SEAW Spring Webinar

Engineering Requirements for Mass Timber Buildings

Wednesday, June 12, 2019

Presented by

Structural Engineers Association of Washington

CREDITS

The materials used herein are based on the following as well as standards referenced by these documents:

- IBC 2015, "International Building Code", 2015

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About the Presenters

Hans-Erik Blomgren, PE SE P.Eng. Struct.Eng.
Director of Testing and Characterization, Katerra

At Katerra, Hans-Erik is director of mass timber product and building systems. He has managed certification for the company's cross-laminated timber product line which will be manufactured at a new 270,000 sq. ft factory in Spokane Valley, WA starting in the summer of 2019. As well, he has led Katerra's efforts to technically justify and test cross-laminated timber panel assemblies and systems for code compliant fire, structural, and acoustic use. Hans-Erik represents Katerra on the PRG 320 CLT Manufacturing Standard and AWC Wood Design Standards code writing committees.

Robert Gerard, PE
Associate Fire Engineer, Katerra

Robert Gerard is a licensed Fire Protection Engineer based in Katerra's Seattle office. He holds a Bachelor's Degree in Architectural Engineering from Cal Poly, San Luis Obispo, and a Master's Degree in Fire Engineering from the University of Canterbury in New Zealand. Robert's experience in timber fire safety has seen him involved in timber building research and testing programs around the globe, including placements in London and Sydney in addition to his home base of Washington. His participation in a number of research forums, seminars, conferences and projects has made him an authority on fire safety in timber buildings.

Agenda

11:30-11:35	*Introduction by the SEAW Education Committee*
11:35-12:00	1- Mass Timber Background
12:00-12:20	2- Fundamentals of CLT and Glulam Behavior
12:20-12:40	3- Mass Timber Building Design Requirements
12:40-1:00	4- Best Practice for Building Design
1:00-1:20	5- Additional Requirements
1:20-1:30	Q & A
1:30	*Adjourn*

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Engineering Requirements for Mass Timber Buildings

Hans-Erik Blomgren PE SE P.Eng. Struct.Eng.
Robert Gerard PE, Fire Protection Engineering
Katerra

June 12, 2019

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Presenters

Hans-Erik Blomgren, PE SE P.Eng. Struct.Eng.
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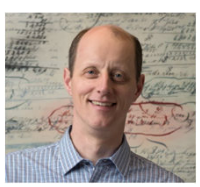

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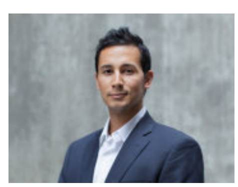

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Learning Objectives

- Understand the structural and fire engineering requirements for mass timber commercial buildings
- Define the IBC (2018) code compliance pathways
- Provide proper specification of materials and assemblies
- Define and apply appropriate design methods

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Agenda

Introduction

Mass Timber Background

Fundamentals of CLT & Glulam Behavior

Mass Timber Building Design Requirements

Best Practice for Building Design

Additional Requirements

Q&A

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The Origins of the Mass Timber Movement

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CLT Missionaries

KLH

HISTORY OF CLT

- 1985 First patent for CLT in France
- 1993 First projects in CLT from P. Schuler and K. Moser in Switzerland and Germany
- 1994 Dissertation Professor Schickhofer
- 1995 Research project Bresta-V and Brsta-H
- 1995 – 1996 Development of press technology
- 1997 Founding KLH
- 1998 First multistory residential building in Styria, Austria
- 1998 First national approvals for Merk in Germany and KLH in Austria and Germany
- 1999 After two years of trial operation - building a new plant
- 2000 – 2004 Building up the European market
- 2005 Olympic games in Torino
- 2005 Establishment of KLH UK in London

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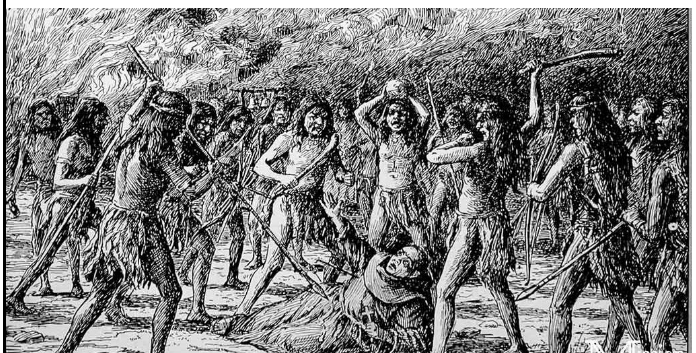
CLT Missionaries



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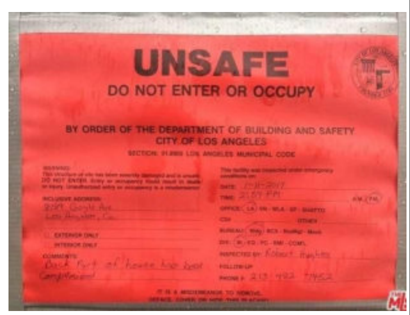
CLT Cowboys



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CLT Pioneers

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CLT Snake Oil Salesman

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CLT Sheriffs

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CLT Civilization

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CLT Global Product Supply

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CLT – Global Manufacturers/Fabricators

SMARTLAM – Montana

X-LAM USA – Alabama

日本CLT協会 – Japan

MPP – Oregon

DR Johnson – Oregon

XLam – New Zealand

KLH – Austria

NORDIC – Quebec

STRUCTURLAM – British Columbia

HASSLACHER NORICA TIMBER – Austria

MAYR MELNHOF HOLZ – Austria

DERIX – Germany

binderholz – Europe

storaenso – Europe

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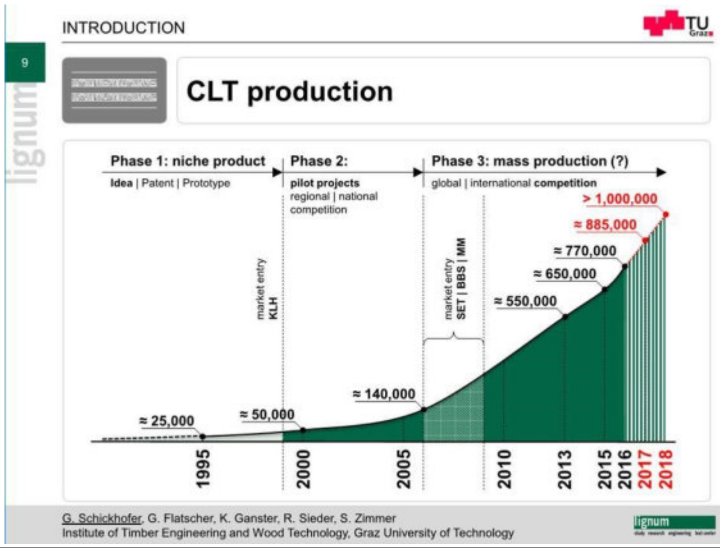
Mass Timber Products – Washington State



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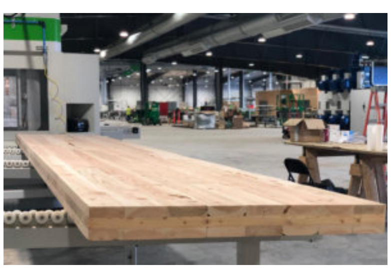
Mass Timber Products – Washington State

VAAGEN TIMBERS

KATERRA

Colville WA

Spokane Valley WA



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Mass Timber Precedents

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Mjøstårnet – Norway (Height = 280ft)

Current CTBUH Record Holder

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Oregon State Peavy Hall – Corvallis




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Oregon State U – Emerson Advance Wood Products Lab




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Catalyst Office/Education – Spokane WA

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The Postmark, Shoreline WA

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T3 – Hines Atlanta GA, Minneapolis MN

Source:
Structurcraft

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Wood Properties

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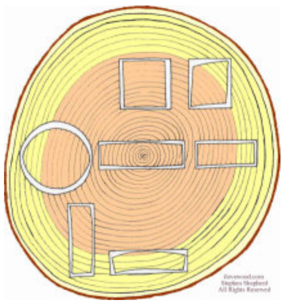
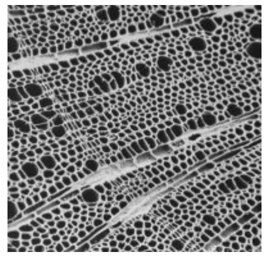
Wood Properties





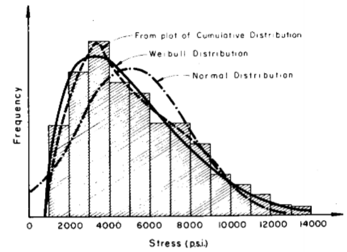
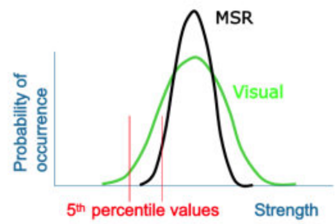


FIG. 1. Histogram and distributions for sample of two hundred and forty 2 × 6 joists (Weibull and normal).



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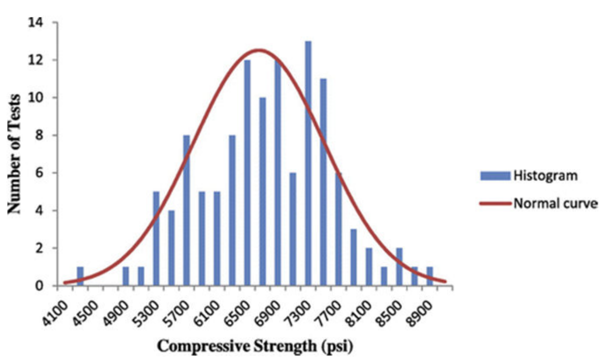
Concrete Properties



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Relative Mechanical Properties

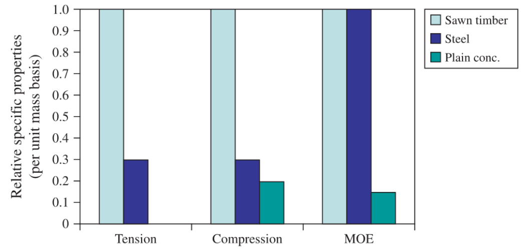

Fig. 2.2: Approximate relative specific mechanical properties of common construction materials



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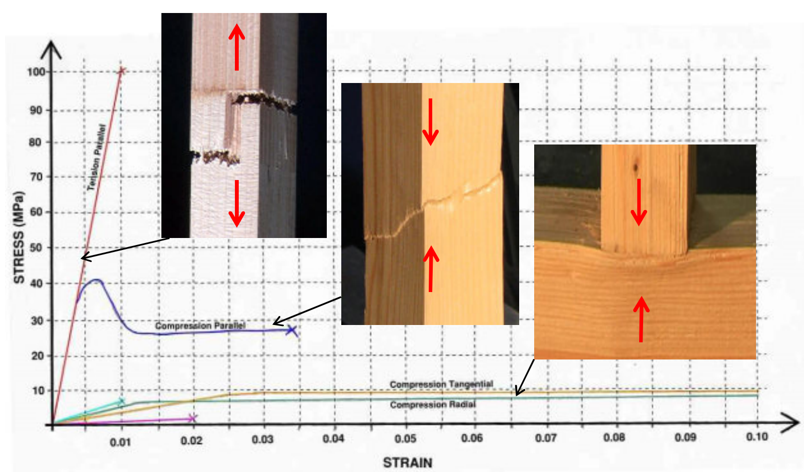
Representative Stress v. Strain Relationship for Wood



