Designation: D7341 – 14

Standard Practice for Establishing Characteristic Values for Flexural Properties of Structural Glued Laminated Timber by Full-Scale Testing[1]

This standard is issued under the fixed designation D7341; 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 practice describes procedures for full scale testing of structural glued laminated timber (glulam) to determine or verify characteristic values used to calculate flexural design properties. Guidelines are given for: *(1)* testing individual structural glued laminated timber lay-ups (with no modeling), *(2)* testing individual glulam combinations (with limited modeling), and *(3)* validating models used to predict characteristic values.

1.2 This practice is limited to procedures for establishing flexural properties (Modulus of Rupture, MOR, and Modulus of Elasticity, MOE). Some of the principles for sampling and analysis presented may be applicable to other properties. However, other properties may require additional testing considerations that are beyond the scope of this practice.

1.3 This practice is not intended to supersede the provisions of Practice D3737, but provides an alternative method for establishing characteristic values. Lay-up combinations developed in accordance with Practice D3737 are not required to be governed by this standard.

NOTE 1—The models described by Practice D3737 have been developed and modified based on more than 50 years of experience and many test programs. In some cases, however, it may be desirable to develop a new model based on other input properties or using lumber materials or grades not covered by that standard.

1.4 Details of production, inspection, and certification are beyond the scope of this document. However, for test results to be representative of production, quality control systems shall be in place to ensure consistent quality. Manufacturing shall conform to recognized manufacturing standards such as ANSI A190.1 or CSA O122.

1.5 Adjustments to characteristic values to determine reference values for design shall be in accordance with Practice D2915 for allowable stress design (ASD) or Specification D5457 for load and resistance factor design (LRFD).

1.6 Adjustments to ASD reference values for end-use conditions intended for design purposes shall be performed in accordance with Practice D3737. The same adjustment factors shall apply to LRFD reference values, except that the ASD *load duration* factor shall be replaced by an appropriate LRFD *time effect* factor as determined in accordance with recognized industry practice.

1.7 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *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]

D198 Test Methods of Static Tests of Lumber in Structural Sizes

D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

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

D3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)

D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material

D5456 Specification for Evaluation of Structural Composite Lumber Products

D5457 Specification for Computing Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design

D6815 Specification for Evaluation of Duration of Load and Creep Effects of Wood and Wood-Based Products

[1] This practice is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.02 on Lumber and Engineered Wood Products.

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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.

2.2 *Other Standards:*
AITC Test T119 Full Size End Joint Tension Test[3]
ANSI A190.1 American National Standard for Wood Products – Structural Glued Laminated Timber[4]
CSA O122 Structural Glued Laminated Timber[5]
PS-20 Voluntary Product Standard, ALS[6]

3. Terminology

3.1 *Definitions*—For definitions of terms related to wood, refer to Terminology D9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent properties, n*—Mechanical properties as related to the actual cross-sectional dimensions of the structural glued laminated timber.

3.2.2 *characteristic value, n*—A test statistic from which design values can be derived by the application of appropriate adjustment factors.

3.2.2.1 *Discussion*—For strength properties of structural glued laminated timber, this value is typically a fifth percentile estimate with 75 % confidence. For deformation-based properties, such as modulus of elasticity, this value is represented by the average value. Other statistics are permitted to be used as characteristic values for input properties of laminations depending on the model. Characteristic values for structural glued laminated timber are typically based on apparent properties.

3.2.3 *combination, n*—A series of lay-ups having similar lamination properties (grades, species, and end joint strengths), similar percentages of grade placement in the areas of critical stresses, and similar predicted properties, that are grouped together for design purposes.

NOTE 2—An example of a lay-up combination based on Practice D3737 would be a 24F-V4 Douglas fir combination.

3.2.4 *lay-up, n*—The specific arrangement of well-defined lamination grades for a single structural glued laminated timber depth.

3.2.5 *model, n*—A mathematical method for predicting characteristic values for full-scale laminated timber based on the input properties of the individual laminations.

3.2.6 *reference value, n*—The characteristic value of a material that has been adjusted by the procedures in Practice D2915 or Specification D5457 for use in design equations, but has not been adjusted for end-use conditions.

3.2.7 *structural-glued-laminated timber, n*—An engineered, stress-rated product of a timber laminating plant comprising assemblies of specially selected and prepared wood laminations securely bonded together with adhesives, with the following characteristics: (*1*) the grain of all laminations is approximately parallel longitudinally; and (*2*) the laminations may be comprised of pieces end-joined to form any length, of pieces placed or glued edge-to-edge to make wider ones or pieces bent to curved form during gluing.

