Fire, Acoustics and Structural Design of Mass Timber: How They're all Integrated

Mark Bartlett, PE, Regional Director, WoodWorks – Wood Products Council

Photo: Texas Timber Frames

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

Course Description

Mass timber represents a rapidly advancing technology that can be utilized as an alternative to steel and concrete to frame a variety of mid- and high-rise building types. As it transitions from novelty to mainstream, many architects and engineers are finding they need a deeper understanding of the unique design considerations associated with this new construction type. Intended to provide practical knowledge that can be applied to projects, this workshop focuses on five key mass timber design topics: fire resistance, acoustics, structural grid layout, building enclosure, and durability—while introducing a number of completed mass timber projects to illustrate applied solutions. Cost efficiency, detailing best practices, design team integration, and lessons learned will make this half-day seminar a must-attend building design event for anyone interested in mass timber design.

Learning Objectives

1. Consider how various aspects of mass timber fire performance apply (or don't apply) to code-compliant low- and mid-rise vs. high-rise buildings.
2. Highlight best practice details and assemblies to achieve code-compliant acoustical performance in mass timber buildings.
3. Discuss building enclosure design principles for mass timber buildings.
4. Identify approaches to designer/building official interaction needed to realize successful mass timber commercial projects.

What's Unique About Mass Timber?

Structure = Finish = Fire Protection

Photo: Structurlam

It’s (Relatively) New

Photo: John Klein

Not A Commodity Product

Photo: Marcus Kauffman

Mass Timber Optimization = Mass Timber Success

T3 Minneapolis | Architects: Michael Green Architecture, DLR Group | Photo: Ema Peter

FRAMING OPTIONS | POST, BEAM + PLATE

Photo: WoodWorks

FRAMING OPTIONS | HYBRID STEEL + MASS TIMBER

FRAMING OPTIONS | HYBRID LIGHT-FRAME + MASS TIMBER

Photo: Seagate Structures

FRAMING OPTIONS | POST + PLATE

Photo: Lendlease

FRAMING OPTIONS | HONEYCOMB

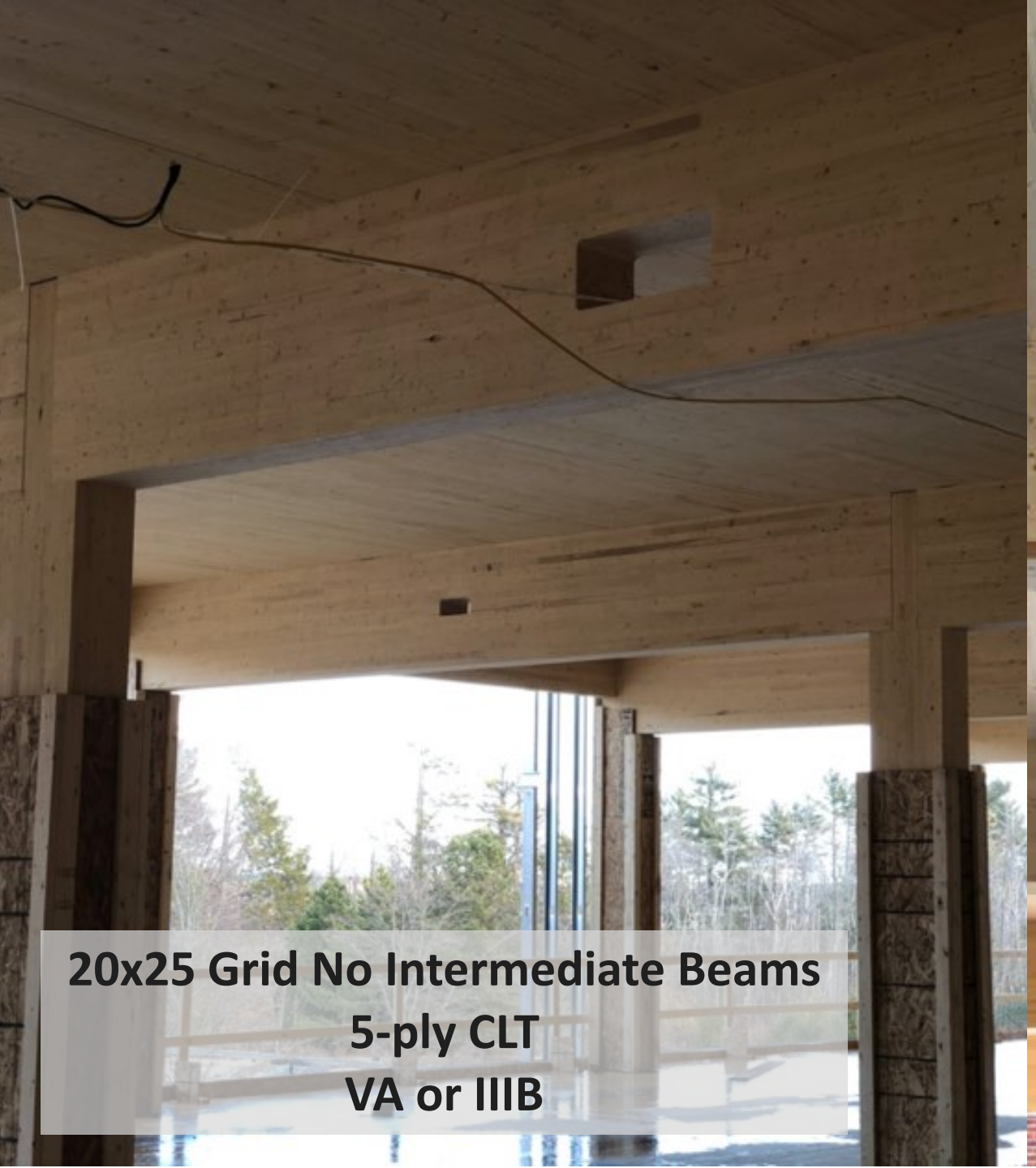
Mass Timber Construction Types
3-4 Story Building Options

