Fire and Structural Analysis for Mass Timber Buildings

Jessica Scarlett, Scott Breneman, and Ricky McLain

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

Course Description

Traditionally, the role of the structural engineer on building projects has focused on structure-related tasks – member sizing, connection detailing, general notes, and specifications for structural components. Design criteria such as fire-resistance ratings, acoustics, and aesthetics have primarily been the architect's domain. However, when it comes to mass timber, especially tall timber buildings, the structure often contributes to the building's passive fire resistance while functioning as an exposed finish. This combination of structure, finish, and fire resistance makes the mass timber design process a necessarily collaborative effort between architect and engineer. This webinar will discuss how these topics are interrelated and will provide examples of fire and structural designs that meet 1- and 2-hour rating requirements of mid-rise and tall mass timber buildings within the IBC.

Learning Objectives

1. Explain the building code requirements for fire-resistance ratings of exposed mass timber structural elements in mid-rise and tall structures.
2. Explore the options of structural char calculations vs. furnace fire testing in order to demonstrate compliance with code-mandated hourly ratings of mass timber floor, roof and wall panels.
3. Highlight changes to the 2021 and 2024 IBC which permit taller mass timber buildings, with more exposed timber surfaces.
4. Review the options of designing fire protected connections and penetrations in an exposed mass timber building.

Glue Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo: Freres Lumber

Photo: StructureCraft

Photo: LendLease

Photo: LEVER Architecture

Dowel-Laminated Timber (DLT)

Photo: StructureCraft

Nail-Laminated Timber (NLT)

Photo: Think Wood

Glue-Laminated Timber (GLT)

Plank orientation

Photo: StructureCraft

Photo: StructureCraft

Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

Key Early Design Decisions

Construction Type – Primarily based on building size & occupancy

	Construction Type (All Sprinklered Values)							
	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)							
A, B, R	270	180	85	85	85	85	70	60
	Allowable Number of Stories above Grade Plane (IBC Table 505.4)							
A-2, A-3, A-4	18	12	6	4	4	3	3	2
B	18	12	9	6	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area Factor (At) for SM, Feet^2 (IBC Table 506.2)							
A-2, A-3, A-4	135,000	90,000	56,250	45,000	42,000	28,500	34,500	18,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	184,500	123,000	76,875	61,500	72,000	48,000	36,000	21,000

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A-2, A-3, A-4	18	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
B	18	12	9	[illegible]	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area Factor (At) for SM, Feet² (IBC Table 506.2)							
A-2, A-3, A-4	135,000	90,000	56,250	45,000	42,000	28,500	34,500	18,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	184,500	123,000	76,875	61,500	72,000	48,000	36,000	21,000

For low- to mid-rise mass timber buildings, there may be multiple options for construction type. There are pros and cons of each, don't assume that one type is always best.

Key Early Design Decisions

Fire-Resistance Ratings

- Driven primarily by construction type
- Rating achieved through timber alone or non-com protection required?

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	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[g]	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1 1/2	1	1	HT	1[b,c]	0

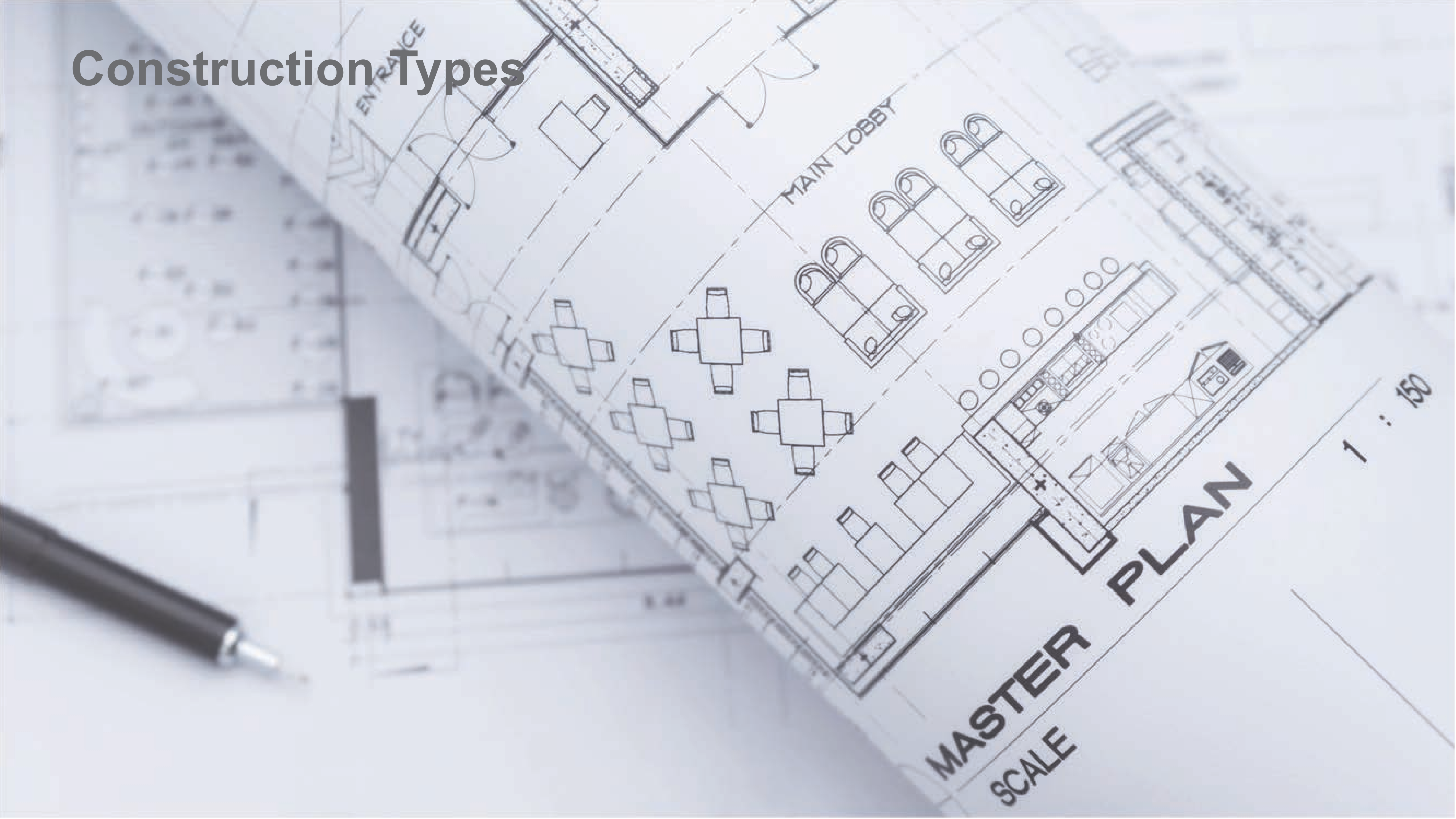
Key Early Design Decisions

Fire-Resistance Ratings (FRR)

- Thinner panels (i.e. 3-ply) generally difficult to achieve a 1+ hour FRR
- 5-ply CLT / 2x6 NLT & DLT panels can usually achieve a 1- or 2-hour FRR
- Construction Type | FRR | Member Size | Grid (or re-arrange that process but follow how one impacts the others)

Panel	Example Floor Span Ranges
3-ply CLT (4-1/8" thick)	Up to 12 ft
5-ply CLT (6-7/8" thick)	14 to 17 ft
7-ply CLT (9-5/8")	17 to 21 ft
2x4 NLT	Up to 12 ft
2x6 NLT	10 to 17 ft
2x8 NLT	14 to 21 ft
5" MPP	10 to 15 ft

Construction Types

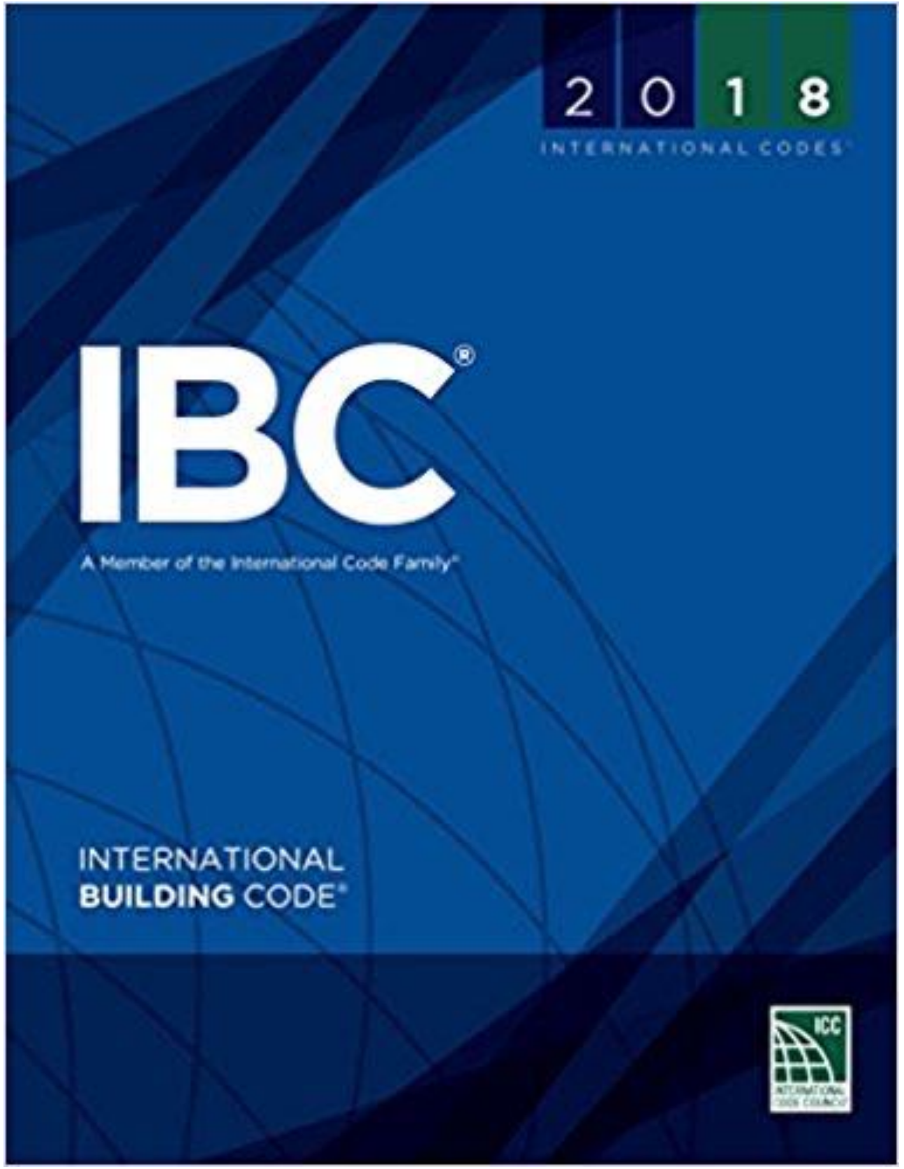


Construction Types

When does the code allow mass timber to be used?

IBC defines mass timber systems in IBC Chapter 2 and notes their acceptance and manufacturing standards in IBC Chapter 23

Permitted anywhere that combustible materials and heavy timber are allowed, plus more



Construction Types

IBC defines 5 construction types: I, II, III, IV, V
A building must be classified as one of these

Construction Types I & II:
All elements required to be non-combustible materials

However, there are exceptions including several for mass timber

Construction Types

Where does the code allow MT to be used?

- <u>Type IB & II</u>: Roof Decking

Photo Credit: DeStafano & Chamberlain, Inc, Robert Benson Photography

Image: StructureCraft Builders

Construction Types

All wood framed building options:

<u>Type III</u>
Exterior walls non-combustible (may be FRTW)
Interior elements any allowed by code, including mass timber

<u>Type V</u>
All building elements are any allowed by code, including mass timber

Types III and V are subdivided to A (protected) and B (unprotected)

<u>Type IV (Heavy Timber)</u>
Exterior walls non-combustible (may be FRTW OR CLT)
Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)

Photo Credit: Hacker Architects, Jeremy Bittermann

Construction Types

Where does the code allow MT to be used?

- Type III: Interior elements (floors, roofs, partitions/shafts) and exterior walls if FRT

ICE Block I, RMW Architecture & Interiors, Buehler Engineering, Bernard André Photography

Construction Types

Where does the code allow MT to be used?

- Type IV: Any exposed interior elements & roofs, must meet min. sizes; exterior walls if CLT or FRT. Concealed space limitations (varies by code version)

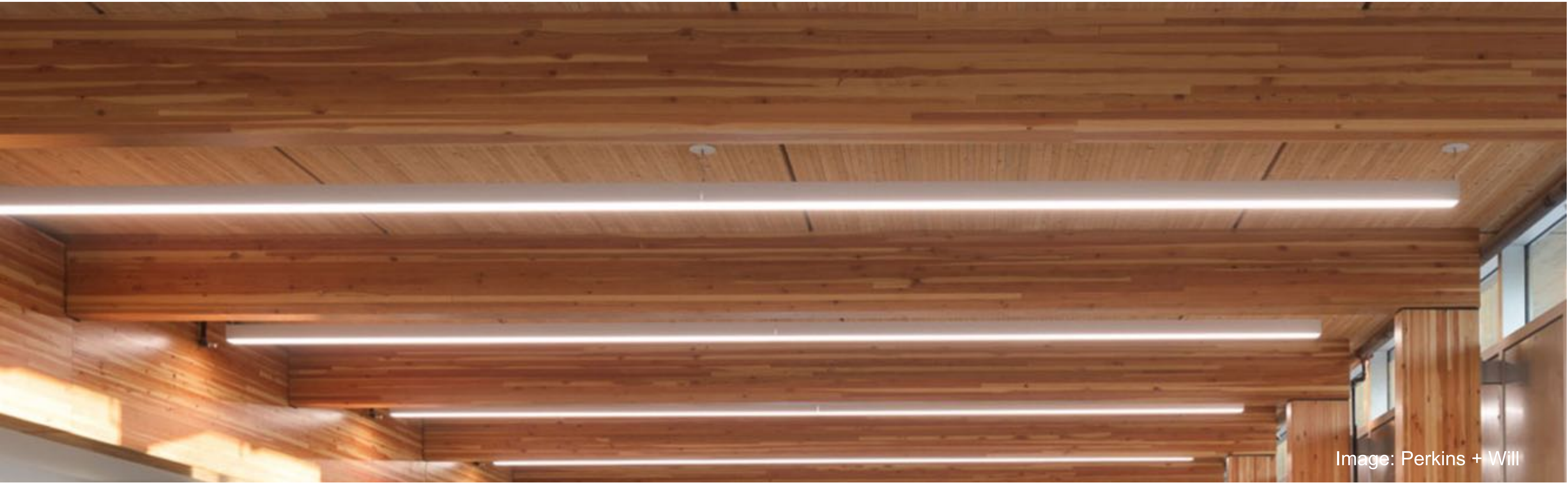


Image: Perkins + Will

Construction Types

Type IV construction permits exposed heavy/mass timber elements of min. sizes.

Framing		Solid Sawn (nominal)	Glulam (actual)	SCL (actual)
Floor	Columns	8 x 8	$6^3/_4$ x 8¼	7 x 7½
	Beams	6 x 10	5 x 10½	5¼ x 9½
Roof	Columns	6 x 8	5 x 8¼	5¼ x 7½
	Beams*	4 x 6	3 X $6^7/_8$	3½ X 5½

Minimum Width by Depth in Inches
See IBC 2018 2304.11 or IBC 2015 602.4 for Details

*3" nominal width allowed where sprinklered

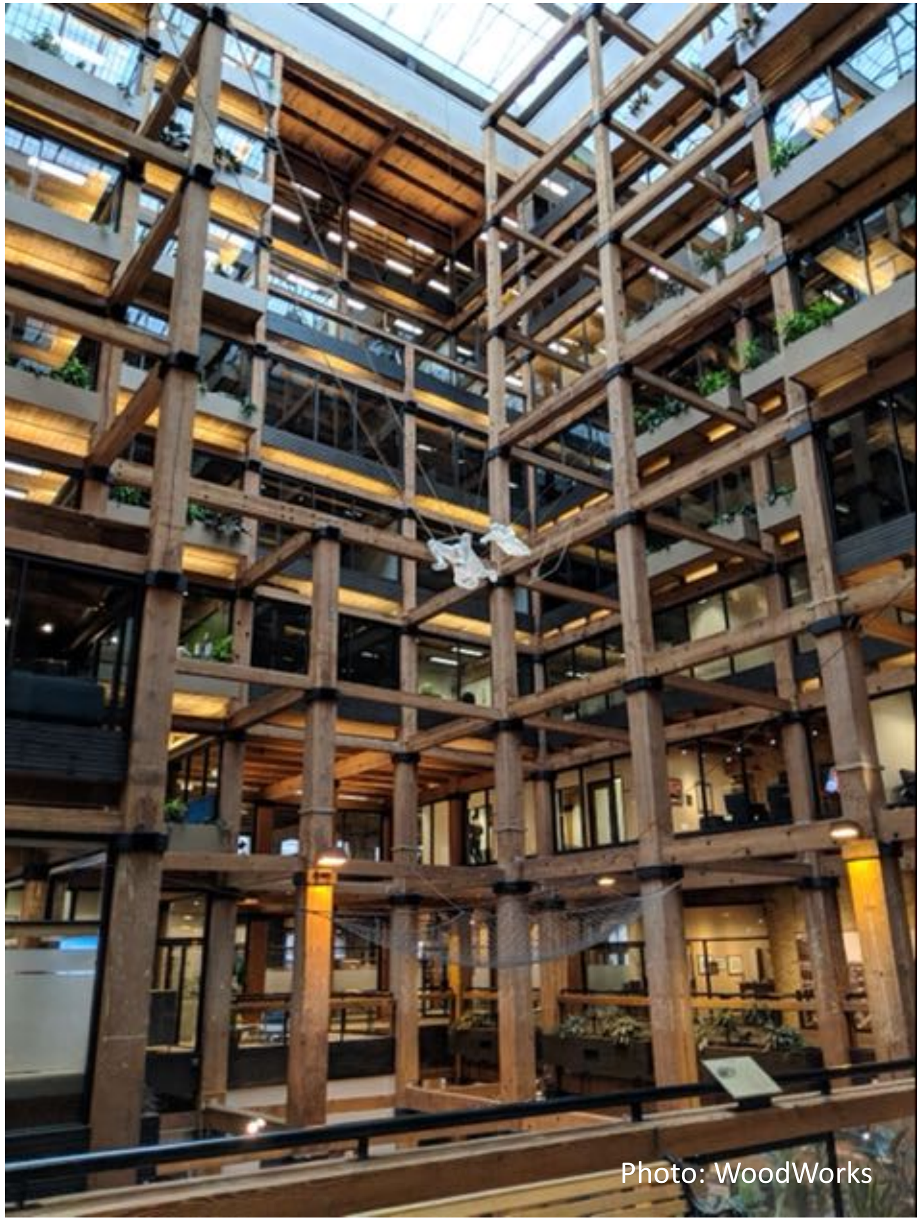


Photo: WoodWorks

Construction Types

Where does the code allow MT to be used?

