WoodWorks™
WOOD PRODUCTS COUNCIL

Mass Timber Structural Design: Engineering Modern Timber Structures

Presenter Name

Photo: Alex Schreyer

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

This presentation will provide a detailed look at the structural design processes associated with a variety of mass timber products, including glued-laminated timber (glulam), cross-laminated timber (CLT), and nail-laminated timber (NLT). Applications for the use of these products in gravity force-resisting systems under modern building codes will be discussed. Other technical topics will include and an introduction to lateral systems common in mass timber buildings, mass timber floor vibration criteria, and connection options. Mass timber framing components are often left exposed to act as a finish while taking advantage of their aesthetics. As such, they are often required to provide a fire-resistance rating demonstrating their ability to maintain structural integrity in the event of a fire. This session will also discuss structural design of mass timber elements under fire conditions.

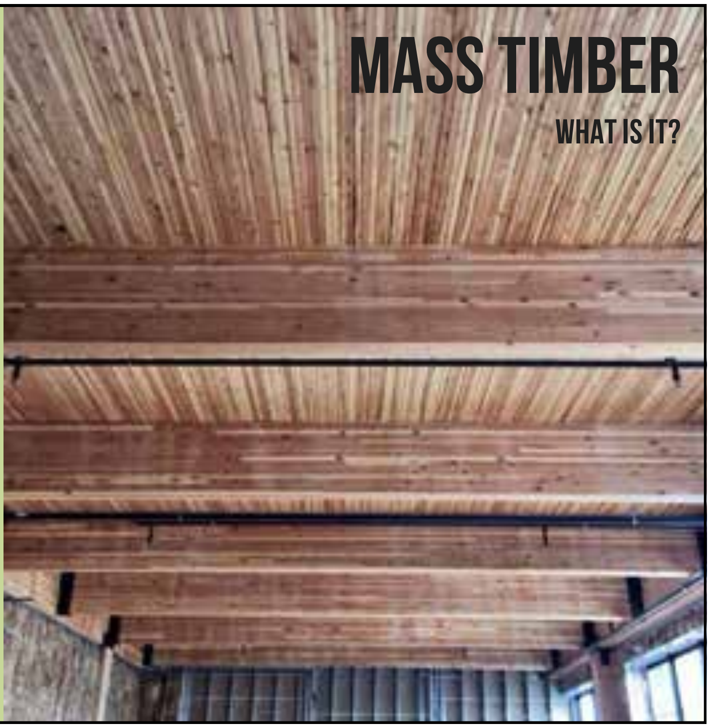
Learning Objectives

1. Compare properties and performance characteristics of mass timber products and review their unique design considerations.
2. Demonstrate structural layout options available in common mass timber framing systems through project examples
3. Highlight strategies for integrating wind and seismic force resisting systems into a mass timber gravity system
4. Provide code recognized path for justification of fire resistance of exposed structural timber elements.

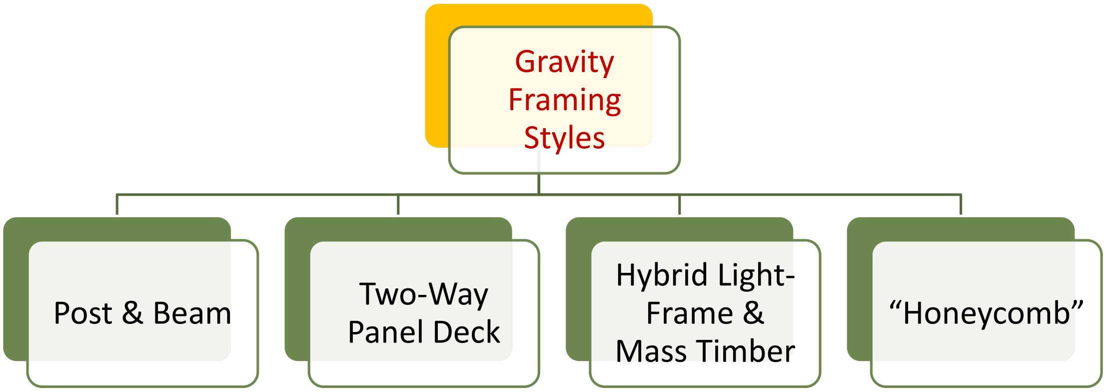
MASS TIMBER

WHAT IS IT?

MASS TIMBER IS A CATEGORY OF FRAMING STYLES OFTEN USING SMALL WOOD MEMBERS FORMED INTO LARGE PANELIZED SOLID WOOD CONSTRUCTION INCLUDING CLT, NLT OR GLULAM PANELS FOR FLOOR, ROOF AND WALL FRAMING



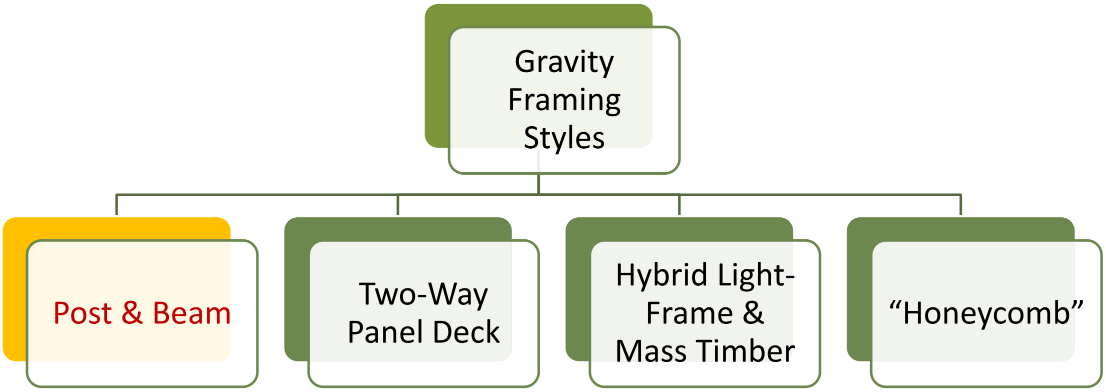
Mass Timber Structural Framing Systems



Gravity Framing Styles

- Post & Beam
- Two-Way Panel Deck
- Hybrid Light-Frame & Mass Timber
- “Honeycomb”

Mass Timber Structural Framing Systems



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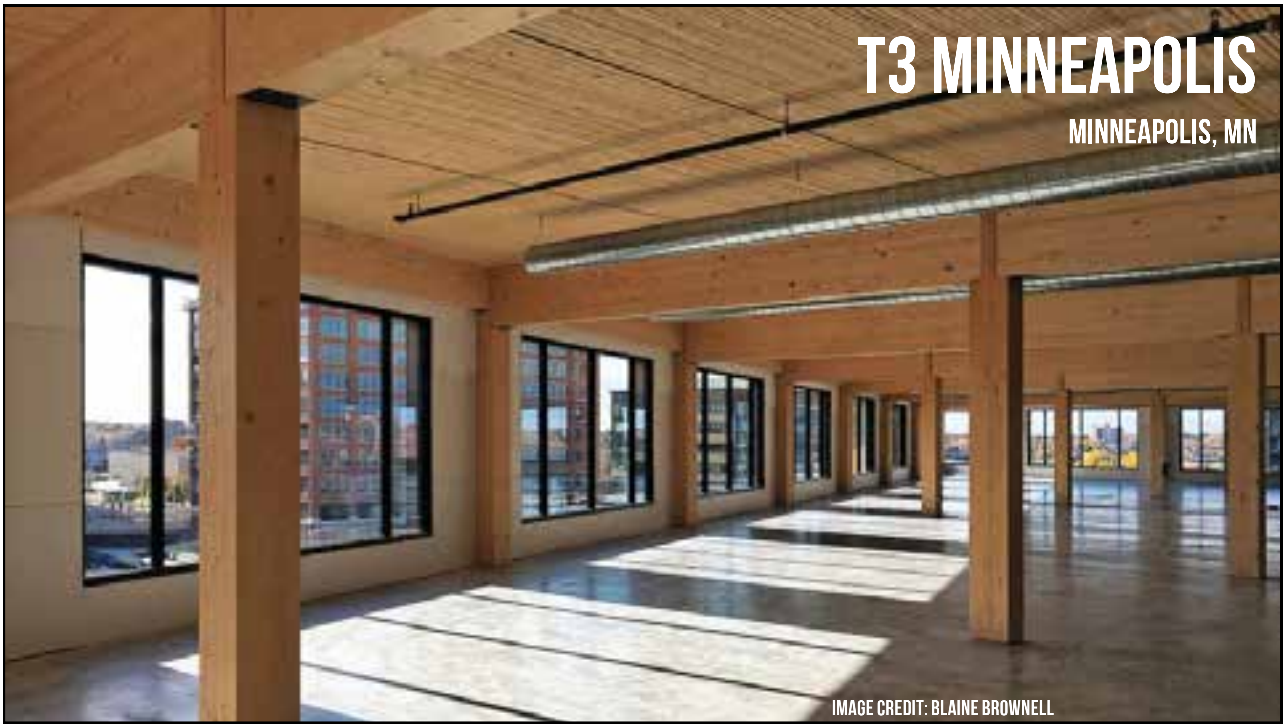
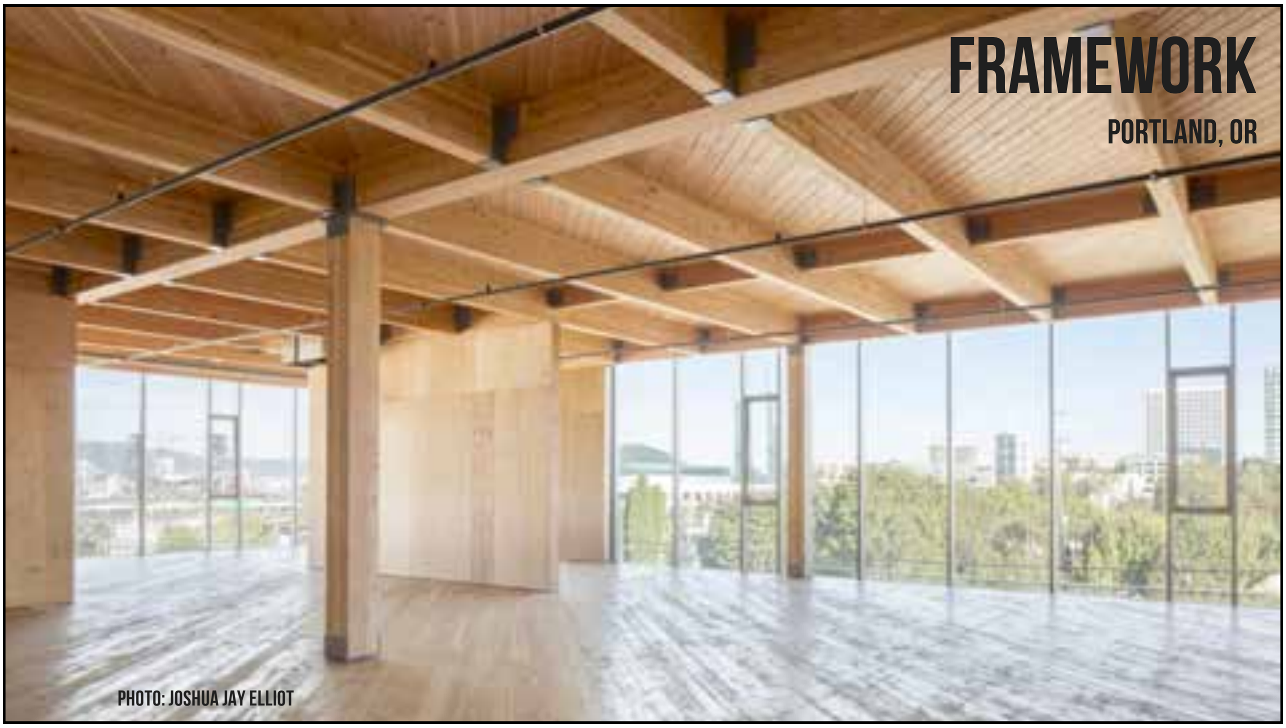


T3 MINNEAPOLIS

MINNEAPOLIS, MN

IMAGE CREDIT: BLAINE BROWNELL



FRAMEWORK

PORTLAND, OR

PHOTO: JOSHUA JAY ELLIOT

UMASS DESIGN BUILDING

AMHERST, MA

PHOTO CREDIT: ALEX SCHREYER

HUDSON BUILDING

VANCOUVER, WA

DEVELOPER: KILLIAN PACIFIC AND MACKENZIE
PHOTO CREDIT: WOODWORKS

Mass Timber Structural Framing Systems

- Gravity Framing Styles
  - Post & Beam
  - Two-Way Panel Deck
  - Hybrid Light-Frame & Mass Timber
  - “Honeycomb”

BROCK COMMONS

VANCOUVER, BC

5 PLY CLT PANELS, 2-WAY SPAN
~9'X13' GRID OF COLUMNS

IMAGES: ACTON OSTRY ARCHITECTS

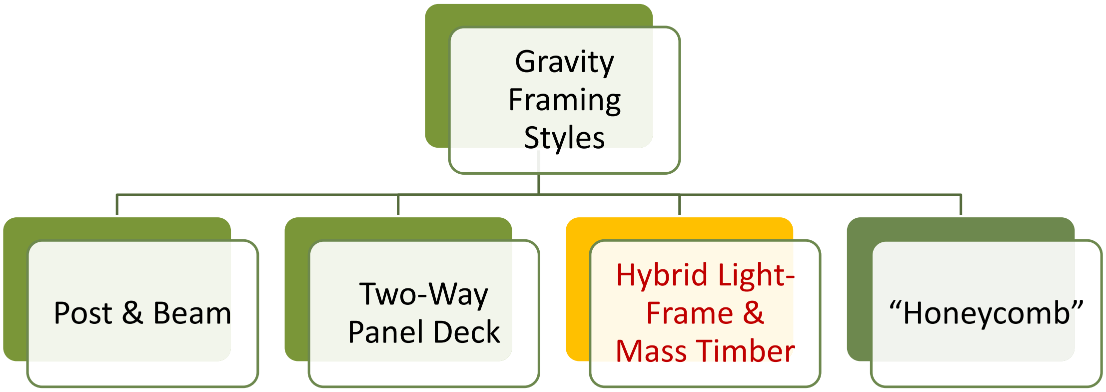
CHICAGO HORIZON PAVILION

CHICAGO, IL

56' SQUARE KIOSK
2 LAYERS OF 3-PLY, 4-1/8" CLT ROOF PANELS IN OPPOSITE DIRECTIONS, EACH PANEL 8' X 56', CREATING 2 WAY SPANNING PLATE

PHOTO CREDIT: TOM HARRIS

Mass Timber Structural Framing Systems



Gravity Framing Styles

Post & Beam

Two-Way Panel Deck

Hybrid Light-Frame & Mass Timber

"Honeycomb"

