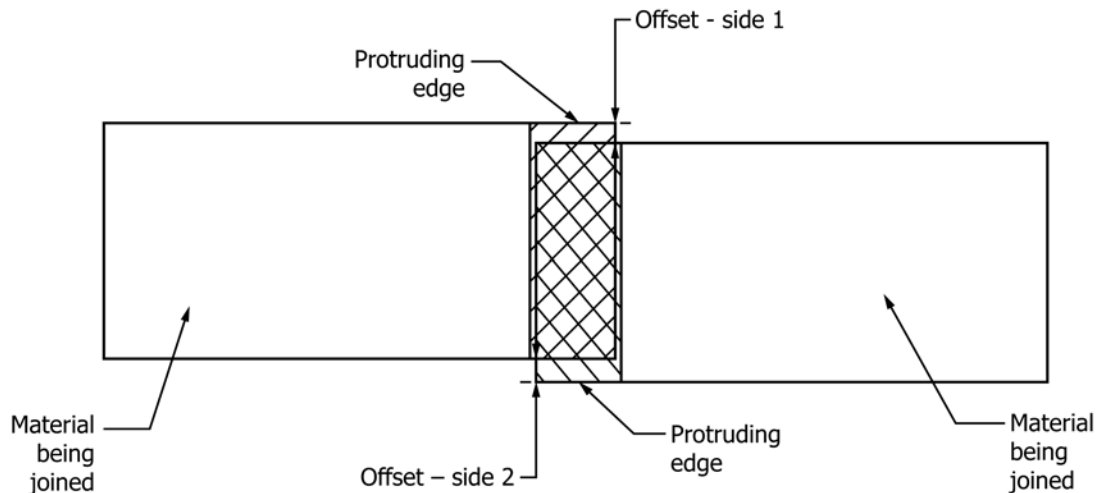


FIG. 3 End-Joint Offset

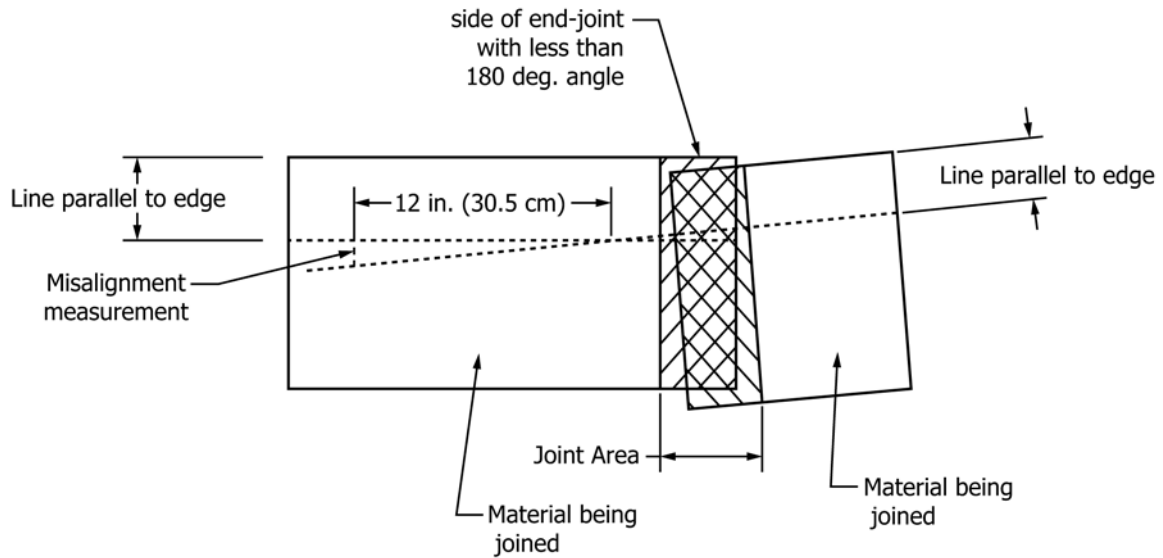


FIG. 4 End-Joint Misalignment

made, state the range of moisture content assumed and the environmental conditions or conditioning supporting this assumption.