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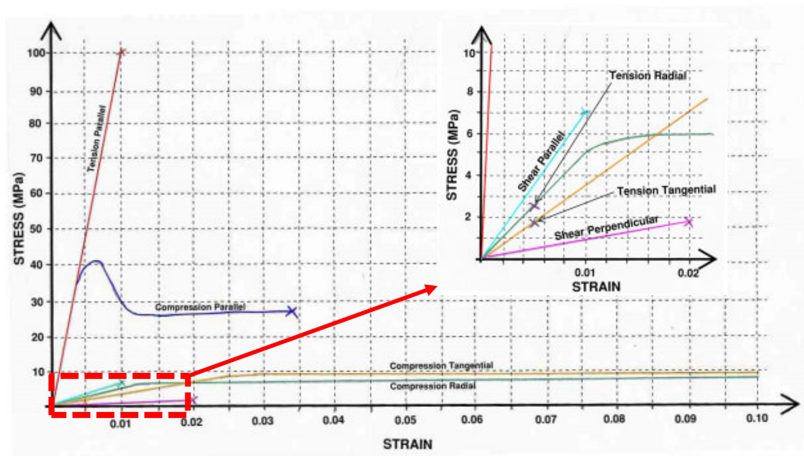
Representative Stress v. Strain Relationship for Wood



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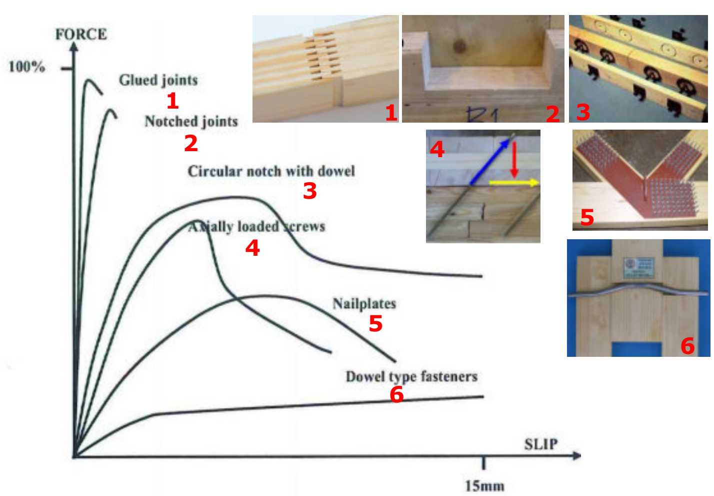
Representative Load Deformation Relationship for Fasteners



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Truss Chord Splice - Axially Loaded Screws

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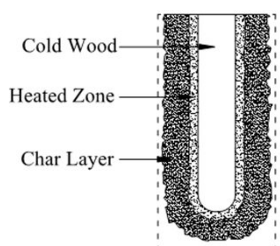
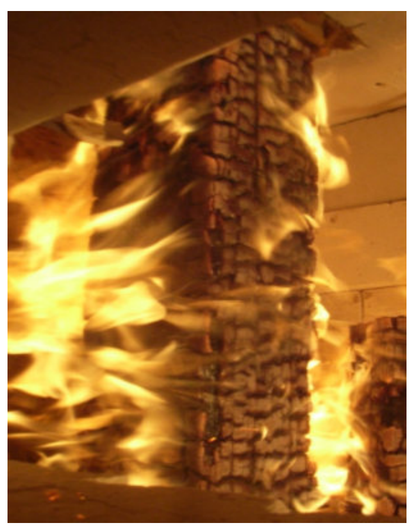
Fire Properties





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Fire Properties

Char rate (NDS / TR-10)

Table 4.1.1.4A Char Depth and Effective Char Depth
(for β_n = 1.5 inches/hour)

Required Fire Resistance (hr)	Char Depth, a_{char} (in.)	Effective Char Depth, a_{eff} (in.)
1-Hour	1.5	1.8
1½-Hour	2.1	2.5
2-Hour	2.6	3.2

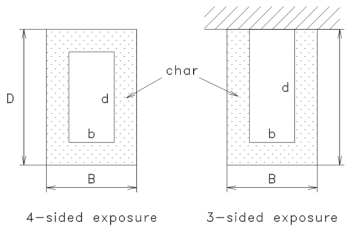

Table 4.1.1.4B Effective Char Depth (for CLT with β_n=1.5 inches/hour)

Required Fire Resistance (hr)	Lamination Thickness, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
	Char Depth, a_{char} (in.)								
1-Hour	1.8	1.8	1.7	1.7	1.7	1.6	1.5	1.5	1.5
1½-Hour	2.8	2.7	2.6	2.5	2.4	2.4	2.4	2.3	2.2
2-Hour	3.7	3.6	3.4	3.4	3.2	3.2	3.0	3.0	3.0
	Effective Char Depth, a_{eff} (in.)								
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

*Accounts for delamination

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IBC Construction Types

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Combustibility

How easily a substance will ignite and burn
ASTM E136 – Test Method for Behavior of Materials



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Combustibility

How easily a substance will ignite and burn
ASTM E136 – Test Method for Behavior of Materials

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IBC Construction Types

Building classification based on materials (2018 IBC Chapter 6)

Element	Type I	Type II	Type III	Type IV	Type V
Primary frame	Non-combustible	Non-combustible	Combustible	Combustible	Combustible
External walls	Non-combustible	Non-combustible	**Non-combustible*	**Non-combustible*	Combustible
Internal walls	Non-combustible	Non-combustible	Combustible	Combustible	Combustible
Floors	Non-combustible	Non-combustible	Combustible	Combustible	Combustible
Roofs	Non-combustible*	Non-combustible*	Combustible	Combustible	Combustible

** CLT permitted with non-combustible protection*

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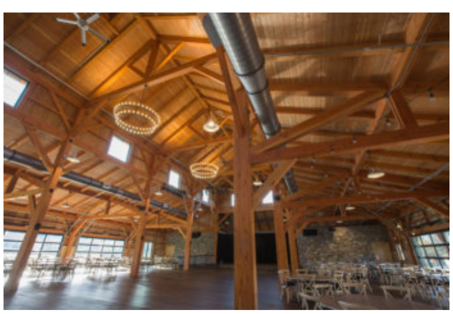
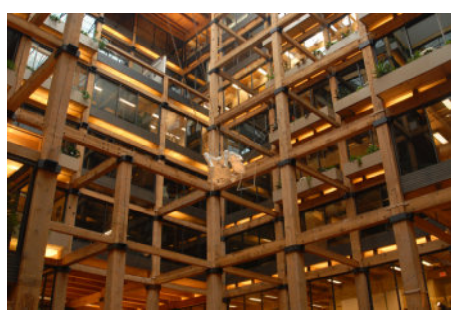
IBC Construction Types

Types III and IV (2018 IBC 602.3 and 602.4)

- Noncombustible exterior, combustible interior
- Type IV: No concealed spaces





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IBC Construction Types

Type V (2015 IBC 602.5)

- Any material permitted by code

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IBC Construction Types

Construction type allowances (2018 IBC Chapter 6)

Parameter	I-A	I-B	II-A	II-B	III-A	III-B	IV-HT	V-A	V-B
Allowable Height	UL	180	85	75	85	75	85	70	60
Allowable # Stories	UL	12	5	5	5	5	5	4	3
Allowable Area	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000
FRR									
Primary Frame	3	2	1	0	1	0	HT	1	0
Ext Bearing Walls	3	2	1	0	2	2	2	1	0
Int Bearing Walls	3	2	1	0	1	0	HT	1	0
Floors	2	2	1	0	1	0	HT	1	0
Roof	1-1/2	1	1	0	1	0	HT	1	0

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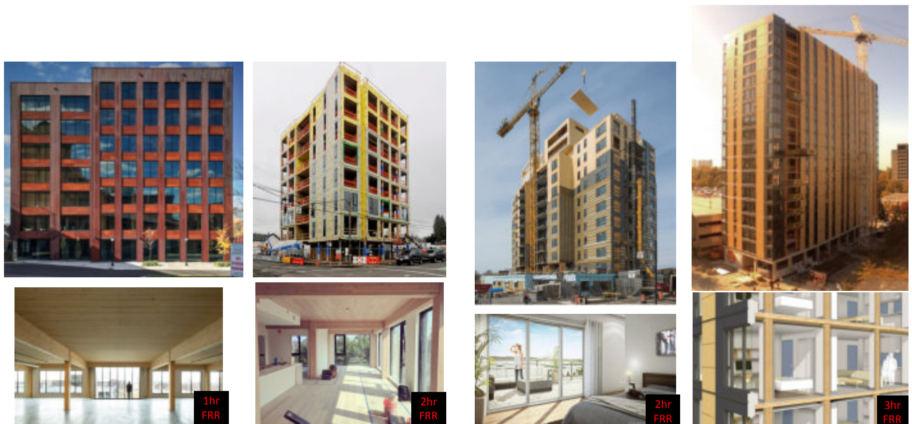
Tall Wood Buildings



Type IV - T3, Minneapolis MN
6-Story wood over 1 Story Concrete
<85ft, Exposed Wood

Type IVC - Carbon 12, Portland OR
8-Story wood over 1 Story Concrete
<85ft, Exposed Wood

Type IVB - Origine, Quebec CA
12-Story Wood
>85ft, Partially Encapsulated

Type IVA - Brock Commons, Vancouver BC
18-Story Wood/Concrete Hybrid
>85ft, Fully Encapsulated

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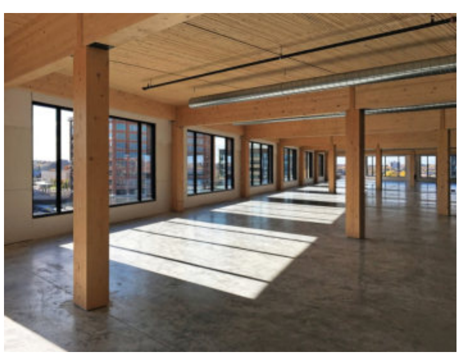
Tall Wood Buildings

Modern mass timber buildings

- Larger and tall engineered timber structures



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Tall Wood Buildings

Type IV-A, -B, -C, HT Construction (TWB / 2021 IBC)

Parameter	IV-A*	IV-B*	IV-C*	IV-HT
Allowable Height	270	180	85	85
Allowable # Stories	18	12	9	5
Allowable Area	184,500	123,000	76,875	61,500
Exposed Area	0%	Up to 20/40%	100%	100%
Sprinkler Protection	NFPA 13	NFPA 13	NFPA 13	NFPA 13
FRR				
Primary Frame	3	2	2	HT
Ext Bearing Walls	3	2	2	2
Int Bearing Walls	3	2	2	HT
Floors	2	2	2	HT
Roof	1-1/2	1	1	HT
Concealed Spaces	Permitted	Permitted	Permitted	NP

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Design Values and Design Methods

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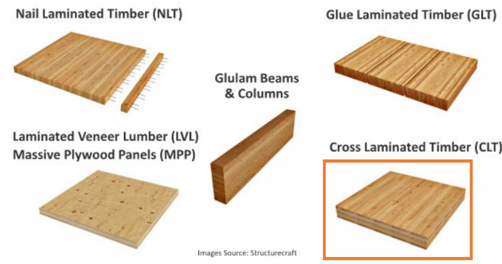
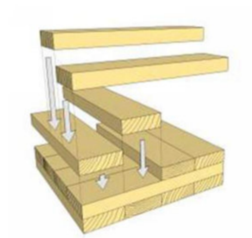
Cross-Laminated Timber

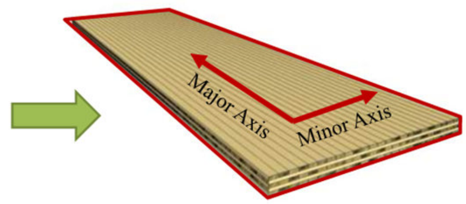
Definition:

Cross-laminated Timber (CLT) is a large-format, prefabricated, solid-engineered wood panel product consisting of several layers of kiln-dried and planed lumber boards stacked in alternating directions, bonded with structural adhesives and pressed to form a solid, dimensionally stable, rectangular panel.