- <u>Type V</u>: All interior elements, roofs & exterior walls

Image: Christian Columbres Photography

Construction Types

Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler

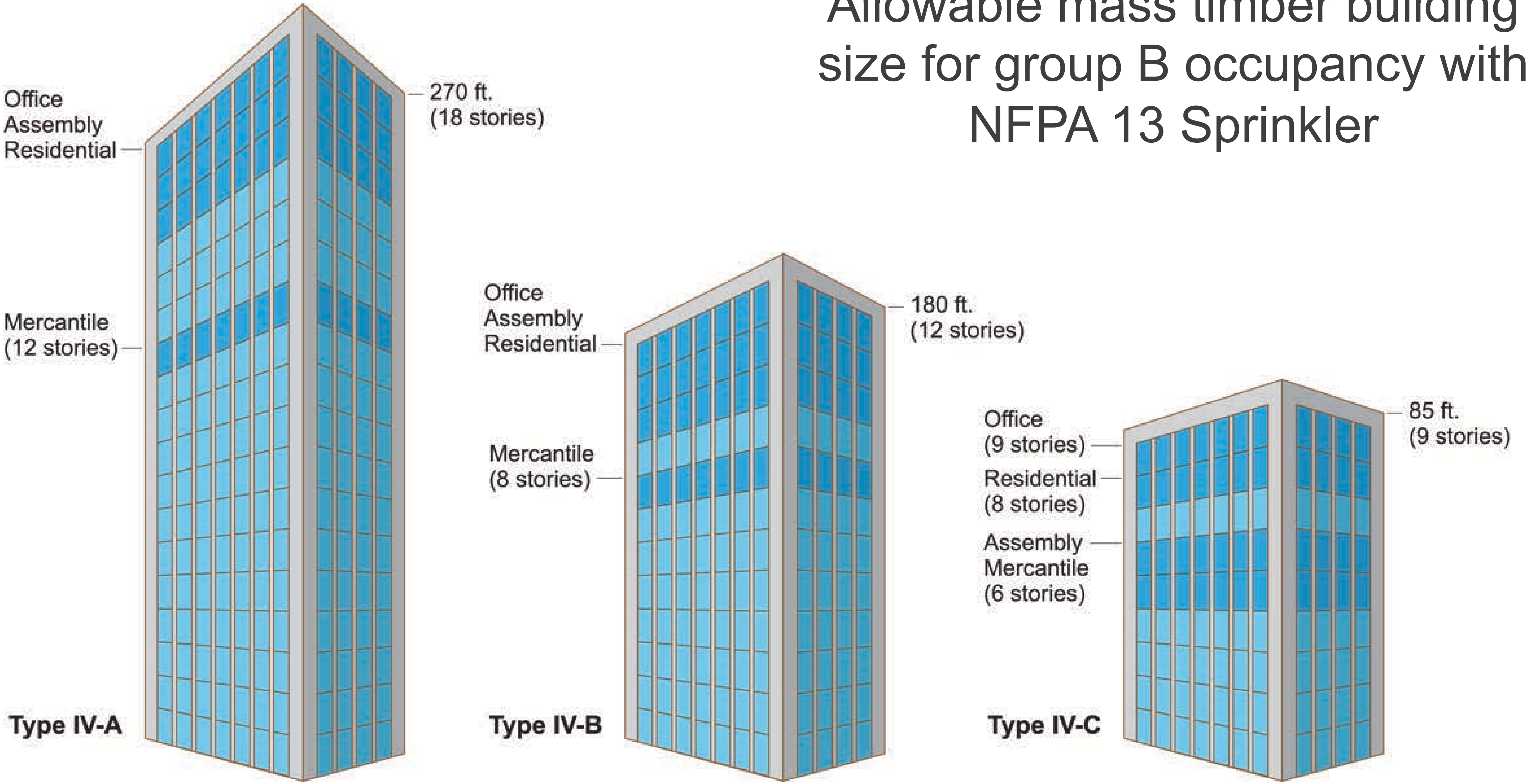
Type III: 6 stories

Type IV: 6 stories

Type V: 4 stories

Construction Types

New Options in 2021 IBC
Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler



IV-C

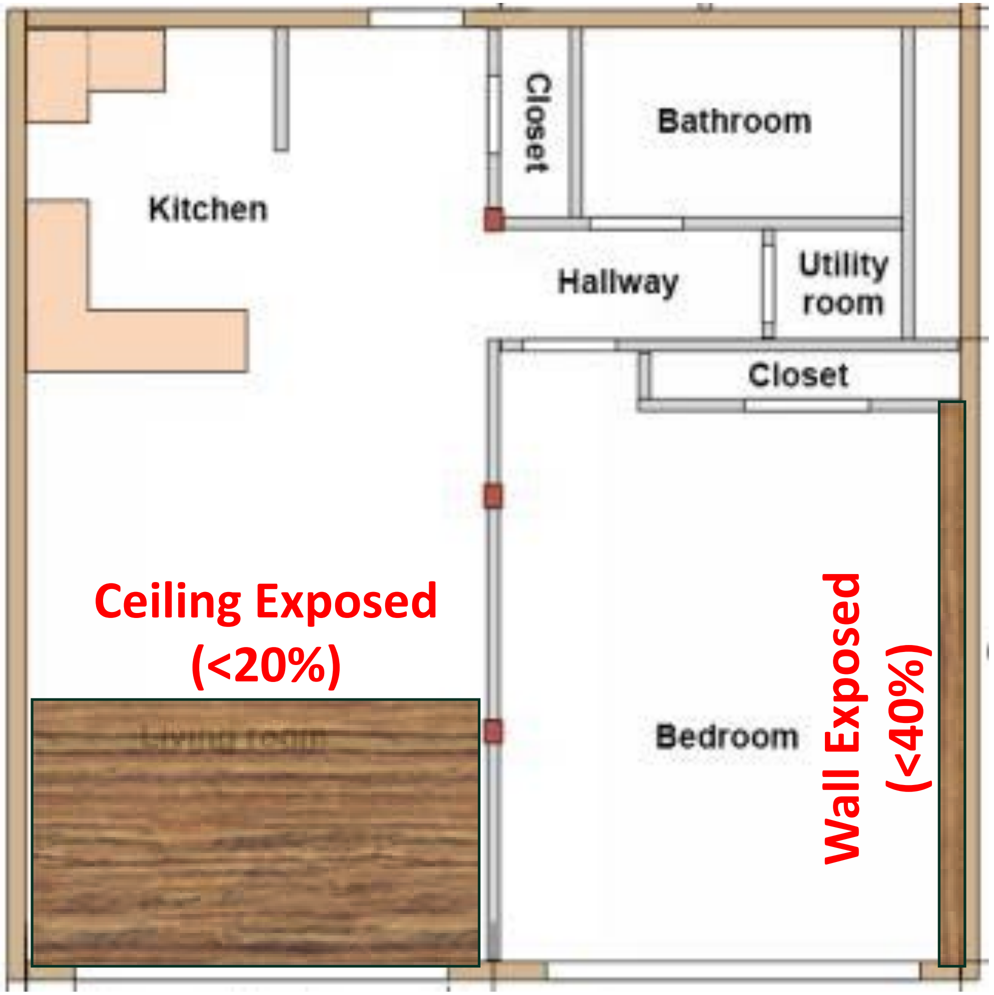
All timber surfaces may be exposed

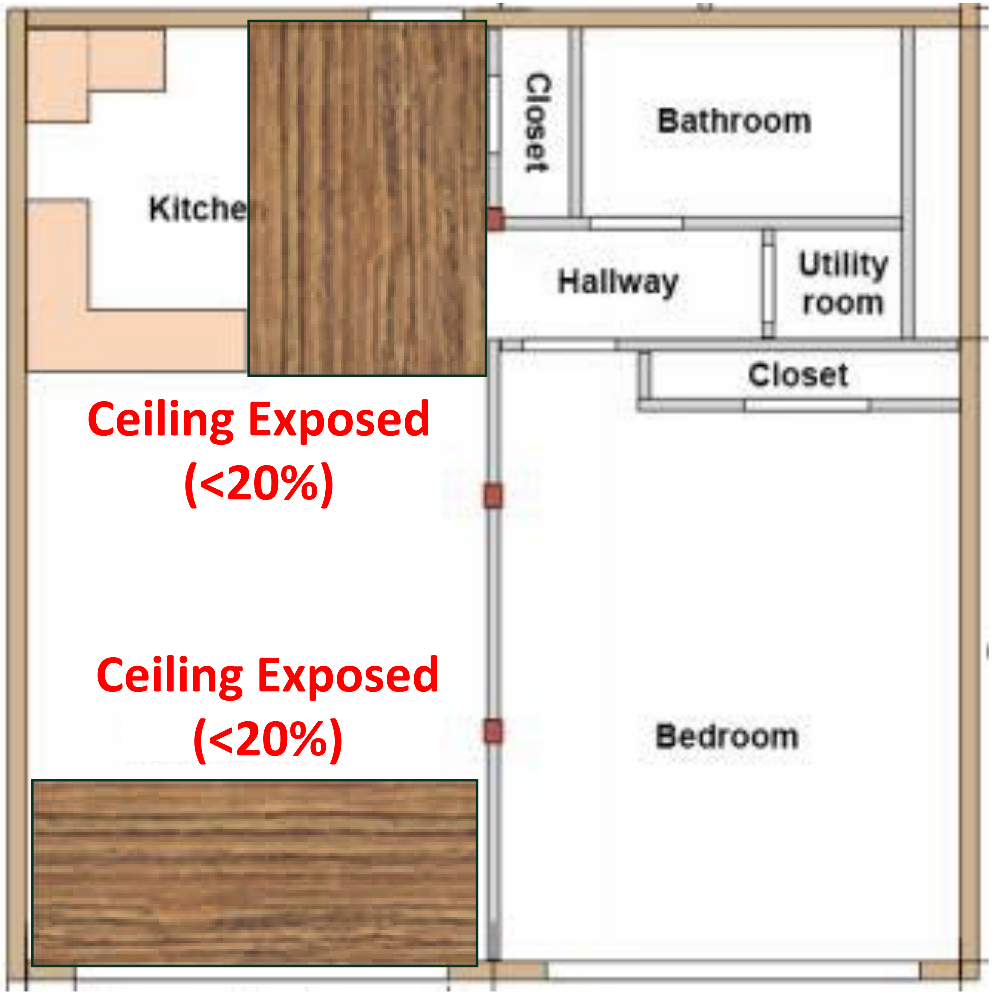
IV-B

Some timber surfaces may be exposed

Type IV-B Protection vs. Exposed

IV-B





Credit: AWC

IV-A

Key Early Design Decisions

Construction type influences FRR

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	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[g]	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1½	1	1	HT	1[b,c]	0

Source: 2021 IBC

Key Early Design Decisions

Construction type influences FRR

- Type IV-HT Construction (minimum sizes)
- **<u>Other than type IV-HT</u>**: Demonstrated fire resistance

Method of demonstrating FRR (calculations or testing) can impact member sizing


NGC Testing Services

Fire Testing Laboratory

ACCREDITED Testing Laboratory TL-218

TEST REPORT

Page 1 of 53

for

American Wood Council

222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

Standard Methods of
Fire Tests of Building Construction and Materials
ASTM E 119 – 11a

Test Report No: WP-1950

Assignment No: K-1089

Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)

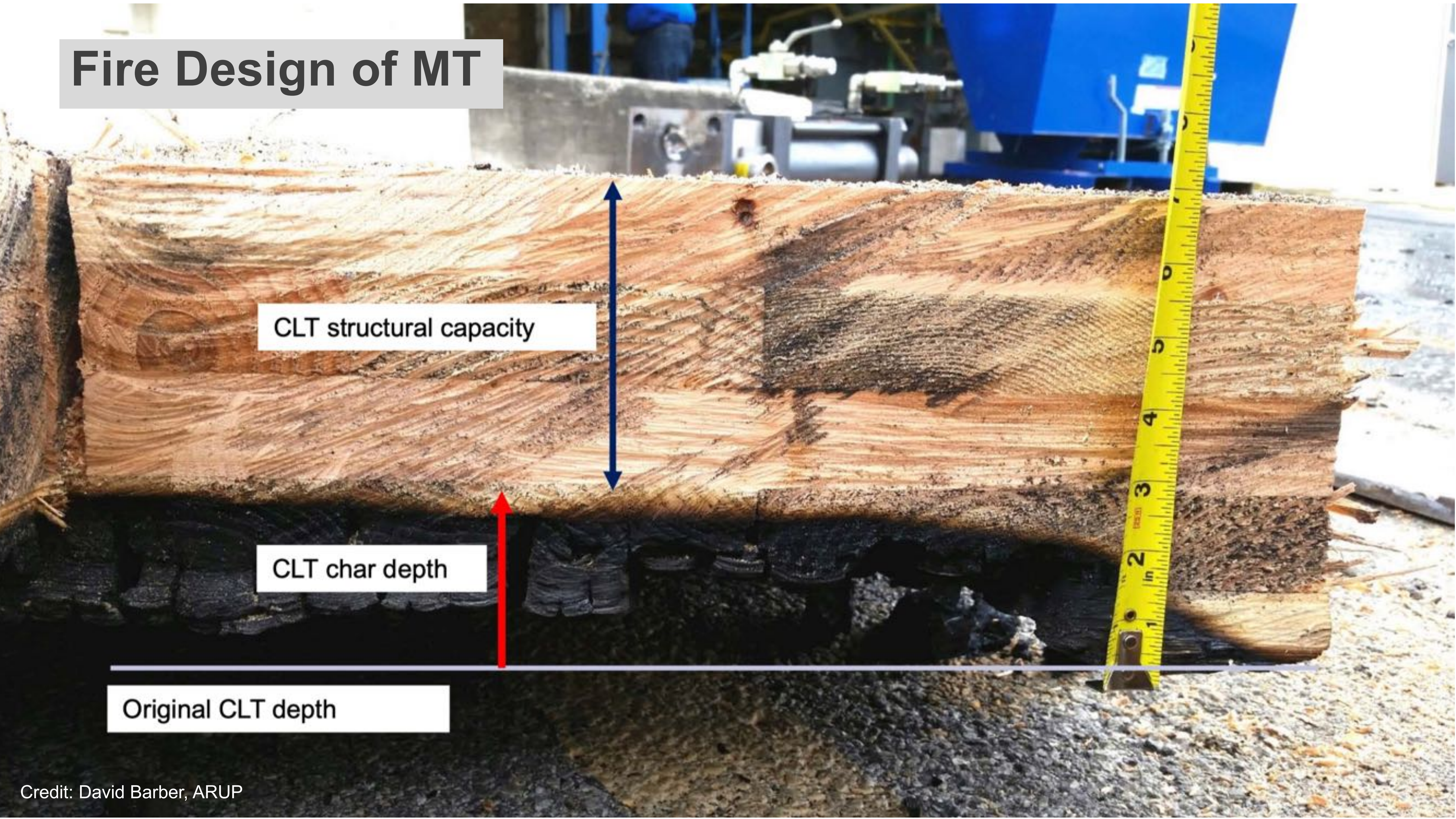
Test Date: October 4, 2012

Report Date: October 15, 2012

Prepared by:
Michael J. Rizzo
Test Engineer

Reviewed by:
Robert J. Menchetti
Director, Laboratory Facilities and Testing Services

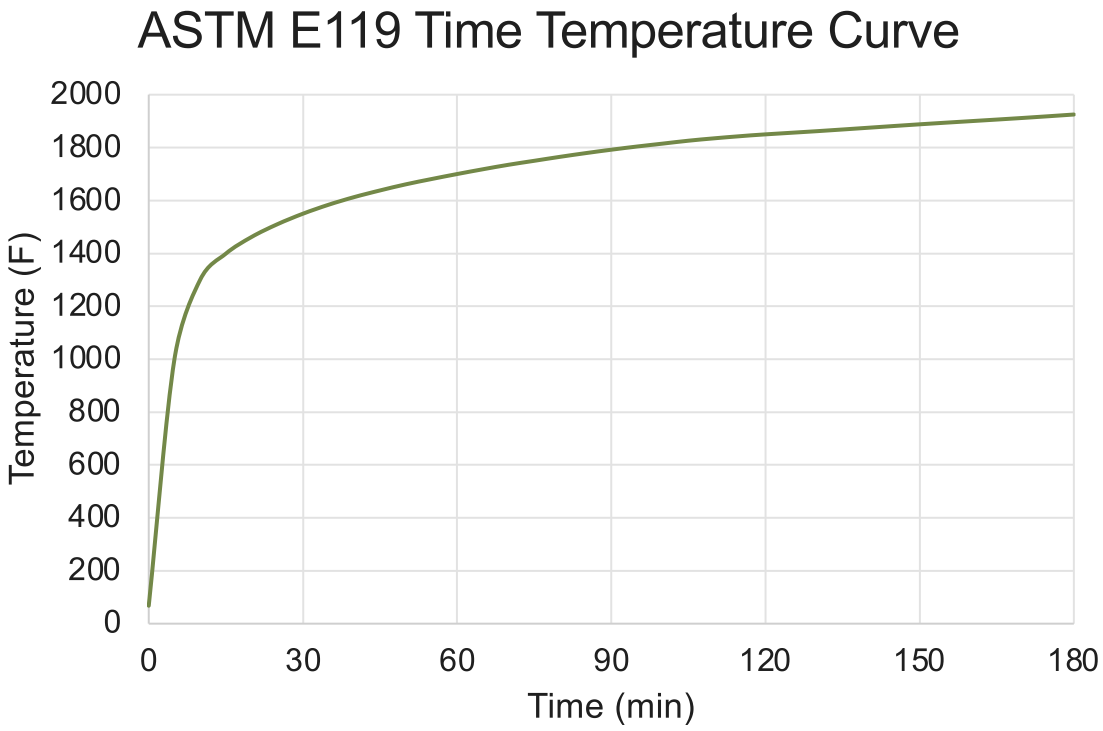
Fire Design of MT



Credit: David Barber, ARUP

Demonstrating Fire Resistance Ratings

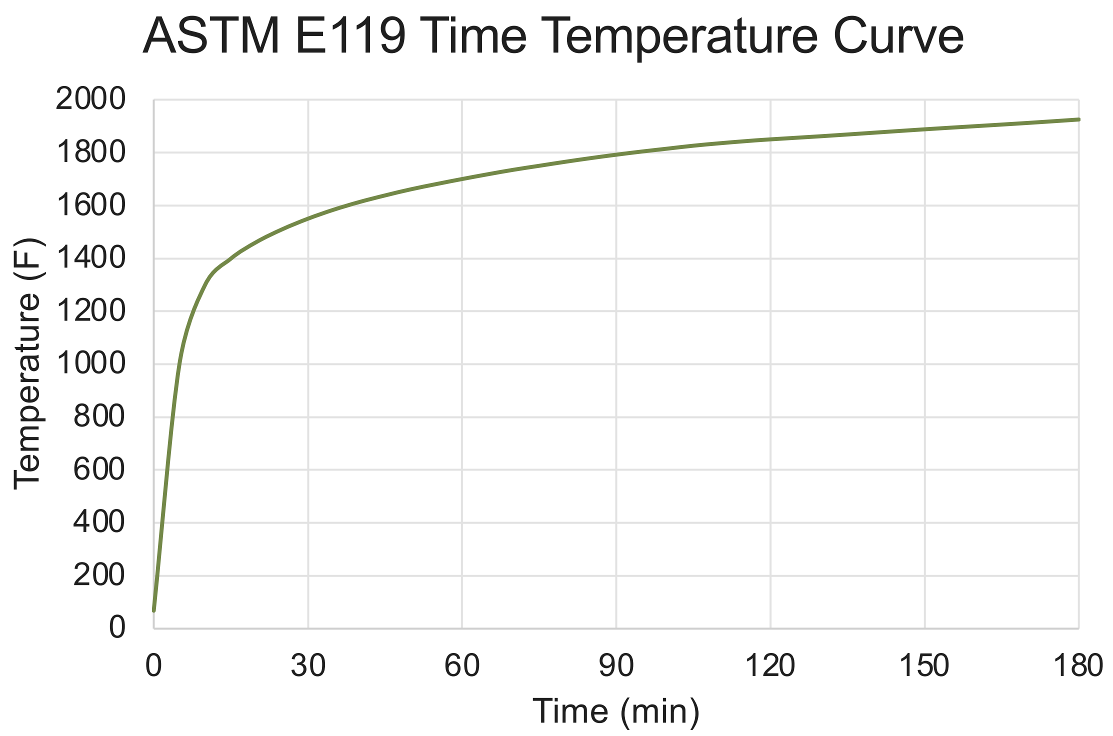
Fire Resistance Ratings Based on ASTM E119 Testing



- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
  1. Fire-resistance designs in “approved sources”
  2. Prescriptive assemblies in IBC 721
  3. Calculations per IBC 722
  4. Engineering analysis based on tested assemblies
  5. Alternative methods per IBC 104.11
  6. Fire-resistance design certified by approved agency

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings Based on ASTM E119 Testing



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Test reports from approved 3rd party fire test labs

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings Based on ASTM E119 Testing

WESTERN FIRE CENTER, INC.
2204 Parrott Way, Kelso, Washington 98626
Phone: 360-423-1400 | Fax: 360-423-5003

Fire Resistance Testing of CLT Floor/C
Assemblies

Indicative testing conducted following the test methodology de
ASTM E119: Standard test methods for fire tests of buildi
construction materials

Conducted For:

Oregon State University
College of Forestry – Wood Science & Engineerin
106 Richardson Hall
Corvallis, OR 97331

WFCi Report #16046a

Test Date: October 26, 28, & November 1, 2016

Report Issued: December 2, 2016

TEST REPORT

Intertek

REPORT NUMBER: 102891256SAT-001
ORIGINAL ISSUE DATE: February 27, 2017
REVISED DATE: N/A

EVALUATION CENTER
16015 Shady Falls Road
Elmendorf, TX 78112
Phone: (210) 635-8100
Fax: (210) 635-8101
www.intertek.com

RENDERED TO

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

PRODUCT EVALUATED: CrossLam® CLT Un-restrained Load-Bearing Floor/Ceiling Assembly
EVALUATION PROPERTY: Fire Resistance

Report of Testing a CrossLam® CLT Un-restrained Load-Bearing

SOUTHWEST RESEARCH INSTITUTE®

CHEMISTRY AND CHEMICAL ENGINEERING

FIRE TECHNOLOGY DEPARTMENT

FIRE PERFORMANCE EVALUATION OF AN UNRESTRAINED LOAD-BEARING FLOOR ASSEMBLY TESTED IN ACCORDANCE WITH ASTM E119-20, *STANDARD TEST METHODS FOR FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS*

FINAL REPORT
Consisting of 22 Pages

SwRI® Project No. 01.27009.01.407b
Test Date: January 31, 2022
Report Date: March 2, 2022

Prepared for:

Structurlam Mass Timber U.S. Inc.
1800 Sturgis Road
Conway, AR 72034

Submitted by:
Curtis Roberds
Digitally signed by Curtis Roberds
Date: 2022.03.03 10:19:08 -06'00'

Approved by:
Matthew S Blais
Digitally signed by Matthew S Blais
Date: 2022.03.03 10:23:55 -06'00'

