Designation: D4688/D4688M – 14

Standard Test Method for Evaluating Structural Adhesives for Finger Jointing Lumber[1]

This standard is issued under the fixed designation D4688/D4688M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is designed to evaluate adhesives for finger jointing lumber used in the manufacture of a variety of bonded structural wood products such as structural glued laminated timber. It tests the tensile strength of joints under the following treatments: dry with no treatment, wet after one vacuum-pressure soak treatment, and wet after cyclic boil-dry treatment.

1.2 This test method is intended neither for quality control as the test assemblies are selected for the absence of defects usually found in run-of-the-mill finger joints nor as a substitute for in-plant qualification of end joints, including full-scale joint tests.

NOTE 1—This test method is specifically designed to evaluate adhesives for use in finger jointing lumber using small scale test specimens cut from carefully selected finger joint assemblies. In contrast, plant qualification and quality control require tests of full scale end joints selected randomly from production, designed to evaluate parameters beyond adhesive performance which affect the performance of the end use product.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D907 Terminology of Adhesives

D2559 Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions

D5266 Practice for Estimating the Percentage of Wood Failure in Adhesive Bonded Joints

E4 Practices for Force Verification of Testing Machines

3. Terminology

3.1 *Definitions*—Many terms in this test method are defined in Terminology D907.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *billet, n*—a piece cut from a vertical finger joint assembly as an intermediate step in making specimens.

3.2.2 *horizontal finger joint, n*—a joint formed by bonding two precut members shaped like fingers where the profile is visible on the edge of the lumber (see Fig. 1a).

3.2.3 *vertical finger joint, n*—a joint formed by bonding two precut members shaped like fingers where the profile is on the wide face of the lumber (see Fig. 1b).

3.2.4 *finger joint assembly, n*—a short portion of two boards joined at their ends by an adhesively bonded finger joint to create a longer piece, frequently referred to as an *assembly*.

3.2.5 *sample, n*—a group of finger joint assemblies obtained from a finger joint production line or laboratory prepared finger joints selected for statistical purposes.

3.2.6 *specimen, n*—an individual test piece prepared to specific dimensions for the purpose of determining the adhesive performance in accordance with the tension tests described in this test method.

4. Significance and Use

4.1 This test method is specifically designed to measure the performance of adhesives in finger joints manufactured under production line conditions.

4.1.1 The test method can be adapted to evaluate the adhesive performance of laboratory produced finger joints using commercial finger joint cutting heads with finger joints produced following the adhesive manufacturers recommendations. The conditions under which the finger joints were produced, including any limitations, are to be reported in 9.1.2.2 (see Note 2).

[1] This test method is under the jurisdiction of ASTM Committee D14 on Adhesives and is the direct responsibility of Subcommittee D14.30 on Wood Adhesives.

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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.

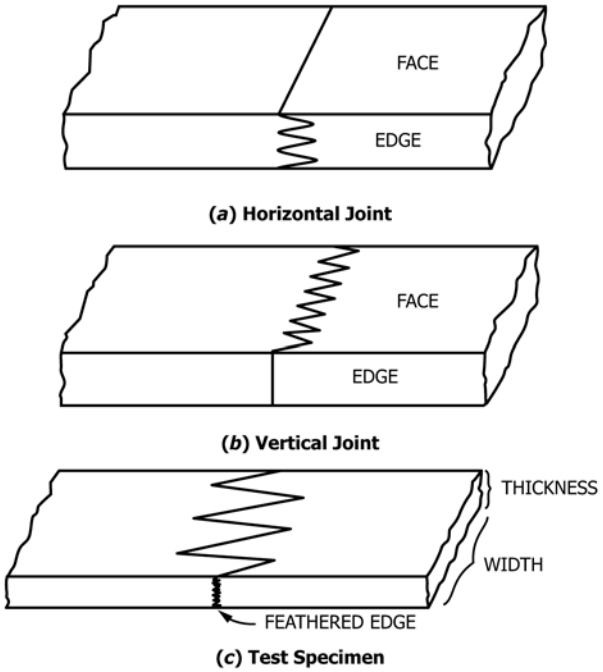


FIG. 1 Finger Joint Assembly and Specimen Descriptions

NOTE 2—If laboratory prepared finger joints are to be produced, record details related to adhesive used, its preparation, application to the cut finger joint, appropriate bonding parameters and limitations in the production of the finger joint assemblies.

