ANSI/APA PRG 320-2017

AMERICAN NATIONAL STANDARD

Standard for Performance-Rated Cross-Laminated Timber

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American National Standards Institute
25 West 43rd Street, 4th Floor
New York, NY 10036
www.ansi.org

Published by
APA – The Engineered Wood Association
7011 South 19th Street
Tacoma, WA 98466

Cover photo courtesy of Structurlam

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APA – The Engineered Wood Association

Approved October 6, 2017
Errata Incorporated
American National Standards Institute

FOREWORD (This Foreword is not a part of American National Standard ANSI/APA PRG 320-2017)

This standard provides requirements and test methods for qualification and quality assurance for performance-rated cross-laminated timber (CLT), which is manufactured from solid-sawn lumber or structural composite lumber (SCL) intended for use in construction applications. Product performance classes are also specified.

The development of this consensus American National Standard was achieved by following the *Operating Procedures for Development of Consensus Standards* of *APA – The Engineered Wood Association,* approved by the American National Standards Institute (ANSI).

Inquiries or suggestions for improvement of this Standard should be directed to *APA – The Engineered Wood Association* at 7011 South 19th Street, Tacoma, WA 98466, www.apawood.org.

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1. SCOPE

Cross-laminated timber (CLT) panels referenced in this standard are defined in 3.2 and shall be qualified and trademarked in accordance with this standard. This standard provides dimensions and tolerances, performance requirements, test methods, quality assurance, and trademarking for CLT panels.

CLT panels shall be used in dry service conditions, such as in most covered structures, where the average equilibrium moisture content of solid wood is less than 16 percent in the U.S., and is 15 percent or less over a year and does not exceed 19 percent in Canada. CLT panels qualified in accordance with the provisions of this standard are intended to resist the effects of moisture on structural performance as may occur due to construction delays or other conditions of similar severity. Products carrying a trademark of this standard shall be used in accordance with the installation requirements prescribed in the recommendations provided by the CLT manufacturer, an *approved agency*, and/or its trade association. Finger joining, edge gluing, and face gluing between CLT panels, and camber of CLT panels are beyond the scope of this standard.

The annex contained in this standard is mandatory, while notes and appendices are non-mandatory. This standard incorporates the U.S. customary units as well as the International System of Units (SI). The values given in the U.S. customary units are the standard in the U.S. and the SI values given in parentheses are the standard in Canada.

2. REFERENCED DOCUMENTS

This standard incorporates dated references. Subsequent amendments or revisions to these references apply to this standard only when incorporated into this standard by amendments or revisions.

2.1 U.S. Standards

AITC Test T107-2007 Shear Test

ANSI 405-2013 Standard for Adhesives for Use in Structural Glued Laminated Timber

ANSI A190.1-2017 Structural Glued Laminated Timber

ANSI/AWC NDS-2015 National Design Specification for Wood Construction

ASTM D9-12 Standard Terminology Relating to Wood and Wood-Based Products

ASTM D198-15 Standard Test Methods of Static Tests of Lumber in Structural Sizes

ASTM D905-08 (2013) Standard Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading

ASTM D907-15 Standard Terminology of Adhesives

ASTM D1037-12 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials

ASTM D2395-14e1 Standard Test Methods for Specific Gravity of Wood and Wood-Base Materials

ASTM D2559-12ae1 Standard Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions

ASTM D2915-10 Standard Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

ASTM D3737-12 Standard Practice for Establishing Stresses for Structural Glued Laminated Timber (Glulam)

ASTM D4761-13 Standard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Material

ASTM D5055-16 Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists

ASTM D5456-14b Standard Specification for Evaluation of Structural Composite Lumber Products

ASTM D6815-09 (2015) Standard Specification for Evaluation of Duration of Load and Creep Effects of Wood and Wood-Based Products

ASTM D7247-16 Standard Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures

ASTM D7374-08 (2015) Standard Practice for Evaluating Elevated Temperature Performance of Adhesives Used in End-Jointed Lumber

ASTM E119-16a Standard Test Methods for Fire Tests of Building Construction and Materials

US Product Standard PS 1-09 Structural Plywood

US Product Standard PS 20-15 American Softwood Lumber Standard

2.2 Canadian Standards

CAN/CSA O86-14 (Reprint 2016) Engineering Design in Wood

CAN/ULC S101-14 Standard Methods of Fire Endurance Tests of Building Construction and Materials

CSA O112.10-08 (R2013) Evaluation of Adhesives for Structural Wood Products (Limited Moisture Exposure)

CSA O122-16 Structural Glued-Laminated Timber

CSA O141-05 (R2014) Softwood Lumber

CSA O177-06 (R2015) Qualification Code for the Manufacturers of Structural Glued-Laminated Timber

NLGA Standard Grading Rules for Canadian Lumber (2014)

NLGA SPS 1-2017 Special Products Standard for Fingerjoined Structural Lumber

NLGA SPS 2-2017 Special Products Standard for Machine Graded Lumber

NLGA SPS 4-2014 Special Products Standard for Fingerjoined Machine Graded Lumber

NLGA SPS 6-2015 Special Products Standard for Structural Face-Glued Lumber

2.3 International Standards

ISO/IEC 17011-2004 Conformity Assessment—General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies

ISO/IEC 17020-2012 Conformity Assessment—Requirements for Operation of Various Types of Bodies Performing Inspection

ISO/IEC 17025-2005 General Requirements for the Competence of Testing and Calibration Laboratories

ISO/IEC 17065-2012 Conformity Assessment—Requirements for Bodies Certifying Products, Processes, and Services

3. TERMINOLOGY

3.1 Definitions

See the referenced documents for definitions of terms used in this standard.

3.2 Terms Specific to This Standard

ASD Reference Design Value—design value used in the U.S. based on normal duration of load, dry service conditions, and reference temperatures up to 100°F (38°C) for the Allowable Stress Design (ASD)

Adhesive—a substance capable of holding materials together

Adherend—a material held to another material by an adhesive

Approved Agency (U.S.)—an established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been approved by regulatory bodies (see *Qualified Inspection Agency* and *Qualified Testing Agency*)

Approved Agency (Canada)—an established and recognized agency regularly engaged in conducting certification services, when such agency has been approved by regulatory bodies (see *Qualified Certification Agency*)

Bond—the attachment at an interface between adhesive and adherends or the act of attaching adherends together by adhesive

Bondline—the layer of adhesive that attaches two adherends

- ***Face bondline***—the bondline joining the wide faces of laminations in adjacent layers
- ***Edge bondline***—the optional bondline joining the narrow faces of adjacent laminations within one layer

Characteristic Values—the structural property estimate, typically a population mean for stiffness properties or a tolerance limit (5th percentile with 75% confidence) for strength properties, as estimated from the test data that is representative of the population being sampled

Cross-Laminated Timber (CLT)—a prefabricated engineered wood product made of at least three orthogonal layers of graded sawn lumber or structural composite lumber (SCL) that are laminated by gluing with structural adhesives

CLT Length—dimension of the CLT panel measured parallel to the major strength direction

Note 1. The length and width of CLT defined in this standard are based on the CLT panel dimension and may not be related to the end-use, such as wall, roof, and floor, applications.

CLT Panel—a single CLT billet formed by bonding laminations with a structural adhesive

CLT Thickness—dimension of the CLT panel measured perpendicular to the plane of the panel

CLT Width—dimension of the CLT panel measured perpendicular to the major strength direction

Curing—converting an adhesive into a fixed or hardened state by chemical and/or physical action

Delamination—the separation of layers in a laminate due to failure of the adhesive either in the adhesive itself or at the interface between the adhesive and the adherend

Edge (Panel Edge)—the narrow face of a panel that exposes the ends or narrow faces of the laminations

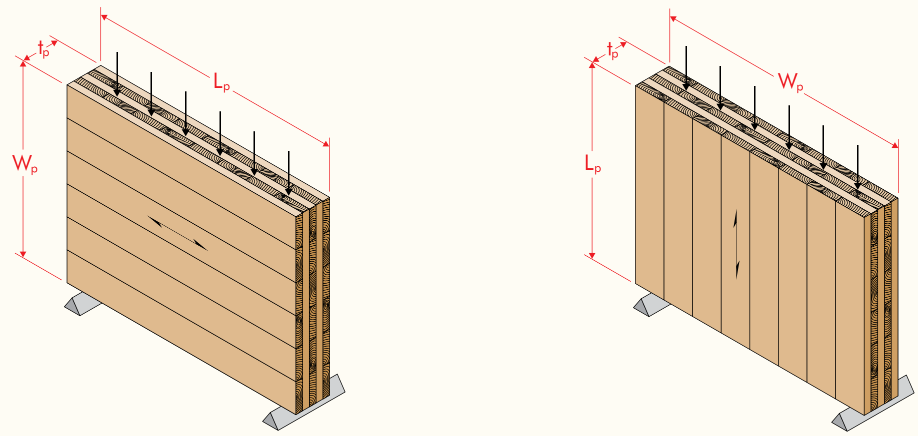
Edgewise Bending—bending of CLT under loads applied to the panel edge (see Figure 1) creating in-plane bending and edgewise shear, also known as in-plane shear or shear through-the-thickness

