Designation: D4761 – 19

Standard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Materials[1]

This standard is issued under the fixed designation D4761; 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.

INTRODUCTION

Numerous evaluations of the mechanical properties of wood-based structural materials have been satisfactorily conducted since the late 1920s, using Test Methods D198. Those methods are best suited to a laboratory environment and are adaptable to a variety of products such as stress-graded lumber, sawn timber, laminated timbers, wood-plywood composite members, reinforced and pre-stressed timbers.

The procedures presented in these test methods have been derived from those set forth in Test Methods D198. They are intended primarily for application to stress-graded lumber, but can be used for other wood-based structural materials as well. The procedures are more flexible than those in Test Methods D198, making testing in a non-laboratory environment more feasible. Thus the test methods can be used on production sites for field testing and quality control, as well as in laboratories for research applications. Key differences from Test Methods D198 are the testing speed, the deflection-measuring procedures for specimens under load, and the detail of data reporting. Furthermore, the test methods do not require that specimens be loaded to failure.

Since these test methods allow latitude in testing procedures, the procedures used shall be fully documented in the test report. It may also be desirable to correlate the results from tests carried out according to these test methods with test results obtained using a traditional procedure, such as that set forth in Test Methods D198.

1. Scope

1.1 These test methods cover the determination of the mechanical properties of stress-graded lumber and other wood-based structural materials.

1.2 These test methods appear in the following order:

	Section
Bending edge-wise	6
Bending flat-wise:	
Center-point loading	7
Third-point loading	8
Axial strength in tension	9
Axial strength in compression	10

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

1.4 *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.*

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

D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

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

[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.

Current edition approved April 1, 2019. Published May 2019. Originally approved in 1988. Last previous edition approved in 2018 as D4761 – 18. DOI: 10.1520/D4761-19.

[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.

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

2.2 *Other Document:*[3]

NIST Voluntary Product Standard PS20 American Softwood Lumber Standard

NOTE 1—The current version of PS20 is given as an example of a product standard applicable to stress-graded lumber. Other product standards may apply to stress-graded lumber. For wood-based structural materials other than stress-graded lumber, relevant product standards may apply.

3. Terminology

3.1 *Definitions*—See Terminologies D9 and E6 and Practices E4 and E177 for definitions of terms used in these test methods.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *breadth—in a bending test*, that dimension of the specimen in the direction perpendicular to the span and perpendicular to the direction of an applied load.

3.2.2 *depth—in a bending test*, that dimension of the specimen in the direction perpendicular to the span and parallel to the direction of an applied load.

3.2.3 *span—in a bending test*, the distance between the center lines of the pivot points upon which the specimen is supported to accommodate a transverse load.

4. Significance and Use

4.1 These test methods provide procedures that are applicable under true field conditions, such as in a plant with specimens not at moisture equilibrium.

4.2 The data established by these test methods can be used as follows:

4.2.1 Develop strength and stiffness properties for the population represented by the material being tested (that is, individual grades, grade combinations, species, species groups, or any other defined, identifiable sample).

4.2.2 Confirm the validity of strength and stiffness properties for the population represented by the material being tested.

4.2.3 Investigate the effect of parameters that have the potential to influence the strength and stiffness properties of the material, such as moisture content, temperature, knot size and location, or slope of grain.

4.3 The procedures chosen in accordance with these test methods shall be fully documented in the report to facilitate correlation with test results obtained through the use of traditional procedures, such as those set forth in Test Methods D198.

5. Precision and Bias

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

[3] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

6. BENDING EDGE-WISE—THIRD-POINT LOADING

6.1 *Scope*

6.1.1 This test method provides procedures for the determination of the strength and modulus of elasticity of stress-graded lumber and other wood-based structural materials in bending edge-wise, where the member depth is typically greater than or equal to the member breadth.

NOTE 2—The use of the terms “edge-wise” and “flat-wise” in these test methods are intended to refer to the geometric limitations described above. They are not intended to mandate that the “joist,” “edge,” “flat,” or “plank” orientation of a composite product needs to be tested using a specific specimen geometry or protocol.

6.2 *Summary of Test Methods*

6.2.1 The specimen is simply supported and loaded by two equal transverse concentrated loads equidistant from the reaction points and each other. The specimen is loaded at a prescribed rate until failure occurs or a pre-selected load or deflection is reached. The load and corresponding deflection are recorded when bending stiffness is to be determined. Only the load is measured if the objective of the test is to determine the specimen strength.

6.3 *Apparatus*

6.3.1 *Testing Machine*—A device that combines (*1*) a reaction frame to support the specimen, (*2*) a loading mechanism for applying load at a specified rate, and (*3*) a force-measuring apparatus that can be calibrated to the accuracy requirements of 6.3.3.2 following the procedures outlined in Practices E4.

6.3.1.1 *Load and Reaction Apparatus*—The load and reaction apparatus shall include bearing plates at the load and reaction points that are at least as wide as the specimen breadth and not exceeding the member depth in length. These bearing plates shall have eased edges and sufficient bearing length to avoid a localized crushing failure at the load and reaction points. The apparatus shall also include appropriate mechanisms, such as rollers, to minimize the development of axial forces in the specimen. Each load and reaction point shall include an in-plane pivot point. Bearing plates and rollers shall be initially centered about their pivot points.

6.3.1.2 *Loading Configuration*—The specimen shall be simply supported and loaded by two equal transverse concentrated loads equidistant from the reaction points and each other.

NOTE 3—The apparent modulus of elasticity varies for different loading configurations (see Practice D2915). While the loading configuration that commonly serves as the basis for design assumes a uniformly distributed load, a configuration with two concentrated loads symmetrically placed within the span is usually more suitable for structural tests to determine bending capacity and develop related design values. This configuration also produces a constant bending moment, free of shear, in the portion of the specimen between the load points.