4.2 The results of the test method may be used to certify an adhesive as suitable for finger jointing lumber under production line conditions where the intended end use of the finger jointed lumber may be in a variety of bonded structural wood products.

4.2.1 When the test results are to be used for certification of an adhesive a standard wood species shall be used.

4.2.1.1 Standard species may be found in Table 1 of Specification D2559.

5. Apparatus

5.1 *Test Machine,* capable of applying a tensile force, up to 23 kN (5000 lbf), having an accuracy of ±1 % when calibrated in accordance with Practice E4, and equipped with Templin (wedge-action) grips with grip area of 38 by 75 mm [1½ by 3 in.].

5.2 *Vacuum Pressure Vessel,* capable of drawing and holding a vacuum of at least 635 mm [25 in.] of mercury (sea level) for 30 min, holding a pressure of 620 ± 35 kPa (75 ± 2 psi) for 30 min, and capacity to ensure that all of the specimens are at least 50 mm [2 in.] below the water level during the complete vacuum-pressure cycle.

5.3 *Tank for Boiling,* capacity such that all specimens are at least 51 mm [2 in.] below the water level for the duration of the boil cycles.

5.4 *Oven,* capable of operating continuously for 20 h at 63 ± 2°C [145 ± 5°F] with sufficient air circulation to lower the moisture content of the group of specimens from saturation to no more than 8 % within 20 h.

5.4.1 *Timer,* to shut the oven off automatically is desirable.

6. Specimen Preparation

6.1 Obtain a sample consisting of either 20 horizontal or vertical finger joint assemblies from a finger joint production line or, when evaluating laboratory prepared finger joints, from a population of laboratory prepared finger joints. The boards must be nominal 2 by 4-in. or 2 by 6-in.

6.1.1 Identify and record the wood species, joint configuration, average specific gravity and moisture content.

6.2 *Horizontal Joint* (Fig. 1(*a*)):

6.2.1 Joint one face of each assembly until the finger on the surface is feathered as shown in Fig. 1(*c*).

NOTE 3—In the context of this test method, feathering is described as a process where the surface containing the respective vertical or horizontal joint is planed to approximately center of the visible edge of the joint (see Fig. 1(*c*).

6.2.2 Joint one edge of the assembly for end cutting and ripping at a later stage.

6.2.3 Plane the second face of the assembly until the finger on the surface is feathered while maintaining an assembly thickness of about 35-mm [1⅜-in.].

NOTE 4—It is more important to feather the finger than to maintain the 35-mm [1⅜-in.] thickness.

6.2.4 Cut the assembly to a 305-mm [12-in.] length with the finger joint at the center.

6.2.5 Rip individual specimens 6.4-mm [¼-in.] thick from the assembly starting with the jointed edge of the assembly (see 6.2.2) against the saw guide. A thin hollow-ground rip saw blade is preferred but the important criterion is the straightness of the cut.

6.2.5.1 Check cut specimens for uniform thickness throughout. Thickness shall not vary by more than 0.5 mm [0.02 in.].

6.2.5.2 Number the specimens in order from one side of the assembly to the other.

6.3 *Vertical Joint* (Fig. 1(*b*)):

6.3.1 Joint one edge of the finger joint assembly.

6.3.2 Joint one face of the finger joint assembly.

6.3.3 With the jointed edge against the saw guide, rip billets 40 mm [1⁹⁄₁₆ in.] wide from the assembly.

NOTE 5—The 40-mm [1⁹⁄₁₆-in.] dimension is not critical but this dimension must be enough to allow feathering the fingers in subsequent steps.

6.3.4 Joint and plane the sides of each billet so the exposed sides of the fingers are feathered as described in 6.2.1 and 6.2.3.