Edge Joint—a joint of the narrow faces of adjacent laminations within a CLT layer with or without gluing

Effective Bonding Area—proportion of the lamination wide face averaged over its length that is able to form a close contact bond upon application of pressure

FIGURE 1

EDGEWISE BENDING IN THE MAJOR (LEFT) AND MINOR (RIGHT) CLT STRENGTH DIRECTIONS



End Joint—a joint made by gluing of two pieces of laminations within a CLT layer by the ends

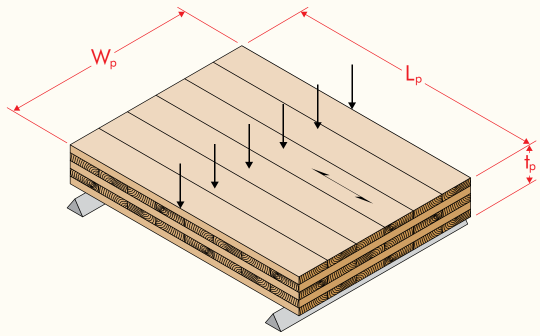
Face—one of the four longitudinal surfaces of a piece or panel

- ***Lamination narrow face—***the face with the least dimension perpendicular to the lamination length
- ***Lamination wide face—***the face with the largest dimension perpendicular to the lamination length
- ***Panel face—***the face of the CLT length-width plane

Flatwise Bending**—**bending of CLT under transverse loads applied to the panel face (see Figure 2) creating out-of-plane bending and flatwise shear, also known as planar or rolling shear

FIGURE 2

FLATWISE BENDING IN THE MAJOR (LEFT) AND MINOR (RIGHT) CLT STRENGTH DIRECTIONS



Lamination**—**a piece of sawn lumber or structural composite lumber, including stress rated boards, remanufactured lumber, or end-joined lumber, which has been prepared and qualified for laminating

Layer**—**an arrangement of laminations of the same thickness, grade, and species combination laid out essentially parallel to each other in one plane

- ***Longitudinal*****—**a layer with the laminations oriented parallel to the major strength direction
- ***Transverse*****—**a layer with the laminations oriented perpendicular to the major strength direction, also referred to as cross layer

Layup**—**an arrangement of layers in a CLT panel determined by the grade, number, orientation, and thickness of laminations

Note 2. Typical CLT layups in this standard are listed in Annex A. Other (Custom) CLT layups may be established in accordance with 7.2.1.

LSD Design Value**—**design value used in Canada based on standard-term duration of load, dry service conditions, and temperatures up to 122°F (50°C) except for occasional exposures to 150°F (65°C) for the Limit States Design (LSD)

Major Strength Direction**—**general direction of the grain of the laminations in the outer layers of the CLT panel

Manufacturing Standard**—**a document that establishes the minimum requirements for manufacturing practices, staff, facilities, equipment, and specific quality assurance processes, including inspection (in the U.S.) and/or certification (in Canada), by which the product is manufactured

Mill Specification**—**a manufacturing specification based on product evaluation to be used for quality assurance purposes by the manufacturer and the *approved agency*

Minor Strength Direction**—**perpendicular to the major strength direction of the CLT panel

Qualified Certification Agency (Canada)—an agency meeting the following requirements:

a. has trained personnel to perform product certification in compliance with all applicable requirements specified in this standard,

b. has procedures to be followed by its personnel in performance of the certification,

c. has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being certified,

d. is not owned, operated, or controlled by any such company, and

e. is accredited by a recognized accreditation body under ISO/IEC 17065

Qualified Inspection Agency (U.S.)—an agency meeting the following requirements:

a. has trained personnel to verify that the grading, measuring, species, construction, bonding, workmanship, and other characteristics of the products as determined by inspection in compliance with all applicable requirements specified in this standard,

b. has procedures to be followed by its personnel in performance of the inspection,

c. has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being inspected,

d. is not owned, operated, or controlled by any such company, and

e. is accredited by a recognized accreditation body under ISO/IEC 17020

Qualified Testing Agency—an agency meeting the following requirements:

a. has access to the facilities and trained technical personnel to conduct testing on the characteristics of the products by sampling and testing in compliance with all applicable requirements specified in this standard,

b. has procedures to be followed by its personnel in performance of the testing,

c. has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being tested,

d. is not owned, operated, or controlled by any such company, and

e. is accredited by a recognized accreditation body under ISO/IEC 17025

Recognized Accreditation Body—an organization complying with ISO/IEC 17011 and recognized by the regulatory body having jurisdiction as qualified to evaluate and accredit certification agencies, inspection agencies and/or testing agencies

Remanufactured Lumber—lumber that meets the requirements of Section 5.4 of ANSI A190.1 in the U.S., or NLGA SPS 1, 2, 4, or 6 in Canada

Structural Composite Lumber (SCL) —an engineered wood product that is intended for structural use and bonded with adhesives, and meeting the definition and requirements of ASTM D5456

Wood Failure—the rupturing of wood fibers from the specified block shear test on bonded specimens, measured as the area of wood fiber remaining at the bondline and expressed as a percentage of total area involved in such failure

4. SYMBOLS

4.1 CLT Section and Mechanical Properties

Symbol	Definition	Reference(s)
$E_{e,0}$	Effective edgewise bending modulus of elasticity of CLT, in psi (MPa), in the major strength direction, used with $I_{e,0}$ when calculating edgewise bending stiffness	8.5.5.2
$E_{e,90}$	Effective edgewise bending modulus of elasticity of CLT, in psi (MPa), in the minor strength direction, used with $I_{e,90}$ when calculating edgewise bending stiffness	8.5.5.2
$(EI)_{eff,f,0}$	Effective flatwise bending stiffness of CLT, in lbf-in²/ft (N-mm²/m) of width, in the major strength direction	8.5.3.2 and Tables A2 and A4
$(EI)_{eff,f,90}$	Effective flatwise bending stiffness of CLT, in lbf-in²/ft (N-mm²/m) of width, in the minor strength direction	8.5.3.2 and Tables A2 and A4
$f_{b,e,0}$	Effective LSD specified edgewise bending strength of CLT, in MPa, in the major strength direction, used with $S_{e,0}$ when calculating LSD edgewise bending moment resistance.	8.5.5.2
$F_{b,e,0}$	Effective ASD reference edgewise bending stress of CLT, in psi, in the major strength direction, used with $S_{e,0}$ when calculating ASD reference edgewise bending moment.	8.5.5.2
$f_{b,e,90}$	Effective LSD specified edgewise bending strength of CLT, in MPa, in the minor strength direction, used with $S_{e,90}$ when calculating LSD edgewise bending moment resistance.	8.5.5.2
$F_{b,e,90}$	Effective ASD reference edgewise bending stress of CLT, in psi, in the minor strength direction, used with $S_{e,90}$ when calculating ASD reference edgewise bending moment.	8.5.5.2
$(f_bS)_{eff,f,0}$	Effective LSD flatwise bending moment resistance of CLT, in N-mm/m of width, in the major strength direction	8.5.3.2 and Table A4
$(F_bS)_{eff,f,0}$	Effective ASD reference flatwise bending moment of CLT, in lbf-ft/ft of width, in the major strength direction	8.5.3.2 and Table A2
$(f_bS)_{eff,f,90}$	Effective LSD flatwise bending moment resistance of CLT, in N-mm/m of width, in the minor strength direction	8.5.3.2 and Table A4
$(F_bS)_{eff,f,90}$	Effective ASD reference flatwise bending moment of CLT, in lbf-ft/ft of width, in the minor strength direction	8.5.3.2 and Table A2
$f_{v,e,0}$	LSD specified edgewise shear strength of CLT, in MPa, in the major strength direction, used with t_p when calculating LSD edgewise shear resistance.	8.5.6.2
$F_{v,e,0}$	ASD reference edgewise shear stress of CLT, in psi, in the major strength direction, used with t_p when calculating ASD reference edgewise shear capacity.	8.5.6.2
$f_{v,e,90}$	LSD specified edgewise shear strength of CLT, in MPa, in the minor strength direction, used with t_p when calculating LSD edgewise shear resistance.	8.5.6.2
$F_{v,e,90}$	ASD reference edgewise shear stress of CLT, in psi, in the minor strength direction, used with t_p when calculating ASD reference edgewise shear capacity	8.5.6.2
$G_{e,0}$	Effective modulus of rigidity (shear modulus) in edgewise bending of CLT, in psi (MPa), in the major strength direction, used with t_p when calculating edgewise shear stiffness	8.5.6.2
$G_{e,90}$	Effective modulus of rigidity (shear modulus) in edgewise bending of CLT, in psi (MPa), in the minor strength direction, used with t_p when calculating edgewise shear stiffness	8.5.6.2
$(GA)_{eff,f,0}$	Effective shear stiffness in flatwise bending of CLT in lbf/ft (N/m) of width in the major strength direction	8.5.4.2, and Tables A2 and A4
$(GA)_{eff,f,90}$	Effective shear stiffness in flatwise bending of CLT in lbf/ft (N/m) of width in the minor strength direction	8.5.4.2, and Tables A2 and A4
$I_{e,0}$	Gross moment of inertia of CLT in edgewise bending in the major strength direction, in in.⁴ (mm⁴), for a specific panel width (beam depth), calculated as $\frac{W_p^3 t_p}{12}$	8.5.5.2
$I_{e,90}$	Gross moment of inertia of CLT in edgewise bending in the minor strength direction, in in.⁴ (mm⁴), for a specific panel length (beam depth), calculated as $\frac{L_p^3 t_p}{12}$	8.5.5.2
L_p	Length of CLT panel in ft (m), measured in the major strength direction	Figures 1 and 2