30.1.4 Speed of testing, means of control of the speed of testing, and time to failure.

30.1.5 Details of any deviations from the prescribed or recommended procedures as outlined in these test methods.

30.2 For off-line test methods, the report should also include the following:

30.2.1 Method of selection of the tension edge for bending specimens.

30.2.2 Description of the population sampled, including (1) species or species group; (2) specimen geometry (for example, nominal cross-section and length); (3) end-joint profile (for example, theoretical dimension of fingers, tip gaps, and shoulders) and joint orientation; (4) adhesive used (including a reference to the adhesive qualification test report) and the method of curing; (5) grade or grades combination; and (6) any wood product treatment at the time of production (for example preservative treatment), if applicable.

30.2.3 Description of the sample, including (1) sample size; (2) conditioning, if applicable; (3) temperature of specimens at

the time of testing; (4) degree of cure of the adhesive; (5) number of specimens that failed during the test; and (6) the level of wood product treatment (for example chemical retention levels), if applicable.

30.2.4 Data on test specimens, including, as applicable: (1) grade, (2) actual cross-sectional dimensions, (3) moisture content, (4) maximum load, and (5) failure description and location.

30.3 For in-line test methods, the report should also include:

30.3.1 Proofload test levels.

30.3.2 Proofload test repeatability results.

31. Precision and Bias

31.1 The precision and bias of these test methods have not yet been established.

32. Keywords

32.1 cyclic delamination; end-joint; finger joint; lumber; mechanical properties; proofloading; scarf joint; strength

(Mandatory Information)**A1. FAILURE MODE CLASSIFICATION OF TESTED SPECIMENS**

A1.1 The types of failure that occur in finger jointed specimens due to tension loading may be roughly classified into six modes. Determine the failure mode of each specimen based on the written and graphical description given in **Fig. A1.1**.

A1.2 Failure modes 1 and 2 require the evaluator to make a distinction between less than 70 % wood failure and more than 70 % wood failure. This is often a difficult quantity to judge

from an oblique angle. In difficult cases it is suggested that the fingers be cut off at their roots so that the failed surfaces of the finger can be viewed directly.

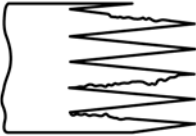
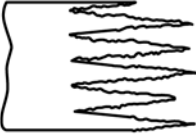
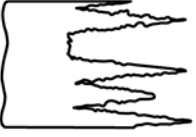


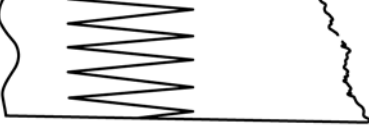
Mode	Description	Example
1	Failure mostly along the bondline surfaces of the joint profile with poor wood failure of any kind (wood failure < 70%).	
2	Failure mostly along the bondline surfaces of the joint profile with good wood shear failure (wood failure > 70%).	
3	Failure mostly along the joint profile but with some failure at the finger roots or scarf tips. Good overall wood shear failure along the joint profile surfaces.	
4	Mostly tensile wood failure at the fingerjoint roots or scarf tips and with high overall wood failure. Little failure of any kind along the joint profile.	
5	Failure beginning at the joint (possibly due to a stress riser) and progressing away from the joint. Essentially 100% wood failure.	
6	Failure away from the joint (not influenced by the joint)--all wood failure.	

FIG. A1.1 Failure Mode Criteria

APPENDIXES

(Nonmandatory Information)

X1. GUIDELINES FOR PRODUCT QUALIFICATION AND QUALITY CONTROL

X1.1 Sample Sizes

X1.1.1 The selection of sample sizes for off-line test methods should follow, for example, Practice D2915. At a minimum, samples sizes should be selected to infer lower fifth percentile strength properties. In assemblies involving a large number of finger joints within a standard test length, considerations should be given to also monitoring the variability within the lower end of the finger joint strength distribution. The need for this will be dictated by how frequently end-joints appear in the assembly, and whether single joints or groups of joints as they appear in a standard length of member are

sampled for off-line testing. See, for example, References (6) or (7) in X7.3 as examples of how end-joint frequency is addressed.

X1.2 Effect of Test Mode on Capacity and Modes of Failure

X1.2.1 For purposes of monitoring the manufacturing practice, each test mode is capable of yielding information on the consistency of the finger joint. This is contingent upon monitoring of the mode of failure and presence or lack of wood failure at the joints. The mode of failure and the amounts of

wood failure are influenced by the joint configuration and the adhesive used. Once it is established what failure modes and levels of wood failure are typical of an in-control process, these can be used to monitor the end-joint manufacturing process.