Demonstrating Fire Resistance Ratings

WoodWorks Inventory of Fire Tested MT Assemblies

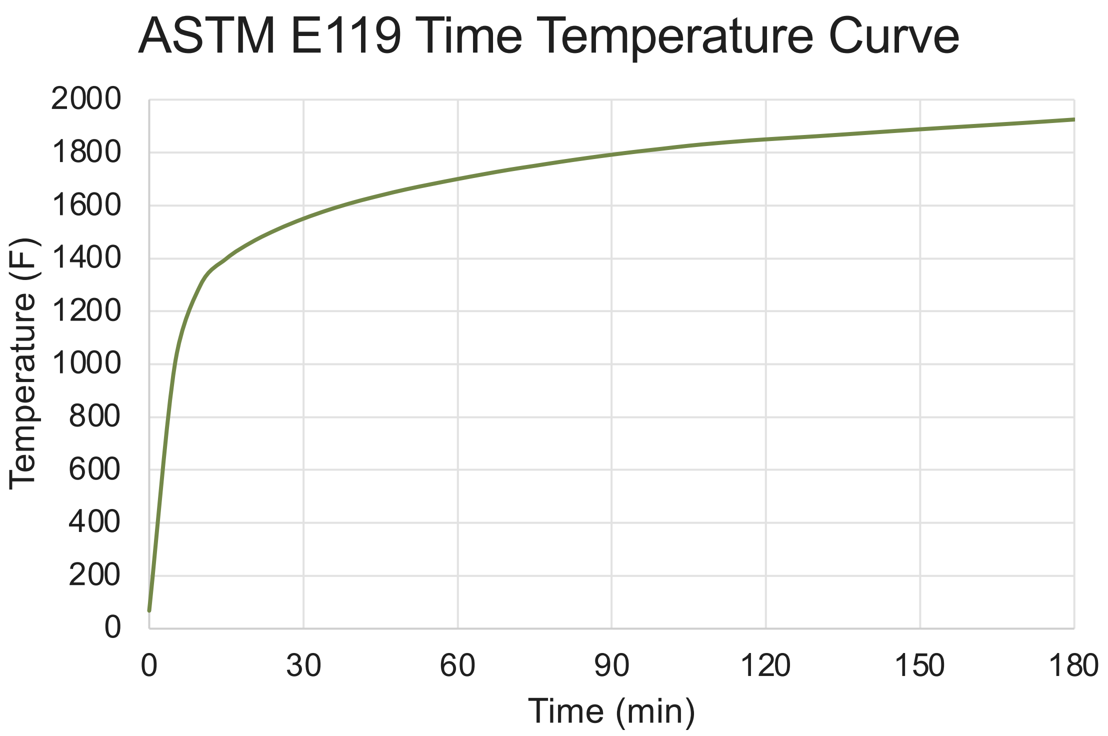
Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies

WOODWORKS WOOD PRODUCTS COUNCIL

Mass Timber Panel	Manufacturer	CLT Grade or Timber Grade	Ceiling Protection	Panel Connection	Floor Topping	Load Rating	Fire Resistance Achieved (Hours)	Source	Testing Lab
3-ply CLT (114mm 4.488 in)	Nordic	SPF 1650 Fb 1.5E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 50% Moment Capactiy	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool beween Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Crete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap & Topside Spline	2" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1950 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 59% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Unreduced 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT [illegible]	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced [illegible]	2.5	1 [illegible]	NRC Fire Laboratory

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings Based on ASTM E119 Testing

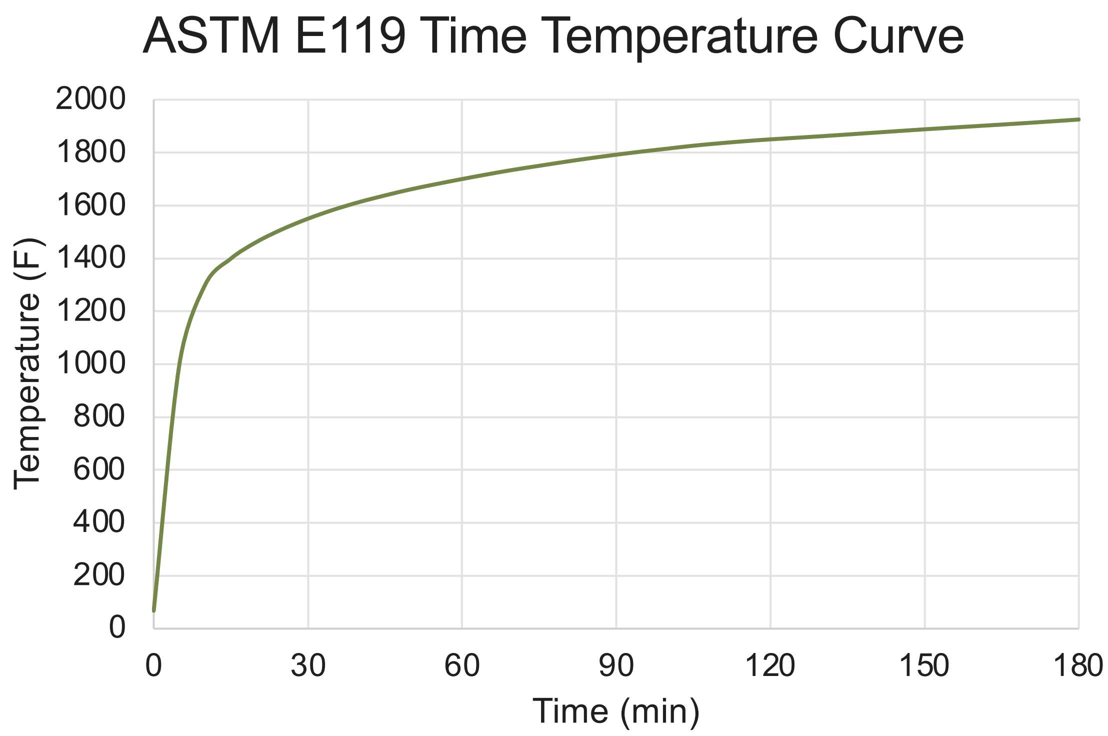


- Pass / Fail Criteria for Selected Time
- IBC 703.3 recognized routes to approval:
  1. Fire-resistance designs in “approved sources”
  2. Prescriptive assemblies in IBC 721
  3. Calculations per IBC 722
  4. Engineering analysis based on tested assemblies
  5. Alternative methods per IBC 104.11
  6. Fire-resistance design certified by approved agency

Calculation methods per NDS

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings Based on ASTM E119 Testing



- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
  1. Fire-resistance designs in "approved sources"
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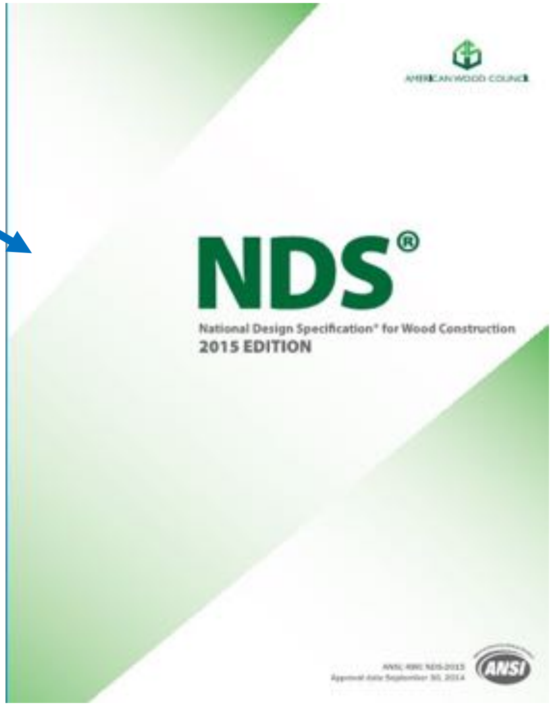
  5. Alternative methods per IBC 104.11
  6. Fire-resistance design certified by approved agency

Approved calculation methods per NDS

Demonstration Fire Resistance Ratings

Calculated FRR of Exposed Timber:
IBC to NDS code compliance path



Code Path for Exposed Wood Fire-Resistance Calculations

IBC 703.3
Methods for determining fire resistance

- Prescriptive designs per IBC 721.1
- ***Calculations in accordance with IBC 722***
- Fire-resistance designs documented in sources
- Engineering analysis based on a comparison
- Alternate protection methods as allowed by 104.11

IBC 722
Calculated Fire Resistance

"The calculated *fire resistance* of exposed wood members and wood decking shall be permitted in accordance with **Chapter 16 of ANSI/AWC National Design Specification for Wood Construction (NDS)**

NDS Chapter 16
Fire Design of Wood Members

- Limited to calculating fire resistance up to 2 hours
- Char depth varies based on exposure time (i.e., fire-resistance rating), product type and lamination thickness. Equations and tables are provided.
- TR 10 and NDS commentary are helpful in implementing permitted calculations.

NDS Chapter 16 Calculation Method

Nominal char rate of 1.5”/hour is recognized in NDS for solid sawn, gluam, CLT, SCL and decking wood products. Effective char depth calculated to account for fire duration.

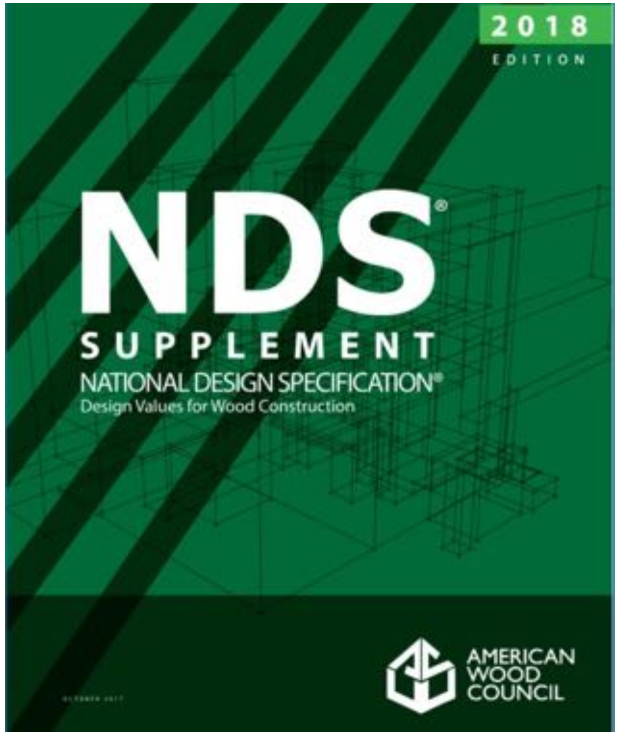
Table 16.2.1A Char Depth and Effective Char Depth (for β_n = 1.5 in./hr.)

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 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

NDS Chapter 16 Calculation Method




NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION 149

FIRE DESIGN OF WOOD MEMBERS

16.1 General 150
16.2 Design Procedures for Exposed Wood Members 150
16.3 Wood Connections 151
Table 16.2.1 Effective Char Rates and Char Layer Thicknesses (for β_n = 1.5 in./hr.) 150
Table 16.2.2 Adjustment Factors for Fire Design 151

16


Credit: FPInnovations

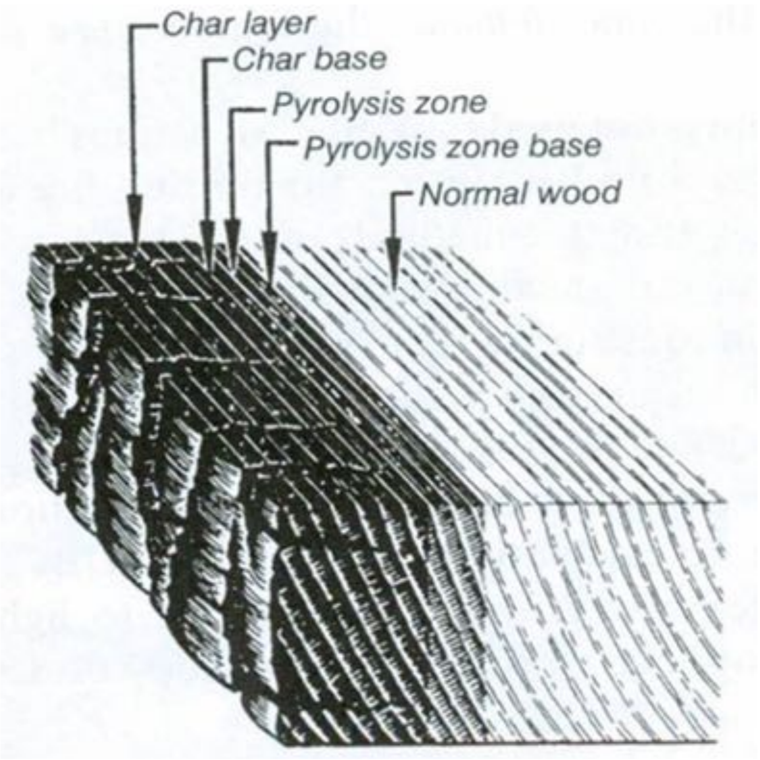
NDS Chapter 16 includes calculation of fire resistance of NLT, CLT, Glulam, Solid Sawn and SCL wood products

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

NDS Chapter 16 Calculation Method

Structural capacity check performed on remaining section, with stress increases



Credit: Forest Products Laboratory

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	-	-	-	-	-

$$a_{char} = \beta_t t^{0.813}$$

Solid Sawn, Glulam, SCL

$$a_{char} = n_{lam} h_{lam} + \beta_t \left(t - \left(n_{lam} t_{gi}\right)\right)^{0.813}$$

CLT

$$a_{eff} = 1.2 a_{char}$$

Effective Char Depth

FRR Design of MT

Method of demonstrating FRR (calculations or testing) can impact member sizing

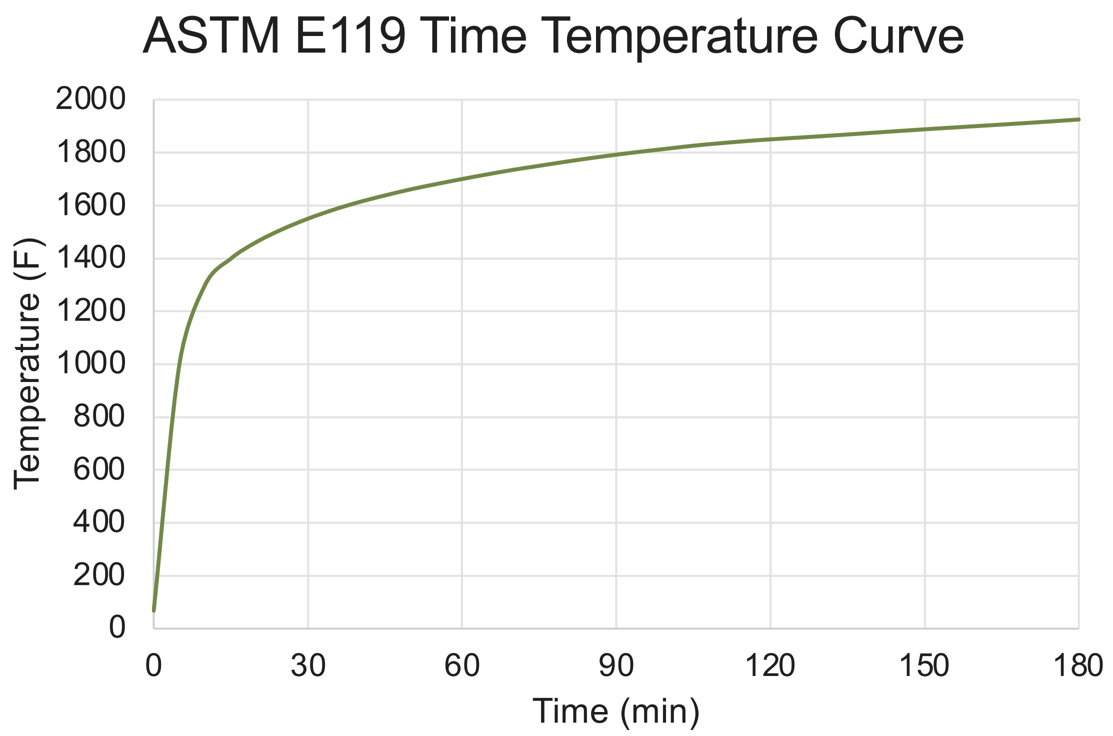
Each has unique benefits:

- **Testing:**
  - Can result in higher FRR for some assemblies when compared to calculations (i.e. 2-hr FRR with 5-ply CLT panel).
  - More universally understood and accepted

- **Calculations:**
  - Can provide more design flexibility
  - Allows for project span and loading specific analysis

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings Based on ASTM E119 Testing



- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
    1. Fire-resistance designs in "approved sources"
    2. Prescriptive assemblies in IBC 721
    3. Calculations per IBC 722
    4. Engineering analysis based on tested assemblies
    5. Alternative methods per IBC 104.11
    6. Fire-resistance design certified by approved agency

For example, a "UL Listing"

1 Hour Fire Resistance Rated Mass Timber Floor?

But what about 1 hour rating without ceiling protection?

Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies

WOODWORKS WOOD PRODUCTS COUNCIL

Mass Timber Panel	Manufacturer	CLT Grade or Timber Grade	Ceiling Protection	Panel Connection	Floor Topping	Load Rating	Fire Resistance Achieved (Hours)	Source	Testing Lab
3-ply CLT (114mm 4.488 in)	Nordic	SPF 1650 Fb 1.5E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 50% Moment Capactiy	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool beween Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Crete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap & Topside Spline	2" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT	Nordic	SPF 1950 Fb MSR	None	Half-Lap	None	Reduced	1.5	1	NRC Fire Laboratory

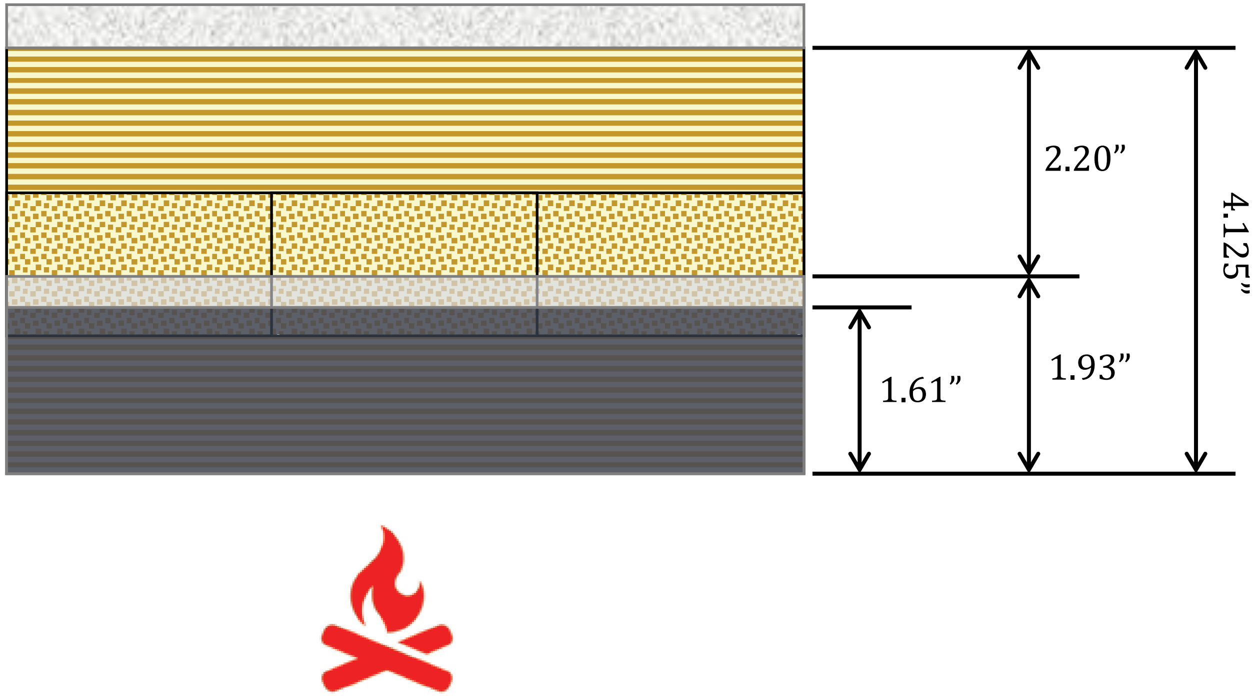
Calculated Structural Fire Resistance Rating of CLT

