

ANSI/ASAE EP559.1 W/Corr. 1 AUG2010 (R2014)

Design Requirements and Bending Properties for Mechanically Laminated Wood Assemblies



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Revision approved August 2010; reaffirmed January 2015 as an American National Standard

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Developed by the ASAE Mechanically Laminated Post Design Subcommittee of the Structures Group; approved by the Structures and Environment Division Standards Committee; adopted by ASAE December 1996; approved as an American National Standard February 1997; reaffirmed by ANSI February 2003; reaffirmed by ASAE February 2003; reaffirmed by ASABE and ANSI February 2008; revised and approved by ANSI August 2010; corrigenda 1 issued March 2011; reaffirmed by ASABE December 2014; reaffirmed by ANSI January 2015.

Corrigenda 1 corrected publication errors in equation 3 (7.3.1).

Keywords: Beams, Columns, Girders, Laminated Lumber, Laminating, Lumber, Wood Design, Wood Structures

1 Purpose and Scope

1.1 The purpose of this Engineering Practice is to establish guidelines for designing and calculating allowable bending properties of mechanically laminated wood assemblies used as structural members.

1.2 The scope of this Engineering Practice is limited to mechanically laminated assemblies with three or four wood laminations that have the following characteristics:

1.2.1 The actual thickness of each lamination is between 38 and 51 mm (1.5 and 2.0 in.).

1.2.2 All laminations have the same depth (face width), d .

1.2.3 Faces of adjacent laminations are in contact.

1.2.4 The centroid of each lamination is located on the centroidal axis of the assembly (axis Y-Y in Figure 1a), that is, no laminations are offset.

1.2.5 Concentrated loads are distributed to the individual laminations by a load distributing element.

1.2.6 All laminations are of the same grade and species of lumber or structural composite lumber.

1.2.7 There is no more than one common end joint per lamination within a splice region.

1.3 The provisions of this Engineering Practice do not apply to assemblies designed for biaxial bending. The design requirements in clause 4, and allowable bending properties in clauses 5 and 6, are only for uniaxial bending about axis Y-Y (Figure 1a). Spliced assemblies with butt joints shall have sufficient lateral support to prevent out-of-plane (lateral) movement or buckling, and/or delamination in the splice region.

1.4 This Engineering Practice does not preclude the use of assembly designs not meeting the criteria in clauses 1.2 and 1.3.



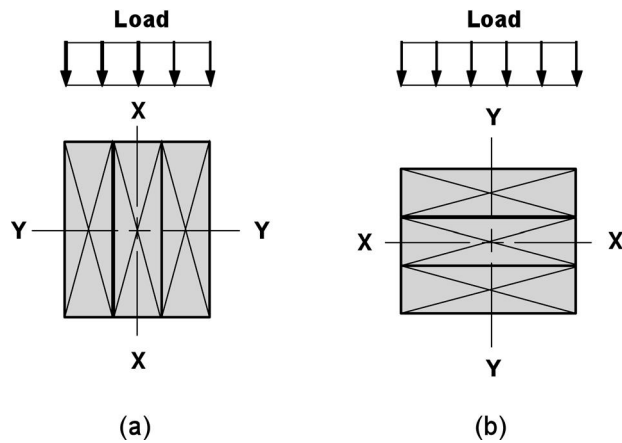


Figure 1 – (a) Vertically laminated, (b) horizontal laminated assemblies

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this Engineering Practice. At the time of publication, the editions were valid. All standards are subject to revision, and parties to agreements based on this Engineering Practice are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Standards organizations maintain registers of currently valid standards.

AF&PA (2005), National Design Specification (NDS) for Wood Construction

AITC Test T110-2007, Cyclic Delamination Test

ANSI/TPI 1-2007, National Design Standard for Metal Plate Connected Wood Truss Construction

ANSI/AITC 405-2008, Standard for Adhesives for Use in Structural Glued Laminated Timber

ASTM A153/A153M-05, Specifications for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

ASTM A 653/A 653M-09, Standard Specification for Steel Sheet, Zinc-Coated (galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process

ASTM B 695, Standard Specification for Coating of Zinc Mechanically Deposited on Iron and Steel

ASTM D 198-08, Standard Methods of Static Testing of Timbers in Structural Sizes

ASTM D 245-06, Standard Methods for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

ASTM D 3737-08, Standard Methods for Establishing Stresses for Structural Glued-Laminated Timber (Glulam)

ASTM D 7469-08, Standard Test Methods for End Joints in Structural Wood Products

AWPA U1-09, Use Category System: User Specification for Treated Wood

NIST PS20-05, American Softwood Lumber Standard

3 Definitions

3.1 mechanically laminated assembly (mech-lam): A structural assembly consisting of suitably selected wood layers joined with nails, screws, bolts, and/or other mechanical fasteners. Individual wood layers may be comprised of solid-sawn lumber or structural composite lumber such as laminated strand lumber (LSL), laminated veneer lumber (LVL) or parallel strand lumber (PSL).

