Designation: D 7199 – 07

Standard Practice for Establishing Characteristic Values for Reinforced Glued Laminated Timber (Glulam) Beams Using Mechanics-Based Models[1]

This standard is issued under the fixed designation D 7199; 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 covers mechanics-based requirements for calculating characteristic values for the strength and stiffness of reinforced structural glued laminated timbers (glulam) manufactured in accordance with applicable provisions of ANSI/AITC A190.1, subjected to quasi-static loadings. It addresses methods to obtain bending properties parallel to grain, about the x-x axis (F_{bx} and E_x) for horizontally-laminated reinforced glulam beams. Secondary properties such as bending about the y-y axis (F_{by}), shear parallel to grain (F_{vx} and F_{vy}), tension parallel to grain (F_t), compression parallel to grain (F_c), and compression perpendicular to grain ($F_{c\perp}$) are beyond the scope of this practice. When determination of secondary properties is deemed necessary, testing according to other applicable methods, such as Test Methods D 143, D 198 or analysis in accordance with Practice D 3737, is required to establish these secondary properties. Reinforced glulam beams subjected to axial loads are outside the scope of this standard. This practice also provides minimum test requirements to validate the mechanics-based model.

1.2 The practice also describes a minimum set of performance-based durability test requirements for reinforced glulams, as specified in Annex A1. Additional durability test requirements shall be considered in accordance with the specific end-use environment. Appendix X1 provides an example of a mechanics-based methodology that satisfies the requirements set forth in this standard.

1.3 Characteristic strength and elastic properties obtained using this standard may be used as a basis for developing design values. However, the proper safety, serviceability and adjustment factors including duration of load, to be used in design are outside the scope of this standard.

1.4 This practice does not cover unbonded reinforcement, prestressed reinforcement, nor shear reinforcement.

1.5 The values stated in SI units are to be regarded as standard. The mechanics based model may be developed using SI or in.-lb units.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

- D 9 Terminology Relating to Wood and Wood-Based Products
- D 143 Test Methods for Small Clear Specimens of Timber
- D 198 Test Methods of Static Tests of Lumber in Structural Sizes
- D 905 Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading
- D 1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens
- D 2559 Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions
- D 2915 Practice for Evaluating Allowable Properties for Grades of Structural Lumber
- D 3039/D 3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
- D 3410/D 3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
- D 3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
- D 4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material

[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.

D 5124 Practice for Testing and Use of a Random Number Generator in Lumber and Wood Products Simulation

2.2 *Other Standard:*

ANSI/AITC A190.1 Structural Glued Laminated Timber[3]

3. Terminology

3.1 *Definitions*—Standard definitions of wood terms are given in Terminology D 9 and standard definitions of structural glued laminated timber terms are given in Practice D 3737.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bonded reinforcement*—a reinforcing material that is continuously attached to a glulam beam through adhesive bonding.

3.2.2 *bumper lamination*—a wood lamination continuously bonded to the outer side of reinforcement.

3.2.3 *compression reinforcement*—reinforcement placed on the compression side of a flexural member.

3.2.4 *conventional wood lamstock*—solid sawn wood laminations with a net thickness of 2 in. or less, graded either visually or through mechanical means, finger-jointed and face-bonded to form a glulam.

3.2.5 *development length*—the length of the bond line along the axis of the beam required to develop the design tensile strength of the reinforcement.

3.2.6 *fiber-reinforced polymer (FRP)*—any material consisting of at least two distinct components: reinforcing fibers and a binder matrix (a polymer). The reinforcing fibers are permitted to be either synthetic (for example, glass), metallic, or natural (for example, wood), and are permitted to be long and continuously-oriented, or short and randomly oriented. The binder matrix is permitted to be either thermoplastic (for example, polypropylene or nylon) or thermosetting (for example, epoxy or vinyl-ester).

3.2.7 *laminating effect*—an apparent increase of lumber lamination tensile strength because it is bonded to adjacent laminations within a glulam beam. This apparent increase may be attributed to a redirection of stresses around knots and grain deviations through adjacent laminations.

3.2.8 *partial length reinforcement*—reinforcement that is terminated within the length of the timber.

3.2.9 *reinforcement*—any material that is not a conventional lamstock whose mean longitudinal ultimate strength exceeds 20 ksi for tension and compression, and whose mean tension and compression MOE exceeds 3000 ksi, when placed into a glulam timber. Acceptable reinforcing materials include but are not restricted to: fiber-reinforced polymer (FRP) plates and bars, metallic plates and bars, FRP-reinforced laminated veneer lumber (LVL), FRP-reinforced parallel strand lumber (PSL).