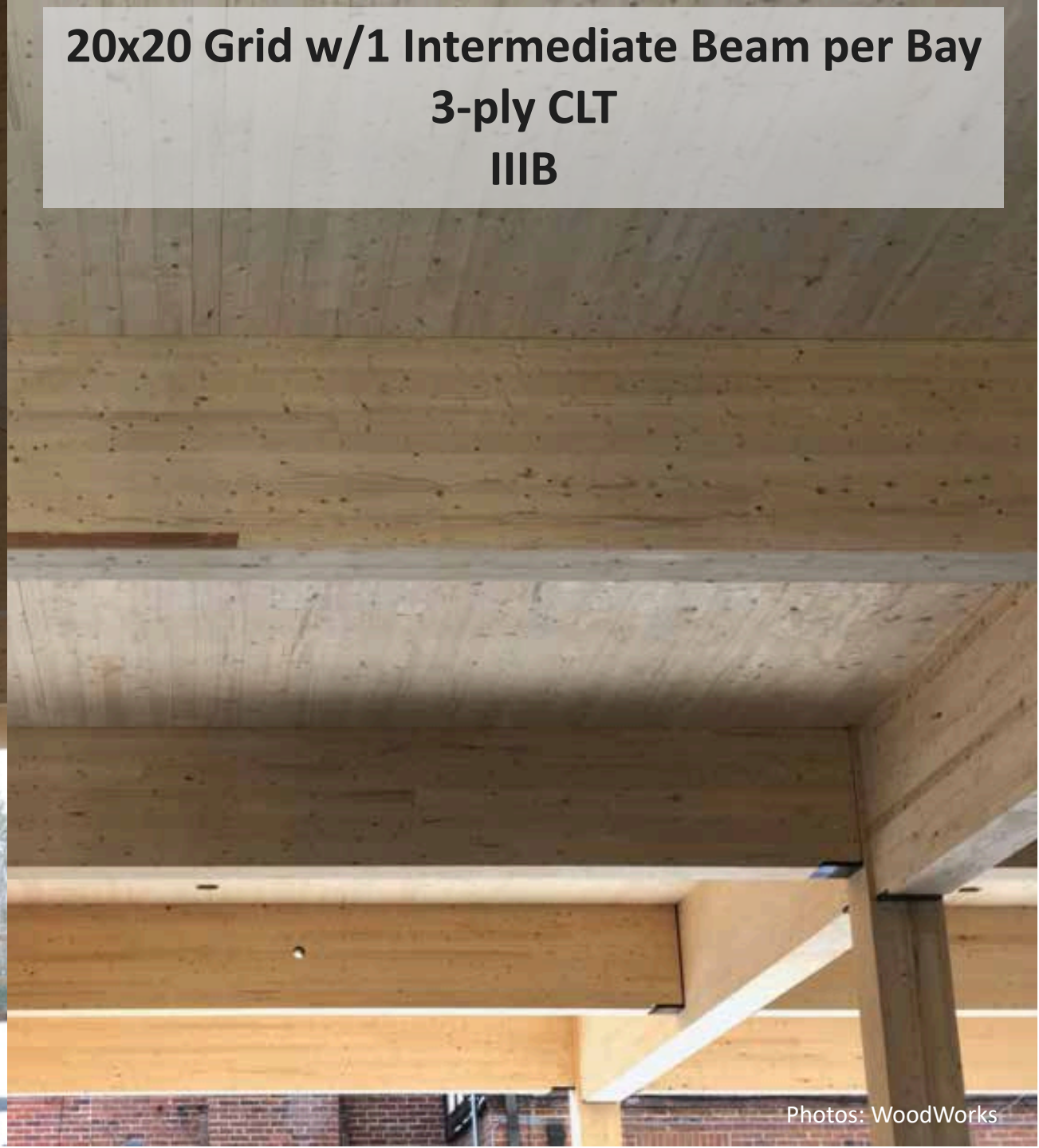
111 East Grand, Neumann Monson Architects, photo Mike Sinclair

