A Comprehensive Introduction to Mass Timber Design

Presented by WoodWorks | March 26, 2024

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- **Mass Timber Construction Demo**
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- **WoodWorks Manufacturer and Supplier Partner Presentations**
  Wednesday 4 pm to 4:30 pm | Thursday 10:30 to 11:30 am

Meet the team and find resources! Booth # 856

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

Course Description

As mass timber transitions from novelty to mainstream, more architects and engineers are finding they need a full systems understanding of the unique design considerations associated with these types of structures. Intended for those new to mass timber design, or those looking to refresh their design knowledge, this workshop will take a step-by-step approach to the practical design and engineering of mass timber buildings. Breakout sessions at the 2024 International Mass Timber Conference will examine specific design and construction topics in depth, and this pre-conference workshop will equip attendees with the baseline experience needed to expand their knowledge in the main track sessions and start their own mass timber designs. Topics will include mass timber products, code compliance, fire resistance, new tall mass timber construction types, structural design and layout, connection detailing, acoustics, MEP integration, and more. Project examples throughout will also highlight and emphasize design solutions implemented on real structures.

Learning Objectives

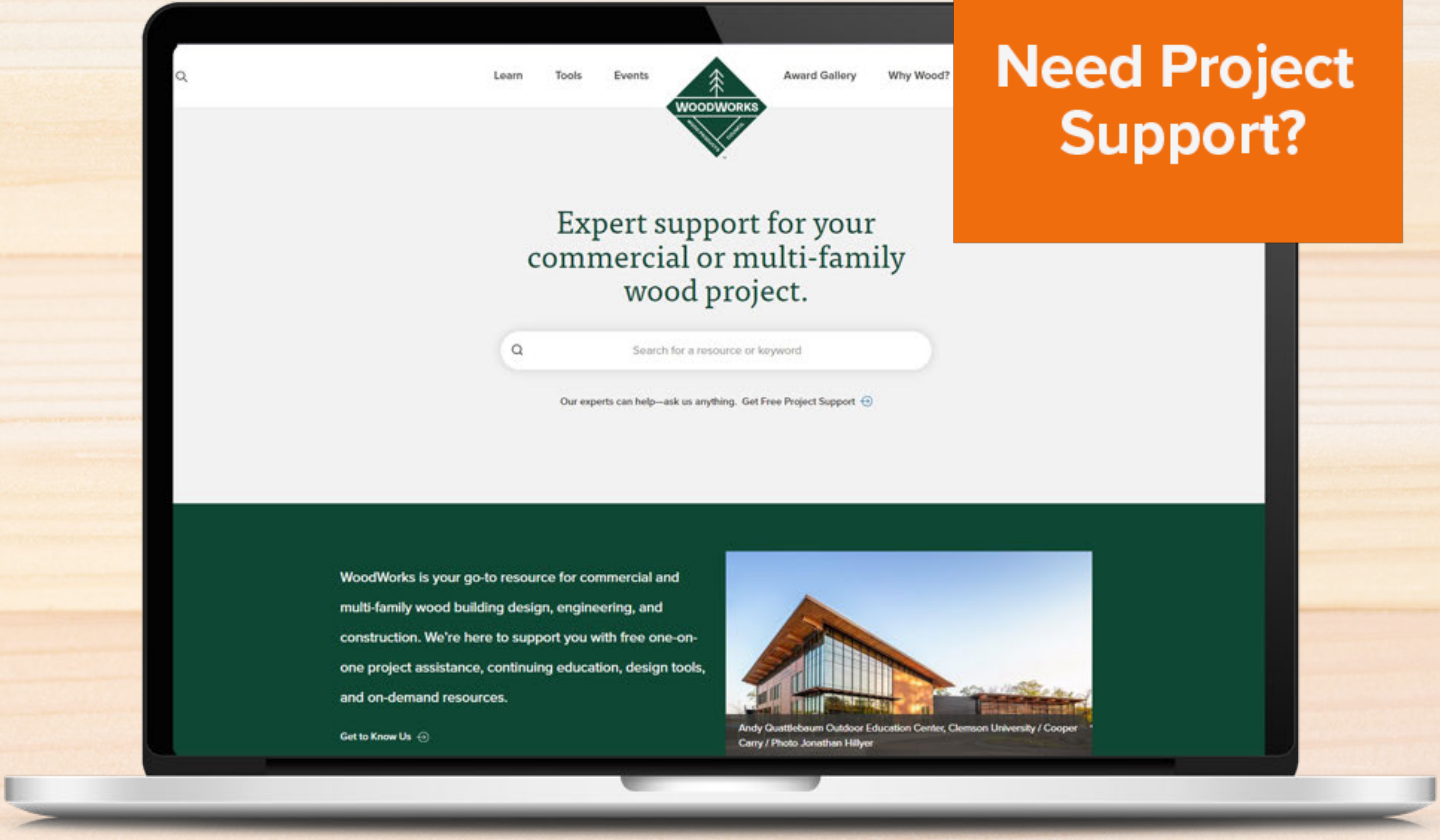
1. Identify construction types within the International Building Code where a mass timber structure is permitted.
2. Discuss the impacts of construction type on required fire-resistance ratings of structural elements, noting how these ratings impact member spans and grids.
3. Demonstrate structural design steps for members and connections in common mass timber framing systems.
4. Highlight effective methods of integrating MEP services in a mass timber building and discuss their relative impacts on cost, aesthetics, occupant comfort, and future tenant renovations.

Agenda

A Comprehensive Introduction to Mass Timber Design

12:00 – 1:00 pm	***Mass Timber Primer: Products, Codes Applications and Fire-Resistance Design,*** Mark Bartlett, PE and Jeff Peters, PE, CGC, WoodWorks
1:00 – 1:15 pm	Break
1:15 – 2:30 pm	***Structural Design: Member Sizing, Optimized Grids, Connections and Lateral Load Resistance,*** Kate Carrigg PE and Anthony Harvey, PE, WoodWorks
2:30 – 2:45 pm	Break
2:45 – 4:00 pm	***Acoustics, Vibration, MEPF Integration, Embodied Carbon and LCA,*** John O'Donald, PE, Eric Gu, PhD, PE, LEED Green Associate and Chelsea Drenick, SE, WoodWorks

woodworks.org



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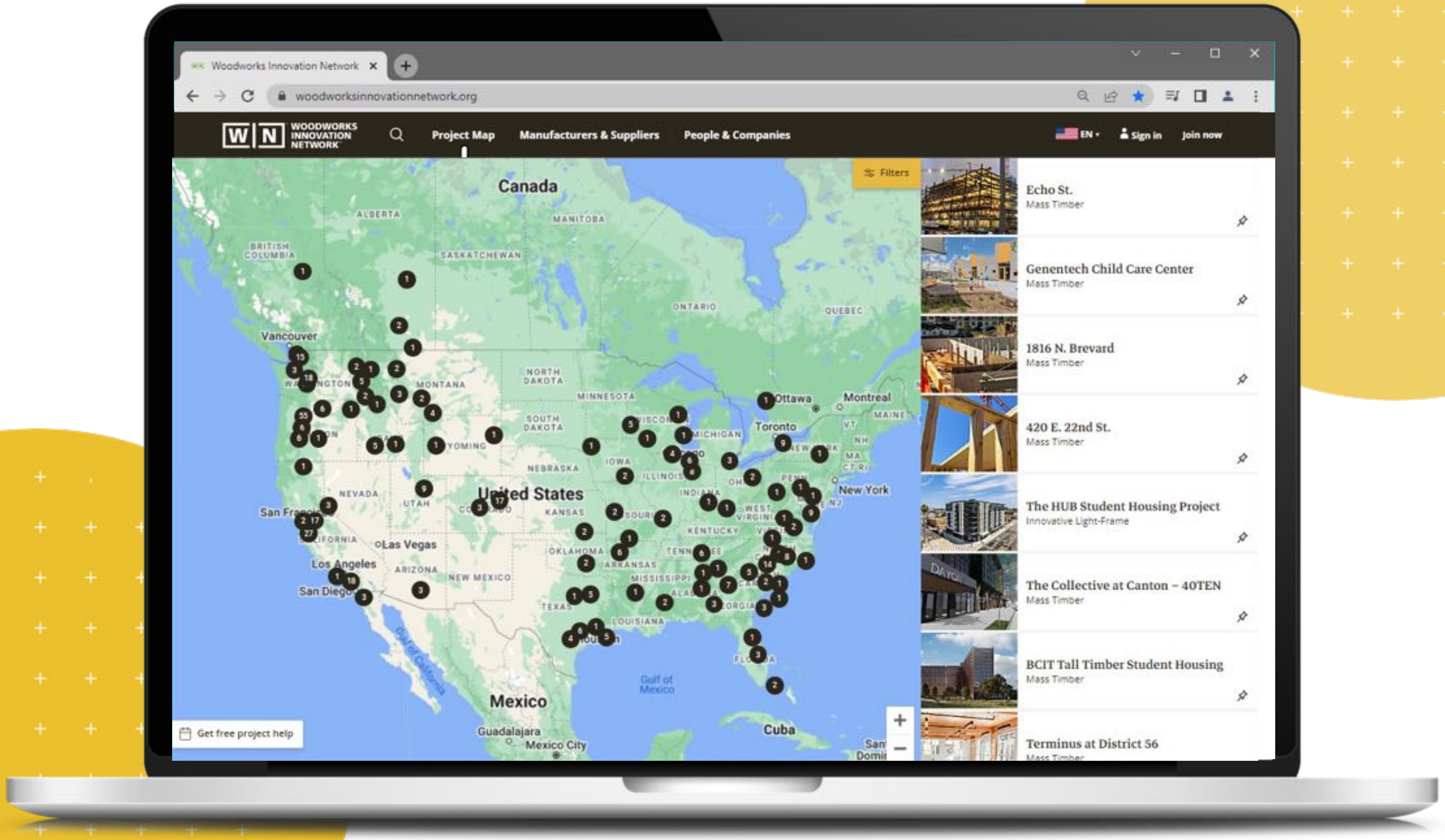
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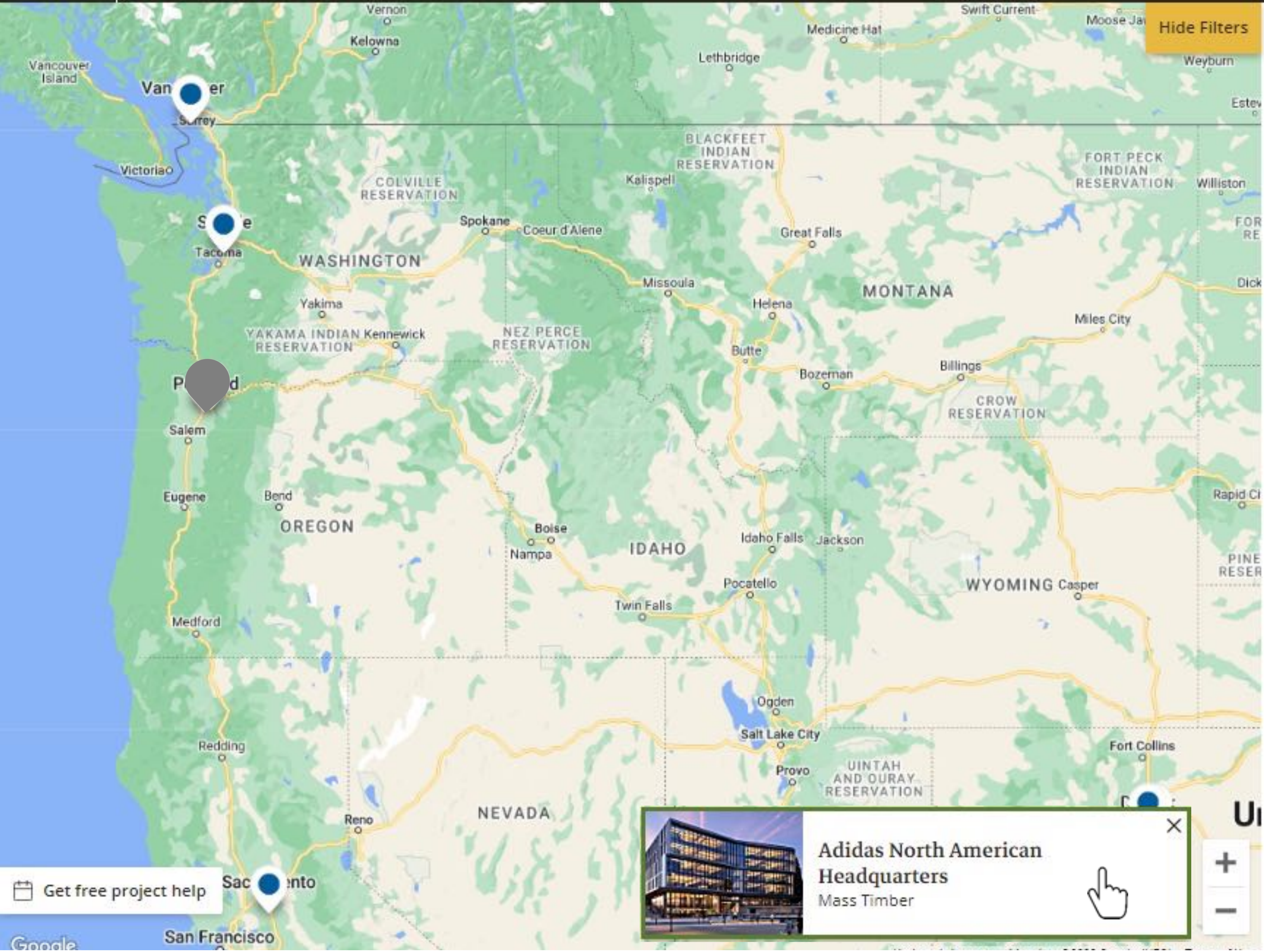