CLT is a part of the mass timber family.







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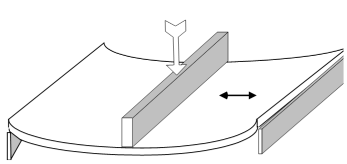
CLT Flatwise Bending and Shear Behavior

CLT is an orthotropic plate element.

Bending and shear behavior are significantly influenced by the cross-wise layup of the laminations

Rolling shear of the transverse layups is characterized by low strength and low stiffness.

In the CLT Handbook and accepted by APA-PRG 320 (but not defined in NDS) a simplified analytical model called the *shear analogy method* (Blaß and Fellmoser) is derived to provide reasonably accurate closed-form equations to calculate design values.



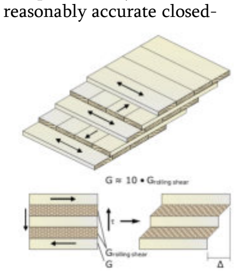
General Relationship for most softwood species

E_0 = E parallel to grain
E_{90} = E perpendicular to grain ~E/30

G_0 ~ $E_0/16$

G_0 = G parallel to grain
G_{90} = G_R rolling shear ~$G_0/10$

E_0 ~ $16xG_0$ ~ $160xG_{90}$



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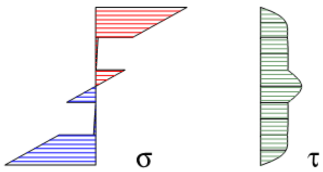
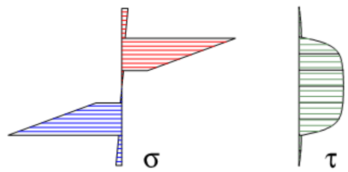
CLT Cross Section Stresses





5-Ply Major Axis

5-Ply Minor Axis

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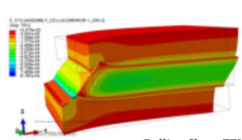
Rolling Shear Influence

Deflection Equation (USDA Handbook):

$$\delta = \underset{\text{(Flexure)}}{\frac{k_b \cdot W \cdot L^3}{E \cdot I}} + \underset{\text{(Shear)}}{\frac{k_s \cdot W \cdot L}{G \cdot A'}}$$

Table 9–1. Values of k_b and k_s for several beam loadings

Loading	Beam ends	Deflection at	k_b	k_s
Uniformly distributed	Both simply supported	Midspan	5/384	1/8
	Both clamped	Midspan	1/384	1/8
Concentrated at midspan	Both simply supported	Midspan	1/48	1/4
	Both clamped	Midspan	1/192	1/4
Concentrated at outer quarter span points	Both simply supported	Midspan	11/768	1/8
	Both simply supported	Load point	1/96	1/8
Uniformly distributed	Cantilever, one free, one clamped	Free end	1/8	1/2
Concentrated at free end	Cantilever, one free, one clamped	Free end	1/3	1



Rolling Shear FEM Model

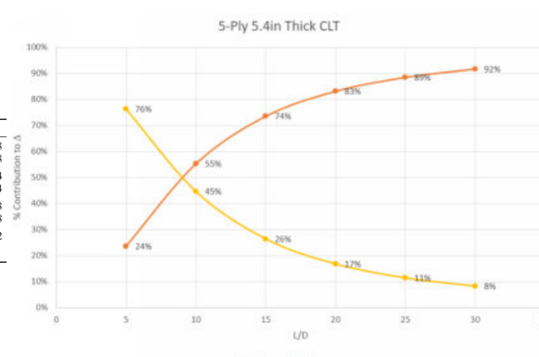


Figure 2. CLT deformation contribution from flexure and shear.

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CLT Test Specimen Failure Modes

Photo 8: Flatwise Shear Failure – Major Axis 3-ply

Specimen
Span/Depth ~6

Photo 2: Flexural Bending Failure – Major Axis 3-ply

Specimen
Span/Depth ~30

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CLT Layups and Associated Design Values

Example:

DRAFT

Table 1: Allowable Design Properties for Lumber Laminations used in Katerra CLT

Major Strength Direction						Minor Strength Direction					
$f_{b,0}$ (psi)	E (10^6 psi)	$f_{t,0}$ (psi)	$f_{c,0}$ (psi)	$f_{v,0}$ (psi)	$f_{s,0}$ (psi)	$f_{b,90}$ (psi)	E (10^6 psi)	$f_{t,90}$ (psi)	$f_{c,90}$ (psi)	$f_{v,90}$ (psi)	$f_{s,90}$ (psi)
875	1.4	550	1150	135	45	500	1.2	250	650	135	45

Note: Properties are based on visual grade SPF-#1/#2, and #3 for Major and Minor Strength Directions, respectively.

Table 2: Allowable Design Capacities for Katerra CLT in the US

	CLT Thickness (in)	Lamination Thicknesses in CLT Layup (in)									Major Strength Direction				Minor Strength Direction			
		=	⊥	=	⊥	=	⊥	=	⊥	=	$F_bS_{eff,0}$ (lb-ft/ft)	$EI_{eff,0}$ (10^6 lb-in²/ft)	$GA_{eff,0}$ (10^6 lb/ft)	$V_{s,0}$ (lb/ft)	$F_bS_{eff,90}$ (lb-ft/ft)	$EI_{eff,90}$ (10^6 lb-in²/ft)	$GA_{eff,90}$ (10^6 lb/ft)	$V_{s,90}$ (lb/ft)
3-Ply	3.2	1.08	1.08	1.08							1254	46	0.36	1166	97	1.51	0.41	389
	3.5	1.08	1.38	1.08							1464	59	0.37	1274	159	3.15	0.51	497
	3.8	1.38	1.08	1.38							1788	78	0.45	1382	97	1.51	0.42	389
	4.1	1.38	1.38	1.38							2049	96	0.46	1490	159	3.15	0.52	497
5-Ply	5.4	1.08	1.08	1.08	1.08	1.08					2884	176	0.72	1551	844	39.4	0.81	1125
	6.0	1.08	1.38	1.08	1.38	1.08					3351	227	0.74	1622	1203	66.5	1.02	1353
	6.3	1.38	1.08	1.38	1.08	1.38					4122	293	0.91	1900	985	50.2	0.84	1202
	6.8	1.35	1.35	1.35	1.35	1.35					4512	344	0.90	1941	1318	77	1.02	1406
7-Ply	7.6	1.08	1.08	1.08	1.08	1.08	1.08	1.08			5098	435	1.07	1959	1944	151	1.22	1555
	9.7	1.38	1.38	1.38	1.38	1.38	1.38	1.38			8324	908	1.37	2503	3174	315	1.56	1987
9-Ply	11.2	1.38	1.08	1.38	1.08	1.38	1.08	1.38	1.08	1.38	11342	1437	1.82	2292	3992	486	1.69	1778
	12.4	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	12904	1810	1.83	2347	5619	782	2.08	2154

Note: Tabulated Values are alowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS.

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Flatwise Bending and Shear NDS Chapter 10 Design Method

10.2 Reference Design Values

10.2.1 Reference Design Values

Reference design values for cross-laminated timber shall be obtained from the cross-laminated timber manufacturer's literature or code evaluation report.

10.2.2 Design Section Properties

Reference design values shall be used with design section properties provided by the cross-laminated timber manufacturer based on the actual layup used in the manufacturing process.

Table 10.3.1 Applicability of Adjustment Factors for Cross-Laminated Timber

		ASD only	ASD and LRFD					LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Column Stability Factor	Bearing Area Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
$F_b(S_{eff})' = F_b(S_{eff})$	x	C_D	C_M	C_t	C_L	-	-	2.54	0.85	λ
$F_t(A_{parallel})' = F_t(A_{parallel})$	x	C_D	C_M	C_t	-	-	-	2.70	0.80	λ
$F_v(t_v)' = F_v(t_v)$	x	C_D	C_M	C_t	-	-	-	2.88	0.75	λ
$F_s(Ib/Q)_{eff}' = F_s(Ib/Q)_{eff}$	x	-	C_M	C_t	-	-	-	2.88	0.75	-
$F_c(A_{parallel})' = F_c(A_{parallel})$	x	C_D	C_M	C_t	-	C_P	-	2.40	0.90	λ
$F_{c\perp}(A)' = F_{c\perp}(A)$	x	-	C_M	C_t	-	-	C_b	1.67	0.90	-
$(EI)_{app}' = (EI)_{app}$	x	-	C_M	C_t	-	-	-	-	-	-
$(EI)_{app-min}' = (EI)_{app-min}$	x	-	C_M	C_t	-	-	-	1.76	0.85	-

10.4 Special Design Considerations

10.4.1 Deflection

$$(EI)_{app} = \frac{EI_{eff}}{1 + \dfrac{16K_s I_{eff}}{A_{eff} L^2}} \qquad (10.4\text{-}1)$$

Table 10.4.1.1 Shear Deformation Adjustment Factors, K_s

Loading	End Fixity	K_s
Uniformly Distributed	Pinned	11.5
	Fixed	57.6
Line Load at midspan	Pinned	14.4
	Fixed	57.6
Line Load at quarter points	Pinned	10.5
Constant Moment	Pinned	11.8
Uniformly Distributed	Cantilevered	4.8
Line Load at free-end	Cantilevered	3.6

Deflection Due to Creep:

$$\Delta_T = K_{cr}\,\Delta_{LT} + \Delta_{ST} \qquad (3.5\text{-}1)$$

where:

K_{cr} = time dependent deformation (creep) factor
= 2.0 for cross-laminated timber used in dry service conditions as defined in 10.1.5.

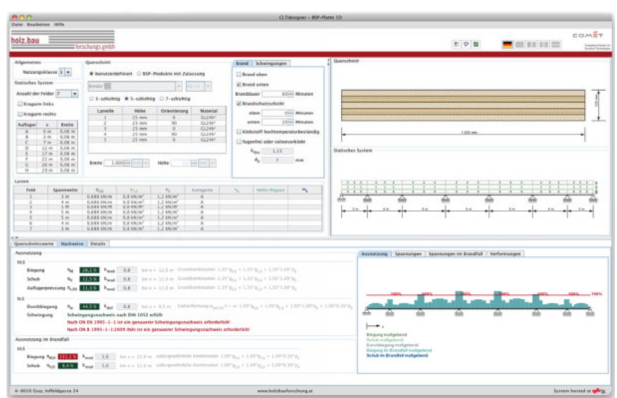
Flatwise Bending and Shear Design method – CLT Designer

TU Graz

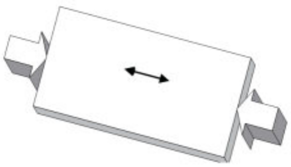
CLT Designer – To Eurocode 5
www.cltdesigner.at

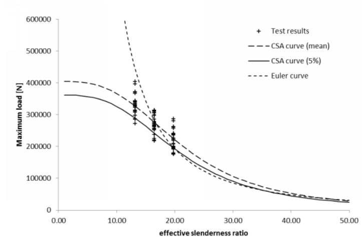
Provides Explicit Analysis for 1, 2, 3 span CLT floors, with design checks for:
- Strength
- Deflection
- Vibration
- Fire

Major European CLT manufacture product Lines are Included. Custom layups can be created.



Edgewise - Compression - (Tension)





3.7 Solid Columns

3.7.1 Column Stability Factor, C_P

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

c = 0.9 for structural glued laminated timber, structural composite lumber, and cross-laminated timber

Source: Horvat et al.