X1.2.2 Target strength levels for finger joints are typically derived from the published or claimed strength value for the wood segments being fingerjoined. When selecting a test mode for the finger joints, consideration should be given to how the product will be used and how performance on other relevant but untested modes can be inferred. An example of this would be a product that is not primarily used in tension and consequently are assigned tension design values that are conservative compared to the assigned bending design values. In this case, use of the tension mode to qualify or monitor the fingerjoining manufacturing process may not be adequate for assessing the bending strength. Similarly, consideration should be given to using a tension test when the product is used primarily in tension.

X1.2.3 The test mode is generally specified in the product standard.

X1.2.4 There are structural glued wood products that have a minimum percentage of wood failure as part of the end-joint qualification requirements and special instructions for including, or not including, test data where the failure is away from the end-joint. Failures away from the joint are not uncommon and should be noted when they occur. In these cases, it may be acceptable to use the test result to imply a minimum joint strength. However, if there is a high frequency of failure occurring away from the joint at the test load level below what is necessary for the purposes of the test program or to monitor the joint quality, then consideration should be given to using another test mode.

X1.3 Recommended Tests and Frequency of Testing

X1.3.1 The responsiveness of the on-going quality monitoring program should reflect the immediacy of change in the performance of the end-joint when there are quality issues related to the input materials (for example, lumber and adhesives) and the manufacturing process (for example, end pressure, process used to cure or accelerate the curing, and machining of the end-joints and fit). A study of parameters affecting the quality should be undertaken if there is insufficient experience to identify an appropriate sampling frequency and sample size.

X1.3.2 The start-up of a new end-joint manufacturing facility, and the temporary shutdown and subsequent start-up of an existing end-joint production process may introduce quality issues that may not appear in a continuous process. End-joint evaluation procedures focused on these situations may be required.

X1.4 Optional Tests and Characteristics for Monitoring

X1.4.1 Finger joint delamination resistance is independent of the strength requirements. In addition to providing insight into the durability of the joints, the test can also be used to assess the manufacturing quality of the joint. This includes adhesive bond quality and the fit of the joint. It is possible for

a process to go out-of-control for finger joint delamination resistance but not for strength. This, for example, could indicate a process that is yielding end-joints of inconsistent quality but with high enough strength to meet the minimum strength requirements. Possible end-joint performance issues that could arise from a process that exhibits these characteristics include excessive variability, and poor performance in the modes not tested as part of the on-going quality monitoring program.

X1.5 Proofloading

X1.5.1 Proofloading test rates are generally high so that overall production rates are not impeded. Typical rates permit the specimens to be loaded and unloaded in about 1 to 3 s. Although the load levels are generally well below the average strength levels of the production, the loading rates are still significantly higher than that typically used for full-size wood product evaluation tests such as Test Methods D4761. A summary of rate of loading studies may be found in Karacabeyli and Barrett (1993),³ who suggested an equation based on data from a number of published studies on this topic for adjusting the bending strength of lumber for rate of loading effects. Although in general the studies reviewed indicate an increase in measured bending strength with increasing rate of loading, the suggested equation show a less than 5 % increase in bending strength at typical on-line proofloading rates compared to off-line proofloading rates such as those given in Test Methods D4761. Studies on rate of loading effects in tension are more limited than in bending, but the magnitude of the effect appear to be similar.

X1.5.2 The in-line proofloading test configuration need not match the off-line test configuration. When selecting a proofloading test configuration, consideration should not only be given to selecting a test mode and configuration that correlates to the standard off-line test condition(s), but also meets practical needs such as maintaining reasonable production rates and be capable of dealing with breakages during proofload testing.

X1.5.3 An example of tension proofloading of end-joints may be found in References (5) and (6) in X7.3.

X1.6 Off-Line Bending Test Configuration

X1.6.1 The standard permits an off-line bending test to be conducted using either a three-point or a four-point loading scheme. Historically, the flexure capacity of an end-joint profile has been established and monitored using a four-point load configuration with the end-joint positioned within the maximum moment region that occurs between the load points. With some material and end-joint profile combinations, it is recognized that this scheme may result in a significant percentage of non-joint failures. This is especially true when the distance between the symmetrical load points well exceeds the end-joint profile length. When this happens, the actual bending capacity of the joint has not been established and can only be

³ Karacabeyli, E., and Barrett, D., "Rate of Loading Effects on Strength of Lumber," *Forest Products Journal*, Vol 43, No. 5, 1993, pp. 28–36.

conservatively characterized as having at least the strength demonstrated by the surrounding material.