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Adidas North American Headquarters
Mass Timber

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- [ ] Structural Composite Lumber (e.g. LVL and LSL) 0
- [ ] Timber-Frame / Post and Beam 2
- [ ] Wood structural panels 0
- [ ] Wood-Concrete Composite Systems 0

Other Properties

- [ ] Wood Design Award Winner 2
- [ ] Affordable Housing 1
- [ ] Business Case Study Available 0
- [ ] Spec Office 1
- [ ] Technical Case Study Available 1

Number of Stories

1 — 12

Year Built

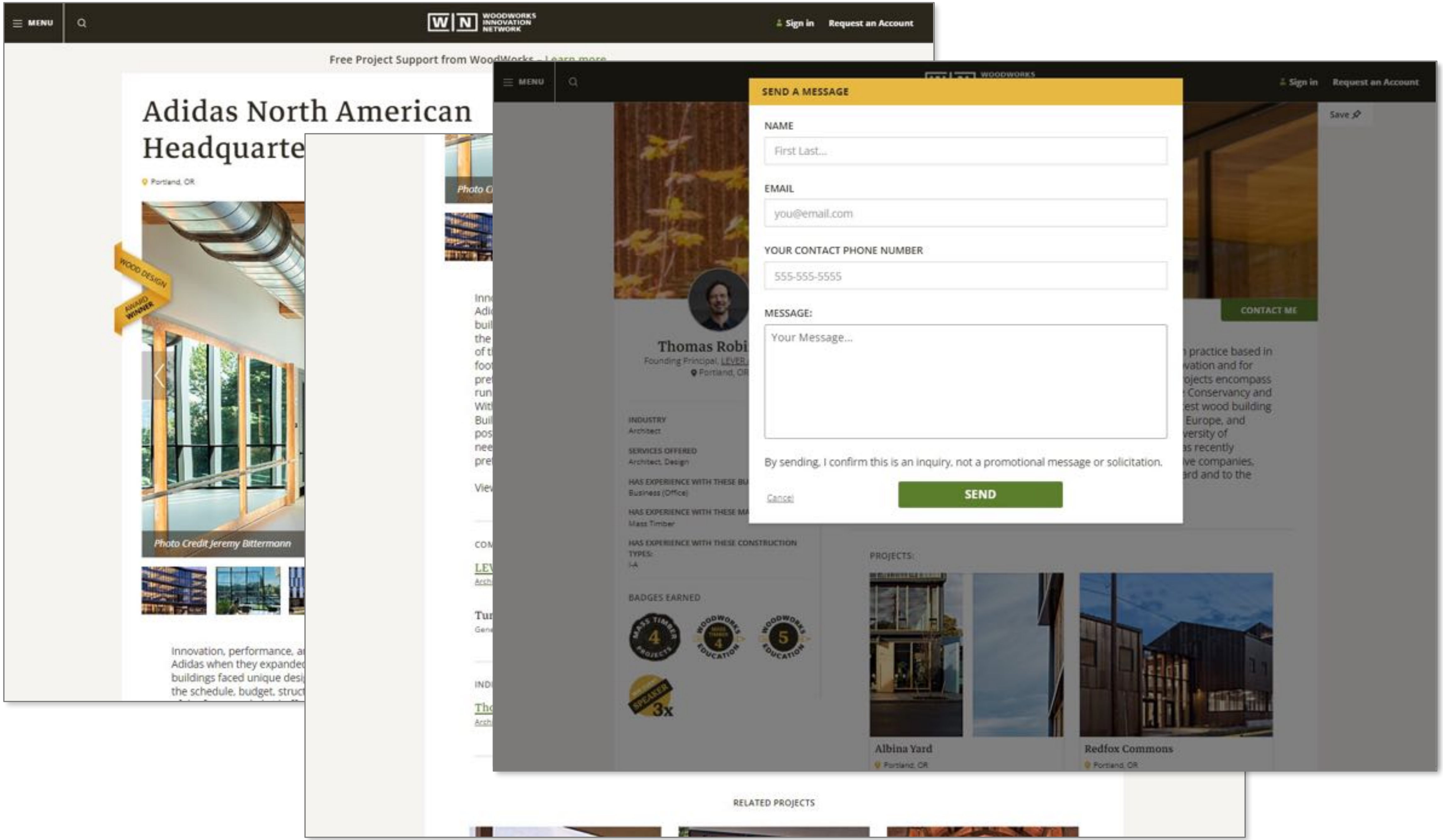
Select...

Construction Types

- [ ] I-A 0
- [ ] I-B 0
- [ ] II-A 0
- [ ] II-B 0
- [ ] III-A 3
- [ ] III-B 1
- [ ] IV-A 0
- [ ] IV-B 1
- [ ] IV-C 0
- [ ] IV-HT 2
- [ ] Unknown 0
- [ ] V-A 0
- [ ] V-B 1

Square Footage

- [ ] < 10,000 18
- [ ] 10,000 - 50,000 72
- [ ] 50,000 - 200,000 74
- [x] 200,000 + 8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Adidas North American Headquarte
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WOOD DESIGN AWARD WINNER
Photo Credit Jeremy Bittermann
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Adidas when they expande
buildings faced unique desi
the schedule, budget, struc
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PROJECTS:
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Portland, OR

Learning Objectives

1. Identify construction types within the International Building Code where a mass timber structure is permitted.

2. Discuss the impacts of construction type on required fire-resistance ratings of structural elements, noting the impacts these ratings have on member spans and grids.

3. Demonstrate structural design steps for members and connections in common mass timber framing systems.

4. Highlight effective methods of integrating MEP services in a mass timber building and discuss their relative impacts on cost, aesthetics, occupant comfort, and future tenant renovations.

Mass Timber Primer: Products, Codes Applications, Fire-Resistance Design

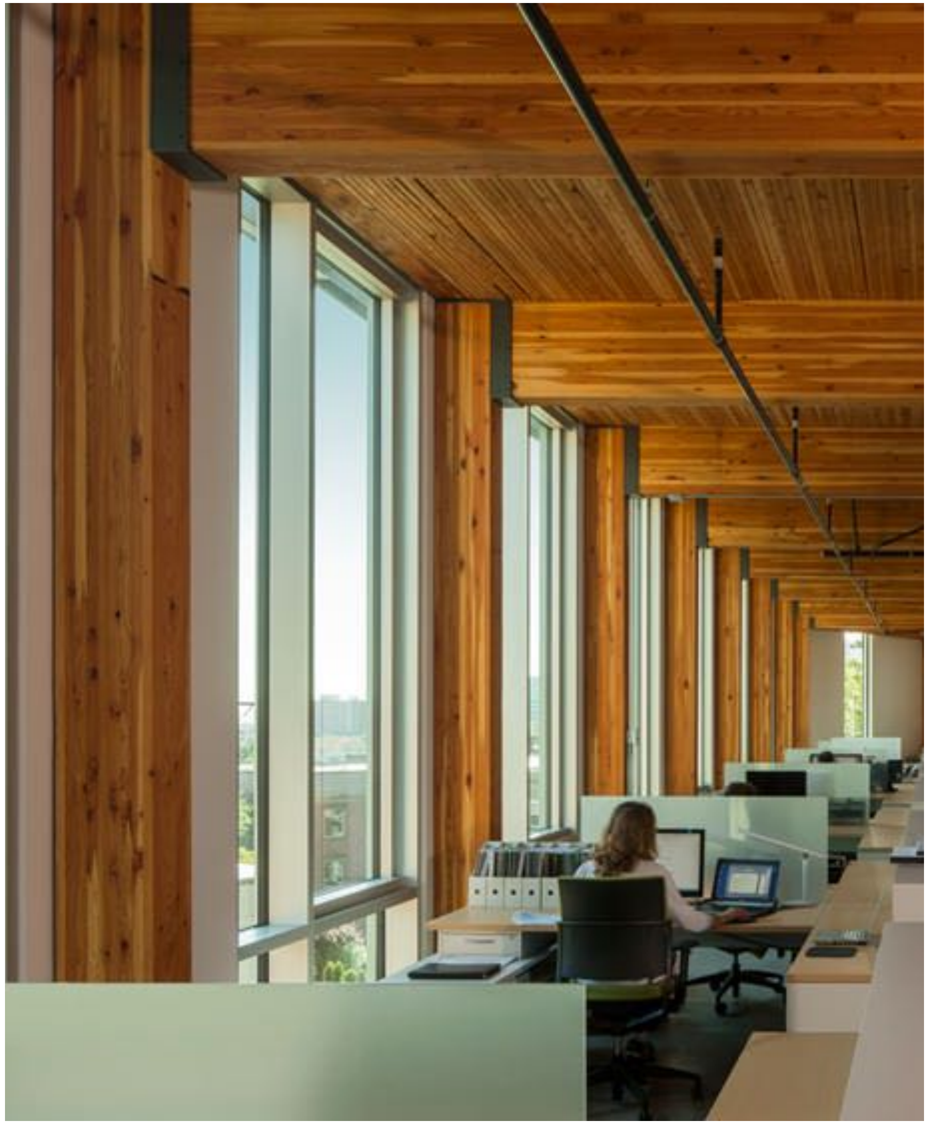
March 27, 2023

Presented by Mark Bartlett and Jeff Peters

Adidas East Village Expansion / LEVER Architecture / photo Jeremy Bittermann

Light-Frame Wood
Photo: WoodWorks

Heavy Timber
Photo: Benjamin Benschneider



Mass Timber
Photo: John Stamets

Mass Timber Building Options

Post and Beam

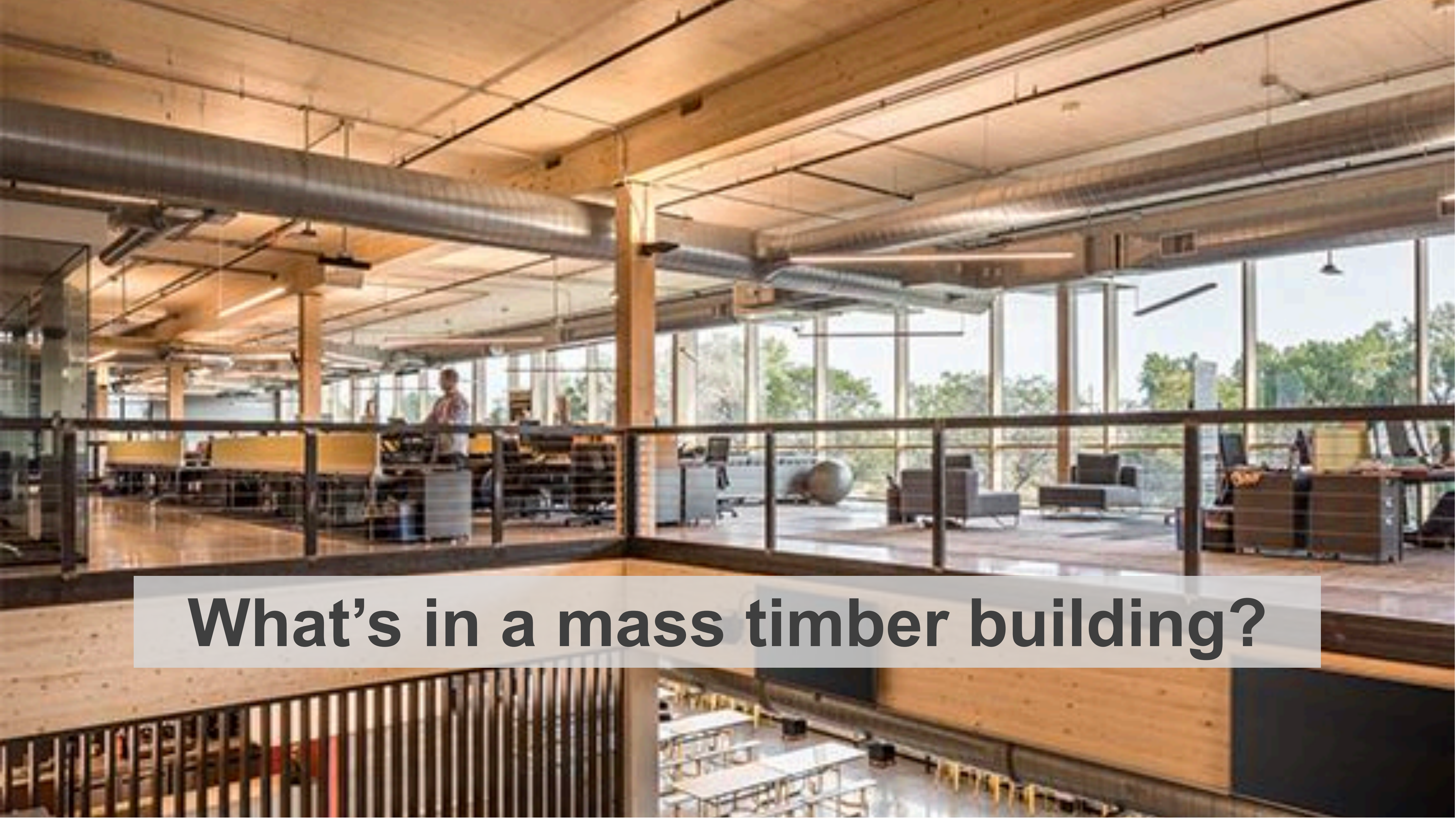
Flat Plate

Honeycomb

Mass Timber Building Options

Hybrid: Light-frame

Hybrid: Steel framing



What’s in a 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

Mass Timber Products

Glulam

Glulam specs:

Typical Widths:

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

Typical Depths:

Increments per # of lams from 6” to 60”+
Western species lams are typically 1-1/2” thick
Southern pine lams are typically 1-3/8” thick

Typical Species:

Douglas-Fir, Southern Pine, Spruce
Also available in cedar & others

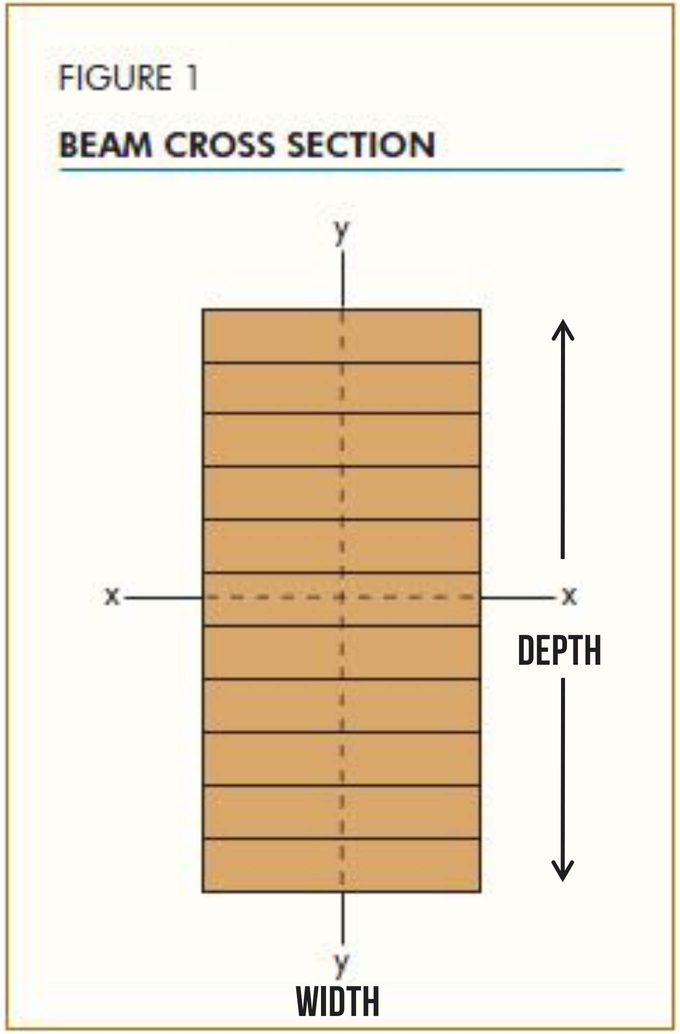


IMAGE: APA GLULAM PRODUCT GUIDE

Mass Timber Products

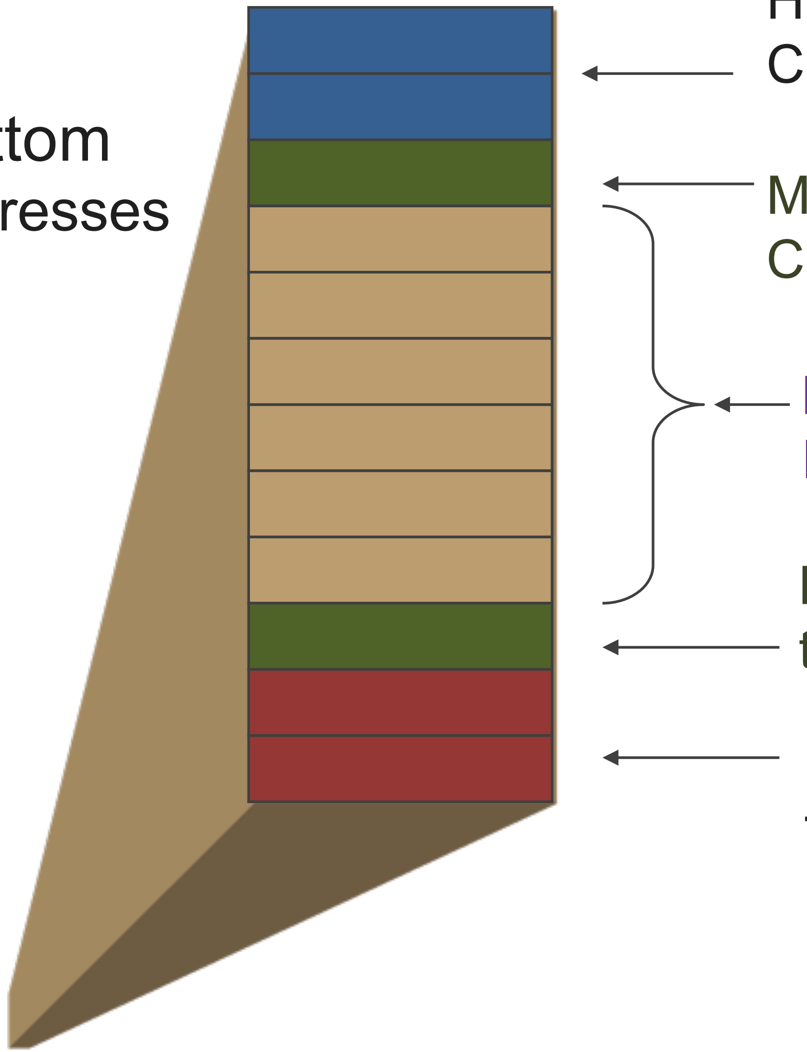
Glulam

Glulam layup:

Vary strength of laminations

- Higher strength lams at top and bottom
    - Higher Tension and compression stresses
- Lower strength lams in center plies

Image: APA



Mass Timber Products

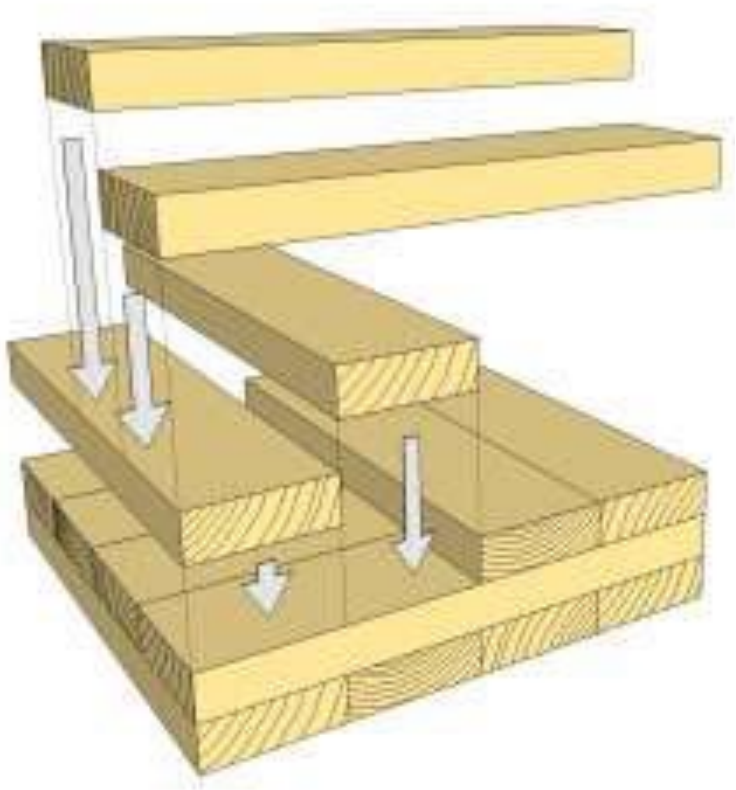
Cross-Laminated Timber (CLT)

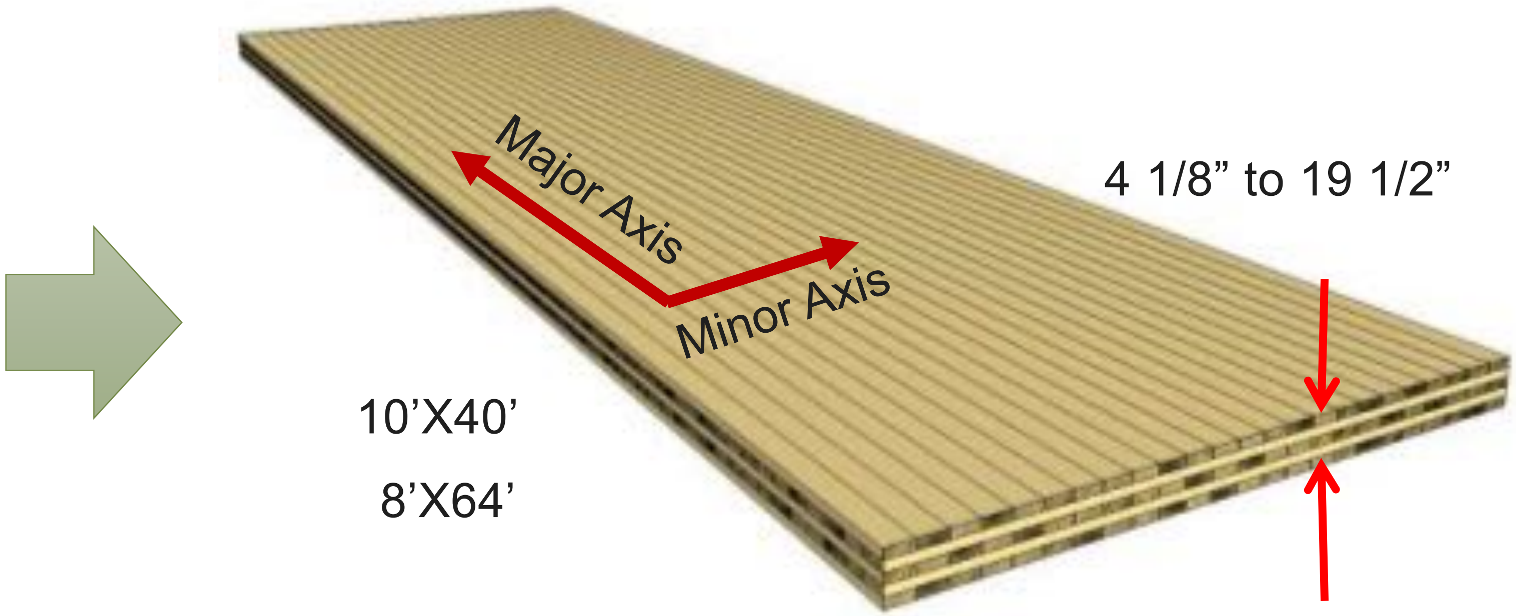
Mass Timber Products

Cross-Laminated Timber (CLT)

What is CLT?

- Solid wood panel
- 3 layers min. of solid sawn lams
- 90 deg. cross-lams
- Similar to plywood sheathing





Common CLT Layups

Most Designs
Least $/sf

3-ply 3-layer

5-ply 5-layer

7-ply 7-layer

9-ply 9-layer

Mass Timber Products

Cross-Laminated Timber (CLT)

Image Source: Structurlam Products LP

CLT Prefabrication

- Finished panels are planed, sanded, cut to size.
- Openings are cut with precise CNC routers.
- Third party inspection at factory
- Custom engineered for material efficiency
- Custom designed for project
- Each panel numbered, delivered & installed in predetermined sequence

Photo: WoodWorks

Offices at Southstone Yards

Frisco, TX

Building Facts	242,000 sf, 7 stories
	Office
	Completed 2023

Developer	Crow Holdings Development
Architect	Duda|Paine and Gensler
Engineer	Thornton Tomasetti

Offices at Southstone Yards
Frisco, TX

- First Mass Timber building in North Texas
- Anchor building for 45-acre development

Duda|Paine Architects
Gensler
Thornton Tomasetti
Photo: WoodWorks

Photo: Nick Johnson, Tour D Space

INTRO

Cleveland, OH

Building Facts	512,000 sf, 9 stories
	8 stories Mass Timber over 1 podium
	Type IV-B
	Mixed Use
	Completed 2022

Developer	Harbor Bay Ventures
Architect	Hartshorne Plunkard Architecture
Engineer	Forefront Structural Engineers
General Contractor	Panzica Construction

INTRO

Cleveland, OH

- One of the first to utilize new IV-B construction type.
- Worked with the city to expose 50% of MT ceilings.