Symbol	Definition	Reference(s)
$S_{e,0}$	Gross section modulus of CLT in edgewise bending in the major strength direction, in in.^{3} (mm^3) for a specific CLT width (beam depth), calculated as $\frac{W_p^2 t_p}{6}$	8.5.5.2
$S_{e,90}$	Gross section modulus of CLT in edgewise bending in the minor strength direction, in in.^{3} (mm^3) for a specific CLT length (beam depth), calculated as $\frac{L_p^2 t_p}{6}$	8.5.5.2
t_p	Gross thickness of CLT panel, in in. (mm)	Figures 1 and 2, Tables A2 and A4, and 8.5.6.2
$v_{s,0}$	LSD flatwise shear resistance, in N/m of width, in the major strength direction	8.5.4.2 and Table A4
$V_{s,0}$	ASD reference flatwise shear capacity, in lbf/ft of width, in the major strength direction	8.5.4.2 and Table A2
$v_{s,90}$	LSD flatwise shear strength, in N/m of width, in the minor strength direction	8.5.4.2 and Table A4
$V_{s,90}$	ASD reference flatwise shear capacity, in lbf/ft of width, in the minor strength direction	8.5.4.2 and Table A2
W_p	Width of CLT panel in ft (m), measured in the minor strength direction	Figures 1 and 2

4.2 Lamination mechanical properties

Symbol	Definition	Reference(s)
E	Modulus of elasticity of a lamination, in psi (MPa)	Tables 1, A1, and A3
f_b	Characteristic bending strength or LSD specified bending strength of a lamination, in psi (MPa)	Tables 1 and A3
F_b	ASD reference bending stress of a lamination, in psi	Table A1
f_c	Characteristic axial compressive strength or LSD specified axial compressive strength of a lamination, in psi (MPa)	Tables 1 and A3
F_c	ASD reference axial compressive stress of a lamination, in psi	Table A1
f_s	Characteristic planar (rolling) shear strength or LSD specified planar (rolling) shear strength of a lamination, in psi (MPa)	Tables 1 and A3
F_s	ASD reference planar (rolling) shear stress of a lamination, in psi	Table A1
f_t	Characteristic axial tensile strength or LSD specified axial tensile strength of a lamination, in psi (MPa)	Tables 1 and A3
F_t	ASD reference axial tensile stress of a lamination, in psi	Table A1
f_v	Characteristic shear strength or LSD specified shear strength of a lamination, in psi (MPa)	Tables 1 and A3
F_v	ASD reference shear stress of a lamination, in psi	Table A1
G	Modulus of rigidity (shear modulus) of a lamination, in psi (MPa)	Tables A1 and A3

5. PANEL DIMENSIONS AND DIMENSIONAL TOLERANCES

5.1 Thickness

The thickness of CLT shall not exceed 20 inches (508 mm).

5.2 CLT Dimensional Tolerances

Dimension tolerances permitted at the time of manufacturing shall be as follows:

- Thickness: ± 1/16 inch (1.6 mm) or 2% of the CLT thickness, whichever is greater
- Width: ± 1/8 inch (3.2 mm) of the CLT width
- Length: ± 1/4 inch (6.4 mm) of the CLT length

Textured or other face or edge finishes are permitted to alter the tolerances specified in this section. The designer shall compensate for any loss in cross-section and/or specified strength of such alterations.

Note 3. The manufacturer may be contacted for recommendations.

5.3 Squareness

Unless specified otherwise, the length of the two panel face diagonals measured between panel corners shall not differ by more than 1/8 inch (3.2 mm).

5.4 Straightness

Unless specified otherwise, deviation of edges from a straight line between adjacent panel corners shall not exceed 1/16 inch (1.6 mm).

6. COMPONENT REQUIREMENTS

6.1 Laminations—Lumber

6.1.1 Lumber species

Any softwood lumber species or species combinations recognized by American Lumber Standards Committee (ALSC) under PS 20 or Canadian Lumber Standards Accreditation Board (CLSAB) under CSA O141 with a minimum published specific gravity of 0.35, as published in the National Design Specification for Wood Construction (NDS) in the U.S. and CSA O86 in Canada, shall be permitted for use in CLT manufacturing provided that other requirements specified in this section are satisfied. The same lumber species or species combination shall be used within a single layer of CLT. Adjacent layers of CLT shall be permitted to be made of different species or species combinations.

6.1.2 Lumber grades

The minimum grade of lumber in the parallel layers of CLT shall be 1200f-1.2E MSR or visual grade No. 2. The minimum grade of lumber in the perpendicular layers of CLT shall be visual grade No. 3. Remanufactured lumber shall be considered as equivalent to solid-sawn lumber when qualified in accordance with Section 5.4 of ANSI A190.1 in the U.S. or SPS 1, 2, 4, or 6 in Canada. Proprietary lumber grades meeting or exceeding the mechanical properties of the lumber grades specified above shall be permitted for use provided that they are qualified in accordance with the requirements of an *approved agency*.

Note 4. ASTM D5055 provides guidance for proprietary lumber grades used specifically in I-joist applications.

6.1.3 Lamination sizes

a. ***Major Strength Direction***—The net width of a lamination shall not be less than 1.75 times the lamination thickness for the parallel layers.

b. ***Minor Strength Direction***—If the laminations in the perpendicular (cross) layers are not edge bonded, the net width of a lamination shall not be less than 3.5 times the lamination thickness for the perpendicular (cross) layers unless the interlaminar shear strength and creep are evaluated by testing in accordance with Section 8.5.4.1 and the principles of ASTM D6815, respectively.

c. ***Both Directions***—The net thickness of a lamination for all layers at the time of gluing shall not be less than 5/8 inch (16 mm) or more than 2 inches (51 mm). In addition, the lamination thickness shall not vary within the same CLT layer.

6.1.4 Moisture content

The moisture content of the lumber at the time of CLT manufacturing shall be 12 ± 3%. The moisture content of the SCL at the time of CLT manufacturing shall be 8 ± 3%.

6.1.5 Face-bonding surface

All face-bonding surfaces shall be planed prior to face bonding and except for minor local variations, shall be free of raised grain, torn grain, skip, burns, glazing or other deviations from the plane of the surface that might interfere with the contact of sound wood fibers in the bonding surfaces. All face-bonding surfaces shall be free from dust, foreign matter, and exudation that are detrimental to satisfactory bonding.

Note 5. It may be necessary to plane the lamination surface within 48 hours of face bonding for some wood species.

6.1.6 Face-bonding dimensional tolerances

At the time of face-bonding, variations in thickness across the width of a lamination shall not exceed ±0.008 inch (0.2 mm). The variation in thickness along the length of a lamination shall not exceed ±0.012 inch (0.3 mm). Bow and cup shall not be so great that they will not be straightened out by pressure in bonding.

6.2 Laminations—Structural Composite Lumber

SCL products meeting the requirements of ASTM D5456 and the equivalent specific gravity specified in 6.1.1 shall be permitted for use. SCL laminations must also meet the requirements of 6.1.3 through 6.1.6.