X1.6.2 For some test objectives, such as the isolation of a manufacturing process parameter, assessing the variability in joint capacity, or the evaluation of volume effects for finger jointed materials with a relatively short profile length, it is preferable to develop a more accurate understanding of the joint capacity and reduce the number of non-joint related failures in the test program. For this reason, the three-point load configuration was added as an alternative for finger jointed materials that places both the concentrated transverse load and the joint within the center of the test span. Testing in this alternative configuration aligns the maximum moment with the finger joint position and enhances the probability that the bending test failure will occur at the finger joint. This

provision has not been extended to scarf joints, since the tips of their profiles can extend appreciably beyond the maximum moment region with a three-point load configuration.

X1.6.3 The type of bending load configuration chosen for an end-joint evaluation should be made after carefully considering the test objectives. As demonstrated by Table A1.1 of Specification **D5456**, it is well established that the results are not necessarily interchangeable between load configurations. For end-joints capable of supporting a bending capacity near that of the material being joined, the three-point test configuration or a four-point configuration with closely spaced load points will often result in a higher average capacity measurement than a four-point test configuration with well-spaced load points due to volume effects of the source material.

X2. FACTORS AFFECTING JOINT PERFORMANCE

X2.1 Joint Profile and Orientation

X2.1.1 The joint profile and the orientation of the joint (horizontal or vertical) have an effect on the joint performance. When the joint profile or orientation is changed, it is necessary to re-establish by qualification testing whether or not the strength requirements are met. The testing accomplishes two objectives: (1) if the profile and orientation selected can deliver the level of performance desired given the input material (for example, adhesive and wood substrate); and (2) if the manufacturing process can produce reliable end-joints using the particular profile and orientation. An example of the latter would be switching to a finger joint profile that utilizes a longer finger. Although a profile with a longer finger may give higher structural capacities, it may be more difficult to work with.

X2.2 Wood Adhesive

X2.2.1 *Wood Failure Assessment:*

X2.2.1.1 Wood failure assessment is best conducted on dry specimens where the fibrous material, if present, can be seen along both sides of the joint profile. Failure along the profile of the finger joint should not lead to the conclusion of a defective joint without consideration of wood failure and the relative strength of the joint to the adherent. Within a population of specimens, it is not uncommon to have both the strongest and weakest specimens fail along the profile and to have some of the intermediate strength specimens fail away from the joint location.

X2.2.2 *Extreme Exposure Conditions:*

X2.2.2.1 Unless otherwise stated, the end-use of an end-jointed product is normally assumed as being dictated by whatever end-uses are accepted for the unjointed segments. In addition to normal service conditions traditionally covered by structural design codes, extreme conditions may need to be considered. Examples include end-joined lumber used under severe wet use conditions. In addition to considering the effect of the conditions on the performance of the adhesive, the conditions will likely require the use of a chemical treatment to protect the wood components. If so, the long-term interaction

between the adhesive and the chemical treatment and the bondability of the chemically treated wood, if applicable, should be assessed. Other considerations include the performance of the bondline at elevated temperatures, especially temperatures associated with fire exposures, and at extremely low temperatures. End-joint performance under elevated temperature conditions will depend on the elevated temperature level and exposure duration, and the applied stress level. Reliable estimates of these exposure conditions will be product and end-use specific and depend on the performance objectives.

X2.2.2.2 Test Method **D7247** and Practices **D1183** provide methods for assessing the structural performance of a bondline exposed to elevated temperature by comparing the shear strength of a bondline at ambient and at elevated temperatures, to the shear strength of solid wood at the same ambient and elevated temperatures.

X2.2.2.3 Test Method **D3434** is an accelerated test method for assessing bonded products to severe wet service conditions. It requires automated test equipment.