3.2.10 *shear reinforcement*—reinforcement intended to increase the shear strength of the beam. This standard does not cover shear reinforcement.

3.2.11 *tension reinforcement*—reinforcement placed on the tension side of a flexural member.

3.3 *Symbols*:

Arm = moment arm, distance between compression and tension force couple applied to beam cross-section

b = beam width

C = total internal compression force within the beam cross-section (see Fig. 2)

CFRP = carbon fiber reinforced polymer

d = beam depth

E = long-span flatwise-bending modulus of elasticity for wood lamstock (Test Methods D 4761; also see Fig. 1)

F_b = allowable bending stress parallel to grain

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

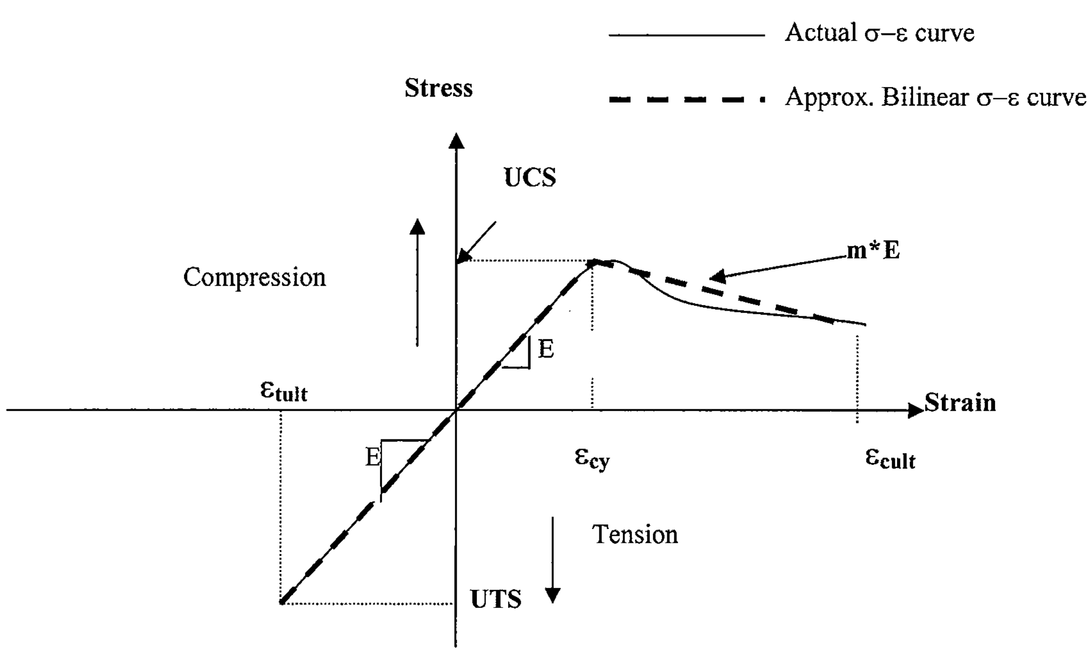
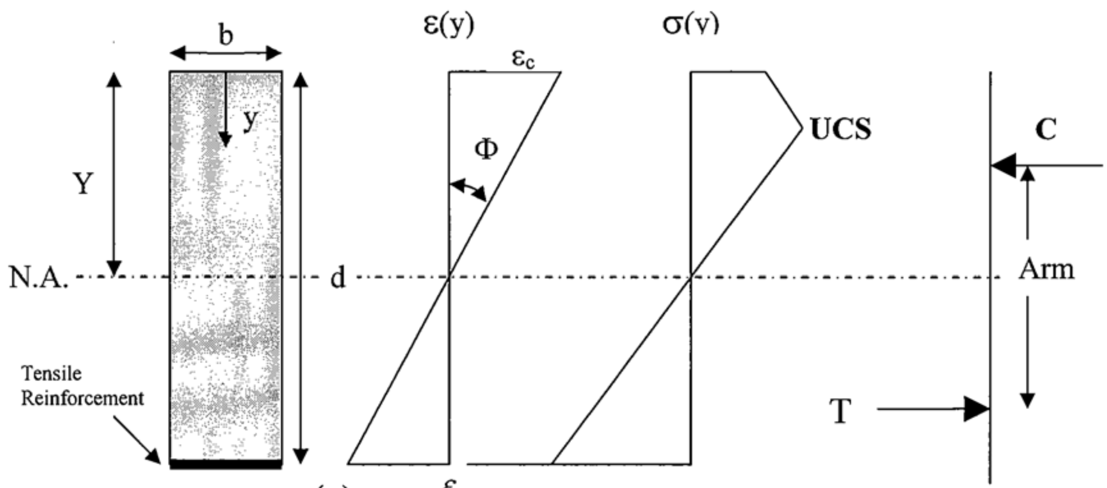