6.3.1.3 *Lateral Supports*—When necessary to restrict specimen out-of-plane displacement, lateral supports shall be used. Specimens having a depth-to-breadth ratio of three or greater are subject to lateral instability during loading and shall be evaluated for adequate lateral support. Any provided lateral supports shall restrain out-of-plane displacement, but allow movement of the specimen in the direction of load application with minimal frictional or other in-plane restraint.

6.3.2 *Deflection-Measuring Apparatus*—A measurement device shall be used to monitor the deflection of the specimen when the bending stiffness is to be determined. Deflection shall be permitted to be measured directly as the displacement of the loading head of the testing machine or as direct measurement of the specimen movement relative to the reaction frame at mid-span. In the former case, deflection is expressed as the average displacement of the load-bearing plates with respect to the reaction-bearing plates. If, because of the design of the apparatus, the deflection measurement includes extraneous components, the deflection data shall be permitted to be adjusted for such extraneous components. However, if the extraneous components are an appreciable portion of the total measurement, then the test apparatus shall be re-examined for its suitability. In all instances, the report shall include a complete description of test conditions, extraneous components, and data adjustment procedures.

NOTE 4—Possible sources of extraneous components of deflection with either measurement type might include: flexure of the load and reaction frame components, slack or looseness in the fixture connections, crushing of the material surface at the bearing plates, and/or geometric imperfections of the tested material. These factors typically result in an overestimation of the member deflection and a conservative underestimation of the measured stiffness. Provided test results with extraneous components are repeatable over the range of materials typically tested, adjustment factors to remove this bias may be developed based upon matched correlations for similar tests of similar materials using Test Methods D198. As an alternative, a mid-span yoke-mounted deflection device similar to that described by Test Methods D198 may be used with these procedures to improve accuracy and mitigate the need for adjustment.

6.3.3 *Accuracy:*

6.3.3.1 The two load points shall be located within ±1⁄16 in. (1.6 mm) of the position determined in accordance with 6.3.1.2 and 6.4.2.2.

6.3.3.2 The force-measuring apparatus shall be such as to permit load measurements with an error not to exceed ±1.0 % of the load for loads greater than or equal to 1000 lbf (4450 N). For loads smaller than 1000 lbf, the error shall not exceed ±10 lbf (45 N).

6.3.3.3 The deflection-measuring apparatus shall be such as to permit deflection measurements with an error not to exceed ±1.0 % of the deflection with deflections greater than or equal to 0.150 in. (4 mm).

NOTE 5—Bending stiffness estimates obtained from total specimen deflections of 0.150 in. (4 mm) or less have a significant measurement error component and are not recommended.

6.3.3.4 The cross-sectional dimensions of the member shall be measured to at least three significant figures.

6.4 *Specimen*

6.4.1 *Cross Section*—Unless the effect of cross-section modifications is a test evaluation objective, the specimen shall be tested without modifying the dimensions of the commercial cross section.

6.4.2 *Length:*

6.4.2.1 The minimum specimen length shall be the span, determined in accordance with 6.4.2.2, plus an extension beyond the center lines of the end reactions, such that the specimen will not slip off the bearing plates at the end reactions during the test. In cases where the unsupported specimen length outside the span at an end reaction (overhang) exceeds ten times the specimen depth, report the amount of overhang at each end reaction.

6.4.2.2 The span depends on the purpose of the test program. It is customary to express the span as a multiple of the specimen depth. While spans that currently serve as a basis suitable for testing range from 17 to 21 times the depth of the specimen, other spans shall be permitted.

NOTE 6—Practice D2915 gives an indication of the impact that varying span-to-depth ratios have upon the measured member stiffness. The depth in this section refers to the relevant size specified in the size classification of the applicable product standard. As an example for stress-graded lumber, the depth used to determine the span will typically be the dressed dry size specified in the size classification of the current version of PS20. For example, 3.5 in. (89 mm) should be used to calculate the span-to-depth ratio for members with a nominal depth of 4 in.

6.4.3 *Conditioning*—Specimens shall be permitted to be tested as produced or conditioned (for example, temperature, moisture content, or treatment), depending on the purpose of the test program. If the temperature of the specimens at the time of testing is less than 45 °F (7 °C) or more than 90 °F (32 °C), that temperature shall be reported.

6.5 *Procedure*

6.5.1 *Specimen Measurements:*

6.5.1.1 Before testing, measure and record the cross-sectional dimensions of every specimen at the center of the span unless another location is more appropriate to the purpose of the test.

6.5.1.2 Following the test, measure the moisture content of the specimens at a location away from the ends 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. The number of moisture content samples shall be determined using Practice D7438 guidelines, with consideration of the expected moisture content variability, and any related requirements in the referenced product standards.

6.5.2 *Lengthwise Positioning*—The positioning of the specimen across the span with respect to specific specimen characteristics shall be addressed by a within-piece sampling plan for the test program. The procedure shall be documented and the resulting specimen length shall comply with the provisions of 6.4.2. The plan shall also detail how the tension edge is selected.

NOTE 7—Two possible approaches used for lengthwise positioning may be to locate the specimen across the span without bias regarding defects or to locate specific defects near the center of the span and to deliberately or randomly position a defect at the tension or compression side of the specimen, depending upon the test objectives.

6.5.3 *Speed of Testing*—The test rate shall be such that the sample target failure load is achieved in approximately 1 min. It is recommended that the failure load be reached in not less than 10 s nor more than 10 min.

NOTE 8—Some caution is warranted here. A test rate to achieve the average failure load for the sample in approximately 1 min will differ from that to achieve a lower percentile load for the same sample in approximately 1 min.