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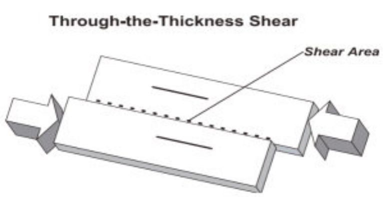
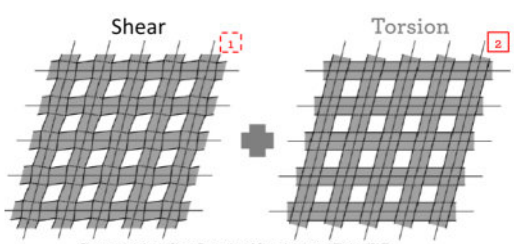
Edgewise – In-Plane Shear





Figures taken from "Shear Properties of Cross Laminated Timber (CLT) under in-plane load: Test Configuration and Experimental Study" by P. Dietsch.

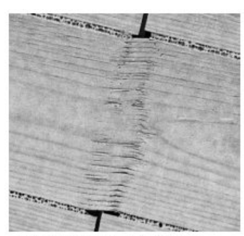


Figure taken from "Shear Properties of Cross Laminated Timber (CLT) under in-plane load: Test Configuration and Experimental Study" by P. Dietsch.

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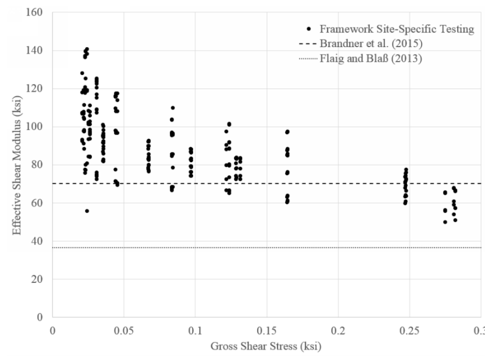
CLT Edgewise Shear Stiffness – Project Testing

Table 1. Comparison of CLT to reinforced concrete in-plane stiffness.

	Reinforced Concrete f'_c = 5000psi	CLT9 DF No. 1 E = 1800ksi	CLT9 / Concrete
EI_{eff}	2015ksi * I_g	1025ksi * I_g	50%
GA_{eff}	1610ksi * A_g	(35 to 75 ksi) * A_g	2 to 5%

Notes:
1. Cracked section modifiers for concrete taken as 0.5 for EI_{eff} and 1.0 for GA_{eff}.
2. GA_{eff} for CLT based on Flaig and Blaß (2013) and Brandner et al. (2015).



Source: Zimmerman

CLT Edgewise Shear – Strength Testing

PRG 320 Strength test standard ASTM D5456 a3
Sample size - 28 specimens
Specimen span/depth = 5.5
The characteristic value is divided by 2.1 to determine the ASD design value (Empirical)

$$\tau_{Apparent} = \frac{3V}{2t_1}\frac{\left[\left(t_1 + 2\frac{E_2}{E_1}t_2\right)d^2 - 2\frac{E_2}{E_1}t_2h^2\right]}{\left[\left(t_1 + 2\frac{E_2}{E_1}t_2\right)d^3 - 2\frac{E_2}{E_1}t_2h^3\right]}$$

Equation 1

CLT Edgewise Shear Strength Design Values

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ICC-ES Evaluation Report — ESR-3631

Issued September 2016

This report is subject to renewal September 2017.

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TABLE 3—REFERENCE DESIGN VALUES FOR IN-PLANE SHEAR OF THE STRUCTURLAM CROSSLAM® CLT PANELS[1]

GRADE	LAYUP DESIGNATION	FACE LAMINATION ORIENTATION (psi)	
		=[2]	⊥[2]
V2M1.1	105V	130	195
	175V	180	195[4]
	245V	180[3]	195[4]
	315V	180[3]	195[4]

For **SI**: 1 psi = 6,895 Pa

[1]The tabulated values are reference design values intended for Allowable Stress Design (ASD).
[2] "=": Major strength direction and "⊥": Minor strength direction.
[3]Based on test results from 175V.
[4]Based on test results from 105V.

APA Product Report® PR-L306
Revised September 5, 2018 — Page 4 of 4

Table 3. Allowable In-Plane Shear Stress for Nordic X-Lam[(a)] (For Use in the U.S.)

CLT Layup	Layup ID	Thickness, t_p (in.)	Allowable In-Plane Shear Stress	
			$F_{v,e,0}$ (psi)	$F_{v,e,90}$ (psi)
E1	78-3s	3 1/8	155[(b)]	190[(b)]
	89-3s	3 1/2	155	190[(b)]
	105-3s	4 1/8	155	190
	131-5s	5 1/8	185[(c)]	215[(c)]
	140-4s	5 1/2	145	190[(b)]
	143-5s	5 5/8	185[(c)]	215[(c)]
	175-5s	6 7/8	185	215
	197-7s	7 3/4	155[(b)]	215[(c)]
	213-7l	8 3/8	185[(c)]	215[(c)]
	220-7s	8 5/8	185[(c)]	215[(c)]
	244-7s	9 5/8	185[(c)]	215[(c)]
	244-7l	9 5/8	185[(c)]	215[(c)]
	267-9l	10 1/2	155[(b)]	215[(c)]
	314-9l	12 3/8	185[(c)]	215[(c)]

For SI: 1 psi = 0.006895 MPa

Edgewise Shear Strength Values Attained By:
- Structurlam
- Nordic
- KLH
- (Katerra)

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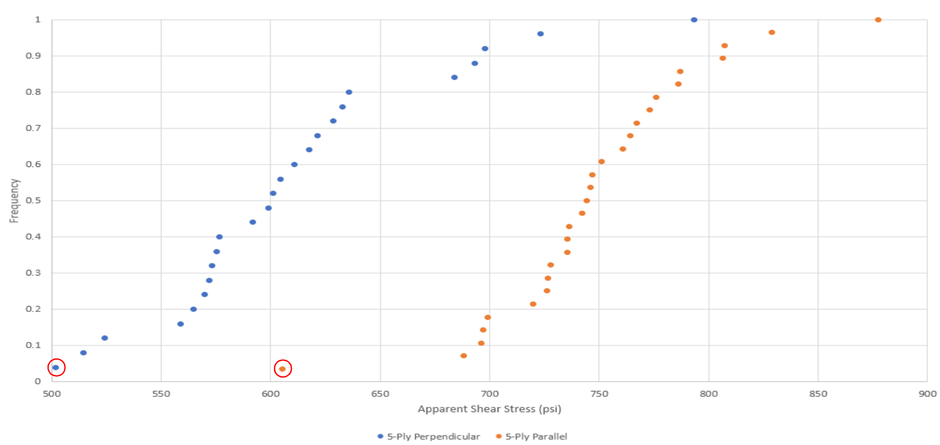
ASTM D5456 CLT 5-Ply Apparent Shear Stress Results



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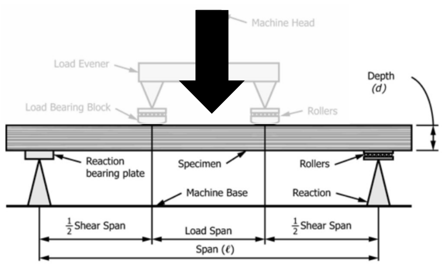
CLT Edgewise Shear – Stiffness Testing

PRG 320 Strength test standard ASTM D198 Sections 45 - 52
Sample size - 28 specimens
Specimen span/depths = 5.5, 6.5, 8.5, and 20
The shear modulus is the measured slope of line per Fig. 17



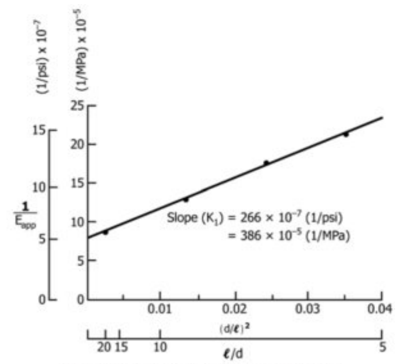


FIG. 17 Determination of Shear Modulus

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CLT Edgewise Shear Behavior – Stiffness Calculated

A calculated method for edgewise shear stiffness is provided in Flaig M. and Blass H. (2013):

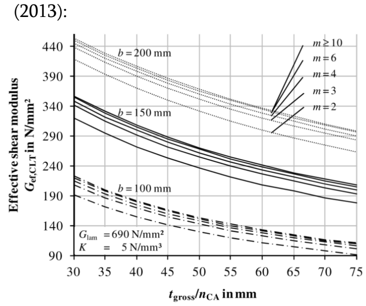

Figure 7: Effective shear modulus of CLT-beams

b = lamination width (mm)
nca = number of face bond lines
tgross = total thickness (mm)
m = number of longitudinal lamellae

<u>Suggested design method – for use with NDS:</u>

$$G_{eff,CA} = \frac{Kb^2}{5} \cdot \frac{n_{CA}}{t_{gross}} \cdot \frac{m^2}{(m^2+1)} \quad \text{Eqn A}$$

$$G_{eff,CLT} = \left(\frac{1}{G_{lam}} + \frac{1}{G_{eff,CA}}\right)^{-1} \quad \text{Eqn B}$$

where:

K = slip modulus of crossing areas (Use K = 14735 lb/in^3)
b = width of lamella
m = number of longitudinal lamellae
n_{CA} = number of glue lines within CLT cross section thickness
t_{gross} = CLT cross section thickness
G_{lam} = individual lamination shear modulus, psi (Use longitudinal E/16)

Example values of GA_{eff} are provided in Table A

Table A. Example GA_{eff} for in-plane shear[1]

	Number of Layers			
	3	5	7	9
G_{eff}	28.7 ksi	32.3 ksi	33.7 ksi	34.5 ksi
GA_{eff}	118.3 kips/in	222.0 kips/in	324.5 kips/in	426.6 kips/in

1. Calculated values of G_{eff} and GA_{eff} are based on use of Equations C-B7 and C-B8 with the following inputs: E=1,400000 psi, lamella width b = 5.5 inches, number of longitudinal lamellae based on a 48" panel width, slip modulus of crossing areas K = 14,735 lb/in^3 (4.0 N/mm^3) and lamella thickness =1.375 inch.

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Edgewise Bending Behavior – Strength & Stiffness

CLT On Edge – Long Span Roof Beams

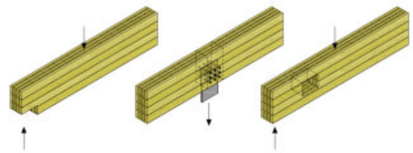
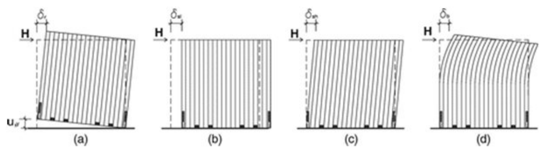


Fig. 2: Cross-laminated timber beams are less susceptible to cracking since cross-layers oriented orthogonally to the beam axis take effect of reinforcement



Uplift | Sliding | Shear | Flexure

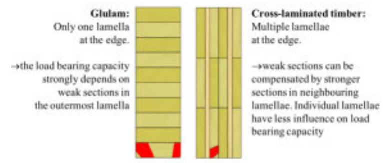


Fig. 3: Homogenisation due to parallel alignment of boards

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Glulam Beam & Column Specification

