AMERICAN NATIONAL STANDARD

ANSI/APA PRG 320-2025

Standard for Performance-Rated Cross-Laminated Timber

AMERICAN NATIONAL STANDARD

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APA – The Engineered Wood Association

Approved January 27, 2025
American National Standards Institute

FOREWORD **(This Foreword is not a part of American National Standard ANSI/APA PRG 320-2025)**

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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ANSI/APA PRG 320-2025 Standard for Performance-Rated Cross-Laminated Timber

1. SCOPE

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

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% in the U.S. and is 15% or less over a year without exceeding 19% 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 marked in accordance with 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 ASTM Standards

ASTM D9-20 *Standard Terminology Relating to Wood and Wood-Based Products*

ASTM D198-22a *Standard Test Methods of Static Tests of Lumber in Structural Sizes*

ASTM D905-08 (2021) *Standard Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading*

ASTM D907-15 (2023) *Standard Terminology of Adhesives*

ASTM D1037-12 (2020) *Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials*

ASTM D1990-19 *Standard Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens*

ASTM D2395-17 (2022) *Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Base Materials*

ASTM D2559-12a (2018) *Standard Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions*

ASTM D2915-17 (2022) *Standard Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products*

ASTM D3737-18 (2023) e1 *Standard Practice for Establishing Stresses for Structural Glued Laminated Timber (Glulam)*

ASTM D4444-13 (2018) *Standard Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters*

ASTM D4761-19 *Standard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Material*

ASTM D5456-21e1 *Standard Specification for Evaluation of Structural Composite Lumber Products*

ASTM D6570-18a (2023) e1 *Standard Practice for Assigning Allowable Properties for Mechanically Graded Lumber*

ASTM D6815-22a *Standard Specification for Evaluation of Duration of Load and Creep Effects of Wood and Wood-Based Products*

ASTM D7247-17 *Standard Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures*

ASTM D7374-21 *Standard Practice for Evaluating Elevated Temperature Performance of Adhesives Used in End-Jointed Lumber*

2.2 CSA Standards

CAN/CSA O86:24 *Engineering Design in Wood*

CAN/CSA O122-16 (R2021) *Structural Glued-Laminated Timber*

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

CSA O112.10-08 (R2022) *Evaluation of Adhesives for Structural Wood Products (Limited Moisture Exposure)*

CSA O141-23 *Canadian Standard Lumber*

CSA O177-23 *Qualification Code for the Manufacturers of Structural Glued-Laminated Timber*

2.3 Other Standards

AITC Test T107-2007 *Shear Test*

ANSI 405-2023 *Standard for Adhesives for Use in Structural Glued Laminated Timber*

ANSI A190.1-2022 *Product Standard for Structural Glued Laminated Timber*

ANSI/AWC NDS-2024 *National Design Specification for Wood Construction*

ISO/IEC 17011-2017 *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 17025-2017 *General Requirements for the Competence of Testing and Calibration Laboratories*

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

NLGA Standard Grading Rules for Canadian Lumber (2022)

NLGA SPS 1-2023 *Special Products Standard for Fingerjoined Structural Lumber*

NLGA SPS 2-2024 *Special Products Standard for Machine Graded Lumber*

NLGA SPS 4-2024 *Special Products Standard for Fingerjoined Machine Graded Lumber*

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

U.S. Product Standard PS 1-22 *Structural Plywood*

U.S. Product Standard PS 20-20 *American Softwood Lumber Standard*

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 Allowable Stress Design (ASD)

Adherend—material held to another material by an adhesive

Adhesive—chemical substance capable of attaching surfaces for transferring loads between them (aka Glue)

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

Approved Agency (U.S.)—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*)

Billet—unfinished CLT panel formed by a single pressing operation

Note 1: *One or several finished CLT panels may be produced from a billet.*

Bond—*n.* attachment between surfaces created with an adhesive

Bond—*v.* to create an attachment between surfaces with an adhesive

Bondline—layer of adhesive that attaches two materials (adherends)

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

Characteristic Values—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 representative of the population being sampled

Certificate of Conformance—certificate issued by an approved agency certifying the product as in conformance to a standard or standards

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

CLT Grade—class of CLT determined by the combination of grades of laminations in the longitudinal and transverse layers

Note 2: *Basic CLT grades and layups in this standard are listed in Annex A. Custom CLT grades and layups may be established in accordance with 7.1.2 (see Layup).*

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

Note 3: *The length and width of CLT defined in this standard are based on the CLT panel face layer orientation and may not be related to the end-use applications, such as wall, roof, and floor.*

CLT Panel—single piece of CLT

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

CLT Width—dimension of the CLT panel measured parallel to the minor strength direction

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

Delamination—separation of bonded adherends in a joint

Note 4: *Appears as a rupture in the bond either in the adhesive or at the interface between the adhesive and the adherend, or as a combination of both.*

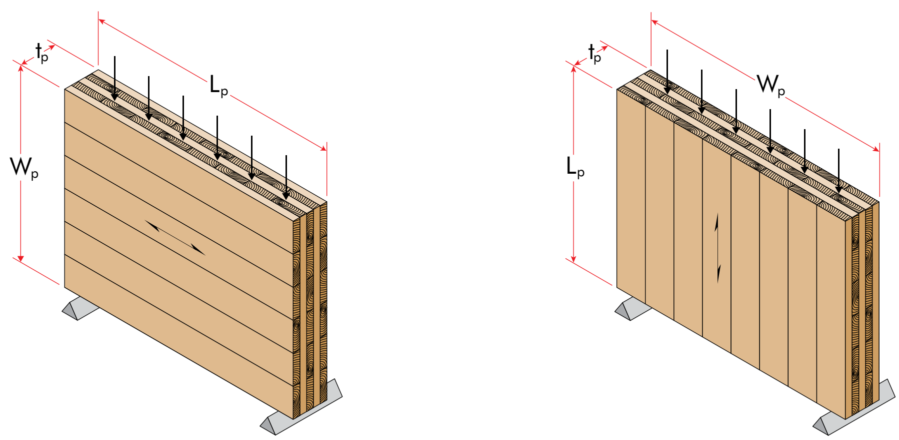
Note 5: *For a specimen, the average delamination is calculated as the ratio of the total length of delamination on all exposed bondlines divided by the total length of all exposed bondlines, in percent.*

Edge (Panel Edge)—narrow face of a panel that exposes the ends and 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

FIGURE 1

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



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

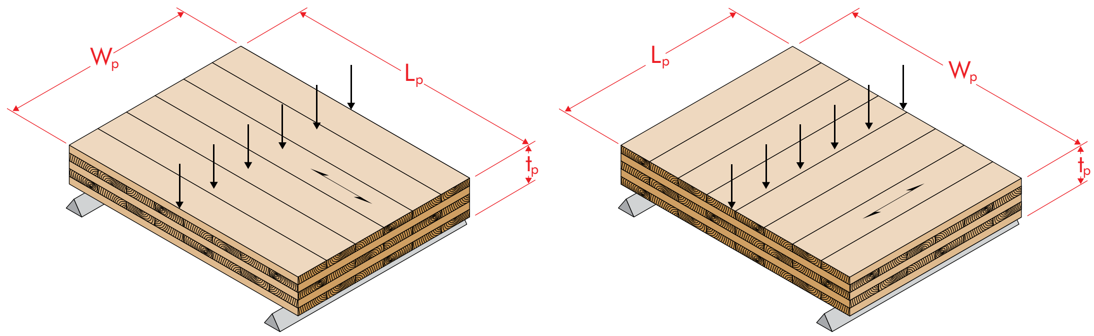
Face—one of the four longitudinal surfaces of a piece or panel

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



Joint—*n.* interface between two surfaces

- **Edge Joint—**joint of the narrow faces of adjacent laminations in a CLT layer with or without adhesive
- **End Joint—**joint formed by bonding of machined, mated surfaces at the ends of two pieces of laminations in a CLT layer
- **Face Joint—**joint formed by bonding faces of laminations in adjacent layers in a CLT panel

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

Layer—arrangement of laminations laid out parallel to each other in one plane

- **Longitudinal layer—**layer with the laminations oriented in the major strength direction of the CLT panel

Transverse layer—layer with the laminations oriented in the minor strength direction of the CLT panel, also referred to as cross layer

Layup—arrangement of layers in a CLT panel determined by the species, grade(s), number, orientations, and thickness(es) of layers

- **Balanced Layup—**CLT panel construction where the structural layers in the CLT at the time of manufacturing are symmetrical in species, grade(s), number, orientations, and thickness(es) around the center of the CLT panel thickness
- **Unbalanced Layup—**CLT panel construction which is not a balanced layup

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

Manufactured Lumber—lumber that meets the requirements of Section 6.4 of ANSI A190.1 in the U.S., or NLGA SPS 1, 4, or 6 in Canada

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

Qualified Certification Agency (Canada)—U.S. or Canada-based 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.)—U.S. or Canada-based 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—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—U.S. or Canada-based 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

Sample—one or more items taken as representative of a population or portion of material taken without bias from a bulk of material for assessment

Specimen—individual piece of material or product selected for testing

Standard Lumber Grade—structural lumber grade that is found in the grading rules of a recognized rules-writing agency approved by the American Lumber Standard Committee (ALSC) Board of Review or Canadian Lumber Standards Accreditation Board (CLSAB) and has design values published in the National Design Specification (NDS) Supplement in the U.S. or CSA O86 in Canada

Strength Direction—direction in reference to bending strength of the CLT panel

- **Major Strength Direction—**direction with the greater strength in bending of the CLT panel

Note 6: *In balanced layups, the major strength direction is the general direction of the wood fibers in the surface layers considered in the engineering model of the CLT panel.*

Note 7: *Wood fibers in the decorative/appearance layers that are not considered in the engineering model are not necessarily an indicator of the major strength direction of the CLT panel.*

Note 8: *For some unbalanced layups, the major strength direction may be difficult to define or determine without a model calculation (see X3.3).*

- **Minor Strength Direction—**direction with the lesser strength in bending of the CLT panel

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

Wood Failure—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

Symbol	Definition	Reference(s)
$I_{e,0}$	Gross moment of inertia of CLT in edgewise bending in the major strength direction, in in.[4] (mm[4]), 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] (mm[4]), 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
$S_{e,0}$	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 A1 and A3
$E_{\perp}$	Modulus of elasticity in the transverse direction of a lamination, in psi (MPa)	Appendix X3
f_b	Characteristic bending strength or LSD specified bending strength of a lamination, in psi (MPa)	Table 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)	Table 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)	Table 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)	Table 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)	Table 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
$G_{\perp}$	Modulus of rigidity (shear modulus) in the transverse direction of a lamination, in psi (MPa)	Appendix X3

5. PANEL DIMENSIONS AND DIMENSIONAL TOLERANCES

5.1 CLT Thickness

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

5.2 CLT Dimensional Tolerances

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

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

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 9: *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

6.1.1 General

Lumber meeting the requirements of 6.1.2 and structural composite lumber meeting the requirements of 6.1.3 shall be permitted for use as laminations in CLT manufacturing and shall meet the requirements specified in 6.1.4 through 6.1.8. Laminations within the same layer shall be of the same thickness, type, grade, and species or species combination.

Note 10: *Laminations in different layers may be of different thicknesses, types, grades, and species or species combinations.*

6.1.2 Sawn Lumber Laminations

a. **Lumber species –** Lumber of any softwood or hardwood species or species combinations recognized by American Lumber Standard 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.

b. **Standard lumber grades –** Dimension lumber shall be graded in accordance with rules approved by the American Lumber Standard Committee (ALSC) Board of Review or the Canadian Lumber Standards Accreditation Board (CLSAB). The minimum grade of lumber in the longitudinal layers shall be 1200f-1.2E MSR or visual grade No. 2 and the minimum grade of lumber in the transverse layers shall be visual grade No. 3.

c. **Non-standard lumber grades –** Dimension lumber graded and quality-controlled by established rules other than those approved by ALSC Board of Review or CLSAB shall be permitted provided that the lumber is mechanically graded and the design values for strength and stiffness are determined by an *approved agency* in accordance with ASTM D6570 and meet or exceed those of the minimum Standard Lumber Grades specified in 6.1.2.b.

Note 11: *Due to the difficulties in establishing equivalency in accordance with ASTM D1990, the use of visually graded non-standard lumber for CLT production is beyond the scope of this standard.*

d. **Manufactured lumber –** Manufactured lumber shall be considered as equivalent to solid-sawn lumber when qualified in accordance with Section 6.4 of ANSI A190.1 in the U.S. or SPS 1, 2, 4, or 6 in Canada.

e. **Grading enhancements –** When a CLT manufacturer chooses to use grading enhancements to increase selected design values of standard lumber grades covered in 6.1.2.b, the increased design values shall be qualified and subject to ongoing quality assurance in accordance with the requirements of an *approved agency*. The *approved agency* shall establish sampling criteria to ensure qualification samples are representative of subsequent production. The sample size for qualification of mean-based design values shall be determined in accordance with ASTM D2915 with 5% precision and 95% confidence. The sample size for qualification of 5% tolerance limit-based design values shall include a minimum of 53 pieces.

6.1.3 Structural Composite Lumber (SCL) Laminations

Laminated Strand Lumber (LSL), Laminated Veneer Lumber (LVL), Oriented Strand Lumber (OSL), and Parallel Strand Lumber (PSL) meeting the requirements of ASTM D5456 and with a minimum published equivalent specific gravity of 0.35 shall be permitted.

Note 12: *The CLT manufacturer should contact the SCL manufacturer to ensure that protective coatings have not been applied to the surface of the SCL that may hamper the face bonding of the SCL laminations.*

6.1.4 Lamination Sizes

a. **Width –** For longitudinal layers (major strength direction), the net lamination width shall not be less than 1.75 times the net lamination thickness. For transverse layers (minor strength direction), the net width of a lamination or manufactured lumber, or the combined width of a lamination edge-joined with adhesives shall not be less than 3.5 times the net lamination thickness unless the interlaminar shear strength and creep are evaluated by testing in accordance with Section 8.5.4 and the principles of ASTM D6815, respectively. Laminations made of SCL shall be permitted to be full CLT width.

b. **Thickness –** The net lamination thickness in any layer at the time of gluing shall not be less than 5/8 inch (16 mm) or more than 2 inches (51 mm). The lamination thickness shall not vary within the same CLT layer subject to the tolerances specified in 6.1.7.

6.1.5 Moisture Content

The moisture content of the laminations at the time of CLT manufacturing shall be 16% or less and shall be within 3% of the average moisture content from the qualification conducted in accordance with 6.3.3, 8.2.5, and 8.2.6. In addition, the moisture content of laminations shall meet the recommendations provided by the adhesive manufacturer.

The moisture content of a piece of lumber shall be taken as the average moisture content throughout the cross sections measured along the length of the piece. All moisture meters used for lumber segregation shall be calibrated in accordance with ASTM D4444.

Note 13: *The lamination moisture content corresponding to the end-use moisture conditions should be considered for glue bond tests in accordance with 8.2.*

6.1.6 Face-bonding Surface

a. **General –** Laminations shall be prepared to provide bonding surfaces for adhesive bond performance required by this standard and to meet the recommendations provided by the adhesive manufacturer.

Note 14: *Satisfactory face-bonding surfaces are typically free from dust, foreign matter, and exudation that are detrimental to adhesive bond performance.*

b. **Lumber –** All face-bonding surfaces shall be planed or sanded prior to face bonding. The process used to prepare bonding surfaces shall be approved by the *approved agency*.

Note 15: *Satisfactory face-bonding surfaces are typically 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, except for minor local variations. It may be necessary to plane or sand the lumber lamination surfaces within 48 hours of face bonding for some wood species.*

c. **SCL –** Planing or sanding of face-bonding surfaces prior to face bonding shall not be required unless indicated otherwise by the adhesive bond qualification or required to meet lamination thickness tolerances.