NOTE 9—For stress-graded lumber, a rate of motion of the testing machine loading head of approximately 3 in. (76 mm)/min will usually permit the test to be completed in the prescribed time for span-to-depth ratios of 17:1 and in cases where the target failure load is the average failure load for the sample.

6.5.4 *Load-Deflection Data*—Obtain load-deflection data, if required, using the apparatus specified in 6.3.2.

NOTE 10—Load and deflection data should be captured to define the linear stiffness and at least include the design load range of the product being tested. Capturing the data from 10 to 40 % of the expected maximum load is typically sufficient to achieve this goal. For stress-graded lumber, data obtained for loads corresponding to maximum stresses in the specimen ranging from 400 to 1000 psi (3 to 7 MPa) will usually be adequate for stiffness calculations.

6.5.5 *Maximum Load*—If the purpose of the test is to determine strength properties, record the maximum load attained in the test.

NOTE 11—In proof loading, the intended load target may not be reached or may be exceeded slightly. The target load should be reported along with the actual attained load.

6.5.6 *Record of Failure*—For a destructive test, describe the characteristic causing failure, and its location within the span.

NOTE 12—An example of a coding scheme for recording characteristic type and failure location in stress-graded lumber is given in Appendix X1.

6.6 *Report*

6.6.1 The report content depends on the purpose of the test program. The report shall include, at the minimum, the following information:

6.6.1.1 Description of the testing machine, including a drawing or photograph of the test setup, the span, fixturing, and the deflection-measuring apparatus, if applicable.

6.6.1.2 Description of calibration procedures, frequency, and records.

6.6.1.3 Method used for the measurement of the moisture content of specimens.

6.6.1.4 Speed of testing and means of control of the speed of testing.

6.6.1.5 Specimens lengthwise positioning and selection of the tension edge.

6.6.1.6 As applicable, the type of load-deflection data for the calculation of the stiffness of specimens, including a description of test conditions, extraneous components, and data adjustment procedures in accordance with 6.3.2.

6.6.1.7 Description of the population sampled, in accordance with Practice D2915.

6.6.1.8 Description of the sample, including (*1*) sample size, (*2*) conditioning, if applicable, (*3*) temperature of specimens at the time of testing, and (*4*) number of specimens that failed during the test.

6.6.1.9 Data on specimens, including, as applicable, (*1*) grade, (*2*) actual cross-sectional dimensions, (*3*) moisture content, (*4*) overhang in accordance with 6.4.2.1, (*5*) load-deflection data, (*6*) maximum load, (*7*) time to maximum load, and (*8*) failure description and location.

NOTE 13—The Appendices of Test Methods D198 provide equations that may be employed to further convert this data into modulus of rupture, modulus of elasticity, and other useful normalized quantities depending upon the test objectives.

6.6.1.10 Details of any deviations from the prescribed or recommended procedures as outlined in this test method.

7. BENDING FLAT-WISE—CENTER-POINT LOADING

7.1 *Scope*

7.1.1 This test method provides procedures for the determination of long-span modulus of elasticity of lumber and other wood-based structural materials in flat-wise bending under center-point load, where the member breadth is typically greater than the member depth (Note 2).

7.2 *Determination of Long-Span Modulus of Elasticity*

7.2.1 Long-span modulus of elasticity (E) is defined as the modulus of elasticity calculated from deflection measured in a flat-wise test with center point loading and a span-depth ratio (L/h) of approximately 100 ± 10.

NOTE 14—The long-span E is sometimes used to estimate the member modulus of elasticity with minimized influence from shear deflection.

7.3 *Summary of the Test Method*

7.3.1 A known concentrated transverse load is applied at mid-span of a simply supported specimen oriented flatwise. A displacement measurement device is used to determine the deflection of the specimen under the load. The modulus of elasticity (E) is determined by relating the applied load and deflection to the size of specimen and the span.

7.4 *Apparatus*

7.4.1 *Support System*—Any support system shall be permitted that provides unrestrained support at both end reactions. The reaction point at one end shall be constructed so that stability is provided for a piece of twisted lumber, such as a pedestal with a single point reaction, a reaction point that is designed to tilt to match the twist of the lumber, or special shims that restrain the specimen from rocking on the reaction supports. Each load or reaction point shall include an in-plane pivot point. Bearing plates, when employed, shall be initially centered about their pivot points.

7.4.2 *Accuracy*

7.4.2.1 *Span*—The load point shall be located within ±1⁄16 in. (1.6 mm) of the position determined in accordance with 7.2.1 and 7.5.1.

7.4.2.2 *Test Loads*—Weights used for test loads shall be compact and known to an accuracy of ±0.05 lbm (23 g).

7.4.2.3 *Deflection-Measuring Apparatus*—The specimen deflection shall be measured using a device with the capacity to measure displacement up to at least 1 in. (25 mm) with an accuracy of ±1%.

7.4.2.4 The cross-sectional dimensions of the member shall be measured to at least three significant figures.

7.4.3 A weight of approximately 5.0 lbm. (2.3 kg) shall be used for pre-loading. Further weights in 5.0 or 10.0 lbm. (2.3 to 4.5 kg) increments shall be used to apply test loads.

NOTE 15—Three 5-lbm. (2.3 kg) weights and one 10-lbm. (4.5 kg) weight have been found to provide an adequate combination of weights for nominal 2 by 4 through nominal 2 by 12 surfaced dimension lumber sizes.

7.5 *Specimen*

7.5.1 *Cross Section*—Unless the effect of cross-section modifications is a test evaluation objective, the specimen shall be tested without modifying the dimensions of the commercial cross section.

7.5.2 *Length*—The minimum specimen length shall be the span, determined in accordance with 7.6.2 plus an extension beyond the center lines of the end reactions, such that the specimen will not slip off the bearing plates at the end reactions during the test.