FIG. 1 Typical Stress-Strain Relationship for Wood Lamstock, with Bilinear Approximation



$$\varepsilon(y) = \varepsilon_c - \frac{\varepsilon_c}{Y} * y$$

NOTE—A simplified rectangular block stress distribution can be used but it must be shown that it accurately represents the stress distribution.

FIG. 2 Example of Beam Section with Strain, Stress, and Force Diagrams

F_x = internal horizontal force on the beam cross-section (see Eq 2)

GFRP = Glass fiber-reinforced polymer

LEL = lower exclusion limit (point estimate with 50 % confidence, includes volume factor)

LTL = lower tolerance limit (typically calculated with 75 % confidence)

$M_{applied}$ = external moment applied to the beam cross-section

$M_{internal}$ = internal moment on the beam cross-section

MC = moisture content (%)

MOE = modulus of elasticity

MOR = modulus of rupture

$MOR_{5\%}$ = 5 % one-sided lower tolerance limit for modulus of rupture, including the volume factor

$MOR_{BL5\%}$ = 5 % one-sided lower tolerance limit for modulus of rupture corresponding to failure of the bumper lamination, including the volume factor

$m*E$ = downward slope of bilinear compression stress-strain curve for wood lamstock (see Fig. 1)

N.A. = neutral axis

T = total internal tension force within the beam cross-section (see Fig. 2)

UCS = ultimate compressive stress parallel to grain

UTS = ultimate tensile stress parallel to grain

Y = distance from extreme compression fiber to neutral axis (see Fig. 2)

y = distance from extreme compression fiber to point of interest on beam cross-section (see Fig. 2)

ϵ_c = strain at extreme compression fiber of beam cross-section (see Fig. 2)

ϵ_{cult} = compression strain at lamstock failure (see Fig. 1)

ϵ_{cy} = compression yield strain at lamstock UCS (see Fig. 1)

ϵ_{tult} = tensile strain at lamstock failure (see Fig. 1)

$\epsilon(y)$ = strain distribution through beam depth (see Fig. 2)

ρ = tension reinforcement ratio (%); cross-sectional area of tension reinforcement divided by cross-sectional area of beam between the c.g. of tension reinforcement and the extreme compression fiber

ρ' = compression reinforcement ratio (%); cross-sectional area of compression reinforcement divided by cross-sectional area of beam between the c.g. of compression reinforcement and the extreme tension fiber

$\sigma(y)$ = stress distribution through beam depth (see Fig. 2)

4. Requirements for Mechanics-Based Analysis Methodology

NOTE 1—At a minimum, the mechanics-based analysis shall account for: *(1)* Stress-strain relationships for wood laminations and reinforcement; *(2)* Strain compatibility; *(3)* Equilibrium; *(4)* Variability of mechanical properties; *(5)* Volume effects; *(6)* Finger-joint effects; *(7)* Laminating effects; and *(8)* Stress concentrations at termination of reinforcement in beams with partial length reinforcement. In addition to the above factors, characteristic values developed using the mechanics-based model need to be further adjusted to address end-use conditions including moisture effects, duration of load, preservative treatment, temperature, fire, and environmental effects. The development and application of these additional factors are outside the scope of this practice. Annex A1 addresses the evaluation of durability effects. The minimum output requirements for the analysis are mean MOE (based on gross section) and 5% LTL MOR with 75 % confidence (based on gross section), both at 12 % MC. These analysis requirements are described below.

4.1 *Stress-strain Relationships*:

4.1.1 *Conventional Wood Lamstock*:

4.1.1.1 The stress-strain relationship shall be established through in-grade testing following Test Methods D 198 or Test Methods D 4761, or other established relationships as long as the resulting model meets the criteria established in Section 5. Test lamstock shall be sampled in sufficient quantity from enough sources to insure that the test results are representative of the lamstock population that will be used in the fabrication of the beams. Follow-up testing shall be performed annually in