6.1.7 Face-bonding Dimensional Tolerances

At the time of face bonding, the thickness variation across the width of a lumber lamination shall not exceed ±0.008 inch (0.20 mm) and the thickness variation across the width of a SCL lamination shall not exceed ±0.008 inch (0.20 mm) in every 12-inch (30.5 mm) width. The thickness variation along the length of a lumber or SCL lamination shall not exceed ±0.012 inch (0.30 mm).

Note 16: *Cup and twist, if present, should be small enough to be flattened out by pressure in bonding.*

6.1.8 Gaps Between Adjacent Lamination Edges

At the time of CLT manufacturing, laminations in the CLT layers shall be tightly fit. Gaps between unbonded adjacent lamination edges (edge joint gaps) are permitted as follows:

Edge joint gaps in face layers shall not exceed 1/4 inch (6.4 mm) and edge joint gaps between adjacent lamination edges in other layers shall not exceed 3/8 inch (9.5 mm).

Note 17: *Edge joint gaps are typically caused by imperfections such as crook or twist in individual laminations, which prevent contact along the full length of edges. Consequently, small gaps may occur in a layer at the time of manufacturing. These gaps are not typically present between all laminations in the layer or along the full length of individual edges. Small natural growth characteristics of lumber, such as knots and wane, are not considered as part of an edge joint gap and should not be included in the measurements. The intent of this standard is for the laminations to be tightly fit with no individual gap exceeding the prescribed limits.*

Note 18: *This provision applies at the time when the CLT billet exits the press and the quality assurance measures are implemented at the plant. Gaps in face layers may increase slightly as CLT billets or panels season.*

Note 19: *When edge joints of laminations are not bonded with an adhesive or not filled with a filler, small air gaps are common for CLT (see Note 17). These gaps will affect the air tightness through the CLT thickness, and the effect will depend on the number of CLT layers and actual gap size as manufactured. If air tightness is an important requirement, such as in fire containment, thermal resistance, or sound attenuation, additional measures should be incorporated in the assembly design, such as the use of an air-tight membrane (e.g., concrete floor topping or finished gypsum wallboard ceiling for floor-ceiling assemblies or finished gypsum wallboard or plaster for wall assemblies).*

6.2 Adhesives

Adhesives used for CLT manufacturing shall meet the requirements specified in this section.

6.2.1 Requirements in the U.S.

Adhesives used in CLT shall meet the requirements of ANSI 405 with the following exceptions:

a. Section 3.1.6 of ANSI 405 is not required, and

b. The CSA O177 small-scale flame test (Sections 3.1.7 and 4.7 of ANSI 405) shall be conducted using CLT specimens of the same size and geometry as the structural glued laminated timber specimens.

6.2.2 Requirements in Canada

Adhesives used in CLT shall meet the requirements of CSA O112.10, and Sections 3.1.3, 3.1.7, 4.3, and 4.7 of ANSI 405 with the following exception:

a. The CSA O177 small-scale flame test (Sections 3.1.7 and 4.7 of ANSI 405) shall be conducted using CLT specimens of the same size and geometry as the structural glued laminated timber specimens.

Note 20: *The CSA O177 small-scale flame test specimens should be made with orthogonal 0.78-inch (20 mm) laminations to replicate a CLT configuration, resulting in eight laminations (6.3 inches or 160 mm) in height, and approximately 6 inches (150 mm) in width and 1.6 inches (40 mm) in thickness. There should be no edge joints within the inner six laminations. Whenever possible, the pith should be centered along the lamination.*

6.2.3 Elevated Temperature Performance Requirements in the U.S. and Canada

Adhesives shall be evaluated and comply with the requirements for elevated temperature performance in accordance with Annex B.

Note 21: *The intent of the elevated temperature performance evaluation is to identify and exclude use of adhesives that permit CLT char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire.*

6.3 Lamination Joints

6.3.1 General

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

6.3.2 End Joints in Laminations

End joints in each lamination shall be either finger-jointed or scarf-jointed. Butt joints shall not be permitted. The manufacturing of end joints shall follow ANSI A190.1 in the U.S. or CSA O122 in Canada. The strength, wood failure, and bond durability of lamination end joints shall be qualified in accordance with the requirements specified herein and Section 13.1.1 of ANSI A190.1.

a. Full-size end-joint specimens shall be prepared from lumber or SCL selected at random from stock meeting the requirements of 6.1.1 through 6.1.5. Additional requirements specified in the CLT plant manual procedures and quality manuals shall be followed.

b. A minimum of 30 full-size end-joint specimens shall be tested in tension. The specimens shall be centered between the grips of the testing machine, which are spaced at minimum 24 inches (610 mm) apart and tested to failure in approximately 3 to 5 minutes at a constant rate of loading. The accuracy of the load measurements shall be within ±1%. Average wood failure of all end-joint specimens tested shall be equal to or greater than 80%. The characteristic tensile strength of the end joints (5th percentile with 75% confidence) shall be equal to or greater than 2.1 times the ASD tension design value in the U.S. or 1.1 times the LSD specified tensile strength in Canada of the laminating lumber or SCL.

c. A minimum of five individual end-joint specimens shall be selected and tested for bond durability. Each specimen shall have a length of approximately 6 inches (152 mm) or the length of the end joint plus 1/2 inch (12.7 mm), whichever is larger, with the end joint located approximately in the center of the specimen. The specimen shall be crosscut through the center of the joint with a saw kerf of 1/8 inch (3.2 mm) or less to create two specimens with a length of approximately 3 inches (76 mm) or one-half of the end joint length plus 1/4 inch (6.4 mm), whichever is larger, and each having at least 1/4 inch (6.4 mm) of the end joint remaining after crosscutting. The specimens shall be tested for bond durability in accordance with the method in 8.2.6(b) and the average delamination of all bondlines in each specimen shall be 5% or less for softwoods or 8% or less for hardwoods.

6.3.3 Edge and Face Joints Between Laminations

a. The wood failure of the edge (when required for structural performance) and face joints in the block shear specimens (see Figure 4) prepared in accordance with 8.2.4 and tested in accordance with 8.2.5 shall meet the following requirements. The wood failure of each specimen shall be the average wood failure from multiple bondlines in each individual specimen.

   1. The average wood failure from all specimens combined shall be 80% or greater for softwoods and hardwoods except that the average wood failure from all specimens combined for hardwoods with a specific gravity greater than 0.42, as published in the NDS, shall be 60% or greater,

   2. At least 95% of all specimens (or 100% with less than 20 specimens) shall have wood failure of 60% or greater for softwoods and hardwoods except that at least 95% of all specimens (or 100% with less than 20 specimens) shall have wood failure of 50% or greater for hardwoods with a specific gravity greater than 0.42, and

   3. For any specimen with wood failure below 50% for softwoods and hardwoods, or 40% for hardwoods with a specific gravity greater than 0.42, a second block shear specimen shall be permitted to be prepared from the adjacent area in the same original CLT panel and tested in accordance with 8.2.5. The wood failure of such a second specimen shall be 80% or greater for softwoods and hardwoods except that the wood failure of such a second specimen shall be 60% or greater for hardwoods with a specific gravity greater than 0.42.

b. The delamination for the edge (when required for structural performance) and face joints in the delamination specimens (see Figure 5) prepared in accordance with 8.2.4 and tested in accordance with 8.2.6 shall meet the following requirements. The delamination of each specimen shall be the average delamination from multiple bondlines in each individual specimen.

   1. The delamination of each specimen shall be 5% or less for softwoods or 8% or less for hardwoods, and

   2. For any specimen with delamination exceeding 5% but not exceeding 10% for softwoods, or exceeding 8% but not exceeding 13% for hardwoods, a second delamination specimen shall be permitted to be prepared from the adjacent area in the same original CLT panel and tested in accordance with 8.2.6. The delamination of such a second specimen shall be 5% or less for softwoods or 8% or less for hardwoods.

For CLT products using SCL laminations, the SCL-to-lumber and SCL-to-SCL face bonds shall be permitted to be evaluated in accordance with the short-span flatwise bending tests specified in Section A4.2 of ASTM D5456 except that a single vacuum-pressure-soak cycle shall be permitted, and the average strength retention shall be 75% or greater.

7. CLT PERFORMANCE CRITERIA

CLT shall meet the performance requirements established in this section.

7.1 CLT Grade and Layup Requirements

CLT grades and layups 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*. Each custom CLT grade shall have unique designation assigned by the *approved agency*.

7.1.1 Basic CLT Grades and Layups

Basic CLT grades and layups are those provided in Annex A.

Note 22: *As illustrated in Tables A2 and A4, the basic CLT grades and layups are balanced and symmetrical about the neutral axis, with alternating layers of the same lamination thickness.*

7.1.2 Custom CLT Grades and Layups

CLT grades and layups that are not listed in Annex A shall be considered as custom grades and layups. Custom CLT grades and layups shall be permitted when approved by an *approved agency* in accordance with the qualification and mechanical test requirements specified in 8.4 and 8.5.

Note 23: *Custom CLT grades and layups may be asymmetric, contain different lamination thicknesses, and have adjacent layers oriented in the same direction.*

7.2 Structural Performance Requirements

Design values for each CLT grade and layup shall be developed using an engineering model recognized by an approved agency and shall be evaluated and confirmed by test results in accordance with 8.4 and 8.5.

Note 24: *Design values for basic CLT grades and layups are provided in Table A2 for use in the U.S. and Table A4 for use in Canada based on the engineering model shown in Appendix X3.*

7.3 Appearance Classifications

CLT panel appearance shall be as agreed upon between the end-user and the CLT manufacturer.

Note 25: *Appendix X1 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, SCL, adhesives, and end, face, and edge joints are provided in Section 6 and summarized in Table 1. This section provides requirements for plant qualification and CLT qualification tests to meet the structural performance levels specified in Tables A2 and A4.

TABLE 1

SUMMARY OF QUALIFICATION REQUIREMENTS

Qualification for	Standard(s)	Referenced Section(s) in This Standard
Lumber	Grading Rules/Manufacturing Standard	6.1.1, 6.1.2, 6.1.4 through 6.1.7
SCL	ASTM D5456	6.13
Adhesives	This standard	6.2
End Joints	This standard	6.3.2 and 8.2.6(b)
Face Joints	This standard	6.1.6, 6.1.7, 6.3.3, 8.2, and 8.3
Edge Joints (if applicable)	This standard	6.1.8, 6.3.3, and 8.2
CLT Panel Dimensions	This standard	5
CLT Panel Structural Performance	ASTM D198 or ASTM D4761	7.2 and 8.5

8.2 Plant and Process Qualification

8.2.1 General

The CLT plant shall be 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 and minor strength direction (hereafter referred to as "plant and process qualification panels"; see Figure 3). A minimum of two replicate CLT qualification panels shall be manufactured for each combination of factors considered in 8.2.2. The two replicate CLT qualification panels shall not be extracted from a single billet.

Plant and process qualification panels shall be prepared at the facility or at an alternative facility acceptable to the *approved agency*. All plant and process 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 Plant and Process Qualification Panels

Manufacturing processes used to manufacture 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 26: *For example, 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 specimen and the rigid platen. In addition, the specimen 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 plant and process qualification shall include assembly time, lamination 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 Plant and Process Qualification Panels

Plant and process 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 27: *For panels larger than the specified qualification panel size, the panels may be trimmed to the specified size to facilitate conditioning.*

8.2.4 Specimens

A minimum of six specimens (three for block shear tests, i.e., "B" specimens and three for delamination tests, i.e., "D" specimens) shall be extracted from each plant and process qualification panel at the locations shown in Figure 3 and labeled to indicate the panel number and the specimen position within the panel. The block shear "B" specimens and delamination "D" specimens shall be prepared in such a way that all laminations in the major strength direction are continuous (i.e., do not include an edge joint in laminations). In the minor strength direction, a maximum of one edge joint between laminations shall be allowed in each specimen. To meet this specimen requirement, additional "B" and "D" specimens shall be considered in the specimen preparation.

The "B" and "D" specimens shall be prepared in accordance with the test specimen configuration shown in Figures 4 and 5, respectively. If the plant and process qualification panel is larger than the specified 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
$a = 4 \pm 1$ inches, $L_1 = 24$ to 36 inches, and $L_2 = 24$ to 36 inches (1 inch = 25.4 mm)

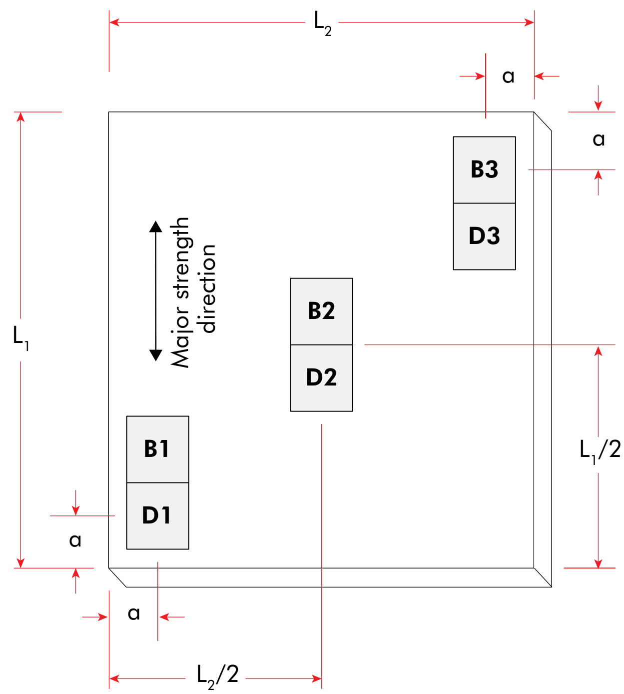
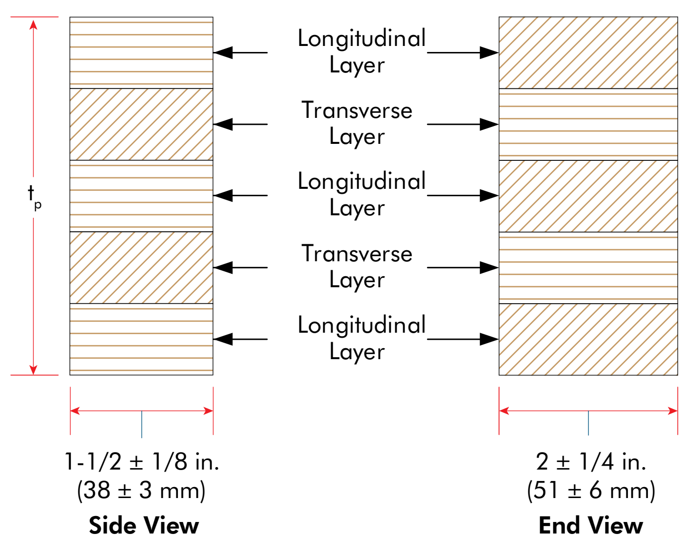


FIGURE 4

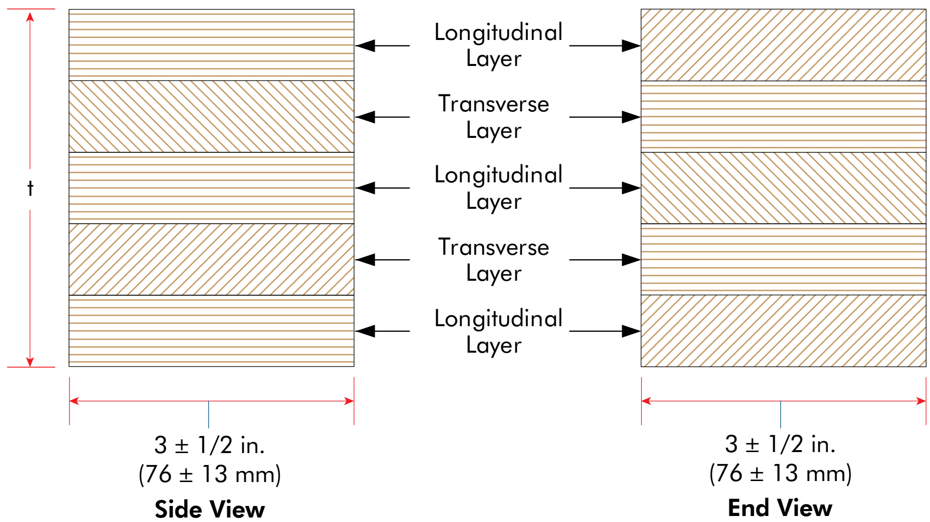
STRAIGHT-BLOCK SHEAR SPECIMEN CONFIGURATION (5-PLY CLT SHOWN)



Shear specimen configurations conforming to Figure A, B, or D of AITC Test T107 or Figure 1 of CSA O177 are deemed to comply

FIGURE 5

DELAMINATION SPECIMEN CONFIGURATION (5-PLY CLT SHOWN)



See 8.2.4 for permissible edge joints in the minor strength direction

8.2.5 Shear Tests

a. The block shear specimens obtained in accordance with 8.2.4 shall be subjected to the shear test specified herein and meet the wood failure requirements specified in 6.3.3.

b. The block shear specimens shall be placed in a standard shearing tool and tested in shear by compression loading at a uniform rate of loading of 0.50 ± 0.05 inch/min (12.7 ± 1 mm/min). The specimen shall be positioned in the shearing tool with the bondline in the shearing plane.