Photos: Nick Johnson, Tour D Space

Hartshorne Plunkard Architecture
Forefront Structural Engineers

The Beam on Farmer

Tempe, AZ

Building Facts	184,000 sf, 5 stories
	Type IV-HT or B
	Office
	Completed 2022

Developer	Mortenson
Architect	RSP Architecture
Engineer	PK Associates
General Contractor	Mortenson

The Beam on Farmer

Tempe, AZ

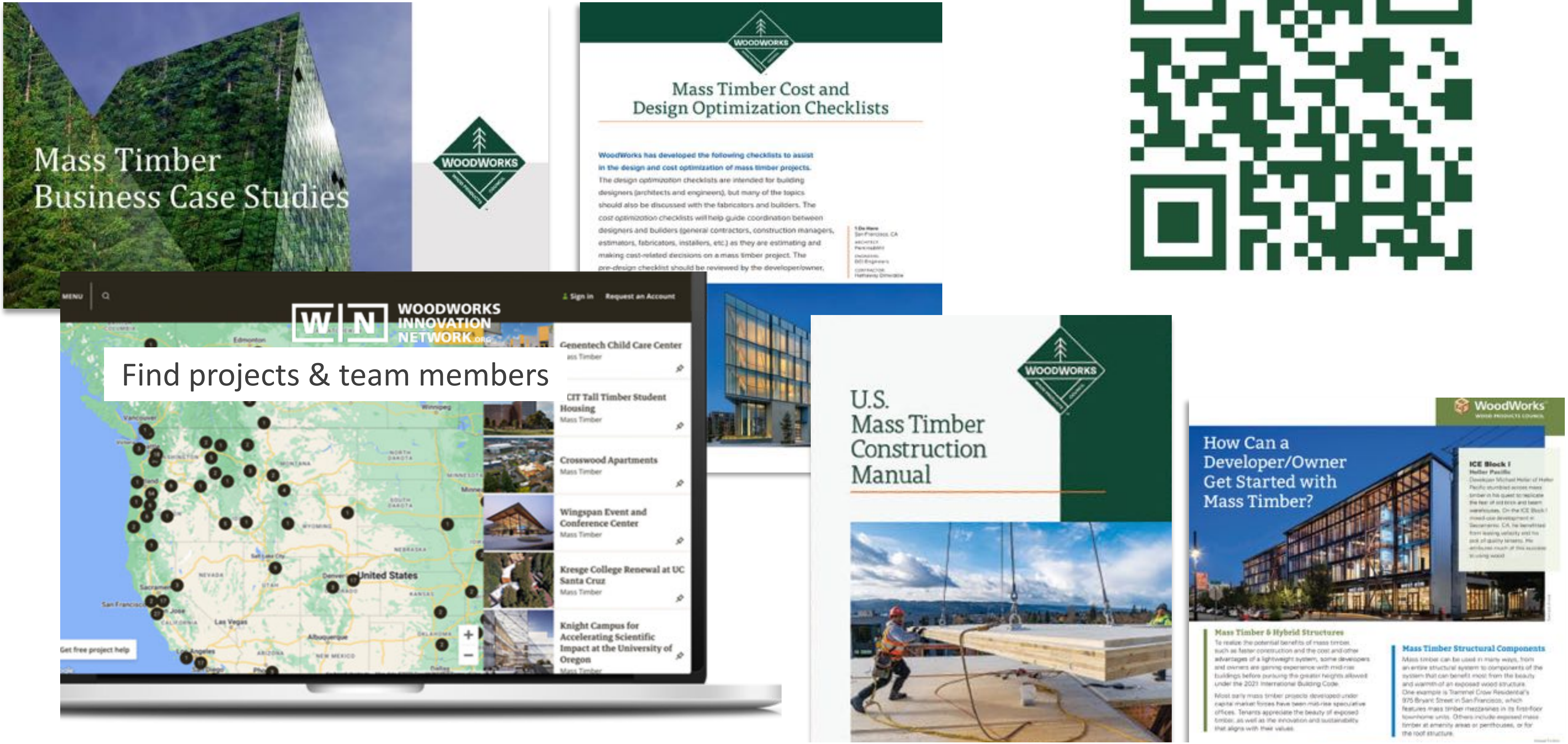
- The first CLT office building in Arizona
- Named for the distinctive glulam beams

Photos: Jason Roehner Photographs

RSP Architects
PK Associates

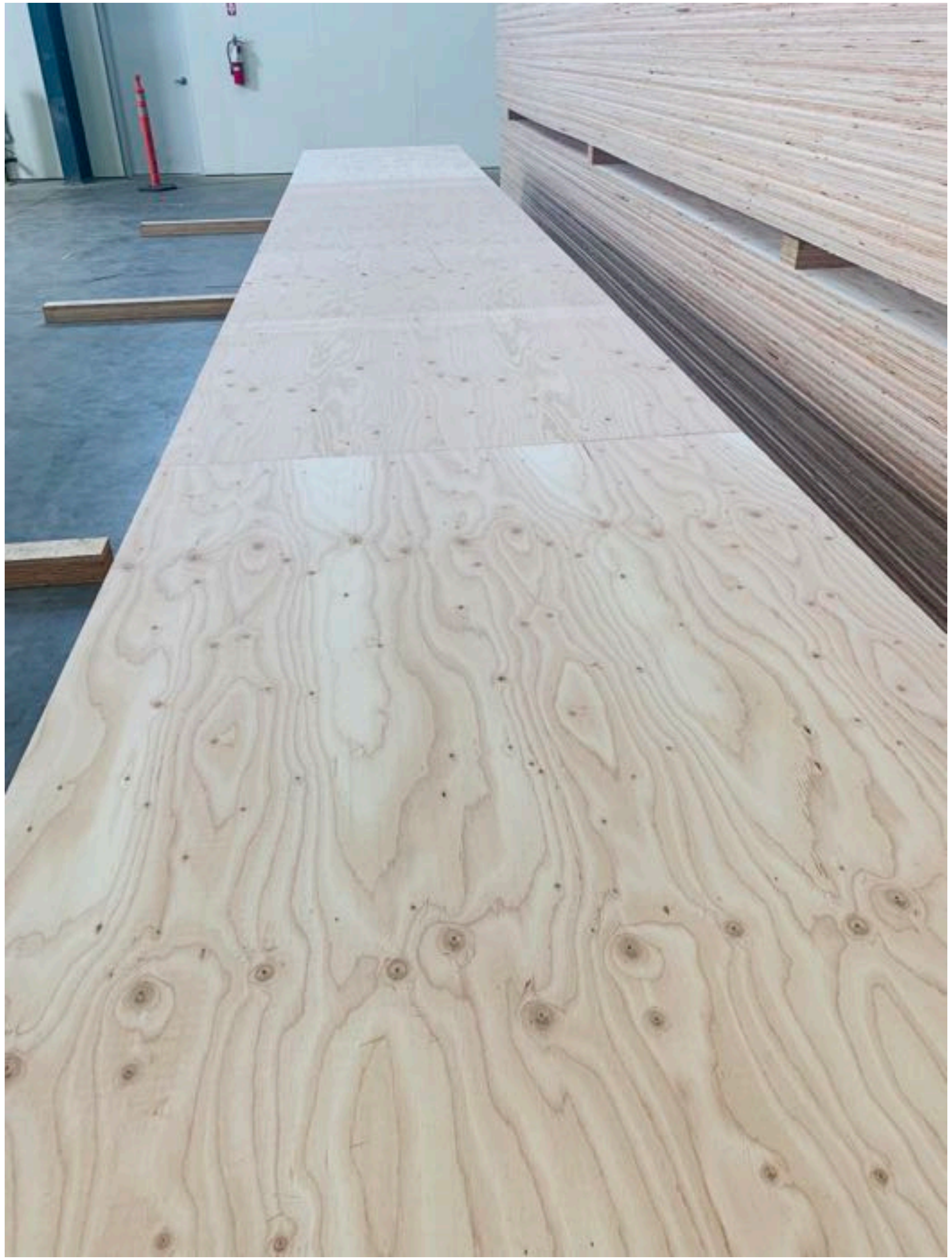
Resources for Developers/Owners

Scan to download



Mass Timber Products

Cross-Laminated Timber with SCL Laminations



Photos: Freres Lumber

1510 Webster

Oakland, CA

Rendering: oWow

Building Facts	193,290 sf, 18 stories 16 stories Mass Timber Type IV-A Mixed Use Expected Completion 2024
Developer	oWow
Architect	oWow
Engineer	DCI Engineers
General Contractor	oWow

1510 Webster

Oakland, CA

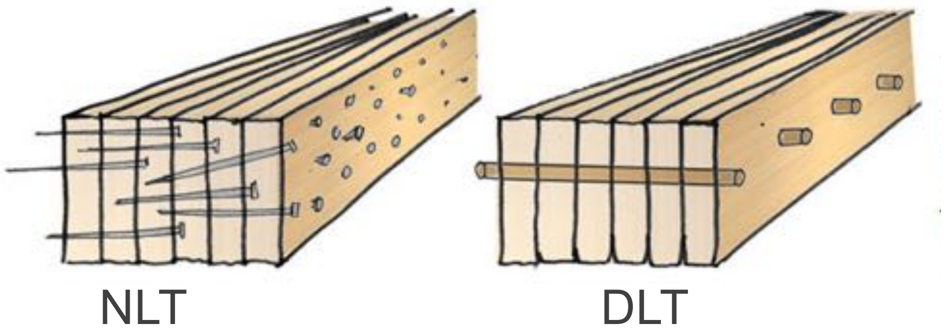
- 18 stories mass timber over one-level concrete
- Type IV-A Construction
- Mass Timber with concrete cores and staircases.

Photos: Flor Projects

oWow
DCI Engineers


Mass Timber Products
Dowel-Laminated Timber (DLT)
Photo Credit: StructureCraft

Dowel-Laminated Timber (DLT)



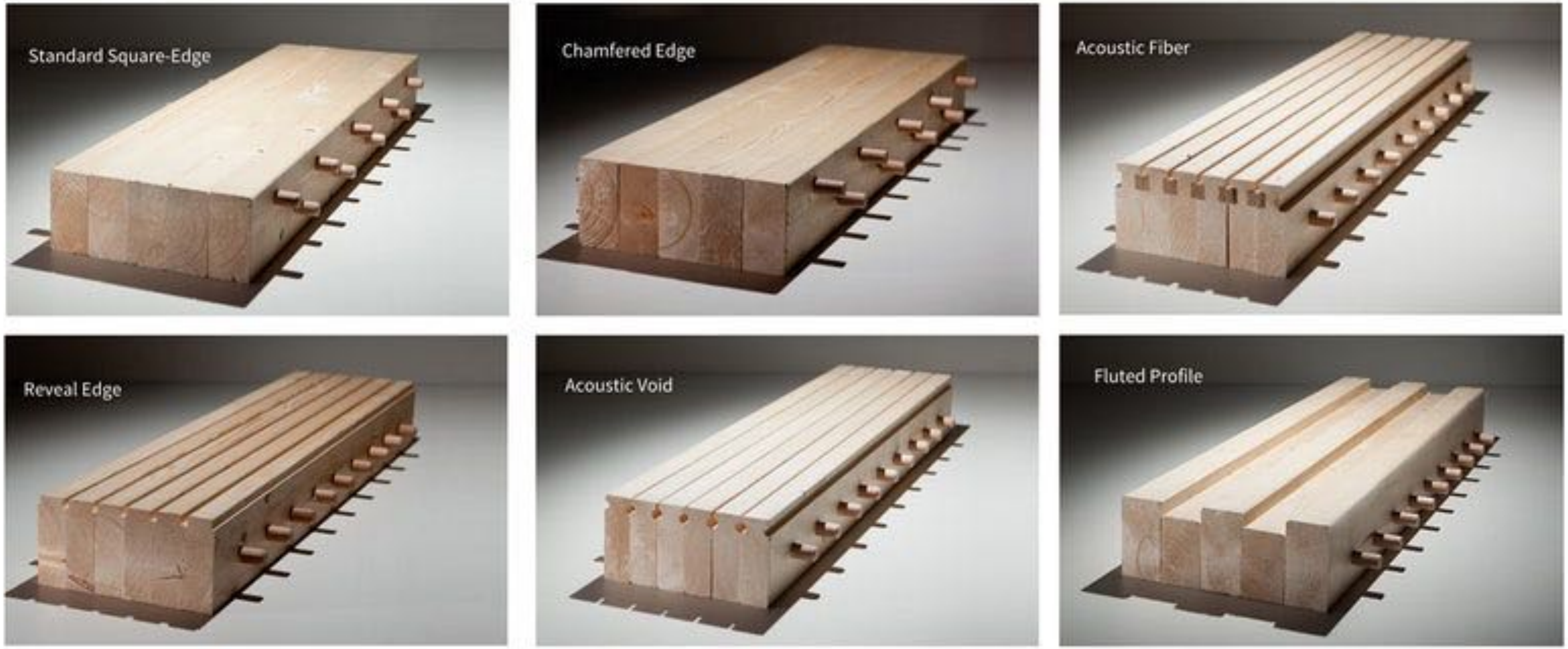


Photo credit: StructureCraft

111 East Grand

Des Moines, IA

Credit: StructureCraft

4 story, 66,800 SF Spec office building
DLT panels, glulam frame

Credit: Nuemann Monson Architects
courtesy: Ryan Companies

Mass Timber Products

Nail-Laminated Timber (NLT) panels

Photo: Think Wood

NLT shrinkage/expansion design

Nail-laminated timber (NLT) is mechanically laminated to create a solid timber panel. NLT is created by placing dimension lumber (nominal 2x, 3x, or 4x) on edge and fastening the individual laminations together with nails.