NDS Ch 16 char model of 4 1/8” CLT with (3) 1-3/8” Layers with 1 Hour FRR

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

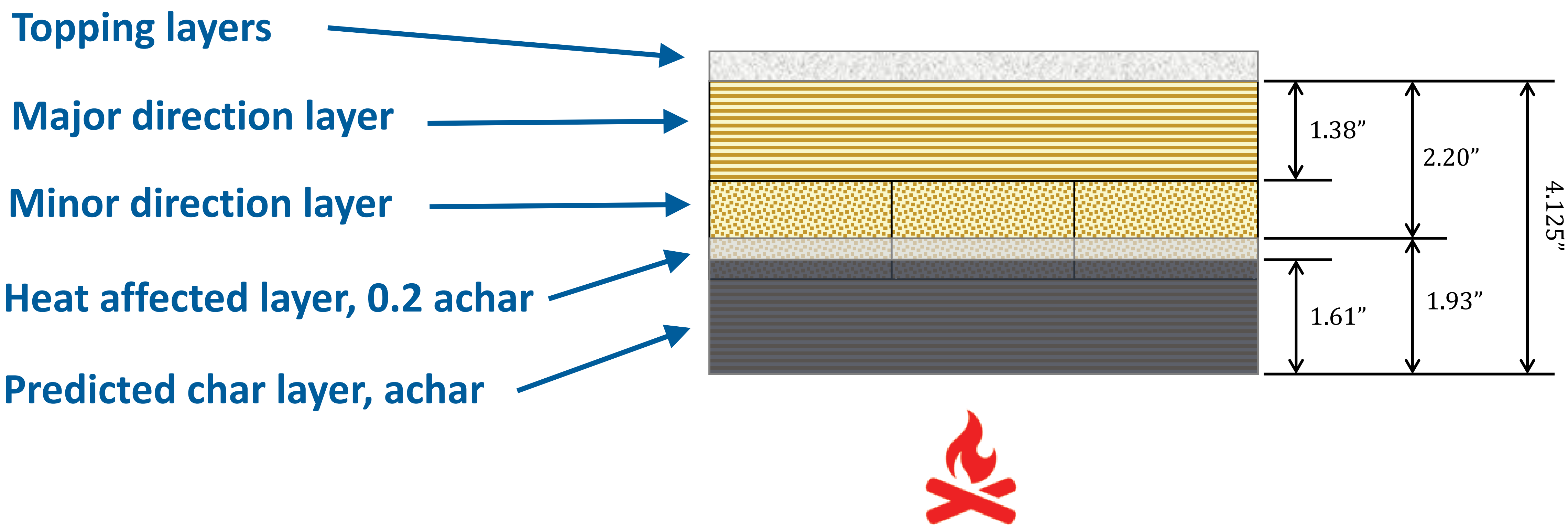
Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

$$
\begin{aligned}
a_{eff} &= 1.2a_{char} \\
&= 1.9 \ \text{in. tabulated} \\
&= 1.93 \ \text{in. calculated} \\
a_{char} &= 1.61 \ \text{in. calculated}
\end{aligned}
$$



Demonstrating Fire Resistance Ratings

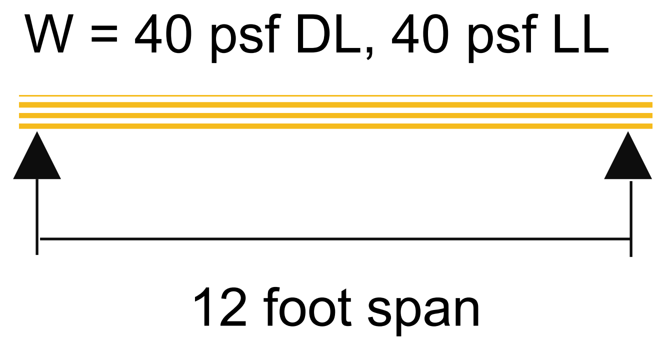
NDS Ch 16 char model of 4 1/8" CLT with (3) 1-3/8" Layers with 1 Hour FRR



After 1-hour standard fire expose, typical exposed 3-ply CLT is structurally 1 layer of solid lumber in plank orientation spanning in major direction

Flatwise Flexural Strength Design

Given:
- 12 foot, simple span floor
- 40 psf live load, 40 psf total dead load
- Using V1 4 1/8" 3-Ply CLT



Gravity Checks:
- ASD applied D+L moment $M_b = wL^2/8 = (80\text{psf})\ (12\text{ft})^2/8\ = 1440\ \text{lb-ft/ft}$
- ASD flexural strength: $F_b S_{eff} = 2090\ \text{lb-ft/ft}$, per PRG 320 Table A1

$F_b S_{eff} = 2090\ \text{lb-ft/ft}\ \ >\ M_b = 1440\ \text{lb-ft/ft}$, flexural strength OK.

- Need to also look at deflections, vibrations, etc

Strength under 1-hour fire?

Demonstrating Fire Resistance Ratings

NDS Ch 16 char model of 4 1/8” V1 CLT with (3) 1-3/8” Layers with 1 Hour FRR

$S = 12 \text{ in/ft } (1.375\text{in})^2 / 6 = 3.78 \text{ in}^3/\text{ft}$

$F_b = 900 \text{ psi}$ *PRG 320 Table A1*

$F_b' = F_b \; 2.85 \; C_F \; C_{fu}$ *NDS Table 16.2.20*

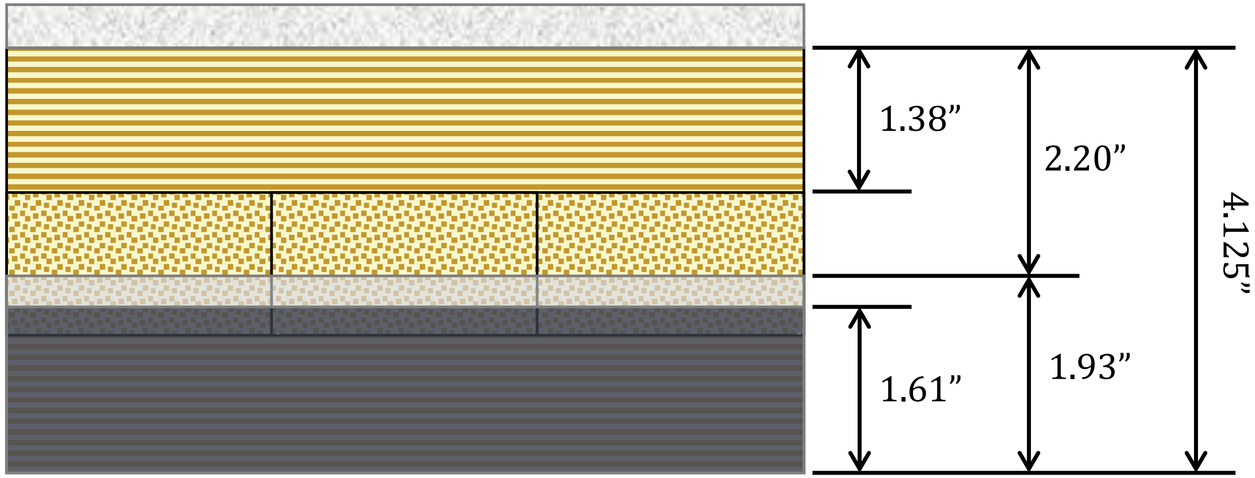
For 2x6* DF #2 sized lamella:

$C_F = 1.3$

$C_{fu} = 1.15$

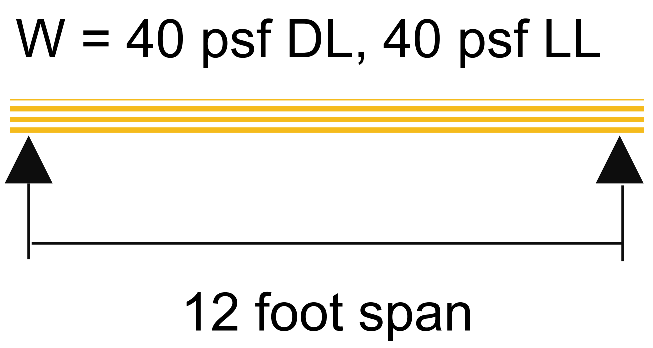
$F_b' = 900\text{psi } (2.85)(1.3)(1.15) = 3845 \text{ psi}$

$(F_b S)' = 3845 \text{ psi } (3.78 \text{ in}^3/\text{ft}) / (12 \text{ in/ft}) = 1208 \text{ lb-ft/ft}$



Common lamella are based on 2x6 and 2x4 sizes lumber… Consult with the selected manufacturer or specify acceptable sizes

Flatwise Flexural Strength Design



Given:

- 40 psf live load, 40 psf total dead load
- Using V1 4 1/8" 3-Ply CLT
- ASD flexural strength @ 1 hr FRR: $(F_bS)' = 1208$ lb-ft/ft

Strength under 1-hour fire, 12-foot span

- ASD applied D+L moment $M_b = wL^2/8 = (80\text{psf})\,(12\text{ft})^2/8 = 1440$ lb-ft/ft

Capacity $(F_bS)' = 1208$ lb-ft/ft $<$ $M_b = 1440$ lb-ft/ft, flexural strength NOT OK.

Strength under 1-hour fire, 8-foot span

- ASD applied D+L moment $M_b = wL^2/8 = (80\text{psf})\,(9\text{ft})^2/8 = 810$ lb-ft/ft

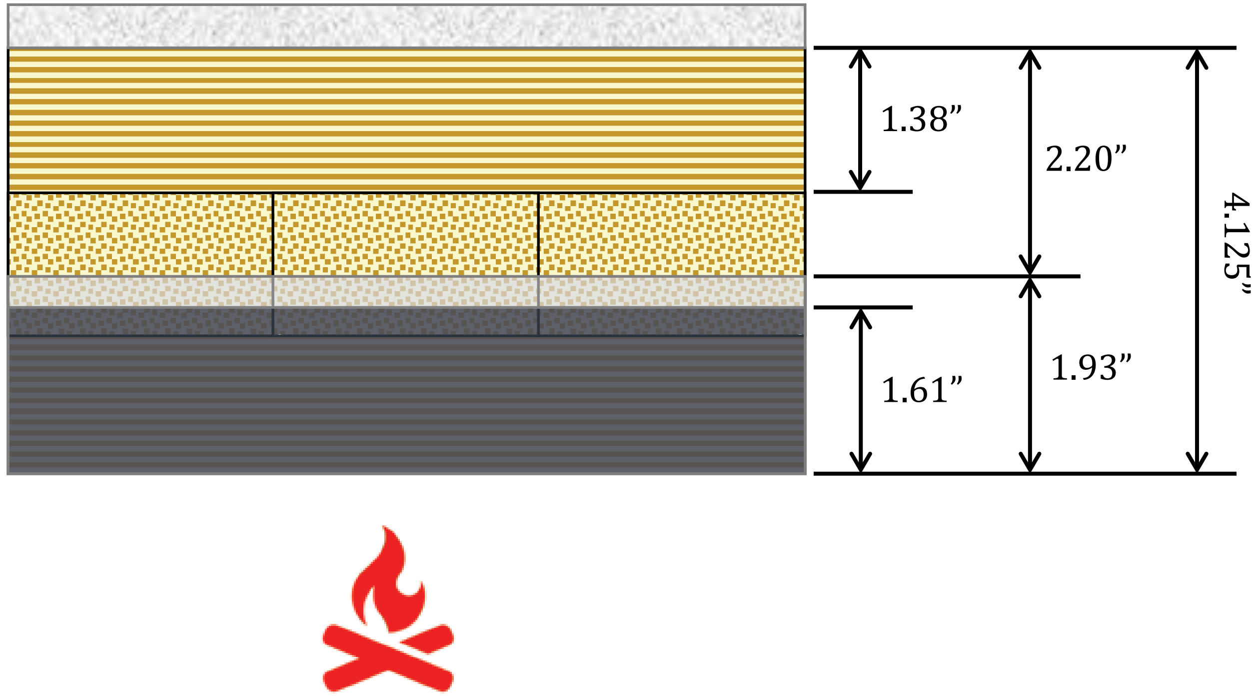
Capacity $(F_bS)' = 1208$ lb-ft/ft $>$ $M_b = 810$ lb-ft/ft, flexural strength OK.

Demonstrating Fire Resistance Ratings

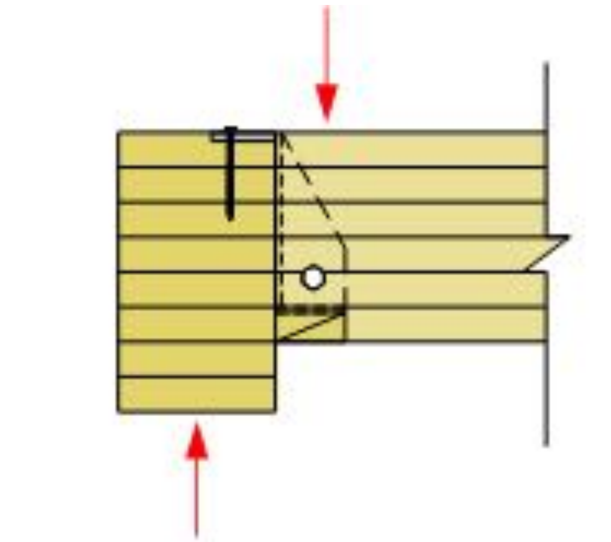
Considerations when using 1-layer of CLT as lumber in plank orientation

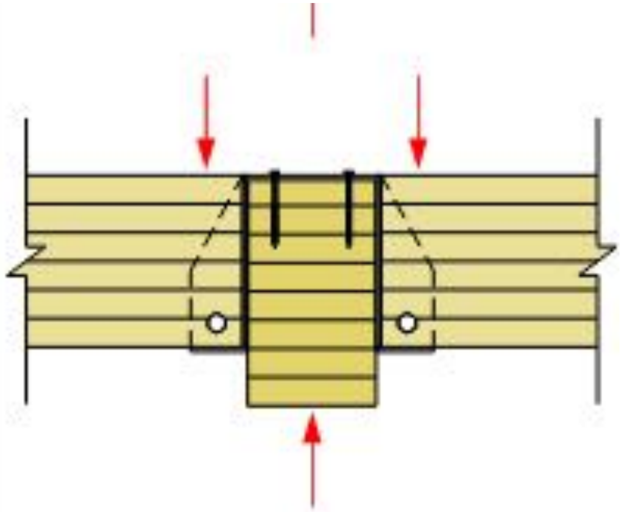
A: Common solid-sawn lumber lamella in CLT are planed 2x6 and 2x4 sizes lumber. If using size or flat-use increase factors per NDS, consult with the selected manufacturer as to what is used or specify acceptable sizes.

B: ASTM E119 for Fire Resistance Ratings does not have a deflection limit. However, designers should consider impact of deflections on *structural stability*. E.g. a 10-inch deflection in a 10-foot span may be deemed as not acceptable by the engineer.



Fire Resistance of Connections





All Photos by WoodWorks

Fire Resistance of Connections – Protection Strategies

Right-sized bearing areas

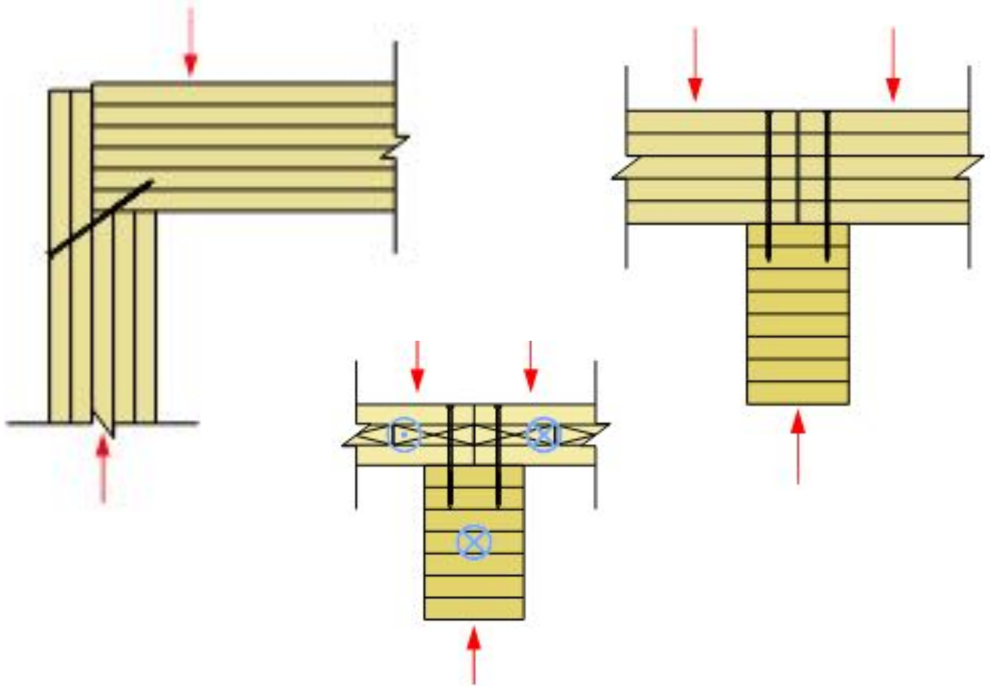
Concealed connectors

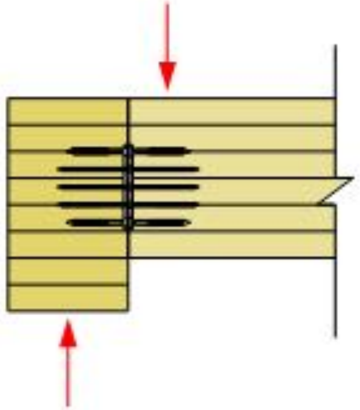
Wood protection

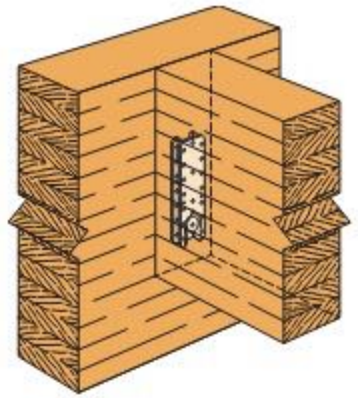
Gypsum protection

Fire Resistance of Connections – Protection Strategies

Right-sized bearing areas

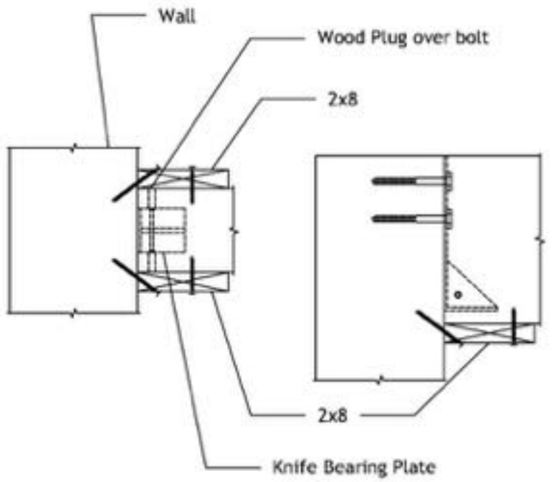






Concealed connectors

Fire Resistance of Connections – Protection Strategies



Example in AWC TR-10

Photo WoodWorks

Gypsum protection

Discussion in AWC TR-10

Wood protection

Demonstrating Fire Resistance Ratings

Fire Resistance Ratings of Connections

- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
    1. Fire-resistance designs in “approved sources”
    2. Prescriptive assemblies in IBC 721
    3. Calculations per IBC 722
    4. Engineering analysis based on tested assemblies
    5. Alternative methods per IBC 104.11
    6. Fire-resistance design certified by approved agency

WoodWorks Inventory

Table 4: North American Fire Resistance Tests of Connections

Connection Type	Connection Style	Assembly Description	Connection Details	L
Beam to Column	Concealed	CLT Floor over 8.75"x18" Glulam Beam with concealed connector to 16.5" x 14.25" Glulam Column	Ricon S VS 290x80 (Steel)	
Beam to Column	Concealed	CLT Floor over 10.75"x24" Glulam Beam with concealed connector to 16.5" x 14.25" Glulam Column	Double Ricon S VS 200x80 (Steel)	
Beam to Column	Concealed	CLT Floor over 10.75"x24" Glulam Beam with concealed connector to 16.5" x 14.25" Glulam Column	Megant 430 x 150 (Aluminum)	
Beam to Column	Concealed	CLT Floor over 9.78" x 18" Glulam Beam with 1 concealed connector to 16" x 16" Glulam Column	Single Simpson Strong-Tie CBH2.37x9.97	
Beam to Column	Concealed	CLT Floor over 14.25" x 27" Glulam Beam with 4 concealed connectors to 16" x 16" Glulam Column	Four Simpson Strong-Tie CBH2.37x9.97	
Beam to Column	Concealed	CLT Floor over 6.75" x 14.25" Glulam Beam with 1 concealed connector to 16" x 16" Glulam Column	Single Simpson Strong-Tie CBH2.37x9.97	
Beam to Column	Concealed	CLT Floor over 12.75" x 27" Glulam Beam with 4 concealed connectors to 16" x 16" Glulam Column	Four Simpson Strong-Tie CBH2.37x9.97	

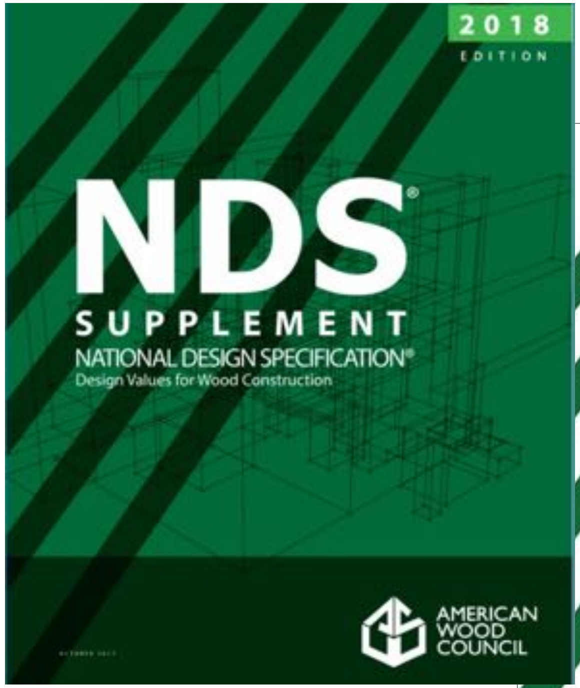
* ASTM E119 does not explictily include provisions for testing of connections, however the standard time temperature curves were used