6.3 Adhesives

a. In the U.S., adhesives used for CLT manufacturing shall meet the requirements of ANSI 405 with the exception that Section 2.1.6 of ANSI 405 (either ASTM D3434 or CSA O112.9) is not required. In addition, adhesives shall be evaluated for heat performance in accordance with Section 6.1.3.4 of DOC PS1.

b. In Canada, adhesives shall meet the requirements of CSA O112.10, and Sections 2.1.3 and 3.3 (ASTM D7247 heat durability) of ANSI 405. In addition, adhesives shall be evaluated for heat performance in accordance with Section 6.1.3.4 of DOC PS1.

c. For use in both the U.S. and Canada, adhesives shall meet both ***a*** and ***b*** in this section.

Note 6. The intent of the heat performance evaluation is to determine whether an adhesive has exhibited heat delamination characteristics[1], which may increase the char rate of the CLT when exposed to fire in certain applications. If heat delamination occurs, the CLT manufacturer is recommended to consult with the adhesive manufacturer and the approved agency to develop an appropriate adjustment in product manufacturing and/or an end-use recommendation.

6.4 Lamination Joints

6.4.1 General

The lamination joints of CLT shall meet the requirements specified in this section.

6.4.2 End joints in laminations

The strength, wood failure, and durability of lamination end joints shall be qualified in accordance with Section 12.1.3 of ANSI A190.1 and meet the requirements specified therein the U.S., or shall be qualified in accordance with Section 9.5 of CSA O177 and meet the requirements specified therein in Canada.

1 Information on heat delamination may be found in the *Proposed Heat Durability Test for Classifying Adhesives in Crossed-Layer Wood Products—An Exploratory Study* published by the FPInnovations, Canada, in November 2010.

6.4.3 Edge and face joints in laminations

The wood failure and durability of the face and edge (when required for structural performance) joints shall be qualified in accordance with Section 12.1.2 of ANSI A190.1 and meet all requirements, except for the shear strength, specified in Section 12.1.2.(b) of that standard in the U.S., or shall be qualified in accordance with Sections 9.2 and 9.3 of CSA O177 and meet all requirements, except for the shear strength, specified therein in Canada.

7. CLT PERFORMANCE CRITERIA

CLT shall meet the performance requirements established in this section.

7.1 Layup Requirements

The arrangement of orthogonal layers shall be specified in the manufacturing standard of each CLT plant when qualified in accordance with the requirements specified in this section and by an *approved agency*.

7.2 Structural Performance Requirements

Structural performance shall be evaluated for each CLT layup unless otherwise noted in this section. CLT shall meet the minimum structural performance based on the properties shown in Table 1 multiplied by the section properties provided by the manufacturer and accepted by an *approved agency* when evaluated and confirmed by test results in accordance with 8.5. CLT panels manufactured with SCL layers, which do not meet Table 1 requirements, shall be qualified in accordance with 7.2.1.

TABLE 1

REQUIRED CHARACTERISTIC TEST VALUES[a,b,c,d] FOR LAMINATIONS USED IN PRG 320 CLT

	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
CLT Layup	f_b (psi)	E (10^6 psi)	f_t (psi)	f_c (psi)	f_v (psi)	f_s (psi)	f_b (psi)	E (10^6 psi)	f_t (psi)	f_c (psi)	f_v (psi)	f_s (psi)
E1	4,095	1.7	2,885	3,420	425	140	1,050	1.2	525	1,235	425	140
E2	3,465	1.5	2,140	3,230	565	185	1,100	1.4	680	1,470	565	185
E3	2,520	1.2	1,260	2,660	345	115	735	0.9	315	900	345	115
E4	4,095	1.7	2,885	3,420	550	180	945	1.3	525	1,375	550	180
V1	1,890	1.6	1,205	2,565	565	185	1,100	1.4	680	1,470	565	185
V2	1,835	1.4	945	2,185	425	140	1,050	1.2	525	1,235	425	140
V3	1,575	1.4	945	2,375	550	180	945	1.3	525	1,375	550	180

For SI: 1 psi = 0.006895 MPa

a. See Section 4 for symbols.

b. Tabulated values are test values and shall not be used for design. See Annex A for design properties.

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

d. The characteristic values shall be determined as follows from the published reference design value unless otherwise justified by the *approved agency*:

f_b = 2.1 x published ASD reference bending stress (F_b),

f_t = 2.1 x published ASD reference tensile stress (F_t),

f_c = 1.9 x published ASD reference compressive stress parallel to grain (F_c),

f_v = 3.15 x published ASD reference shear stress (F_v)

Note 7. The "E" designation indicates a CLT layup based on the use of E-rated or MSR laminations in the longitudinal layers and the "V" designation indicates a CLT layup based on the use of visually graded laminations in the longitudinal layers. Visually graded laminations are used in the transverse layers for both "E" and "V" layups. The specific species and grade of the longitudinal layers and the corresponding transverse layers for each "E" and "V" designation are based on the layups shown in Annex A.

7.2.1 *Custom CLT layups*

Custom CLT layups permitted when approved by an *approved agency* in accordance with the qualification and mechanical test requirements (see 8.4 and 8.5) specified in this standard. In this case, a unique CLT layup designation shall be assigned by the *approved agency* if the custom product represents a significant product volume of the manufacturer to avoid duplication with an existing CLT grade designation that has been assigned to other manufacturers.

Note 8. Annex A provides the design capacities for some CLT layups. The custom CLT layups are intended for layups that are different from those provided in Tables 1, A1, A2, A3, and A4, and may include double outer layers or unbalanced layups when clearly identified for installation, as required by the manufacturer and the approved agency.

7.3 Appearance Classifications

CLT panel appearance shall be as agreed to between the buyer and the seller.

Note 9. Appendix A contains examples of CLT appearance classifications for reference.

8. QUALIFICATION AND PRODUCT MARKING

8.1 Qualification Requirements

Required qualification tests for CLT components, such as lumber, adhesives, and end, face, and edge joints are provided in Section 6 and summarized in Table 2. This section provides requirements for plant qualification and CLT qualification tests to meet the structural performance levels specified in Tables A2 and A4.

TABLE 2

SUMMARY OF QUALIFICATION REQUIREMENTS

Qualification for	Standard(s)	Referenced Section(s) in This Standard
Lumber	Grading Rules/Manufacturing Standard	6.1.1 to 6.1.4
SCL	ASTM D5456	6.2
Adhesives	AITC 405 or CSA O112.10	6.3
End Joints	Section 12.1.3 of ANSI/A190.1 and/or Section 9.5 of CSA O177	6.4.2
Face Joints	Section 12.1.2 of ANSI A190.1 and/or Sections 9.2 and 9.3 of CSA O177	6.1.5, 6.1.6, 6.4.3, 8.2, and 8.3
Edge Joints (if applicable)	Section 12.1.2 of ANSI A190.1 and/or Sections 9.2 and 9.3 of CSA O177	6.4.3
CLT Panel Dimensions	—	5
CLT Panel Structural Performance	ASTM D198 or ASTM D4761	7.2 and 8.5

8.2 Plant Pre-Qualification

8.2.1 General

The CLT plant shall be pre-qualified for the manufacturing factors considered (see 8.2.2) using full-thickness qualification panels of 24 inches (610 mm) or more in the major strength direction and 18 inches (457 mm) or more in the minor strength direction (hereafter referred to as "Pre-qualification panels"). A minimum of two replicate CLT pre-qualification panels shall be manufactured for pre-qualification for each combination of factors considered in 8.2.2. The two replicate CLT pre-qualification panels shall not be extracted from a single full-size CLT panel.

Note 10. A pre-qualification panel of 24 inches (610 mm) or more in the minor strength direction is recommended, particularly for thicker CLT products.

Pre-qualification panels shall be prepared at the facility or at an alternative facility acceptable to the *approved agency*. All pre-qualification panels shall be:

a. Of the same approximate length and width at the time of pressing;

b. Pressed individually; and

c. Taken from approximately the geometric center of the larger panel, if applicable.

8.2.2 Fabrication of pre-qualification panels

Application of pressure to manufacture pre-qualification panels shall reflect the key characteristics of the manufacturing equipment, including the platen and glue spreader (as applicable) that is or will be used in the facility to be qualified. The applicability of the results shall be documented by the *approved agency*.

Note 11. For example, pre-qualification panels for facilities using a vacuum press or an air bag should be clamped using a vacuum press or an air bag inserted between the sample and the rigid platen. In addition, the sample preparation facility should distinguish between, for example, roller versus curtain coating and single spread versus double spread, which varies in the uniformity of the adhesive spread.