IMAGE: ADERA

IMAGE: SEAGATE STRUCTURES

Mass Timber Structural Framing Systems

- Gravity Framing Styles
  - Post & Beam
  - Two-Way Panel Deck
  - Hybrid Light-Frame & Mass Timber
  - “Honeycomb”

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

- 62,600 SF, 4 STORY HOTEL, 92 PRIVATE ROOMS
- CLT UTILIZED FOR WALLS, ROOF PANELS, AND FLOOR PANELS

IMAGE CREDIT: LEND LEASE

Redstone Arsenal Hotel
Huntsville, AL

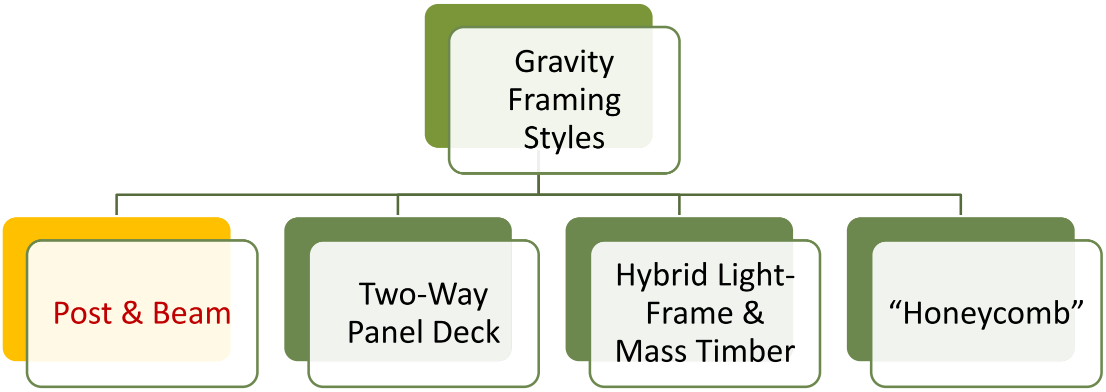
Image Credit: Lend Lease

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: IHG® Army Hotels, Lendlease

Mass Timber Structural Framing Products


Gravity Framing Styles

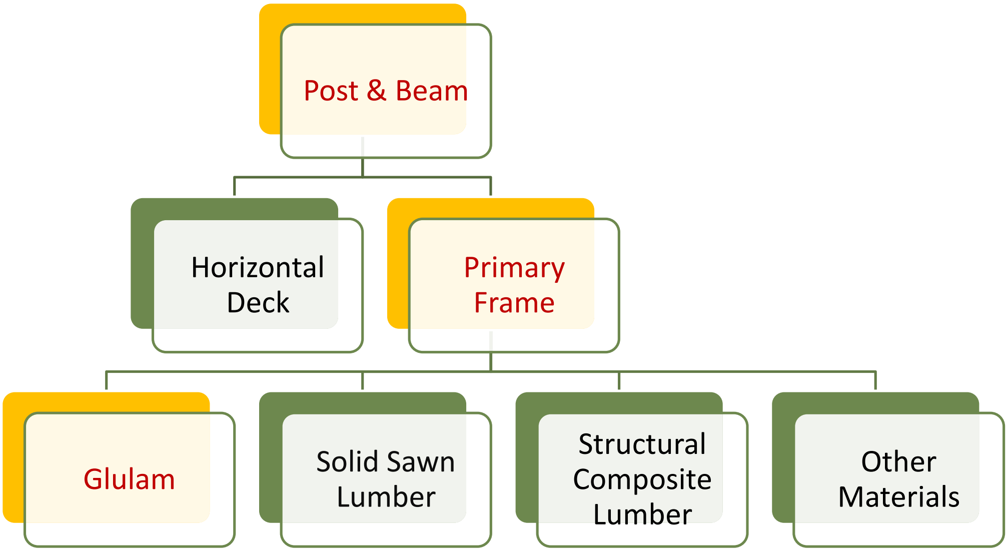
Post & Beam

Two-Way Panel Deck

Hybrid Light-Frame & Mass Timber

“Honeycomb”

Mass Timber Structural Framing Systems


Post & Beam

Horizontal Deck

Primary Frame

Glulam

Solid Sawn Lumber

Structural Composite Lumber

Other Materials

GLULAM STRUCTURAL DESIGN

GLULAM SPECS:

TYPICAL WIDTHS:

3-1/8”, 3-1/2”, 5-1/8”, 5-1/2”, 6-3/4”, 8-3/4”, 10-3/4”, 12-1/4”

TYPICAL DEPTHS:

INCREMENTS PER # OF LAMS FROM 6” TO 60”±
WESTERN SPECIES LAMS ARE TYPICALLY 1-1/2” THICK
SOUTHERN PINE LAMS ARE TYPICALLY 1-3/8” THICK

TYPICAL SPECIES:

DOUGLAS-FIR, SOUTHERN PINE, SPRUCE
ALSO AVAILABLE IN CEDAR & OTHERS

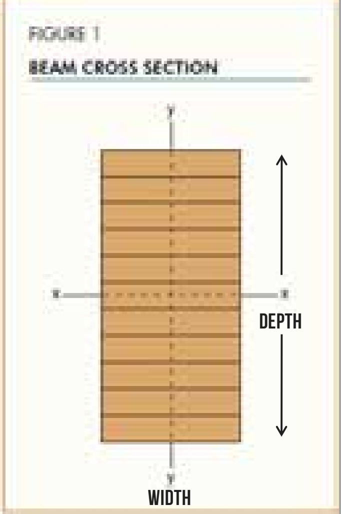


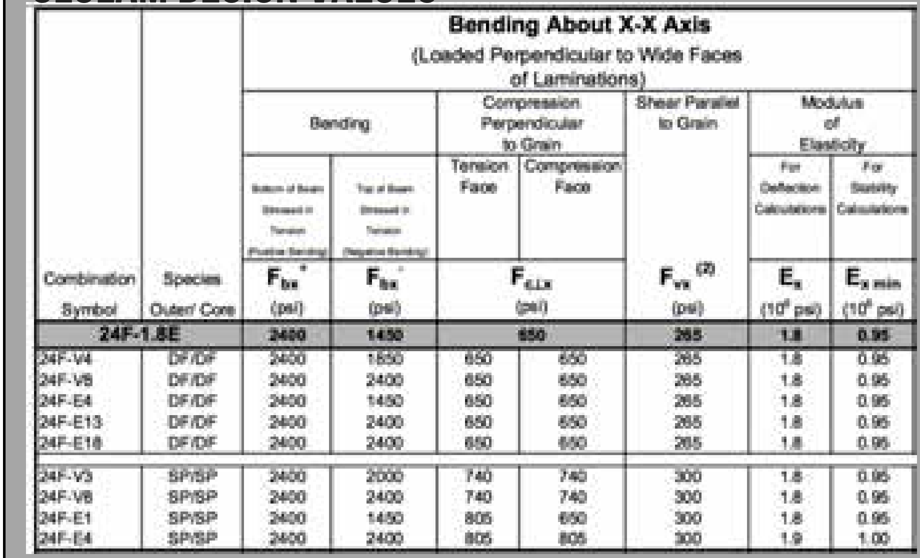
FIGURE 1

BEAM CROSS SECTION

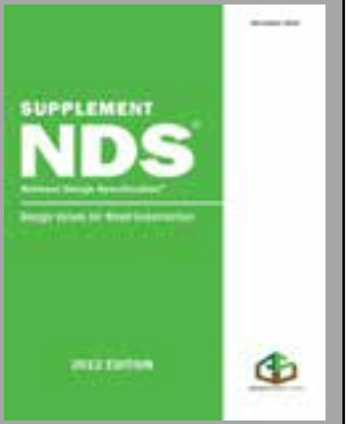
IMAGE: APA GLULAM PRODUCT GUIDE

GLULAM STRUCTURAL DESIGN

GLULAM DESIGN VALUES



		Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)						
		Bending		Compression Perpendicular to Grain		Shear Parallel to Grain	Modulus of Elasticity	
		Bottom of Beam Stressed in Tension (Positive Bending)	Top of Beam Stressed in Tension (Negative Bending)	Tension Face	Compression Face		For Deflection Calculations	For Stability Calculations
Combination Symbol	Species Outer/ Core	F_{bx}^{+} (psi)	F_{bx}^{-} (psi)	$F_{c\perp x}$ (psi)		$F_{vx}^{(2)}$ (psi)	E_x (10^6 psi)	$E_{x\,min}$ (10^6 psi)
24F-1.8E		2400	1450	650		265	1.8	0.95
24F-V4	DF/DF	2400	1850	650	650	265	1.8	0.95
24F-V8	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-E4	DF/DF	2400	1450	650	650	265	1.8	0.95
24F-E13	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-E18	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-V3	SP/SP	2400	2000	740	740	300	1.8	0.95
24F-V8	SP/SP	2400	2400	740	740	300	1.8	0.95
24F-E1	SP/SP	2400	1450	805	650	300	1.8	0.95
24F-E4	SP/SP	2400	2400	805	805	300	1.9	1.00



SOURCE: NDS SUPPLEMENT TABLE 5A

GLULAM STRUCTURAL DESIGN

GLULAM BEAM CAPACITIES

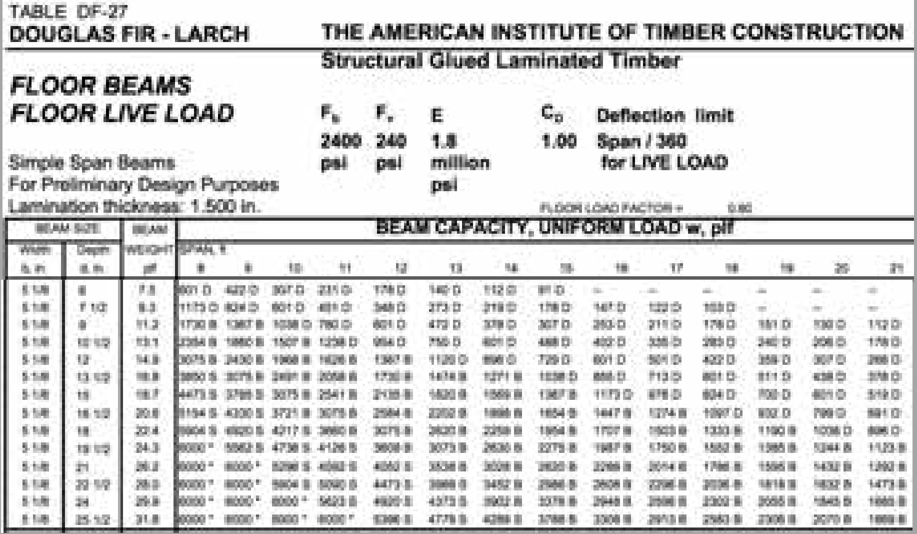


TABLE DF-27

DOUGLAS FIR - LARCH

THE AMERICAN INSTITUTE OF TIMBER CONSTRUCTION

Structural Glued Laminated Timber

FLOOR BEAMS
FLOOR LIVE LOAD

F_b	F_v	E	C_D	Deflection limit
2400 psi	240 psi	1.8 million psi	1.00	Span / 360 for LIVE LOAD

Simple Span Beams
For Preliminary Design Purposes
Lamination thickness: 1.500 in.

FLOOR LOAD FACTOR = 0.80

BEAM CAPACITY, UNIFORM LOAD w, plf

BEAM SIZE Width b, in	Depth d, in	BEAM WEIGHT plf	SPAN, ft 8	9	10	11	12	13	14	15	16	17	18	19	20	21
5 1/8	6	7.5	601 D	422 D	307 D	231 D	178 D	140 D	112 D	91 D	–	–	–	–	–	–
5 1/8	7 1/2	9.3	1173 D	824 D	601 D	451 D	348 D	273 D	219 D	178 D	147 D	122 D	103 D	–	–	–
5 1/8	9	11.2	1730 B	1367 B	1038 D	780 D	601 D	472 D	378 D	307 D	253 D	211 D	178 D	151 D	130 D	112 D
5 1/8	10 1/2	13.1	2354 B	1860 B	1507 B	1238 D	954 D	750 D	601 D	488 D	402 D	335 D	283 D	240 D	206 D	178 D
5 1/8	12	14.9	3075 B	2430 B	1968 B	1626 B	1367 B	1120 D	896 D	729 D	601 D	501 D	422 D	359 D	307 D	266 D
5 1/8	13 1/2	16.8	3850 S	3075 B	2491 B	2058 B	1730 B	1474 B	1271 B	1038 D	855 D	713 D	601 D	511 D	438 D	378 D
5 1/8	15	18.7	4473 S	3795 S	3075 B	2541 B	2135 B	1820 B	1569 B	1367 B	1173 D	978 D	824 D	700 D	601 D	519 D
5 1/8	16 1/2	20.6	5194 S	4330 S	3721 B	3075 B	2584 B	2202 B	1898 B	1654 B	1447 B	1274 B	1097 D	932 D	799 D	691 D
5 1/8	18	22.4	5904 S	4920 S	4217 S	3660 B	3075 B	2620 B	2259 B	1954 B	1707 B	1503 B	1333 B	1190 B	1036 D	896 D
5 1/8	19 1/2	24.3	6000 *	5562 S	4738 S	4126 S	3608 B	3073 B	2630 B	2275 B	1987 B	1750 B	1552 B	1385 B	1244 B	1123 B
5 1/8	21	26.2	6000 *	6000 *	5298 S	4592 S	4052 S	3536 B	3028 B	2620 B	2289 B	2014 B	1786 B	1595 B	1432 B	1292 B
5 1/8	22 1/2	28.0	6000 *	6000 *	5904 S	5092 S	4473 S	3988 S	3452 B	2986 B	2608 B	2296 B	2036 B	1818 B	1632 B	1473 B
5 1/8	24	29.9	6000 *	6000 *	6000 *	5623 S	4920 S	4373 S	3902 B	3378 B	2949 B	2598 B	2302 B	2055 B	1845 B	1665 B
5 1/8	25 1/2	31.8	6000 *	6000 *	6000 *	6000 *	5398 S	4776 S	4288 S	3788 B	3308 B	2913 B	2583 B	2306 B	2070 B	1869 B

AITC BEAM CAPACITY TABLES HTTP://WWW.AITC-GLULAM.ORG/CAPACITY.ASP

S = CONTROLLED BY SHEAR, D = CONTROLLED BY DEFLECTION, B = CONTROLLED BY BENDING

SOURCE: APA

GLULAM STRUCTURAL DESIGN

GLULAM CAMBER

- GLULAM CAN BE MANUFACTURED WITH CAMBER TO OFFSET DEAD LOAD DEFLECTION
- VERY IMPORTANT FOR LONG SPAN MEMBERS
- GLULAM INDUSTRY RECOMMENDS CAMBER = 1.5 TIMES CALCULATED DEAD LOAD DEFLECTION