Note 28: *A shearing tool for testing block shear specimens in shear by compression loading is described in ASTM D905. The ASTM D905 shear block test is intended for the assessment of adhesive bonds in wood products with bonded layers parallel to each other and with the grain oriented in the same direction, such as glulam. In the case of CLT, one half of the specimen is compressed parallel to the grain, which may produce longitudinal shear along the bondline, while the other half is compressed perpendicular to the grain, which may produce rolling shear along the shear plane. It is likely that the half of the specimen loaded perpendicular to the grain undergoes substantial deformation during the test, which may lead to crushing or tensile rupture perpendicular to the grain (peeling). These complications make interpretation of the shear block test on CLT specimens challenging and are likely to increase uncertainties related to the determination of wood failure fraction values. Therefore, it is important to include the description of the failure mode(s) in the test report.*

8.2.6 Cyclic Delamination Test

a. The delamination specimens obtained in accordance with 8.2.4 shall be subjected to the cyclic delamination test specified herein and meet the delamination requirements specified in 6.3.3(b).

b. The initial weight of the delamination specimens shall be measured to the nearest gram and recorded prior to placing the specimens in an autoclave or similar pressure vessel that can safely withstand a minimum of 75 psi (517 kPa) of pressure. The specimens shall be weighted down and covered with water at a temperature of 65 to 85°F (18 to 29°C). A vacuum of 10 to 12 psi (69 to 85 kPa, which is equivalent to 20 to 25 inches or 510 to 640 mm Hg) shall be drawn and held for 30 minutes. The vacuum shall then be released and a pressure of 75 ± 5 psi (517 ± 34 kPa) shall be applied for 2 hours. The specimens shall be removed from the autoclave and dried in a drying oven with forced air circulation at a temperature of approximately 160°F (71°C) until their weight is approximately between 110% and 115% of their original weight. During drying, the specimens shall be spaced at approximately 2 inches (50 mm) apart and with their end-grain surfaces parallel to the direction of the air flow. After drying to 110% to 115% of their initial weight, the specimens shall be removed from the oven, and delamination measured immediately and recorded.

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. The manufacturer's visual grading rules established to achieve the effective bond area shall include major visual characteristics, such as wane, knots, decay, pitch pockets, torn grain, and raised grain, 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) by 48 inches (1,220 mm).

Note 29: *A template with a square opening, i.e., 48 inches (1,220 mm) by 48 inches (1,220 mm), may be used to facilitate inspection.*

8.4 Qualification for Structural Performance

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 CLT grades and layups intended for qualification, a qualification plan shall be developed and accepted by an *approved agency* in accordance with the requirements prescribed in this section.

8.4.1 Required Mechanical Property Qualification

The flatwise bending and flatwise shear properties of CLT grades at extreme depths 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 U.S. 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. For unbalanced layups, qualification tests shall be conducted on both positive and negative flatwise bending moment capacities (resistances).

8.5.1 Sampling

Test specimens, including the width of laminations, 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.

Note 30: *Both flatwise and edgewise bending moment, and shear capacities in the U.S. and both flatwise and edgewise bending moment, and shear resistances in Canada may be affected by the lamination width used in the CLT manufacturing. A significant change in the lamination width from original qualification will require subsequent requalification in accordance with 8.6 and Table 2.*

8.5.2 Moisture Conditioning

CLT specimens 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 specimens 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 U.S., 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

If the manufacturer intends to publish edgewise bending properties, edgewise bending stiffness and bending moment capacity (resistance) shall be evaluated in accordance with 8.5.5.1 and 8.5.5.2. If the specimens are not pre-conditioned to a standard moisture content level prior to testing, which may not be feasible depending on the size of the test specimens, the calculated bending strength and stiffness shall be adjusted to the standard moisture content using the procedures given in ASTM D2915 for CLT made of lumber laminations or ASTM D5456 made of SCL laminations. 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

Separate qualification shall be conducted for each layup. In the U.S. and Canada, the average edgewise bending stiffness determined from qualification tests divided by the calculated gross 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 gross 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 gross 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

If the manufacturer intends to publish edgewise shear properties, edgewise shear stiffness and capacity (resistance) shall 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 31: *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

Separate qualification shall be conducted for each layup. For use in the U.S. or Canada, the average edgewise shear stiffness determined from qualification tests divided by the CLT thickness (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 U.S., 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 Change Qualification

Significant 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 significant changes listed or equivalent to that listed in Table 2.

TABLE 2

SUBSEQUENT QUALIFICATION IN RESPONSE TO SIGNIFICANT 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)	
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 8.4 and 8.5 is at the discretion of the approved agency[a]
C	8.4, 8.5	▪ Increase in billet width or length of more than 20%	
D	8.5.3 and 8.5.5 as applicable	▪ Increase in the net lamination width of more than 2 inches (51 mm) from the lamination width used in the product qualification in either major or minor CLT strength direction[b]	
E	8.5.4 and 8.5.6 as applicable	▪ Decrease in the net lamination width of more than 2 inches (51 mm) from the lamination width used in the product qualification in either major or minor CLT strength direction[b]	

a. Changes involving two or more manufacturing parameters shall be considered for reevaluation in accordance with 8.4 and 8.5.

b. Lamination width shall comply with 6.1.4.

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*. Control values for quality assurance shall be established during product evaluation to ensure conformance to performance requirements in this standard.

8.8 Certification and Marking

8.8.1 Certification

CLT products represented as conforming to this standard shall bear the stamp or certificate of conformance 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 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);

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

h. A production lot number or job identification number as a means to trace the CLT product back to the production and quality control records at the manufacturing facility.

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 along the longest dimension of the CLT panel 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 the information specified in 8.8.2(c), (d), (e), and (h). In addition, custom products shall be accompanied by a certificate of conformance to this standard including all of the information listed in 8.8.2. When 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 32: *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 been qualified 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 approved 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 ongoing quality assurance in accordance with Table 3 and meet the strength (required for end joints only), wood failure, and durability requirements specified herein. The sampling shall be well-spaced in each production shift to avoid sampling concentration in the production time. Special considerations for face bonding of the CLT panel as a whole are provided in 9.3.1 through 9.3.4.

TABLE 3

SUMMARY OF OFFLINE TESTS – FOR DAILY REQUIREMENTS

Test	Minimum Number of Specimens	Requirements	Referenced Section(s) in This Standard
Face and Edge Joints[a,b,c]	1 specimen per billet up to 4 specimens per production shift	Wood Failure	6.3.3(a) and 8.2.5
	1 specimen per billet up to 2 specimens per production shift	Delamination	6.3.3(b) and 8.2.6
End Joints[a,c,d,e]	1 specimen per 5,000 joints produced up to 8 specimens per production shift	Tensile Strength	6.3.2(b)
	1 specimen per production shift	Delamination	6.3.2(c)

a. For each adhesive, lamination type, and species combination used.

b. Edge joint daily tests are required only when the edge joint is a structural requirement.

c. For each production line.

d. All grades and widths shall be tested over time. In each shift, at least one specimen shall represent the highest grade and widest width produced during the shift.

e. If delamination exceeds the requirements specified in 6.3.2(c) after one cycle, a second cycle shall be performed on the same specimen, in which case the delamination shall be 10% or less.

9.3.1 Effective Bonding Area

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

Note 33: *To maintain an effective bond area, lumber laminations in adjacent layers may need to be oriented such that the bark and pith faces of adjacent pieces are generally alternated.*

9.3.2 Lumber Lamination Grade Limits

Grade limits intended to limit the amount of lumber 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.

9.3.4 Additional Consideration for Face Joints

Sampling of face joints for quality assurance shall consider the large bonding area for a typical CLT panel and avoid a constant location at all times. Core shear specimens based on AITC Test T107 shall be permitted to be used in place of the block shear specimens specified in 8.2.4 and 8.2.5 for the quality assurance of face joints provided that a correlation factor between core shear and block shear specimens are evaluated in accordance with AITC Test T107 except that a minimum of 40 block shear specimens and an equal number of core shear specimens shall be tested. The correlation shall be documented and included in the in-plant manufacturing standard after the approval by the approved agency. The correlation factor shall be reevaluated at least annually.

9.3.5 Additional Consideration for End Joints

For each production line, sampling of end joints shall include all grades and widths of laminations over time for each adhesive, lamination type, and species combination used. Each combination of grade, width, adhesive, lamination type, and species combination shall be tracked separately for quality assurance. For each production line, at least one end joint tested for each shift shall represent the highest grade and widest width for each adhesive, lamination type, and species combination produced during the shift.

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 bondlines;

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 engineer 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 PRG-320 CLT (Mandatory)

This Annex provides the design properties for basic CLT grades and layups listed in Table A2 using the lamination design values provided in Table A1. The CLT grades and layups represent the CLT production intended for use by the CLT manufacturers in North America and are based on the following:

- 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
- E5: 650f-1.5E Hem-fir MSR lumber in all longitudinal layers and No. 3 Hem-fir 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
- V1(N): No. 2 Douglas fir-Larch (North) lumber in all longitudinal layers and No. 3 Douglas fir-Larch (North) 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
- V4: No. 2 Spruce-pine-fir South lumber in all longitudinal layers and No. 3 Spruce-pine-fir South Lumber in all transverse layers
- V5: No. 2 Hem-fir lumber in all longitudinal layers and No. 3 Hem-fir lumber in all transverse layers
- VH1: No. 2 Yellow poplar lumber in all longitudinal and transverse layers
- S1: 2250f-1.5E Laminated Veneer Lumber (LVL) in all longitudinal and transverse layers
- S2: 1900f-1.3E Laminated Strand Lumber (LSL) in all longitudinal and transverse layers
- S3: 1750f-1.3E Oriented Strand Lumber (OSL) in all longitudinal and transverse layers

TABLE A1

ASD REFERENCE DESIGN VALUES[a] FOR LAMINATIONS USED IN BASIC CLT GRADES (FOR USE IN THE U.S.)

	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
CLT Grade	F_b (psi)	E [b] (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	F_b (psi)	E [b] (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
E5	1,650	1.5	1,020	1,700	150	50	500	1.2	300	725	150	50
V1	900	1.6	575	1,350	180	60	525	1.4	325	775	180	60
V1(N)	850	1.6	500	1,400	180	60	475	1.4	300	825	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
V4	775	1.1	350	1,000	135	45	450	1.0	200	575	135	45
V5	850	1.3	525	1,300	150	50	500	1.2	300	725	150	50
VH1	700	1.3	400	575	145	45	700	1.3	400	575	145	45
S1	2,250	1.5	1,500	1,950	130	40	2,250	1.5	1,500	1,950	130	40
S2	1,900	1.3	1,300	1,650	150	50	1,900	1.3	1,300	1,650	150	50
S3	1,750	1.3	1,200	1,500	115	35	1,750	1.3	1,200	1,500	115	35

For SI: 1 psi = 0.006895 MPa

a. The ASD reference design values for laminations in the basic CLT grades made of visually graded lumber are based on 2x12 lumber. Because the basic CLT grades do not limit the lamination sizes used, the ASD reference design values for laminations in basic CLT grades are not increased for the lamination size, repetitive member, and flat use adjustment factors when calculating the ASD reference design properties for basic CLT grades provided in Table A2.

b. The tabulated E values are published E for lumber and flatwise (plank) apparent E for SCL.

The ASD reference design capacities for the basic CLT grades with 3, 5, and 7 layers are provided in Table A2. These capacities were derived analytically using the Shear Analogy Model[1] (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.

1. Gagnon, S. and M. Popovski. 2011. *Structural Design of Cross-Lminated Timber Elements.* In: Chapter 3, *CLT Handbook.* FPInnovations, Canada

TABLE A2

ASD REFERENCE DESIGN VALUES[(a)] FOR BASIC CLT GRADES AND LAYUPS (FOR USE IN THE U.S.)

CLT Grade	t_p (in.)	Lamination Thickness (in.) in CLT Layup							Major Strength Direction				Minor 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)	$(F_bS)_{eff,f,90}$ (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	1,490	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	2,480	1,370	81	1.2	1,490
	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	3,475	3,150	313	1.8	2,480
E2	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	1,980	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	3,300	1,440	95	1.1	1,980
	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	4,625	3,300	364	1.7	3,300
E3	4 1/8	1 3/8	1 3/8	1 3/8					2,800	81	0.35	1,160	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	1,930	955	61	0.87	1,160
	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	2,700	2,210	234	1.3	1,930
E4	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.50	1,820	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	3,025	1,230	88	1.2	1,820
	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	4,225	2,850	338	1.9	3,025
E5	4 1/8	1 3/8	1 3/8	1 3/8					3,825	101	0.46	1,650	160	3.1	0.55	550
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,800	389	0.92	2,750	1,370	81	1.1	1,650
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,575	962	1.4	3,850	3,150	312	1.7	2,750
V1	4 1/8	1 3/8	1 3/8	1 3/8					2,090	108	0.53	1,980	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	3,300	1,440	95	1.2	1,980
	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	4,625	3,300	364	1.8	3,300
V1(N)	4 1/8	1 3/8	1 3/8	1 3/8					1,980	108	0.53	1,980	150	3.6	0.59	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,550	415	1.1	3,300	1,300	95	1.2	1,980
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,025	1,027	1.6	4,625	3,000	364	1.8	3,300
V2	4 1/8	1 3/8	1 3/8	1 3/8					2,030	95	0.46	1,490	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	2,480	1,370	81	1.0	1,490
	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	3,475	3,150	312	1.6	2,480

Continued on next page

TABLE A2 (Continued)

ASD REFERENCE DESIGN VALUES[a] FOR BASIC CLT GRADES AND LAYUPS (FOR USE IN THE U.S.)