3.2 nail-laminated assembly (nail-lam): Used interchangeably with “mechanically laminated assembly” when nails are the only fastener used to join individual layers.

3.3 screw-laminated assembly (screw-lam): Used interchangeably with “mechanically laminated assembly” when screws are the only fastener used to join individual layers.

3.4 vertically laminated assembly: An assembly primarily designed to resist bending loads applied parallel to the planes of contact between individual layers (Figure 1a). Virtually all mechanically laminated assemblies are designed as vertically laminated assemblies.

3.5 horizontally laminated assembly: An assembly primarily designed to resist bending loads applied normal to the planes of contact between individual layers (Figure 1b). Mechanically laminated assemblies designed as horizontally laminated assemblies do not fall under the scope of this Engineering Practice.

3.6 unspliced assembly: A mechanically laminated assembly that contains no end joints or contains only certified structural glued end joints.

3.6.1 certified structural glued end joint: Any end joint that meets the material and manufacturing requirements outlined in clause 4.5.

3.7 spliced assembly: A mechanically laminated assembly that contains one or more common end joints.

3.7.1 common end joint: An end joint that does not meet requirements for classification as a certified structural glued end joint. Common end joints include, but are not limited to: glued scarf joints and glued finger joints that do not meet the requirements of clause 4.5, butt joints, and metal connector plate (MCP) reinforced butt joints.

3.8 overall splice length, L : The distance between the two farthest removed (extreme outer) common end joints in a group of end joints that contains one common end joint in each layer (Figure 2).

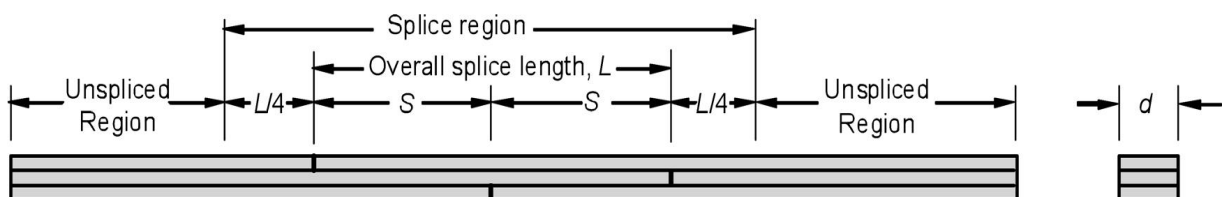


Figure 2 – Spliced assembly definitions

3.9 joint spacing, S : The distance between end joints (Figure 2). When end joints are equally spaced and there is only one end joint in each layer, S is equal to the overall splice length divided by $n - 1$, where n is the number of layers.

3.10 splice region: That portion of an assembly located between and within a distance of $L/4$ of a group of common end joints. In an assembly with one end joint in each layer, the total length of the splice region is equal to $1.5L$ (Figure 2). Although there can be more than one splice region per assembly, the splice regions shall not overlap.

3.11 unspliced region: Those portions of an assembly not included in a splice region (Figure 2).

3.12 joint arrangement: The relative location of end joints in a spliced assembly.

3.13 allowable stress design (ASD): A method of sizing a structural member such that elastically computed stresses produced in the member by design loads (a.k.a. nominal or service loads) do not exceed the member's specified allowable stress. Also called "working stress design".

3.14 load and resistance factor design (LRFD): A method of sizing a structural member such that the computed forces produced in the member by factored design loads do not exceed the member's factored resistance (design strength). Also called "strength design".

4 Material and Manufacturing Requirements

4.1 Lumber. Laminations (lumber) shall be identified by the grade mark of, or certificate of inspection issued by, a lumber grading or inspection bureau or agency recognized as being competent (see NIST PS20).

4.2 Preservative wood treatment. Any mechanically laminated assembly or portion thereof that is in ground contact or in fresh water shall be pressure preservative-treated in accordance with AWP A U1 Use Category 4B requirements for sawn products as given in Table 1. This level of treatment shall extend a minimum of 400 mm (16 in.) above the ground or waterline. Mech-lam assemblies that are located above ground, but are exposed to all weather cycles, including prolonged wetting, should be treated in accordance with AWP A U1 Use Category 4A requirements for sawn products as given in Table 1.