7.5.3 *Conditioning*—The procedures of 6.4.3 shall be followed.

7.6 *Procedure*

7.6.1 *Specimen Measurements*—The procedures of 6.5.1 shall be followed.

7.6.2 Space the reaction points to provide a span-to-depth ratio for the specimen of approximately 100 ± 10 for use in the calculation of the modulus of elasticity. The span used shall be recorded.

7.6.3 Place the displacement measurement device midway between the reaction points and adjust it so the downward deflection of the specimen can be measured when loaded. Construct or arrange the apparatus such that the relative position of the deflection measurement device to the reaction points is not changed more than 0.001 in. (0.025 mm) when the load weight is placed on the specimen.

7.6.4 Place the specimen flatwise on the reaction points and in firm contact with both end reactions.

7.6.5 Apply the 5.0 lbm (2.3 kg) pre-load weight to the specimen at or near mid-span and either tare the deflection measurement device or take an immediate reading.

7.6.6 Load the specimen at mid-span and immediately take a deflection measurement device reading. This load shall be such that it will induce approximately 0.2 in. (5 mm) or more deflection.

7.6.7 Determine and record the deflection of the specimen due to the load applied in 7.6.6.

7.6.8 Long-span modulus of elasticity is determined using the following equation:

$$E = PL^3/(48\Delta I)$$

where:

E = modulus of elasticity, psi (MPa),
P = increment of applied load in 7.6.6, lbf (N),
L = span, in. (mm),
Δ = increment of deflection from 7.6.7 corresponding to the increment of applied load, in 7.6.6, in. (mm), and
I = moment of inertia, in.^{4} (mm^4).

7.7 *Report*

7.7.1 The content of the report depends on the purpose of the test program. The report shall include, at the minimum, all applicable information as presented in 6.6.

8. BENDING FLAT-WISE—THIRD-POINT LOADING

8.1 *Scope*

8.1.1 This test method provides procedures for the determination of bending strength and stiffness of stress-graded lumber and other wood-based structural materials in flat-wise bending on short spans under third-point load, where the member breadth is typically greater than the member depth (Note 2).

8.2 *Summary of the Test Methods*

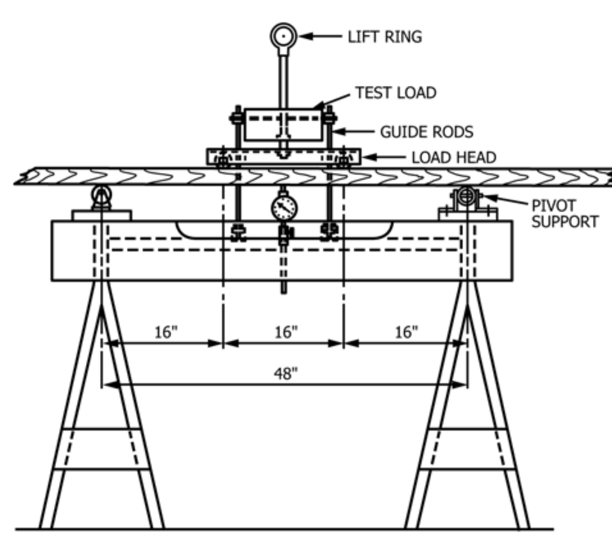
8.2.1 The specimen is simply supported and loaded on the wide face by two equal transverse concentrated loads equidistant from the reaction points and each other. The specimen is loaded at a prescribed rate until failure occurs or a pre-selected load or deflection is reached. The load and corresponding deflection are recorded when bending stiffness is to be determined. Only the load is measured if the objective of the test is to determine or verify the specimen strength.

8.2.2 If the data collection is only to determine specimen stiffness, then a step-wise load shall be permitted that includes pre-loading and then adding a known weight for deflection measurement.

8.3 *Apparatus*

8.3.1 *Testing Machine*—A device that combines (*1*) a reaction frame to support the specimen; (*2*) a loading mechanism for applying load at a specified rate or prescribed load interval; and (*3*) a force-measuring apparatus that can be calibrated to the requirements of 8.3.3.2, following the procedures outlined in Practices E4. If the test is used only to determine member bending stiffness using known weights, then a force-measuring device is not specifically required. Fig. 1 illustrates the traditional device meeting the requirements of these test methods for bending stiffness measurement using a known test load.

8.3.1.1 *Load and Reaction Apparatus*—The load and reaction apparatus shall include bearing plates at the load and reaction points that are at least as wide as the specimen breadth and not exceeding the member depth in length. These bearing plates shall have eased edges and sufficient bearing length to avoid a localized crushing failure at the load and reaction points. The apparatus shall also include appropriate mechanisms, such as rollers, to minimize the development of axial forces in the specimen. Each load and reaction point shall include an in-plane pivot point. If only the bending stiffness is to be determined in accordance with 8.2.2, then roller support surfaces similar to those depicted in Fig. 1 are permitted in



16 in. = 410 mm
48 in. = 1220 mm
This device is used for assessment of bending stiffness in third-point, flat-wise bending on a span-to-depth ratio of 32 for 1½-in. (38-mm) thick lumber.

FIG. 1 Schematic of Static Third-Point Bending Testing Device

place of bearing plates. Bearing plates, when employed, shall be initially centered about their pivot points.

8.3.1.2 *Loading Configuration*—The simply supported specimen shall be subjected to two equal transverse concentrated loads equidistant from the reaction points and each other (Note 3).