		Lamination Thickness (in.) in CLT Layup							Major Strength Direction				Minor Strength Direction			
CLT Grade	t_p (in.)	=	⊥	=	⊥	=	⊥	=	$(F_bS)_{eff,f,0}$ (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)	$(F_bS)_{eff,f,90}$ (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)
V3	4 1/8	1 3/8	1 3/8	1 3/8					1,740	95	0.49	1,820	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	3,025	1,230	88	1.0	1,820
	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	4,225	2,825	338	1.6	3,025
V4	4 1/8	1 3/8	1 3/8	1 3/8					1,800	74	0.38	1,490	140	2.6	0.41	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,150	285	0.76	2,480	1,230	68	0.82	1,490
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	7,325	706	1.1	3,475	2,825	260	1.2	2,480
V5	4 1/8	1 3/8	1 3/8	1 3/8					1,980	88	0.45	1,650	160	3.1	0.48	550
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,550	337	0.91	2,750	1,370	81	0.97	1,650
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,025	835	1.4	3,850	3,150	312	1.5	2,750
VH1	4 1/8	1 3/8	1 3/8	1 3/8					1,630	88	0.49	1,490	220	3.4	0.49	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			3,750	337	0.98	2,480	1,910	88	0.98	1,490
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	6.625	836	1.5	3,475	4,400	337	1.5	2,480
S1	4 1/2	1 1/2	1 1/2	1 1/2					6,225	132	0.61	1,440	845	5.1	0.61	480
	7 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2			14,325	506	1.2	2,400	7,325	132	1.2	1,440
	10 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	25,325	1,252	1.8	3,350	16,850	506	1.8	2,400
S2	4 1/2	1 1/2	1 1/2	1 1/2					5,250	114	0.53	1,800	715	4.4	0.53	600
	7 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2			12,100	438	1.1	3,000	6,175	114	1.1	1,800
	10 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	21,400	1,085	1.6	4,200	14,225	438	1.6	3,000
S3	4 1/2	1 1/2	1 1/2	1 1/2					4,850	114	0.53	1,260	655	4.4	0.53	420
	7 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2			11,150	438	1.1	2,100	5,700	114	1.1	1,260
	10 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	19,700	1,085	1.6	2,950	13,000	438	1.6	2,100

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

a. This table represents the basic CLT grades and layups. Custom CLT grades and layups that are not listed in this table shall be permitted in accordance with 7.1.2.

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

F_bS (lbf-ft/ft) and Vs (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 LSD design resistances for basic CLT grades and layups are listed in Table A4 using the LSD design values for the laminations provided in Table A3. 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, Spruce-pine-fir South, and Yellow poplar lumber in Canada, the CLT Grades E4, V1, V3, V4, and VH1 are not listed in Tables A3 and A4.

TABLE A3

LSD SPECIFIED STRENGTH[a] AND MODULUS OF ELASTICITY FOR LAMINATIONS USED IN BASIC CLT GRADES (FOR USE IN CANADA)

CLT Grade	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
	f_b (MPa)	E[b] (MPa)	f_t (MPa)	f_c (MPa)	f_v (MPa)	f_s (MPa)	f_b (MPa)	E[b] (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
E5	23.9	10,300	11.4	18.1	1.6	0.53	7.0	10,000	3.2	9.2	1.6	0.53
V1(N)	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
V5	11.0	11,000	6.2	14.8	1.6	0.53	7.0	10,000	3.2	9.2	1.6	0.53
S1	28.7	10,300	19.1	21.5	1.7	0.56	28.7	10,300	19.1	21.5	1.7	0.56
S2	24.2	8,900	16.6	18.2	1.9	0.64	24.2	9,300	16.6	18.2	1.9	0.64
S3	22.3	8,900	15.3	16.5	1.5	0.49	22.3	8,900	15.3	16.5	1.5	0.49

For SI: 1 MPa = 145 psi

a. The LSD design values for laminations in the basic CLT grades made of visually graded and MSR lumber are based on 2x12 lumber except for the specified tensile strength made of MSR lumber. Because the basic CLT grades do not limit the lamination sizes used, the LSD design values for laminations in basic CLT grades are not increased for the lamination size and system factors in accordance with CSA O86 when calculating the LSD design properties for basic CLT grades provided in Table A4. The LSD specified tensile strength values for MSR lumber are based on 2x8 lumber and not permitted to be increased for the system factor in accordance with CSA O86 when calculating the LSD design properties for basic CLT grades provided in Table A4.

b. The tabulated E values are published E for lumber and flatwise (plank) apparent E for SCL.

TABLE A4

LSD STIFFNESS AND UNFACTORED RESISTANCE VALUES[(a)] FOR BASIC CLT GRADES AND LAYUPS (FOR USE IN CANADA)

CLT Grade	t_p (mm)	Lamination Thickness (mm) in CLT Layup							Major Strength Direction				Minor Strength Direction			
		=	⊥	=	⊥	=	⊥	=	$(f_bS)_{eff,f,0}$ (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	35	1.40	32	9.1	12
	175	35	35	35	35	35			98	4,166	15	58	12	837	18	35
	245	35	35	35	35	35	35	35	172	10,306	22	82	29	3,220	27	58
E2	105	35	35	35					36	958	8.0	44	0.94	36	8.2	15
	175	35	35	35	35	35			83	3,674	16	74	8.2	930	16	44
	245	35	35	35	35	35	35	35	146	9,097	24	103	19	3,569	25	74
E3	105	35	35	35					26	772	5.3	30	0.92	23	6.4	10
	175	35	35	35	35	35			60	2,956	11	50	8.0	605	13	30
	245	35	35	35	35	35	35	35	106	7,313	16	70	18	2,325	19	50
E5	105	35	35	35					36	958	8.0	37	1.40	36	8.2	12
	175	35	35	35	35	35			83	3,674	16	62	12	930	16	37
	245	35	35	35	35	35	35	35	146	9,097	24	87	29	3,569	25	62
V1(N)	105	35	35	35					15	1,023	8.0	44	0.94	36	8.7	15
	175	35	35	35	35	35			35	3,922	16	74	8.2	930	17	44
	245	35	35	35	35	35	35	35	61	9,708	24	103	19	3,571	26	74
V2	105	35	35	35					18	884	7.2	35	1.4	32	7.5	12
	175	35	35	35	35	35			41	3,388	14	58	12	837	15	~~35~~
	245	35	35	35	35	35	35	35	72	8,388	22	82	29	3,213	23	58
V5	105	35	35	35					17	1,023	8.0	37	1.40	36	8.7	12
	175	35	35	35	35	35			38	3,922	16	62	12	930	17	37
	245	35	35	35	35	35	35	35	67	9,708	24	87	29	3,571	26	62
S1	114	38	38	38					51	1,226	8.9	43	6.90	47	8.9	14
	190	38	38	38	38	38			117	4,704	18	71	60	1,226	18	43
	266	38	38	38	38	38	38	38	207	11,647	27	99	138	4,704	27	71

Continued on next page

TABLE A4 (Continued)

LSD STIFFNESS AND UNFACTORED RESISTANCE VALUES[(a)] FOR BASIC CLT GRADES AND LAYUPS (FOR USE IN CANADA)

		Lamination Thickness (mm) in CLT Layup							Major Strength Direction				Minor Strength Direction			
CLT Grade	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)
S2	114	38	38	38					43	1,059	7.7	49	5.80	41	7.7	16
	190	38	38	38	38	38			99	4,064	15	81	51	1,059	15	49
	266	38	38	38	38	38	38	38	175	10,064	23	113	116	4,064	23	81
S3	114	38	38	38					40	1,059	7.7	37	5.40	41	7.7	12
	190	38	38	38	38	38			91	4,064	15	62	47	1,059	15	37
	266	38	38	38	38	38	38	38	161	10,064	23	87	107	4,064	23	62

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

a. This table represents the basic CLT grades and layups.Custom CLT grades and layups that are not listed in this table shall be permitted in accordance with 7.1.2.

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

f_bS (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-mm²/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.

ANNEX B. Practice for Evaluating Elevated Temperature Performance of Adhesives Used in Cross-Laminated Timber Using the Compartment Fire Test (CFT) Method (Mandatory)

B1 Scope

B1.1 This annex is to be used to evaluate the elevated temperature performance of adhesives used in cross-laminated timber (CLT).

B1.2 An unprotected CLT floor-ceiling slab is exposed to specified fire conditions representative of a real fire scenario.

B1.3 The unprotected CLT floor-ceiling slab shall sustain the applied load during the specified fire exposure for a period of 240 minutes without char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire.

B1.4 This annex is used to evaluate the performance of adhesives used in CLT to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment under actual fire conditions

B1.5 This annex 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 annex to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

B2 Referenced Documents

See Section 2 of the standard for referenced documents. Referenced standards specific to this annex are listed below.

ASTM C1396/C1396M-17 *Standard Specification for Gypsum Board*

ASTM E176-21ae1 *Standard Terminology of Fire Standards*

B3 Terminology

B3.1 Definition

Definitions used in this annex are in accordance with Section 3 of the standard, and the terminology standards ASTM D9 and ASTM E176, unless otherwise indicated.

B3.2 Superimposed Load

The additional external load needed to be applied to the slab to result in the specified calculated stresses within the slab when any dead load of the assembly itself is accounted for in the calculations.

B4 Summary of Practice

B4.1 This annex shall be used to evaluate adhesives intended for use in CLT by fire testing a floor-ceiling slab under a vertical load associated with 25% of the effective ASD reference flatwise bending moment of the CLT. The unprotected CLT floor-ceiling slab shall sustain the applied load during the specified fire exposure for a period of 240 minutes without char layer fall-off resulting in a significant temperature increase at the compartment ceiling during the cooling phase of a fully developed fire. The temperature increase is considered significant if, after 150 minutes, any room interior thermocouple at the compartment ceiling exceeds 950°F (510°C) at any time before termination of the test.

B5 Significance and Use

B5.1 CLT used in fire-resistance-rated assemblies shall be able to support the superimposed design load for the specified time under the specified fire exposure without char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire.

B6 Sample Description

B6.1 Dimensions

CLT floor-ceiling sample shall be approximately 8 feet by 16 feet (2,438 mm) by 4,877 mm), with the long dimension spanning in the major strength direction. Clear distance between the supports shall be at least 15 feet (4,572 mm).

B6.2 Fabrication

CLT floor-ceiling test sample shall be at least 5-ply CLT with maximum lamination thickness of 1-3/8 inches (35 mm) and maximum lamination widths of 7-1/4 inches (184 mm). The edge joints in the laminations shall be tight, but shall not be edge-glued.

B6.3 Adhesive

CLT floor-ceiling test sample shall be fabricated using the adhesive being evaluated.

B6.4 Moisture Content

The moisture content of the CLT floor-ceiling test sample shall be not greater than the moisture content specified in Section 6.1.4 of this standard at the time of the fire test.

B7 Test Room Description

B7.1 Test Room Dimensions

A test room shall have interior dimensions of 9 feet ± 4 inches (2,743 mm ± 102 mm) in width by 19 feet ± 4 inches (5,791 mm ± 102 mm) in depth by 8 feet ± 2 inches (2,438 mm ± 51 mm) in height. The test room shall consist of two sections separated by a protected beam across the width of the room, located at approximately 15 feet

(4,572 mm) from the interior of the front wall. The CLT floor-ceiling sample shall be located in the front section of the room. A propane or natural gas diffusion burner shall be used to create the exposing fire. The burner shall be located in the back section of the test room (referred to hereafter as the burner compartment).

Note B1: *A steel frame structure protected with three layers of 5/8-inch (15.9 mm) type X gypsum board conforming to ASTM C1396/C1396M and three layers of 6 pcf (96 kg/m^3) ceramic fiber blanket (four layers of each in the back section) has been found suitable (see Appendix X2 for a detailed description of the test structure that was used in the development of the method described in this annex).*

B7.2 Floor-Ceiling Support

The CLT floor-ceiling slab shall be supported across the full 8-foot (2,438 mm) width of the room by the front wall at one end and by a protected beam at the other end. The beam shall be located at a sufficient distance from the front wall to result in a clear span of at least 15 feet (4,572 mm). The remaining portion of the ceiling over the burner shall be protected.

B7.3 Front Wall

The 8-foot (2,438 mm) tall bearing wall at the front end of the room shall be capable of supporting the CLT floor-ceiling slab for the duration of the fire test.

B7.4 Back Wall

The 8-foot (2,438 mm) tall bearing wall at the back end of the room shall be capable of supporting the protected ceiling over the burner for the duration of the fire test.

B7.5 Non-Loadbearing Side Walls

The 10-foot (3,048 mm) tall, 19-foot (5,791 mm) long side walls of the test room shall be capable of remaining in place without deflection for the duration of the fire test. A narrow gap along each of the side walls shall permit the floor-ceiling slab to deflect freely without contacting the side walls. The gap between the side wall and the CLT floor-ceiling slab shall be covered with ceramic fiber blanket to prevent smoke and hot gases from leaking and exposing the long edges of the CLT slab.

B7.6 Wall Opening Dimensions

All four walls shall be enclosed except for a ventilation opening in the front 8-foot (2,438 mm) wall, which shall have dimensions of 36 ± 2 inches (914 ± 51 mm) in width by 75 ± 2 inches (1,905 ± 51 mm) in height.

B7.7 Protected Beam

The beam shall be located 15 feet ± 4 inches (4,572 ± 102 mm) from the interior of the front wall, and shall be capable of supporting the CLT floor-ceiling slab and the protected ceiling over the burner for the duration of the fire test.

B7.8 Burner Compartment

The back part of the test room shall consist of a 9 feet ± 4 inches (2,743 mm ± 102 mm) wide by 7 feet ± 2 inches (2,134 mm ± 51 mm) high burner compartment, and shall be open to the front part of the test room where the CLT floor-ceiling slab is located. The burner compartment shall be protected to ensure that its walls and ceiling remain in place without deflection for the duration of the fire test.

B8 Instrumentation

B8.1 Hot Gas Layer (Ceiling) Thermocouples

Five 1/8-inch- (3.2 mm) diameter exposed junction Inconel-sheathed type K thermocouples shall be located 4 inches (102 mm) below the ceiling in the following locations: at the center of the exposed ceiling and at the center of each of the four quadrants of the CLT floor-ceiling slab.

Note B2: *To obtain an indication of the temperature evolution at the glue-lines, 1/16 inch- (1.6 mm) diameter grounded junction Inconel-sheathed type K thermocouples can be inserted from the unexposed side of the CLT. Since the thermal exposure conditions vary somewhat between the front and the back of the test room, it is recommended that embedded thermocouples be installed at three locations along the long dimension of the CLT floor-ceiling slab, i.e., at the center and the quarter points of the clear span. It is further recommended that thermocouples be located at the bottom first, second, and third gluelines, and as far as possible from joints and edges. For example, for CLT made with 1-3/8-inch- (35 mm) thick laminations, the following thermocouple locations apply: 1.38, 2.75, and 4.13 inches (35, 70, and 105 mm) from the exposed side (bottom) of the CLT floor-ceiling slab. The measurement uncertainty of the embedded thermocouples is due to the error associated with the assumed depth at which the thermocouple is located, heat conduction along the thermocouple wires, the potential presence of gaps and/or local density variations (such as knots) in the vicinity of the thermocouple, etc. Consequently, the optional embedded thermocouple measurements are indicative, and are not part of the acceptance criteria.*

B8.2 Gaseous fuel shall be supplied to the burner at a time-varying rate to obtain the heat release rate profile established from calibration testing (see Section B10).

B8.3 Temperatures and the fuel flow rate shall be recorded throughout the test.

B9 Loading

B9.1 The superimposed load on the CLT floor-ceiling slab shall result in 25% of the effective ASD reference flatwise bending moment.

B10 Calibration Test Method

B10.1 Calibration testing shall be conducted to determine the fuel flow rate for the qualification tests. The fuel flow rate shall provide an average temperature of the five ceiling thermocouple temperatures as shown in Figure B1. The time-temperature curve in Figure B1 is achieved by using a diffusion burner placed in the back of the test room, and by changing the burner fuel flow rate in steps at 0, 13, 38, 58, and 88 minutes. The average ceiling thermocouple temperature at those times shall be within the tolerances given in Table B1. The temperatures at other times in Table B1 are provided for guidance. In no case shall any ceiling thermocouple temperature drop more than 10% below the average of the recorded ceiling thermocouple temperatures.