X2.2.3 *Effect of Sample Storage Conditions:*

X2.2.3.1 Generally samples are drawn from continuous production and the production is held until the samples representing the period of production have been tested and found to be in compliance as specified in the quality control program. The samples should not only be representative of the production at the time of sampling, but they should also be stored under conditions that are similar to the conditions under which the production is stored. At the time of sampling, the adhesive may not be fully cured or the production may be held under conditions, which are less than ideal for achieving adequate adhesive cure. Storage of the quality control test samples under conditions that favor adhesive cure may result in quality control test results that may not be representative of the product being shipped. This is particularly important for products that may be expected to withstand, for example, moisture and moderate structural stresses during transport and construction.

X2.3 Wood Moisture Content

X2.3.1 It may be necessary to monitor the moisture content at several points in the end-joint manufacturing process in order to assess the effect of wood moisture content on the end-joint performance. When and how often the moisture content should be recorded will depend on whether there is a

desire to monitor the impact of moisture content on, for example, the machining of the joint, adhesive penetration, rate of adhesive cure, the mode of failure, and the final joint strength.

X2.3.2 The choice of either Test Methods **D4442** or Practice **D7438** is dictated by the desired accuracy and convenience.

X3. PRODUCT AND JOINT PERFORMANCE LEVELS

X3.1 Considerations

X3.1.1 In addition to variability in the performance of individual end-joints, the location and number of end-joints appearing in a product may also occur randomly. Qualification and quality control programs that strictly monitor the performance of single end-joints should take into account the

expected spacing and frequency of occurrence of end-joints in a unit length of end-jointed product. For a given variability in single end-joint performance, the near minimum strength of groups of end-joints in a unit length of end-jointed product will tend to decrease as the group size increases.

X4. DURABILITY AND DELAMINATION CONDITIONING

X4.1 Considerations

X4.1.1 Several standards include conditioning regimens, which may be useful for the evaluation of the end-jointed lumber's ability to withstand exposure to moisture. Some of these include: Test Methods **D1101** and **D3434**, Practices **D1151** and **D1183**, and Specification **D2559**. Other conditioning procedures may also be followed.

applied to assessing finger joints. In addition to assessing the moisture resistance of finger joints, the test may also be used on an ongoing basis to monitor the manufacturing quality and consistency, independently of the joint strength.

X4.2 Durability Conditioning and Testing

X4.2.1 It may be desirable to evaluate the strength and failure mode of end-joints after exposure to moisture or accelerated aging regimens. The off-line tension and bending test described in these methods can be used on specimens that have been subjected to durability conditioning prior to the test.

X4.3.2 The wetting and drying conditions are selected to assess the ability of the bondline to resist the wood shrinkage stresses. It is important that the conditions produce moisture contents in the vicinity of the exposed end-grain that are below the fiber saturation point so that drying stresses are developed, but not too high as to cause excessive wood checking. Under these conditions, the specimen's core moisture content may still be relatively high.

X4.2.2 The need for durability conditioning and assessment may vary according to the end product, of which the end-joint is a part. Product standards may specify required performance levels after specimens have been subjected to one or more conditioning regimens.

X4.3 Delamination Conditioning and Testing

X4.3.1 Delamination test methods were originally developed to provide an accelerated means of measuring the resistance to delamination of structural laminated wood members intended for exterior service. They have since been

X4.3.3 These test methods specify only the drying times, drying temperature, and final moisture content for the delamination conditioning. Therefore, considerable latitude is provided in selecting actual operating conditions, which will have an influence on the delamination test results. The intent is to dry the specimen rapidly enough to generate typical drying stresses on the bondline without causing excessive checking in the wood, which would relieve the shrinkage stresses and thus the stresses on the bondline. Consideration should be given to the specimen size (which will influence the moisture gradient within the specimen and thus the shrinkage stresses) and the number of specimens being dried simultaneously (which will influence the drying rate).

X5. REDUCED CROSS-SECTION TEST SPECIMENS

X5.1 Considerations

X5.1.1 It is permissible to rework or rip specimens into smaller cross-sections provided it is demonstrated that the test values and the manner in which the values are processed result in a conservative assessment for both conforming and non-conforming products.

X5.1.2 Specimens may be ripped to produce side-matched specimens for the purpose of assessing the quality under different test modes or conditioning prior to testing. The purpose of extracting matched specimens is to minimize the effect of wood strength when evaluating the quality of the manufactured finger joint. When using side-matching and establishing criteria for assessing the results and relating it to full cross-section performance, it should be noted that there may be significantly higher variations in wood strength properties radially with respect to the annual growth rings, than tangentially. Furthermore, a small cross-section containing the pith may exhibit different strength properties than its side-matched specimen.