Mass Timber Construction Types

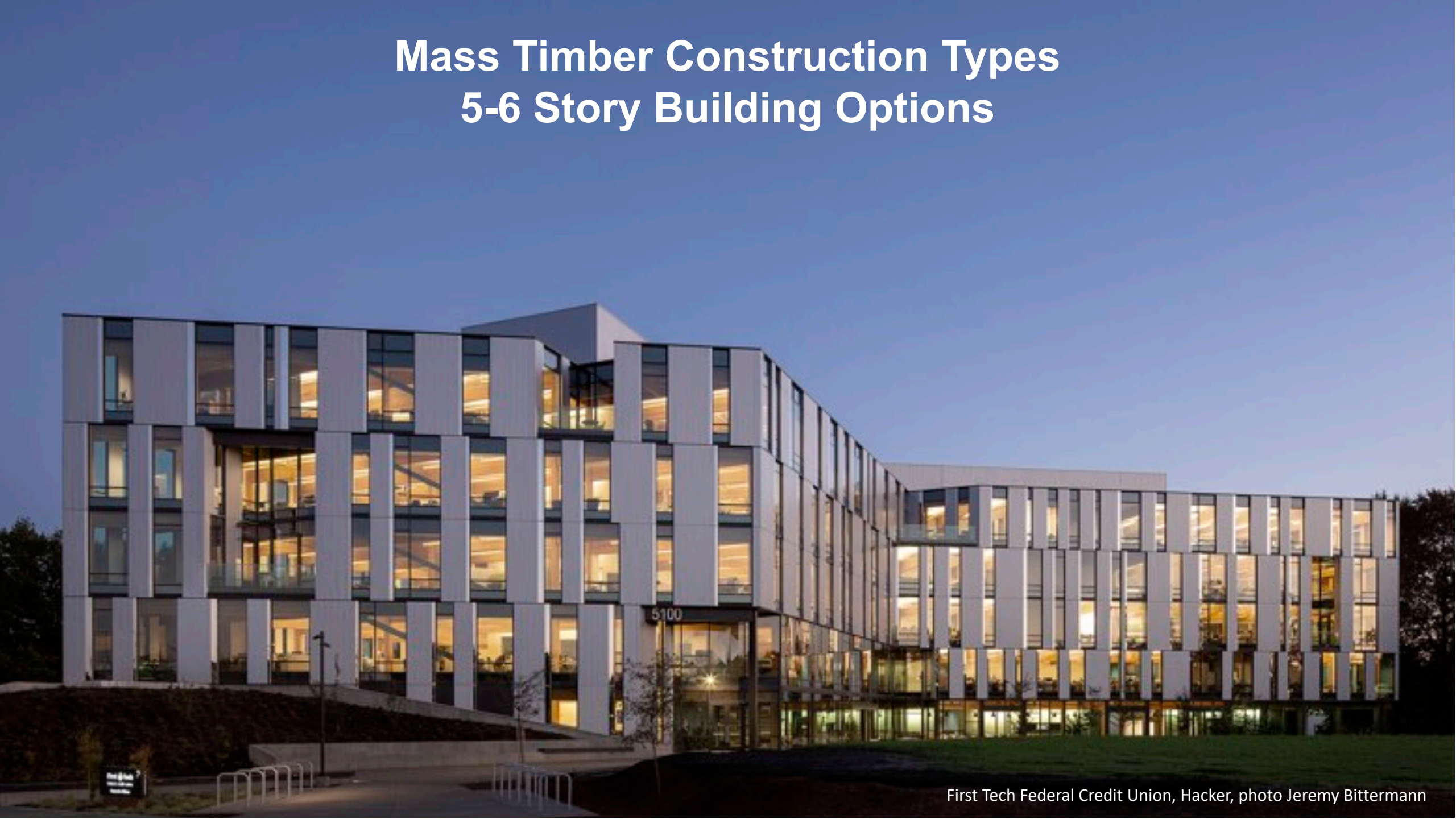
3-4 Story Building Options

	Type IIIB	Type VA
Allowable Building Height	4 stories / 75 ft	4 stories / 70 ft
Allowable Area	57k SF / 171k SF	54k SF / 162k SF
Interior FRR	0 HR	1 HR
Interior materials	Any material	Any material
Interior partitions	0 HR non-bearing	0 HR non-bearing
Exterior Bearing Walls	FRTW or Non-com, 2 HR	Any material, 1 HR
Concealed Spaces	Permitted	Permitted
	3-ply Floors **No CLT ext. walls** **Connections/Penetrations not rated**	**5-ply Floors** **CLT ext. walls** **Connections/Penetrations rated**


20x25 Grid No Intermediate Beams
5-ply CLT
VA or IIIB


20x20 Grid w/1 Intermediate Beam per Bay
3-ply CLT
IIIB
Photos: WoodWorks

Mass Timber Construction Types
5-6 Story Building Options



First Tech Federal Credit Union, Hacker, photo Jeremy Bittermann

Mass Timber Construction Types

5-6 Story Building Options

	Type IIIA	Type IV
Allowable Building Height	6 stories / 85 ft	6 stories / 85 ft
Allowable Area	85.5k SF / 256.5k SF	108k SF / 324k SF
Interior FRR	1 HR	HT
Interior materials	Any material	HT
Interior partitions	0 HR non-bearing	1 HR non-bearing or HT
Exterior Bearing Walls	FRTW or Non-comb., 2 HR	FRTW or CLT or Non-comb., 2 HR
Concealed Spaces	Permitted	Not permitted in 2015 & 2018 IBC

5-ply Floors
No CLT ext. walls
Connections/Penetrations rated

3-ply Floors
CLT ext. walls
Connections/Penetrations rated??
Steel/concrete members??
Interior partitions rated
Concealed space AMMR