FIGURE 2

BEAM CAMBER PARAMETERS

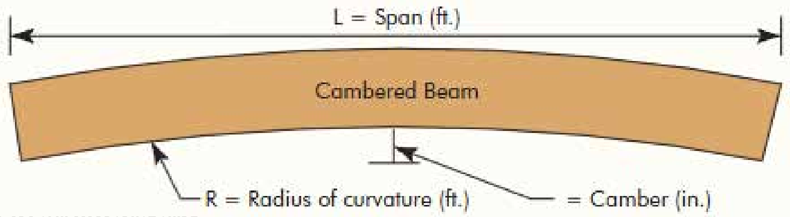


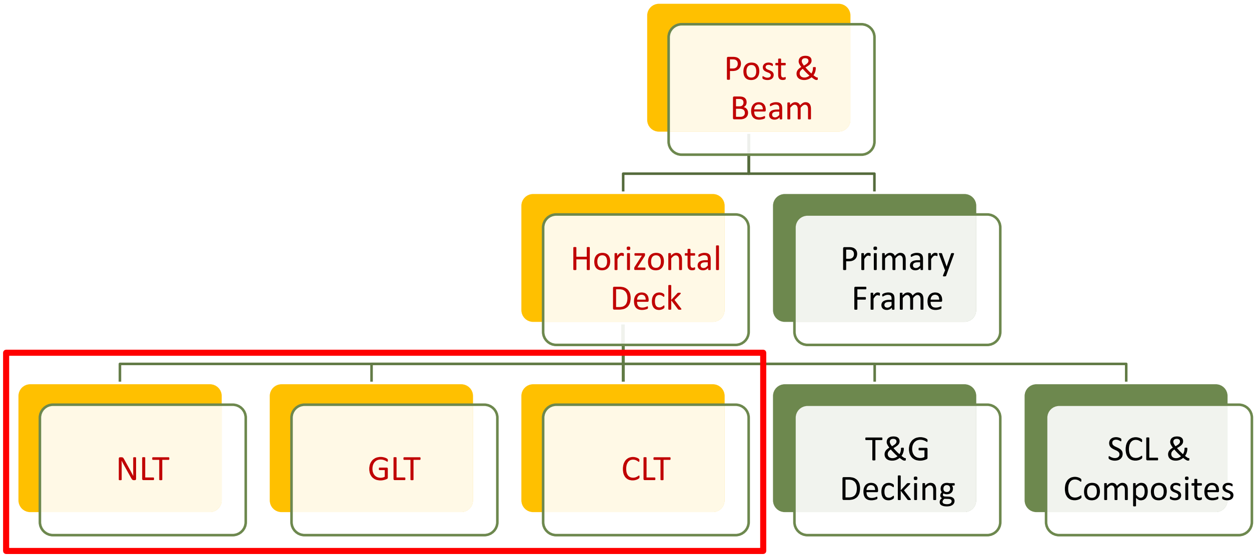
IMAGE: APA GLULAM PRODUCT GUIDE

104’ SPAN GLULAM ARCHES
GLULAM PURLINS @ 4’ O.C

LEMAY AMERICA AUTO MUSUEM
PHOTO CREDIT: WESTERN WOOD STRUCTURES

BUFFALO HARBOR CENTER RINK 1, BUFFALO, NY
PHOTO: HARBORCENTER.COM

Mass Timber Structural Framing Products



Post & Beam

Horizontal Deck

Primary Frame

NLT

GLT

CLT

T&G Decking

SCL & Composites

MASS TIMBER PRODUCTS

HORIZONTAL FRAMING

NAIL-LAMINATED TIMBER (NLT)

CROSS-LAMINATED TIMBER (CLT)

GLUE-LAMINATED TIMBER (GLT)

TONGUE & GROOVE DECKING (T&G)

TIMBER CONCRETE COMPOSITE

STRUCTURAL COMPOSITE LUMBER

IMAGE SOURCE: STRUCTURECRAFT

NAIL LAMINATED TIMBER

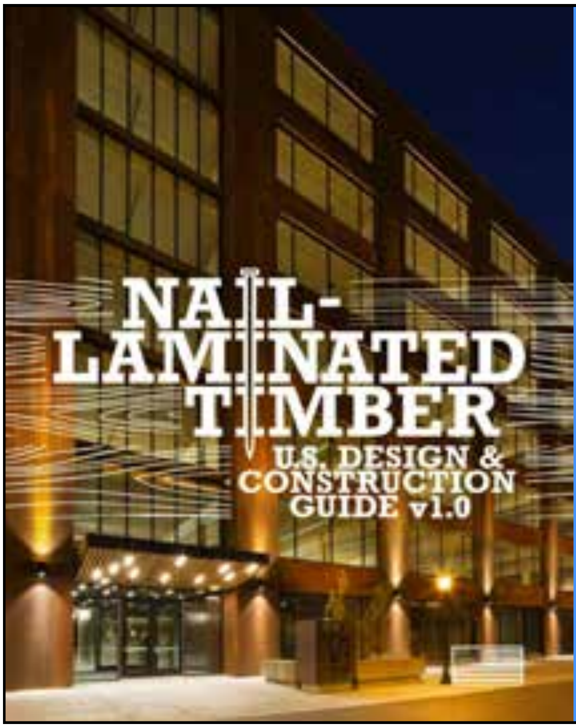
PHOTO CREDIT: STRUCTURECRAFT

NLT STRUCTURAL DESIGN

NAIL-LAMINATED TIMBER (NLT) =

A STRUCTURAL PANEL OF SQUARE-EDGED DIMENSIONAL LUMBER LAMINATIONS (USUALLY 2X) SET ON EDGE AND NAILED WIDE FACE TOGETHER

- RECOGNIZED IN IBC 2304.9.3 (MECHANICALLY LAMINATED DECKING)
- NDS 15.1.1 PROVIDES DISTRIBUTION FACTORS FOR CONCENTRATED LOADS
- CAN BE USED FOR FLOOR, ROOF DECKING. OCCASIONALLY USED FOR SHAFT WALLS



NLT STRUCTURAL DESIGN

CONTENT INCLUDES:

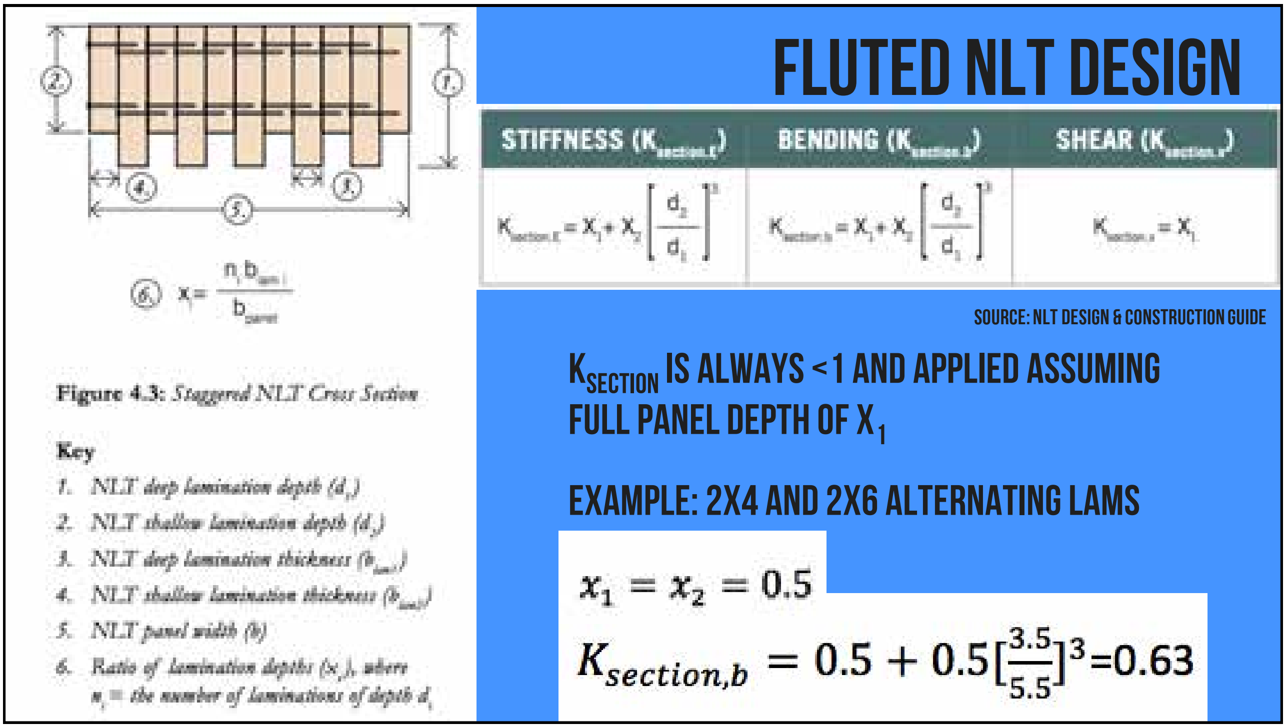
- ARCHITECTURE
- FIRE
- STRUCTURE
- ENCLOSURE
- SUPPLY AND FABRICATION
- CONSTRUCTION AND INSTALLATION
- ERECTION ENGINEERING

HTTPS://WWW.RETHINKWOOD.COM/WEBFORM/DOWNLOAD-NLT-HANDBOOK

NLT STRUCTURAL DESIGN

NLT SHRINKAGE/EXPANSION DESIGN:

RULE OF THUMB: LEAVE GAP BETWEEN ½” AND ONE PLY WIDE PER 8’-10’ WIDE PANEL



⑥ $x_i = \frac{n_i b_{lam,i}}{b_{panel}}$

Figure 4.3: *Staggered NLT Cross Section*

Key

1. *NLT deep lamination depth (d_1)*
2. *NLT shallow lamination depth (d_2)*
3. *NLT deep lamination thickness ($b_{lam,1}$)*
4. *NLT shallow lamination thickness ($b_{lam,2}$)*
5. *NLT panel width (b)*
6. *Ratio of lamination depths (x_i), where n_i = the number of laminations of depth d_i*

FLUTED NLT DESIGN

STIFFNESS ($K_{section,E}$)	BENDING ($K_{section,b}$)	SHEAR ($K_{section,v}$)
$K_{section,E} = X_1 + X_2\left[\frac{d_2}{d_1}\right]^3$	$K_{section,b} = X_1 + X_2\left[\frac{d_2}{d_1}\right]^3$	$K_{section,v} = X_1$

SOURCE: NLT DESIGN & CONSTRUCTION GUIDE

$K_{SECTION}$ IS ALWAYS <1 AND APPLIED ASSUMING FULL PANEL DEPTH OF X_1

EXAMPLE: 2X4 AND 2X6 ALTERNATING LAMS

$$x_1 = x_2 = 0.5$$

$$K_{section,b} = 0.5 + 0.5[\frac{3.5}{5.5}]^3{=}0.63$$

BULLITT CENTER

SEATTLE, WA

PHOTO CREDIT: BULLITT CENTER

BULLITT CENTER

SEATTLE, WA

2X4 NLT ROOF DECK

2X6 NLT FLOOR DECK

FLOOR ASSEMBLY TOP TO BOTTOM:

3” CONCRETE TOPPING, ACOUSTICAL MAT, WSP, 2X6 NLT

PHOTO CREDIT: JOHN STAMETS

Cross Laminated Timber

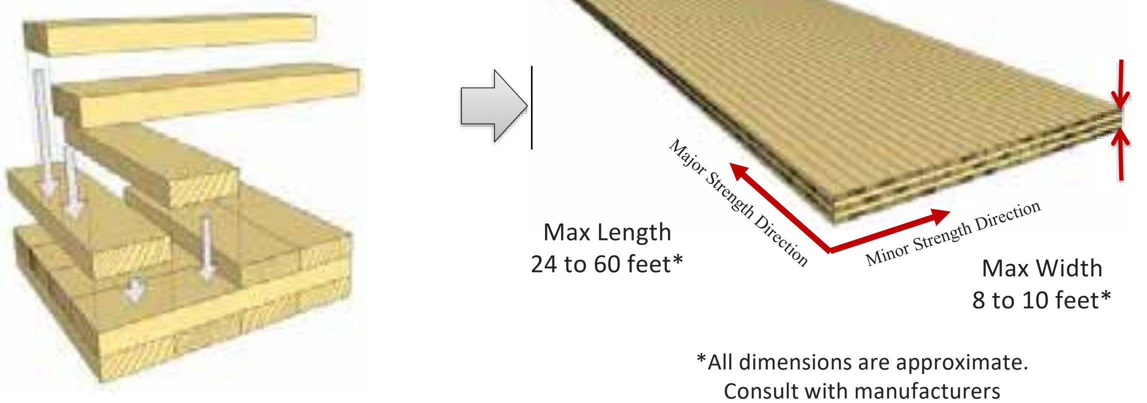
Considerations:

- Large light-weight panels
- Dimensionally stable
- Precise CNC machining available
- Recognized by IBC
- Dual Directional span capabilities
- Often architecturally exposed
- Fast on-site construction

Graphic Credit: StructureCraft

What is CLT?

3+ layers of laminations
Typically Solid Sawn Laminations
Cross-Laminated Layup



*All dimensions are approximate.
Consult with manufacturers

First Tech Credit Union, Hillsboro, Oregon
Photo Credit: Structurlam Products

North American CLT Product Standard

Standard for Performance-Rated Cross-Laminated Timber

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

The Standard Covers:
- U.S. and Canada Use
- Panel Dimensions and Tolerances
- Component Requirements
- Structural Performance Requirements
- Panel and Manufacturing Qualification
- Marking (Stamping)
- Quality Assurance

CLT Stress Grades

Stress Grade	Major Strength Direction	Minor Strength Direction
E1	1950f-1.7E MSR SPF	#3 Spruce Pine Fir
E2	1650f-1.5E MSR DFL	#3 Doug Fir Larch
E3	1200f-1.2E MSR Misc	#3 Misc
E4	1950f-1.7E MSR SP	#3 Southern Pine
V1	#2 Doug Fir Larch	#3 Doug Fir Larch
V2	#1/#2 Spruce Pine Fir	#3 Spruce Pine Fir
V3	#2 Southern Pine	#3 Southern Pine

Standard (Non-mandatory) CLT stress grade in PRG 320-2012.
Other custom stress grades including structural composite lumber (SCL) permitted

Common CLT Layups

3-ply 3-layer

5-ply 5-layer

7-ply 7-layer

7-ply 5-layer

9-ply 9-layer

9-ply 7-layer

PRG 320 Defined Layups

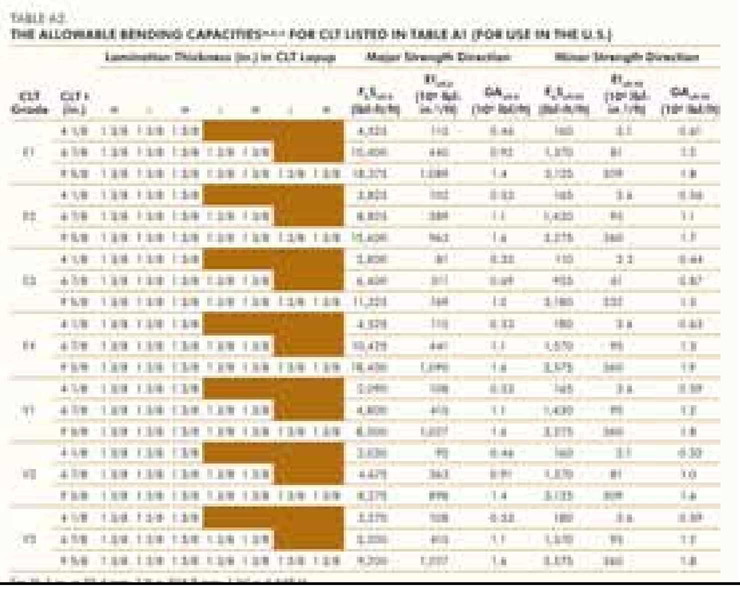


TABLE A2

THE ALLOWABLE BENDING CAPACITIES FOR CLT LISTED IN TABLE A1 (FOR USE IN THE U.S.)