6.3.5 Rip four individual specimens of 6.4-mm [¼-in.] thickness from each billet of the assembly as in 6.2.5.

6.3.5.1 Number the specimens in order from one side of the assembly to the other. Use the same order for each assembly.

6.4 Inspect specimens for defects. Assemblies yielding specimens that have obvious strength-reducing characteristics such as: low visual density, knots, steep slope of grain, compression wood, compression failures, decay, pitch pockets, or stress risers due to errors in specimen preparation shall be rejected.

6.5 Condition all specimens to equilibrium moisture content (EMC) at 2 ± 2°C [68 ± 3°F] and 65 ± 5 % relative humidity. Monitor the weight of randomly selected specimens periodically to determine when equilibrium is reached.

6.6 Weigh all specimens to the nearest 0.01 g and record the weight. Measure the width and thickness of the specimens to the nearest 0.25 mm [0.010 in.] and record the measurements.

6.7 Randomly assign two specimens from each of the 20 finger joint assemblies in the sample to each test (that is, dry, soak, and boil). (Note this requires only six specimens from each assembly, the other specimens are extra.) Fig. 2 shows the source and distribution of the specimens.

NOTE 6—Thus: 20 assemblies × 2 specimens/assembly = 40 specimens/test.

7. Procedure

7.1 *Dry Test* (No Treatment):

7.1.1 As described in 6.7, assign 40 specimens to this test. Test each specimen in tension to failure by loading at a rate of 5 mm/min [(0.20 in./min]. Maintain a space of 155 ± 6 mm [6 ± 0.25 in.] between the ends of the jaws of the grips. Record the load at failure.

NOTE 7—Be very careful to align the specimen with the principal axis of the test grip. Failure to do this will increase the variability of the results. Markings, spacers on the grips, or some other device is recommended to ensure proper front-to-rear alignment, and a plumb bob or other device is recommended to ensure the vertical alignment.

7.1.2 Determine and record the percentage of wood failure and the failure mode using the criteria given in Annex A1 independent of any knowledge of the strength test result.

7.2 *Cold Water Vacuum-Pressure Soak Test:*

7.2.1 As described in 6.7, assign 40 specimens to this test. Place specimens in a vacuum-pressure vessel with spacers between them so that water has free access to all surfaces. Fill the vessel with tap water at 18.5 to 27.5°C [65 to 80°F] so that all specimens are at least 51 mm [2 in.] below the surface of the water. After filling, seal the vessel and draw a vacuum of at least 635 mm [25 in.] of mercury (sea level). Hold the vacuum for 30 min, then release the vacuum and apply pressure of 620 ± 35 kPa (75 ± 2 psi). Hold this pressure for 2 h, then release. Remove the specimens from the pressure vessel and place them submerged in water at room temperature. Remove the specimens individually from the water, and test while wet within 1 h.