Demonstrating Fire Resistance Ratings

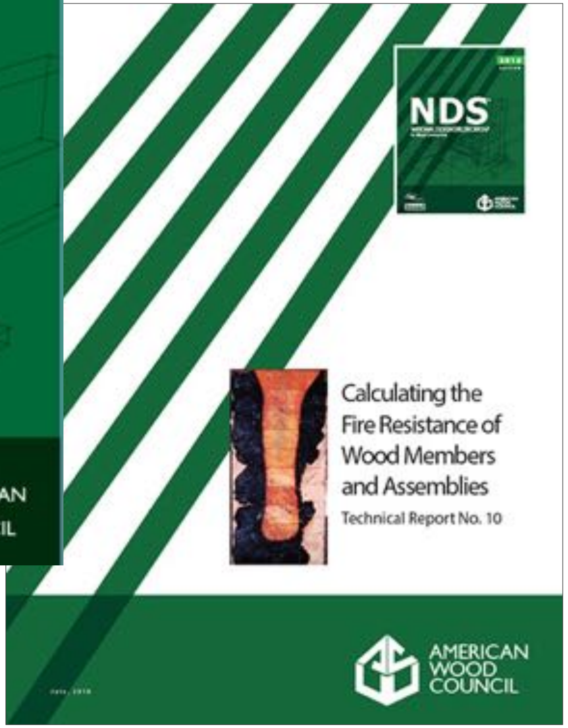
Fire Resistance Ratings of Connections

- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
  1. Fire-resistance designs in "approved sources"
  2. Prescriptive assemblies in IBC 721
  3. Calculations per IBC 722
  4. Engineering analysis based on tested assemblies
  5. Alternative methods per IBC 104.11
  6. Fire-resistance design certified by approved agency

AWC Publications



NDS
Wood Cover



TR-10
Wood & Gypsum Cover

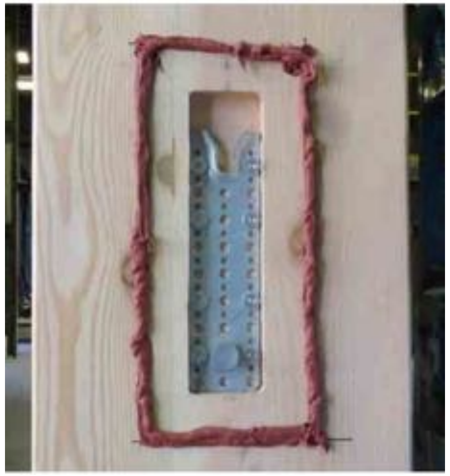
Demonstrating Fire Resistance Ratings

Fire Resistance Ratings of Connections

- Tested Assemblies (IBC 703.2)
- Analytical Methods (IBC 703.3):
  1. Fire-resistance designs in "approved sources"
  2. Prescriptive assemblies in IBC 721
  3. Calculations per IBC 722
  4. Engineering analysis based on tested assemblies
  5. Alternative methods per IBC 104.11
  6. Fire-resistance design certified by approved agency

Tapes, Caulks and Sealants
Primarily for smoke, draft, and flame block in gaps and intersections

Credit 3M



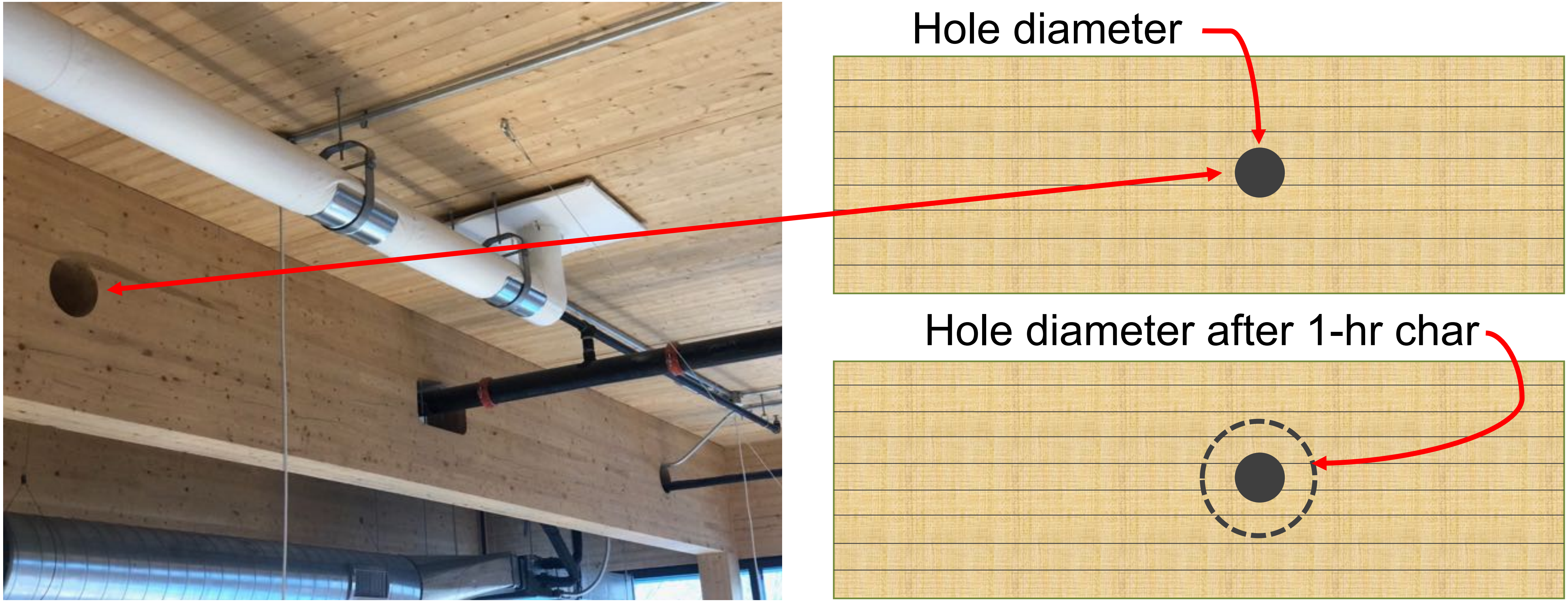
Credit Arup

Credit Hilti

Penetrations & Firestopping

Beam penetrations:

- If FRR = 0-hr, analyze structural impact of hole diameter only
- If FRR > 0-hr, account for charred hole diameter or firestop penetration

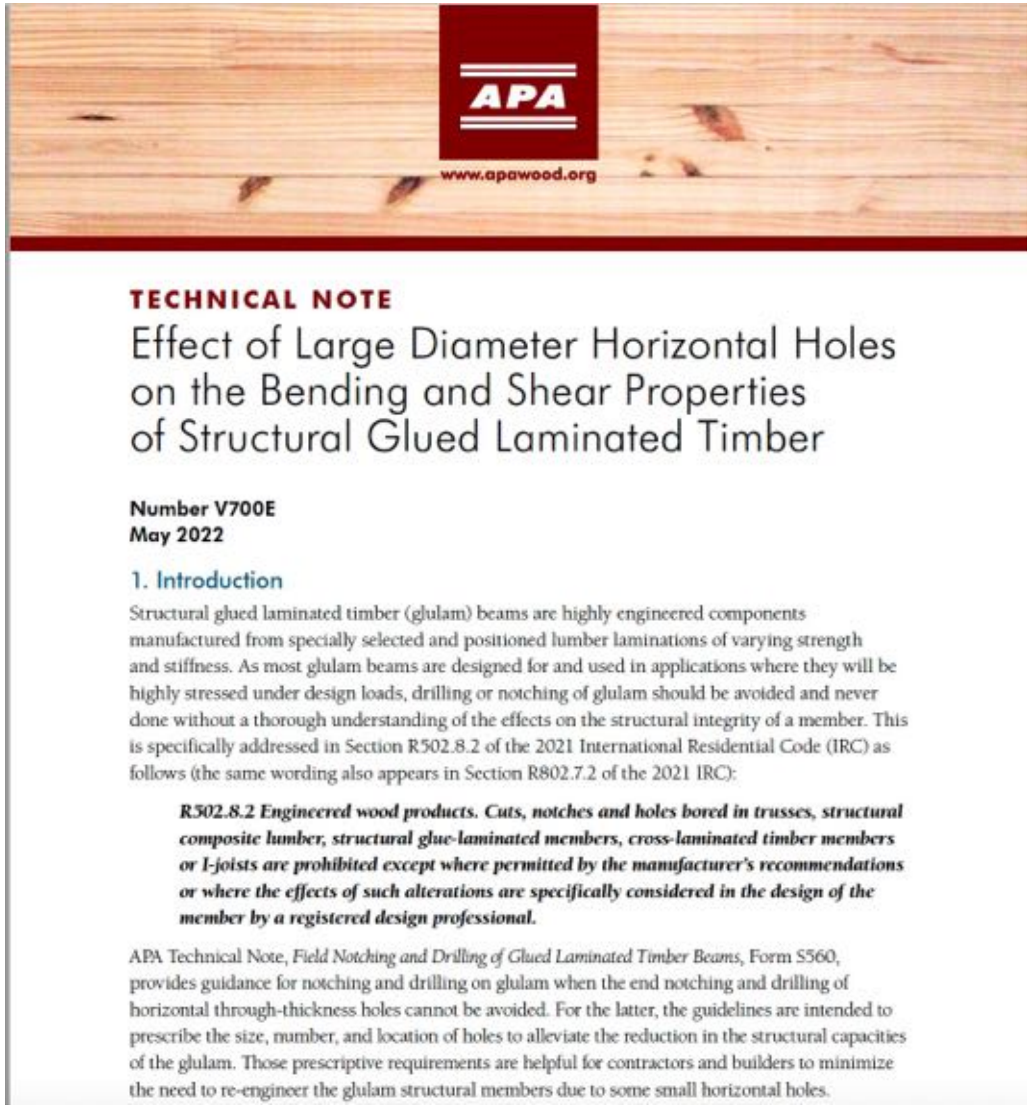


Penetrations & Firestopping

Document provides a method of calculating the bending moment capacity, bending stiffness, and shear capacity of a glulam beam with large horizontal holes.

Based on a maximum hole diameter of:

- 2d/3 for glulam members up to 24” deep
- 16” for glulam members deeper than 24”



TECHNICAL NOTE

Effect of Large Diameter Horizontal Holes on the Bending and Shear Properties of Structural Glued Laminated Timber

Number V700E
May 2022

1. Introduction

Structural glued laminated timber (glulam) beams are highly engineered components manufactured from specially selected and positioned lumber laminations of varying strength and stiffness. As most glulam beams are designed for and used in applications where they will be highly stressed under design loads, drilling or notching of glulam should be avoided and never done without a thorough understanding of the effects on the structural integrity of a member. This is specifically addressed in Section R502.8.2 of the 2021 International Residential Code (IRC) as follows (the same wording also appears in Section R802.7.2 of the 2021 IRC):

> ***R502.8.2 Engineered wood products. Cuts, notches and holes bored in trusses, structural composite lumber, structural glue-laminated members, cross-laminated timber members or I-joists are prohibited except where permitted by the manufacturer's recommendations or where the effects of such alterations are specifically considered in the design of the member by a registered design professional.***

APA Technical Note, *Field Notching and Drilling of Glued Laminated Timber Beams*, Form S560, provides guidance for notching and drilling on glulam when the end notching and drilling of horizontal through-thickness holes cannot be avoided. For the latter, the guidelines are intended to prescribe the size, number, and location of holes to alleviate the reduction in the structural capacities of the glulam. Those prescriptive requirements are helpful for contractors and builders to minimize the need to re-engineer the glulam structural members due to some small horizontal holes.

Penetrations & Firestopping

Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies

WOODWORKS WOOD PRODUCTS COUNCIL

CLT Panel	Exposed Side Protection	Penetrating Item	Penetrant Centered or Offset in Hole	Firestopping System Description	F Rating	T Rating	Test Protocal	Source	Testing Lab
5-ply (175mm 6.875")	None	2" nominal electrical metal tubing (EMT)	0.5" offset from center	4.21 in diameter hole. The void between the CLT and pipe at the top was filled with Roxul Safe mineral wool leaving a 1/2 in deep void at the top of the assembly. Hilti FS-One Max Intumescent Firestop Sealant was applied to a depth of 1/2 in on the top of the assembly between the CLT and pipe. Pipe insulated with Roxul ProRox for 24" beyond non-exposed face.	1.5 hours	1.5 hours	ASTM E814	25	QAI Laboratories January 24, 2017
5-ply (175mm 6.875")	None	3" PVC pipe	Not noted in test report	4.5 in diameter hole. Firestopping installation and products based on UL System C-AJ-2228.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" Aquatherm Green Pipe (SDR7.4)	Not noted in test report	6 in diameter hole. Firestopping installation and products based on UL System C-AJ-1551.	1 hour	1 hour	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" cast iron pipe	Not noted in test report	5.375 in diameter hole. Firestopping installation and products based on UL System C-AJ-1427.	2 hours	0.5 hour	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" Aquatherm Green Pipe (SDR7.4)	Not noted in test report	3.5 in diameter hole. Firestopping installation and products based on UL System C-AJ-2228.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	1-3/4" threaded steel rod (A722 GR 150)	Not noted in test report	3.125 in diameter hole. Threaded rod inserted into 2.5 in diameter steel sleeve (Sch. 40). Firestopping installation and products based on UL System C-AJ-1551.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	3" PVC pipe	Not noted in test report	4.5 in diameter hole. Firestopping installation and products based on UL System C-AJ-2228.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" Aquatherm Green Pipe (SDR7.4)	Not noted in test report	6 in diameter hole. Firestopping installation and products based on UL System C-AJ-1551.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" cast iron pipe	Not noted in test report	5.375 in diameter hole. Firestopping installation and products based on UL System C-AJ-1427.	2 hours	1 hour	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	4" Aquatherm Green Pipe (SDR7.4)	Not noted in test report	3.5 in diameter hole. Firestopping installation and products based on UL System C-AJ-2228.	2 hours	2 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	1-3/4" threaded steel rod (A722 GR 150)	Not noted in test report	3.125 in diameter hole. Threaded rod inserted into 2.5 in diameter steel sleeve (Sch. 40). Firestopping installation and products based on UL System C-AJ-1551.	2 hours	1.5 hours	ASTM E814	37	WFCi September 6-8, 2017
5-ply (175mm 6.875")	None	Metallic pipe with insulation or cable	May be centered or offset. Offset may range from 1/2 in to 2-9/16 in	Max 6 in diameter hole. Fill annular space with min. 5 in thick layer of mineral wool insulation. For wall applications, apply 3/4 in thick layer of Hilti FS-ONE MAX firestop intumescent sealant on both sides of the wall assembly. For floor applications, apply 3/4 in thick layer of Hilti FS-ONE MAX firestop intumescent sealant on the top side of the floor/ceiling assembly.	2 hours	0.25 hours	ASTM E814	38	Intertek October 26, 2021
5-ply (175mm 6.875")	None	Max. 4 in diameter cable bundle with nominal 44% visual fill of cables within opening	May be centered or offset. Offset may range from 1/2 in to 1 in	Max 6 in diameter hole. Fill annular space with min. 5 in thick layer of mineral wool insulation. For wall applications, apply 3/4 in thick layer of Hilti FS-ONE MAX firestop intumescent sealant on both sides of the wall assembly. For floor applications, apply 3/4 in thick layer of Hilti FS-ONE MAX firestop intumescent sealant on the top side of the floor/ceiling assembly.	2 hours	0.25 hours	ASTM E814	39	Intertek October 26, 2021

FRR Design of MT


WoodWorks™
WOOD PRODUCTS COUNCIL

Fire-Resistive Design of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

Richard McLain, PE, SE • Senior Technical Director • WoodWorks
Scott Breneman, PhD, PE, SE • Senior Technical Director • WoodWorks

For many years, exposed heavy timber framing elements have been permitted in U.S. buildings due to their inherent fire-resistance properties. The predictability of wood's char rate has been well-established for decades and has long been recognized in building codes and standards.

Today, one of the exciting trends in building design is the growing use of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction. Like heavy timber, mass timber products have inherent fire resistance that allows them to be left exposed and still achieve a fire-resistance rating. Because of their strength and dimensional stability, these products also offer a low-carbon alternative to steel, concrete, and masonry for many applications. It is this combination of exposed structure and strength that developers and designers across the country are leveraging to create innovative designs with a warm yet modern aesthetic, often for projects that go beyond traditional norms of wood design.

This paper has been written to support architects and engineers exploring the use of mass timber for commercial and multi-family construction. It focuses on how to meet fire-resistance requirements in the International Building Code (IBC), including calculation and testing-based methods. Unless otherwise noted, references refer to the 2018 IBC.

Mass Timber & Construction Type

Before demonstrating fire-resistance ratings of exposed mass timber elements, it's important to understand under what circumstances the code currently allows the use of mass timber in commercial and multi-family construction.

A building's assigned construction type is the main indicator of where and when all wood systems can be used. IBC Section 602 defines five main options (Type I through V) with all but Type IV having subcategories A and B. Types III and V permit the use of wood framing throughout much of the structure and both are used extensively for modern mass timber buildings.

Type III (IBC 602.3) – Timber elements can be used in floors, roofs and interior walls. Fire-retardant-treated wood (FRTW) framing is permitted in exterior walls with a fire-resistance rating of 2 hours or less.

Type V (IBC 602.5) – Timber elements can be used throughout the structure, including floors, roofs and both interior and exterior walls.

Type IV (IBC 602.4) – Commonly referred to as 'Heavy Timber' construction, this option

Carbon12 | Portland, Oregon
Kaiser Group | Path Architecture
Munzing Structural Engineering

Mass Timber Fire Design Resource

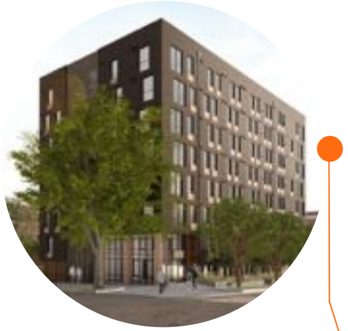
- Code compliance options for demonstrating FRR
- Free download at woodworks.org

TALL WOOD

= 20 in-design tall wood projects

= tall wood project in construction or completed

INTRO Cleveland
Cleveland, OH
9 stories –
8 mass timber

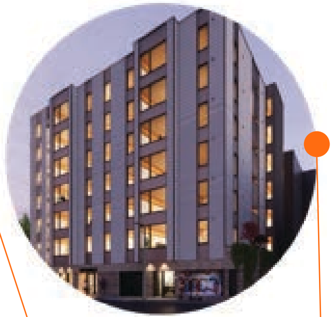


Heartwood
Seattle, WA
8 stories mass timber

Carbon 12
Portland, OR
8 stories mass timber

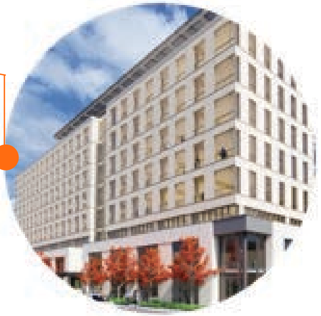
Ascent
Milwaukee, WI
25 stories –
19 mass timber

Minnesota Places
Portland, OR
8 stories - 7 mass timber

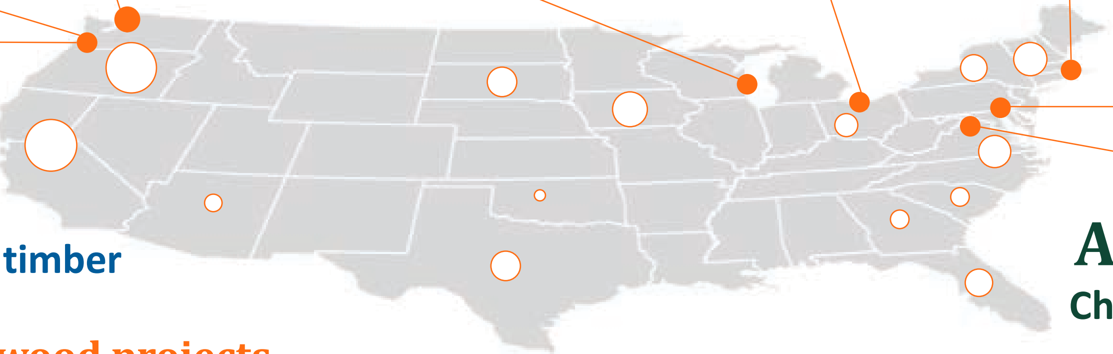


11 E Lenox
Boston, MA
7 stories mass timber

80 M Street
Washington DC
10 stories – 3-story mass timber vertical addition



Apex Plaza
Charlottesville, VA
8 stories –
6 mass timber



WoodWorks is supporting 189 tall wood projects

Minnesota Places, rendering Wright Architecture; Carbon 12, Kaiser+Path, photo Andrew Pogue; Heartwood, rendering Atelier Jones; INTRO Cleveland, Harbor Bay Real Estate Advisors, HPA Architecture; Ascent, Korb + Associates Architects, Thornton Tomasetti; 11 E Lenox, rendering Monte French Design Studio; 80 M Street, Hickok Cole Architects, Columbia Property Trust; Apex Plaza, rendering William McDonough + Partners


Photos: Baumberger Studio/PATH Architecture

PRECEDENT PROJECTS | CARBON 12 | PORTLAND, OR

INTRO, CLEVELAND

9 Stories | 115 ft

8 Timber Over 1 Podium

Type IV-B

Variance to expose ~50% ceilings

Photo: Harbor Bay Real Estate Advisors, Image Fiction | Architect: Hartshorne Plunkard Architecture

APEX PLAZA
CHARLOTTESVILLE, VA

8 STORIES
6 TIMBER OVER 2 PODIUM, 100 FT

PRIMARILY OFFICE SPACE

Photo: William McDonough + Partners | Architect: William McDonough + Partners

11 E LENOX, BOSTON, MA

Credit: H + O Structural Engineering

ASCENT, MILWAUKEE

Tallest Mass Timber Building in the World

Photo: CD Smith Construction |
Architect: Korb & Associates Architects

80 M ST, WASHINGTON, DC

3 STORY VERTICAL ADDITION
7 STORY EXISTING BUILDING

Photo: WoodWorks | Architect: Hickok Cole

HEARTWOOD, SEATTLE

8 STORIES

Workforce Housing

Photo: Atelier Jones |
Architect: Atelier Jones

Type IV-C   66,000 SF

MINNESOTA PLACES, PORTLAND

8 STORIES

Affordable Housing

Photo: Wright Architecture|
Architect: Wright Architecture

Type IV-C   72 Units   7 Stories of Timber over Podium

ICC INTERNATIONAL CODE COUNCIL®

3 YEAR CODE CYCLE

Source: ICC

Fire Safe Implementation of Mass Timber In Tall Buildings

Research of the fire performance of CLT and Glued Laminated Timber buildings, with visible wood surfaces.