3rd Party Product Certification of CLT

APA PRODUCT REPORT

DRJ Cross-Laminated Timber
Riddle Laminators, Inc.
PR-L320

APA PRODUCT REPORT

Structurlam CrossLam
Structurlam Products LP
PR-L314

ICC-ES Report
ESR-3631

APA PRODUCT REPORT

SmartLam Cross-Laminated Timber
SmartLam, LLC
PR-L319

APA PRODUCT REPORT

Nordic X-Lam
Nordic Structures
PR-L306

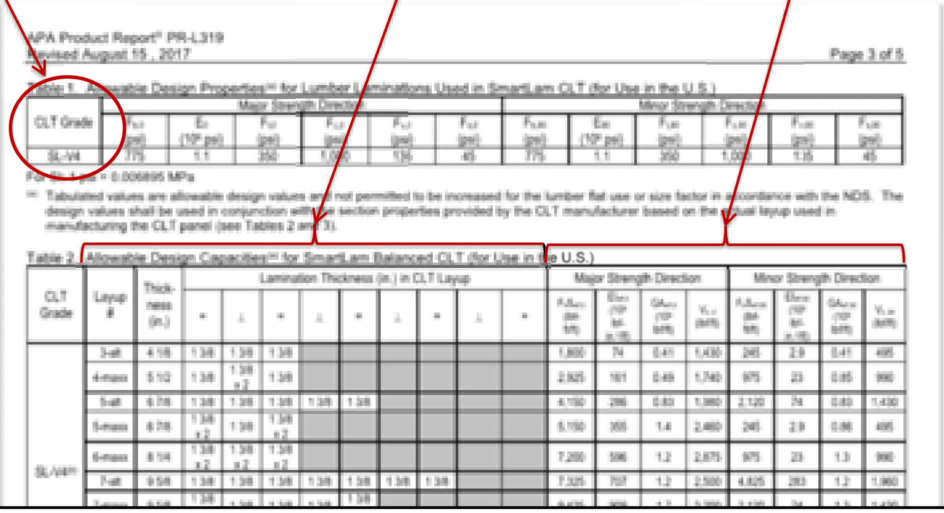
Intertek

CLT Product Reports

Stress Grade
(standard or custom)

Layup
(standard or custom)

Panel Properties



APA Product Report® PR-L319
Revised August 15, 2017

Page 3 of 5

Table 1. Allowable Design Properties(a) for Lumber Laminations Used in SmartLam CLT (for Use in the U.S.)

CLT Grade	Major Strength Direction						Minor Strength Direction					
	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{s,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{v,90}$ (psi)	$F_{s,90}$ (psi)
SL-V4	775	1.1	350	1,000	135	45	775	1.1	350	1,000	135	45

For SI: 1 psi = 0.006895 MPa

(a) Tabulated values are allowable design values and not permitted to be increased for the lumber flat use or size factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Tables 2 and 3).

Table 2. Allowable Design Capacities(a) for SmartLam Balanced CLT (for Use in the U.S.)

CLT Grade	Layup #	Thickness (in.)	Lamination Thickness (in.) in CLT Layup									Major Strength Direction				Minor Strength Direction			
			∥	⊥	∥	⊥	∥	⊥	∥	⊥	∥	$F_bS_{eff,f,0}$ (lbf-ft/ft)	$EI_{eff,f,0}$ (10^6 lbf-in.²/ft)	$GA_{eff,f,0}$ (10^6 lbf/ft)	$V_{s,0}$ (lbf/ft)	$F_bS_{eff,f,90}$ (lbf-ft/ft)	$EI_{eff,f,90}$ (10^6 lbf-in.²/ft)	$GA_{eff,f,90}$ (10^6 lbf/ft)	$V_{s,90}$ (lbf/ft)
SL-V4(b)	3-alt	4 1/8	1 3/8	1 3/8	1 3/8							1,800	74	0.41	1,430	245	2.8	0.41	495
	4-mass	5 1/2	1 3/8	1 3/8 x2	1 3/8							2,825	161	0.49	1,740	975	23	0.85	990
	5-alt	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8					4,150	286	0.83	1,980	2,120	74	0.83	1,430
	5-mass	6 7/8	1 3/8 x2	1 3/8	1 3/8 x2							5,150	355	1.4	2,460	245	2.8	0.86	495
	6-mass	8 1/4	1 3/8 x2	1 3/8 x2	1 3/8 x2							7,200	596	1.2	2,875	975	23	1.3	990
	7-alt	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	707	1.2	2,500	4,825	283	1.2	1,980

Structural Design Standardization

National Design Specification for Wood Construction
2015 Edition

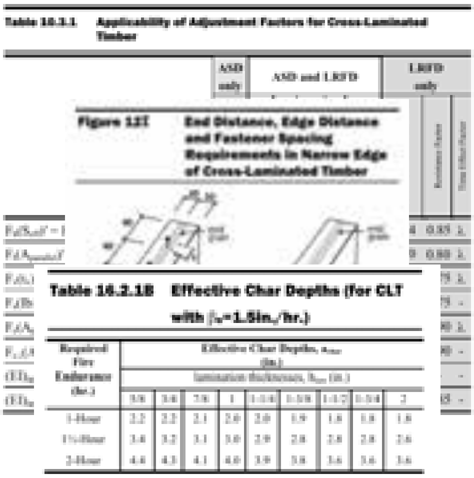


Table 10.3.1 Applicability of Adjustment Factors for Cross-Laminated Timber

	ASD only	ASD and LRFD	LRFD only

Figure 12T End Distance, Edge Distance and Fastener Spacing Requirements in Narrow Edge of Cross-Laminated Timber

Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Model Building Code Acceptance

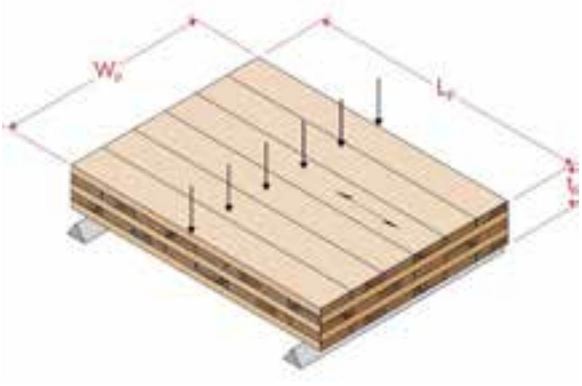
2015 International Building Code

Highlights of CLT Provisions in IBC 2015

- CLT is generally available for use in Type III, IV and V construction.
- IBC 2015 Chapter 6 Defines Dimensions of CLT to qualify as Heavy Timber (Type IV Construction)
  - 6” Walls
  - 4” Floors
  - 3” Roofs
  - Non Fire-Retardant Treated CLT allowed in Exterior Walls of Type IV construction in many conditions. (IBC 2015 602.4)

The Heavy Timber construction size requirements only apply to Type IV Construction

FLATWISE Panel Loading



Span in MAJOR Strength Direction
“Parallel” Direction

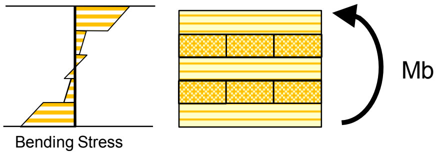
Span in MINOR Strength Direction
“Perpendicular” Direction

Reference & Source: ANSI/APA PRG 320-2017

Flatwise Flexural Strength

Design properties based on an Extreme Fiber Model:

Flexural Capacity Check:



$$M_b \leq (F_bS_{eff})'$$

M_b = applied bending moment

$(F_bS_{eff})'$ = adjusted bending capacity

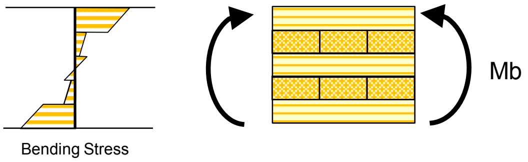
S_{eff} = effective section modulus

F_b = reference bending design stress of outer lamination

Reference: NDS 2015

Flatwise Flexural Strength

Flexural Capacity Check (**ASD**)



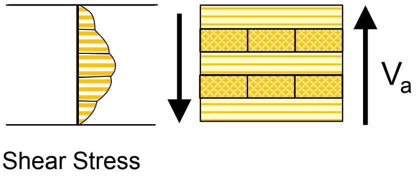
$$(F_bS_{eff})' = \underset{\text{per NDS}}{C_D}\ \underbrace{C_M\ C_t\ C_L}_{\text{Commonly 1.0}}\ \underbrace{(F_bS_{eff})}_{\text{Provided as combined value}}$$

$$M_b \leq C_D\ (1.0)\ (F_bS_{eff})$$

Reference: NDS 2015

Flatwise Shear Strength

Design Properties based on Extreme Fiber Model:



Shear Capacity Check:

$$V_a \leq F_s(Ib/Q)_{eff}'$$

V_a = applied shear

$F_s(IbQ_{eff})'$ = adjusted shear strength

Jargon Alert! AKA "Planar Shear", "Out-of-Plane Shear", or "Rolling Shear" Strength

"Planar Shear": Wood Structural Panel Term

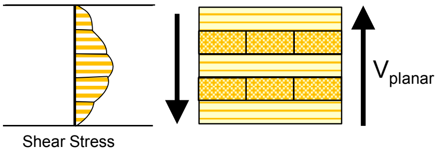
"Out-of-Plane Shear": Structural Engineering Term

"Rolling Shear": CLT Term

Reference: NDS 2015

Flatwise Shear Strength

Design Properties based on Extreme Fiber Model:



Shear Capacity Check (ASD):

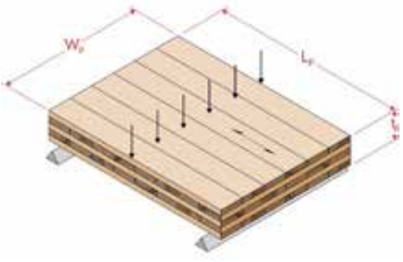
$$F_s(IbQ)_{eff}' = \underbrace{C_M\,C_t}_{\text{Commonly 1.0}}\,\underbrace{(F_s(IbQ)_{eff})} = C_M\,C_t\,\underbrace{V_s}_{\text{From Manufacturer}}$$

$$V_{planar} \leq (1.0)\,V_s$$

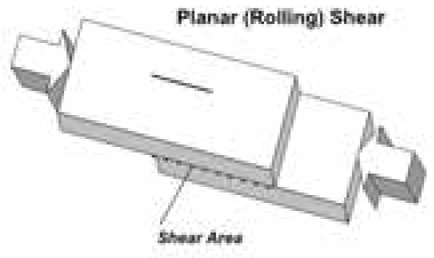
Note: Duration of Load Effects (Cd and λ) NOT applicable to Flatwise Shear Strength in the NDS

Reference: NDS 2015 & Product Reports

Shear Force Terminology



Source: ANSI/APA PRG 320-2017



Source: NDS 2015 Manual

Planar Shear
Rolling Shear
Shear-In-the-Plane?
Out-of-plane forces?
FLATWISE Shear in PRG 320 2017

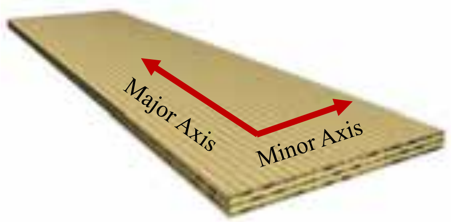
NDS 2015: $F_s(Ib/Q)_{eff}$
PRG 320 Product Reports: $V_{s,0}$ & $V_{s,90}$

Flatwise Shear Strength

Rolling Shear

Source: CSA O86-14, 2016 Supplement

Flatwise CLT Panel Section Properties

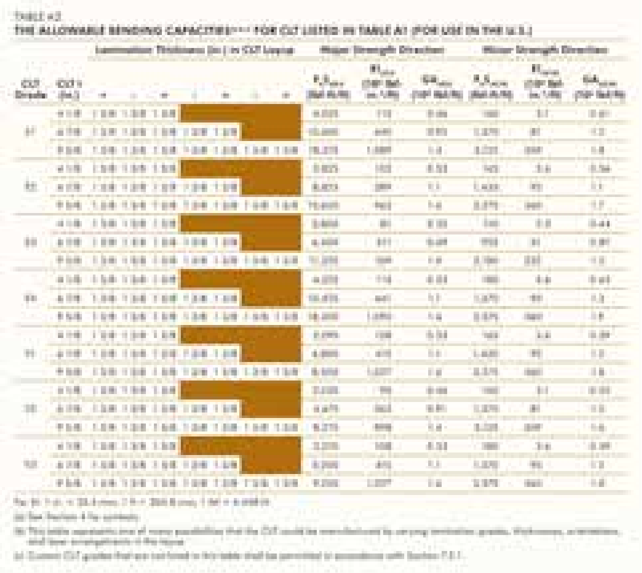


Flexural Strength:	$F_bS_{eff,0}$	$F_bS_{eff,90}$
Flexural Stiffness:	$EI_{eff,0}$	$EI_{eff,90}$
Shear Strength:	$V_{s,0}$	$V_{s,90}$
Shear Stiffness:	$GA_{eff,0}$	$GA_{eff,90}$

Values in RED provided by CLT manufacturer

Reference: PRG 320 and CLT Product Reports

Using PRG 320 Standard Grades for Design?



PRG 320 includes pre-defined Stress Grades, Layups and related Design Properties

Is doesn't tell you what CLT grades and layups are available.