8.3.1.3 If an incremental load system is used for bending stiffness measurement in accordance with 8.2.2, then the pre-load shall be sufficient to force the specimen into contact with the supports, firmly seat moveable parts, and produce sufficient deflection to permit establishing the base for the incremental measurement. The known incremental load used for the stiffness determination shall be of sufficient magnitude to produce deflection greater than 0.050 in. (1.3 mm)

NOTE 16—In North American practice, these incremental loads are selected to give deflections ranging from 0.070 in. (1.8 mm) to 0.210 in. (5.3 mm), with a minus tolerance of approximately 10 %, at respective E levels of 1.0 and 3.0×10^6 psi (6.9 GPa and 21 GPa) for dimension sizes ranging from 2 by 3 to 2 by 10 (38 by 63 to 38 by 235 mm).

8.3.1.4 Deflections in the load and reaction apparatus shall be measured to determine that either they are negligible or that calibration of the system can compensate for the deflections. (See also 8.3.2.)

NOTE 17—As the span/depth ratio decreases, the magnitude of the applied load must be increased to produce deflections in the range required by 8.3.1.3. Stability of the applied load is a safety consideration in design of the apparatus. For high loads, the applied loads may need to be hung rather than supported as shown in Fig. 1. These higher loads may also increase deflections in the support apparatus.

8.3.2 *Deflection-Measuring Apparatus*—A measurement device shall be used to monitor the deflection of the specimen when bending stiffness is to be determined. Deflection is permitted to be measured directly as the displacement of the loading head of the testing machine or as direct measurement of the specimen movement relative to the support frame at mid-span. In the former case, deflection is expressed as the average displacement of the load-bearing plates with respect to the reaction bearing plates. If, because of the design of the apparatus, the deflection measurement includes extraneous components, the deflection data is permitted to be adjusted for such extraneous components (Note 4). In all instances, the report shall include a complete description of test conditions, extraneous components, and data adjustment procedures.

8.3.3 *Accuracy:*

8.3.3.1 The two load points shall be located within ±1⁄16 in. (1.6 mm) of the position determined in accordance with 8.3.1.2 and 6.4.2.2.

8.3.3.2 The force-measuring apparatus, when used, shall be such as to permit load measurements with an error not to exceed ±1.0 % of the load. When known weights are used to measure the bending stiffness through incremental loading, these weights shall be calibrated to within ±1 % of the stipulated value.

8.3.3.3 The deflection-measuring apparatus shall be such as to permit deflection measurements with an error not to exceed ±1.0 % of the deflection for deflections greater than or equal to 0.150 in. (4 mm) (Note 5).

8.3.3.4 The cross-sectional dimensions of the member shall be measured to at least three significant figures.

8.4 *Specimen*

8.4.1 *Cross Section*—Unless the effect of cross-section modifications is a test evaluation objective, test the specimen without modifying the dimensions of the commercial cross section.

8.4.2 *Length:*

8.4.2.1 The minimum specimen length shall be the span, determined in accordance with 6.4.2, plus an extension beyond the center lines of the end reactions to accommodate the bearing plates, such that the specimen will not slip off the end reactions during the test. The specimen length and selected span shall be reported.

NOTE 18—It is common for a flatwise bending test for nominal 2 in. (38 mm) lumber to be conducted using a span that is 32 times the actual depth. Other span/depth ratios may also be used. Because this method is a short-span test, the specimen length will often exceed the minimum length required in 8.4.2.1.

8.4.2.2 In cases where the unsupported specimen overhang exceeds ten times the specimen depth, report the amount of overhang at each end reaction.

8.4.2.3 If this method is used to determine bending strength, then specimen length shall be adjusted after the span location is determined in accordance with 8.5.2.1 to provide equal overhangs at both end reactions.

8.4.2.4 If this method is used for bending stiffness only, then unequal overhangs shall be permitted. A weight shall be permitted to be placed directly over a support to stabilize the specimen where a long off-centered overhang is present.

8.4.3 *Conditioning*—The procedures of 6.4.3 shall be followed.

8.5 *Procedure*

8.5.1 *Specimen Measurement*—The procedures of 6.5.1 shall be followed.

8.5.2 *Test Setup:*

8.5.2.1 *Lengthwise Positioning*—The positioning of the specimen across the span with respect to specific specimen characteristics shall be addressed by a within-piece sampling plan. The procedure shall be documented and the resulting specimen length shall comply with the provisions of 8.4.2. The plan shall also detail how the tension edge is selected (Note 7).

8.5.3 *Speed of Testing:*

8.5.3.1 *Strength and Stiffness by Continuous Loading*—The practices of 6.5.3 shall be followed.

8.5.3.2 *Stiffness Determination by Incremental Loading Test*—If the incremental loading method is used, a pre-load shall be applied, followed by the incremental load. Loads shall be applied and deflections recorded rapidly to prevent the influence of creep.

NOTE 19—It is common North American practice to complete the pre-load, deflection device reading or tare, prescribed load application, and the incremental deflection measurement within approximately 6 s.

8.5.4 *Load-Deflection Data:*

8.5.4.1 *Strength and Stiffness by Continuous Loading*—Obtain load-deflection data, as required, using the apparatus specified in 8.3.2 (Note 10).

8.5.4.2 *Stiffness Determination by Incremental Loading Test*—A deflection reading shall be taken or the device tared immediately after the pre-load application. A reading shall also be taken immediately after the incremental load application. The difference between the two readings shall be used for the determination of stiffness.

8.5.5 *Maximum Load*—If the purpose of the test is to determine strength properties, record the maximum load attained in the test (Note 11).

NOTE 20—In proof loading, the intended load target may not be reached or may be exceeded slightly. For some applications, it is recommended that both the actual attained load and the target load be recorded.

8.5.6 *Record of Failure*—For a destructive test, describe the characteristic causing failure, and its location within the span (Note 12).

8.6 *Report*

8.6.1 The content of the report depends on the purpose of the test program. The report shall include, at the minimum, all applicable information as outlined in 6.6.