The main aim of this research project was to identify safe limits of exposed mass timber surface areas that correspond with performance criteria used for previous U.S. Building Code Changes.

Source: RISE

WHY ANOTHER ROUND OF COMPARTMENT FIRE TESTING?

Conservatism: ATF lab tests based on older generation CLT adhesives

2018 ATF tests were initiated before the 2018 version of ANSI/APA PRG 320 was published and the tested CLT was not compliant with the new product standard.


USDA
United States Department of Agriculture

Compartment Fire Testing of a Two-Story Mass Timber Building

Samuel L. Zelinka
Laura E. Hasburgh
Keith J. Bourne
David R. Tucholski
Jason P. Ouellette

Forest Service
Forest Products Laboratory
General Technical Report FPL–GTR–247
May 2018

Source: RISE, USDA FS FPL & AWC

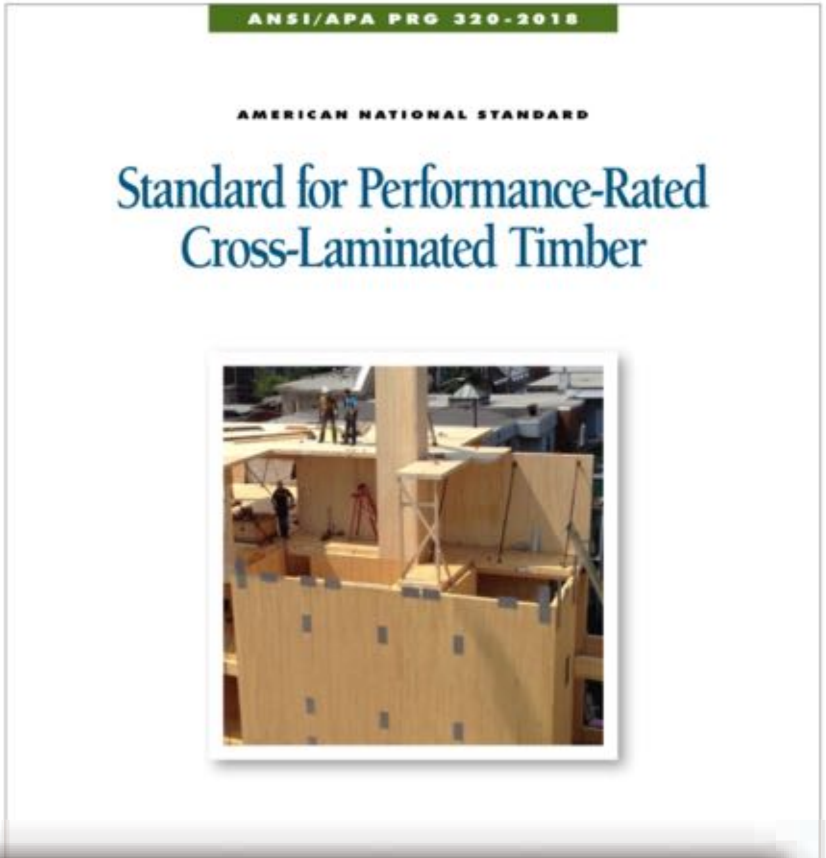
CLT Fire Performance – Fire Re-Growth

In tall buildings, preventing fire re-growth is key.
Fire re-growth is a phenomenon in which the heat-release rate of a fire intensifies following a decay phase. Fire re-growth can be initiated when delamination occurs, as this exposes un-charred wood surfaces, thereby resulting in an influx of fuel available for consumption by the fire.

CLT Fire Performance – PRG 320

PRG 320 is manufacturing & performance standard for CLT

2018 edition (referenced in 2021 IBC) added new elevated temperature adhesive performance requirements validated by full-scale and medium-scale qualification testing to ensure CLT does not exhibit fire re-growth



ANNEX B. PRACTICE FOR EVALUATING ELEVATED TEMPERATURE PERFORMANCE OF ADHESIVES USED IN CROSS-LAMINATED TIMBER (MANDATORY)

RISE Tests, 2020
Photo: RISE

G147-21

IBC: 602.4.2.2.2, 602.4.2.2.4

Change to 2024 IBC: IV-B Ceiling Exposure

Proponents: Susan Jones, atelierjones, llc, representing atelierjones, llc (susan@atelierjones.com); Stephen DiGiovanni, representing Self (sdigiovanni@clarkcountynv.gov); Carl Baldassarra, Wiss Janney Elstner Associates, representing Self (cbaldassarra@wje.com)

2021 International Building Code

602.4.2.2 Interior protection. Interior faces of all *mass timber* elements, including the inside face of exterior *mass timber* walls and *mass timber* roofs, shall be protected, as required by this section, with materials complying with Section 703.3.

602.4.2.2.1 Protection time. *Noncombustible protection* shall contribute a time equal to or greater than times assigned in Table 722.7.1(1), but not less than 80 minutes. The use of materials and their respective protection contributions specified in Table 722.7.1(2) shall be permitted to be used for compliance with Section 722.7.1.

Revise as follows:

602.4.2.2.2 Protected area. Interior faces of *mass timber* elements, including the inside face of exterior *mass timber walls* and *mass timber roofs*, shall be protected in accordance with Section 602.4.2.2.1.

Exceptions: Unprotected portions of *mass timber*ceilings and walls complying with Section 602.4.2.2.4 and the following:

1. Unprotected portions of mass timber ceilings and walls complying with one of the following:
   - 1.1. Unprotected portions of *mass timber* ceilings, including attached beams, shall be permitted and shall be limited to an area less than or equal to ~~20~~ 100 percent of the floor area in any *dwelling unit* or *fire area.*
   - 1.2. Unprotected portions of *mass timber* walls, including attached columns, shall be permitted and shall be limited to an area less than or equal to 40 percent of the floor area in any *dwelling unit* or *fire area.*
   - 1.3. Unprotected portions of both walls and ceilings of *mass timber*, including attached columns and beams, in any *dwelling unit* or *fire area* shall be permitted in accordance with Section 602.4.2.2.3.
2. *Mass timber* columns and beams that are not an integral portion of walls or ceilings, respectively, shall be permitted to be unprotected without restriction of either aggregate area or separation from one another.

Change to 2024 IBC: IV-B Exposure Separation

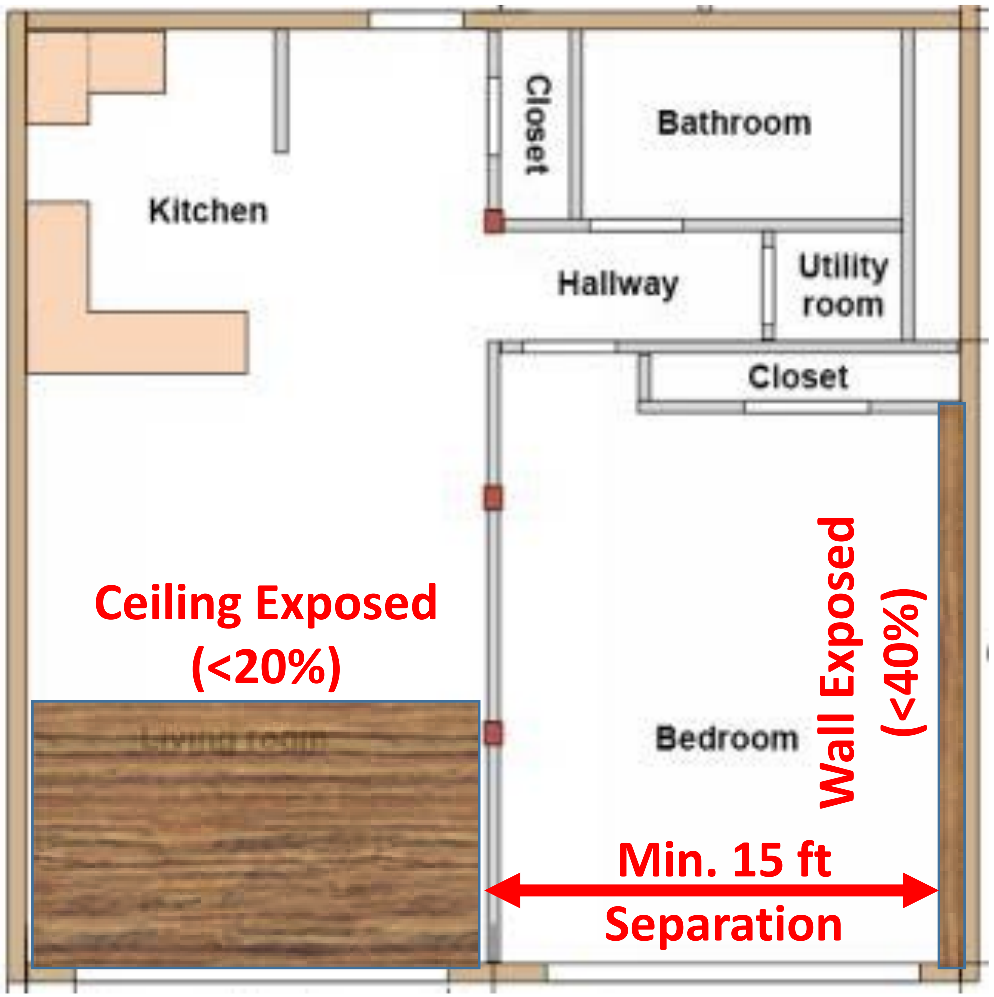
Revise as follows:

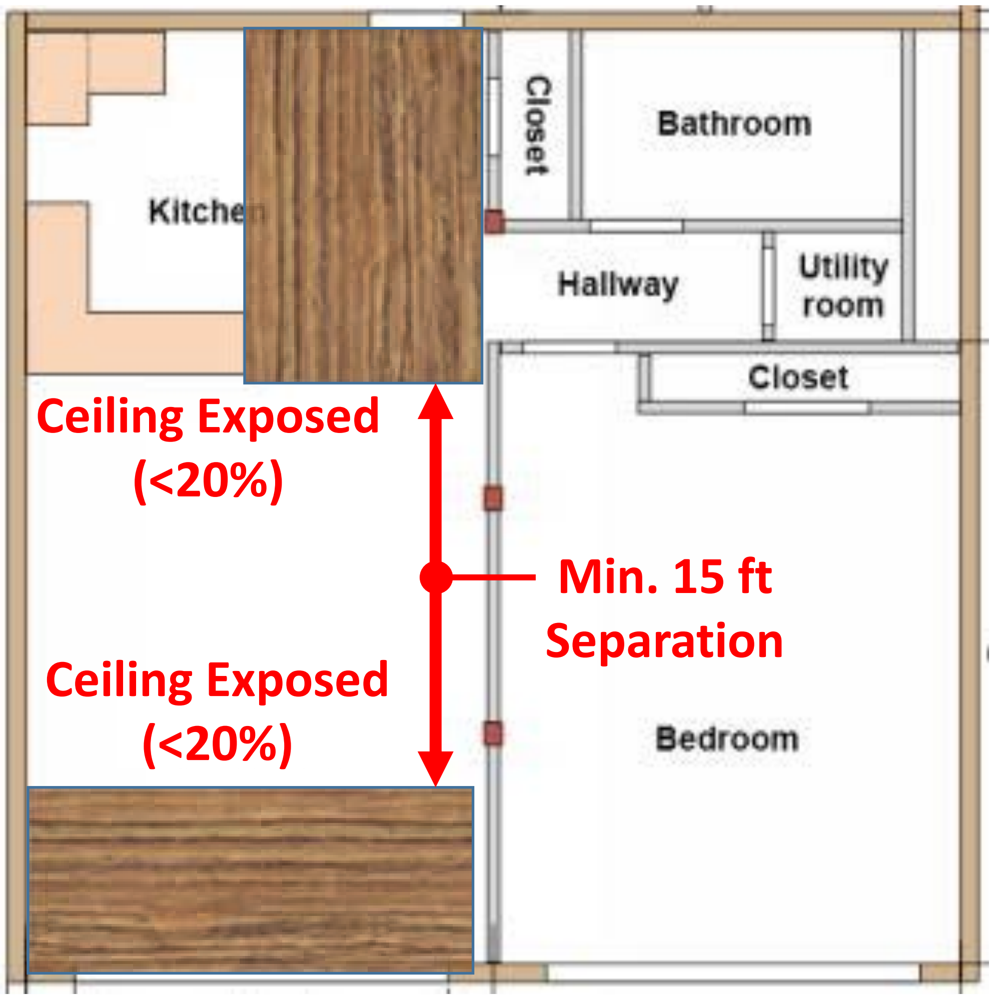
602.4.2.2.4 Separation distance between unprotected mass timber elements. In each *dwelling unit* or *fire area*, unprotected portions of *mass timber* walls ~~and ceilings~~ shall be not less than 15 feet (4572 mm) from unprotected portions of other walls ~~and ceilings, measured horizontally along the ceiling and from other unprotected portions of walls~~ measured horizontally along the floor.

Type IV-B Protection vs. Exposed

IV-B

2021 IBC Allowances



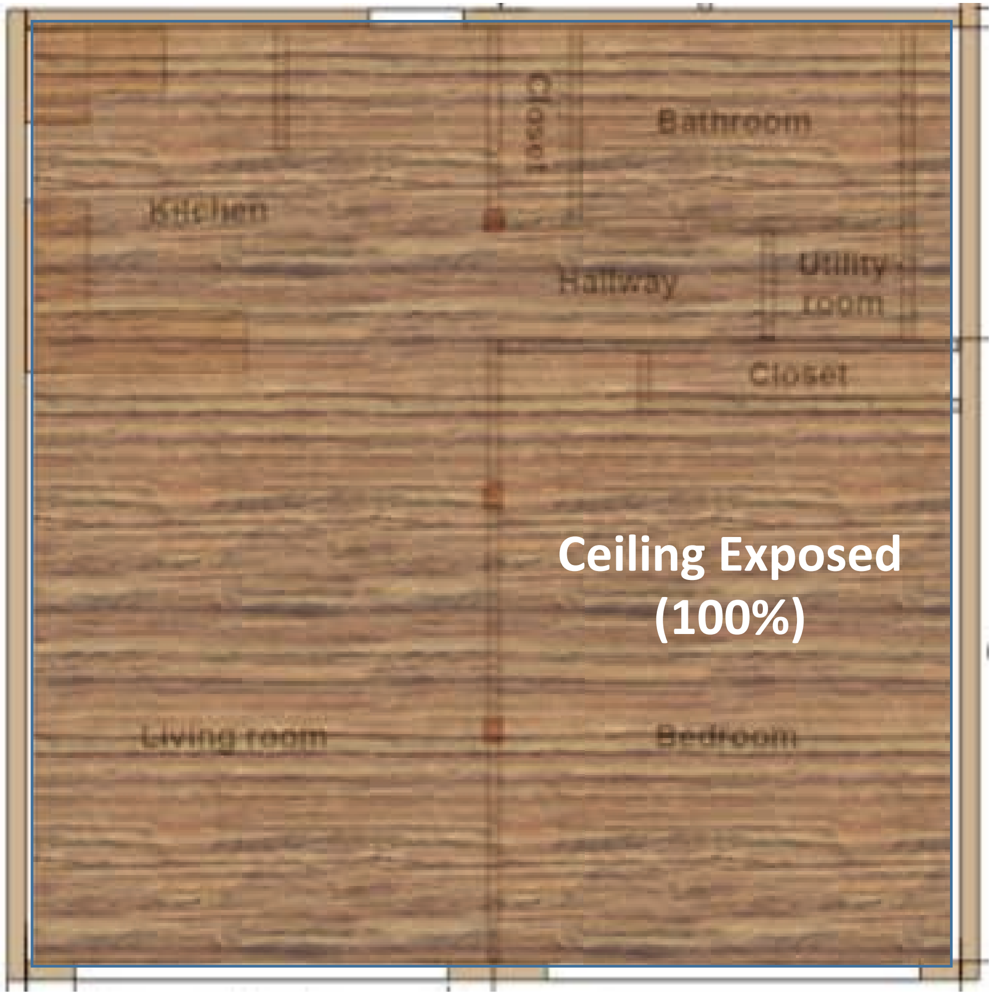


Credit: AWC

Type IV-B Protection vs. Exposed

IV-B

2024 IBC Allowances



Credit: AWC

No separation req'd between wall & ceiling

Floor Surface Protection

Min. 1” thick NC protection required on mass timber floors in IV-A and IV-B. Not required in IV-C

Floor Surface Protection

F174-21

IFC: 3303.5

Proponents: David Tyree, representing AWC (dtyree@awc.org); Raymond O'Brocki, AWC, representing AWC (robrocki@awc.org)

2021 International Fire Code

Revise as follows:

3303.5 Fire safety requirements for buildings of Types IV-A, IV-B and IV-C construction. Buildings of Types IV-A, IV-B and IV-C construction designed to be greater than six stories above *grade plane* shall comply with the following requirements during construction unless otherwise *approved* by the *fire code official*.

1. Standpipes shall be provided in accordance with Section 3313.
2. A water supply for fire department operations, as *approved* by the *fire code official* and the *fire chief*.
3. Where building construction exceeds six stories above *grade plane* and noncombustible protection is required by Section 602.4 of the *International Building Code*, at least one layer of noncombustible protection shall be installed on all building elements on floor levels, including mezzanines, more than four levels below active mass timber construction before additional floor levels can be erected.

   ~~Exception~~ Exceptions:

   1. Shafts and vertical exit enclosures shall not be considered part of the active mass timber construction.
   2. Noncombustible material on the top of mass timber floor assemblies shall not be required before erecting additional floor levels.

4. Where building construction exceeds six stories above *grade plane*, required exterior wall coverings shall be installed on floor levels, including mezzanines, more than four levels below active mass timber construction before additional floor levels can be erected.

   Exception: Shafts and vertical exit enclosures shall not be considered part of the active mass timber construction.

Credit: ICC

Tall Mass Timber Code Adoptions

Learn Tools Events Award Gallery Why Wood? About

Status as of July 2022

The 2021 International Building Code (IBC) has been published and is available for purchase through the International Code Council. This version of the code includes three new construction types—IV-A, IV-B and IV-C—that allow the use of mass timber or noncombustible materials in buildings up to 18, 12 and nine stories (respectively). Additionally, Group A changes to be incorporated in the 2024 IBC have been voted on and results ratified by ICC. One significant change relative to construction type IV-B is the allowance for exposure of mass timber ceilings and integral beams. The 2021 IBC permitted these areas to have 20% exposure while the 2024 IBC will permit 100% exposure. See the full code change language, which was approved as submitted, here.

The following jurisdictions have adopted the tall mass timber provisions in the 2021 and/or 2024 IBC, either whole or with local amendments.