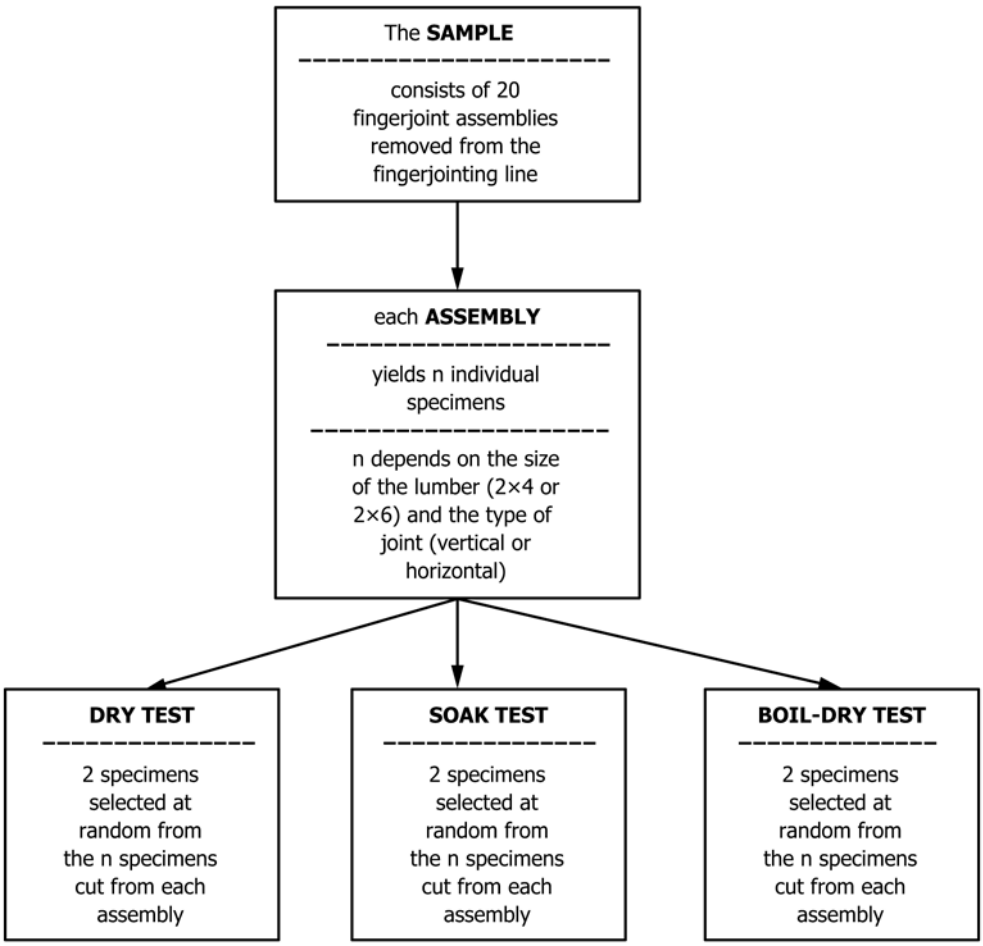


FIG. 2 Flowchart of the Source and Allocation of Individual Test Specimens

7.2.2 Test wet in tension as described in 7.1.1. Record the load at failure.

7.2.3 Dry tested specimens to less than 8 % moisture content, then determine and record the percentage of wood failure and the failure mode as described in 7.1.2.

7.3 *Cyclic Boil Test:*

7.3.1 As described in 6.7, assign 40 specimens to this test. Place specimens in the boil tank with spacers so that water has free access to all surfaces. Fill with water such that the specimens are at least 51 mm [2 in.] below the water level. Boil specimens for 4 h, then dry them in an oven at 63 ± 2°C [145 ± 5°F] with sufficient air circulation to lower the moisture content to ±3 % of their conditioned weight recorded in 6.6 in no more than 20 h.

NOTE 8—The rate of air circulation, the size of the load of specimens in the oven, and the spacing of the specimens greatly affect drying time and the steepness of the moisture gradient in the specimen. Variation of these factors strongly affects the repeatability of the test method. In order to obtain acceptable repeatability (within-laboratory variability) and reproducibility (between laboratories), the drying should be conducted so that the specimens reach ±3 % of their original weight within the same drying period in every test. One way to do this is to monitor the weight of the specimens and adjust the oven vents so the specimens reach the target weight in 15 to 20 h. As an aid, the drying time and airflow required can be established with the extra specimens cut from the 20 assemblies.

7.3.2 Repeat the boil-dry cycle five more times; except during the final cycle do not dry the specimens. Remove the specimens from the boiling vessel and cool in running water at 18 to 27°C [65 to 80°F] for 1 h. Remove the specimens individually from the water, and test while wet within 1 h.

7.3.3 Test wet in tension as described in 7.1.1. Record the load at failure.

7.3.4 Dry tested specimens to less than 8 % moisture content, then determine and record the percentage of wood failure and the failure mode as described in 7.1.2.

NOTE 9—Nonmandatory guidelines for joint performance follow:

Mode 1	An unacceptable failure.
Modes 2 and 3	Unconditionally acceptable failure.
Modes 4, 5, and 6	Conditionally acceptable failure if strength is acceptable.

8. Calculation of Results

8.1 Calculate the tensile stress at failure in megapascals (pounds-force per square inch) as the load at failure in newtons (pounds-force) divided by the cross-sectional area of the specimen provided by the measurements of 6.6.