Source: Western Arch Rib

Manufacturing Standard
- ANSI A190.1, 405, 117
- CSA O122, O177
- EN 14080

Species Group
- DF-L/SPF/AC/Euro Spruce

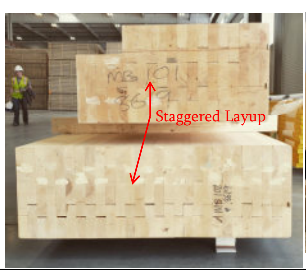
Adhesive
- PRF/MF/PUR

Stress Class
Camber
Lamination thickness
Layup width
- Staggered, Block Glue

Layup Type
- Balanced/Unbalanced

Intended Use
- Beam/Column
- Fire rating
- Interior/Exterior

Appearance Classification
Moisture Content
Metal hardware connections



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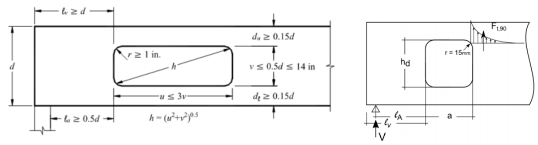
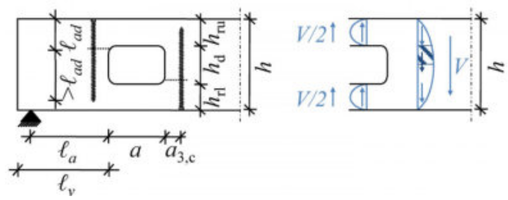
Glulam Beams – Building Service Penetrations

AITC TECHNICAL NOTE 19
GUIDELINES FOR EVALUATION OF HOLES AND NOTCHES IN STRUCTURAL GLUED LAMINATED TIMBER BEAMS
(July 2012)





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Glulam Beams – Notches & Concentrated Loads

AITC TECHNICAL NOTE 19
GUIDELINES FOR EVALUATION OF HOLES AND NOTCHES IN STRUCTURAL GLUED LAMINATED TIMBER BEAMS
(July 2012)

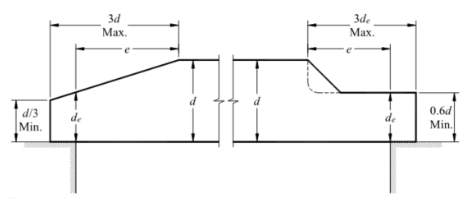
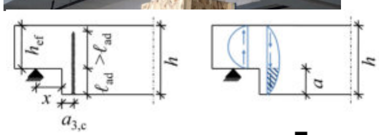
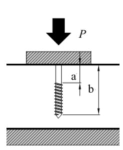
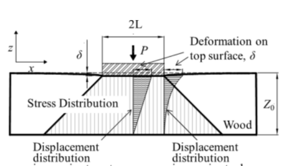
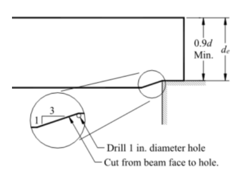


Figure 5. *Notch restrictions on compression face at ends*









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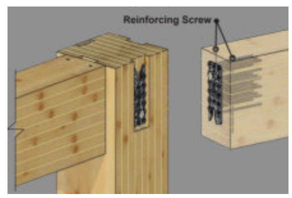
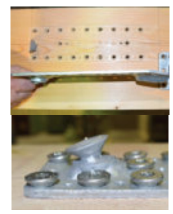
Glulam Beam-Column Connections – Seismic Drift Testing

Deformation Compatibility to Satisfy ASCE 7-10 12.12.5

(Source: KPFF)





(Source: My Ti Conn)

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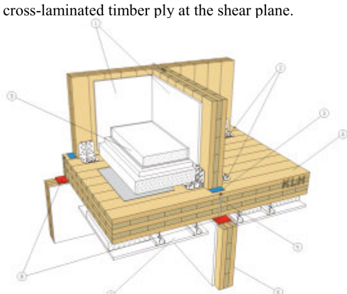
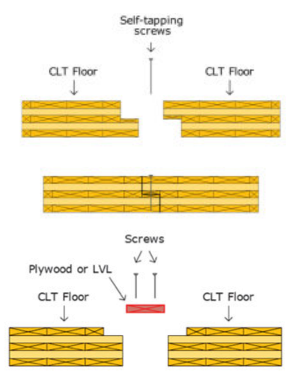
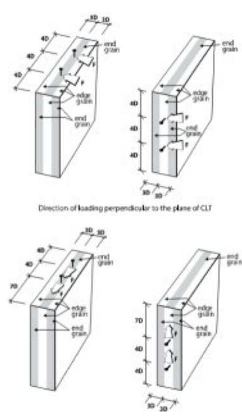
NDS – CLT Fastener Design Requirements

12.3.3.5 Dowel bearing strengths, F_e, for dowel-type fasteners installed into the panel face of cross-laminated timber shall be based on the direction of loading with respect to the grain orientation of the cross-laminated timber ply at the shear plane.







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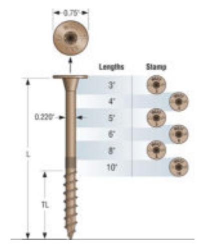
Mass Timber Threaded Fasteners



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- ETA
- Pending - IAPMO (AC 233)

PRODUCT APPROVALS
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- ICC-ES (AC 233)

PRODUCT APPROVALS
- IAPMO (AC 233)

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CLT Fastener Design Engineering Guidance

February 26, 2018

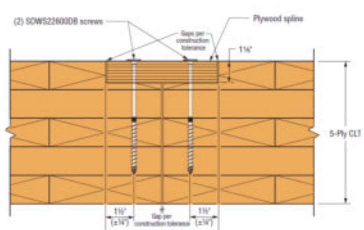
RE: Simpson Strong-Tie® Strong-Drive® SDWS Timber Screws to Fasten Plywood Single-Surface Splines on CLT Diaphragms

To Whom It May Concern;

Table 1. Reference allowable load and slip modulus for SDWS Timber Screws (SDWS22400DB and SDWS22600DB) for CLT surface spline fastening with 1-1/8-in. APA rated Sturd-I-Floor wood structural panel, single-surface splines.

CLT Wood Species Combination	Allowable load per Fastener (lb.)	Slip Modulus (in./K)
DFL	375	0.017
SPF-N SPF-S	335	0.017

1. Allowable loads are given at C_D=1.0 and maybe increased up to C_D=1.6 as permitted by the building code.
2. Applicable adjustments shall be applied following the ANSI/AWC NDS-15 or NDS-18.
3. Design values are applicable for all grain orientation combinations of major strength directions in the CLT and the wood structural panel spline and grades of CLT for the species combinations listed.
4. Designer is responsible to check shear capacity of spline (shear through the thickness and rolling shear).



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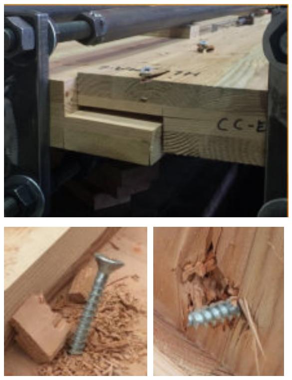
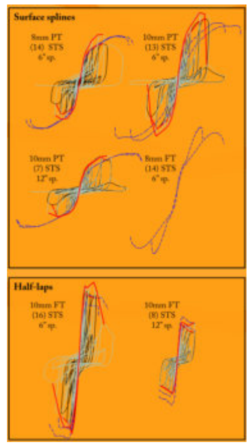
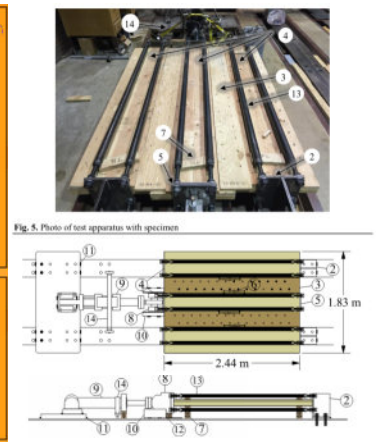
CLT Fasteners – OSU Testing







(Source: Sullivan et al)

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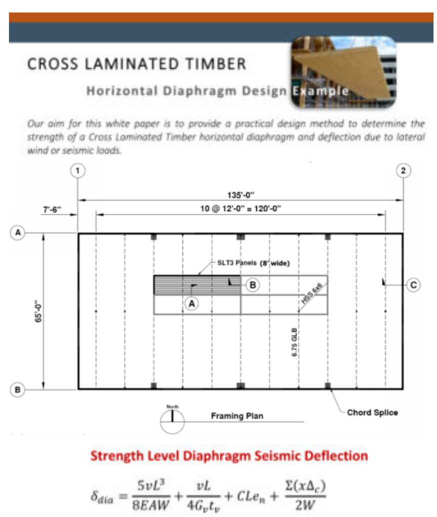
CLT Diaphragm Floor Design Example

A method of design is presented that aligns with the framework of IBC and ASCE 7.

The AWS WDSC is currently balloting proposed code language and commentary for CLT diaphragm for 2021 SPDWS.

The AIA Seattle Mass Timber Group is working with SEAW EEC to draft an white paper on this subject.



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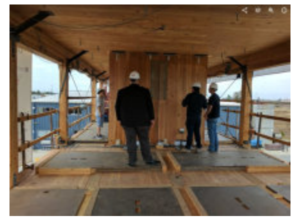
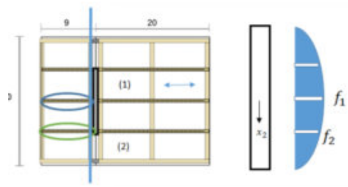
CLT Diaphragms Floor Shake Table Testing

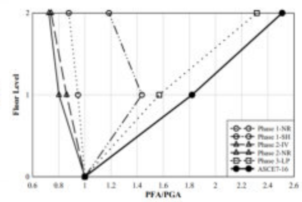
A method of design based on ASCE 7-16 Alternative Diaphragm option.

P.I. – Dr. Andre Barbosa



TALLWOOD DESIGN INSTITUTE





Source: Barbosa et al

Fire Rated Mass Timber Members

Code Requirements: Approvals

Code compliance:

- Pre-application meeting(s)
- Construction type awareness
- Code compliance documentation
- Fire protection strategy

Code Requirements: Fire-Resistance Rating

Fire-Resistance rating (FRR):

Period of time a building element is intended to perform a given structural function

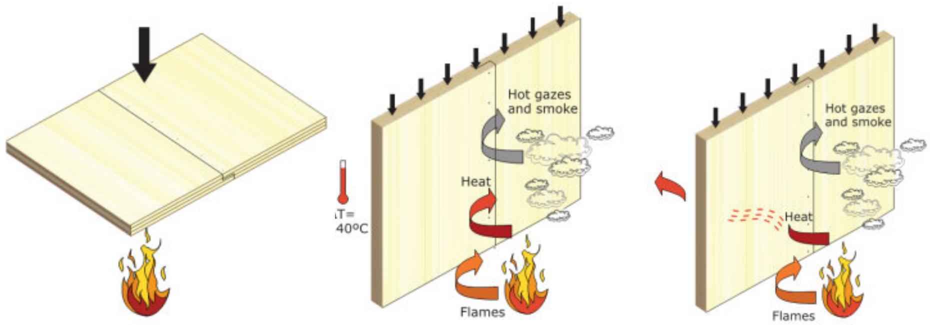
FRR's defined by Table 601

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Code Requirements: Fire-Resistance Rating

Performance criteria
- Stability
- Integrity
- Insulation



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Code Requirements: Fire-Resistance Rating

Methods of compliance (2018 IBC 703.3)
- ASTM E119 Standard Fire Test
- Prescriptive design (Section 721)
- Calculations (Section 722)
- Engineering analysis (PBD)

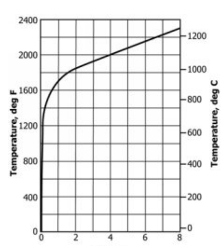

FIG. 1 Time-Temperature Curve

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Code Requirements: Fire-Resistance Rating

2018 IBC Required Fire-Resistance Ratings (2018 IBC Table 601)

Parameter	I-A	I-B	II-A	II-B	III-A	III-B	IV-HT	V-A	V-B
Allowable Height	UL	180	85	75	85	75	85	70	60
Allowable # Stories	UL	12	5	5	5	5	5	4	3
Allowable Area	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000
FRR									
Primary Frame	3	2	1	0	1	0	HT	1	0
Ext Bearing Walls	3	2	1	0	2	2	2	1	0
Int Bearing Walls	3	2	1	0	1	0	HT	1	0
Floors	2	2	1	0	1	0	HT	1	0
Roof	1-1/2	1	1	0	1	0	HT	1	0