- Oregon – Appendix P Tall Wood Buildings within the 2019 Oregon Structural Specialty Code
- Washington – Washington State Building Code
- City of Denver, Colorado – Appendix U Tall Wood Buildings (page 187) within the 2019 Denver Building Code
- Utah – Chapter 2a: Tall Wood Buildings of Mass Timber Construction, incorporated as part of the State Construction Code
- California – Supplement to the 2019 California Building Code
- Virginia – Supplement 2021 IBC Mass Timber Provisions within the 2018 state building code
- Maine – Emergency Rule 3, amendments to the Maine Uniform Building and Energy Code (Section 5, item 25)
- Georgia – Appendix P to the 2018 IBC
- Idaho – Amendments to the Idaho Building Code
- Howard County, Maryland – adoption of the 2021 IBC
- Texas Jurisdictions:
  - City of Dallas – Ordinance 32198 which incorporates some 2021 and 2024 IBC allowances for tall mass timber
  - City of Austin – adoption of the 2021 IBC
  - City of Bryan – adoption of the 2021 IBC
  - City of Carrollton – adoption of the 2021 IBC
  - City of Plano – adoption of the 2021 IBC
  - City of Grand Prairie – adoption of the 2021 IBC
  - City of Fort Worth – adoption of the 2021 IBC

MASS TIMBER FIRE RESISTANCE DESIGN

Credit: FPInnovations

2 Hour FRR for Mass Timber

FRR Requirements for Tall Mass Timber Structures (hours)

Building Element	IV-A	IV-B	IV-C
Primary Frame	3	2	2
Exterior Bearing Walls	3	2	2
Interior Bearing Walls	3	2	2
Roof Construction	1.5	1	1
Primary Frame at Roof	2	1	1
Floor Construction	2	2	2

Source: 2021 IBC Table 601

Floor panels for all, primary frame for most, bearing walls for most

Noncombustible Protection

Noncombustible Protection Required (IV-A, IV-B)

	IV-A	IV-B	IV-C	IV-HT
Roof below Mass Timber	60 min	40 min*	Not Req.	Not Req.
Primary Frame @ Roof	80 min	40 min*	Not Req.	Not Req.
Primary Frame	120 min	80 min*	Not Req.	Not Req.
Below Mass Timber Floor	80 min	80 min*	Not Req.	Not Req.
Above Mass Timber Floor	1” Min NC Material	1” Min NC Material	Not Req.	Not Req.

Requirements Per new 602.4. * Some MT permitted to be exposed.

MT Fire Resistance Ratings (FRR)

IBC 722.7

The fire resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element (MT) added to the protection time of the noncombustible (NC) protection.

+

= FRR

MT Fire Resistance Ratings (FRR)

However, FRR Doesn't always need to be from a combination of MT + NC. In some cases, just NC can be used, in other cases, just MT can be used:

IBC 602.4
Mass timber elements shall meet the fire resistance rating requirements of this section based on either the fire resistance rating of the noncombustible protection, the mass timber, or a combination of both.

Type IV-A Fire Resistance Ratings (FRR)

IV-A

Primary Frame (3-hr) + Floor Panel Example (2-hr):

Minimum 1" noncombustible material

Mass timber floor panel

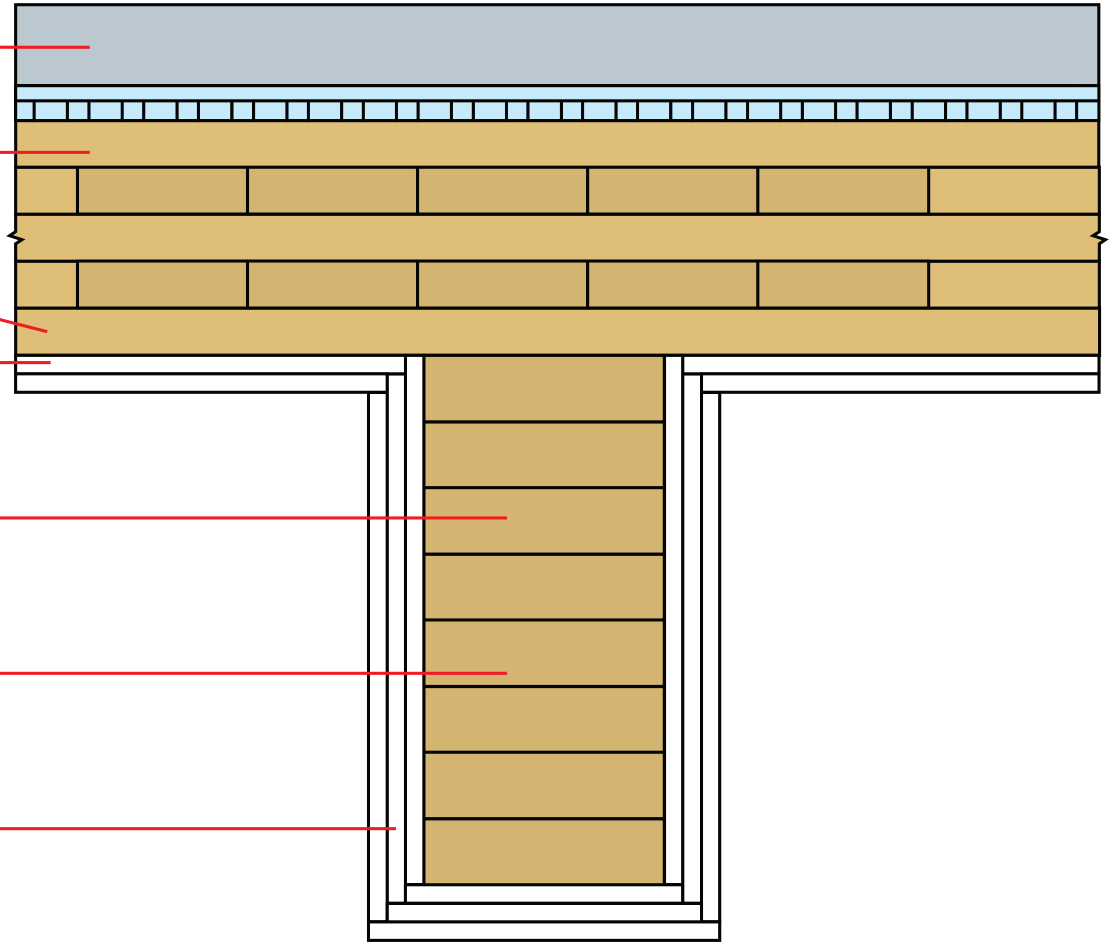
40 minutes of MT FRR

Two layers 5/8" Type X gypsum

Glulam beam (primary structural frame)

60 minutes of MT FRR

Three layers 5/8" Type X gypsum



Type IV-B Fire Resistance Ratings (FRR)

IV-B

Primary Frame (2-hr) + Floor Panel (2-hr)

Minimum 1" noncombustible material

Mass timber floor panel

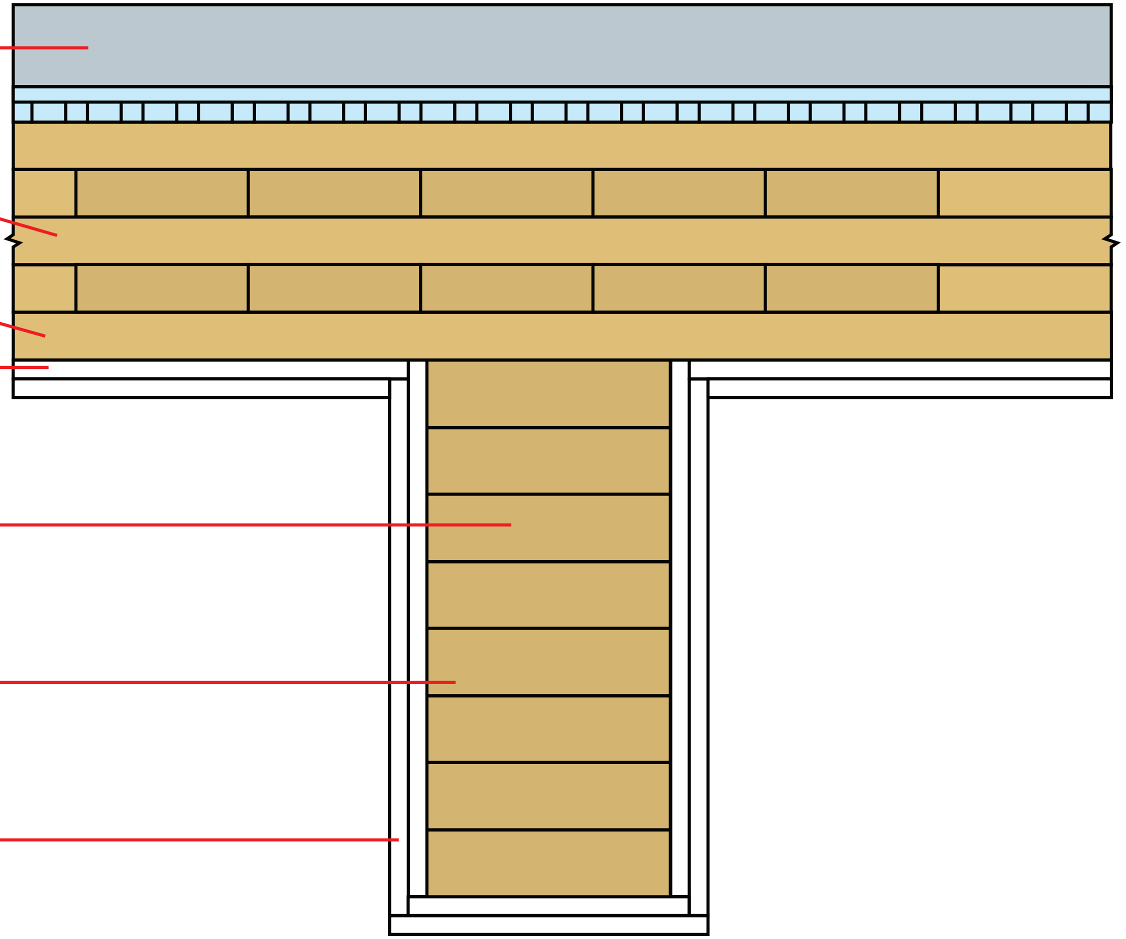
40 minutes of MT FRR

2 layers 5/8" Type X gypsum

Glulam beam (primary structural frame)

40 minutes of MT FRR

Two layers 5/8" Type X gypsum



Type IV-B Fire Resistance Ratings (FRR)

IV-B

Primary Frame (2-hr) + Floor Panel Example (2-hr)

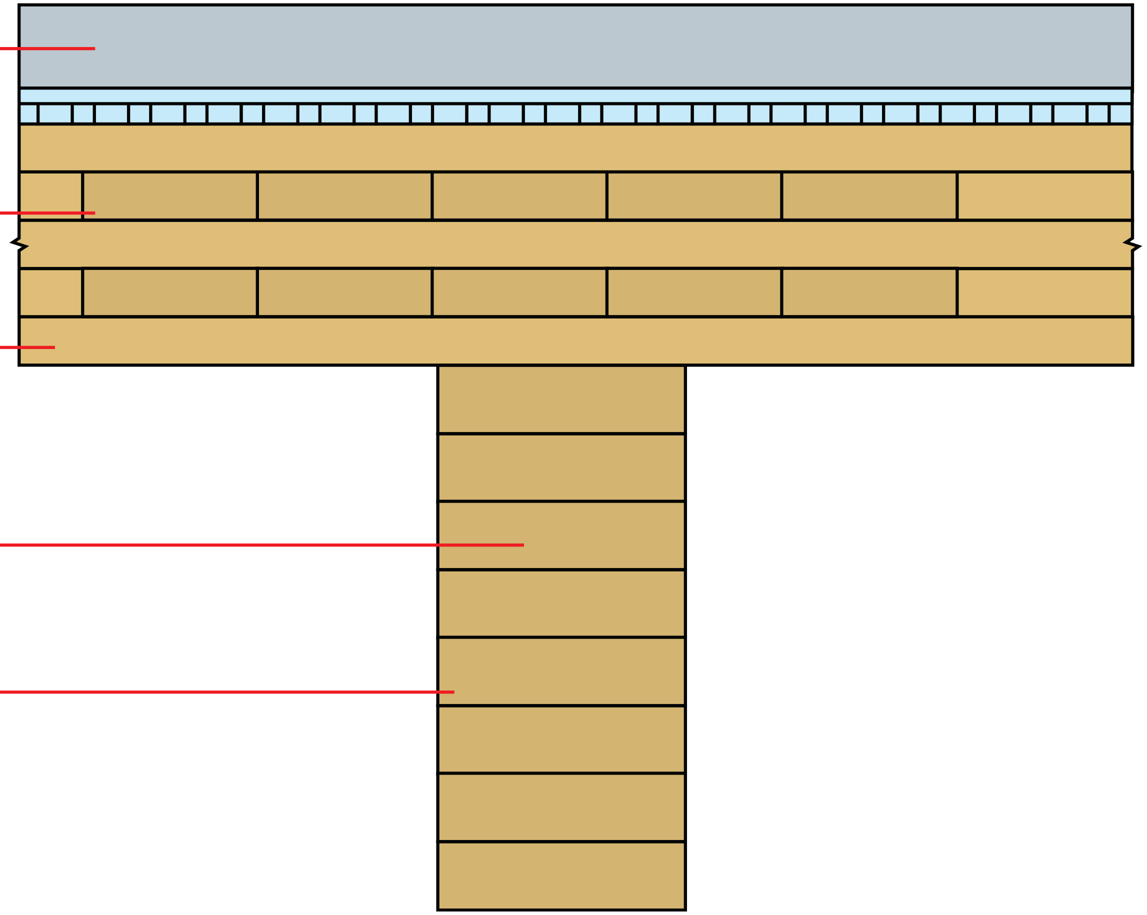
Minimum 1" noncombustible material

Mass timber floor panel

2-hr of MT FRR;
noncombustible material not required

Glulam beam (primary structural frame)

2-hr of MT FRR;
Noncombustible material not required



Type IV-C Fire Resistance Ratings (FRR)

IV-B

Primary Frame (2-hr) + Floor Panel Example (2-hr)

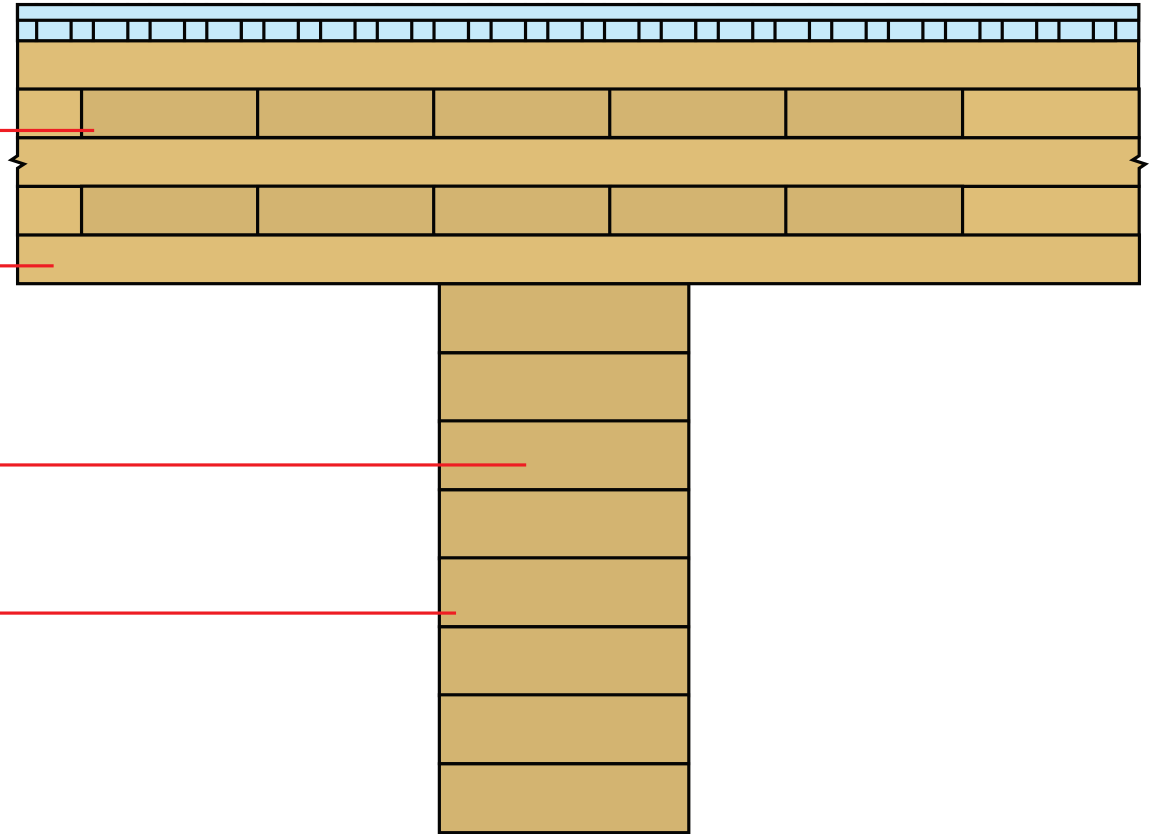
Noncombustible material not required

Mass timber floor panel

2-hr of MT FRR;
noncombustible material not required

Glulam beam (primary structural frame)

2-hr of MT FRR;
Noncombustible material not required

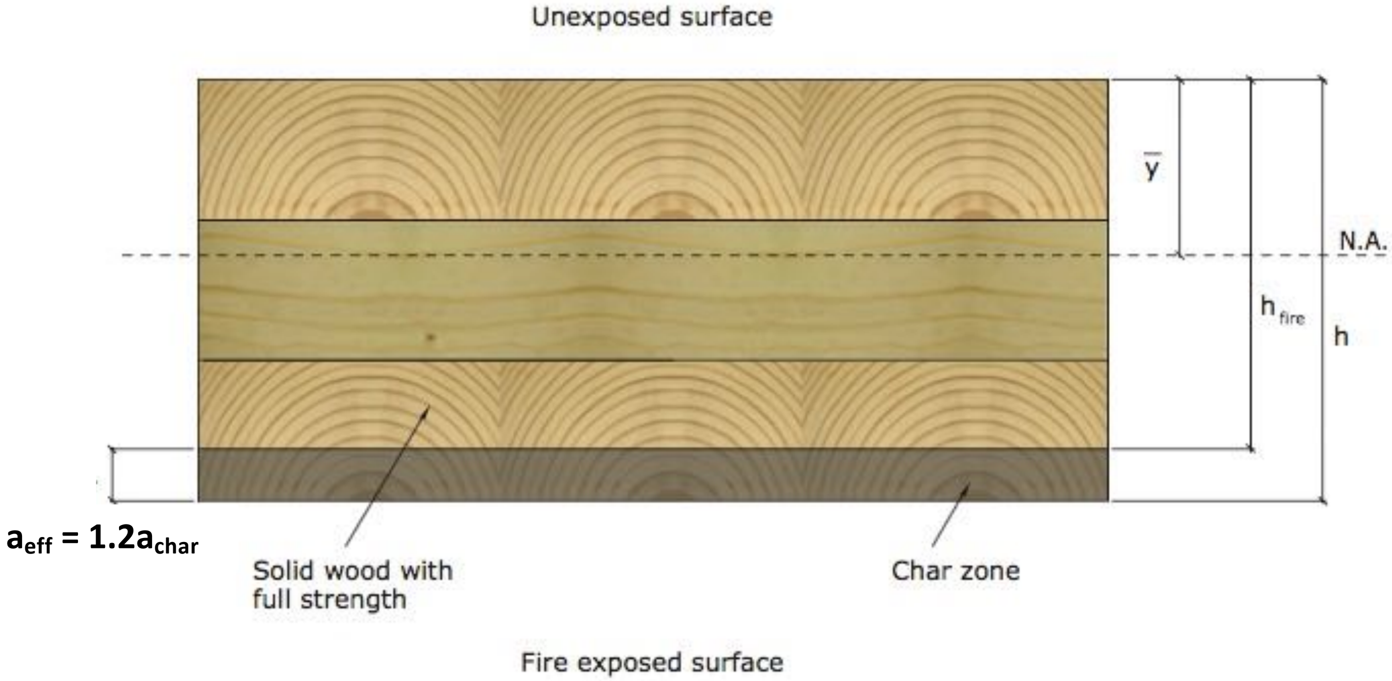


MT Fire Resistance Ratings (FRR)

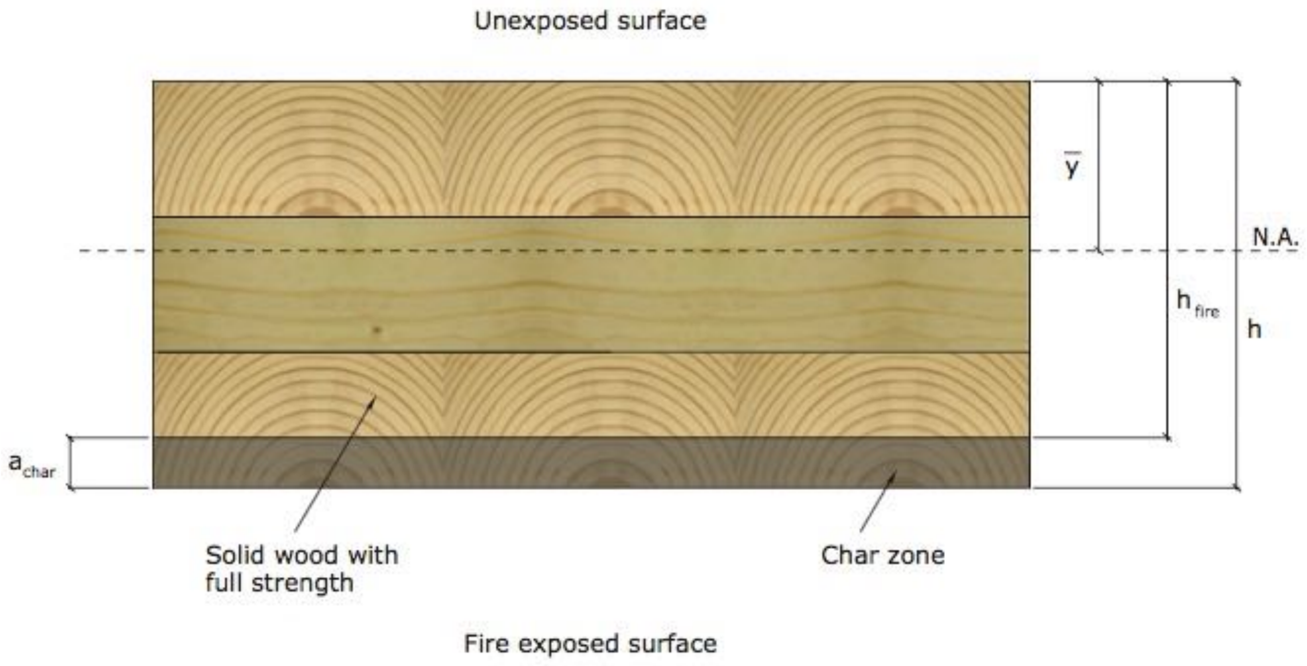
How do you determine FRR of MT?