Coordinate your design with manufactures availability and information

Deflection Creep Factor

Deformation to Long Term Loads

$$\Delta_T = K_{cr}\,\Delta_{LT} + \Delta_{ST}$$ NDS Eq 3.5-1

Δ_{ST}	Deflection due to short-term loading
Δ_{LT}	Immediate deflection due to long term loading
K_{cr}	2.0 for CLT in dry service conditions

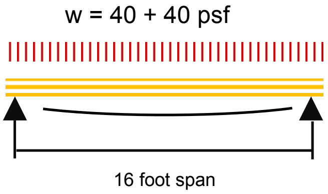
Design Example:

Δ_{ST} from 40psf = 0.159 in

Δ_{LT} from 40psf = 0.159 in

Δ_T = 2.0 (0.159) + 0.159 = 0.477 in

= L / 403



Reference: NDS 2015

Working with CLT: Know Your Supply Chain

- CLT Manufactures different CLT grades and maximum panel sizes
- CLT Manufacturers have specific CNC capabilities
- 3rd Party Fabricators can have additional CNC capabilities

Photo: DR Johnson

Photo: Sauter Timber

US Building Code Requirements for Vibration

None

Barely discussed in IBC, NDS, etc.
ASCE 7 Commentary Appendix C has some discussion, no requirements

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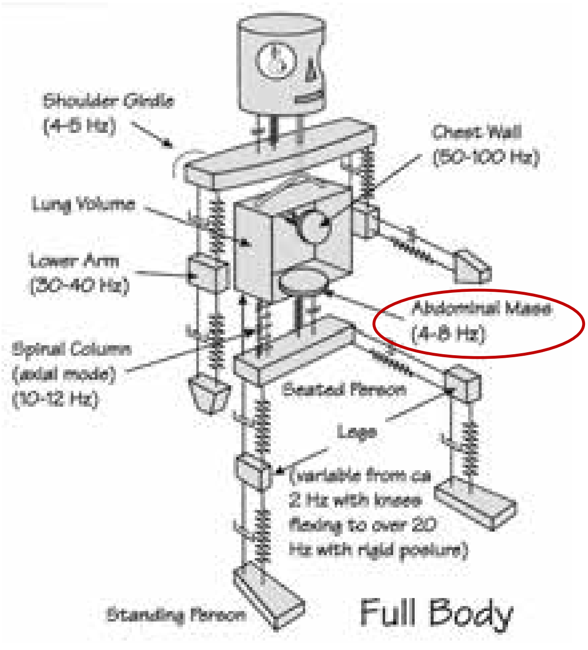
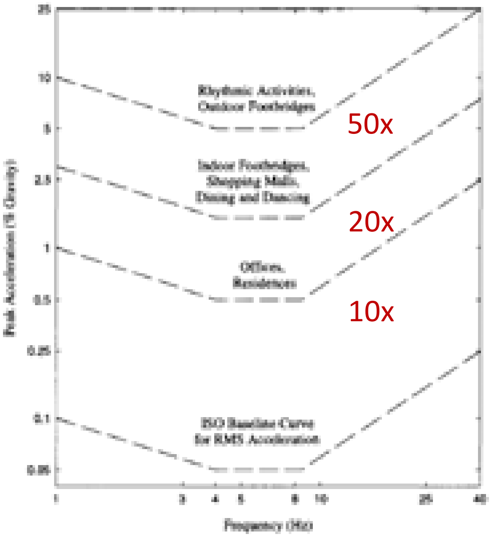


Illustration: Sven-Olof Emanuelsson

Human Body Dynamics

Floor Vibration Criteria – Human Comfort

Acceleration



0.05% g

Illustration: Murray et al., 1997

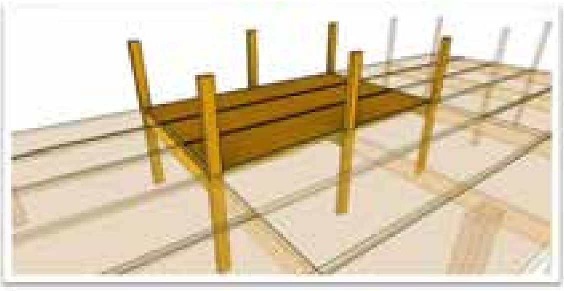
Range of Acceptable Perception of Acceleration

0.5% to 5% g (vertical)

Framing Materials Properties for Vibration

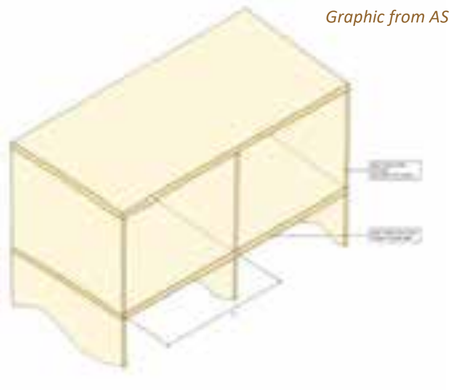
Material	Floor Weight (psf)	Damping	Material Stiffness (10^6 psi)	Material Mass (pcf)	Example Floor System
Concrete	100-150	1-5%	3.2-5.8	120-150	2-way slab on columns
Steel	50-100	0.5-5%	30	490	Concrete on metal deck on purlins and girders
Mass Timber	15-65	1-6%	1.2-1.8	30-40	Beam *or* wall supported
Wood Frame	10-40	2-12%	1.2-2.0	30-40	Wall supported

Beam vs Wall Supported Floors



Graphic from StructureCraft

Mass Timber Panels on Grid of Beams.
Frequency of Floor < Frequency of Panel
Vibration of Floor > Vibration of Panel
Vibration Design Depends on Beams



Graphic from ASPECT

Mass Timber Panels on Bearing Walls

Low Frequency Floor?

Maybe

High Frequency Floor?

At all but longer floor spans

Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal → FEM/Time History

Δ < L/480

f_n > 14 Hz

Woeste & Dolan — ***Wood Frame***

FPI/CLT Handbook — ***Mass Timber***

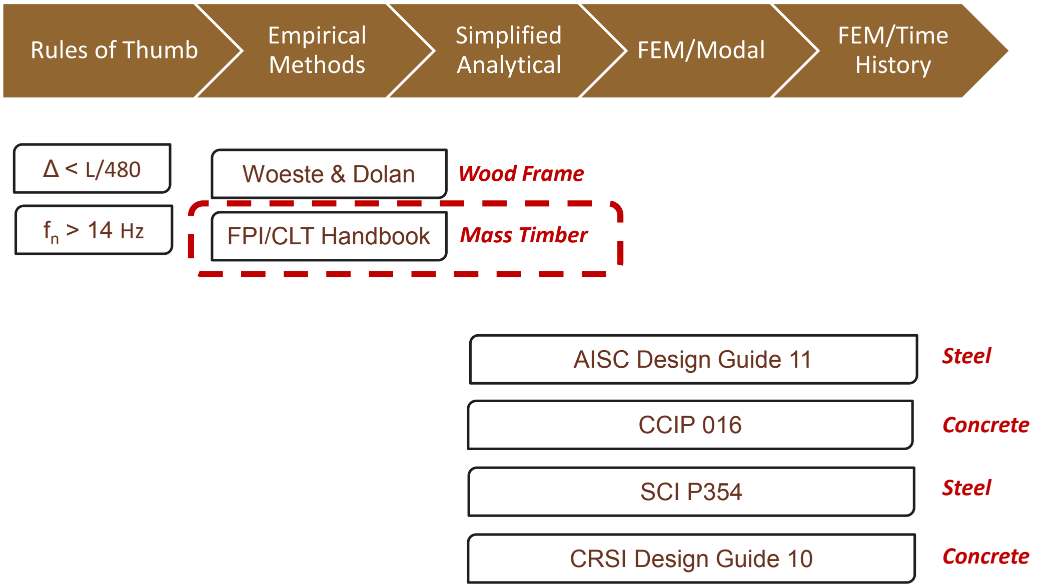
AISC Design Guide 11 — ***Steel***

CCIP 016 — ***Concrete***

SCI P354 — ***Steel***

CRSI Design Guide 10 — ***Concrete***

Vibration Design Methods



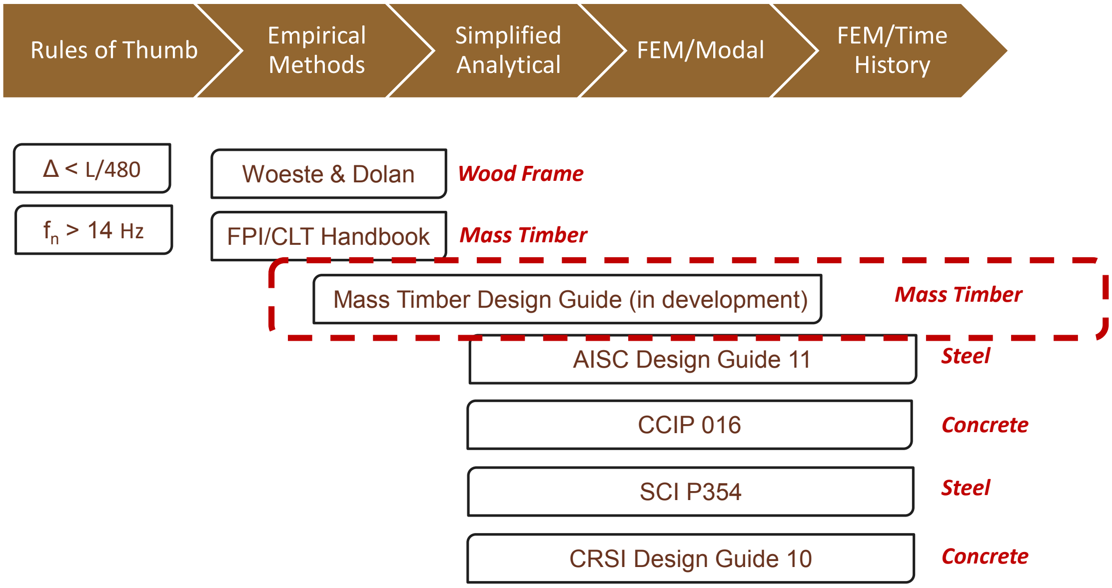
Rules of Thumb
Empirical Methods
Simplified Analytical
FEM/Modal
FEM/Time History

$\Delta < L/480$
$f_n > 14$ Hz

Woeste & Dolan — ***Wood Frame***
FPI/CLT Handbook — ***Mass Timber***

AISC Design Guide 11 — ***Steel***
CCIP 016 — ***Concrete***
SCI P354 — ***Steel***
CRSI Design Guide 10 — ***Concrete***

Vibration Design Methods



Rules of Thumb
Empirical Methods
Simplified Analytical
FEM/Modal
FEM/Time History

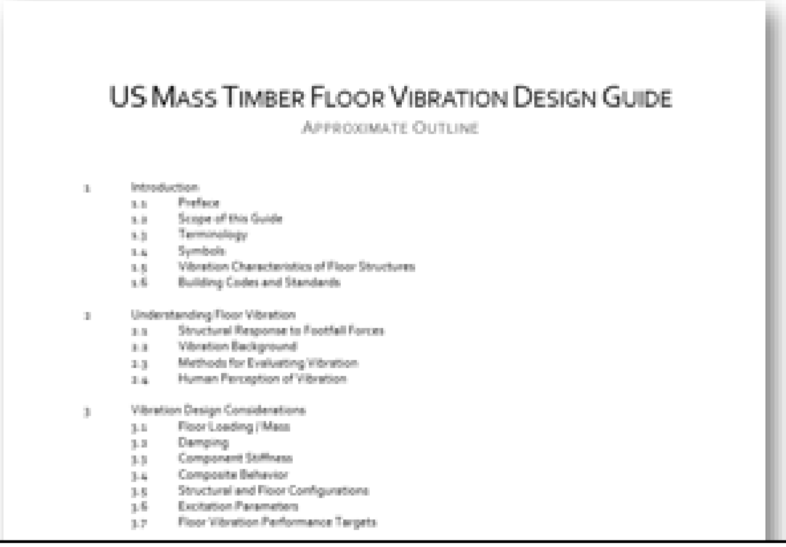
$\Delta < L/480$
$f_n > 14$ Hz

Woeste & Dolan — ***Wood Frame***
FPI/CLT Handbook — ***Mass Timber***
Mass Timber Design Guide (in development) — ***Mass Timber***

AISC Design Guide 11 — ***Steel***
CCIP 016 — ***Concrete***
SCI P354 — ***Steel***
CRSI Design Guide 10 — ***Concrete***

US Mass Timber Vibration Design Guide

USDA Wood Innovations Grant funded project in progress



US MASS TIMBER FLOOR VIBRATION DESIGN GUIDE

APPROXIMATE OUTLINE

1 Introduction
  1.1 Preface
  1.2 Scope of this Guide
  1.3 Terminology
  1.4 Symbols
  1.5 Vibration Characteristics of Floor Structures
  1.6 Building Codes and Standards

2 Understanding Floor Vibration
  2.1 Structural Response to Footfall Forces
  2.2 Vibration Background
  2.3 Methods for Evaluating Vibration
  2.4 Human Perception of Vibration

3 Vibration Design Considerations
  3.1 Floor Loading / Mass
  3.2 Damping
  3.3 Component Stiffness
  3.4 Composite Behavior
  3.5 Structural and Floor Configurations
  3.6 Excitation Parameters
  3.7 Floor Vibration Performance Targets

Guide to be published by
WoodWorks
in early 2020

Project Team: WoodWorks, KPFF, Aspect, StructureCraft, & Fast+Epp

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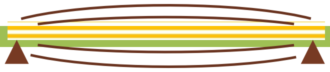
FPI/CLT Handbook Method



Limit CLT Floor Span such that

Frequency $f > 9.0$ Hz

Span $L \leq \frac{1}{12.05}\frac{(EI_{app})^{0.293}}{(\rho A)^{0.122}}$

Based on:
- Un-topped CLT
- Single, Simple span
- Bearing wall supports.