Factors considered for pre-qualification evaluation shall include assembly time, lumber moisture content, adhesive spread rate, clamping pressure, and wood surface temperature, as specified in the manufacturing standard of the plant and accepted by the *approved agency*.

8.2.3 Conditioning of pre-qualification panels

Pre-qualification panels shall be stored in an indoor environment for a minimum of 24 hours or until the adhesive has cured sufficiently to permit evaluation, whichever is longer.

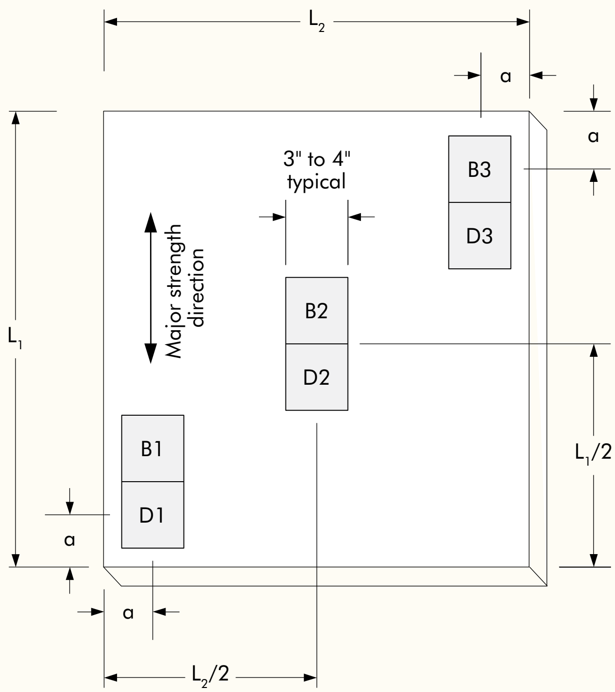
Note 12. For panels larger than the specified pre-qualification panel size, the panels may be trimmed to the specified size to facilitate conditioning.

8.2.4 Specimens

Six square/rectangular specimens (three for block shear tests, i.e., "B" specimens and three for delamination tests, i.e., "D" specimens) shall be extracted from each pre-qualification panel at the locations shown in Figure 3 and labeled to indicate the panel number and the specimen position within the panel. If the pre-qualification panel is larger than the specified pre-qualification panel size, the pre-qualification sampling area shall be 24 inches (610 mm) to 36 inches (910 mm) square located at the geometric center of the panel.

FIGURE 3

BLOCK SHEAR ("B") AND DELAMINATION ("D") SPECIMEN LOCATIONS
a = 4 ± 1 inches, L_1 = 24 to 36 inches, and L_2 = 24 to 36 inches (1 inch = 25.4 mm)



8.2.5 *Test methods and requirements*

The specimens obtained in accordance with 8.2.4 shall be qualified and meet the requirements specified in 6.4.3 of this standard.

8.3 Qualification of Effective Bond Area

8.3.1 *General*

The manufacturer shall establish visual grading rules for the bonded faces and limit the average glue skip to maintain an average effective bond area of 80% or more.

Note 13. Alternatively, glue skips may be treated as delamination.

The manufacturer's visual grading rules established to achieve the effective bond area shall include major visual characteristics based on characteristic measurements consistent with standard lumber grading rules.

8.3.2 *Sample selection and inspection*

Samples shall be drawn from representative production of laminations meeting the manufacturer's visual grading rules and positioned in accordance with the in-plant manufacturing standard. The layer formed by the laminations shall be verified by the *approved agency* to provide an effective bond area of 80% or more over any randomly selected area not less than 48 inches (1,220 mm) square.

Note 14. A template with a square opening may be used to facilitate inspection.

8.4 Qualification for Structural Performance

Following plant pre-qualification, a representative sample of CLT panels shall be manufactured for qualification tests in accordance with 8.4.1 and 8.4.2. Depending on the number of layups intended for qualification, a qualification plan shall be developed and accepted by an *approved agency* in accordance with the principles prescribed in this section.

8.4.1 *Required mechanical property qualification*

The flatwise bending and flatwise shear properties of CLT layups in both major and minor strength directions shall be tested in accordance with 8.5.3 and 8.5.4 to confirm the design values shown in Table A2 for use in the US or Table A4 for use in Canada, or the design values approved by an *approved agency*.

8.4.2 *Optional mechanical property qualification*

When edgewise bending and edgewise shear properties are to be approved by an *approved agency,* qualification tests shall be conducted in accordance with 8.5.5 and 8.5.6, respectively.

8.5 Mechanical Property Qualification

The design values from required mechanical property qualification (8.4.1) and optional mechanical property qualification (8.4.2) shall be approved by an *approved agency* in accordance with this section.

8.5.1 *Sampling*

Test samples shall be representative of typical production and shall be sampled at the manufacturing facility by an *approved agency* using the layup intended for qualification. The sample size required for stiffness capacities shall be sufficient for estimating the population mean within 5% precision with 75% confidence, or 10 specimens, whichever is greater. In general, a sample size larger than 10 is needed when the coefficient of variation is greater than 13%. The sample size required for strength capacities shall be sufficient for estimating the characteristic value with 75% confidence in accordance with ASTM D2915.

8.5.2 *Sample conditioning*

CLT panel samples shall be stored in an indoor environment for a minimum of 24 hours or until the adhesive has cured sufficiently to permit evaluation, whichever is longer. The CLT samples at the time of mechanical tests shall have an average moisture content of not less than 8%.

8.5.3 *Flatwise bending properties*

Flatwise bending stiffness and bending moment capacity (resistance) shall be evaluated in accordance with 8.5.3.1 and 8.5.3.2

8.5.3.1 *Flatwise bending test methods*

Flatwise bending tests shall be conducted in both major and minor strength directions in accordance with the third-point load method of Sections 4 through 12 of ASTM D198 or Section 8 of ASTM D4761 using the specimen width of not less than 12 inches (305 mm) and the on-center span equal to approximately 30 times the specimen depth for the tests in the major strength direction and approximately 18 times the specimen depth for the tests in the minor strength direction. The weight of the CLT panel is permitted to be included in the determination of the flatwise bending moment capacity (resistance).

8.5.3.2 Flatwise bending qualification requirements

In the U.S. and Canada, the average flatwise bending stiffness determined from qualification tests shall equal or exceed the published flatwise bending stiffness [$(EI)_{eff,f,0}$ or $(EI)_{eff,f,90}$].

In the U.S., the characteristic flatwise bending moment capacity determined from qualification tests shall equal or exceed the published ASD reference flatwise bending moment capacity [$(F_bS)_{eff,f,0}$ or $(F_bS)_{eff,f,90}$] times 2.1. In Canada, the characteristic flatwise bending moment resistance determined from qualification tests shall equal or exceed the published LSD flatwise bending resistance [$(f_bS)_{eff,f,0}$ or $(f_bS)_{eff,f,90}$] divided by 0.96.

8.5.4 Flatwise shear properties

Flatwise shear stiffness and capacity (resistance) shall be evaluated in accordance with 8.5.4.1 and 8.5.4.2.

8.5.4.1 Flatwise shear test methods

Flatwise shear stiffness tests shall be conducted in both major and minor strength directions in accordance with Sections 45 through 52 of ASTM D198.

Flatwise shear tests shall be conducted in both major and minor strength directions in accordance with the center-point load method of Sections 4 through 12 of ASTM D198 or Section 7 of ASTM D4761 using the specimen width of not less than 12 inches (305 mm) and the on-center span equal to 5 to 6 times the specimen depth. The bearing length shall be sufficient to avoid bearing failure, but not greater than the specimen depth. All specimens are to be cut to length with no overhangs allowed.

8.5.4.2 Flatwise shear qualification requirements

In the U.S. and Canada, the average flatwise shear stiffness determined from qualification tests shall equal or exceed the published shear stiffness in flatwise bending [$(GA)_{eff,f,0}$ or $(GA)_{eff,f,90}$].

In the US, the characteristic flatwise shear capacity determined from qualification tests shall equal or exceed the published ASD reference flatwise shear capacity ($V_{s,0}$ or $V_{s,90}$) times 2.1. In Canada, the characteristic flatwise shear resistance determined from qualification tests shall equal or exceed the published LSD flatwise shear resistance ($v_{s,0}$ or $v_{s,90}$) divided by 0.96.

8.5.5. Edgewise bending properties

Edgewise bending stiffness and bending moment capacity (resistance) shall be permitted to be evaluated in accordance with 8.5.5.1 and 8.5.5.2. The volume, creep and load duration effects of edgewise bending capacity (resistance) shall be evaluated in accordance with the principles of Sections 7.4.1 and 7.4.2 of ASTM D5456.