3.2.8 *well-defined grade, n*—A lumber grade with specific limits on acceptable characteristics, such as knots, slope of grain, density, modulus of elasticity, tensile strength, etc., to ensure reproducibility in production.

4. Modeling Requirements

4.1 *General:*

4.1.1 *Purpose for Modeling*—For test results to be applicable to structural glued laminated timber sizes that are not tested, it is necessary to relate the properties of the component laminations to the beam properties through the use of an analytical model.

4.1.2 *Predictive Models*—Models that will be used to develop new combinations, predict characteristic values, and assign design values shall be able to predict accurately these values for a broad range of combinations. These results must be validated by full-scale tests according to appropriate test methods for the property of interest.

4.1.3 *Single Combination*—For comparing different lay-ups and identifying critical sizes for testing within a single combination, transformed section analysis is sufficient to predict the stresses on each grade in the lay-up relative to the stresses in the tested lay-up. No further modeling shall be required.

4.1.4 *Single Lay-Up*—All modeling requirements shall be waived if the test results are limited to a single, well-defined lay-up (that is, the number of laminations is fixed, the lamination properties are well defined, and the size (depth) tested is representative of the size intended for production).

4.2 *Minimum Model Inputs:*

4.2.1 *General*—At a minimum, a suitable model shall be based on defined lamination properties representative of the material used for each lamination and shall account for the placement of different qualities of laminations throughout the cross section.

4.2.2 *Lamination Properties*—The model shall account for both lumber and end joint properties.

4.2.2.1 *Lumber Grade*—The species and grades of lumber used in structural glued laminated timber shall be well defined to ensure consistent performance between the grades used in test members and future production members. Strength and stiffness properties for the laminations shall be assigned according to the lumber grade. For deterministic models, the properties assigned to the grade shall be a representative characteristic value for the grade. For probabilistic models, a parametric distribution of values shall be determined to represent the grade.

(1) Species—The species or groups of species permitted by the grade shall be well defined and shall be represented in the tested members.

(2) Modulus of Elasticity—For each grade of lumber used, the modulus of elasticity shall be determined in accordance with Test Methods D198 or D4761 or by the procedures of Specification D5456 or Practice D245.

[3] Available from the West Coast Lumber Inspection Bureau (WCLIB), 6980 S. W. Varns, Tigard, OR 97223, http://www.wclib.org.
[4] Available from APA—The Engineered Wood Association, 7011 South 19th Street, Tacoma, WA 98466, http://www.apawood.org.
[5] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.
[6] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

(3) Strength—Strength values shall be assigned to each grade of lumber used in the laminated timber. Values shall be determined by testing in accordance with Test Methods D198 or D4761 or by the procedures of Specification D5456 or Practice D245. Strength values are also permitted to be assigned to a grade zone based on its interaction with the beam as a whole. (For example, the I_K/I_G model used in Practice D3737 assigns strength values in this way.)

(4) Creep—Structural composite lumber for use in structural glued laminated timber shall demonstrate creep performance similar to solid wood as demonstrated by Specification D6815.

4.2.2.2 *End Joint Strength*—The model shall include the effect of end joints (if used) stressed in tension. Appropriate end joint tensile strengths shall be determined by full-scale tension testing in accordance with AITC Test T119 and maintained through in-plant quality control procedures.

4.2.3 *Arrangement of Grades (Lay-Up)*—The arrangement of laminations of varying quality throughout a laminated timber can significantly alter the stress distribution and performance of the member. The model shall account for these effects if more than one grade of laminations is to be used. The placement of grades shall be well defined to ensure proper modeling and reproducibility in production.

4.3 *Minimum Model Analyses:*

4.3.1 *Transformed-Section Analysis*—The stresses at the location of each change of grade in a cross section shall be determined using transformed section analysis. For deterministic analyses, the average modulus of elasticity of each lumber grade shall be used. The use of probabilistic models with simulated values of modulus of elasticity is also acceptable.

4.3.2 *Prediction of Properties*—The model shall predict characteristic values for the laminated timber's apparent properties, based on the input lamination properties. Additionally, for strength properties, the model shall account for the possibility of any grade of lamination in the member controlling the strength of the timber. The model shall identify the critical or controlling grade zone.