8.2 Estimate the 25th, 50th, and 75th percentiles for the group of specimens in the following manner:

8.2.1 Arrange the specimens in order of increasing strength.

8.2.2 Estimate the 25th percentile as the average of the 10th and 11th lowest strength values.

8.2.3 Estimate the 50th percentile as the average of the 20th and 21st values.

8.2.4 Estimate the 75th percentile as the average of the 30th and 31st strength values.

8.3 Determine the upper and lower adjacent values (see definition below) for the group of specimens. Determine the outliers (test values outside the range expressed by the upper and lower adjacent values).

25th percentile	=	$Q1$	= the value below which 25 % of the observations fall.
50th percentile	=	$Q2$	= the value below which 50 % of the observations fall.
75th percentile	=	$Q3$	= the value below which 75 % of the observations fall.
Upper adjacent value	=		the largest observation equal to or less than the quantity $Q3 + 1.5(Q3 - Q1)$.
Lower adjacent value	=		the smallest observation greater than or equal to the quantity $Q1 - 1.5(Q3 - Q1)$.
Outliers	=		observations greater than the upper adjacent value or less than the lower adjacent value.

8.4 Calculate the mean and standard deviation. Specimens exhibiting failure mode 6 may be excluded from the calculation. Include specimens with failure modes 1, 2, 3, 4, and 5 in the calculation unless the strength value is an outlier or the wood is of poor quality (such as compression wood, etc.).

9. Report

9.1 Include the following general information in the report:

9.1.1 Complete identification of the adhesive tested including type, source, manufacturers' code numbers, form, and any other pertinent information,

9.1.2 Details of adhesive application, wood species, joint profile, and bonding conditions used to prepare the finger jointed boards,

9.1.2.1 Finger joint production line from which prepared boards were selected, including any additional pertinent information or details relating to the finger joint production line.

9.1.2.2 If laboratory prepared finger joints and finger joint assemblies, details related to type of joints used, their preparation including other pertinent information and any limitations involved with preparation of the finger joint assemblies or evaluation of adhesive performance,

9.1.3 Conditioning procedure used before testing,

9.1.4 Temperature and relative humidity of the test room,

9.1.5 Number of finger joint assemblies represented in the test,

9.1.6 Number of specimens per assembly tested in each test (dry, soaked, and boiled), and

9.1.7 The average load at failure and percentage of wood failure for each assembly tested.

9.2 Include the following statistical information in the report:

9.2.1 The range of test values,

9.2.2 The 25th, 50th, and 75th percentile values,

9.2.3 The upper and lower adjacent values,

9.2.4 Outliers identified by finger joint assembly and specimen number,

9.2.5 Failure mode 6 specimens identified by finger joint assembly and specimen number,

9.2.6 Specimens with defects of material or bonding discovered after testing identified by finger joint assembly and specimen number,

9.2.7 The mean and standard deviation,

9.2.8 The statistical mode (most frequent value) of the observed failure modes, and

9.2.9 The failure mode 1 specimens identified by finger joint assembly and specimen number.

10. Precision and Bias

10.1 A measure of the precision of this test method covering all possible types of finger joints has not been determined. It is unlikely that a precision statement could be determined to cover all possible cases because many factors that affect precision, such as wood species, finger geometry, cutting tool sharpness, the adhesive, and the bonding conditions, are not specified by these test methods. The precision of this test method for a given sample may be compared to any previous test using the parameters listed in 8.2. The precision of this test method for a given sample may also be compared to the precision determined in a series of tests conducted by four laboratories during the development of this test method. A summary of these results, including the sources of variation, is given in Appendix X1. However, it must be remembered that factors beyond the control of this test method affect precision.

10.2 This test method has no bias because the tensile strength of finger joints is defined only in terms of this test method.

11. Keywords

11.1 accelerated aging; billet; failure mode; finger joint; horizontal joint; structural joint; vertical joint

ANNEX

(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.[3]

[3] Consult Practice D5266 for additional guidance.