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Code Requirements: Fire-Resistance Rating

Mass Timber Fire-Resistance Ratings (2021 IBC Table 601)

Parameter	IV-A*	IV-B*	IV-C*	IV-HT
Allowable Height	270	180	85	85
Allowable # Stories	18	12	9	5
Allowable Area	184,500	123,000	76,875	61,500
Exposed Area	0%	Up to 20/40%	100%	100%
Sprinkler Protection	NFPA 13	NFPA 13	NFPA 13	NFPA 13
FRR				
Primary Frame	3	2	2	HT
Ext Bearing Walls	3	2	2	2
Int Bearing Walls	3	2	2	HT
Floors	2	2	2	HT
Roof	1-1/2	1	1	HT
Concealed Spaces	Permitted	Permitted	Permitted	NP

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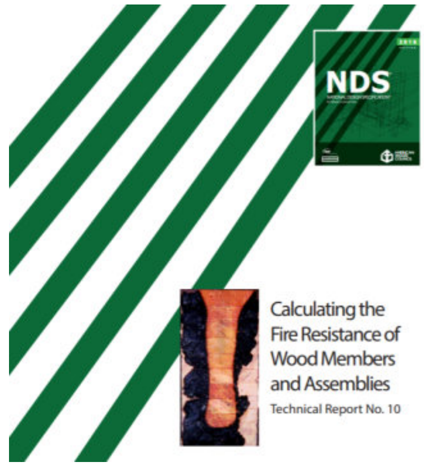
Code Requirements: Fire-Resistance Rating

FRR's for Mass Timber

- Calculated method using:
- NDS Chapter 16 and AWC TR-10
- Demand / Capacity calculations for the required FRR

NDS Chapter 16 and AWC TR-10



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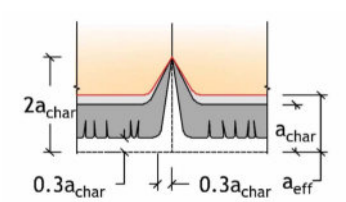
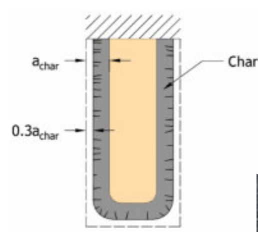
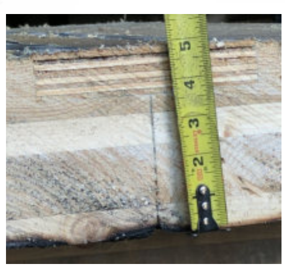
Code Requirements: Fire-Resistance Rating

Wood char and contraction (TR-10)







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Code Requirements: Fire-Resistance Rating

Char rates and adjustment factors (NDS / TR-10)

CLT

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

Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (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

Glulam

Table 16.2.1A Char Depth and Effective Char Depth (for β_n = 1.5 in./hr.)

Required Fire Resistance (hr.)	Char Depth, a_{char} (in.)	Effective Char Depth, a_{eff} (in.)
1-Hour	1.5	1.8
1½-Hour	2.1	2.5
2-Hour	2.6	3.2

Table 1.4.2 Allowable Design Stress to Average Ultimate Strength Adjustment Factors

	F	*1/k*	*c*	*Assumed COV*	*K*
Bending Strength	F_b	2.1 [1]	1-1.645 COV_b	0.16 [2]	2.85
Tensile Strength	F_t	2.1 [1]	1-1.645 COV_t	0.16 [2]	2.85
Shear Strength	F_v	2.1 [1]	1-1.645 COV_v	0.14 [2]	2.75
Compression Strength	F_c	1.9 [1]	1-1.645 COV_c	0.16 [2]	2.58
Buckling Strength	E_{05}	1.66 [4]	1-1.645 COV_E	0.11 [5]	2.03

Code Requirements: Fire-Resistance Rating

Delamination (CLT EN 1995)

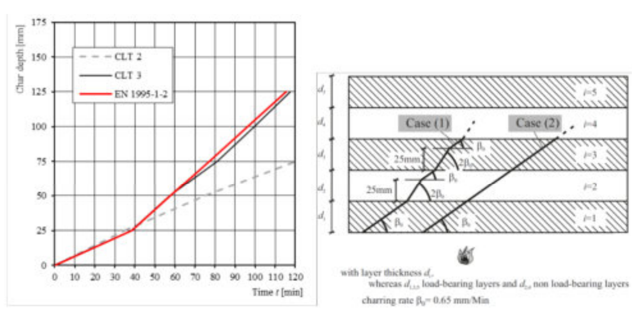

Figure 24. Comparison of char depth for the 175 thick CLT elements with the char model given in EN 1995-1-2(left). EN 1995-1-2 model using the double charring rate (Case 1) (right).

Code Requirements: Fire-Resistance Rating

ASTM E119 Full-scale furnace testing

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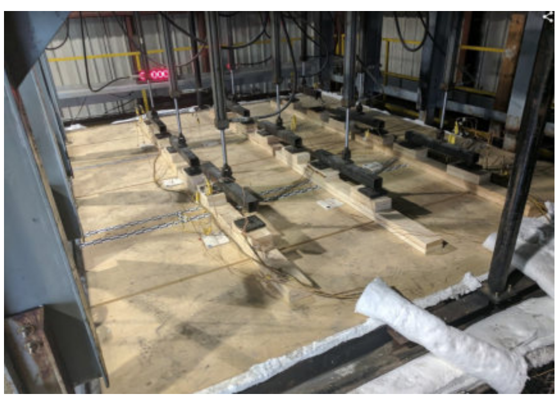
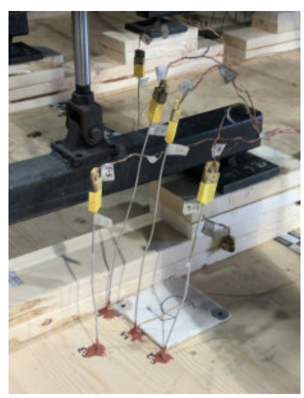
Code Requirements: Fire-Resistance Rating

ASTM E119 Full-scale furnace testing





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Code Requirements: Fire-Resistance Rating

ASTM E119 Full-scale furnace testing

85 June 12, 2019 Engineering Requirements for Mass Timber Buildings

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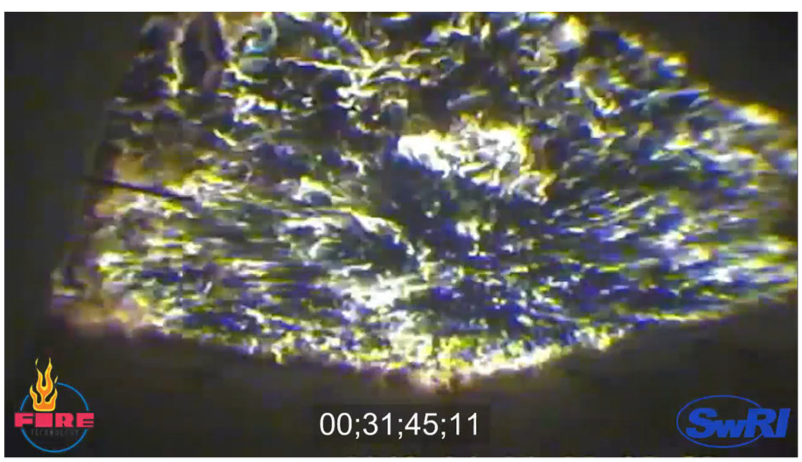
Code Requirements: Fire-Resistance Rating

ASTM E119 Full-scale furnace testing



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Code Requirements: Fire Protection Systems

Passive systems:

- Encapsulation (non-combustible protection)
- Charring
- Firestopping




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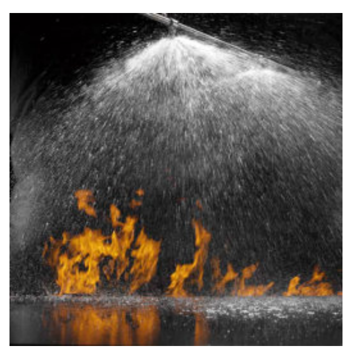
Code Requirements: Fire Protection Systems

Active systems:

- Fire extinguishers
- Fire alarm systems
- Automatic sprinkler protection





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Code Requirements: Fire Protection Systems

Allowances for exposed mass timber

- Type IV-A: 0% exposed
- Type IV-B: 20-40% exposed
- Type IV-C: 100% exposed

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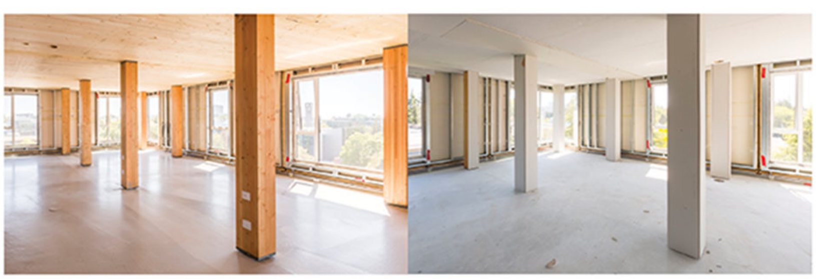
Code Requirements: Fire Protection Systems

Allowances for exposed mass timber

- Type IV-A: 0% exposed
- Type IV-B: 20-40% exposed
- Type IV-C: 100% exposed



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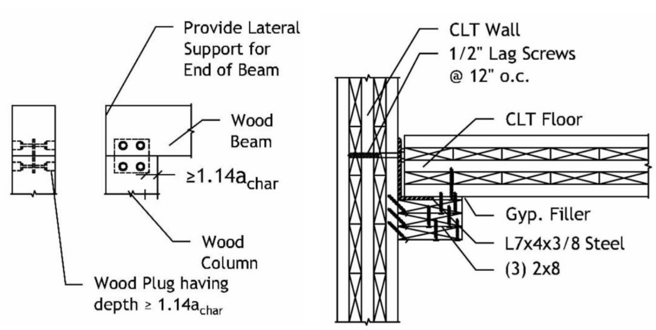
Fire Rated Mass Timber Beam Connections

Code Requirement: Connection Protection

Connections protected for the required FRR:

- Wood
- Fire-rated gypsum board
- Other approved materials



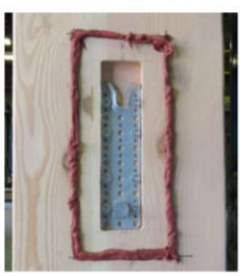
Code Requirement: Connection Protection

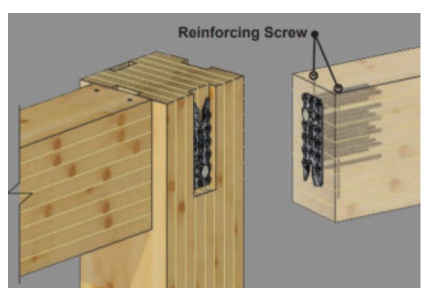
ASTM E119 Beam-column loaded furnace test

Source: Softwood Lumber Board

Code Requirement: Connection Protection

ASTM E119 Beam-column loaded furnace test





Beam 1:
Ricon 290

Beam 2:
2x Ricon 200

Source: Softwood Lumber Board

Code Requirement: Connection Protection

ASTM E119 Beam-column loaded furnace test

Source: Softwood Lumber Board

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Code Requirement: Connection Protection

ASTM E119 Beam-column loaded furnace test

Source: Softwood Lumber Board

96 June 12, 2019 Engineering Requirements for Mass Timber Buildings

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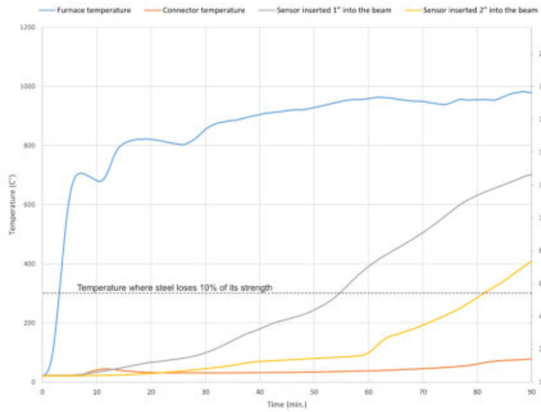
Code Requirement: Connection Protection

Thermocouple temperature data



Test #2: Double Ricon S VS 200x80test, temperature vs time

Source: Softwood Lumber Board

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Code Requirement: Connection Protection

Fire-resistance rating summary

Test	Beam	Connector	Applied Load	FRR
1	8.75" x 18" (222mm x 457mm)	1 x Ricon S VS 290x80	3,905lbs (17.4kN)	1hr
2	10.75" x 24" (273mm x 610mm)	Staggered double Ricon S VS 200x80	16,620lbs (73.9kN)	1.5hrs
3	10.75" x 24" (273mm x 610mm)	1 x Megant 430	16,620lbs (73.9kN)	1.5hrs

All connectors passed and achieved at least 1hr FRR.