Does not account for:
- Supporting beam flexibility
- Multi-span conditions
- Additional floor mass (topping slab, etc)

Reference: US CLT Handbook, Chapter 7

FPI Span Limit for Basic CLT Grades / Layups

Grade	Layup	Thickness	FPI Span Limit
E1	3ply	4 1/8”	12’ 5”
	5ply	6 7/8”	17’ 4”
	7ply	9 5/8”	21’ 8”
E2	3ply	4 1/8”	12’ 0”
	5ply	6 7/8”	16’ 8”
	7ply	9 5/8”	20’ 10”
E3	3ply	4 1/8”	11’ 7”
	5ply	6 7/8”	16’ 1”
	7ply	9 5/8”	20’ 1”
E4	3ply	4 1/8”	12’ 2”
	5ply	6 7/8”	17’ 0”
	7ply	9 5/8”	21’ 3”

Grade	Layup	Thickness	FPI Span Limit
V1	3ply	4 1/8”	12’ 2”
	5ply	6 7/8”	17’ 0”
	7ply	9 5/8”	21’ 3”
V2	3ply	4 1/8”	11’ 11”
	5ply	6 7/8”	16’ 8”
	7ply	9 5/8”	20’ 10”
V3	3ply	4 1/8”	12’ 0”
	5ply	6 7/8”	16’ 9”
	7ply	9 5/8”	21’ 0”

Approximate FPI Span Limits:

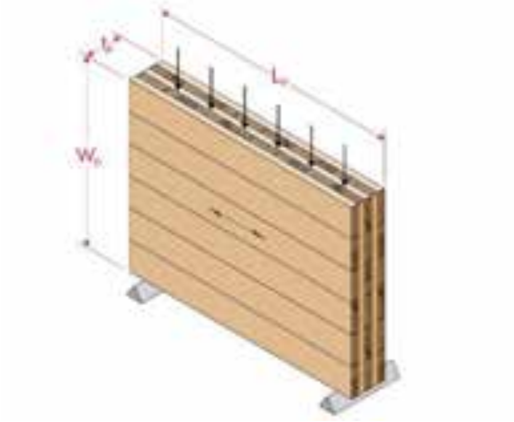
3-ply:	**11 to 12 ft**
5-ply:	**16 to 17 ft**
7-ply:	**20 to 21 ft**

Limitations:

- **Does not account for strength or deflections**
- **Does not account for beam flexibility**
- **Does not account for project specifics**

Edgewise Structural Properties

EDGEWISE Panel Loading



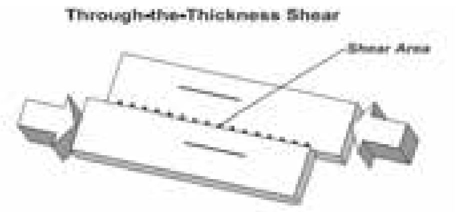
Span in MAJOR Strength Direction

Span in MINOR Strength Direction

Reference & Source: ANSI/APA PRG 320-2017

Shear Force Terminology & Jargon

Source: ANSI/APA PRG 320-2017



Source: NDS 2015 Manual

Through-the-Thickness Shear
In-plane Shear Forces
EDGEWISE Shear in PRG 320-2017

NDS 2015: $F_v(t_v)$
PRG 320-2017: $F_{v,e,0}\, t_p$ & $F_{v,e,90}\, t_p$

CLT in Lateral Force Resisting Systems

CLT Panels have a significant in-plane shear strength.

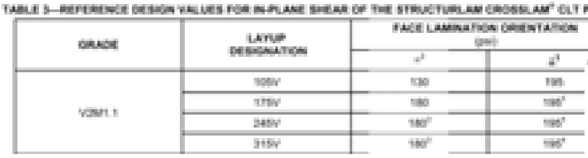


TABLE 3—REFERENCE DESIGN VALUES FOR IN-PLANE SHEAR OF THE STRUCTURLAM CROSSLAM® CLT PANELS

GRADE	LAYUP DESIGNATION	FACE LAMINATION ORIENTATION (psi)	
		∥	⊥
V2M1.1	105V	130	195
	175V	180	195
	245V	180	195
	315V	180	195

Source: ICC-ES *ESR 3631*

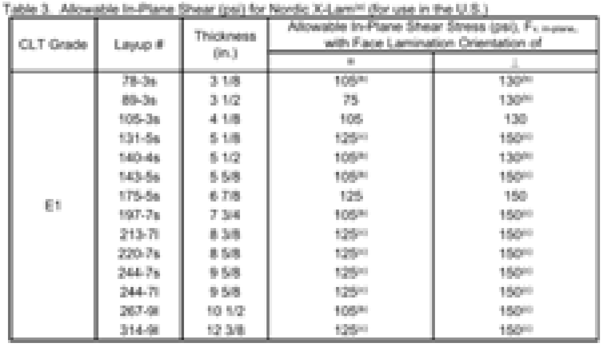


Table 3. Allowable In-Plane Shear (psi) for Nordic X-Lam™ (for use in the U.S.)

CLT Grade	Layup #	Thickness (in.)	Allowable In-Plane Shear Stress (psi), $F_{v,\text{in-plane}}$, with Face Lamination Orientation of	
			∥	⊥
E1	78-3s	3 1/8	105	130
	89-3s	3 1/2	75	130
	105-3s	4 1/8	105	130
	131-5s	5 1/8	125	150
	140-4s	5 1/2	105	130
	143-5s	5 5/8	105	150
	175-5s	6 7/8	125	150
	197-7s	7 3/4	105	150
	213-7l	8 3/8	125	150
	220-7s	8 5/8	125	150
	244-7s	9 5/8	125	150
	244-7l	9 5/8	125	150
	267-9l	10 1/2	105	150
	314-9l	12 3/8	125	150

Source: *APA Product Report PR-L306*

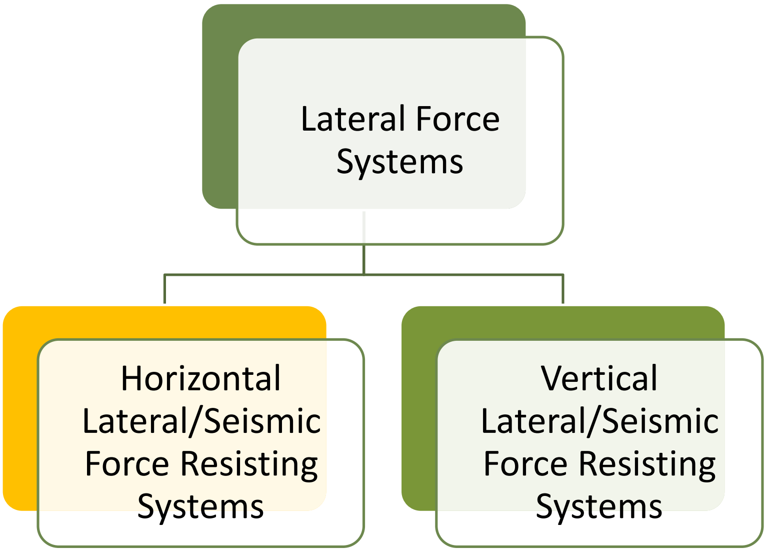
~75 to 195+ PSI Allowable Edgewise Shear

~900 to 2300 PLF *per Inch of Thickness.*

Consult with the Manufacturers for Details

Standard test method defined using ASTM D198

Mass Timber Lateral Systems



Lateral Force Systems

Horizontal Lateral/Seismic Force Resisting Systems

Vertical Lateral/Seismic Force Resisting Systems

NLT DIAPHRAGM DESIGN

NLT DIAPHRAGM DESIGN:

LACK OF TESTED, PUBLISHED DIAPHRAGM VALUES FOR BARE NLT LEAD MANY ENGINEERS TO COVERING WITH WOOD STRUCTURAL PANELS. DESIGN AS A BLOCKED, SHEATHED DIAPHRAGM. USE SDPWS TABLE 4.2A/4.2B

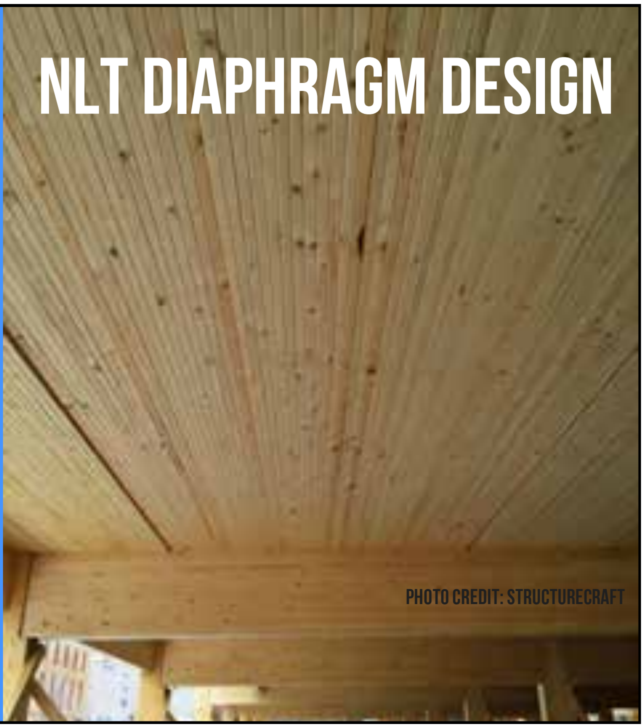


PHOTO CREDIT: STRUCTURECRAFT

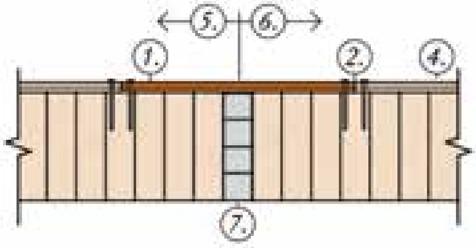
NLT DIAPHRAGM DESIGN

PHOTO CREDIT: STRUCTURECRAFT

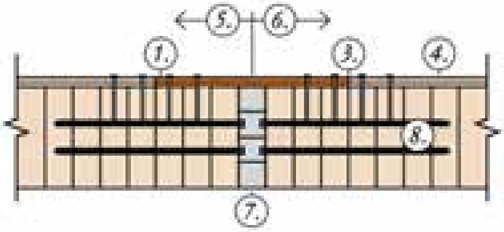
PRE-FABRICATED PANELS OFTEN PRE-SHEATHED

ONCE INSTALLED, ADD STITCHING STRIPS, TAPE JOINT IF APPLICABLE

NLT DIAPHRAGM DESIGN



Typical Diaphragm



High Load Diaphragm

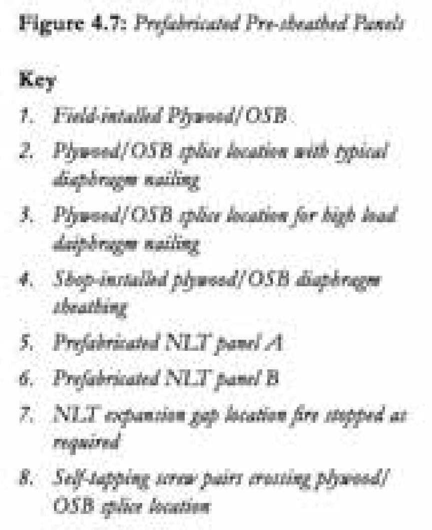


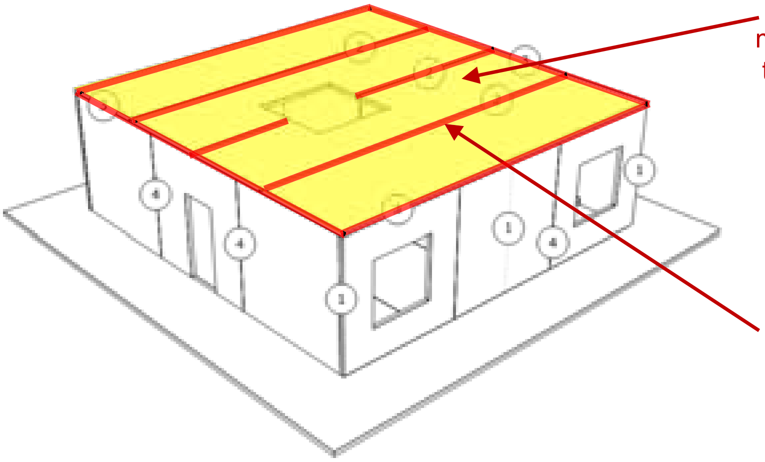
Figure 4.7: *Prefabricated Pre-sheathed Panels*

Key

1. *Field-installed Plywood/OSB*
2. *Plywood/OSB splice location with typical diaphragm nailing*
3. *Plywood/OSB splice location for high load daiphragm nailing*
4. *Shop-installed plywood/OSB diaphragm sheathing*
5. *Prefabricated NLT panel A*
6. *Prefabricated NLT panel B*
7. *NLT expansion gap location fire stopped as required*
8. *Self-tapping screw pairs crossing plywood/ OSB splice location*

SOURCE: NLT DESIGN & CONSTRUCTION GUIDE

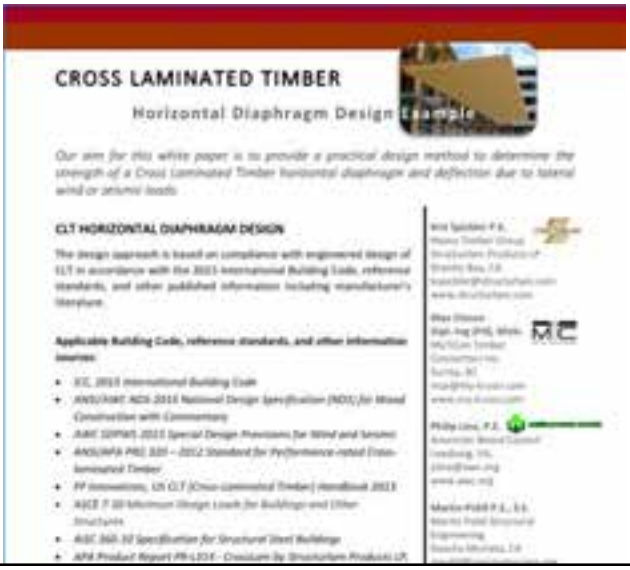
CLT Diaphragms



Strength of CLT rarely (never?) governs. Capacity provided by manufactures via ASTM standard testing. Standard to be included in PRG 320 Update.