Mass Timber Products

Nail-Laminated Timber (NLT) panels

NLT panels can be built on-site/in-place or pre-fabricated offsite

Photo Credit: John Stamets

Photo Credit: Structurecraft

T3 Minneapolis

Mass Timber Products

Glue-Laminated Timber (GLT) panels

Image source: Structurecraft

Glulam decking:

- Similar to deep glulam beams laid on their side
- Same code references and manufacturing standards as glulam beams and columns
- Be careful of design stresses and layups used – spec uniform layup (all lams same species & grade)

Mass Timber Products

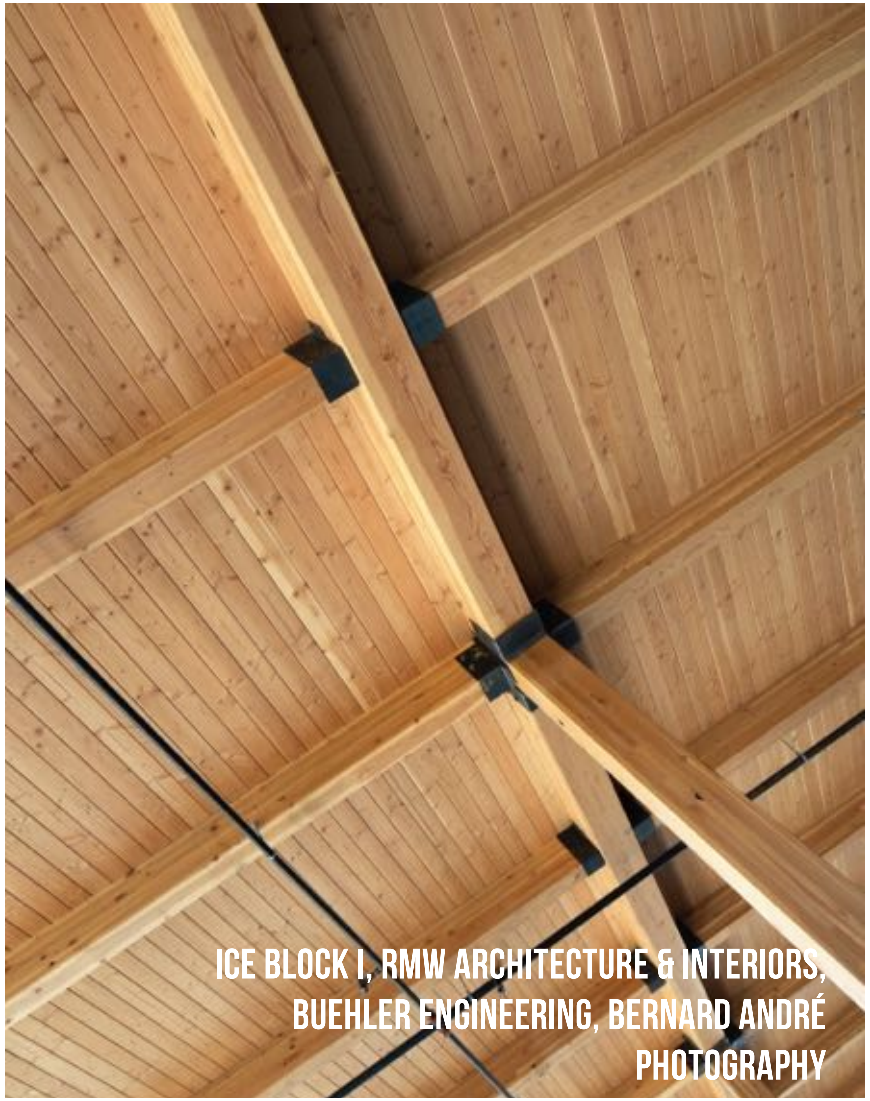
Glue-Laminated Timber (GLT) panels


Photo credit: Structure Fusion


Photo credit: Unalam

Mass Timber Products

Tongue and Groove Decking



Tongue and Groove Decking:

2x, 3x or 4x solid or laminated wood decking laid flat with interlocking tongue and groove on narrow (side) face

- Recognized in IBC 2304.8 (lumber decking)
- 2x usually has a single T&G; 3x and 4x usually have a double T&G
- 6” and 8” are common widths
- Can be used for floor, roof decking

Ice Block I

Sacramento, CA

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

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 mass timber to be used?

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

Portland International Jetport

- LEED Gold
- Completed 2012

Construction Type IB
Exposed Timber Roof Decking and Framing

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

Construction Types

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

Type III:
6-stories (B)
5-stories (R)

Credit: Ema Peter

Type IV-HT: 6-stories (B) | 5-stories (R)

Credit: Christian Columbres Photography

Type V:
4-stories (B)
4-stories (R)

MARKET DRIVERS FOR MASS TIMBER

PRIMARY DRIVERS

» Construction Efficiency & Speed
» Construction site constraints – Urban Infill
» Innovation/Aesthetic

SECONDARY DRIVERS

» Carbon Reductions
» Structural Performance – lightweight

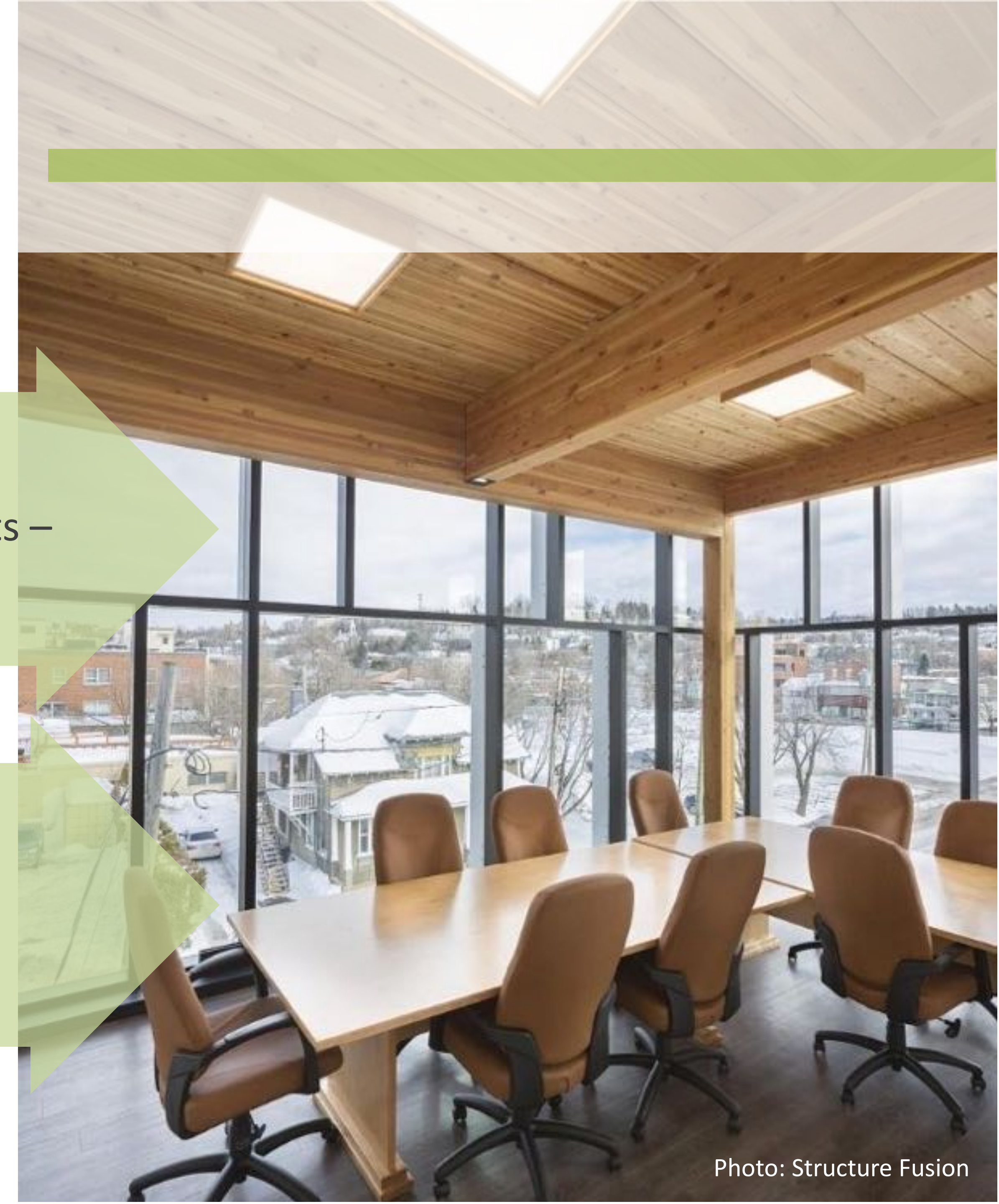
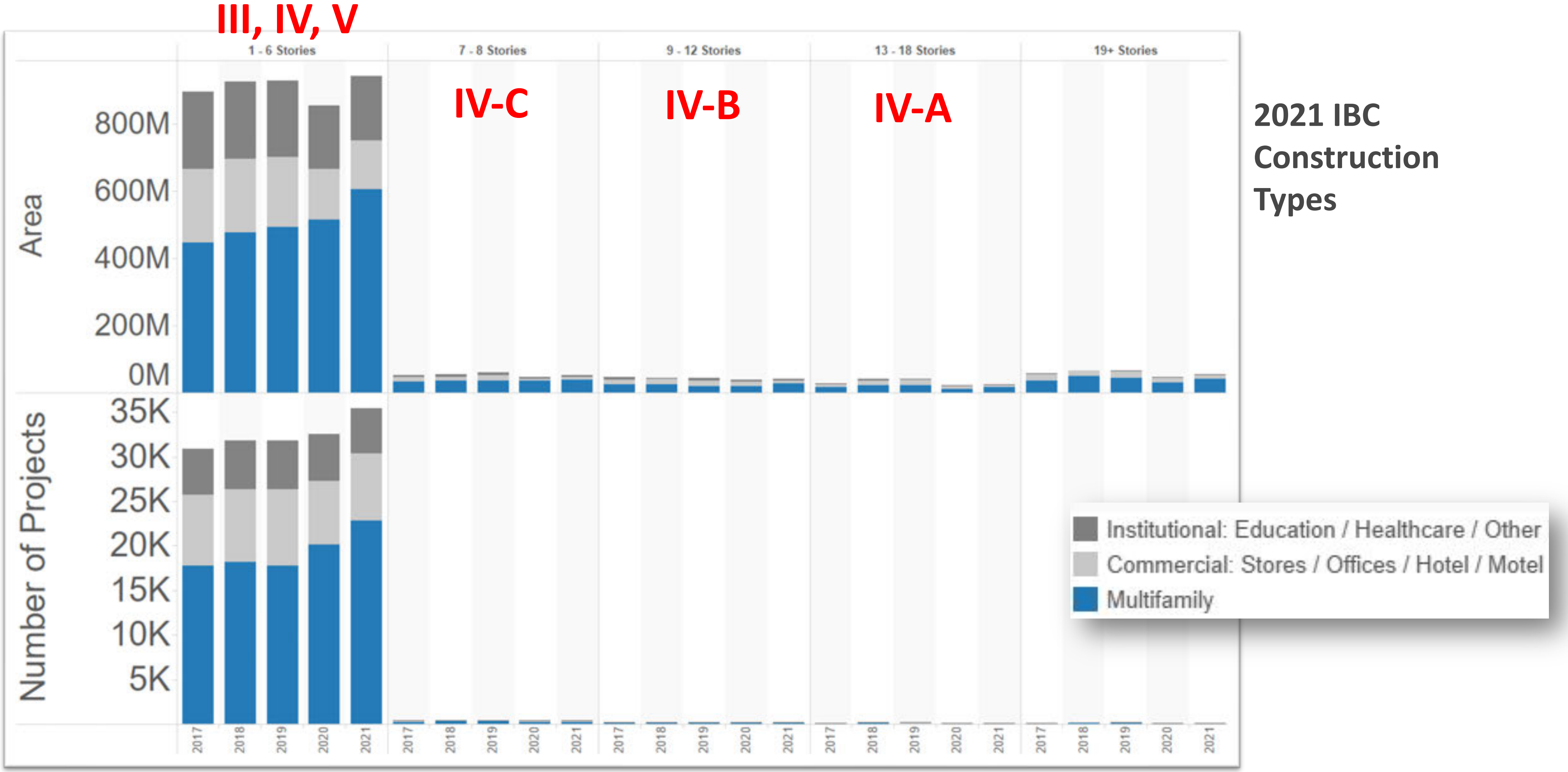