2 Options:

1. **Calculations in Accordance with IBC 722 → NDS Chapter 16**
2. **Tests in Accordance with ASTM E119**



MT Fire Resistance Ratings (FRR)



CLT fire design:

- Lam thickness affects char depth
- Partially charred cross layers are typically neglected for structural checks

MT Fire Resistance Ratings (FRR)

CLT fire design example:

- 2-hour rating req'd
- Try 5-ply, 6-7/8", V1
- Span = 15 ft, DL = 55 psf, LL = 40 psf

Credit: Marcus Kauffman

MT Fire Resistance Ratings (FRR)

CLT fire design example:

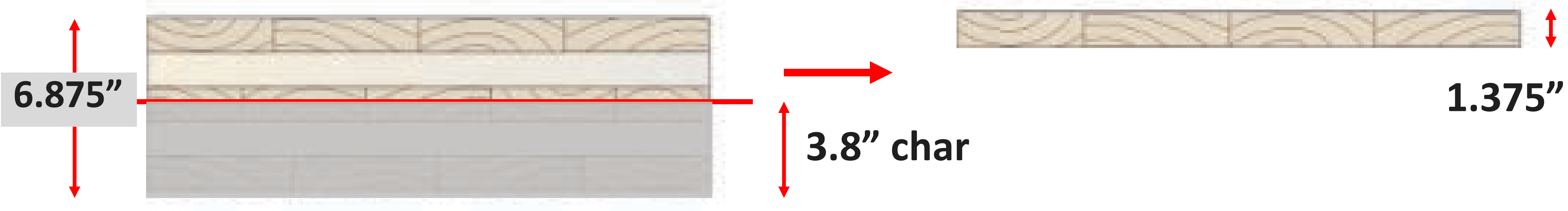
- 2-hr with 1-3/8” laminations
- Total char depth = 3.8”

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

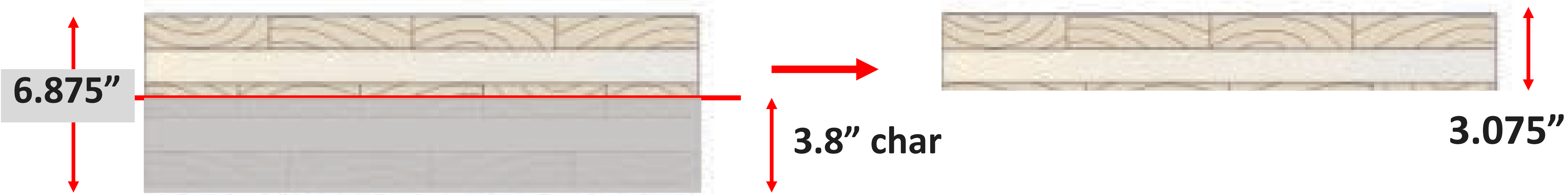
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

MT Fire Resistance Ratings (FRR)

Option 1: neglect minor axis layer and partial major axis layer. Assess as single layer

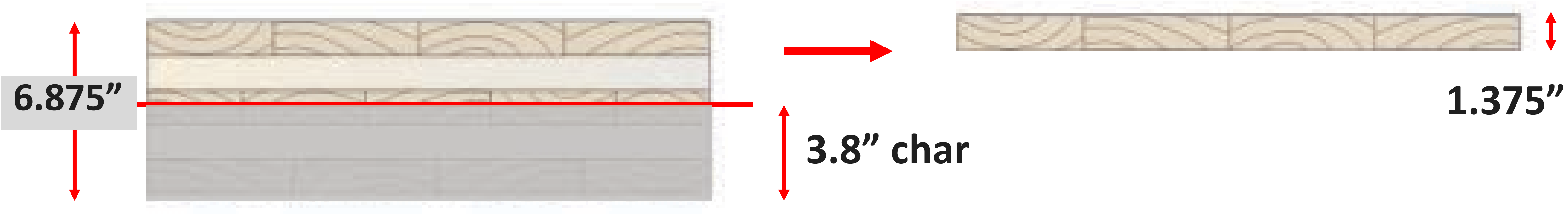


Option 2: account for partial major axis layer and minor axis layer. Assess using shear analogy method



MT Fire Resistance Ratings (FRR)

Option 1: neglect minor axis layer and partial major axis layer. Assess as single layer



$S = bd^2/6 = (12)(1.375)^2/6 = 3.78\ in^3$ $C_F = 1.3$ (assume 2x6 lamella) $C_{fu} = 1.15$

$M_{all} = F_b{'}S_{eff} = (900\ psi)(3.78\ in^3)(1.3)(1.15)(2.85) =$ **1208 lb-ft/ft**

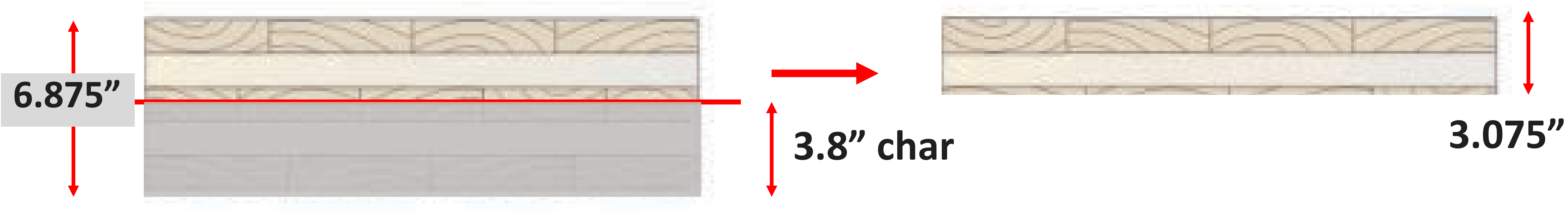
$M_{max} = w\ L^2 / 8 = (55+40psf)\ (15\ ft)^2 / 8 =$ **2672 lb-ft/ft**

$M_{max} > M_{all}$ therefore panel is inadequate for 2-hour fire design using option 1

Common lamella are based on 2x6 and 2x4 sizes lumber… Consult with the selected manufacturer or specify acceptable sizes

MT Fire Resistance Ratings (FRR)

Option 2: account for partial major axis layer and minor axis layer. Assess using shear analogy method



MT Fire Resistance Ratings (FRR)

Option 2: account for partial major axis layer and minor axis layer. Assess using shear analogy method

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

X3.1 General

This appendix provides engineering formulas for the determination of CLT design values published in Annex A based on the shear-analogy model and CSA O86. This methodology has been recognized by the consensus-based canvas committee that developed this standard.

X3.2 Flatwise Bending Moment

$$(F_bS)_{eff,f,0} = \left(\frac{1}{12}\right) 0.85\, F_{b,major}\, S_{eff,f,0} \quad \text{[X3-1 ASD]}$$

$$(f_bS)_{eff,f,0} = 0.85\, f_{b,major}\, S_{eff,f,0} \quad \text{[X3-1 LSD]}$$

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

PRG 320-2019

MT Fire Resistance Ratings (FRR)

Option 2: account for partial major axis layer and minor axis layer. Assess using shear analogy method

8.5.3 Fire Resistance of CLT – Structural Requirement

The procedure set forth in CAN/ULC S101 is applicable to floor and roof assemblies and requires fire exposure to the underside of the specimen being tested. When wall assemblies are evaluated, the specimen is exposed to fire from one side only. This structural requirement is essential in limiting the risk of structural failure or collapse of physical elements due to the effects of a fire.

Step 3: Finding the location of the neutral axis and section properties of the effective reduced cross-section

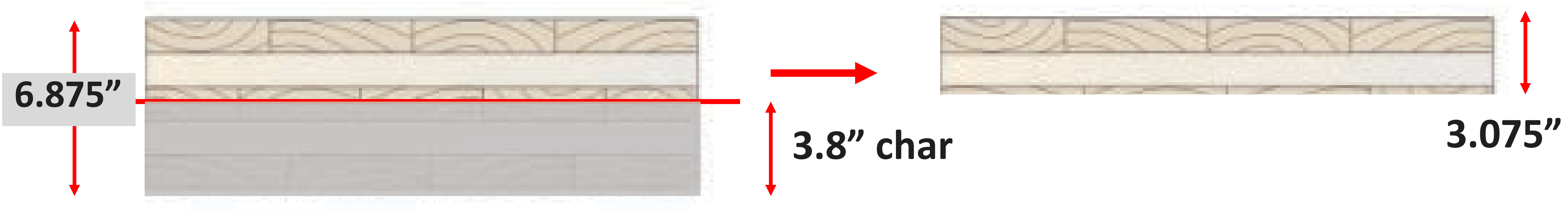
$$\bar{y} = \frac{\sum_i \tilde{y}_i h_i E_i}{\sum_i h_i E_i}$$

2019 CA CLT Handbook

Helpful for CLT with asymmetric layups

MT Fire Resistance Ratings (FRR)

Option 2: account for partial major axis layer and minor axis layer. Assess using shear analogy method



Shear Analogy Check Results:

$S = 9.8\ in^3$

$M_{all} = F_b S_{eff}$ = (628 lb-ft/ft)(2.85) = **1790 lb-ft/ft**

$M_{max} = w L^2 / 8$ = (55+40psf) $(15\ ft)^2 / 8$ = **2672 lb-ft/ft**

$M_{max} > M_{all}$ therefore panel is inadequate for 2-hour fire design using shear analogy

MT Fire Resistance Ratings (FRR)

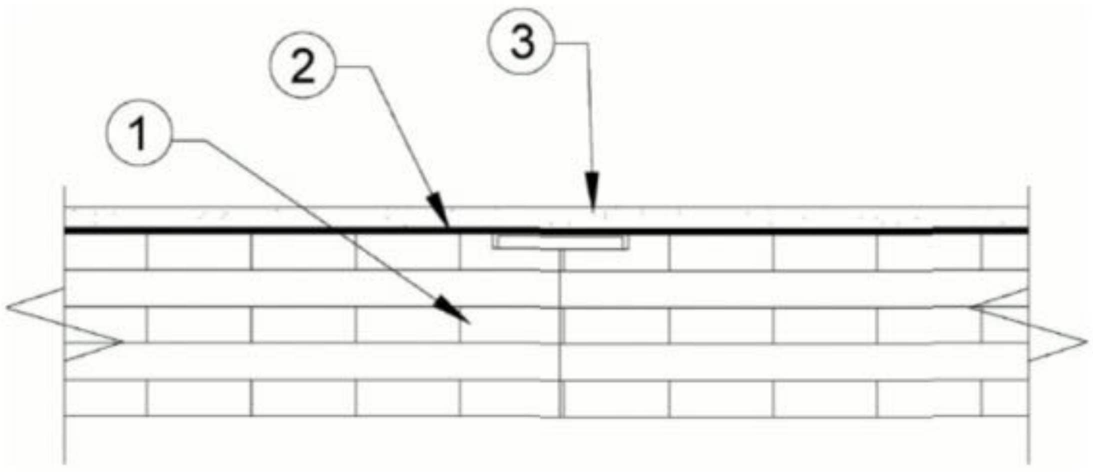
NDS Chapter 16 Char Calculations vs. ASTM E119 Tested Assembly

- **NDS Chpt 16 calcs check structural integrity**
- **E119 checks structural integrity, hose stream and unexposed surface temperature**
- **TR 10 provide thermal checks**

Unrestrained Assembly Rating - 1-1/2 Hr.

Restricted Load Condition - 50% 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.**



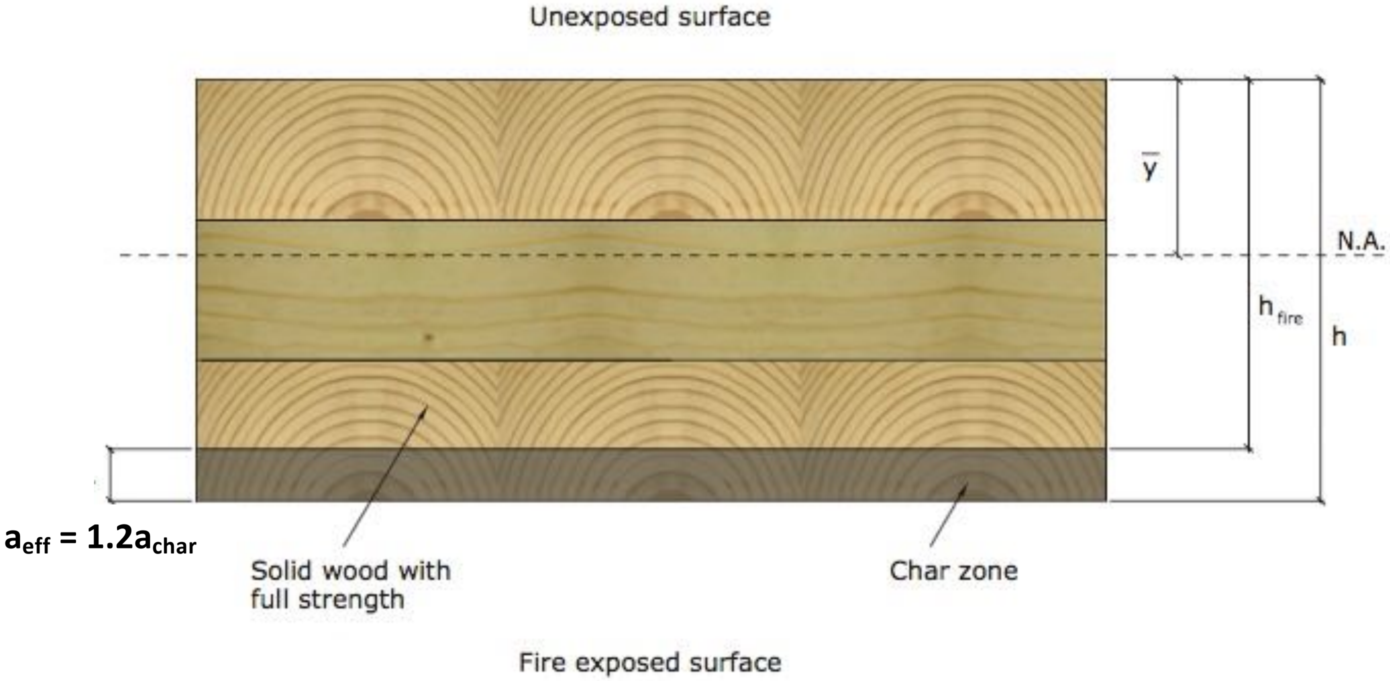
MT Fire Resistance Ratings (FRR)

How do you determine FRR of MT?

2 Options:

1. **Calculations in Accordance with IBC 722 → NDS Chapter 16**
2. **Tests in Accordance with ASTM E119**


Credit: Urban One



MT Fire Resistance Ratings (FRR)

Inventory of Fire Tested MT Assemblies

Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies

WoodWorks
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CLT Panel	Manufacturer	CLT Grade or Major x Minor Grade	Ceiling Protection	Panel Connection in Test	Floor Topping	Load Rating	Fire Resistance Achieved (Hours)	Source	Testing Lab
3-ply CLT (114mm 4.488 in)	Nordic	SPF 1650 Fb 1.5 EMSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105 mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 50% Moment Capactiy	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X Gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool beween Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1 M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Crete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap & Topside Spline	2" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1950 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 59% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Unreduced 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced 101% Moment Capacity	2.5	1 (Test 7)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	SmartLam	SL-V4	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 4)	Western Fire Center 10/26/2016
5-ply CLT (175mm 6.875")	SmartLam	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 5)	Western Fire Center 10/28/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 6)	Western Fire Center 11/01/2016
5-ply CLT (160mm 6.3")	KLH	CV3M1	None	Half-Lap & Topside spline	None	Loaded, See Manufacturer	1	18	SwRI [illegible]

MT Fire Resistance Ratings (FRR)

Inventory of Fire Tested MT Assemblies

2-Hour Floor Panel Options with Ceiling Side Exposed:

Mass Timber Panel	Ceiling Protection	Panel Connection	Floor Topping	Applied Load	Span	Fire Resistance Achieved (Hours)
5-ply CLT (175mm 6.875")	None	Topside Spline	None	10,800 lb (60 psf)	12'	2
5-ply CLT (175mm 6.875")	None	Half-Lap & Topside Spline	2" gypsum topping	70 psf	12ft - support widths	2
5-ply CLT (175mm 6.875")	None	Topside Spline	1-1/2" Maxxon Cyp-Grete 2000 over Maxxon Reinforcing Mesh	75 psf (3.6 kPA) supplemental. 90psf including Gyp-Crete + self weight	12 ft	2.5
5-ply CLT (6.3")	None	Half-Lap & Surface Spline	None	17,800 lb (~ 108 psf)	12'	2
5-ply CLT (180mm 7.09")	None	Topside Spline	None	18,000 lb (185 psf)	12'	2
5-ply CLT (175mm 6.875")	None	Half-Lap	1/2" plywood with 8d nails.	95.2 psf live, 113.4 psf total	13' 5" clear	2
5-ply CLT (175mm 6.875")	None	Half-Lap	1/2" plywood with 8d nails.	95.2 psf live, 115.6 psf total	13' 5" clear	2
5-ply CLT (175mm 6.875")	None	Half-Lap	1/2" plywood with 8d nails.	95.2 psf live, 116.3 psf total	13' 5" clear	2
5-ply CLT (175mm 6.875")	None	Topside Spline	2 staggered layers of 1/2" cement boards	4.40 kN/m2 or 91.8 psf	15'10" - supports (2x3.5" or 89mm)	2

MT Fire Resistance Ratings (FRR)

Extrapolating tested loading & span results:

*Need to also look at deflections, vibrations, etc

Applied Load	Span	Fire Resistance Achieved (Hours)	Moment resulting from tested load and span (lb*ft)	Allowable total load (psf) at 14 ft span	Allowable total load (psf) at 15 ft span	Allowable total load (psf) at 16 ft span	Allowable total load (psf) at 17 ft span
10,800 lb (60 psf)	12'	2	1080	44	38	34	30
70 psf	12ft - support widths	2	1260	51	45	39	35
75 psf (3.6 kPA) supplemental. 90psf including Gyp-Crete + self weight	12 ft	2.5	1620	66	58	51	45
17,800 lb (~ 108 psf)	12'	2	1944	79	69	61	54
18,000 lb (185 psf)	12'	2	3330	136	118	104	92
95.2 psf live, 113.4 psf total	13' 5" clear	2	2552	104	91	80	71
95.2 psf live, 115.6 psf total	13' 5" clear	2	2601	106	92	81	72
95.2 psf live, 116.3 psf total	13' 5" clear	2	2617	107	93	82	72
4.40 kN/m2 or 91.8 psf	15'10" - supports (2x3.5" or 89mm)	2	2877	117	102	90	80

![WoodWorks Wood Products Council]

TECHNICAL BRIEF

Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures

Richard McLain, PE, SE • Senior Technical Director – Tall Wood, WoodWorks

Changes to the 2021 International Building Code (IBC) have created opportunities for wood buildings that are much larger and taller than prescriptively allowed in past versions of the code. Occupant safety, and the need to ensure fire performance in particular, was a fundamental consideration as the changes were developed and approved. The result is three new construction types—Type IV-A, IV-B and IV-C—which are based on the previous Heavy Timber construction type (renamed Type IV-HT), but with additional fire protection requirements.

One of the main ways to demonstrate that a building will meet the required level of passive fire protection, regardless of structural materials, is through hourly fire-resistance ratings (FRRs) of its elements and assemblies. The IBC defines an FRR as *the period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests, or the methods based on tests, prescribed in Section 703.*

FRRs for the new construction types are similar to those required for Type I construction, which is primarily steel and concrete.[1] (See Table 1.) They are found in IBC Table 601, which includes FRR requirements for all construction types and building elements; however, other code sections should be checked for overriding provisions (e.g., occupancy separation, shaft enclosures, etc.) that may alter the requirement.

Ascent I Milwaukee, WI
Architect: Korb + Associates Architects
Structural Engineer: Thornton Tomasetti

Image: Korb + Associates Architects

TABLE 1:
FRR Requirements (Hours) for Tall Mass Timber Construction Types and Existing Type I

Building Element	I-A Unlimited stories,	IV-A Max. 18 stories,	I-B Max. 12 stories,	IV-B Max. 12 stories,	IV-C Max. 9 stories,
Interior Bearing Walls	3	3	2	2	2

Tall Timber Fire-Resistance Design

Questions?

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901 East Sixth, Thoughtbarn-Delineate Studio, Leap!Structures, photo Casey Dunn

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