9. AXIAL STRENGTH IN TENSION

9.1 *Scope*

9.1.1 This test method provides procedures for the determination of the axial tensile strength of stress-graded lumber and other wood-based structural materials.

9.2 *Summary of the Test Method*

9.2.1 The specimen is subjected to an axial tensile load applied near its ends. The specimen is loaded at a prescribed rate and the load is measured until failure occurs or a preselected load is reached.

9.3 *Apparatus*

9.3.1 *Testing Machine*—The test machine shall combine (*1*) a loading mechanism for applying an axial tensile load at a specified rate, and (*2*) a force-measuring apparatus that can be calibrated to the accuracy requirements of 9.3.3 following procedures outlined in Practices E4.

9.3.2 *Grips or Clamping Devices*—Tensile loads from the testing machine shall be transferred to the specimen such that (*1*) the specimen damage due to clamping is minimized, and (*2*) slippage is minimized during load application.

9.3.2.1 *Distance Between Grips*—The clear distance between grips depends on the purpose of the test program and the material being tested. The clear distance between grips shall be specified prior to testing and shall be reported.

NOTE 21—It is recommended that the clear distance between grips be at least 25 times the width of the specimen in order to minimize problems of end fixity, increase the opportunity for stress to distribute across the entire cross-section, and to properly account for the effect of grain deviations on strength. Because of practical limitations on the use of equipment for field testing, this may not always be feasible for wider materials. Nevertheless, clear distances between grips greater than twelve times the width of the specimen are recommended. For lumber, the width here refers to the dressed dry size specified in the size classification of the current version of PS20. To minimize problems in the interpretation of data results, it is further recommended that all specimens be tested at the same clear distance between grips.

9.3.3 *Accuracy:*

9.3.3.1 The force-measuring apparatus shall be such as to permit load measurements with an error not to exceed ±1.0 % of the load.

9.3.3.2 The cross-sectional dimensions of the member shall be measured to at least three significant figures.

9.4 *Specimen*

9.4.1 *Cross Section*—See 6.4.1.

9.4.2 *Length*—The minimum specimen length shall be the clear distance between grips, determined in accordance with 9.3.2.1, plus any required length to achieve contact along the full length of the grips.

9.4.3 *Conditioning*—See 6.4.3.

9.5 *Procedure*

9.5.1 *Specimen Measurements*—The procedures of 6.5.1 shall be followed.

9.5.2 *Lengthwise Positioning*—The positioning of the tested clear distance between grips within the total length of the member shall be addressed by a within-piece sampling plan. The procedure shall be documented and the resulting specimen length shall comply with the provisions of 9.4.2 (Note 7).

9.5.3 *Test Setup*—Center the specimen in the grips, taking care to have the long axis of the specimen coincide with the direction of load application.

9.5.4 *Speed of Testing*—The test rate shall be such that the sample target failure load is achieved in approximately 1 min (Note 8). It is recommended that the failure load be reached in not less than 10 s nor more than 10 min.

NOTE 22—For stress-graded lumber, a stress rate of approximately 4000 psi (30 MPa)/min will usually permit the test to be completed in the prescribed time, in cases where the target failure load is the average failure load for the sample.

9.5.5 *Maximum Load*—See 6.5.5.

9.5.6 *Record of Failure*—See 6.5.6.

9.6 *Report*

9.6.1 The content of the report depends on the purpose of the test program. The report shall include, at the minimum, the clear distance between the grips used for the tests and all applicable information as presented in 6.6.

10. AXIAL STRENGTH IN COMPRESSION

10.1 *Scope*

10.1.1 This test method provides procedures for the determination of the axial compressive strength of stress-graded lumber and other wood-based structural materials.

10.2 *Summary of the Test Method*

10.2.1 The specimen is subjected to an axial compressive load applied at its ends. The specimen is loaded at a prescribed rate until failure occurs or a preselected load is reached. This test method permits either tests of commercial lengths or tests of short specimens cut from commercial lengths (see Appendix X2).

10.3 *Apparatus*

10.3.1 *Testing Machine*—The test machine shall combine (*1*) a loading mechanism for applying an axial compressive load at a specified rate and (*2*) a force-measuring apparatus that can be calibrated to the accuracy requirements of 10.3.4 following procedures outlined in Practices E4.

10.3.2 *Bearing Blocks*—Load shall be applied through bearing blocks to transmit the compressive load from the testing machine to the specimen such that (*1*) the load is uniformly applied over the full contact surfaces, and (*2*) eccentric loading of the specimen is prevented. At least one spherical bearing block shall be used. It shall be permitted to use grips or clamping devices instead of bearing blocks provided that eccentric loading is avoided.

10.3.3 *Lateral Supports*—Sufficient lateral supports shall be provided to prevent buckling of the specimen during the test. These supports are permitted to be either continuous or intermittent, depending upon the size of the specimen. With either type, they shall allow specimen movement in the direction of load application with minimal frictional restraint. If intermittent supports are provided, they shall be spaced so that the distance between supports on a given face of the specimen is not more than 17 times the radius of gyration of the cross section about the centroidal axis parallel to the face considered.

10.3.3.1 If tests are to be run on commercial lengths of lumber, then support shall be intermittent.

10.3.3.2 If tests are to be run on short specimens cut from commercial lengths, then either intermittent or continuous support within the loading mechanism shall be permitted.

10.3.4 *Accuracy:*

10.3.4.1 The force-measuring apparatus shall be such as to permit load measurements with an error not to exceed ±1.0 % of the load.

10.3.4.2 The cross-sectional dimensions of the member shall be measured to at least three significant figures.

10.4 *Specimen*

10.4.1 *Sampling*—Full-length members shall be selected and tested in accordance with the sampling plan, unless short sections are to be selected for testing. If short specimens of lumber are to be tested, then at least two specimens shall be cut from each sampled piece in accordance with Annex A1. These short specimens shall represent the weakest sections in axial strength in compression as judged by experienced grading personnel.