Note B3: *A burner consisting of a 2-by-6-by-1-foot- (610-by-1,829-by-305-mm) tall steel box with open top, filled with gravel and supplied with propane gas has been found suitable. See Appendix X2 for a detailed description of the burner that was used in the development of the method described in this annex.*

B10.2 The CLT floor-ceiling slab shall be protected from the bottom with three layers of 5/8-inch (15.9 mm) Type X gypsum wallboard conforming to ASTM C1396/C1396M. The gypsum wallboard shall be attached with Type S drywall screws every 12 inches (305 mm) o.c. with a minimum penetration into the wood of at least 1 inch (25.4 mm).

B11 Qualification Test Method

B11.1 The fuel flow rate determined in Section B10.1 shall be used for the qualification tests.

B11.2 The unprotected CLT floor-ceiling slab, complying with Section B6, shall be tested for 240 minutes.

Note B4: *If the CLT floor-ceiling slab clearly fails prior to 240 minutes, the test should be permitted to be terminated early.*

B12 Acceptance Criteria

B12.1 The unprotected CLT floor-ceiling slab shall sustain the applied load during the specified fire exposure for a period of 240 minutes.

B12.2 After 150 minutes, none of the ceiling thermocouples shall exceed 950°F (510°C).

B13 Report

B13.1 The report shall contain the following minimum information:

B13.1.1 Description of the CLT floor-ceiling sample including the lamination species, lamination dimensions, slab thickness, and the manufacturer;

B13.1.2 Adhesive manufacturer, adhesive type, and adhesive formulation identification;

B13.1.3 Description of the test room construction;

B13.1.4 Description of the loading method;

B13.1.5 Results of the calibration test including the fuel flow rates and thermocouple data;

B13.1.6 Time-temperature curve for the ceiling thermocouples; and

B13.1.7 Visual observations during and after the test.

FIGURE B1

CALIBRATION TIME-TEMPERATURE CURVE

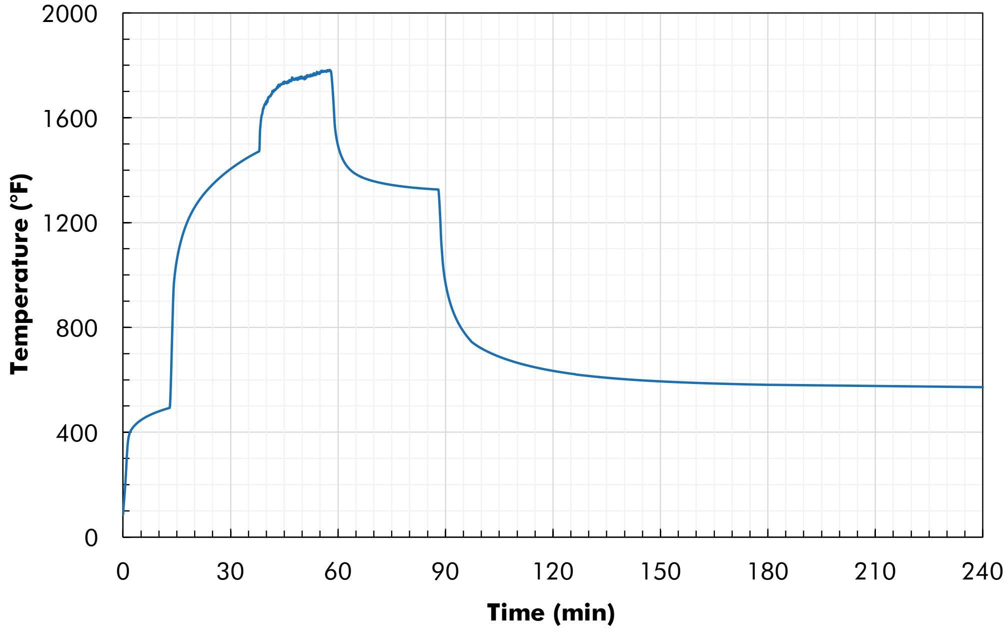


TABLE B1

CALIBRATION TEMPERATURES AND TOLERANCES AT SPECIFIC TIMES

Time (min.)	Temperature (°F)	Tolerance (°F)	Temperature (°C)	Tolerance (°C)
13	493	±36	256	±20
28	1383		751	
38	1472	±45	800	±25
48	1746		952	
58	1778	±54	970	±30
68	1366		741	
78	1338		725	
88	1326	±45	719	±25
120	634		335	
150	594		312	
180	581	±36	305	±20
240	572		300	

APPENDIX X1. Examples of CLT Appearance Classifications (Non-Mandatory)

This appendix contains examples of CLT appearance classifications for CLT panels manufactured with lumber laminations 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 end-user and the CLT manufacturer.

X1.1 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 inch^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.

X1.2 Industrial Appearance Classification

An appearance classification normally suitable for use in concealed applications where appearance is not of primary concern. Specific characteristics of this classification 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 X2. Test Setup Used in the Development of Annex B (Non-Mandatory)

X2.1 Introduction

This appendix provides a detailed description of the room that was used in the development of the test method described in Annex B.

X2.2 Test Room

A test room was constructed with nominal interior dimensions 9 feet 4 inches (2,845 mm) in width, 19 feet (5,791 mm) in length, and 8 feet (2,438 mm) in height. The ventilation opening in the front wall was nominally 36 inches (914 mm) in width by 75 inches (1,905 mm) in height. The test room was built directly on the concrete floor of the laboratory, but the test room floor was protected with several layers of type X gypsum board. Drawings of the finished test room can be found in Figures X2-1 through X2-4. A detailed description follows.

Two steel I-beams of 12 inches (305 mm) in height and 41 lbf/foot (0.6 kN/m) by weight welded together were located at approximately 15 feet (4,572 mm) from the front wall to subdivide the test room into two sections. The ceiling of the front section was left open and allowed for the exposure of a 16-foot- (4,877 mm) long by 8-foot- (2,438 mm) wide mass timber ceiling panel. The panel was simply supported by the front wall at one end (bearing length ≈ 6 inches or 152 mm), and by the steel I-beam at the other end (bearing length ≈ 5-1/4 inches or 133 mm). The sides of the panel were not supported, and the panel was allowed to deflect freely between the two side walls. A gas burner to create the desired fire exposure was located in the back section of the room, as shown in Figure X2-5. Construction details for the test room walls, floor and ceiling are as follows:

X2.2.1 Front Wall

The front wall of the test room consisted of 8-foot- (2,438 mm) tall and 6-inch- (152 mm) deep, 16-gauge steel studs at 12 inches (305 mm) on center, and with 16-gauge track top and bottom. The interior surface of the frame was covered with three layers of 5/8-inch (15.9 mm) type X gypsum board (National Gypsum Fire-Shield®), 20-gauge galvanized sheet steel, and three layers of 1-inch- (25.4 mm) thick ceramic fiber blanket (Morgan Thermal Ceramics 6 pcf or 96 kg/m^3 Cerablanket®). The exterior surface was covered with two layers of 5/8-inch (15.9 mm) type X gypsum board, 20-gauge galvanized sheet steel (top half only), and one layer of 1-inch- (25.4 mm) thick ceramic fiber blanket (additional layers of blanket were used at the soffit and above the ventilation opening).

X2.2.2 Side Wall

The side walls of the test room consisted of three layers of 4-foot- (1,219 mm) wide by 10-foot- (3,048 mm) tall 5/8-inch (15.9 mm) type X gypsum board attached to steel racks. The interior surface of the gypsum board was covered with three layers of 1-inch- (25.4 mm) thick ceramic fiber blanket. An additional layer of blanket was attached to the side walls in the back section of the test room. In the front section of the test room, the web of a 6-inch- (152 mm) deep steel stud covered with 16-gauge track was attached to the side walls at 8 feet (2,438 mm) above the floor. The bottom of the covered studs was protected with three layers of 5/8-inch (15.9 mm) type X gypsum board. Two layers were used to protect the vertical and top surfaces. The studs and track mounted along the side walls were covered with four layers of ceramic fiber blanket to reduce the width of the opening in the front section of the test room from 9 feet 4 inches (2,845 mm) to 8 feet 5 inches (2,565 mm), as shown in Figure X2-5. The gaps along the edges of the panel were filled with ceramic fiber blanket, and the top and bottom of the gaps were then covered with a strip ceramic fiber blanket attached to the panel and a side wall of the test room, as shown in Figure X2-6.

X2.2.3 Back Wall

The back wall of the test room consisted of 8-foot- (2,440 mm) tall, 3-5/8-inch- (92 mm) deep, 18-gauge steel studs at 12 inches (305 mm) on center and with 18-gauge track top and bottom. The interior surface of the frame was covered with four layers of 5/8-inch (15.9 mm) type X gypsum board and three layers of 1-inch- (25.4 mm) thick ceramic fiber blanket. The exterior surface was not finished. An opening at the bottom of the back wall allowed the 2-inch- (50.8 mm) diameter propane pipe nipple from the burner to pass-through to connect to the supply hose outside the test room. The opening was sealed with ceramic fiber blanket.

X2.2.4 I-beams

The space between the exposed surfaces of the flanges and web were filled with several layers of 5/8-inch (15.9 mm) type X gypsum board, and the beams were then wrapped with four layers of 1-inch- (25.4 mm) thick ceramic fiber blanket.

X2.2.5 Back Section Ceiling

The ceiling above the burner consisted of a spare 4.5-foot (1,372 mm) by 8-foot (2,438 mm) CLT panel, protected with four layers of 5/8-inch (15.9 mm) type X gypsum board and four layers of 1-inch-(25.4 mm) thick ceramic fiber blanket. The front edge of the CLT panel was supported by one of the two I-beams. At the back edge, the CLT panel was attached to a 3-1/2-inch (89 mm) by 3-1/2-inch (89 mm) by 1/4-inch (6.4 mm) angle iron welded to the racks supporting the side walls.

Fastener details are as follows:

First layer of gypsum board: 1-7/8-inch (48 mm) No. 6 type S bugle head drywall screws.

Second layer of gypsum board: 2-1/2-inch (64 mm) No. 6 type S bugle head drywall screws.

Third and fourth layer of gypsum board: 3-inch (76 mm) No. 8 type S bugle head drywall screws.

First and second layer of ceramic fiber blanket: 4-1/2-inch (114 mm) coarse thread screws with 1-inch (25.4 mm) washers.

Third and fourth layer of ceramic fiber blanket: 12-gauge galvanized steel wire bent into horseshoe shape.

Screw spacing was approximately 12 inches (305 mm). Wires were used where needed. All joints were staggered with at least 1 foot (305 mm) separation.

X2.3 Gas Burner

X2.3.1 Burner Construction

A gas burner was constructed to create the exposing fire. The burner consisted of a 6-foot- (1,829 mm) long by 2-foot- (610 mm) wide by 1-foot- (305 mm) tall steel box with open top. Five pieces of 2-inch (51 mm) by 3-inch (76 mm) steel rectangle tube were welded to the bottom plate, elevating the burner approximately 2 inches (51 mm) above the floor (see Figure X2-5). The burner was supplied with propane through a 2-inch-(51 mm) diameter pipe. The gas flow was evenly distributed to eight downward-facing release points as shown in Figure X2-7. The burner was filled with coarse gravel to ensure relatively uniform propane flow at the top surface (see Figure X2-5).

TABLE X2.1

BURNER HRR STEP PROFILE

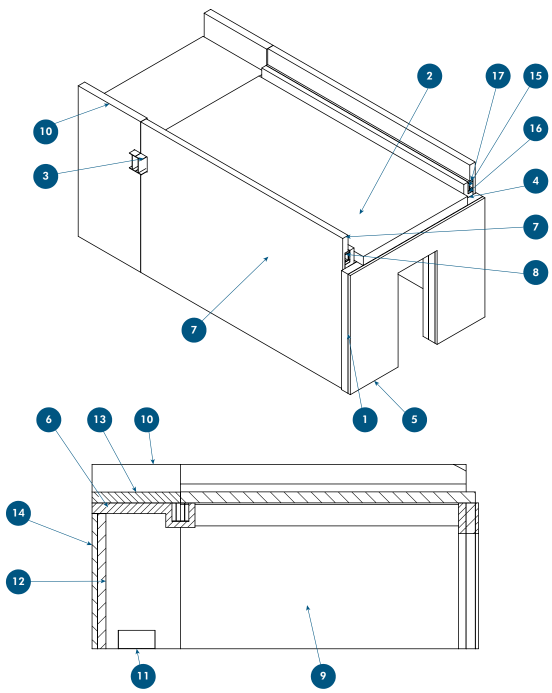
Start (min.)	End (min.)	HRR (kW)
0	13	250
13	38	1075
38	58	1377
58	88	834
88	End of Test	250

X2.3.2 Burner Heat Release Rate Profile

Propane was supplied from two tanks via a vaporizer, a regulator, and a 2-inch-(51 mm) diameter pipe with several shut-off valves and a control valve. The propane flow rate was manually controlled, and measured with a Coriolis mass flow sensor. The burner profile is shown in Table X2-1 and Figure X2-8.

FIGURE X2.1

3-D VIEW OF TEST ROOM



Item No.	Description	Quantity
1	Front Wall	1
2	CLT Panel	1
3	I-beam 12 x 41	2
4	Front Wall Interior Insulation	1
5	Front Wall Exterior Insulation	1
6	Burner Section Ceiling Insulation	1
7	Side Wall CLT Section	2
8	Side Wall Studs and Track	4
9	Side Wall Stud Insulation Blanket	2
10	Burner Section Side Wall	2
11	Burner	1
12	Burner Section Back Wall	1
13	Burner Section CLT Panel	1
14	Burner Section Outside Gyp	1
15	Side Wall Stud-side Gyp	2
16	Side Wall Stud Under Gyp	2
17	Side Wall Stud Top Gyp	2

FIGURE X2.2

PLAN VIEW AND SIDE ELEVATION (SECTION) OF TEST ROOM (Units in inches)

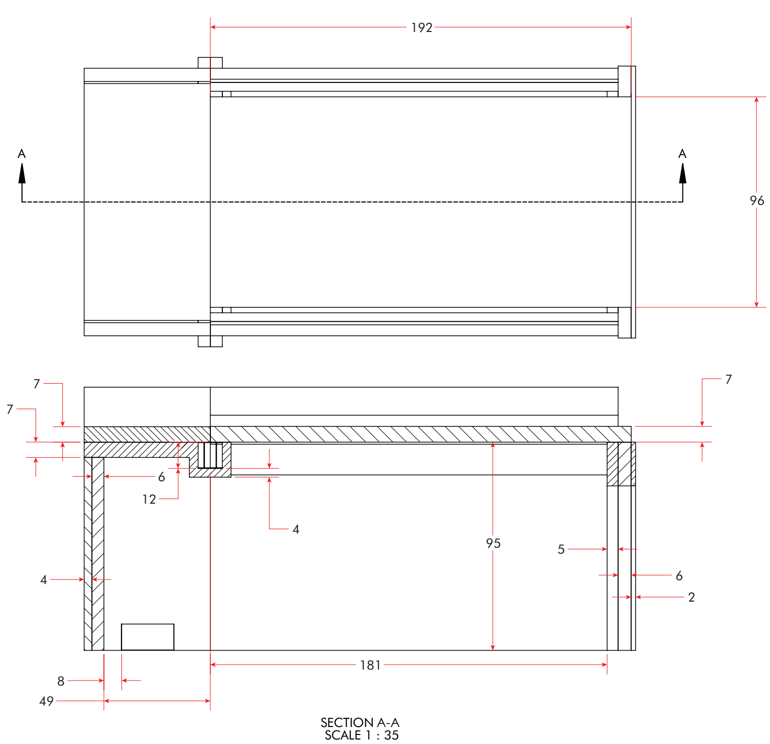


FIGURE X2.3

PLAN VIEW (SECTION) AND SIDE ELEVATION (SECTION) OF TEST ROOM (Units in inches)