Source: Softwood Lumber Board

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CLT Walls

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CLT Shear Wall Lateral Systems

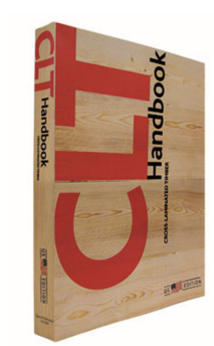
Statewide Alternate Method
January 2015

State of Oregon
Building Codes Division
Better Buildings for Oregon

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

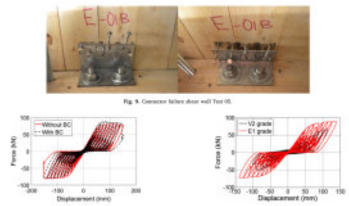
Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

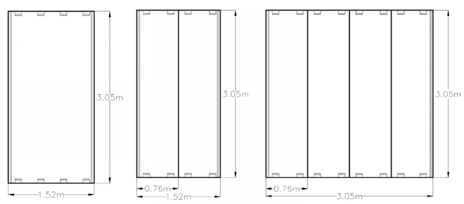
Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R[a]	Overstrength Factor, Ω_0[g]	Deflection Amplification Factor, C_d[b]	Structural System Limitations Including Structural Height, h_n (ft) Limits[c] — Seismic Design Category B	C	D[d]	E[d]	F[e]
17. Light-frame walls with shear panels of all other materials	14.1 and 14.5	2	2 ½	2	NL	NL	35	NP	NP
18. Light-frame (cold-formed steel) wall systems using flat strap bracing	14.1	4	2	3 ½	NL	NL	65	65	65
19. Cross-laminated timber shear walls[l]	14.1 and 14.5	2	2 ½	2	NL	NL	NL	NL	NL

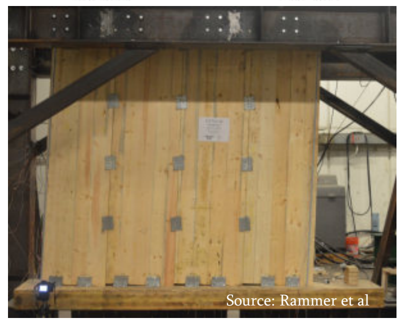


100

CLT Shear Walls – FEMA P-695






Source: Rammer et al

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Best Practice: CLT Floor Plates - Multifamily

102 June 12, 2019 Engineering Requirements for Mass Timber Buildings

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Mass Timber Products

CLT
(Walls, Floors)

Glulam
(Columns, Beams)

Fastening Systems
(Screws, Plates)

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Cross-Laminated Timber – IBC Definition

104 June 12, 2019 Engineering Requirements for Mass Timber Buildings

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Project Requirements

Project	Multifamily Project
Jurisdiction	Anywhere USA
Code	IBC 2018
Use	R-2
Stories	5 wood over concrete podium
Height	<85ft
Sprinklered	Yes
Construction Type	VA (or IIIA)
Fire Resistive Rating	1hr

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CLT Floor Plates

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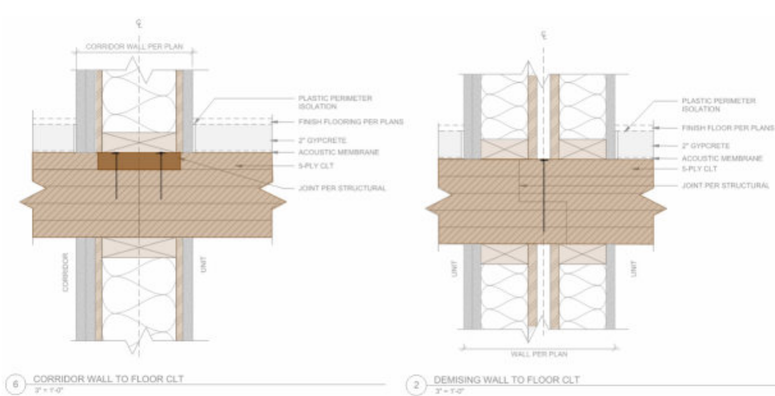
Floor Details



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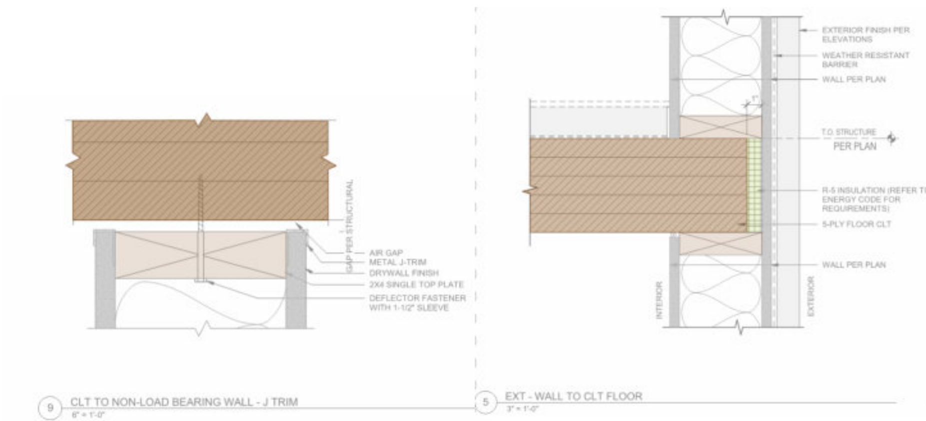
Floor Details



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CLT Floor Plate – Structural

CLT Product Certifications

- APA PRG 320
- Product Reports (e.g. APA, ICC-ES)

CLT Design Methods

- NDS Chapter 10 (bending, shear, tension, compression)
- NDS Chapter 12 (fasteners)
- NDS Chapter 16 (fire char calculated method)

Diaphragms CLT Horizontal Diaphragm Design Example

Fasteners

- IBC Chapter 23, or
- ICC-AC 233

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.

602.3 Type III. Type III construction is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by this code. *Fire-retardant-treated wood* framing complying with Section 2303.2 shall be permitted within *exterior wall* assemblies of a 2-hour rating or less.

602.5 Type V. Type V construction is that type of construction in which the structural elements, *exterior walls* and interior walls are of any materials permitted by this code.

ACCEPTANCE CRITERIA FOR CROSS-LAMINATED TIMBER PANELS FOR USE AS COMPONENTS IN FLOOR AND ROOF DECKS

AC455

ACCEPTANCE CRITERIA FOR ALTERNATE DOWEL-TYPE THREADED FASTENERS

AC233

110 June 12, 2019 Engineering Requirements for Mass Timber Buildings

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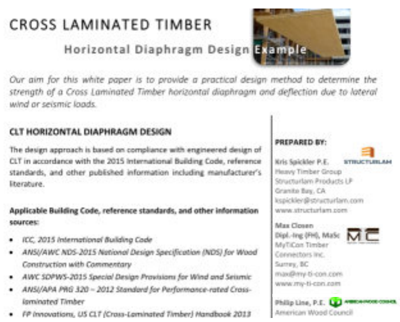
Floor Diaphragms – Design Method

Diaphragms: CLT Horizontal Diaphragm Design Example

Project-specific design method provided by the SEoR



CROSS LAMINATED TIMBER

Horizontal Diaphragm Design Example

Our aim for this white paper is to provide a practical design method to determine the strength of a Cross Laminated Timber horizontal diaphragm and deflection due to lateral wind or seismic loads.

CLT HORIZONTAL DIAPHRAGM DESIGN

The design approach is based on compliance with engineered design of CLT in accordance with the 2015 International Building Code, reference standards, and other published information including manufacturer's literature.

Applicable Building Code, reference standards, and other information sources:

- *ICC, 2015 International Building Code*
- *ANSI/AWC NDS-2015 National Design Specification (NDS) for Wood Construction with Commentary*
- *AWC SDPWS-2015 Special Design Provisions for Wind and Seismic*
- *ANSI/APA PRG 320 – 2012 Standard for Performance-rated Cross-laminated Timber*
- *FP Innovations, US CLT (Cross-Laminated Timber) Handbook 2013*

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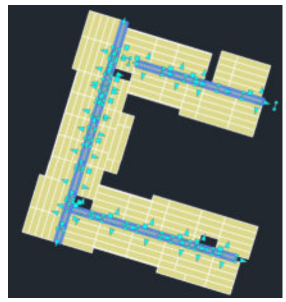
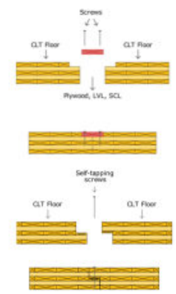
www.my-ti-con.com

Philip Line, P.E.
American Wood Council

IBC Section 1604.4 Analysis

Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system that provides a complete load path capable of transferring loads from their point of origin to the load-resisting elements.





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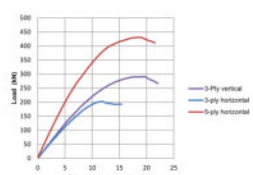
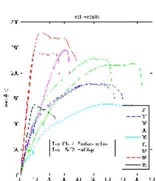
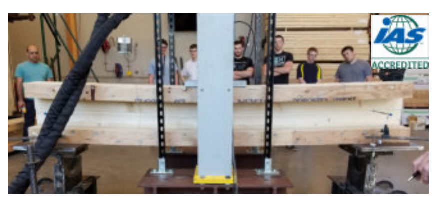
Diaphragm Testing



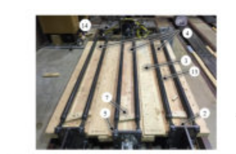


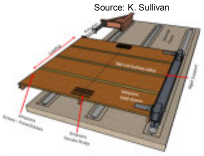


ASTM D5456 In-Plane Shear Strength (WSU)

UCSD Shake Table Testing (2017)

Source: K. Sullivan





CLT Spline Joint Connection (OSU) CLT Floor System Tests (Clemson)

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CLT Floor Plate - Fire

CLT Fire Ratings:

- FRR to ASTM E 119
- Firestops to ASTM E 814
- Flame spread & smoke index to ASTM E 84

703.3 Methods for determining fire resistance. The application of any of the methods listed in this section shall be based on the fire exposure and acceptance criteria specified in ASTM E 119 or UL 263. The required *fire resistance* of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

1. Fire-resistance designs documented in approved sources.
2. Prescriptive designs of fire-resistance-rated building elements, components or assemblies as prescribed in Section 721.
3. Calculations in accordance with Section 722.
4. Engineering analysis based on a comparison of building element, component or assemblies designs having *fire-resistance ratings* as determined by the test procedures set forth in ASTM E 119 or UL 263.
5. Alternative protection methods as allowed by Section 104.11.
6. Fire-resistance designs certified by an approved agency.