10.4.2 *Cross Section*—See 6.4.1.

10.4.3 *Length*—The length of the specimen shall be at least 2.5 times its greater cross-sectional dimension.

NOTE 23—The greater cross-sectional dimension refers to the relevant size specified in the size classification of the applicable product standard. As an example for stress-graded lumber, the specimen length will be at least 2.5 times its width where width refers to the dressed dry size specified in the size classification of the current version of PS20, for example, 3.5 in. (89 mm) for a nominal 4 in. (102 mm).

10.4.4 *Conditioning*—See 6.4.3.

10.5 *Procedure*

10.5.1 *Specimen Preparation*—Trim the specimen to the proper length so that the contact surfaces are plane, parallel to each other, and normal to the long axis of the specimen.

10.5.2 *Specimen Measurements*—The procedures of 6.5.1 shall be followed.

10.5.3 *Test Setup*—Center the specimen on the bearing blocks or in the grips, taking care to have the long axis of the specimen coincide with the direction of load application.

10.5.4 *Speed of Testing*—The test rate shall be such that the failure is achieved in approximately 1 min (Note 8). It is recommended that the failure load not be reached in less than 10 s nor more than 10 min.

NOTE 24—For stress-graded lumber, a deformation rate of approximately 0.01 in./in.·min (0.01 mm/mm·min) will usually permit the test to be completed in the prescribed time, in cases where the target failure load is the average failure load for the sample.

10.5.5 *Maximum Load*—See 6.5.5.

10.5.6 *Record of Failure*—See 6.5.6.

10.6 *Report*

10.6.1 The content of the report depends on the purpose of the test program. The report shall include, at the minimum, all applicable information as presented in 6.6.

11. Keywords

11.1 lumber; mechanical properties; wood-base

ANNEX

(Mandatory Information)

A1. SAMPLING FOR SHORT SPECIMEN AXIAL STRENGTH IN COMPRESSION TESTS OF LUMBER

A1.1 The use of the short specimen axial strength in compression tests to produce data comparable to tests of commercial lengths depends on proper selection of the weakest short-length specimen from the commercial length. The procedures of these test methods shall be followed.

A1.1.1 *Compression Sample Preparation:*[4]

A1.1.1.1 Locate the most strength-reducing characteristic in the piece (Note A1.1).

A1.1.1.2 Mark and cut the board to the required length with the strength-reducing characteristic centered in the length. The minimum specimen lengths according to lumber size are as follows: 14 in. (350 mm) for a nominal 2 by 4; 18 in. (450 mm) for a nominal 2 by 6; 26 in. (650 mm) for a nominal 2 by 8; and 26 in. (650 mm) for nominal 2 by 10.

A1.1.1.3 Locate the next most strength-reducing characteristic.

A1.1.1.4 Mark and cut the board as stated in A1.1.1.2.

NOTE A1.1—For pieces in which the two largest strength-reducing characteristics are less than the required length apart, but still well separated, cut the piece halfway between the two. Then cut each test piece to the required length. Where the two characteristics are not well

[4] Barrett, J. D., "Comparison of Two ASTM D198 Compression Parallel-to-Grain Test Methods," ASTM Committee D07 Meeting, Tacoma, WA, 1987.

separated, include both in one piece (even if it has to be longer than required). Then choose a second test section as above.

A1.2 When analyzing the results of a sample of lumber to obtain near-minimum test results comparable to tests of commercial lengths, assign to each piece the lowest test value of the two (or more) tests run on that piece.

APPENDIXES

(Nonmandatory Information)

X1. RECORDING SCHEME

X1.1 The following is an example of a recording scheme to describe (*1*) characteristics in stress-graded lumber, and (*2*) specimen failure (type and cause) for stress-graded lumber.

X1.1.1 *Characteristics Description*—The recording scheme *CC – DD* where *CC* = a two-digit number identifying a characteristic and *DD* = a two-digit number unless otherwise specified, describing the extent of the characteristic listed in Table X1.1.

X1.1.2 *Specimen Failure Description*—The type of failure is recorded using the following code:

Type of Failure	Code
Tension side failure	000
Compression side failure	001
Combined tension and compression failure	002
Lateral buckling failure	003
Shear failure	004
Grip slip (tension only)	005
Failure at edge of grip (tension only)	006

X1.1.2.1 The cause of failure usually is associated with a characteristic. Accordingly, the recording scheme in Table X1.1 is used to describe the cause of failure. If failure occurs in clear wood, however, there is no need to record *CC* and *DD*. If failure occurs at a knot, a code "*XXYYAABB*" is recorded, unless otherwise indicated in Fig. X1.1, where *X, Y, A*, and *B* are knot measurements shown in Fig. X1.1, for ten types of knots. In the case of Type 10 knots (two or more knots in the same cross section), the code 10 is followed by the percentage of the cross-section occupied by the knots (two-digit number). For example, 1033 represents a combination of two or more knots occupying 33 % of the cross section.