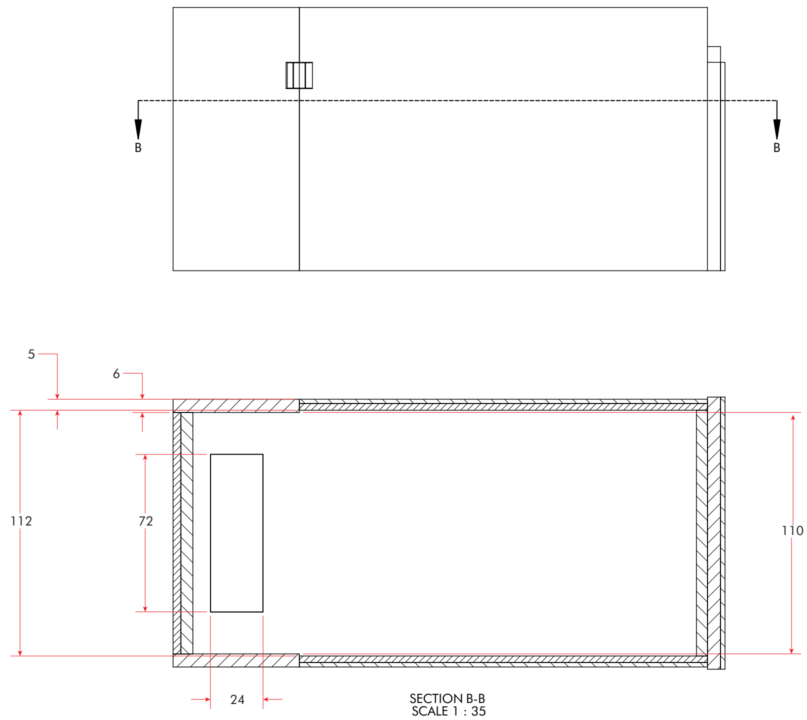


FIGURE X2.4

FRONT ELEVATION AND CONSTRUCTION DETAIL TO NARROW GAP ALONG SIDES OF CLT SAMPLE (Units in inches)

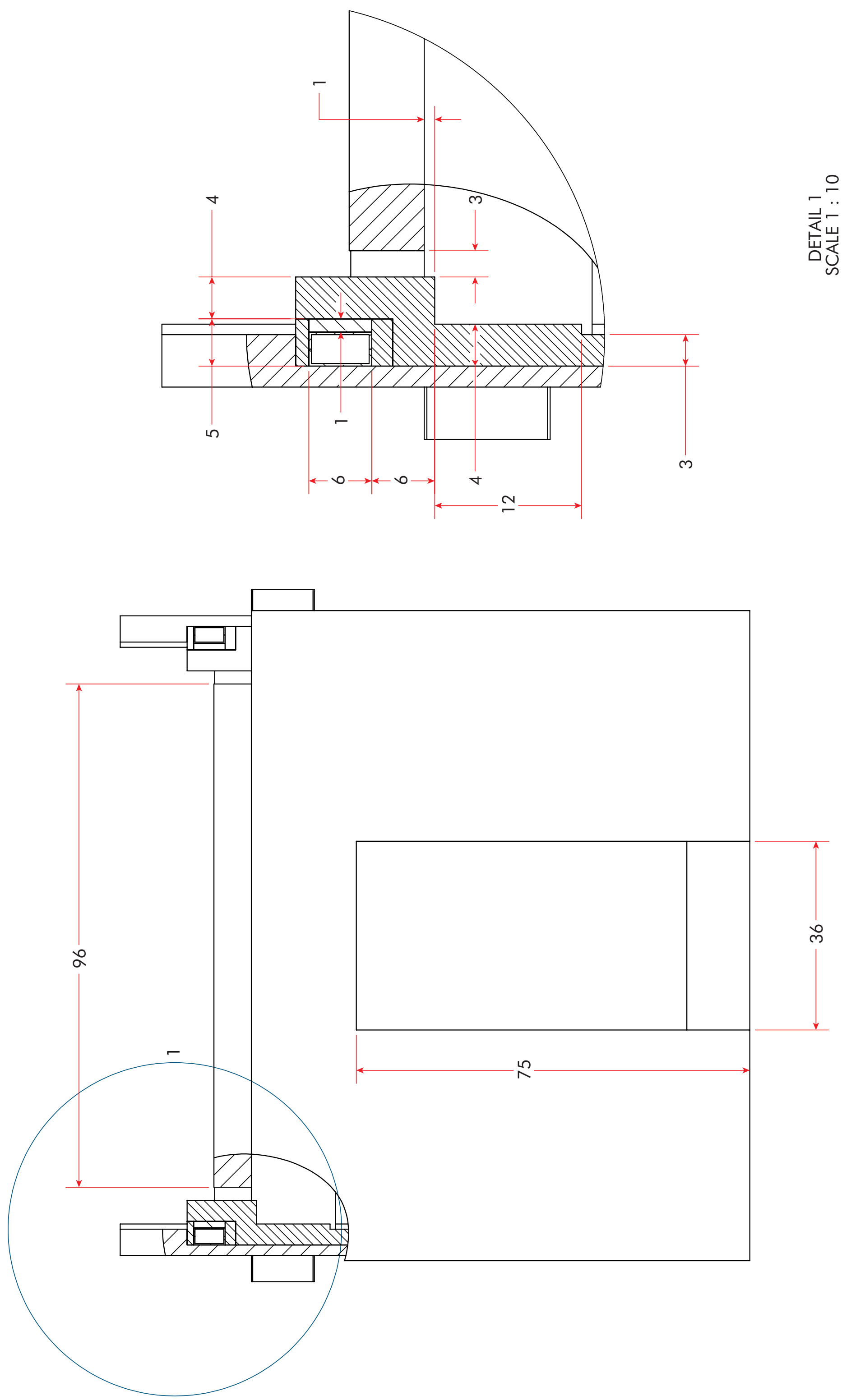


FIGURE X2.5

PROPANE DIFFUSION BURNER

FIGURE X2.6

PICTURE ILLUSTRATING CERAMIC FIBER COVER AROUND PANEL PERIMETER

FIGURE X2.7

SCHEMATIC OF BURNER ILLUSTRATING DISTRIBUTION OF PROPANE FLOW

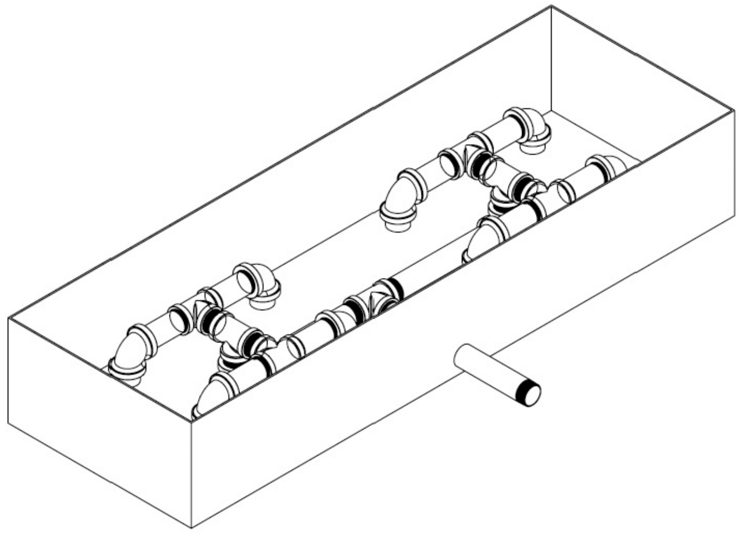
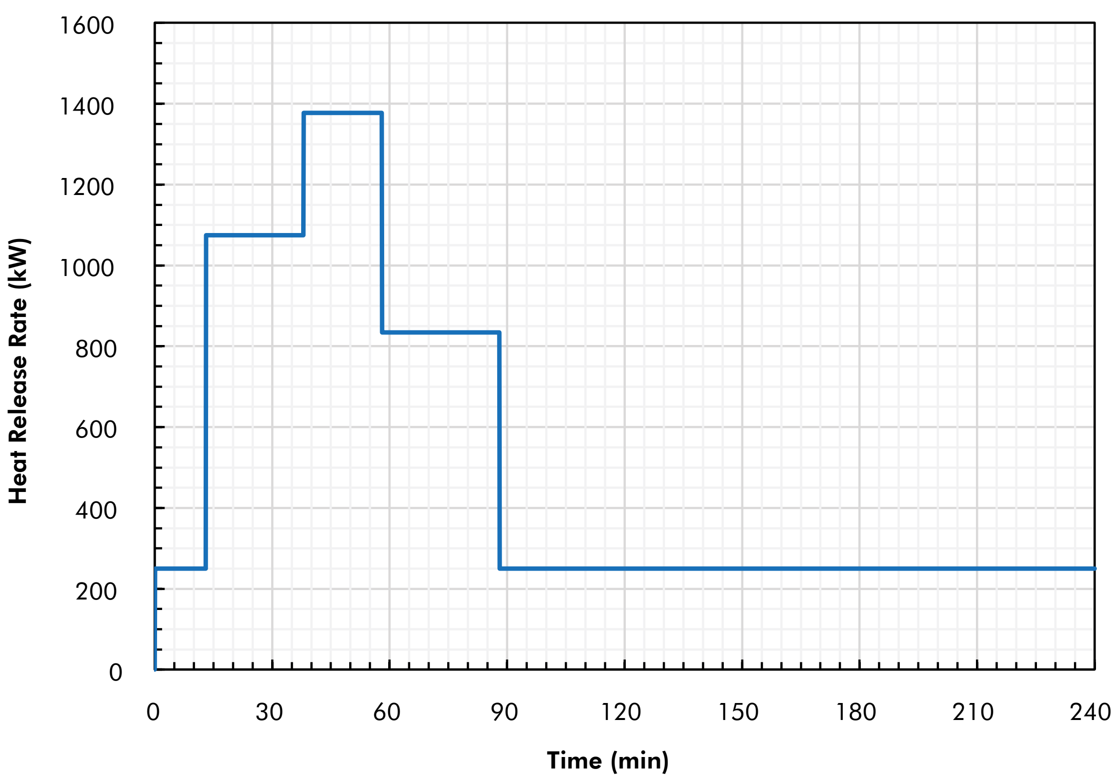


FIGURE X2.8

BURNER HEAT RELEASE RATE PROFILE



APPENDIX X3. An Engineering Model Used in the Development of CLT Design Values in Annex A (Non-Mandatory)

X3.1 General

This appendix provides engineering formulas for the determination of CLT design values published in Annex A based on the shear-analogy model. This methodology has been recognized by the consensus-based canvas committee that developed this standard.

These formulas are applicable to CLT grades, using laminations with design properties recognized by the *approved agency*. For other grades, additional consideration may be necessary when using these formulas.

For calculating the CLT design properties, such as those shown in Tables A2 and A4, the modulus of elasticity in the transverse direction of lamination, $E_\perp$, is customarily assumed to be E/30, the modulus of rigidity (shear modulus) of lamination, G, is assumed to be E/16, and the modulus of rigidity (shear modulus) of lamination in the transverse direction of lamination, $G_\perp$, is assumed to be G/10. The ASD reference planar (rolling) shear stress, F_s, of the lamination is customarily assumed to be 1/3 of the reference shear strength parallel to grain (F_v) and the LSD specified planar (rolling) shear strength, f_s, of the lamination is customarily assumed to be 1/3 the LSD specified shear strength parallel to grain (f_v).

Design values for balanced layups with alternating layers containing only one grade of laminations in the longitudinal layers and one grade of laminations in the transverse layers can be calculated using X3.2. A general model for the development of design values for any layups is provided in X3.3.

Note X3-1: *The models presented in this appendix are formulated to calculate the design properties of a unit width of CLT of 1 foot for ASD or 1 meter for LSD.*

Note X3-2: *For layups featuring multiple adjacent layers oriented in the same direction with the same lamination grade, the CLT design values can be calculated considering these layers as a single layer with a thickness equal to the combined thickness of these individual layers.*

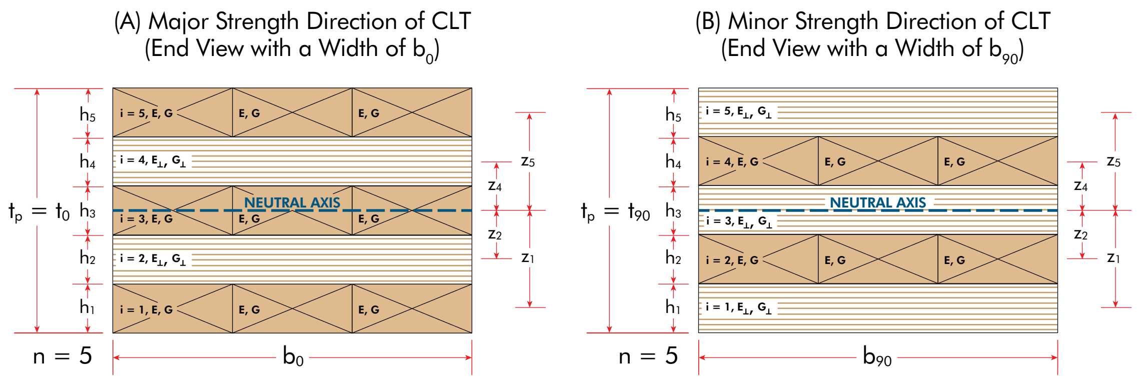
X3.2 Model for Balanced Layups with Alternating Layers

This section applies to the development of CLT design values specifically for balanced layups with alternating layers containing only one grade of laminations in the longitudinal layers and one grade in the transverse layers.

Note X3-3: *The notation for an example 5-layer balanced layup with alternating layers is shown in Figure X3-1. For equations shown in X3.2, the imperial units should be used for ASD and the metric units should be used for LSD.*

FIGURE X3.1

NOTATION FOR AN EXAMPLE 5-LAYER BALANCED LAYUP WITH ALTERNATING LAYERS



X3.2.1 Effective Flatwise Bending Moment

X3.2.1.1 Effective Flatwise Bending Moment in the Major Strength Direction

The effective flatwise bending moment resistance in the major strength direction, $(F_bS)_{eff,f,0}$, in lbf-ft/ft of width, and $(F_bS)_{eff,f,0}$, in N-mm/m of width, shall be calculated in accordance with Eq. X3-1.

$$(F_bS)_{eff,f,0} = \left(\frac{1\ ft}{12\ in.}\right) K_{rb,0}\, F_{b,major}\, S_{eff,f,0} \qquad \text{[X3-1 ASD]}$$

$$(f_bS)_{eff,f,0} = K_{rb,0}\, f_{b,major}\, S_{eff,f,0} \qquad \text{[X3-1 LSD]}$$

Where:

$K_{rb,0}$ = Adjustment factor for bending moment resistance in the major strength direction = 0.85

$F_{b,major}$ = ASD reference bending stress of the laminations in the longitudinal layers, in psi

$f_{b,major}$ = LSD specified bending strength of the laminations in the longitudinal layers, in MPa

$S_{eff,f,0}$ = Effective section modulus in the major strength direction, in in.^{3}/ft (mm^3/m) of width

$= \dfrac{(EI)_{eff,f,0}}{E_{major}} \dfrac{2}{t_p}$ (see X3.2.2.1)

E_{major} = ASD or LSD modulus of elasticity of the laminations in the longitudinal layers, in psi (MPa)

t_p = Gross thickness of CLT panel, in in. (mm)

X3.2.1.2 *Effective Flatwise Bending Moment in the Minor Strength Direction*

The effective flatwise bending moment resistance in the minor strength direction, $(F_bS)_{eff,f,90}$, in lbf-ft/ft of width, and $(f_bS)_{eff,f,90}$, in N-mm/m of width, shall be calculated in accordance with Eq. X3-2.

$$(F_bS)_{eff,f,90} = \left(\frac{1\,ft}{12\,in.}\right) K_{rb,90}\, F_{b,minor}\, S_{eff,f,90} \qquad \text{[X3-2 ASD]}$$

$$(f_bS)_{eff,f,90} = K_{rb,90}\, f_{b,minor}\, S_{eff,f,90} \qquad \text{[X3-2 LSD]}$$

Where:

$K_{rb,90}$ = Adjustment factor for bending moment resistance in the minor strength direction
= 1.0

$F_{b,minor}$ = ASD reference bending stress of the laminations in the transverse layers, in psi

$f_{b,minor}$ = LSD specified bending strength of the laminations in the transverse layers, in MPa

$S_{eff,f,90}$ = Effective section modulus in the minor strength direction, in in.^{3}/ft (mm^3/m) of width

$$= \frac{(EI)_{eff,f,90}}{E_{minor}} \frac{2}{(t_p - t_1 - t_n)} \quad \text{(see X3.2.2.2)}$$

E_{minor} = ASD or LSD modulus of elasticity of the laminations in the transverse layers, in psi (MPa)

$t_1 = t_n$ = Thickness of the laminations in the outermost longitudinal layers, in in. (mm)

n = Number of layers in the panel

X3.2.2 Effective Flatwise Bending Stiffness

The effective flatwise bending stiffness in the major strength direction, $(EI)_{eff,f,0}$, in lbf-in^2/ft (N-mm^2/m) of width, shall be calculated in accordance with Eq. X3-3.