703.2 Fire-resistance ratings. The *fire-resistance rating* of building elements, components or assemblies shall be determined in accordance with the test procedures set forth in ASTM E 119 or UL 263 or in accordance with Section 703.3. The *fire-resistance rating* of penetrations and fire-resistant joint systems shall be determined in accordance Sections 714 and 715, respectively.

714.4.1.2 Through-penetration firestop system. *Through penetrations* shall be protected by an *approved through-penetration firestop system* installed and tested in accordance with ASTM E 814 or UL 1479, with a minimum positive pressure differential of 0.01 inch of water (2.49 Pa). The system shall have an F rating/T rating of not less than 1 hour but not less than the required rating of the floor penetrated.

803.1.1 Interior wall and ceiling finish materials. Interior wall and ceiling finish materials shall be classified in accordance with ASTM E 84 or UL 723. Such *interior finish* materials shall be grouped in the following classes in accordance with their flame spread and *smoke-developed indexes*.

Class A: = Flame spread index 0-25; smoke-developed index 0-450.

Class B: = Flame spread index 26-75; smoke-developed index 0-450.

Class C: = Flame spread index 76-200; smoke-developed index 0-450.

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CLT Floor Plate - Fire

FRR to ASTM E 119

Firestops to ASTM E 814

Flame spread to ASTM E 84

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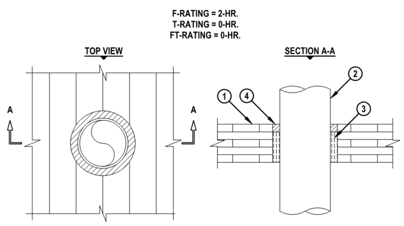
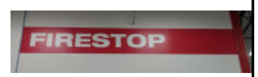
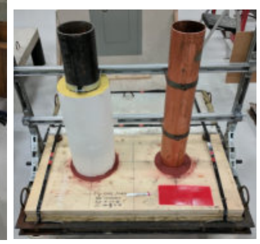
CLT Floor Plate – Firestop Documentation Example

Tested to: ASTM E 814



1. 5-PLY CROSS LAMINATED TIMBER FLOOR ASSEMBLY (MINIMUM 5-1/8" THICK) (2-HR. FIRE-RATING).
2. PENETRATING ITEM TO BE ONE OF THE FOLLOWING :
   A. MAXIMUM 6" NOMINAL DIAMETER STEEL PIPE (SCHEDULE 40 OR HEAVIER).
   B. MAXIMUM 6" NOMINAL DIAMETER CAST IRON PIPE.
   C. MAXIMUM 6" NOMINAL DIAMETER STEEL CONDUIT.
   D. MAXIMUM 4" NOMINAL DIAMETER EMT.
   E. MAXIMUM 3" NOMINAL DIAMETER COPPER PIPE OR TUBING.
   F. MAXIMUM 2" NOMINAL DIAMETER FLEXIBLE STEEL CONDUIT.
3. MINIMUM 4" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED, RECESSED TO ACCOMMODATE SEALANT AND FLUSH WITH BOTTOM SURFACE OF FLOOR.
4. MINIMUM 1" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP SEALANT.





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CLT Floor Plate - Acoustics

- Air-borne sound
- Structure-born sound

SECTION 1207
SOUND TRANSMISSION

1207.1 Scope. This section shall apply to common interior walls, partitions and floor/ceiling assemblies between adjacent *dwelling units* and *sleeping units* or between *dwelling units* and *sleeping units* and adjacent public areas such as halls, *corridors*, *stairways* or *service areas*.

1207.2 Air-borne sound. Walls, partitions and floor/ceiling assemblies separating *dwelling units* and *sleeping units* from each other or from public or service areas shall have a sound transmission class of not less than 50, or not less than 45 if field tested, for air-borne noise when tested in accordance with ASTM E 90. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. This requirement shall not apply to entrance doors; however, such doors shall be tight fitting to the frame and sill.

1207.3 Structure-borne sound. Floor/ceiling assemblies between *dwelling units* and *sleeping units* or between a *dwelling unit* or *sleeping unit* and a public or service area within the structure shall have an impact insulation class rating of not less than 50, or not less than 45 if field tested, when tested in accordance with ASTM E 492.

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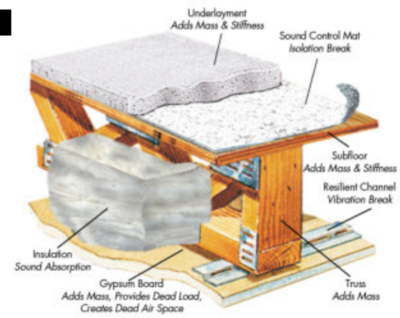
CLT Floor Plate with Gypcrete Topping

CLT Floor Plate with Gypcrete Topping

Assembly Description from Top to Bottom (15.2)	
1	About 2/5 in. (10 mm) carpet or floating flooring on 0.12 in. (3 mm) resilient underlayment (rubber mat, e.g. InsonoBois or similar; textured felt, e.g. Thermason HD or similar)
2	At least 15.6 lb./ft.² (76 kg/m²) wet topping (concrete, gypcrete, gypsum, or similar)
3	Resilient underlayment, e.g. 2/5 in. (10 mm) rubber mat (Insonomat), 3/4 in. (18 mm) textured felt (Felt S-125), 1/2 in. (12 mm) low density wood fiberboard, etc.
4	5-layer CLT of 6 7/8 in. (175 mm)

CLT Floor Assembly



Baseline – Standard Joist Floor

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Acoustic Test Reports

intertek
Total Quality. Assured.

IAS INTERNATIONAL ACCREDITATION SERVICE®

USG CORPORATION
ACOUSTICAL PERFORMANCE RESEARCH REPORT

SCOPE OF WORK
FLOOR ZONE TESTING - SYSTEM SPLIT IN QUADRANTS: BARE GYPSUM FLOOR

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CLT Floor Plate – Summary of Code Requirements

	Item	Code Reference	Test/Standard
Structural	Manufacturing Standard	IBC 2303.1.4	APA PRG 320
	Design Values - Out of Plane	IBC 1706.1	APA Product Reports (ASTM ASTM D198 or D4761)
	Design Values - In-Plane Shear	IBC 1706.1	ICC AC 455 (ASTM D5456 Annex 3)
	Design Method - Out-of-Plane	NDS Chapter 10	-
	Design Method - In Plane	-	-
	Fasteners	NDS Chapter 12	ICC AC 233 (ASTM D1761)
	Fire	NDS Chapter 16	
	Vibration	-	CLT Handbook, etc.
	Special Inspection	IBC 1704.3	-
Fire	Fire Resistive Rating	IBC 703.2	ASTM E119
	Flame Spread	IBC 803.1.1	ASTM E84
	Firestops	IBC 714.4.1.2	ASTM E814
	Fire Joints	IBC 714.3	ASTM E1966
	Concealed Spaces	IBC 718	NFPA 13
	Special Inspection	IBC 1704.3	-
Acoustics	Airborne Sound Transmission	IBC 1207.1	ASTM E90
	Structure-borne Sound Transmission	IBC 1207.1	ASTM E492

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Additional Items

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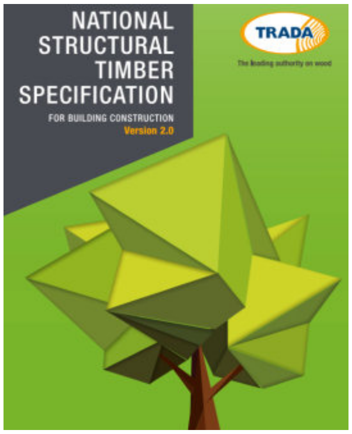
Code of Standard Practice



The NATIONAL STRUCTURAL TIMBER SPECIFICATION (the NSTS) is an ambitious initiative by TRADA to support the rapidly increasing use of timber. It aims to be the definitive, comprehensive, stand-alone national specification for structural timber, complementing the existing national specifications that are widely used for steel and concrete buildings. The NSTS covers information exchange, materials, Fabrication, Erection, protection and Quality Assurance.

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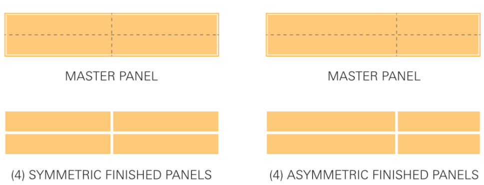
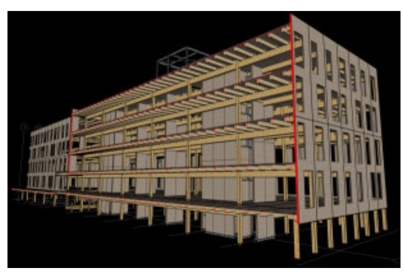
CNC Fabrication – Modelling – Project Delivery

Design for Fabrication





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Special Inspection Requirements

ICC Ad Hoc Committee for Tall Wood is developing a Chapter 17 Table 1705.5.3 for >85ft buildings. Items addressed will include:

- Anchorage of mass timber to deep foundation systems
- Erection and sequence
- Connections required to meet design loads
  - Threaded Fasteners
    - Installation Equipment
    - Pre-drilling holes
    - Screw specification
  - Adhesive anchors
  - Bolted connections
  - Other proprietary concealed connections
- Field gluing
- Fire protection of connections

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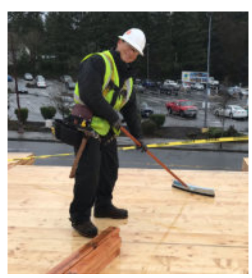
Moisture Control Plan

Structural specifications should require the contractor to submit this document. Mass timber behaves differently that light wood framing.

Scope to include:

- End grain sealer, Taped joints, Squeegee, etc.
- Other coatings/temp coverings
- Active drying and dehumidification
- MC Record Log files – track target values
- Methods of repair/restoration of architecturally exposed wood
- Roofing system application




Guide for On-site Moisture Management of Wood Construction
March 2016
By:
Jieying Wang, Senior Scientist, Advanced Building Systems
FPInnovations

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CLT Sustainability

LEED v4 (MR)

LEED BD+C: New Construction | v4 - LEED v4
Building product disclosure and optimization - environmental product declarations
Possible 2 points

LEED BD+C: New Construction | v4 - LEED v4
Building life-cycle impact reduction
Possible 5 points
Option 4. whole-building life-cycle assessment (3 points)

LEED BD+C: New Construction | v4 - LEED v4
Building product disclosure and optimization - material ingredients
Possible 2 points

FSC vs. SFI
- Land use
- Habitat
- Biodiversity
- Fair Labor
- Indigenous Peoples' Rights
- Local Economies

PEFC

ENVIRONMENTAL PRODUCT DECLARATION
According to ISO 14025

Declaration owner	KLH Massivholz GmbH
Publisher	Institut Bauen und Umwelt (IBU)
Program support	Institut Bauen und Umwelt (IBU)
Declaration number	EPD-KLH-2012111-E
Issue date	01.02.2012
Valid until	31.01.2017

KLH Solid Timber Panels (Cross-Laminated Timer)
KLH Massivholz GmbH

Environmental Product Declaration

Nordic X-Lam™

Product Description

Type III environmental product declaration for cross-laminated timber manufactured at Nordic Structures developed according to PCR for North American Structural and Architectural Wood Products (FPInnovations, November 2011).

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Engineering Requirements for Mass Timber Buildings

Structural Engineers Association of Washington

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