4.3 Restricted use of preservatives. The US Environmental Protection Agency has restricted, but not banned, the use of creosote, pentachlorophenol, and inorganic arsenicals, including CCA. The restrictions are variable. They may require only coating for a specific use, while in other cases they are prohibited. Generally, more restrictions occur where the environment is enclosed, and severe restrictions are imposed around feed and water. For specific criteria and limitations, refer to the appropriate government documents. The primary on-line source for U.S. government regulations is regulations.gov (<http://www.regulations.gov/>). Other sources for information relating to wood preservative treatments include the U.S. Consumer Product Safety Commission (<http://www.cpsc.gov/>) and the National Pesticide Information Center (<http://npic.orst.edu/index.html>).

4.4 Fasteners in treated lumber. Mechanical fasteners used above grade to join waterborne preservative—treated lumber, shall be of AISI type 304 or 316 stainless steel, silicon bronze, or copper, or shall contain a coating applied in accordance with the treated wood or fastener manufacturer's recommendations for AWP A U1 Use Category 4A treatment levels for sawn lumber products. In the absence of manufacturer's recommendations, a minimum of ASTM A653, type G185 zinc-coated galvanized steel, or equivalent, shall be used. Mechanical fasteners that are used below grade to assure compatibility of deformation between treated laminates shall be of AISI type 304 or 316 stainless steel.

4.5 Certified structural glued end joints. Certified structural glued end joints shall be manufactured using adhesives meeting the requirements of 4.5.1. The production process shall be subject to initial qualification in accordance with 4.5.2, daily quality control in accordance with 4.5.3, and periodic auditing by an accredited inspection agency in accordance with 4.5.4.

4.5.1 Adhesives. Adhesives used in certified structural glued end joints shall conform to the requirements of AITC 405.

4.5.2 Initial Qualification. The production of certified structural glued end joints shall be subject to initial qualification by testing a minimum of 30 specimens for strength in accordance with ASTM D7469-08 and a minimum of 5 specimens for delamination in accordance with AITC Test T110.

4.5.2.1 Strength Requirement. The 5% tolerance limit with 75% confidence for bending strength shall meet or exceed 2.1 times the adjusted edgewise bending design value, F_b' , calculated in accordance with the National Design Specifications (NDS[®]) for Wood Construction for normal load duration and dry-service conditions. When the end joint connects lumber with different F_b' values, the required strength shall be based on the lesser of the two F_b' values.

Table 1 – Minimum Preservation Treatment Levels for Mechanically Laminated Wood Assemblies^{a)}

Wood Species →	Southern Pine, Mixed Southern Pine, Radiata Pine, Patula Pine, Caribbean Pine, Ponderosa Pine, Red Pine, Eastern White Pine, Coastal Douglas-fir, Hem-fir, Hem-fir North, Subalpine Fir		Jack Pine, Lodgepole Pine		Western White Spruce, Engelmann Spruce, Sitka Spruce		Spruce-Pine-Fir West		Redwood	
Mechanically Laminated Assemble Use Location →	Exposed Above Ground	In Freshwater or Ground Contact	Exposed Above Ground	In Freshwater or Ground Contact	Exposed Above Ground	In Freshwater or Ground Contact	Exposed Above Ground	In Freshwater or Ground Contact	Exposed Above Ground	In Freshwater or Ground Contact
AWPA Use Category for Sawn Products →	4A	4B	4A	4B	4A	4B	4A	4B	4A	4B
Oilborne and Creosote-Based Treatments	Preservative Retentions kg/m ³ (lbm/ft ³)									
Creosote (CR), Creosote Solution (CR-S), Creosote-Petroleum Solution (CR-PS)	160 (10.0)	160 (10.0)	160 (10.0)	160 (10.0)	160 (10.0)	160 (10.0)	#	#	160 (10.0)	160 (10.0)
Pentachlorophenol (penta) Solvent A (PCP-A), Pentachlorophenol (penta) Solvent C (PCP-C)	8.0 (0.50)	8.0 (0.50)	6.4 (0.40)	8.0 (0.50)	6.4 (0.40)	8.0 (0.50)	#	#	8.0 (0.50)	8.0 (0.50)
Copper Naphthenate	0.96 (0.06)	1.2 (0.075)	0.96 (0.06)	1.2 (0.075)	0.96 (0.06)	1.2 (0.075)	#	#	0.96 (0.06)	1.2 (0.075)
Waterborne Treatments	Preservative Retentions kg/m ³ (lbm/ft ³)									
Acid Copper Chromate (ACC)	8.0 (0.50)	#	8.0 (0.50)	#	8.0 (0.50)	#	#	#	8.0 (0.50)	#
Chromated Copper Arsenate Type C (CCA), Ammoniacal Copper Zinc Arsenate (ACZA)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)
Ammoniacal Copper Quat Type B (ACQ-B)	6.4 (0.40)	9.6 (0.60)	#	#	6.4 (0.40)	9.6 (0.60)	#	#	#	#
Ammoniacal Copper Quat Type C (ACQ-C)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	#	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	#	9.6 (0.60)
Ammoniacal Copper Quat Type D (ACQ-D)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	6.4 (0.40)	9.6 (0.60)	#	9.6 (0.60)	#	9.6 (0.60)
Copper Azole Type C (CA-C)	2.4 (0.15)	5.0 (0.31)	#	5.0 (0.31)	#	#	#	#	#	#
Copper Azole Type B (CA-B)	3.3 (0.21)	5.0 (0.31)	#	5.0 (0.31)	#	#	#	#	#	#
Copper Azole Type A (CBA-A)	6.5 (0.41)	9.8 (0.61)	#	9.8 (0.61)	#	#	#	#	#	#
Waterborne Copper Naphthenate (CuN-W)	1.76 (0.11)	#	1.76 (0.11)	#	#	#	#	#	#	#
a) From AWPA U1-09 # Either no proposal for standardization and/or data demonstrating efficacy of a preservative/species combination has been submitted to AWPA; or the use of the preservative/species combination has been proven ineffective										