X3.2.2.1 *Effective Flatwise Bending Stiffness in the Major Strength Direction*

$$(EI)_{eff,f,0} = \sum_{i=1}^{n}\left(E_i\, b_0 \frac{h_i^3}{12} + E_i\, b_0\, h_i\, z_i^2\right) \qquad \text{[X3-3]}$$

Where:

n = Number of layers in the panel

E_i = Modulus of elasticity of the laminations in the i-th layer, in psi (MPa)
= E, for laminations in the longitudinal layers, in psi (MPa)
= $E_{\perp,}$ for laminations in the transverse layers, in psi (MPa)

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

h_i = Thickness of laminations in the i-th layer, in in. (mm)

z_i = Distance between the centroid of the i-th layer and the neutral axis, in in. (mm)

X3.2.2.2 Effective Flatwise Bending Stiffness in the Minor Strength Direction

The effective flatwise bending stiffness in the minor strength direction, $(EI)_{eff,f,90}$, in lbf-in²/ft (N-mm²/m) of width, shall be calculated in accordance with Eq. X3-4.

$$(EI)_{eff,f,90} = \sum_{i=2}^{n-1} \left(E_i\, b_{90} \frac{h_i^3}{12} + E_i\, b_{90}\, h_i\, z_i^2 \right) \qquad \text{[X3-4]}$$

Where:

n = Number of layers in the panel

E_i = Modulus of elasticity of the laminations in the i-th layer, in psi (MPa)

= E for laminations in the transverse layers, in psi (MPa)

= $E_\perp$ for laminations in the longitudinal layers, in psi (MPa)

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

h_i = Thickness of laminations in the i-th layer, in in. (mm)

z_i = Distance between the centroid of the i-th layer and the neutral axis, in in. (mm)

Note X3-4: *In the accepted shear analogy model for both the effective flatwise bending stiffness in the minor strength direction (Eq. X3-4) and the effective flatwise shear stiffness in the minor strength direction (Eqs. X3-6 and X3-7 below), longitudinal layers outside all transverse layers are assumed to contribute no stiffness to the layup.*

X3.2.3 Effective Flatwise Shear Rigidity

X3.2.3.1 Effective Flatwise Shear Rigidity in the Major Strength Direction

The effective flatwise shear rigidity in the major strength direction, $(GA)_{eff,f,0}$, in lbf/ft (N/m) of width, shall be calculated in accordance with Eq. X3-5.

$$(GA)_{eff,f,0} = \frac{\left(t_p - \frac{h_1}{2} - \frac{h_n}{2} \right)^2}{\left[\left(\frac{h_1}{2\, G_1\, b_0} \right) + \left(\sum_{i=2}^{n-1} \frac{h_i}{G_i\, b_0} \right) + \left(\frac{h_n}{2\, G_n\, b_0} \right) \right]} \qquad \text{[X3-5]}$$

Where:

t_p = Gross thickness of CLT panel, in in. (mm)

h_i = Thickness of laminations in the i-th layer, in in. (mm)

n = Number of layers in the panel

G_i = Modulus of rigidity (shear modulus) of the laminations in the i-th layer, in psi (MPa)

= G for laminations in the longitudinal layers, in psi (MPa)

= $G_\perp$ for laminations in the transverse layers, in psi (MPa)

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

X3.2.3.2 Effective Flatwise Shear Rigidity in the Minor Strength Direction

The effective flatwise shear rigidity in the minor strength direction, $(GA)_{eff,f,90}$, in lbf/ft (N/m) of width, shall be calculated in accordance with Eq. X3-6 or 3-7.

$$\text{For } n \geq 5: (GA)_{eff,f,90} = \frac{\left(t_p - h_1 - \frac{h_2}{2} - \frac{h_{n-1}}{2} - h_n\right)^2}{\left[\left(\frac{h_2}{2\,G_2\,b_{90}}\right) + \left(\sum_{i=3}^{n-2} \frac{h_i}{G_i\,b_{90}}\right) + \left(\frac{h_{n-1}}{2\,G_{n-1}\,b_{90}}\right)\right]} \qquad \text{[X3-6]}$$

$$\text{For } n = 3: (GA)_{eff,f,90} = G_2 h_2 b_{90} \qquad \text{[X3-7]}$$

Where:

n = Number of layers in the panel

t_p = Gross thickness of CLT panel, in in. (mm)

h_i = Thickness of laminations in the *i*-th layer, in in. (mm)

G_i = Modulus of rigidity (shear modulus) of the laminations in the *i*-th layer, in psi (MPa)

= G for laminations in the transverse layers, in psi (MPa)

= $G_{\perp}$ for laminations in the longitudinal layers, in psi (MPa)

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

The following alternative is acceptable.

$$(GA)_{eff,f,90} = \frac{\left(t_p - \frac{h_1}{2} - \frac{h_n}{2}\right)^2}{\left[\left(\frac{h_1}{2\,G_1\,b_{90}}\right) + \left(\sum_{i=2}^{n-2} \frac{h_i}{G_i\,b_{90}}\right) + \left(\frac{h_n}{2\,G_n\,b_{90}}\right)\right]} \qquad \text{[X3-8]}$$

Note X3-5: *Equation X3-8 was used in the 2019 and prior versions of this standard and is retained and used in this standard for consistency with published design values.*

X3.2.4 Flatwise Planar (Rolling) Shear Capacity

X3.2.4.1 Flatwise Planar (Rolling) Shear Capacity in the Major Strength Direction

The flatwise planar (rolling) shear capacity in the major strength direction, $V_{s,0}$, in lbf/ft of width, and $v_{s,0}$, in N/m of width, shall be calculated in accordance with Eq. X3-9.

$$V_{s,0} = F_{s,minor} \frac{2\,t_p\,b_0}{3} \qquad \text{[X3-9 ASD]}$$

$$v_{s,0} = f_{s,minor} \frac{2\,t_p\,b_0}{3} \qquad \text{[X3-9 LSD]}$$

Where:

$F_{s,minor}$ = ASD reference planar (rolling) shear stress of laminations in the transverse layers, in psi

$= \frac{F_{v,\ minor}}{3}$

$F_{v,minor}$ = ASD reference shear stress of laminations in the transverse layers, in psi

$f_{s,minor}$ = LSD specified planar (rolling) shear strength of laminations in the transverse layers, in MPa

$= \frac{f_{v,\ minor}}{3}$

$f_{v,minor}$ = LSD specified shear strength of laminations in the transverse layers, in MPa

t_p = Gross thickness of CLT panel, in in. (mm)

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

X3.2.4.2 Flatwise Planar (Rolling) Shear Capacity in the Minor Strength Direction

The flatwise planar (rolling) shear capacity in the minor strength direction, $V_{s,90}$, in lbf/ft of width, and $v_{s,90}$, in N/m of width, shall be calculated in accordance with Eq. X3-10.

$$V_{s,90} = F_{s,major} \frac{2\ t_{90}\ b_{90}}{3} \quad \text{[X3-10 ASD]}$$

$$v_{s,90} = f_{s,major} \frac{2\ t_{90}\ b_{90}}{3} \quad \text{[X3-10 LSD]}$$

Where:

$F_{s,major}$ = ASD reference planar (rolling) shear stress of laminations in the longitudinal layers, in psi

$= \frac{F_{v,\ major}}{3}$

$F_{v,major}$ = ASD reference shear stress of laminations in the longitudinal layers, in psi

$f_{s,major}$ = LSD specified planar (rolling) shear strength of laminations in the longitudinal layers, in MPa

$= \frac{f_{v,\ major}}{3}$

$f_{v,major}$ = LSD specified shear strength of laminations in the longitudinal layers, in MPa

t_{90} = Effective thickness of CLT panel in the minor strength direction excluding outermost longitudinal layers, in in. (mm)

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

Note X3-6: *For a CLT panel manufactured with multiple adjacent longitudinal layers at the panel faces, all these layers are excluded from* t_{90}.

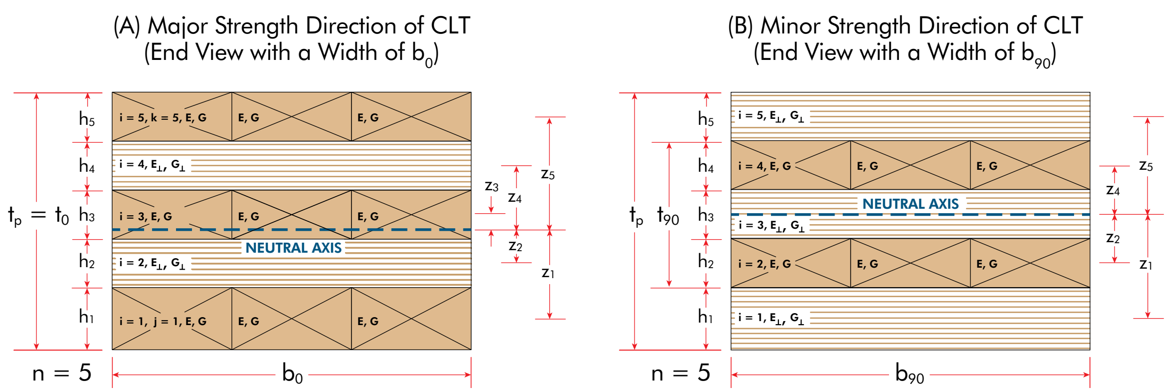
X3.3 General Model for Balanced or Unbalanced Layups

This section applies to the development of CLT design values for any layups where each layer may have different properties, including the lamination grade, thickness, and orientation.

Note X3-7: *The notation for an example 5-layer unbalanced layup is shown in Figure X3-2. For equations shown in X3.3, the imperial units should be used for ASD and the metric units should be used for LSD.*

FIGURE X3.2

NOTATION FOR AN EXAMPLE 5-LAYER UNBALANCED LAYUP



The major strength direction shall be selected such that the effective flatwise bending moment calculated in accordance with X3.3.1.1 is the maximum value of either strength direction.

Note X3-8: *For layups with similar or equal bending moment resistance in both strength directions, calculations in accordance with X3.3.1.1 should be performed assuming each direction is the major strength direction and the direction with the greater result selected as the major strength direction.*

X3.3.1 Effective Flatwise Bending Moment

The effective flatwise bending moment model of X3.3.1 applies only where the flatwise bending moment is limited by an outer longitudinal lamination for the major strength direction and an outer transverse lamination for the minor strength direction.

Note X3-9: *For unbalanced layups, the qualification of effective flatwise bending moment by testing required by the standard should account for potentially different ultimate flatwise bending capacities under positive and negative bending conditions. If the effective flatwise bending moment is not limited by an outer lamination, the bending moment shall be estimated based on analytical and engineering principles.*

X3.3.1.1 Effective Flatwise Bending Moment in the Major Strength Direction

The effective flatwise bending moment resistance in the major strength direction, $(F_bS)_{eff,f,0}$, in lbf-ft/ft of width, and $(f_bS)_{eff,f,0}$, in N-mm/m of width, shall be the lesser of X3.3.1.1.1 and X3.3.1.1.2.

Note X3-10: *This model calculates bending moment resistance values based on an extreme fiber stress check of the outermost laminations at the bottom and top of the panel in the direction of interest. This model assumes the panel bending moment resistance is limited by lamination bending strength (F_b or f_b) when the lamination is in combined tension or compression and bending stresses. The minimum of the bending moment resistance values calculated at the bottom and top of the panel determines the effective bending moment resistance.*

X3.3.1.1.1 Bottom side bending moment resistance:

$$(F_bS)^+_{eff,f,0} = \left(\frac{1\ ft}{12\ in.}\right) K_{rb,0}\, F^+_{b,0}\, S^+_{eff,f,0} \qquad \text{[X3-11 ASD]}$$

$$(f_bS)^+_{eff,f,0} = K_{rb,0}\, f^+_{b,0}\, S^+_{eff,f,0} \qquad \text{[X3-11 LSD]}$$

Where:

$(F_bS)^+_{eff,f,0}$ = Effective ASD reference flatwise bottom bending moment in the major strength direction, in lbf-ft/ft of width

$(f_bS)^+_{eff,f,0}$ = Effective LSD flatwise bottom bending moment resistance in the major strength direction, in N-mm/m of width

$K_{rb,0}$ = Adjustment factor for bending moment resistance in the major strength direction

= 0.85

$F^+_{b,0}$ = ASD reference bending stress of laminations in the bottom longitudinal layer, in psi

$f^+_{b,0}$ = LSD specified bending strength of laminations in the bottom longitudinal layer, in MPa

$S^+_{eff,f,0}$ = Effective section modulus in flatwise bending to the bottom longitudinal layer in the major strength direction, in in.^{3}/ft (mm^3/m) of width

$$= \frac{(EI)_{eff,f,0}}{E^+_0} \times \frac{1}{c^+_0} \quad \text{(see X3.3.2.1)}$$

$(EI)_{eff,f,0}$ = Effective flatwise bending stiffness of CLT, in lbf-in^2/ft (N-mm^2/m) of width, in the major strength direction

E^+_0 = ASD or LSD modulus of elasticity of laminations in the bottom longitudinal layer, in psi (MPa)

c^+_0 = Distance from the neutral axis in the major strength direction to the bottom edge of the bottom longitudinal layer, in in. (mm)

X3.3.1.1.2 Top side bending moment resistance:

$$(F_bS)^-_{eff,f,0} = \left(\frac{1\ ft}{12\ in.}\right) K_{rb,0}\, F^-_{b,0}\, S^-_{eff,f,0} \quad \text{[X3-12 ASD]}$$

$$(f_bS)^-_{eff,f,0} = K_{rb,0} f^-_{b,0}\, S^-_{eff,f,0} \quad \text{[X3-12 LSD]}$$

Where:

$(F_bS)^-_{eff,f,0}$ = Effective ASD reference flatwise top bending moment in the major strength direction, in lbf-ft/ft of width

$(f_bS)^-_{eff,f,0}$ = Effective LSD flatwise top bending moment resistance in the major strength direction, in N-mm/m of width

$K_{rb,0}$ = Adjustment factor for bending moment resistance in the major strength direction

= 0.85

$F^-_{b,0}$ = ASD reference bending stress of laminations in the top longitudinal layer, in psi

$f^-_{b,0}$ = LSD specified bending strength of laminations in the top longitudinal layer, in MPa

$S^-_{eff,f,0}$ = Effective section modulus in flatwise bending to the top longitudinal layer in the major strength direction, in in.^{3}/ft (mm^3/m) of width

$= \frac{(EI)_{eff,f,0}}{E^-_0} \times \frac{1}{c^-_0}$ (see X3.3.2.1)

$(EI)_{eff,f,0}$ = Effective flatwise bending stiffness of CLT, in lbf-in^2/ft (N-mm^2/m) of width, in the major strength direction

E^-_0 = ASD or LSD modulus of elasticity of laminations in the top longitudinal layer, in psi (MPa)

c^-_0 = distance from the neutral axis in the major strength direction to the top edge of the top longitudinal layer, in in. (mm)

X3.3.1.2 Effective Flatwise Bending Moment in the Minor Strength Direction

The effective flatwise bending moment resistance in the minor strength direction, $(F_bS)_{eff,f,90}$, in lbf-ft/ft of width, and $(f_bS)_{eff,f,90}$, in N-mm/m of width, shall be the lesser of X3.3.1.2.1, X3.3.1.2.2, and the effective flatwise bending moment in the major strength direction, as calculated in accordance with X3.3.1.1.