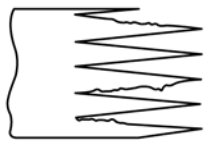
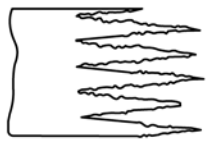
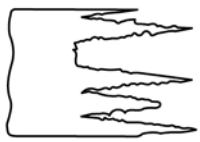
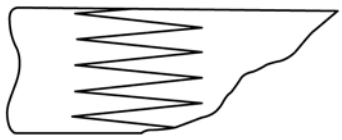
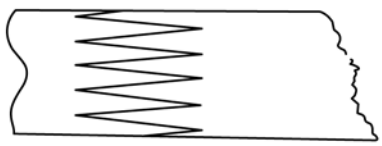
Mode	Description	Example
1	Failure mostly along the bondline surfaces of the joint profile with poor wood failure of any kind (wood failure < 70%).	
2	Failure mostly along the bondline surfaces of the joint profile with good wood shear failure (wood failure > 70%).	
3	Failure mostly along the joint profile 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

APPENDIX

(Nonmandatory Information)

X1. PRECISION AND SOURCES OF VARIABILITY

X1.1 A round-robin study was conducted during the development of the dry, soak, and cyclic boil tests. The study was based on 75 finger-jointed assemblies obtained in a single run from a commercial laminating plant. The jointed assemblies were made with L1 or better laminating grade Douglas fir lumber.[4] The joints were of the horizontal type (Fig. 1), and they were bonded with melamine-urea adhesive. After bonding the assemblies were sent to one laboratory where they were cut into individual specimens. After cutting each assembly was inspected specimen-by-specimen for defects. The 60 best assemblies were selected for actual testing. Each specimen was marked, allocated to one of five participating laboratories, and assigned to a test and trial. Finally the specimens were preconditioned to 12 % EMC before they were sent to the other testing laboratories. All the preparation was done at one laboratory to minimize specimen preparation as a source of variability. Each laboratory conducted three trials of each test using three groups of specimens. No two trials were conducted on the same day. (See Table X1.1.)

TABLE X1.1 Round-Robin Study

Item	Number
Finger joint assemblies	60
Specimens per assembly	15
Total specimens	900
Laboratories	4[A]
Tests	3[B]
Trials per test	3
Specimens within trials	20
Specimens per assembly per trial	1

[A] One of the original five laboratories dropped out.
[B] Dry, soak, and boil.

X1.2 *Results:*

X1.2.1 The results are summarized in Fig. X1.1 with the major breakdown by test. Within a test the results are organized by laboratory and group. The data is represented in the form of Tukey box plots.[5] The horizontal line segment enclosed in the box is the 50th percentile. The horizontal line segments at the top and bottom of the box are the 75th and 25th percentile values, respectively. The horizontal line segments at the ends of the lines extending from the ends of the box are the "adjacent values." Dots above or below the adjacent values are outliers. The *X* inside the box is the mean. The horizontal line extending across all the groups and all the laboratories is the grand mean for the test.