8.5.5.1 Edgewise bending test methods

Bending tests shall be conducted edgewise in both major and minor strength directions in accordance with the third-point load method of Sections 4 through 12 of ASTM D198 or Section 6 of ASTM D4761 using the specimen depth of not less than 12 inches (305 mm) and the on-center span equal to approximately 18 times the specimen depth. The weight of the CLT panel is permitted to be included in the determination of the edgewise bending moment capacity (resistance).

8.5.5.2 Edgewise bending qualification requirements

In the U.S. and Canada, the average edgewise bending stiffness determined from qualification tests divided by the calculated moment of inertia ($I_{e,0}$ or $I_{e,90}$) shall equal or exceed the published edgewise bending modulus of elasticity ($E_{e,0}$ or $E_{e,90}$).

In the U.S., the characteristic edgewise bending moment capacity determined from qualification tests shall equal or exceed the published ASD reference edgewise bending stress ($F_{b,e,0}$ or $F_{b,e,90}$) multiplied by the calculated edgewise section modulus ($S_{e,0}$ or $S_{e,90}$) and an adjustment factor of 2.1. In Canada, the characteristic edgewise bending moment resistance determined from qualification tests shall equal or exceed the published LSD specified edgewise bending strength ($f_{b,e,0}$ or $f_{b,e,90}$) multiplied by the calculated edgewise section modulus ($S_{e,0}$ or $S_{e,90}$) and divided by an adjustment factor of 0.96.

8.5.6. Edgewise shear properties

Edgewise shear stiffness and capacity (resistance) shall be permitted to be evaluated in accordance with 8.5.6.1 and 8.5.6.2.

8.5.6.1 Edgewise shear test methods

Edgewise shear stiffness tests shall be conducted in both major and minor strength directions in accordance with Sections 45 through 52 of ASTM D198.

Edgewise shear capacity (resistance) tests shall be conducted in both major and minor strength directions in accordance with the full-scale test method specified in Annex A3 of ASTM D5456. The web thickness of the I-shaped cross section shall be the CLT thickness. The specimen shall contain at least one edge joint, as applicable, in the middle 1/3 of the specimen depth.

Note 15: Tests have demonstrated that reinforcing the specimens with flanges (creating I-shaped beams) is necessary for development of the shear failure mode. Conducting preliminary tests to confirm the failure mode is recommended prior to producing the entire batch of I-shaped test specimens. Tests have also demonstrated that it may not be possible to fail the 7-ply or thicker CLT beams in shear in both minor and major strength directions. High-capacity testing apparatus is needed in all cases.

8.5.6.2 Edgewise shear qualification requirements

For use in the US or Canada, the average edgewise shear stiffness determined from qualification tests divided by the gross thickness of CLT (t_p) shall equal or exceed the published modulus of rigidity (shear modulus) in edgewise bending ($G_{e,0}$ or $G_{e,90}$).

In the US, the characteristic edgewise shear capacity determined from qualification tests shall equal or exceed the published ASD reference edgewise shear capacity ($F_{v,e,0}\ t_p$ or $F_{v,e,90}\ t_p$) multiplied by an adjustment factor of 2.1. In Canada, the characteristic edgewise shear resistance determined from qualification tests shall equal or exceed the published LSD edgewise shear resistance ($f_{v,e,0}\ t_p$ or $f_{v,e,90}\ t_p$) divided by an adjustment factor of 0.96.

8.6 Process Changes Qualification

Material changes to the manufacturing process or facilities shall be subjected to subsequent qualification testing. The requirements of 8.2 through 8.5 shall be reapplied for material changes listed or equivalent to that listed in Table 3.

TABLE 3

SUBSEQUENT QUALIFICATION IN RESPONSE TO MATERIAL CHANGES

Category	Applicable Sections	Material Change (examples)	Notes
A	8.2 through 8.5	• Press equipment • Adhesive formulation class • Addition or substitution of species from a different species group • Changes to the visual grading rules that reduce the effective bond area or the effectiveness of the applied pressure (e.g., warp permitted)	Excludes replacement with identical press
B	8.2, 8.3	• Other changes to the manufacturing process or component quality not listed above • Adhesive composition (e.g., fillers and extenders)	Additional evaluation in accordance with Section 8.4 is at the discretion of the *approved agency*[a]
C	8.4, 8.5	• Increase in panel width or length of more than 20%	

a. It is recommended that changes involving two or more manufacturing parameters be subjected to evaluation in accordance with 8.4 and 8.5.

8.7 Mill Specification

Upon conformance with the requirements specified in this standard, a manufacturing specification or documentation unique to the product and mill shall be written based on product evaluation. This specification shall be used for quality assurance purposes by the manufacturer and the *approved agency*. Reference values shall be established during product evaluation or from applicable performance requirements in this standard.

8.8 Certification and Trademarking

8.8.1 *Certification*

CLT products represented as conforming to this standard shall bear the stamp of an *approved agency* which (1) either inspects the manufacturer or (2) has tested a random sampling of the finished products in the shipment being certified for conformance with this standard.

8.8.2 *Product marking*

CLT products represented as conforming to this standard shall be identified with marks containing the following information:

a. CLT grade qualified in accordance with this standard;

b. The CLT thickness or identification;

c. The mill name or identification number;

d. The *approved agency* name or logo;

e. The symbol of "ANSI/APA PRG 320" signifying conformance to this standard;

f. Any manufacturer's designations which shall be separated from the grade-marks or trademarks of the *approved agency* by not less than 6 inches (152 mm); and

g. "Top" stamp on the top face of custom CLT panels used for roof or floor if manufactured with an unbalanced layup.

8.8.3 *Frequency of marking*

Non-custom and other required marks in this section shall be placed on standard products at intervals of 8 feet (2.4 m) or less in order that each piece cut from a longer piece will have at least one of each of the required marks.

8.8.4 *Custom products*

For products manufactured to meet specific job specifications (custom products), the marking shall be permitted to contain information less than that specified in 8.8.2. However, custom products shall bear at least one mark containing a required identification. When long CLT products shipped to a job are to be cut later into several members for use in the structure, the frequency of marking required in 8.8.3 shall be followed.

8.8.5 *Voiding marks*

CLT products originally marked as conforming to this standard but subsequently rejected as not conforming thereto shall have any reference to the standard obliterated or voided by the manufacturer.

Note 16. This can be performed by blocking out the stamp with permanent black ink or light sanding.

9. QUALITY ASSURANCE

9.1 Objectives

This section is intended for use with CLT products that have qualified for trademarking under this standard. The purpose of this section is to assure product quality by detecting changes in properties that may adversely affect the CLT performance. In all cases, the criteria to which the CLT products are tested shall be provided in the Mill Specification or equivalent document.

9.2 Process Control

On-going evaluation of the process properties listed in this section shall be performed to confirm that the CLT quality remains in satisfactory compliance to the product specification requirements. Sampling methods and quality assurance testing shall be documented in an in-plant manufacturing standard and accepted by the *approved agency*. All processes and test records relevant to the production shall be retained based on the manufacturer's record retention policy and are subject to audit by the *approved agency*. Production shall be held pending results of the quality assurance testing on representative samples.

9.3 End, Face, and Edge Joints in Laminations

The lamination end joints, face joints, and edge joints (when applicable) shall be sampled and tested for on-going quality assurance in accordance with Table 3 of ANSI A190.1 and meet the strength (required for end joints only), wood failure, and durability requirements specified therein in the U.S., or shall be sampled and tested in accordance with Section 7 of CSA O122 and meet the strength (required for end joints only), wood failure, and durability requirements specified therein in Canada. Special considerations for face bonding of the CLT panel as a whole are provided in 9.3.1 through 9.3.3 of this standard.

9.3.1 *Effective bonding area*

On-grade lumber shall be laid up to maintain an effective bonding area of not less than 80% on surfaces to be bonded for each bondline.

Note 17. To maintain an effective bond area, laminations in cross-plies may need to be oriented such that the bark and pith faces of adjacent pieces are generally alternated.

9.3.2 *Lamination grade limits*

Grade limits intended to limit the amount of lamination warp that will not be corrected upon application of pressure shall be qualified in accordance with 8.3.

9.3.3 *Glue skip in the face bondline*

The average glue skip in a face bondline shall not exceed the level established to maintain the effective bonding area specified in 9.3.1. Glue skips are not assessed as delamination unless the inclusion of such skips does not invalidate the delamination requirements.

9.4 Finished Production Inspection

All production shall be inspected visually, and/or by measurements or testing for conformance to this standard with the following attributes:

a. Dimensions (width, depth and length);

b. Shape, including straightness and squareness;

c. Type, quality and location of structural bond lines;

d. Appearance classification;

e. Layup, including lumber species and grades, placement, and orientation;

f. Moisture content; and

g. Application of the appropriate marks.