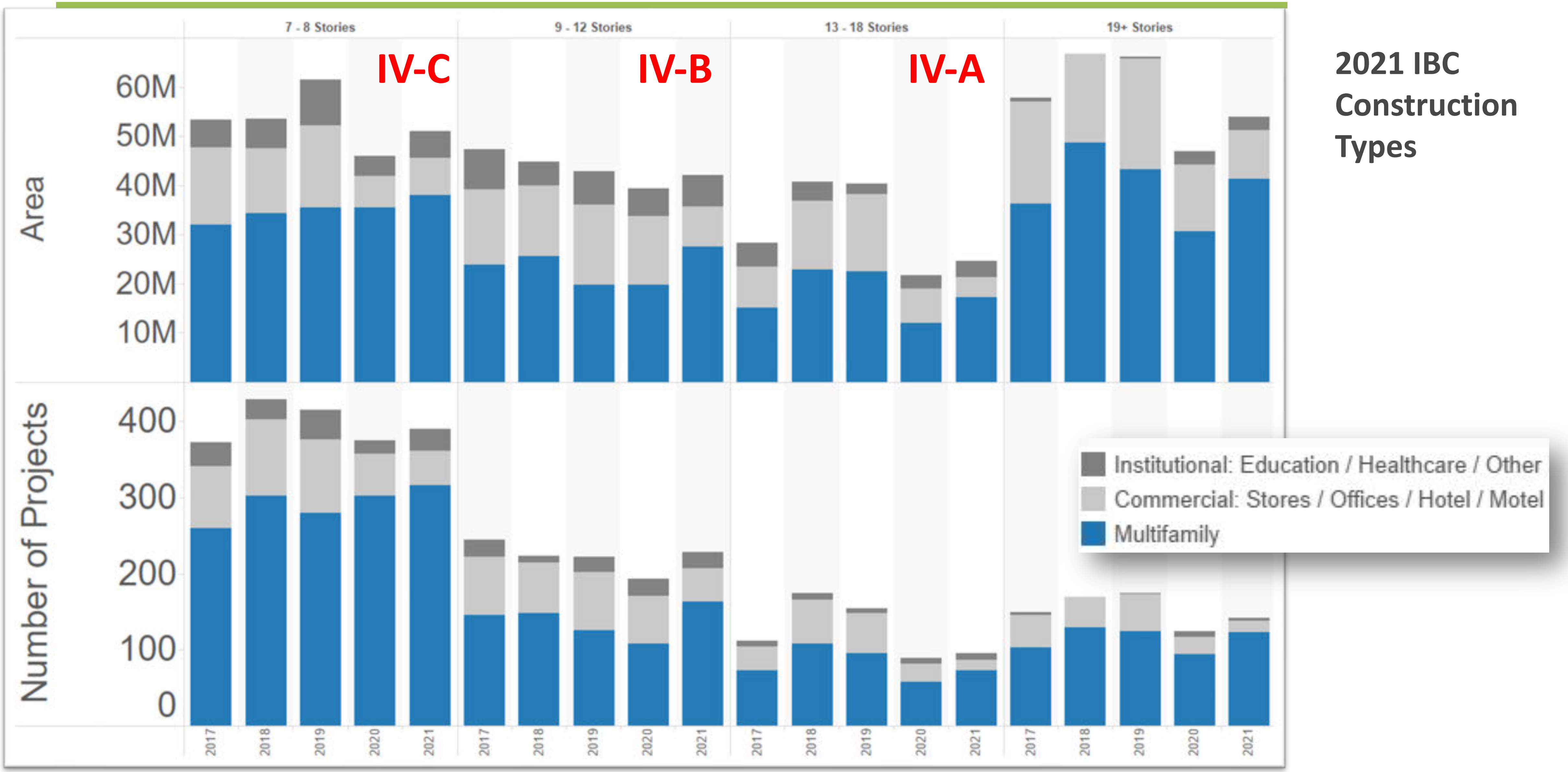
Photo: Structure Fusion

What Portion of the Construction Market is “Tall”?



2021 IBC Construction Types

In What Height Range are Most "Tall" Projects Happening?



2021 IBC Construction Types

U.S. TALL WOOD
DEVELOPMENT AND CHANGES

Interest in tall wood projects in the US was rapidly increasing. Some building officials were reluctant to approved proposed plans, primarily due to lack of code direction and precedent

Empire State Bulding, New York City, New York, 1931

Photo: Seagate Structures

UBC Brock Commons Student Residence, Vancouver, British Columbia, 2016

In December 2015, the ICC Board established the ICC Ad Hoc Committee on Tall Wood Buildings. Objectives:

1. Explore the building science of tall wood buildings
2. Investigate the feasibility, and
3. Take action on developing code changes for tall wood buildings.

Timeline:

Submission of code changes for the 2018 Group A Cycle (IBC) in January 2018 – changes for 2021 IBC

5 Working Groups Created

- July 2016 – November 2017: 5 in-person meetings, numerous conference calls
- 82 issues addressed, one primary topic was **fire performance and life safety**

Taller wood buildings create new set of challenges to address:

AHC established 6 performance objectives:

1. No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered.
2. Highly reliable fire suppression systems to reduce the risk of failure during reasonably expected fire scenarios. The degree of reliability should be proportional to evacuation time (height) and the risk of collapse.

AHC established 6 performance objectives:

3. No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios.
4. No unusual response from typical radiation exposure from adjacent properties to present a risk of ignition of the subject building under reasonably severe fire scenarios.

AHC established 6 performance objectives:

5. No unusual fire department access issues
6. Egress systems designed to protect building occupants during the design escape time, plus a factor of safety.

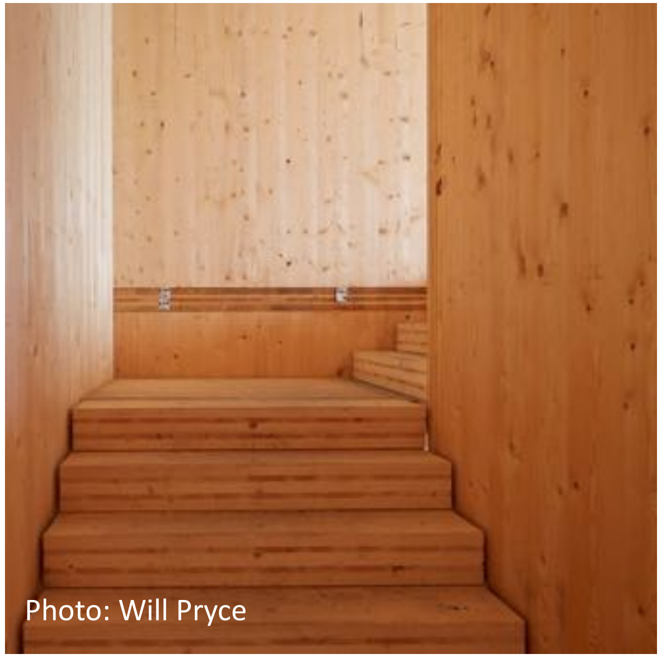


Photo: Will Pryce

U.S. BUILDING CODES

Tall Wood Ad Hoc Committee

Commissioned series of 5 full-scale tests on 2-story mass timber structure at ATF lab in MD, May-June 2017

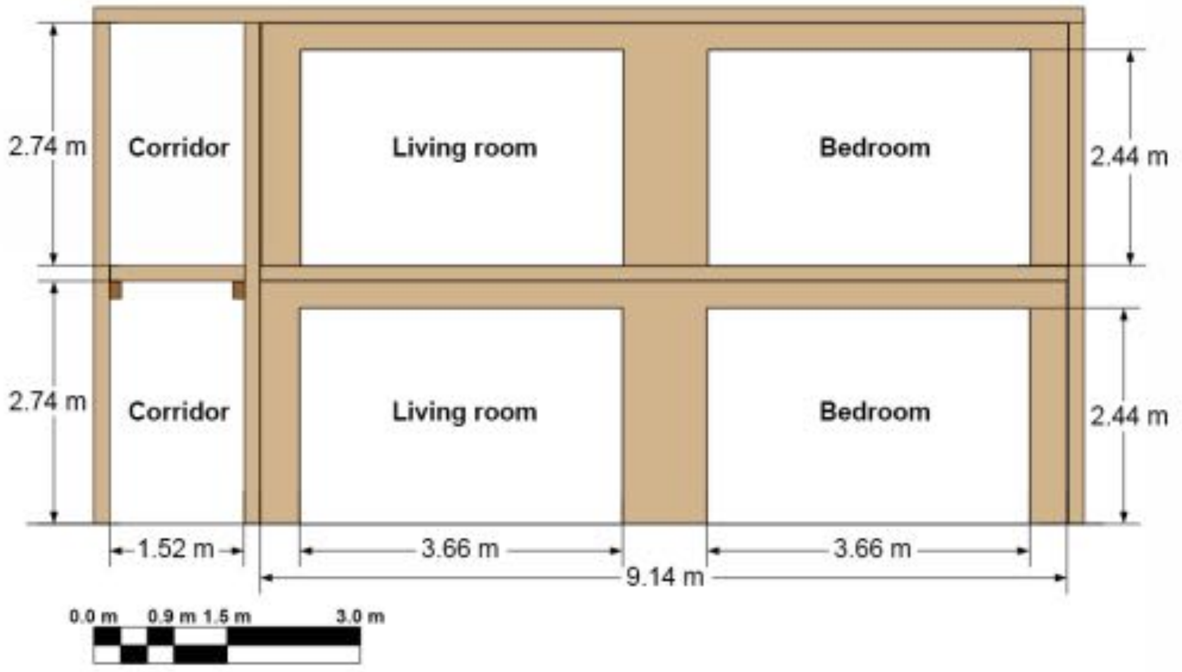


Figure 2. Elevation view of the front of the cross-laminated timber test structure.

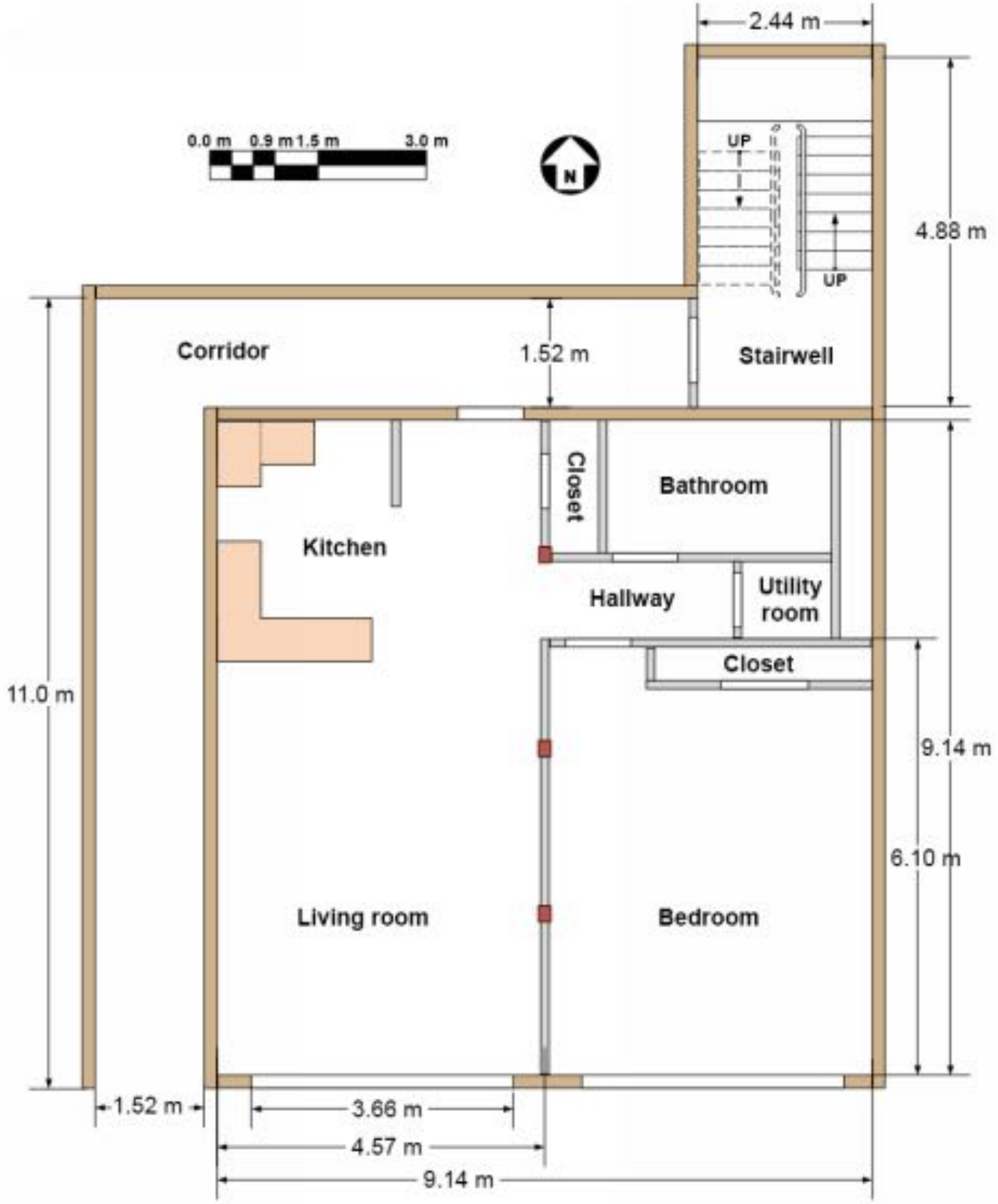


Figure 1. General plan view of cross-laminated timber test structure.

Images: AWC

Photo: LendLease

Photo: LendLease

Photo: LendLease

Photo: LendLease

Photo: LendLease

TALL WOOD APPROVED!

Unofficial results posted Dec 19, 2018

Final votes ratified Jan 31, 2019

AWC: Tall Mass Timber code changes get final approval

Dec 19, 2018

LEESBURG, VA. – The International Code Council (ICC) has released the unofficial voting results on code change proposals considered in 2018, including passage of the entire package of 14 tall mass timber code change proposals. The proposals create three new types of construction (Types IV-A, IV-B and IV-C), which set fire safety requirements, and allowable heights, areas and number of stories for tall mass timber buildings. Official results are expected to be announced during the first quarter of 2019. The new provisions will be included in the 2021 *International Building Code* (IBC).