4.5.2.2 Delamination Requirement. Delamination after one complete cycle shall not exceed 5% for softwoods or 8% for hardwoods. If delamination exceeds these values after one cycle, a second cycle shall be performed on the same specimens, in which case the delamination shall not exceed 10%.

4.5.3 Daily Quality Control. All glued end joints produced during a work shift shall qualify as certified structural glued end joints if all end joints sampled in accordance with clause 4.5.3.1 meet the strength requirements of clause 4.5.3.2 and the delamination requirements of 4.5.3.3.

4.5.3.1 Sampling. The number of end joints to be tested for strength and delamination shall be a minimum of 1 per 200 manufactured joints, but no less than 2 end joints per work shift, with one of these joints being the first produced during the work shift and the other being the last produced during the work shift. In addition, the first production joint produced following a change of end joint cutter heads shall be tested, and the first joint produced following any major change in end joint production variables shall be tested. Major changes include, but are not limited to, changes in lumber dimension, lumber grade, lumber species, lumber treatment, and curing procedure.

4.5.3.2 Strength. A glued end joint must not fail when subjected to the appropriate qualifying proof load (QPL). The QPL is an edge-wise bending load applied in accordance with the requirements of ASTM D7469 with the end joint located midway between load points. The magnitude of the QPL is the load that induces a maximum wood bending stress in the sample equal to 2.1 times the adjusted bending design value, F_b' , calculated in accordance with the *National Design Specifications* (NDS®) for *Wood Construction* for normal load duration and dry-service conditions. When the end joint connects lumber with different F_b' values, the QPL shall be based on the lesser of the two F_b' values.

4.5.3.2.1 End joint failure. Is any failure that is initiated by the joint. This does not include wood fractures that originate at locations away from the joint and extend to the joint where they may then initiate a glue bond failure or wood fracture in the end joint.

4.5.3.2.2 Non joint failure. Is any failure that is not classified as an end joint failure. If a non joint failure occurs prior to full application of the QPL, the test is inconclusive with respect to end joint strength and another end joint specimen must be tested. Where possible, this replacement specimen should be the end joint manufactured immediately before or after the end joint associated with the inconclusive test.

4.5.3.2.3 Documentation of test. A record shall be kept of each test that includes: date and time of test; lumber size, species and grade; qualifying proof load; load rate; and details of any failure that occurs prior to reaching the QPL.

4.5.3.2.4 Use of test specimens. Test specimens that meet the strength requirements of clause 4.5.3.2 without visible or audible signs of failure can be used in the production of laminated assemblies.

4.5.3.3 Cyclic delamination. Tests shall be conducted in accordance with AITC Test T110. Delamination after one complete cycle shall not exceed 5% for softwoods or 8% for hardwoods. If delamination exceeds these values after one cycle, a second cycle shall be performed on the same specimens, in which case the delamination shall not exceed 10%.

4.5.3.3.1 Documentation of test. A record shall be kept of each test that includes: date and time of test, identifying information for batch of end joints being tested, and the required report from AITC Test T110.

4.5.4 Periodic Auditing. All certified structural glued end joints shall be manufactured in facilities that are subject to periodic, unannounced audits by an accredited inspection agency. All processes and records relevant to the production of such end joints shall be subject to audit.

4.5.4.1 Accredited Inspection Agency. An accredited inspection agency is defined as an entity that:

- (a) Operates an inspection system which audits the quality control systems for certified structural end joints.
- (b) Provides the facilities and personnel to perform the audit and to verify the required testing.