X3.3.1.2.1 Bottom side bending moment resistance:

$$(F_bS)^+_{eff,f,90} = \left(\frac{1\ ft}{12\ in.}\right) K_{rb,90}\, F^+_{b,90}\, S^+_{eff,f,90} \quad \text{[X3-13 ASD]}$$

$$(f_bS)^+_{eff,f,90} = K_{rb,90} f^+_{b,90}\, S^+_{eff,f,90} \quad \text{[X3-13 LSD]}$$

Where:

$(F_bS)^+_{eff,f,90}$ = Effective ASD reference flatwise bottom side bending moment in the minor strength direction, in lbf-ft/ft of width

$(f_bS)^+_{eff,f,90}$ = Effective LSD flatwise bottom side bending moment resistance in the minor strength direction, in N-mm/m of width

$K_{rb,90}$ = Adjustment factor for bending moment resistance in the minor strength direction

= 1.0

$F^+_{b,90}$ = ASD reference bending stress of laminations in the bottom transverse layer, in psi

$f^+_{b,90}$ = LSD specified bending strength of laminations in the bottom transverse layer, in MPa

$S^+_{eff,f,90}$ = Effective section modulus in flatwise bending to the bottom transverse layer in the minor strength direction, in in.^{3}/ft (mm^3/m) of width

$= \frac{(EI)_{eff,f,90}}{E^+_{90}} \times \frac{1}{c^+_{90}}$ (see X3.3.2.2)

$(EI)_{eff,f,90}$ = Effective flatwise bending stiffness of CLT, in lbf-in^2/ft (N-mm^2/m) of width, in the minor strength direction

E^+_{90} = ASD or LSD modulus of elasticity of laminations in the bottom transverse layer, in psi (MPa)

c^+_{90} = Distance from the neutral axis in the minor strength direction to the bottom edge of the bottom transverse layer, in in. (mm)

X3.3.1.2.2 Top side bending moment resistance:

$$(F_bS)^-_{eff,f,90} = \left(\frac{1\ ft}{12\ in.}\right) K_{rb,90}\, F^-_{b,90}\, S^-_{eff,f,90} \quad \text{[X3-14 ASD]}$$

$$(f_bS)^-_{eff,f,90} = K_{rb,90}\, f^-_{b,90}\, S^-_{eff,f,90} \quad \text{[X3-14 LSD]}$$

Where:

$(F_bS)^-_{eff,f,90}$ = Effective ASD reference flatwise top side bending moment in the minor strength direction, in lbf-ft/ft of width

$(f_bS)^-_{eff,f,90}$ = Effective LSD flatwise top side bending moment resistance in the minor strength direction, in N-mm/m of width

$K_{rb,90}$ = Adjustment factor for bending moment resistance in the minor strength direction

= 1.0

$F^-_{b,90}$ = ASD reference bending stress of laminations in the top transverse layer, in psi

$f^{-}_{b,90}$ = LSD specified bending strength of laminations in the top transverse layer, in MPa

$S^{-}_{eff,f,90}$ = Effective section modulus in flatwise bending to the top transverse layer in the minor strength direction, in in.^{3}/ft or mm^3/m of width

$= \frac{(EI)_{eff,f,90}}{E^{-}_{90}} \times \frac{1}{c^{-}_{90}}$ (see X3.3.2.2)

$(EI)_{eff,f,90}$ = Effective flatwise bending stiffness of CLT, in lbf-in^2/ft (N-mm^2/m) of width, in the minor strength direction

E^{-}_{90} = ASD or LSD modulus of elasticity of laminations in the top transverse layer, in psi (MPa)

c^{-}_{90} = Distance from the neutral axis in the minor strength direction to the top edge of the top transverse layer in in. (mm)

X3.3.2 Effective Flatwise Bending Stiffness

X3.3.2.1 Effective Flatwise Bending Stiffness in the Major Strength Direction

The effective flatwise bending stiffness in the major strength direction, $(EI)_{eff,f,90}$, in lbf-in^2/ft (N-mm^2/m) of width, shall be calculated in accordance with Eq. X3-15.

$$(EI)_{eff,f,0} = \sum_{i=1}^{n}\left(E_{0,i}\, b_0 \frac{h_i^3}{12} + E_{0,i}\, b_0\, h_i\, z_{0,i}^{\ 2}\right) \quad \text{[X3-15]}$$

Where:

n = Number of layers in the panel

$E_{0,i}$ = Modulus of elasticity of laminations in the *i*-th layer for the major strength direction, in psi (MPa)

= E_i for laminations in a longitudinal layer

= $E_{\perp,i}$ for laminations in a transverse layer between the top and bottom longitudinal layers

= 0 for laminations in a transverse layer outside all longitudinal layers

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

h_i = Thickness of laminations in the *i*-th layer, in in. (mm)

$z_{0,i}$ = Distance between the centroid of the *i*-th layer and the neutral axis in the major strength direction, in in. (mm)

$= y_i - \bar{y}_0$

y_i = Distance from the top of the panel to the centroid of the *i*-th layer, in in. (mm)

$\bar{y}_0$ = Distance from the top of the panel to the neutral axis in the major strength direction, in in. (mm)

$$= \frac{\sum_{i=1}^{n} y_i\, h_i\, E_{0,i}}{\sum_{i=1}^{n} h_i\, E_{0,i}}$$

X3.3.2.2 Effective Flatwise Bending Stiffness in the Minor Direction

The effective flatwise bending stiffness in the minor strength direction, $(EI)_{eff,f,0}$, in lbf-in^2/ft (N-mm^2/m) of width, shall be calculated in accordance with Eq. X3-16.

$$(EI)_{eff,f,90} = \sum_{i=1}^{n} \left(E_{90,i}\, b_{90} \frac{h_i^3}{12} + E_{90,i}\, b_{90}\, h_i\, z_{90,i}^{\;2} \right) \qquad \text{[X3-16]}$$

Where:

n = Number of layers in the panel

$E_{90,i}$ = Modulus of elasticity of laminations in the i-th layer for the minor strength direction, in psi (MPa)

= E_i for laminations in a transverse layer

= $E_{\perp,i}$ for laminations in a longitudinal layer between the top and bottom transverse layers

= 0 for laminations in a longitudinal layer outside all transverse layers

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

h_i = Thickness of laminations in the *i*-th layer, in in. (mm)

$z_{90,i}$ = Distance between the centroid of the *i*-th layer and the neutral axis in the minor strength direction, in in. (mm)

= $y_i - \bar{y}_{90}$

y_i = Distance from the top of the panel to the centroid of the *i*-th layer, in in. (mm)

$\bar{y}_{90}$ = Distance from the top of the panel to the neutral axis in the minor strength direction, in in. (mm)

$$= \frac{\sum_{i=1}^{n} y_i\, h_i\, E_{90,i}}{\sum_{i=1}^{n} h_i\, E_{90,i}}$$

X3.3.3 Effective Flatwise Shear Rigidity

X3.3.3.1 Effective Flatwise Shear Rigidity in the Major Strength Direction

The effective flatwise shear rigidity in the major strength direction, $(GA)_{eff,f,0}$, in lbf/ft (N/m) of width, shall be calculated in accordance with Eq. X3-17.

$$(GA)_{eff,f,0} = \frac{\left(t_0 - \frac{h_j}{2} - \frac{h_k}{2} \right)^2}{\left[\left(\frac{h_j}{2\, G_{0,j}\, b_{90}} \right) + \left(\sum_{i=j+1}^{k-1} \frac{h_i}{G_{0,i}\, b_0} \right) + \left(\frac{h_k}{2\, G_{0,k}\, b_0} \right) \right]} \qquad \text{[X3-17]}$$

Where:

t_0 = Effective thickness of CLT panel in major strength direction, excluding transverse layers outside all longitudinal layers, in in. (mm)

h_i = Thickness of laminations in the i-th layer, in in. (mm)

j = Index of the bottom longitudinal layer of the panel

k = Index of the top longitudinal layer of the panel

$G_{0,i}$ = Modulus of rigidity (shear modulus) in the major strength direction of laminations in the i-th layer, in psi (MPa)

= G_i for laminations in a longitudinal layer, in psi (MPa)

= $G_{\perp,i}$ for laminations in a transverse layer between the top and bottom longitudinal layers, in psi (MPa)

= 0 for laminations in a transverse layer outside all longitudinal layers

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

Note X3-11: *The indices **j** and **k** locate the bottom and top longitudinal layers of the layup. Only these layers and layers between them contribute to the effective flatwise shear rigidity in the major strength direction.*

X3.3.3.2 Effective Flatwise Shear Rigidity in the Minor Strength Direction

The effective flatwise shear rigidity in the minor strength direction, $(GA)_{eff,f,90}$, in lbf/ft (N/m) of width, shall be calculated in accordance with Eqs. X3-18 or X3-19.

$$\text{if } l \neq m\text{: } (GA)_{eff,f,90} = \frac{\left(t_{90} - \frac{h_l}{2} - \frac{h_m}{2}\right)^2}{\left[\left(\frac{h_l}{2\,G_{90,l}\,b_{90}}\right) + \left(\sum_{i=l+1}^{m-1} \frac{h_i}{G_{90,i}\,b_{90}}\right) + \left(\frac{h_m}{2\,G_{90,m}\,b_{90}}\right)\right]} \quad \text{[X3-18]}$$

$$\text{If } l = m\text{: } (GA)_{eff,f,90} = G_{90,l}\,t_l\,b_{90} \quad \text{[X3-19]}$$

Where:

l = Index of the bottom transverse layer of the CLT panel

m = Index of the top transverse layer of the CLT panel

t_{90} = Effective thickness of CLT panel in the minor strength direction, excluding longitudinal layers outside all transverse layers, in in. (mm)

h_i = Thickness of laminations in the i-th layer, in in. (mm)

$G_{90,i}$ = Modulus of rigidity (shear modulus) in the minor strength direction of laminations in the i-th layer, in psi (MPa)

= G_i for laminations in a transverse layer, in psi (MPa)

= $G_{\perp,i}$ for laminations in a longitudinal layer between the top and bottom transverse layers, in psi (MPa)

= 0 for laminations in a longitudinal layer outside all transverse layers

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

Note X3-12: *The indices* ***l*** *and* ***m*** *locate the bottom and top transverse layers of the layup. Only these layers and layers between them contribute to the effective flatwise shear rigidity in the minor strength direction. When there is only one transverse layer, X3-19 applies.*

X3.3.4 Flatwise Planar (Rolling) Shear Capacity

X3.3.4.1 Flatwise Planar (Rolling) Shear Capacity in the Major Strength Direction

The flatwise planar (rolling) shear capacity in the major strength direction, $V_{s,0}$, in lbf/ft of width, and $v_{s,0}$, in N/m of width, shall be calculated in accordance with Eq. X3-20.

$$V_{s,0} = F_{s,minor} \frac{2\, t_0\, b_0}{3} \quad \text{[X3-20 ASD]}$$

$$v_{s,0} = f_{s,minor} \frac{2\, t_0\, b_0}{3} \quad \text{[X3-20 LSD]}$$

Where:

$F_{s,minor}$ = Minimum ASD reference planar (rolling) shear stress of all laminations in transverse layers between the top and bottom longitudinal layers, in psi

$= minimum \left[\frac{F_{v,\,minor}}{3} \right]$

$F_{v,minor}$ = ASD reference shear stress of laminations in a transverse layer, in psi

$f_{s,minor}$ = Minimum LSD specified planar (rolling) shear strength of all laminations in transverse layers between the top and bottom longitudinal layers, in MPa

$= minimum \left[\frac{f_{v,\,minor}}{3} \right]$

$f_{v,minor}$ = LSD specified shear strength of laminations in a transverse layer, in MPa

t_0 = Effective thickness of CLT panel in major strength direction, excluding transverse layers outside all longitudinal layers, in in. (mm)

b_0 = Unit panel width in the major strength direction, 12 in./ft (1,000 mm/m) of width

X3.3.4.2 Flatwise Planar (Rolling) Shear Capacity in the Minor Strength Direction

The flatwise planar (rolling) shear capacity in the minor strength direction, $V_{s,90}$, in lbf/ft of width, and $v_{s,90}$, in N/m of width, shall be calculated in accordance with Eq. X3-21.

$$V_{s,90} = F_{s,major} \frac{2\, t_{90}\, b_{90}}{3} \quad \text{[X3-21 ASD]}$$

$$V_{s,90} = F_{s,major} \frac{2\, t_{90}\, b_{90}}{3} \quad \text{[X3-21 LSD]}$$

Where:

$F_{s,major}$ = minimum ASD reference planar (rolling) shear stress of all laminations in longitudinal layers between the top and bottom transverse layers, in psi

$$= minimum \left[\frac{F_{v,\,major}}{3} \right]$$

$F_{v,major}$ = ASD reference shear stress of laminations in a longitudinal layer, in psi

$f_{s,major}$ = minimum LSD specified planar (rolling) shear strength of all laminations in longitudinal layers between the top and bottom transverse layers, in MPa

$$= minimum \left[\frac{f_{v,\,major}}{3} \right]$$

$f_{v,major}$ = LSD specified shear strength of laminations in the CLT major strength direction, in MPa

t_{90} = Effective thickness of CLT panel in the minor strength direction, excluding longitudinal layers outside all transverse layers, in in. (mm)

b_{90} = Unit panel width in the minor strength direction, 12 in./ft (1,000 mm/m) of width

APPENDIX X4. 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, was 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 the following versions:

- ANSI/APA PRG 320-2012 on October 30, 2012,
- ANSI/APA PRG 320-2017 on October 6, 2017,
- ANSI/APA PRG 320-2018 on February 6, 2018,
- ANSI/APA PRG 320-2019 on January 6, 2020, and
- ANSI/APA PRG 320-2025 (this standard).

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

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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 committee members is available from the committee secretariat upon request.

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Joshua Bartlett	Arclin	
Hans-Erik Blomgren	Timberlab	
Scott Breneman	WoodWorks - Wood Products Council	ExSub Member
Dallin Brooks	National Hardwood Lumber Association	
Tim Bruegman	Hexion, Inc.	ExSub Member
Kevin Cheung	Western Wood Products Association	
Vincent Chui	ICC Evaluation Service Inc.	
David Conner	Timber Products Inspection Inc.	
Levente Denes	West Virginia University	
Richard Desjardins	National Lumber Grades Authority	
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Sylvain Gagnon	FPInnovations	
Bill Gareis	Bostik, Inc.	
Jim Henjum	Smartlam North America	
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Daniel Hindman	Virginia Tech	
Dan Hovanec	PFS-TECO	
Tom Inman	Appalachian Hardwood Manufacturers Inc.	
Dean Lewis	Google	
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ANSI/APA PRG 320-2025
Standard for Performance-Rated Cross-Laminated Timber

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