“Mass timber has been capturing the imagination of architects and developers, and the ICC result means they can now turn sketches into reality. ICC's rigorous study, testing and voting process now

2021 IBC Introduces 3 new tall wood construction types:

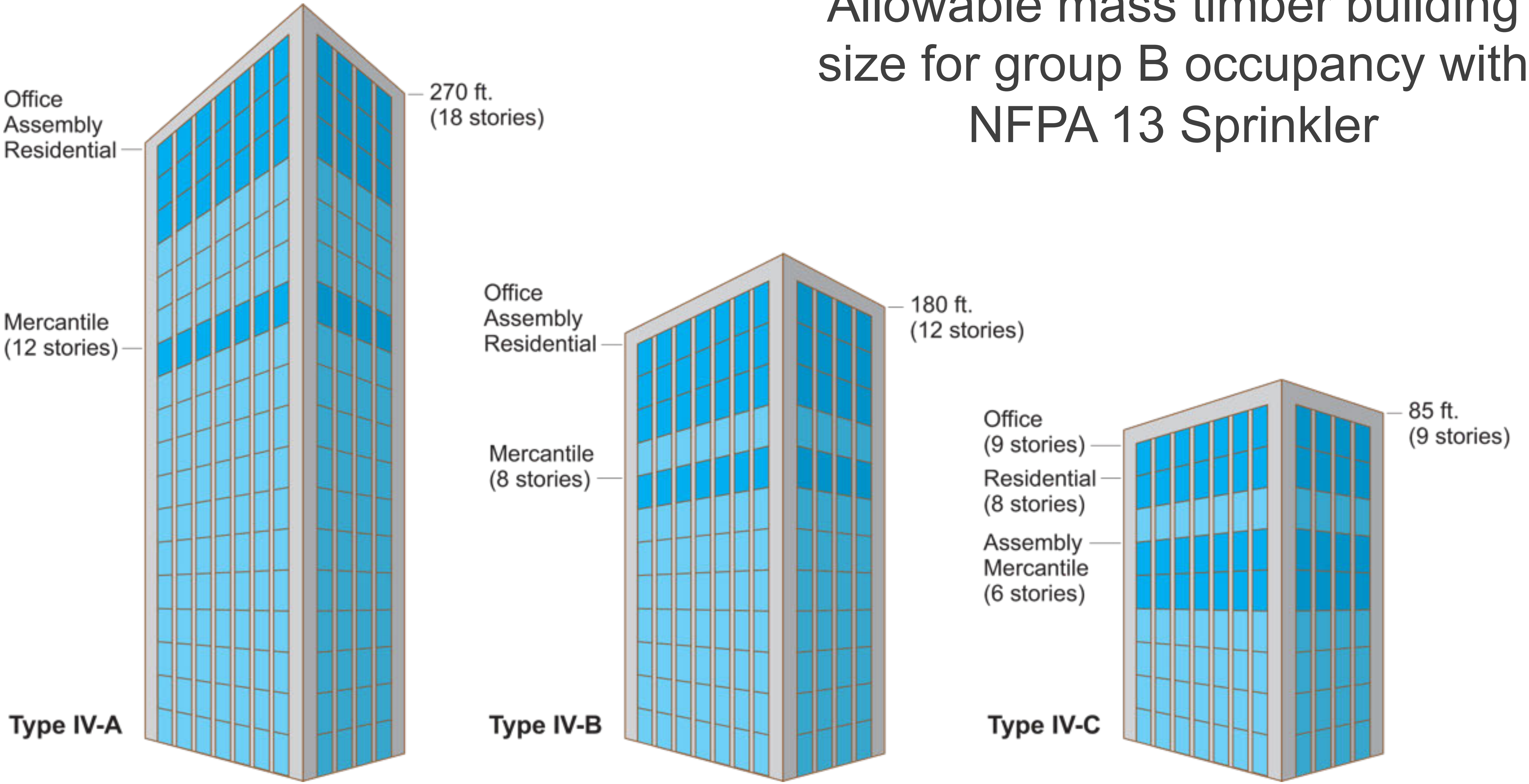
IV-A, IV-B, IV-C

Previous type IV renamed type IV-HT

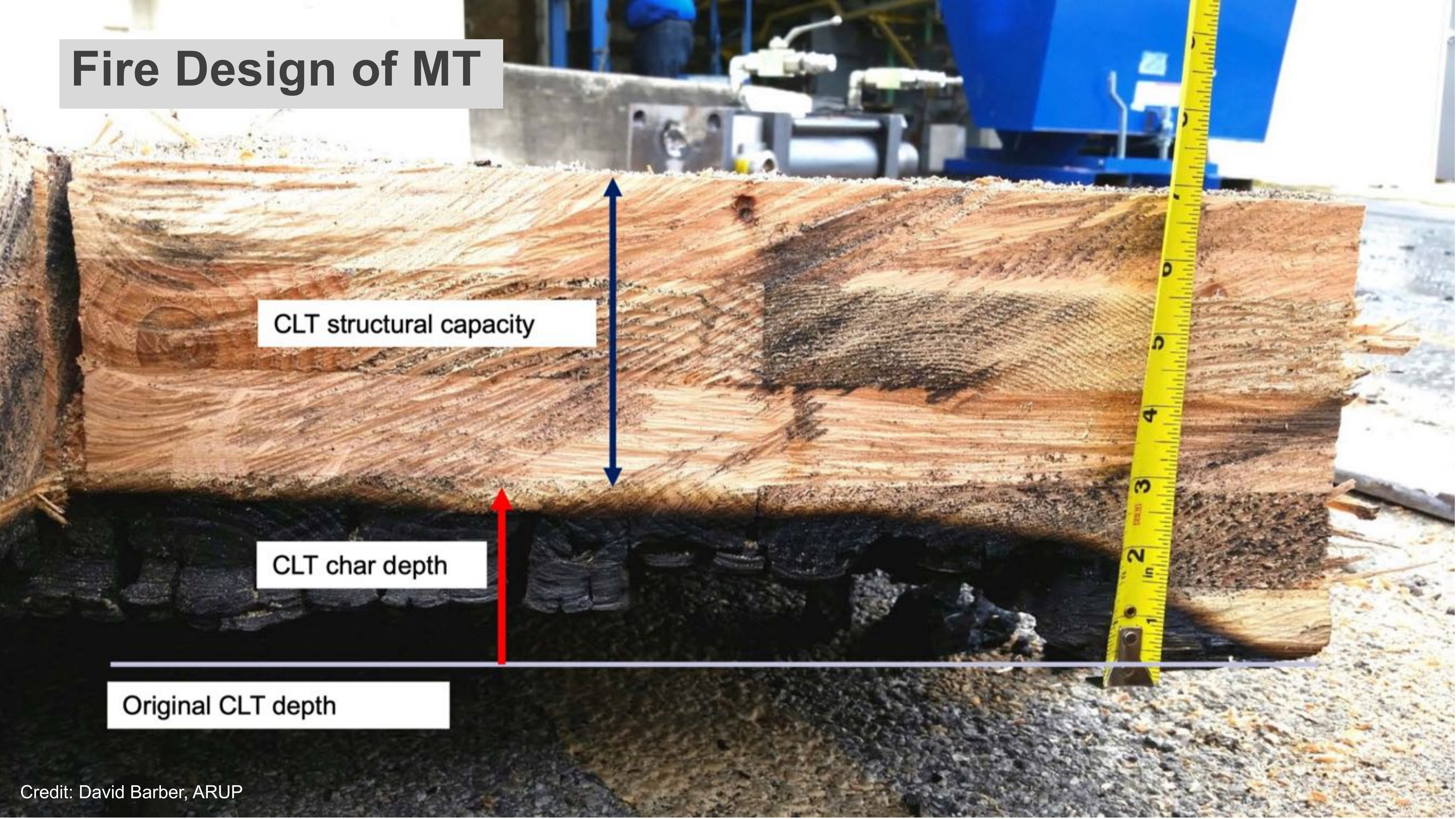
BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B

Construction Types

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



Fire Design of MT



Credit: David Barber, ARUP

Key Early Design Decisions

Fire-Resistance Ratings

- Driven primarily by construction type
- Rating achieved:
  - Timber alone or non-combustible 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

Credit: David Barber, ARUP

Key Early Design Decisions

Construction type influences FRR

- Type IV-HT Construction
    - (minimum sizes: Section 2304.11)

- **<u>Other than type IV-HT</u>**: Demonstrated fire resistance

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


Fire Testing Laboratory

NGC Testing Services

IAS ACCREDITED Testing Laboratory TL-216

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

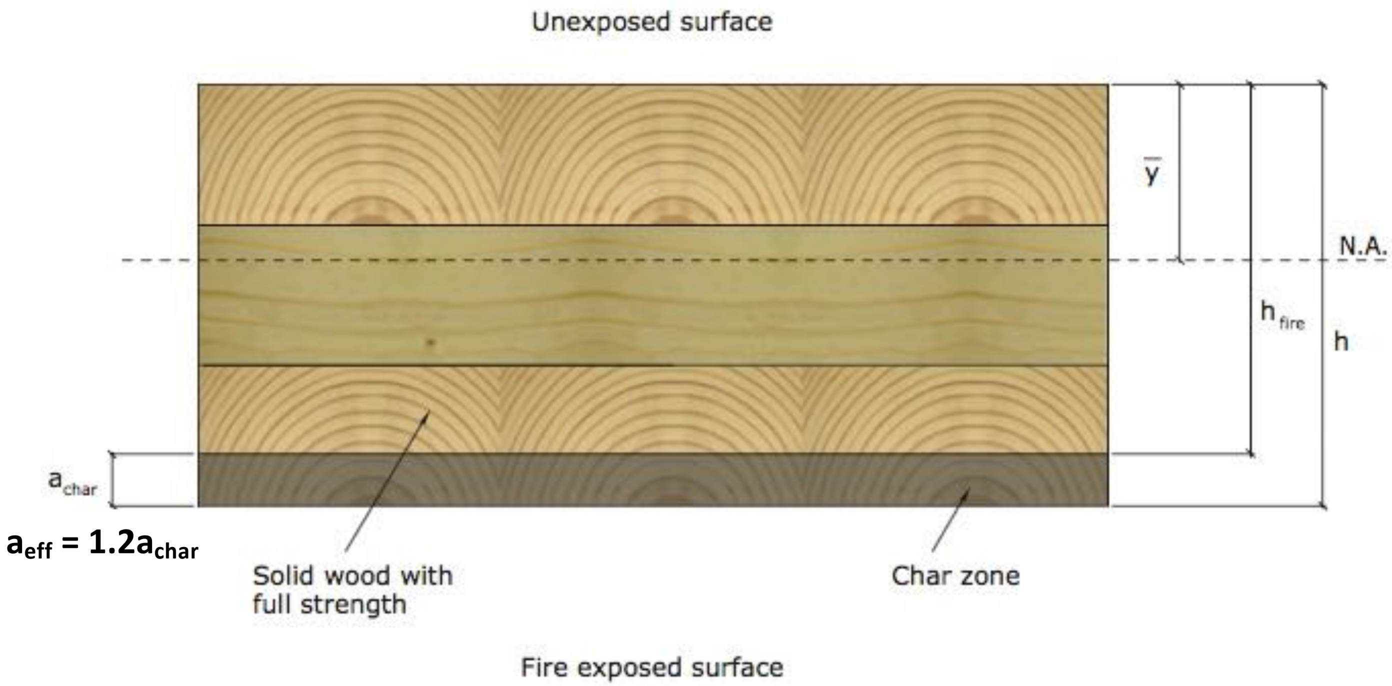
Reviewed by: Robert J. Menchetti, Director, Laboratory Facilities and Testing Services

The results reported in this document apply to specific samples submitted for measurement. No responsibility is assumed for performance of any other specimen. This report may not be reproduced, except in full, without the written approval of the laboratory. The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by this laboratory.

Key Early Design Decisions

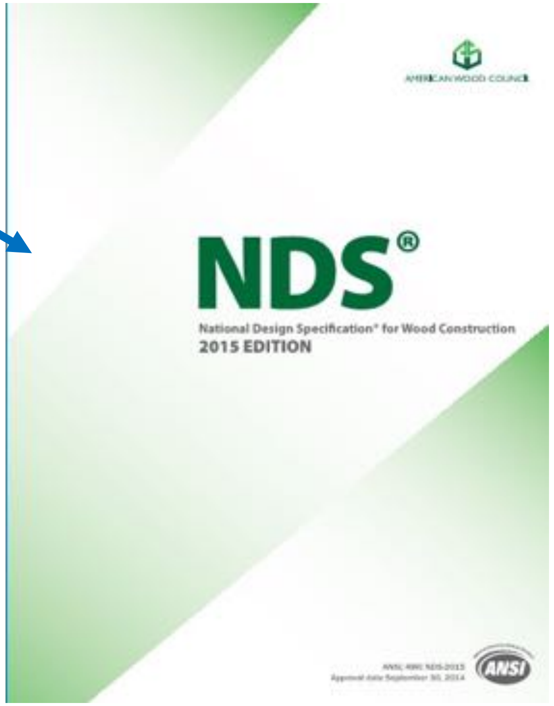
Which Method of Demonstrating FRR of MT is Being Used?