X5.1.3 For purposes of evaluating a fingerjoining process used to manufacture a wide range of finger joint widths, it may be convenient to reduce the samples of various widths to a common width. This enables a single test setup and span to be used for all widths, or for equipment not capable of testing full size specimens to be used.

X5.1.4 When target test load levels intended for full cross-section evaluation are used to assess results from reworked test specimens, the test load levels should be adjusted for the finger orientation of the reworked specimen, and the effect of joint size on the strength. The adjustment should also recognize the removal of the original outer surfaces, especially outer fingers, as the perimeter of the cross-section is generally where there is insufficient adhesive or pressure to provide the maximum bond strength. Care should be taken to minimize damage to the outer fingers when ripping samples.

X5.1.5 Although there is a correlation between the strength of full size and reduced cross-section specimens, there will be differences between the full and reduced cross-section test results even after compensating for cross-section size and the effect of joint size on strength. See, for example, Kent and Leichti (2005)⁴ regarding reduced cross-section specimens.

X5.2 Guidelines

X5.2.1 The following are guidelines for developing test procedures for reduced cross-section specimens:

X5.2.1.1 The specimen preparation procedures should note whether the procedures apply to either horizontal or vertical profile joints.

X5.2.1.2 The reduced cross-section specimen dimension should be specified in advance for each full cross-section size and maintained for the test program. How the reduced cross-section specimens are extracted from the larger specimens should be described.

X5.2.1.3 In the case of finger joints, it is recommended that at least one, but preferably both outer fingers (in the case of horizontal profile joints) be retained in each reduced cross-section test specimen. The minimum specimen dimension in the direction of the profile should be at least two times the pitch so at least one whole finger is retained on either side of the joint.

X5.2.1.4 Bending specimens shall have sufficient length to be tested in accordance with the bending test method specified these test methods.

X5.2.1.5 Tension specimens shall have sufficient length to be tested in accordance with the axial tension test method specified in these test methods, except that the clear distance between the grips may be reduced to four times the larger specimen cross-section dimension plus the joint length.

⁴ Kent, S.M., and Leichti, R.J., "An Assessment of Common Tests Methods to Evaluate the Mechanical Properties of Structural End-Jointed Lumber," *Forest Products Journal*, Vol 55, No. 3, 2005, pp. 32–39.

X6. ADHESIVES

X6.1 Exterior Exposure

X6.1.1 Adhesives used to bond structural wood products are designed for exterior applications, which typically do not include below-ground, ground-contact or marine service application. The adhesives typically conform to the requirements of Specification **D2559** or the appropriate section of the CSA O112 Series M standards for wood adhesives, or both. Exterior adhesives are typically evaluated based on their:

X6.1.1.1 Resistance to compressive shear loading, under both wet and dry conditions.

X6.1.1.2 Resistance to delamination during accelerated exposure to wetting and drying.

X6.1.1.3 Resistance to deformation under static shear loading during exposure to high humidity or a combination of heat and high humidity.

X6.1.1.4 Resistance to mold.

X6.1.1.5 Resistance to bacteria.

X6.2 Other Exposure Conditions

X6.2.1 Structural wood products may be exposed to other conditions that require further evaluation such as:

X6.2.1.1 Elevated temperature (at or below wood charring temperatures).

X6.2.1.2 Wood preservatives.

- X6.2.1.3 Heat aging.
- X6.2.1.4 Freeze-thaw.
- X6.2.1.5 Ultraviolet (UV) cycling.
- X6.2.1.6 Salt water, that is, marine exposure.
- X6.2.1.7 Chemical attack or pH exposure.
- X6.2.1.8 Ground contact, that is, mold and bacteria.