5. Testing Requirements

5.1 *General*—Full-scale member testing can be used to *(1)* establish the properties of a single lay-up, *(2)* determine the properties of a combination, or *(3)* validate a model intended for use in the prediction and assignment of characteristic values. Increased testing shall be required for validation of a model, as compared to verifying the properties of a single combination or lay-up. Standard production procedures shall be followed for the manufacture of all test specimens. Matched end joint specimens shall be manufactured and tested in conjunction with tests of structural glued laminated timber utilizing end joints subject to tension.

5.2 *Test Certification*—Testing shall be witnessed by a qualified third-party agency or conducted by an accredited laboratory that shall certify the test methods and results.

5.3 *Test Method*—Tests for flexural strength and modulus of elasticity shall be conducted in accordance with Test Methods D198 or D4761. If Test Method D4761 is used, the load rate shall be modified to be in accordance with Test Method D198. Specimens shall be tested under dry-service conditions (moisture content < 16 %) and adjusted to the standard moisture content of 12 % in accordance with Practice D2915. The temperature of the test specimens shall not be less than 50°F nor more than 90°F at the time of the tests.

5.4 *Sampling Requirements for a Single Lay-Up:*

5.4.1 *Grading and Lay-Up*—Lamination quality (grades, species, and end joint strength) and grade placement shall be well defined and verified prior to testing.

5.4.2 *Specimen Size(s)*—Specimens for testing shall be the specific size (depth) of a single, well-defined lay-up in accordance with 4.1.4. Width of the specimens shall be representative of the size intended for production. For horizontally laminated beams, a single width is permitted to be considered representative of members with widths not more than 2 in. wider nor 2 in. narrower than the tested width, provided that the selection (grading) criteria relative to the cross-sectional size is the same for each width. For vertically laminated beams, the depth of test specimens shall be representative of intended production sizes, and the width shall be based on the number of laminations and shall be equal to the number of laminations intended for use in production.

5.4.3 *Sample Size*—A minimum of 30 specimens shall be required for each lay-up.

5.4.4 *Facilities*—If the lay-up is intended to be produced in multiple facilities, samples shall be obtained from enough plants to represent all major processing variables including lumber characteristics and end joint strength.

5.5 *Sampling Requirements for a Single Combination:*

5.5.1 *Lay-Ups and Sample Size*—For horizontally laminated beams, a minimum of two critical depths based on a transformed section analysis shall be selected for testing. The lay-ups at the critical depths shall be representative of a group of similar lay-ups within the combination. A minimum of 15 members per critical depth shall be tested with 30 or more members tested for the combination. For vertically laminated beams, a minimum of two widths shall be tested including members with 2 and 4 laminations.

5.5.2 *Specimen Size(s)*—For horizontally laminated beams, the width of test specimens shall be representative of intended production sizes and the depth shall be determined by the critical depths selected in 5.5.1. For horizontally laminated beams, a single width is permitted to be considered representative of members with widths not more than 2 in. wider nor 2 in. narrower than the tested width. For vertically laminated beams, the depth of test specimens shall be representative of intended production sizes, and the widths shall be based on the lamination thickness multiplied by the number of laminations.

5.5.3 *Facilities*—If the combination is intended to be produced in multiple facilities, samples shall be obtained from enough plants to represent all major processing variables including lumber characteristics and end joint strength.

5.6 *Sampling Requirements to Validate a Model to Establish Characteristic Values:*

5.6.1 *Species Groups*—Samples shall include a minimum of three different species groups (or all species groups if scope of

model is limited to less than three groups). Hardwood and softwood species must be evaluated independently. Species groups shall be those established in PS-20 or subsets of such.

5.6.2 *Lay-Ups and Sample Size*—A minimum of two combinations (60 beams total with 30 beams in two different critical depths for each combination) sampled in accordance with 5.5 shall be tested to validate a model that will be used to predict characteristic values for a single species group. The combinations tested shall represent the maximum and minimum characteristic values to be predicted by the model. A minimum of one additional combination (30 beams in two different critical depths) sampled in accordance with 5.5 shall be tested for each additional species group.

A minimum of three softwood species groups shall be tested for validation of a model that will be used to predict characteristic values for softwood species other than those tested. A minimum of three hardwood species shall be tested for validation of a model that will be used to predict characteristic values for hardwood species other than those tested.

5.6.3 *Facilities*—If the model is intended to be used in multiple facilities, samples shall be obtained from enough plants to represent all major processing variables, including lumber characteristics and end joint strength.

5.6.4 *Specimen Size(s)* The range of sizes tested shall be representative of the sizes intended for production and as a minimum shall represent the two critical depths as determined in 5.6.2. The range of sizes tested shall include specimens of the maximum and minimum widths (within 2 in.) intended for production.