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



FRR Design of MT

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



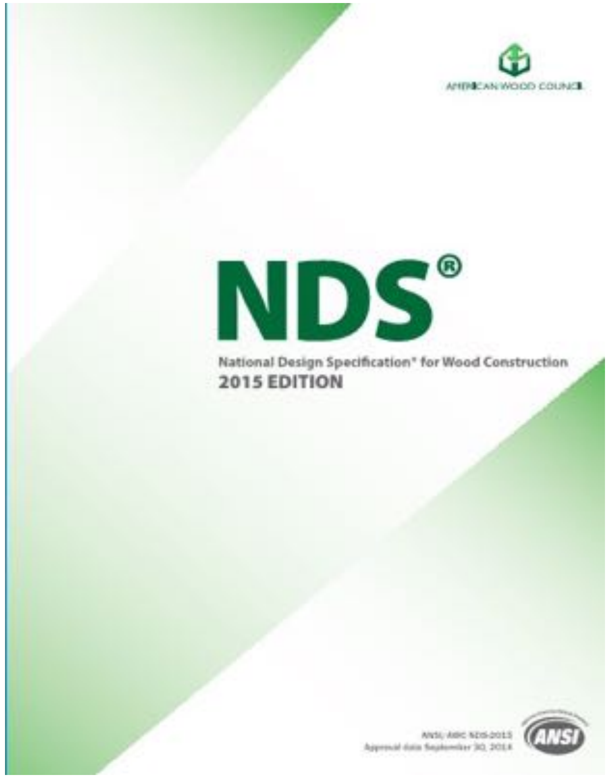
Code Path for Exposed Wood Fire-Resistance Calculations

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.

FRR Design of MT




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

FRR Design of MT

WoodWorks Inventory of Fire Tested MT Assemblies

WOODWORKS
WOOD PRODUCTS COUNCIL

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

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 1.5EMSR 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	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]

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

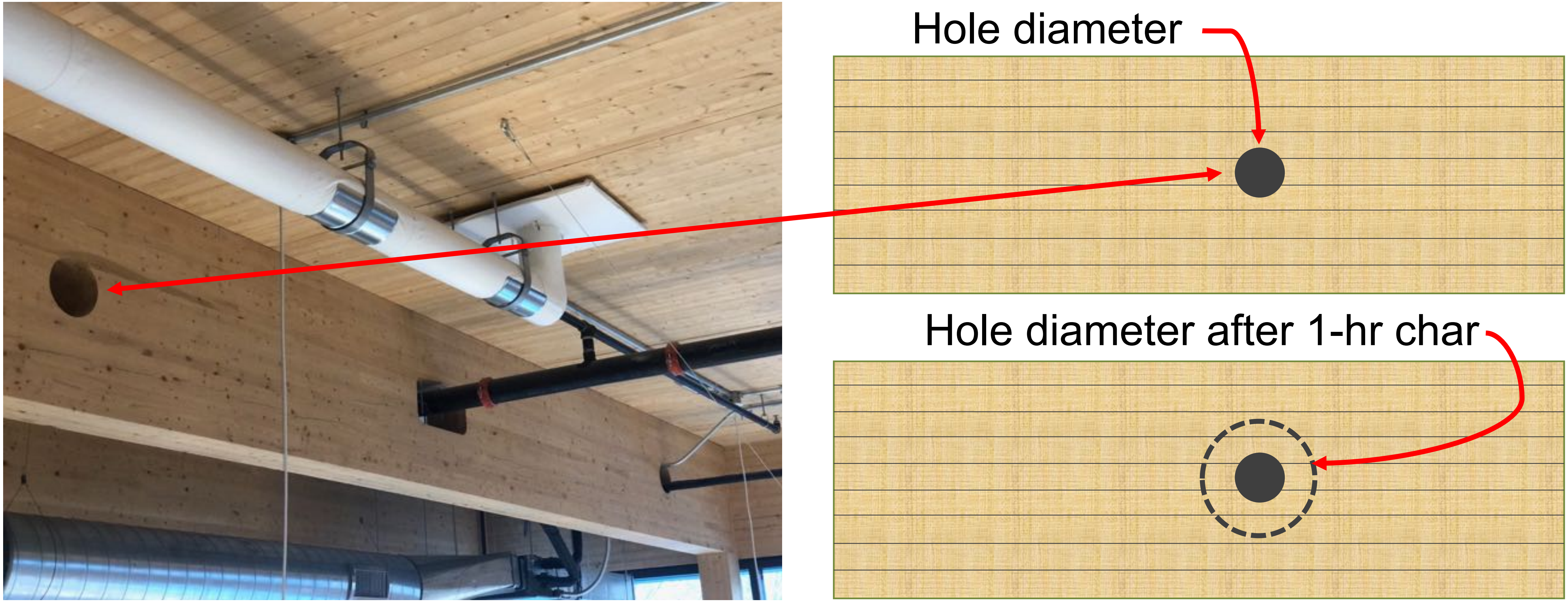
Penetrations & Firestopping

Photo: Alex Schreyer

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

Option 1: MT penetration firestopping via tested products

Penetrations & Firestopping

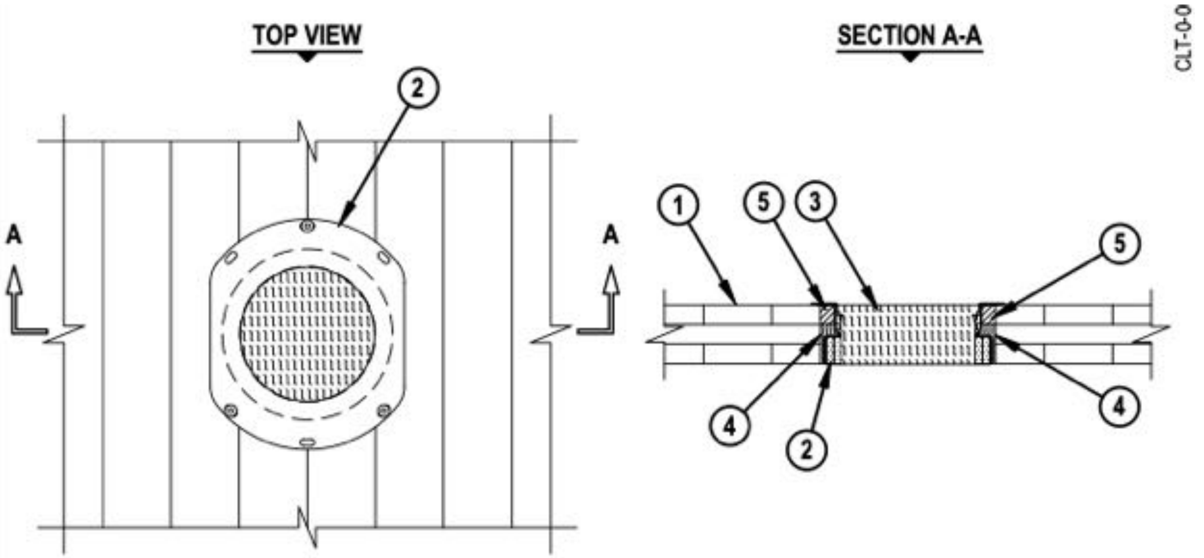
Inventory of Fire Tested Penetrations in MT Assemblies

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

CLT Panel	Exposed Side Protection	Penetrating Item	Penetrant Centered or Offset in Hole	Firestopping System Description	F Rating	T Rating	Stated Test Protocal	Source	Testing Lab
3-ply (78mm 3.07")	None	1.5" diameter data cable bunch	Centered	3.5 in diameter hole. Mineral wool was installed in the 1in. annular space around the data cables to a total depth of approximately 2 – 5/64 in. The remaining 1in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	0.5 hour	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	2" copper pipe	Centered	4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	2.5" sched. 40 pipe	Centered	4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	6" cast iron pipe	Centered	8.35 in diameter hole. Mineral wool was installed in the 1in. annular space around the cast iron pipe to a total depth of approximately 2 – 5/64 in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	Hilti 6 in drop in device. System No.: F-B-2049	Centered	9.01" diameter hole. Mineral wool was installed in the 1 – 1/4in. annular space around the drop-in device to a total depth of approximately 1 – 7/64in and the remaining 1in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64in. hole in the CLT was filled with Hilti FS-One Max caulking.	1 hour	0.75 hour	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	1.5" diameter data cable bunch	Centered	3.5" diameter hole. Mineral wool was installed in the 1in. annular space around the data cables to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	1.5 hours	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	2" copper pipe	Centered	4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	N.A.	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	2.5" sched. 40 pipe	Centered	4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	0.5 hour	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	6" cast iron pipe	Centered	8.35 in diameter hole. Mineral wool was installed in the 1in. annular space around the cast iron pipe to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	N.A.	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	Hilti 6 in drop in device. System No.: F-B-2049	Centered	9.01" diameter hole. Mineral wool was installed in the 1 – 1/4in. annular space around the drop-in device to a total depth of approximately 1 – 7/64in and the remaining 1in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64in. hole in the CLT was filled with Hilti FS-One Max caulking.	2 hours	1.5 hours	CANULC S115	26	Intertek March 30, 2016
5-ply (175mm 6.875")	None	1" nominal PVC pipe	Centered	4.21 in diameter with a 3/4 in plywood reducer flush with the top of the slab reducing the opening to 2.28 in. Two wraps of Hilti CP 648-E W45/1-3/4" Firestop wrap strip at two locations with a 30 gauge steel sleeve which extended from the top of the slab to 1 in below the slab. The first location was with the bottom of the wrap strip flush with the bottom of the steel sleeve and the second was with the bottom of the wrap strip 3 in. from the bottom of the slab. The void between the steel sleeve and the CLT and between the steel sleeve and pipe at the top was filled with Roxul Safe mineral wool leaving a 3/4 in deep void at the top of the assembly. Hilti FS-One Max Intumescent Firestop Sealant was applied to a depth of 3/4 in on the top of the assembly between the plywood and steel sleeve as well as the steel sleeve and pipe.	2 hours	2 hours	ASTM E814	24	QAI Laboratories March 3, 2017

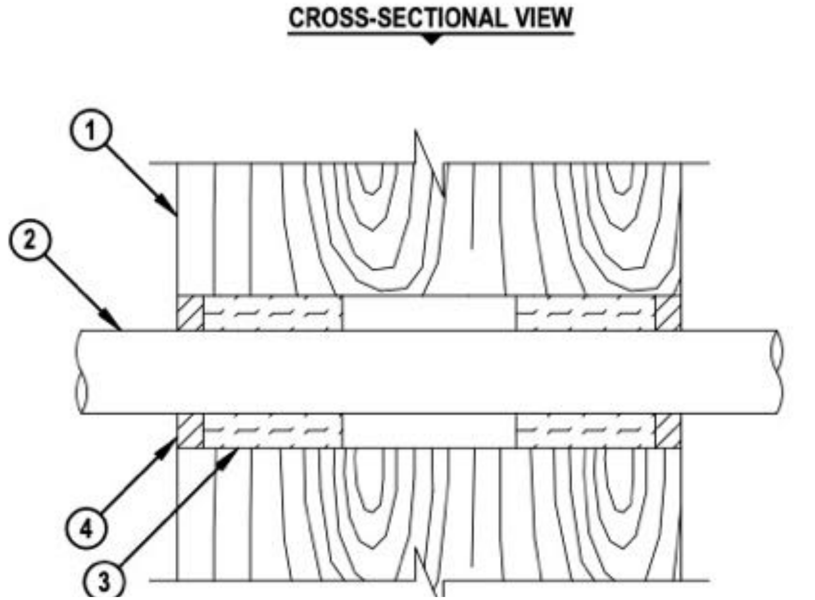
Penetrations & Firestopping

Option 2: MT penetration firestopping of penetrations via engineering judgement details (contact firestop manufacturer)



1. 3-PLY CROSS LAMINATED TIMBER FLOOR ASSEMBLY (MINIMUM 3" THICK) (1-HR. FIRE-RATING).
2. HILTI CFS-DID FIRESTOP DROP-IN DEVICE INSERTED INTO OPENING (SEE TABLE BELOW) AND SECURED TO TOP SURFACE OF CROSS LAMINATED TIMBER FLOOR ASSEMBLY WITH THREE 1/4" x 1" LONG STEEL WOOD SCREWS WITH WASHERS.
3. MINIMUM 3" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED, AND FLUSH WITH TOP AND BOTTOM SURFACE OF CFS-DID FIRESTOP DROP-IN DEVICE.
4. MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED, RECESSED TO ACCOMMODATE SEALANT, AND COMPLETELY FILLING SPACE BETWEEN CFS-DID FIRESTOP DROP-IN DEVICE AND PERIPHERY OF OPENING.
5. MINIMUM 1" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP SEALANT BETWEEN CFS-DID FIRESTOP DROP IN DEVICE AND PERIPHERY OF OPENING.

F-RATING = 1-HR. OR 2-HR. (SEE NOTE NO. 3 BELOW)



1. MASS TIMBER WALL ASSEMBLY (MINIMUM 12" THICK) (1-HR. OR 2-HR. FIRE-RATING).
2. MAXIMUM 2" NOMINAL DIAMETER PVC PLASTIC PIPE (SCH 40).
3. MINIMUM 4" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED AND RECESSED TO ACCOMMODATE SEALANT.
4. MINIMUM 3/4" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP SEALANT.

Thank you!

WOODWORKS
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The Loading Dock / OZ Architecture / KL&A Engineers & Builders / photo Joe Anastasi