X6.3 Applicability to End-Joints

X6.3.1 Adhesive test standards are normally based on evaluation of face-bonded specimens or assemblies, whether it is for strength, durability or creep resistance. The primary intent of these standards is to evaluate the adhesive, as opposed to the bonded product. Although the test conditions (that is, face bonding) may not always be directly applicable to the end product (that is, end-jointing), the information can be used to infer the bondline performance, provided appropriate product specific testing in the form of qualification and ongoing quality control testing is carried out to ensure that a quality bondline has been manufactured. For example, this may consist of product specific testing that ensure that the fit of the joint is good and that failure, when it does occur, predominantly occurs in the wood substrate. In other words, the end-joint will behave in a manner like the unjointed wood substrate even under overload or extreme exposure conditions. Traditionally, this is how the adhesive and product standards have been used to assure acceptable long-term performance or performance under extreme conditions. This is necessary particularly when the performance under extreme conditions can only be practically demonstrated by accelerated test methods. Alternatively, where extreme exposure conditions can be duplicated in a test, it may be possible to set minimum performance levels that are dictated by the adhesive.

X6.3.2 It is recognized that because adhesive test standards are based on face-bonded specimens, the working properties of the adhesive tested may differ from that used for end-joint

bonding. Variations in the adhesive formulation to accommodate end-uses and manufacturing plant conditions are acceptable provided the intent of the adhesive test standards are met with the various formulations. Under these conditions, it is important to document the formulations that fall under the family of adhesives that have been qualified to the applicable adhesive test standard. In the event of performance concerns not related to the manufacture of the bondline but which are related to the basic properties of the adhesive, users of the adhesive in similar applications can be contacted.

X6.4 Adhesive Specifications and Test Standards

X6.4.1 *ASTM Standards:*²

D1151	Practice for Effect of Moisture and Temperature on Adhesive Bonds
D1183	Practices for Resistance of Adhesives to Cyclic Laboratory Aging Conditions
D2559	Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions
D3434	Test Method for Multiple-Cycle Accelerated Aging Test (Automatic Boil Test) for Exterior Wet Use Wood Adhesives
D7247	Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures

X6.4.2 *CSA Standards:*⁵

O112.6	Phenol and Phenol-Resorcinol Resin Adhesives for Wood (High-Temperature Curing)
O112.7	Resorcinol and Phenol-Resorcinol Resin Adhesives for Wood (Room- and Intermediate-Temperature Curing)
O112.9	Evaluation of Adhesives for Structural Wood Products (Exterior Exposure)

⁵ Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, <http://www.csa.ca>.

X7. COMMENTARY TO THE TEXT

X7.1 Scope

X7.1.1 This appendix discusses the need for limiting the applicability of this test method to the end-joints corresponding to the descriptions of 3.2 and the assimilation of test methods for end-joints from various grading agencies and ASTM test standards.

X7.2 Limitations to the Applicability of This Test Method

X7.2.1 Generally, if specimens are failing at the edge of the grips, consideration should be giving to disregard the results unless the load level attained exceeds some predetermined target. Under these circumstances, considerations should be given to redesign the grips to reduce stress concentrations at the grip edge.

X7.2.2 The potential variety of end-joint configurations, assembly and cure is very great. The committee felt that the

applicability of this test method is limited to the general types of end-joints currently in use where there is a reasonable body of technical knowledge. It is intended that the descriptions of 3.2 be modified as the knowledge base expands.

X7.3 References Considered

X7.3.1 There were a number of references available for the committee to consider when defining test methods and conditioning cycles in this document. North American references that the committee reviewed were:

- (1) **D1101** Test Methods for Integrity of Adhesive Joints in Structural Laminated Wood Products for Exterior Use
- (2) **D4688** Test Method for Evaluating Structural Adhesives for Finger Jointing Lumber
- (3) **D4761** Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material

(4) **D5456** Standard Specification for Evaluation of Structural Composite Lumber Products

(5) AITC 200-2004 Manufacturing Quality Control Systems Manual for Structural Glued Laminated Timber⁶

(6) NLGA SPS1 Special Products Standard for Finger-joined Structural Lumber⁷

(7) NLGA SPS4 Special Product Standard for Finger-joined Flange Stock Lumber⁷

(8) Glued Lumber Policy⁸

⁶ Available from the American Institute for Timber Construction (AITC), 7012 S. Revere Parkway Suite 140 Centennial, CO 80112, <http://www.aitc-glulam.org>.

⁷ Available from the National Lumber Grades Authority (NLGA), #302 - 960 Quayside Drive, New Westminster, BC V3M 6G2, Canada, <http://www.nlga.org>.

⁸ Available from the American Lumber Standard Committee (ALSC), P.O. Box 210, Germantown, MD 20875-0210, <http://www.alsc.org>.

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