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

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

1.4 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.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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. 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

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.

- D4761 Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Materials
- D7247 Test Method for Evaluating the Shear Strength of 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 Calibration and 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

3.2.5 *finger length, n*—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).

3.2.6 *finger pitch, n*—distance from a point on one finger to a corresponding point on the adjacent finger measured perpendicular to the length of the finger (Fig. 1).

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

3.2.8 *horizontal finger joint, n*—finger joint where the finger profile appears only on the narrow face of the structural wood product.

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

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

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

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

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

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

3.2.15 *scarf joint, n*—end joint formed by a single tapered profile (Fig. 2).

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, n*—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 *end joint, n*—joint formed by adhesive bonding of machined, mated surfaces at the ends of two pieces of a structural wood product.

3.2.2.1 *Discussion*—Typical end joint configurations include finger joints and scarf joints.

3.2.3 *end-joint specimen, n*—assembly including one or more end joints of the structural wood product.

3.2.4 *finger joint, n*—end joint formed by multiple interlocking tapered profiles (“fingers”) (Fig. 1).

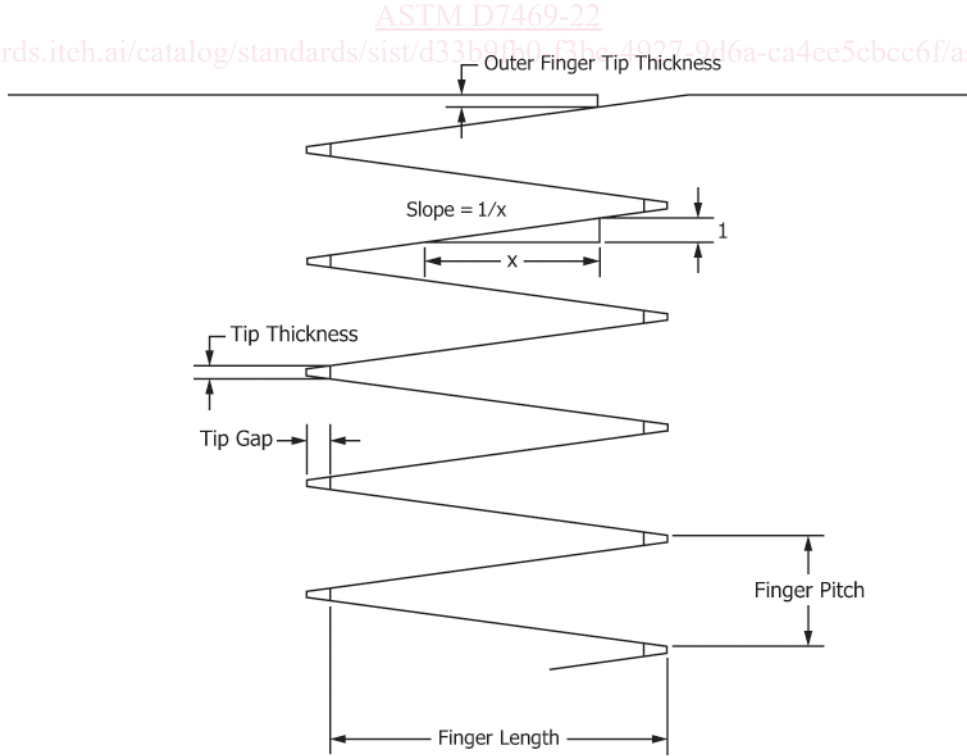


FIG. 1 Finger Joint Profile

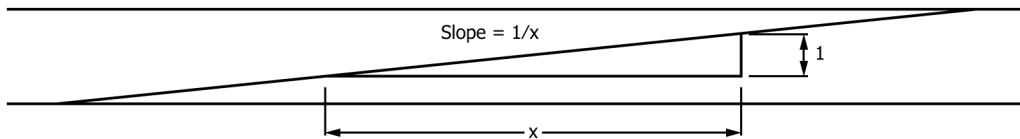


FIG. 2 Scarf Joint Profile

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

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

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

3.2.19 *tip thickness, n*—smallest width of machined finger (Fig. 1).

3.2.20 *vertical finger joint, n*—finger joint where the finger profile appears only on the wide face of the structural wood product.

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. (51 mm).

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 finger-jointed 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 ± 5 °F (70 ± 3 °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 Stickers, 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 ± 5 °F (71 ± 3 °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