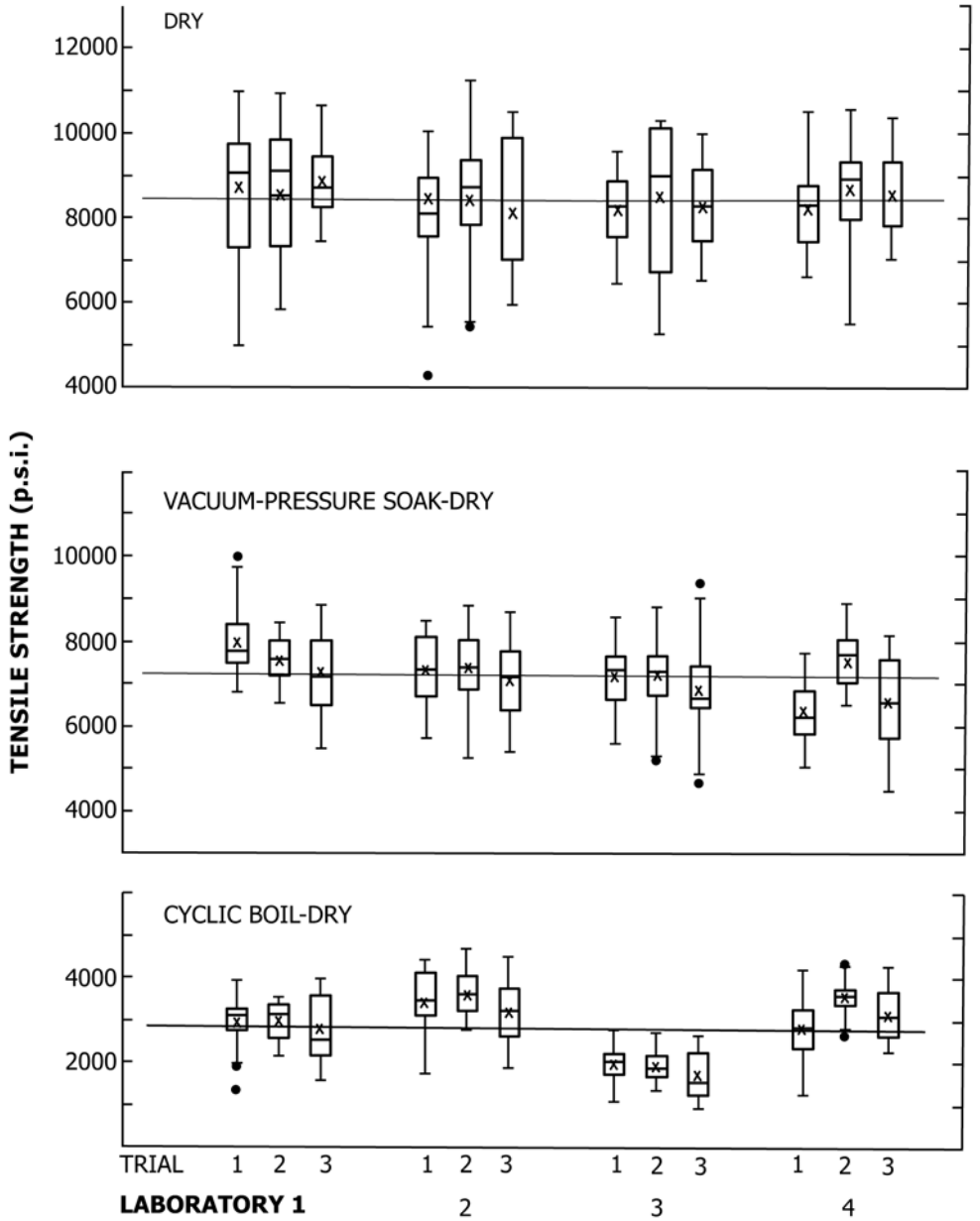
X1.2.2 The dry and soak tests were repeatable (within a laboratory) and reproducible (between laboratories). An analysis of the variance revealed that differences between individual finger joint assemblies accounted for most of the strength variation observed. There were few significant differences between trials of a given test conducted by a given laboratory (repeatability) and none of these differences were of practical significance. Furthermore, differences in equipment or procedure used at the different laboratories did not account for practical differences between the laboratory's results (reproducibility).

X1.2.3 The cyclic boil test was repeatable (within a laboratory) but not reproducible (between laboratories). Differences between individual finger joint assemblies were also an important source of variation in the cyclic boil test. Some differences between trials for a given laboratory were significant, but not of practical importance and the boil test was concluded to be repeatable within a given laboratory where the same equipment and procedure were used from trial to trial. On the other hand, the differences between laboratories were determined to be statistically and practically significant.

NOTE X1.1—This test method was revised to better control conditioning and exposure of specimens after this round-robin study was conducted. The committee anticipates this will improve the reproducibility of results between laboratories.

[4] Standard grading rules for West Coast lumber No. 16. Available from West Coast Lumber Inspection Bureau, P.O. Box 23145, 6980 Varnes Road, Portland, OR 97223.

[5] Cleveland, W. S., and R. McGill, "Graphical Perception and Graphical Methods for Analyzing Scientific Data," *Science*, 229: 828–833, 1985.



NOTE 1—Results obtained by four laboratories conducting three separate trials of the dry, soak, and cyclic boil tests.

FIG. X1.1 Tukey Box Plots