9.5 Minor Variations

A product is considered conforming to this standard when minor variations of a limited extent in non-critical locations exist, or when structural damage or defects have been repaired and, in the judgment of a qualified person, the product is structurally adequate for the use intended. The identity of the product and the nature of the minor variation shall be documented and provided to the designer of record upon request. A qualified person is one who is familiar with the job specifications and applicable design requirements and has first-hand knowledge of the manufacturing process.

ANNEX A. DESIGN PROPERTIES FOR ANSI/APA PRG-320 CLT (MANDATORY)

This Annex provides the design properties for CLT layups listed in Table 1, which represent the production intended for use by the CLT manufacturers in North America and are based on the following layups:

- E1: 1950f-1.7E Spruce-pine-fir MSR lumber in all longitudinal layers and No. 3 Spruce-pine-fir lumber in all transverse layers
- E2: 1650f-1.5E Douglas fir-Larch MSR lumber in all longitudinal layers and No. 3 Douglas fir-Larch lumber in all transverse layers
- E3: 1200f-1.2E Eastern Softwoods, Northern Species, or Western Woods MSR lumber in all longitudinal layers and No. 3 Eastern Softwoods, Northern Species, or Western Woods lumber in all transverse layers
- E4: 1950f-1.7E Southern pine MSR lumber in all longitudinal layers and No. 3 Southern pine lumber in all transverse layers
- V1: No. 2 Douglas fir-Larch lumber in all longitudinal layers and No. 3 Douglas fir-Larch lumber in all transverse layers
- V2: No. 1/No. 2 Spruce-pine-fir lumber in all longitudinal layers and No. 3 Spruce-pine-fir lumber in all transverse layers
- V3: No. 2 Southern pine lumber in all longitudinal layers and No. 3 Southern pine lumber in all transverse layers

TABLE A1

ASD REFERENCE DESIGN VALUES[a,b,c] FOR LAMINATIONS (FOR USE IN THE U.S.)

	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
CLT Layup	F_b (psi)	E^d (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	F_b (psi)	E^d (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)
E1	1,950	1.7	1,375	1,800	135	45	500	1.2	250	650	135	45
E2	1,650	1.5	1,020	1,700	180	60	525	1.4	325	775	180	60
E3	1,200	1.2	600	1,400	110	35	350	0.9	150	475	110	35
E4	1,950	1.7	1,375	1,800	175	55	450	1.3	250	725	175	55
V1	900	1.6	575	1,350	180	60	525	1.4	325	775	180	60
V2	875	1.4	450	1,150	135	45	500	1.2	250	650	135	45
V3	750	1.4	450	1,250	175	55	450	1.3	250	725	175	55

For SI: 1 psi = 0.006895 MPa

a. See Section 4 for symbols.

b. Tabulated values are ASD reference design values and not permitted to be increased for the lumber size and flat use adjustment factors in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Table A2).

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

d. The tabulated E values are published E for lumber. For calculating the CLT design properties shown in Table A2, the transverse E of the lamination is assumed to be E/30, the longitudinal G of the lamination is assumed to be E/16, and the transverse G of the lamination is assumed to be longitudinal G/10.

The ASD reference design capacities for these CLT layups with 3, 5, and 7 layers are provided in Table A2. These capacities were derived analytically using the Shear Analogy Model[2] (the calculated moment capacities in the major strength direction were further multiplied by a factor of 0.85 for conservatism) and validated by testing. The lamination thicknesses are as tabulated. The ASD reference tensile and compressive capacities will be developed and added to future editions of this standard.

TABLE A2

ASD REFERENCE DESIGN VALUES[a,b,c] FOR CLT (FOR USE IN THE U.S.)

CLT Layup	CLT t_p (in.)	Lamination Thickness (in.) in CLT Layup: =	⊥	=	⊥	=	⊥	=	Major Strength Direction: $(F_bS)_{eff,f,0}$ (lbf-ft/ft of width)	$(EI)_{eff,f,0}$ (10^6 lbf-in.²/ft of width)	$(GA)_{eff,f,0}$ (10^6 lbf/ft of width)	$V_{s,0}$ (lbf/ft of width)	Minor Strength Direction: $(F_bS)_{eff,f,90}$ (lbf-ft/ft of width)	$(EI)_{eff,f,90}$ (10^6 lbf-in.²/ft of width)	$(GA)_{eff,f,90}$ (10^6 lbf/ft of width)	$V_{s,90}$ (lbf/ft of width)
E1	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.46	1,430	160	3.1	0.61	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	0.92	1,970	1,370	81	1.2	1,430
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,375	1,089	1.4	2,490	3,125	309	1.8	1,960
E2	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	1,910	165	3.6	0.56	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,825	389	1.1	2,625	1,430	95	1.1	1,910
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,600	963	1.6	3,325	3,275	360	1.7	2,625
E3	4 1/8	1 3/8	1 3/8	1 3/8					2,800	81	0.35	1,110	110	2.3	0.44	385
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			6,400	311	0.69	1,530	955	61	0.87	1,110
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	11,325	769	1.0	1,940	2,180	232	1.3	1,520
E4	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.50	1,750	140	3.4	0.62	605
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	1.0	2,410	1,230	88	1.2	1,750
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,400	1,089	1.5	3,050	2,800	335	1.9	2,400
V1	4 1/8	1 3/8	1 3/8	1 3/8					2,090	108	0.53	1,910	165	3.6	0.59	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,800	415	1.1	2,625	1,430	95	1.2	1,910
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,500	1,027	1.6	3,325	3,275	360	1.8	2,625
V2	4 1/8	1 3/8	1 3/8	1 3/8					2,030	95	0.46	1,430	160	3.1	0.52	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,675	363	0.91	1,970	1,370	81	1.0	1,430
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,275	898	1.4	2,490	3,125	309	1.6	1,960
V3	4 1/8	1 3/8	1 3/8	1 3/8					1,740	95	0.49	1,750	140	3.4	0.52	605
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,000	363	0.98	2,420	1,230	88	1.0	1,750
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	7,100	899	1.5	3,050	2,800	335	1.6	2,400

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N

a. See Section 4 for symbols.

b. This table represents one of many possibilities that the CLT could be manufactured by varying lamination grades, thicknesses, orientations, and layer arrangements in the layup.

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

Note A1. The rounding rules in Table A2 are as follows:

F_bS (lbf-ft/ft) and V_s (lbf/ft)—Nearest 25 for values greater than 2,500, nearest 10 for values between 1,000 and 2,500, or nearest 5 otherwise.

EI (lbf-in.² /ft) and GA (lbf/ft)—Nearest 10^6 for values greater than 10^7, nearest 10^5 for values between 10^6 and 10^7, or nearest 10^4 otherwise.

For use in Canada, the lamination LSD design properties are provided in Table A3 and the CLT LSD design resistances are shown in Table A4. The LSD design resistances are not compatible with the ASD reference design capacities used in the U.S. Since there are no published LSD specified strength and modulus of elasticity for Southern pine lumber in Canada, the CLT Layups E4 and V3 are not listed in Tables A3 and A4.

2 Gagnon, S. and M. Popovski. 2011. *Structural Design of Cross-Laminated Timber elements.* In: Chapter 3, CLT Handbook. FPInnovations, Canada

TABLE A3

LSD SPECIFIED STRENGTH AND MODULUS OF ELASTICITY[a,b,c] FOR LAMINATIONS (FOR USE IN CANADA)

	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
CLT Layup	f_b (MPa)	E^d (MPa)	f_t (MPa)	f_c (MPa)	f_v (MPa)	f_s (MPa)	f_b (MPa)	E^d (MPa)	f_t (MPa)	f_c (MPa)	f_v (MPa)	f_s (MPa)
E1	28.2	11,700	15.4	19.3	1.5	0.50	7.0	9,000	3.2	9.0	1.5	0.50
E2	23.9	10,300	11.4	18.1	1.9	0.63	4.6	10,000	2.1	7.3	1.9	0.63
E3	17.4	8,300	6.7	15.1	1.3	0.43	4.5	6,500	2.0	5.2	1.3	0.43
V1	10.0	11,000	5.8	14.0	1.9	0.63	4.6	10,000	2.1	7.3	1.9	0.63
V2	11.8	9,500	5.5	11.5	1.5	0.50	7.0	9,000	3.2	9.0	1.5	0.50

For SI: 1 MPa = 145 psi

a. See Section 4 for symbols.

b. Tabulated values are LSD design values and not permitted to be increased for the lumber size adjustment factor in accordance with CSA O86. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Table A4).