6. Analysis of Test Results

6.1 *Failure Modes*—Each failed specimen shall be inspected to determine the failure mode(s). The location and type (end joint, lumber, shear, tension, compression, etc.) of observed failures shall be documented and compared to the model. Lamination characteristics influencing failure shall be noted.

6.2 *Mechanical Properties*—For each specimen tested, the magnitude of the apparent properties investigated shall be determined. The maximum stresses on each grade of lamination shall be calculated based on transformed section analysis.

6.3 *Statistical Analyses*—Characteristic values shall be determined for each tested lay-up according to procedures described in Practice D2915.

6.4 *Data Adjustments*—Data shall be permitted to be adjusted to standard conditions of moisture content and size or volume prior to statistical analysis.

7. Applicability of Results

7.1 *Single Lay-Ups*—The results of tests of a single lay-up sampled according to 5.4 shall apply only to the tested lay-up.

7.2 *Combinations*—The results of tests of combinations sampled according to 5.5 shall be considered representative of all lay-ups in the combination, provided that the test results are not less than the predicted stresses or stiffness.

7.3 *Predictive Model Acceptance*—The model shall be accepted if the predicted characteristic values (strength and stiffness) for each lay-up are within one standard error of the characteristic value from the tests as determined by the procedures of Practice D2915. The coefficient of variation for this analysis shall be equal to the lesser of 15 % or the actual value from the tests. Models shall not be approved for assigning characteristic values outside of the range of characteristic values represented in the tested combinations.

NOTE 3—For typical structural glued laminated timber members, the standard error of the bending strength estimate from full-scale bending tests will be within 10 % of the characteristic value for a sample size of 15 or more.

8. Periodic Evaluation

8.1 *Lumber Properties*—The lumber characteristics used as a basis for establishing grades and as inputs to predictive models shall be maintained through continuous process control. Strength and stiffness properties for each grade shall be evaluated periodically or maintained through continuous process control to ensure that they are maintained over time.

8.2 *End Joint Strength*—Lamination end joint strengths shall be subject to ongoing process control to maintain the required strengths.

8.3 *Beam Tests*—Full-scale beam tests shall be conducted to verify the continued applicability of the model used for assigning characteristic values when the trend of the lumber properties or end joint strengths, or both, evaluated in 8.1 and 8.2 warrants such an evaluation.

NOTE 4—The glulam industry typically controls the product quality on the glulam components (end joints, lumber, and glue bond) on an ongoing basis. Therefore, the periodic re-evaluation should be designed by the manufacturer and the third-party inspection agency using the specific lay-up(s) developed under this standard to ensure performance that is consistent with design stresses assigned to the product.

9. Report

The report shall include the following:

9.1 Description of the sample(s), including species, lamination properties, lay-up(s), size(s), conditioning, location of end joints, matched end joint strength, quality control requirements, etc.

9.2 Description of the test machine and setup, including method and location of load application, test span or gauge length, etc.

9.3 Description of measurement methods for dimensions, load, deflections, moisture content, etc.

9.4 Rate of testing and the method of controlling the rate of load application.

9.5 Equation(s) used to determine stresses and elastic moduli.

9.6 Data for specimens, including: dimensions; maximum load or stress, or both; moisture content; time to failure; description and location of failure; load versus deformation curves, etc.

9.7 Description of statistical analyses used to determine characteristic value(s).

9.8 Identification and description of any model(s) used or evaluated.

9.9 Details of any deviations from the recommended procedures.

10. Significance and Use

10.1 Full-scale bending testing is an effective way to determine flexural properties of structural glued laminated timber (glulam) beams. However, testing of large glulam members is cost prohibitive. Mathematical models, when confirmed by full-scale test results, are useful tools to assign flexural properties for glulam. This practice provides guidelines for sampling and testing full-scale glulam beams to determine their flexural properties and to validate mathematical models intended for use in assigning flexural design values.

11. Keywords

11.1 bending; characteristic value; flexural; flexure; full-scale; glulam; laminated; lay-up; modulus; timber

APPENDIX

(Nonmandatory Information)

X1. Commentary

X1.1 Full-scale testing is generally recognized as an acceptable method of establishing design values for structural wood materials. However, structural glued laminated timber requires special sampling and testing methods to ensure that results based on critical sample sizes are representative. This defines minimum testing requirements and acceptable bounds of applicability for glulam test data.