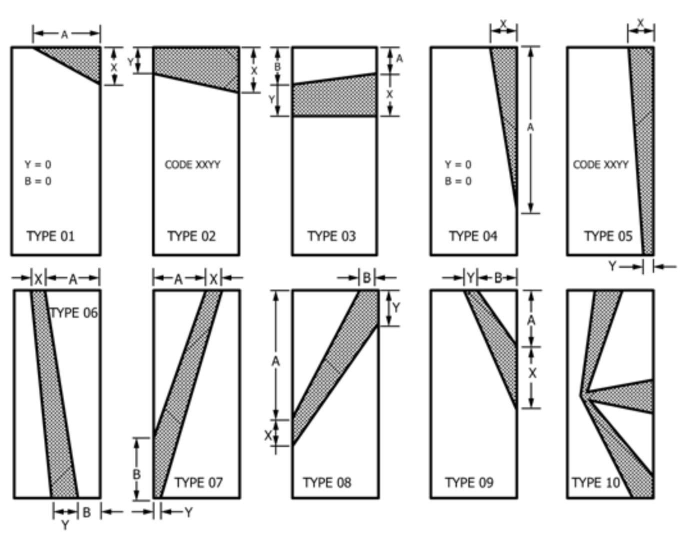


FIG. X1.1 Knot Measurements for Indicating the Description of Knot(s) Causing Specimen Failure

TABLE X1.1 Recording Scheme to Describe Characteristics in Stress-Graded Lumber

Characteristic	*CC*	*DD*	Characteristic	*CC*	*DD*
Narrow face or spike knot intergrown	11	displacement, %	Splits	44	01 for very short 02 for short 03 for medium 04 for long
Narrow face or spike knot encased	12				
Narrow face or spike knot unsound	13				
Wide face knot, center line intergrown	14	knot size (nearest 1⁄16 in.) for example, 08 for ½-in. knot.	Skip	45	01 for light 02 for medium 03 for heavy
Wide face knot, center line encased	15				
Wide face knot, center line unsound	16				
Wide face knot, at edge intergrown	17	knot size (nearest 1⁄16 in.)	Warp	46	00 for ½ of medium 01 for light 02 for medium 03 for heavy
Wide face knot, at edge encased	18				
Wide face knot, at edge unsound	19				
Knots, not well spaced, or combinations	20	cross section, %			
Hole	21	size as knot (nearest 1⁄16 in.)	Mechanical damage	47	cross section, %
			Crossbreak	49	displacement, %
Pin holes	22	cross section, %	Saw cut	50	01 saw cut through edge 02 all other saw cuts
Grub or teredo holes	23				
Speck	31	cross section, %	Slope of grain	51	run of slope[A]
Honeycomb	32				
Unsound wood or peck	33		Wane	52	first digit is number of fourths of width; second is fourths of thickness
Distorted grain, knot cluster, or burl	34	displacement, %			
Heart stain	35	displacement, %	Timber falling breaks	53	01, ⅓ or less of width 02, ⅓ to ⅔ of width 03, ⅔ or more of width
Pitch or bark pockets	41	01 for very small 02 for small 03 for medium 04 for large 15 for very large	Brash failure (not defect related)	54	
			Compression wood	55	
			Coarse grain or exceptionally light weight	56	
Shake	42	01 for light, not through 02 for medium, not through 03 for others, not through 11 for light, through 12 for medium, through 13 for others, through	Local grain deviation on wide face (failure initiated in locally severe grain deviation)	60	run of slope (use 00 if less than 1 in 1)[A]
			Local grain deviation on narrow face (failure initiated in locally severe grain deviation)	70	run of slope as above
Seasoning or roller check	43	01 for surface 02 for small, through 03 for medium, through 04 for large, through	Failure at the point where the sticker crossed the specimen in the package during kiln-drying[B]	99	moisture content at point failure

[A] Expressed in inches, corresponds to a 1-in. rise.
[B] Must be used in conjunction with another characteristic.

X2. BACKGROUND ON USE OF SHORT COMPRESSION PARALLEL TESTS OF LUMBER

X2.1 The use of short specimens cut from commercial lengths of lumber raises two questions: (*1*) how well a person trained in grading could identify the weakest section in a piece of lumber, given two opportunities; and (*2*) how well the short specimen test results compare to the Test Methods D198 test.

X2.1.1 Research at the United States Forest Products Laboratory (USFPL)[5] addressed the first question. A number of pieces of 2 by 4 Southern Pine No. 1 and better and No. 3 grades were selected. A lab technician marked the location of the two sections estimated to be the weakest portion of the piece in axial compression. The sections were also ordered according to which of the two was estimated to be weaker. Then the remainder of the 2 by 4 was marked off into as many specimens as possible. The sample boards were then cut into short specimens and tested in axial compression. The results were as follows: (*1*) given one chance, a technician could identify the weakest section approximately 50 % of the time; (*2*) given two chances, the technician could identify the weakest section of the piece at least 70 to 75 % of the time. Generally, the predictive ability of the technician was inversely related to the quality of the sample; in the clearer type of material, it was harder to predict where the weakest section was located. The results also showed that, even though the technician predicted the weakest section accurately as little as 70 % of the time given two chances, the difference in fifth percentile estimates with the true weakest specimens was only approximately 5 % or less.

X2.1.2 The second question was addressed by comparative studies at Forintek Canada Corp. (now FPInnovations).[4] and between USFPL and Forintek.[5] The Forintek study[4] was conducted on full-size lumber of No. 2 and better grade, in which the quality was marked for the estimated two weakest sections. The full length of the piece was then tested by Test Methods D198 procedures. If the piece failed away from the marked sections, the sections were cut out and tested as short sections. The test results indicated that the difference between the two test methods was at most approximately 2 %, with the short specimen test higher.

X2.1.2.1 The comparative studies between Forintek and the USFPL[5] verified the importance of maintaining intermittent lateral supports to yield a slenderness ratio of not more than 17 (Test Methods D198, Section 20) for full-length tests. When the full-length tests were based on this intermittent support, the difference was negligible between these results and those using the estimated weakest short specimen fully supported.

[5] Green, D. W., and Evans, J. W., "Compression Testing of Lumber: A Comparison of Methods," *Journal of Testing and Evaluation*, Vol 20, No. 2, March 1992, pp. 132–138.