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

d. The tabulated E values are published E for lumber. For calculating the CLT design properties shown in Table A4, the transverse E of the lamination is assumed to be E/30, the longitudinal G of the lamination is assumed to be E/16, and the transverse G of the lamination is assumed to be longitudinal G/10.

TABLE A4

LSD STIFFNESS AND UNFACTORED RESISTANCES VALUES[a,b,c] FOR CLT (FOR USE IN CANADA)

		Lamination Thickness (mm) in CLT Layup							Major Strength Direction				Minor Strength Direction			
CLT Layup	**CLT t_p (mm)**	=	⊥	=	⊥	=	⊥	=	$(f_bS)_{eff,f,0}$ (10^6 N-mm/m of width)	$(EI)_{eff,f,0}$ (10^9 N-mm²/m of width)	$(GA)_{eff,f,0}$ (10^6 N/m of width)	$V_{s,0}$ (kN/m of width)	$(f_bS)_{eff,f,90}$ (10^6 N-mm/m of width)	$(EI)_{eff,f,90}$ (10^9 N-mm²/m of width)	$(GA)_{eff,f,90}$ (10^6 N/m of width)	$V_{s,90}$ (kN/m of width)
E1	105	35	35	35					42	1,088	7.3	34	1.4	32	9.1	12
	175	35	35	35	35	35			98	4,166	15	47	12	836	18	34
	245	35	35	35	35	35	35	35	172	10,306	22	59	28	3,183	27	46
E2	105	35	35	35					36	958	8.0	43	0.94	36	8.2	15
	175	35	35	35	35	35			83	3,674	16	59	8.1	929	16	42
	245	35	35	35	35	35	35	35	146	9,097	24	74	19	3,537	25	58
E3	105	35	35	35					26	772	5.3	29	0.92	23	6.4	10
	175	35	35	35	35	35			60	2,956	11	40	8.0	604	13	29
	245	35	35	35	35	35	35	35	106	7,313	16	50	18	2,299	19	40
V1	105	35	35	35					15	1,023	8.0	43	0.94	36	8.7	15
	175	35	35	35	35	35			35	3,922	16	59	8.1	929	17	42
	245	35	35	35	35	35	35	35	61	9,708	24	74	19	3,537	26	58
V2	105	35	35	35					18	884	7.2	34	1.4	32	7.5	12
	175	35	35	35	35	35			41	3,388	14	47	12	836	15	34
	245	35	35	35	35	35	35	35	72	8,388	22	59	28	3,183	23	46

For SI: 1 mm = 0.03937 in.; 1 m = 3.28 ft; 1 N = 0.2248 lbf

a. See Section 4 for symbols.

b. This table represents one of many possibilities that the CLT could be manufactured by varying lamination grades, thicknesses, orientations, and layer arrangements in the layup.

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

Note A2. The rounding rules in Table A4 are as follows:

$f_b S$ (N-mm/m) and GA (N/m)—Nearest 10^6 for values greater than 10^7, nearest 10^5 for values between 10^6 and 10^7, or nearest 10^4 otherwise.

V_s (kN/m)—Nearest 1 for values greater than 10, nearest 0.1 for values between 10 and 1, or nearest 0.01 otherwise.

EI (N-mm^2/m)—Nearest 10^9 for values greater than 10^{10}, nearest 10^8 for values between 10^9 and 10^{10}, or nearest 10^7 otherwise.

APPENDIX A. EXAMPLES OF CLT APPEARANCE CLASSIFICATIONS (NON-MANDATORY)

This appendix contains examples of CLT appearance classifications for reference only. These requirements are based on the appearance at the time of manufacturing. The actual CLT panel appearance requirements are recommended to be agreed upon between the buyer and the seller.

A1. Architectural Appearance Classification

An appearance classification normally suitable for applications where appearance is an important, but not overriding consideration. Specific characteristics of this classification are as follows:

- In exposed surfaces, all knot holes and voids measuring over 3/4 inch (19 mm) are filled with a wood-tone filler or clear wood inserts selected for similarity with the grain and color of the adjacent wood.
- The face layers exposed to view are free of loose knots and open knot holes are filled.
- Knot holes do not exceed 3/4 inch (19 mm) when measured in the direction of the lamination length with the exception that a void may be longer than 3/4 inch (19 mm) if its area is not greater than 1/2 in.2 (323 mm^2).
- Voids greater than 1/16 inch (1.6 mm) wide created by edge joints appearing on the face layers exposed to view are filled.
- Exposed surfaces are surfaced smooth with no misses permitted.

A2. Industrial Appearance Classification

An appearance classification normally suitable for use in concealed applications where appearance is not of primary concern. Specific characteristics of this grade are as follows:

- Voids appearing on the edges of laminations need not be filled.
- Loose knots and knot holes appearing on the face layers exposed to view are not filled.
- Members are surfaced on face layers only and the appearance requirements apply only to these layers.
- Occasional misses, low laminations or wane (limited to the lumber grade) are permitted on the surface layers and are not limited in length.

APPENDIX B. HISTORY OF STANDARD (NON-MANDATORY)

In March 2010, the APA Standards Committee on Standard for Performance-Rated Cross-Laminated Timber was formed to develop a national standard under the consensus processes accredited by the American National Standards Institute (ANSI). This national consensus standard, designated as ANSI/APA PRG 320, is developed based on broad input from around the world. It should be especially recognized that this standard incorporates draft standards that were developed by FPInnovations in Canada, as part of the joint effort between the U.S. and Canada in the development of a bi-national CLT standard. The first version of this standard was approved by ANSI for publication on December 20, 2011. Subsequent revisions resulted in the publication of ANSI/APA PRG 320-2012 and this standard.

The names of the ANSI/APA PRG 320 Committee members when this version of the standard is published are as shown below. The current list of the committee membership is available from the committee secretariat upon request.

Name	Affiliation	Note
Kevin Below	Cross Laminated Timber Canada Inc.	
Scott Breneman	WoodWorks - Wood Products Council	ExSub Member
Darryl Byle	CLT Solutions LLC	
Kevin Cheung	Western Wood Products Association	
Mark Clark	Hexion Inc.	
Don DeVisser	West Coast Lumber Inspection Bureau	
Bruno Di Lenardo	Canadian Construction Materials Centre	
Pat Farrell	Freres Lumber Company	
Julie Frappier	Nordic Structures	Vice Chair
Sylvain Gagnon	FPInnovations	
Bill Gareis	Ashland Inc.	
Mikhail Gershfeld	California State Polytechnic University	
Ron Goff	ProNet Group Inc.	
Bill Gould	ICC Evaluation Service Inc.	
Ben Herzog	University of Maine	
Chris Kalesnikoff	Kalesnikoff Lumber	
Frank Lam	University of British Columbia	
Dean Lewis	DCI Engineers	
Jeff Linville	Weyerhaeuser Company	
Robert Malczyk	Equilibrium Consulting Inc.	
Andre Morf	Structurlam Products, LP	
Jeff Morrison	Rosboro LLC	
David Moses	Moses Structural Engineers Inc.	
Crawford Murphy	MDS10 PLLC Architects and CLT USA LLC	
Lech Muszynski	Oregon State University	
John Neels	NLGA	
Scott Nyseth	Stonewood Structural Engineers Inc.	
Henry Quesada-Pineda	Virginia Tech	
Douglas Rammer	USDA Forest Products Laboratory	
Alexander Salenikovich	Université Laval	ExSub Member
Sheldon Shi	University of North Texas	
Scott Skinner	Akzo Nobel Coatings Inc.	
Kurt Stochlia	KSPE Inc.	
Ted Szabo	Alberta Innovates Bio-Solutions	
Robert Tudhope	SmartLam LLC	
Phil Vacca	Louisiana-Pacific Corp.	
Chris Whelan	Henkel Corporation	
Tom Williamson	T.Williamson-Timber Engineering LLC	Chair
Steve Winistorfer	PFS TECO	
B.J. Yeh	APA – The Engineered Wood Association	Secretariat
Cory Zurell	Blackwell Structural Engineers	

Inquiries or suggestions for improvement of this standard should be directed to:

Secretariat, ANSI/APA PRG 320
APA – The Engineered Wood Association
7011 South 19th Street
Tacoma, WA 98466
Internet address: www.apawood.org
e-mail address: help@apawood.org

ANSI/APA PRG 320-2017
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APA HEADQUARTERS
7011 So. 19th St. ▪ Tacoma, Washington 98466 ▪ (253) 565-6600 ▪ Fax: (253) 565-7265

www.apawood.org

PRODUCT SUPPORT HELP DESK
(253) 620-7400 ▪ help@apawood.org

Form No. PRG 320-2017A/Revised November 2017