Strength of Connections covered by NDS 2015 and Proprietary Fastener Evaluation Reports

CLT Diaphragm Design Example Paper

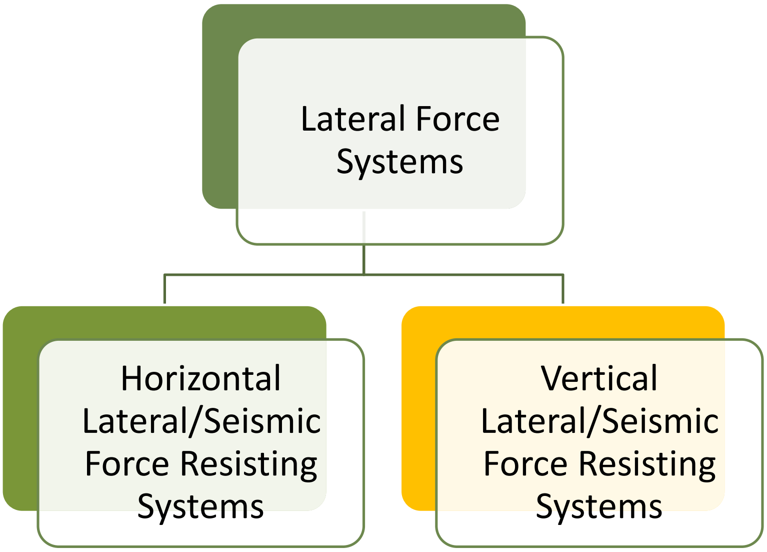


CROSS LAMINATED TIMBER

Horizontal Diaphragm Design Example

http://www.structurlam.com/wp-content/uploads/2016/10/Structurlam-CrossLam-CLT-White-Paper-on-Diaphragms-SLP-Oct-2015.pdf

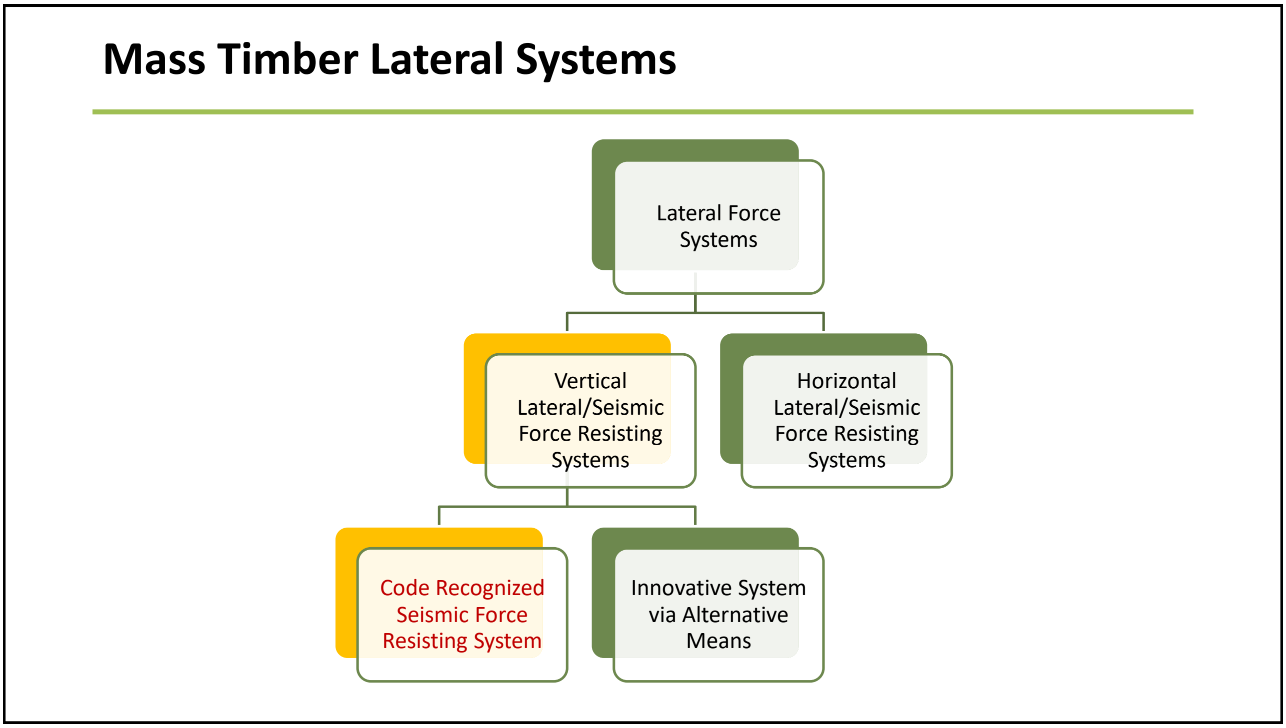
Mass Timber Lateral Systems



Lateral Force Systems

Horizontal Lateral/Seismic Force Resisting Systems

Vertical Lateral/Seismic Force Resisting Systems



Mass Timber Lateral Systems

Lateral Force Systems

Vertical Lateral/Seismic Force Resisting Systems

Horizontal Lateral/Seismic Force Resisting Systems

Code Recognized Seismic Force Resisting System

Innovative System via Alternative Means

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

LIGHT-FRAME WOOD SHEARWALLS

PHOTO CREDIT: WOODWORKS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

CENTRAL CORE – CONCRETE SHEARWALLS

PHOTO CREDIT: STRUCTURECRAFT

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

EXTERIOR STEEL MOMENT FRAME

PHOTO CREDIT: WOODWORKS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

INTERIOR STEEL MOMENT FRAME

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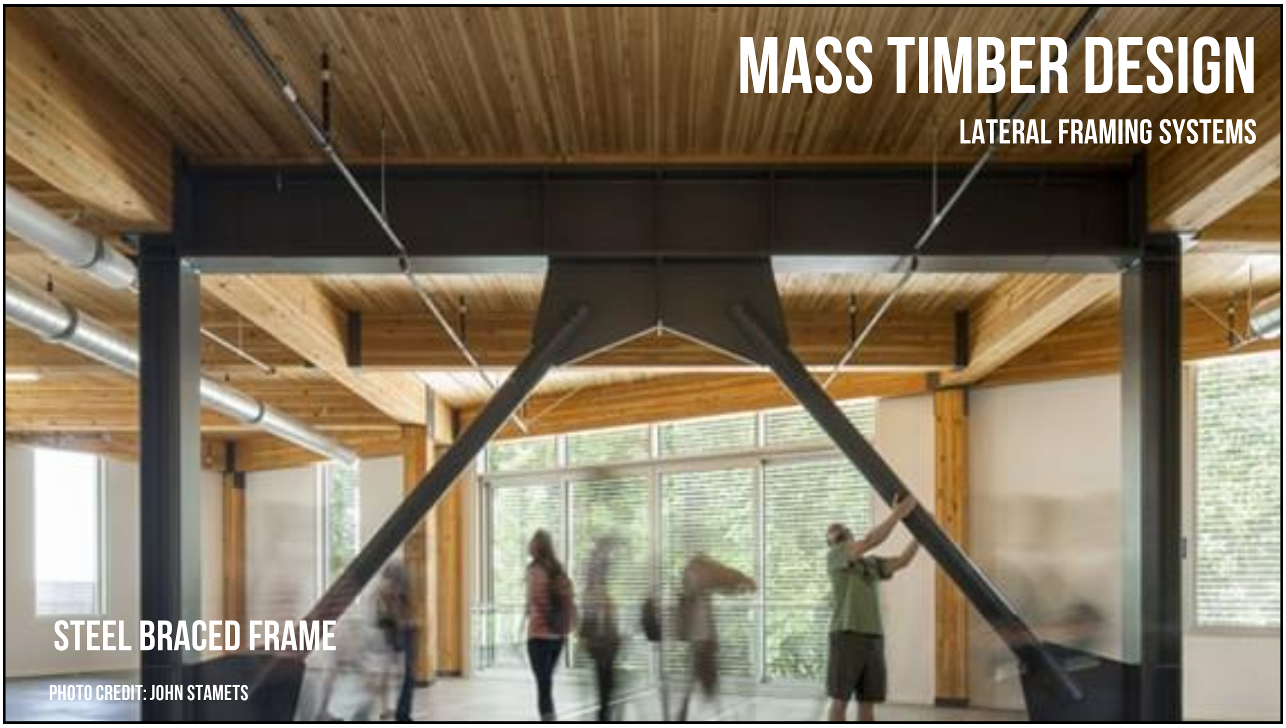


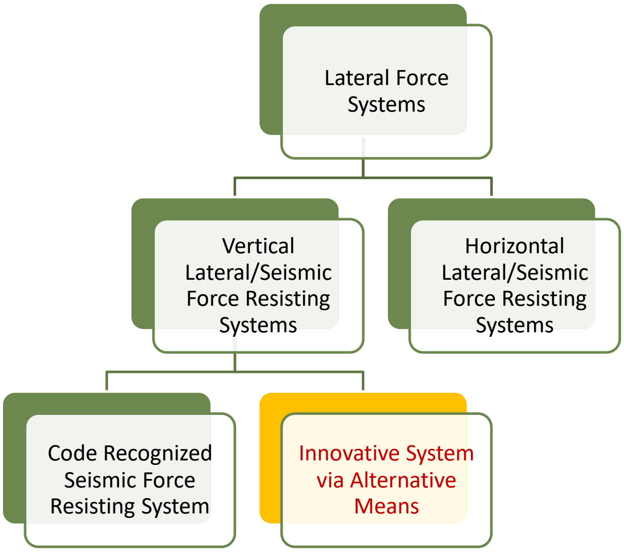
MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

STEEL BRACED FRAME

PHOTO CREDIT: JOHN STAMETS

Tall Wood Structural Systems



Lateral Force Systems

Vertical Lateral/Seismic Force Resisting Systems

Horizontal Lateral/Seismic Force Resisting Systems

Code Recognized Seismic Force Resisting System

Innovative System via Alternative Means

CLT Shear Wall Seismic Design Values

What R value can I use?

Photo: KLH

Photo: FPI

CLT Seismic Design

CLT Seismic Force Resisting Systems **Not** addressed In

ASCE/SEI 7-10 or 7/16

SDPWS 2015

State of Oregon Statewide Alternative

Statewide Alternate Method
January 2015

No. 15-01
Cross-Laminated Timber Provisions
(Ref.: ORS 455.060)

Statewide Alternate Methods *are approved by the Division administrator in consultation with the appropriate advisory board. The advisory board's review includes technical and scientific facts of the proposed alternate method. In addition:*

- *Building officials shall approve the use of any material, design or method*
  addressed in a statewide alternate method.
- *The decision to use a statewide alternate method is at the discretion of the*
- *Statewide alternate methods do not limit the authority of the building official*
  other proposed alternate methods encompassing the same subject matter.

Code Edition: 2014 Oregon Structural Specialty Code (OSSC)

Code Section: OSSC Section 602.4 Type IV, Heavy Timber

Date: January 15, 2015

Initiated by: Building Codes Division

Subject: Cross-Laminated Timber

Background:

Cross-laminated timber (CLT) is an emerging wood product with applications in both residential and non-residential buildings. Oregon BCD has prepared this alternate method which recognizes nationally adopted acceptance of CLT in Type IV Construction through the International Codes Council process. This classification will allow roughly 30 percent taller and larger buildings than

State of Oregon Statewide Alternative

ASCE 7-10 Table 12.2-1 modified by Oregon Buildings Code Division

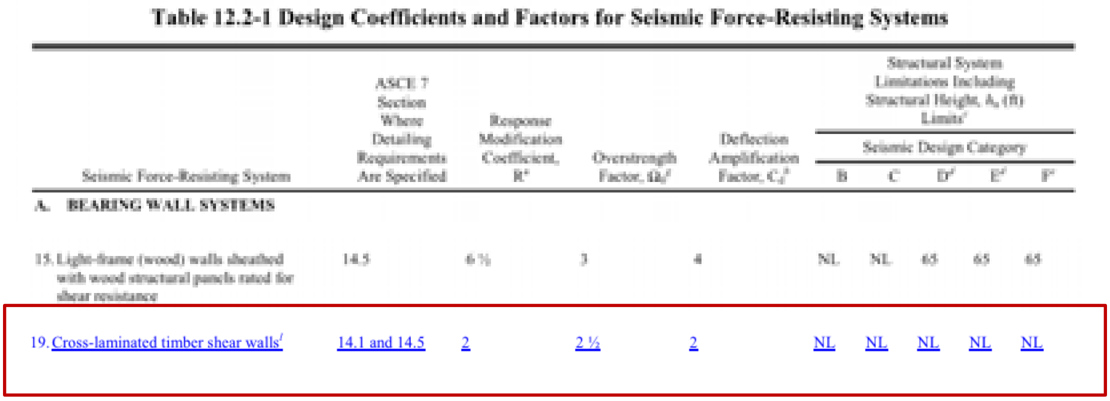


Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, Ω_0^g	Deflection Amplification Factor, C_d^b	Structural System Limitations Including Structural Height, h_n (ft) Limits^c				
					Seismic Design Category				
					B	C	D^d	E^d	F^e
A. BEARING WALL SYSTEMS									
15. Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	14.5	6 ½	3	4	NL	NL	65	65	65
19. Cross-laminated timber shear walls^f	14.1 and 14.5	2	2 ½	2	NL	NL	NL	NL	NL

Innovative Systems

Cross-Laminated Timber Post-Tensioned Rocking Shear Walls

Range of Shear Wall Systems

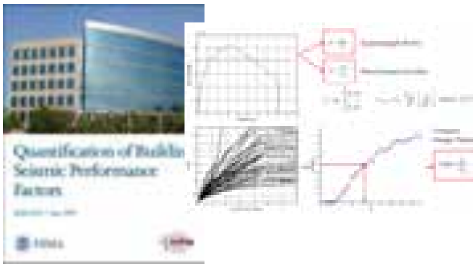
Rocking Wall Systems (R = ~6?)

Ordinary Shear Walls (R = ~2?)

Range of CLT Shear Wall Systems

Seismically Detailed Walls
(R = 4?)

(R = ~3?)



Quantification of Buildin
Seismic Performance
Factors

FEMA

Ongoing FEMA P-695
study by John van de Lindt

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

MASS TIMBER SHEARWALLS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

TIMBER BRACED FRAME

PHOTO CREDIT: ALEX SCHREYER

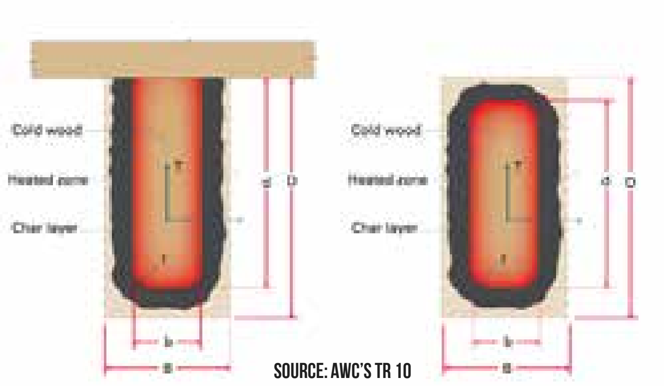
FIRE RESISTANCE

PHOTO CREDIT: FP INNOVATIONS

MASS TIMBER DESIGN

FIRE RESISTANCE

SIMILAR TO HEAVY TIMBER, MASS TIMBER PRODUCTS HAVE INHERENT FIRE RESISTANCE PROPERTIES

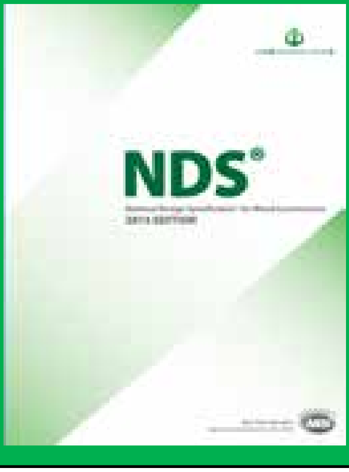


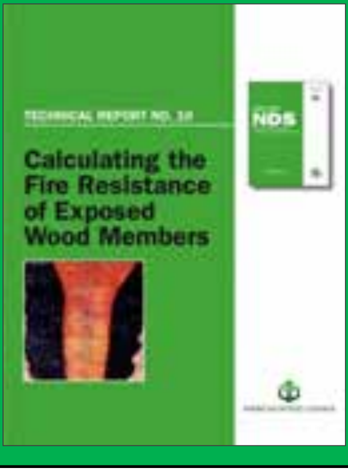
SOURCE: AWC'S TR 10

MASS TIMBER DESIGN

FIRE RESISTANCE

FOR EXPOSED WOOD MEMBERS: IBC 722.1 REFERENCES AWC'S NDS CHAPTER 16 (AWC'S TR 10 IS A DESIGN AID TO NDS CHAPTER 16)





MASS TIMBER DESIGN

FIRE RESISTANCE

NOMINAL CHAR RATE FOR MOST WOOD PRODUCTS IS 1.5"/HR

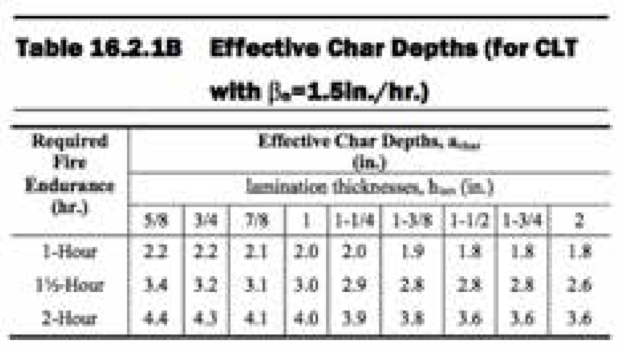


Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

2015 NDS CHAPTER 16 INCLUDES CALCULATION OF FIRE RESISTANCE OF NLT, CLT, GLULAM, SOLID SAWN AND SCL WOOD PRODUCTS

MASS TIMBER DESIGN

FIRE RESISTANCE

NDS TABLE 16.2.2 DESIGN STRESS ADJUSTMENT FACTORS APPLIED TO ADJUST TO AVERAGE ULTIMATE STRENGTH

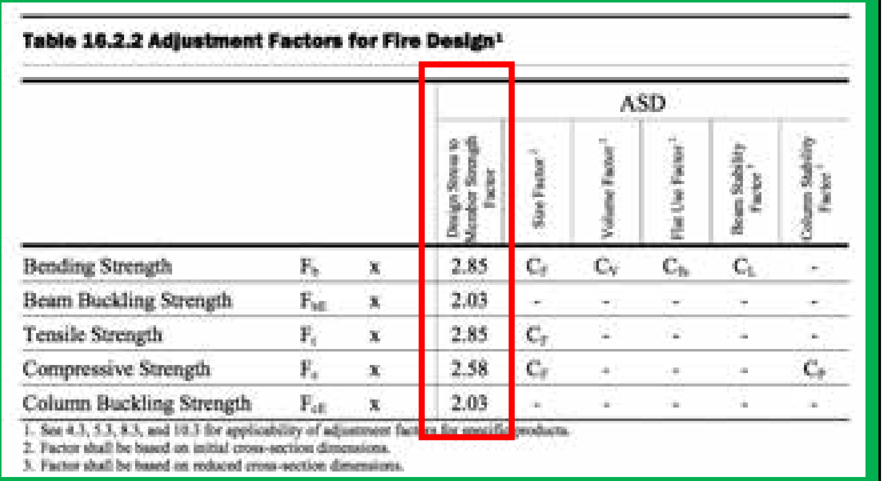


Table 16.2.2 Adjustment Factors for Fire Design[1]

			ASD					
			Design Stress to Member Strength Factor	Size Factor[2]	Volume Factor[2]	Flat Use Factor[2]	Beam Stability Factor[3]	Column Stability Factor[3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-	-	-

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.

MASS TIMBER DESIGN

FIRE RESISTANCE

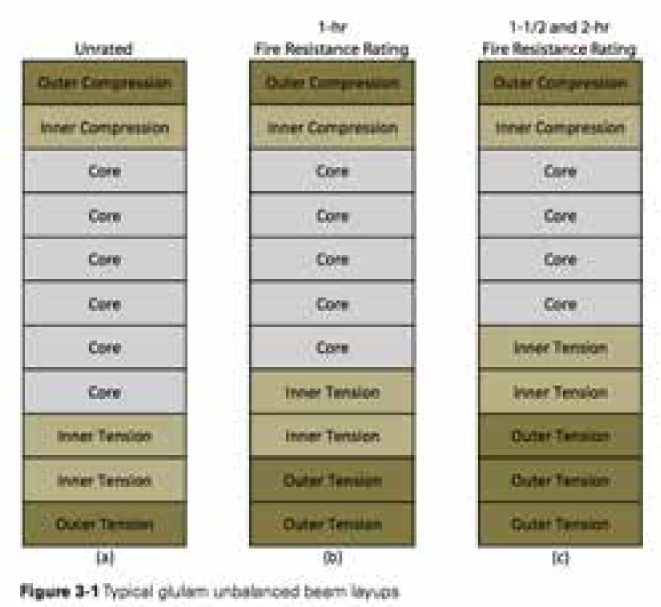


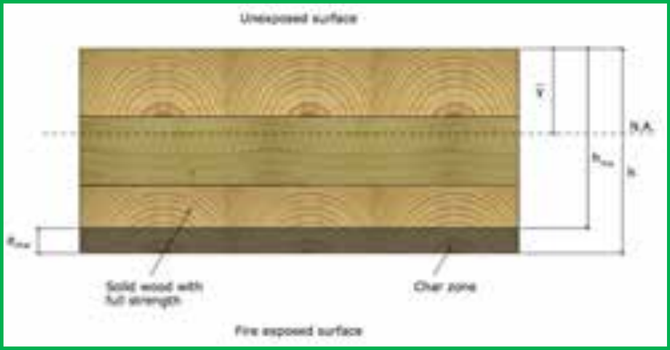
Figure 3-1 Typical glulam unbalanced beam layups

<u>GLULAM BEAM FIRE DESIGN:</u>

- FOR UNBALANCED BEAMS, SUBSTITUTE 1 CORE LAM FOR 1 TENSION LAM FOR 1 HOUR RATING, 2 CORE LAMS FOR 2 TENSION LAMS FOR 1.5 & 2 HOUR RATING
- FOR BALANCED BEAMS, MATCH ON COMPRESSION SIDE

MASS TIMBER DESIGN

FIRE RESISTANCE



CLT FIRE DESIGN:

- LAM THICKNESS AFFECTS CHAR DEPTH
- PARTIALLY CHARRED CROSS LAYERS ARE TYPICALLY NEGLECTED FOR STRUCTURAL CHECKS

MASS TIMBER DESIGN

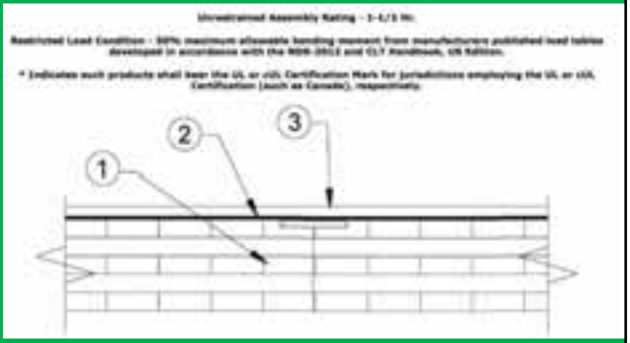
FIRE RESISTANCE

MASS TIMBER FIRE DESIGN METHODS:

NDS Chapter 16 Char Calculations vs. ASTM E119 Tested Assembly

- **NDS Chpt 16 calcs check structural integrity**
- **E119 checks structural integrity, hose stream and unexposed surface temperature**

Reasonable to assume other assembly components such as concrete topping aid in other 2 criteria



Unrestrained Assembly Rating – 1-1/2 Hr.

Restricted Load Condition – 80% maximum allowable bending moment from manufacturers published load tables developed in accordance with the NDS-2012 and CLT Handbook, US Edition.

* Indicates such products shall bear the UL or cUL Certification Mark for jurisdictions employing the UL or cUL Certification (such as Canada), respectively.

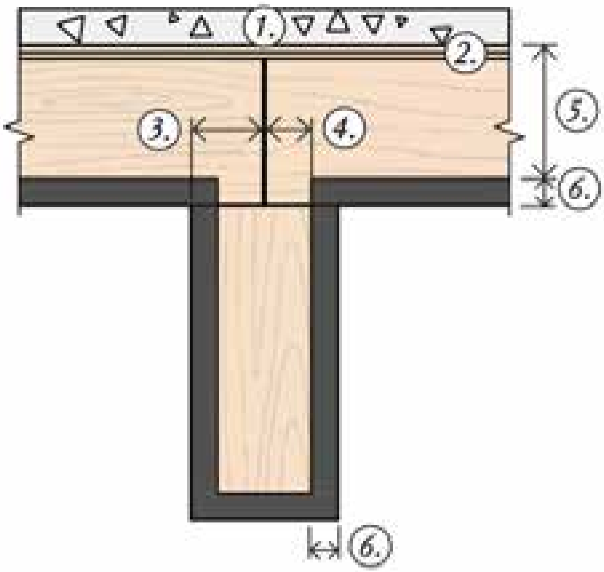


Figure 4.5: *Bearing Reduction where Supported on Exposed Charred Timber Beam*

MASS TIMBER DESIGN

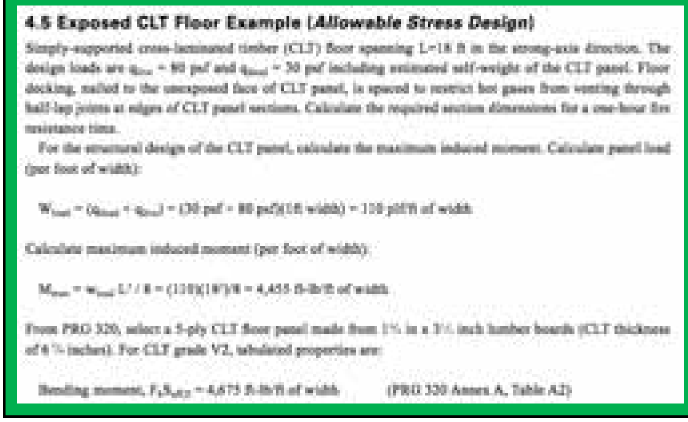
FIRE RESISTANCE

WHEN MASS TIMBER PANELS ARE SUPPORTED ON EXPOSED WOOD BEAMS, CONSIDER REDUCED PANEL BEARING LENGTH DUE TO FIRE DESIGN

MASS TIMBER DESIGN

FIRE RESISTANCE

AWC'S TECHNICAL REPORT 10 INCLUDES DISCUSSION OF FIRE TESTS AND DESIGN EXAMPLES



4.5 Exposed CLT Floor Example (*Allowable Stress Design*)

Simply-supported cross-laminated timber (CLT) floor spanning L=18 ft in the strong-axis direction. The design loads are q_{live} = 80 psf and q_{dead} = 30 psf including estimated self-weight of the CLT panel. Floor decking, nailed to the unexposed face of CLT panel, is spaced to restrict hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a one-hour fire resistance time.

For the structural design of the CLT panel, calculate the maximum induced moment. Calculate panel load (per foot of width):

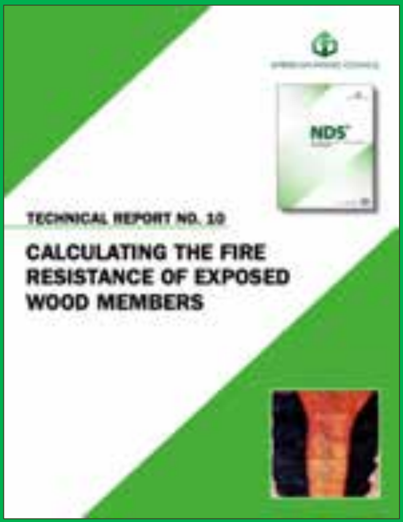
$w_{load} = (q_{dead} + q_{live})$ = (30 psf + 80 psf)(1ft width) = 110 plf/ft of width

Calculate maximum induced moment (per foot of width):

$M_{max} = w_{load} L^2 / 8 = (110)(18^2)/8$ = 4,455 ft-lb/ft of width

From PRG 320, select a 5-ply CLT floor panel made from 1⅜ in x 3½ inch lumber boards (CLT thickness of 6⅞ inches). For CLT grade V2, tabulated properties are:

Bending moment, $F_bS_{eff,0}$ = 4,675 ft-lb/ft of width (PRG 320 Annex A, Table A2)



TECHNICAL REPORT NO. 10

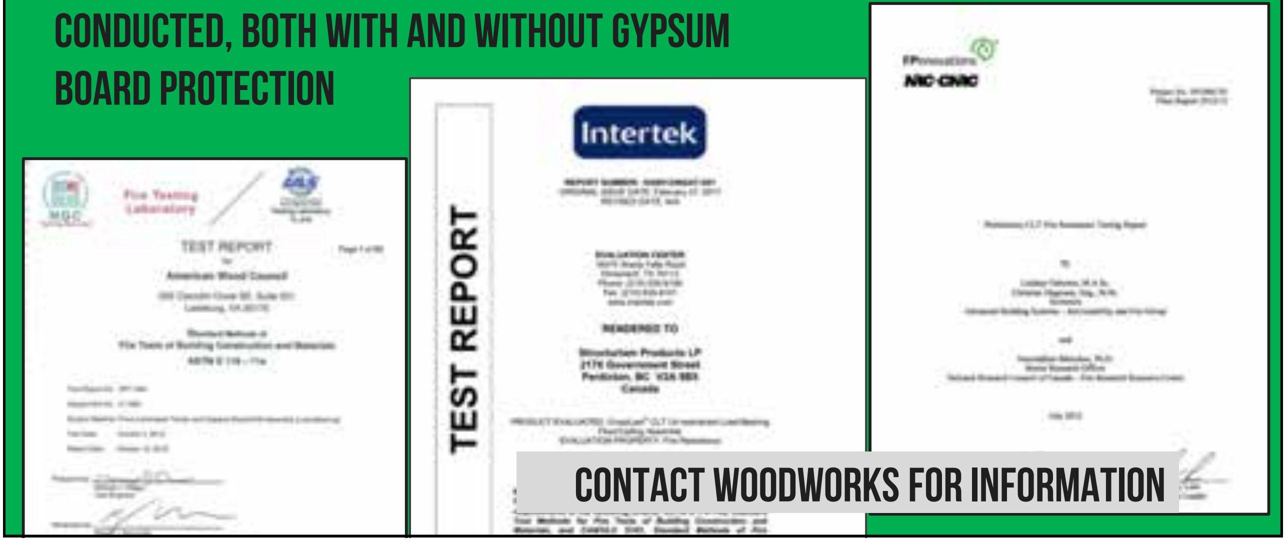
CALCULATING THE FIRE RESISTANCE OF EXPOSED WOOD MEMBERS

FREE DOWNLOAD AT AWC.ORG

MASS TIMBER DESIGN

FIRE RESISTANCE

MANY SUCCESSFUL CLT FIRE TESTS HAVE BEEN CONDUCTED, BOTH WITH AND WITHOUT GYPSUM BOARD PROTECTION



Fire Testing Laboratory

TEST REPORT

American Wood Council

Intertek

TEST REPORT

RENDERED TO

Structurlam Products LP
2176 Government Street
Penticton, BC V2A 8B5
Canada

FPInnovations

NRC·CNRC

CONTACT WOODWORKS FOR INFORMATION

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Speaker Name

Contact Info

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