Connections

Non-rated Connections

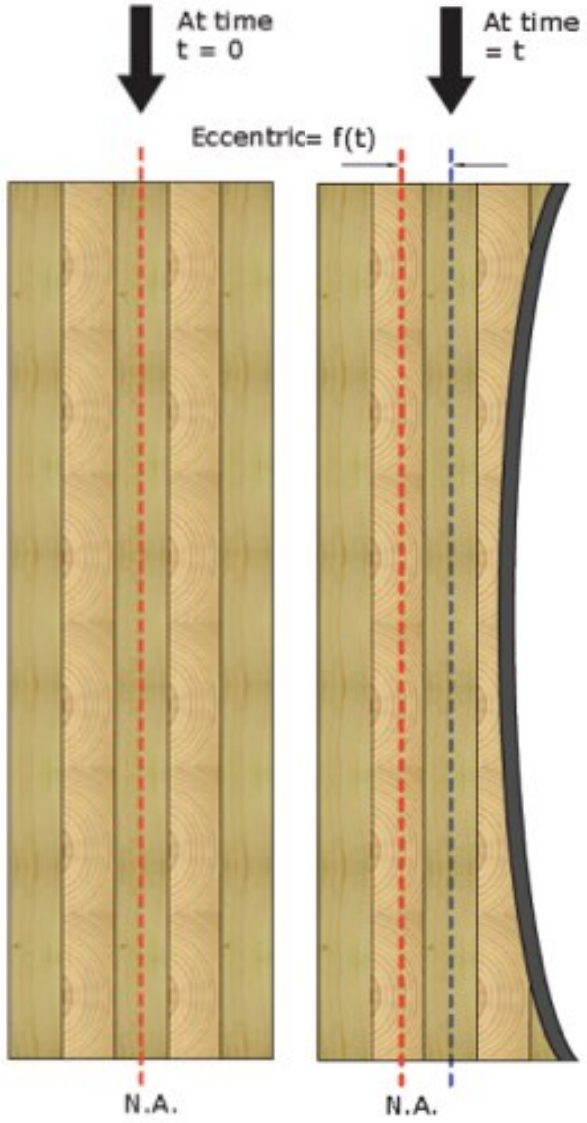
Rated Connections

Photos: WoodWorks

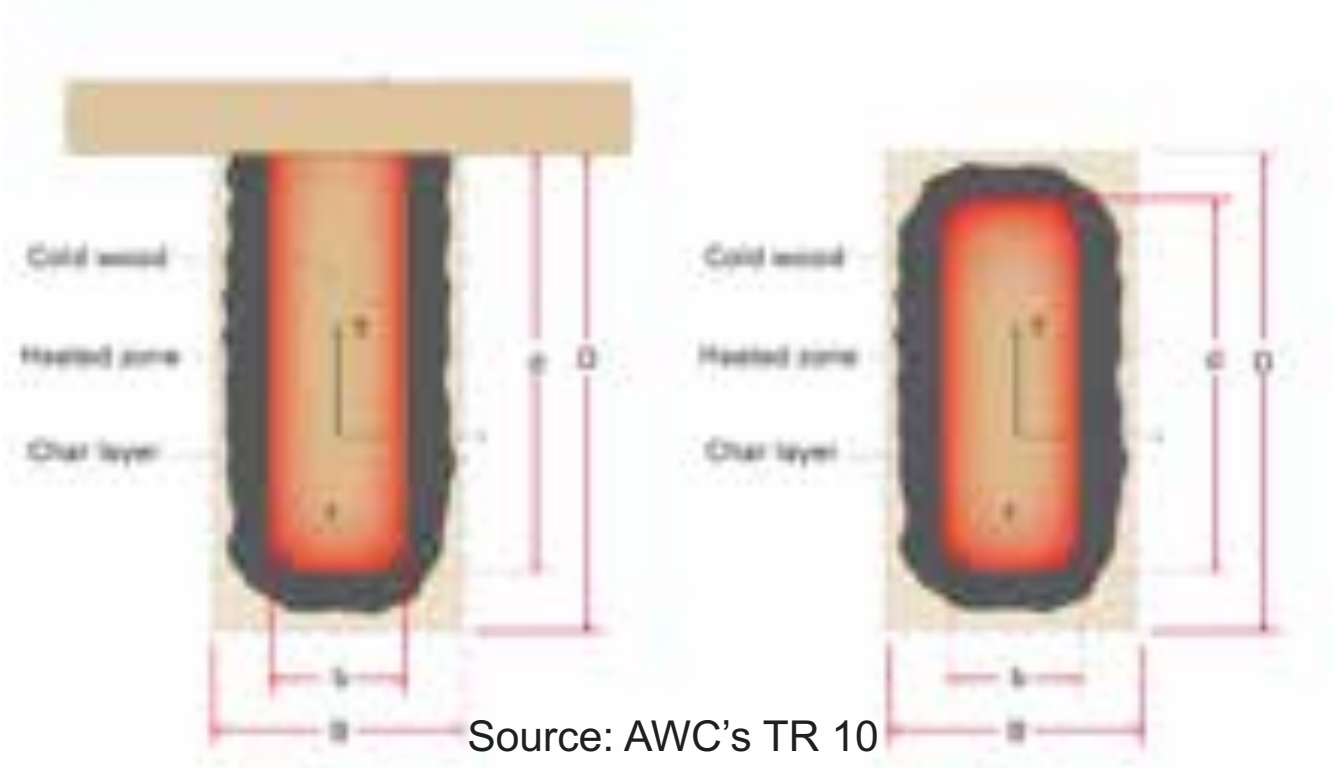
Fire Resistance

Photo Credit: FP Innovations

Mass Timber Fire Resistance



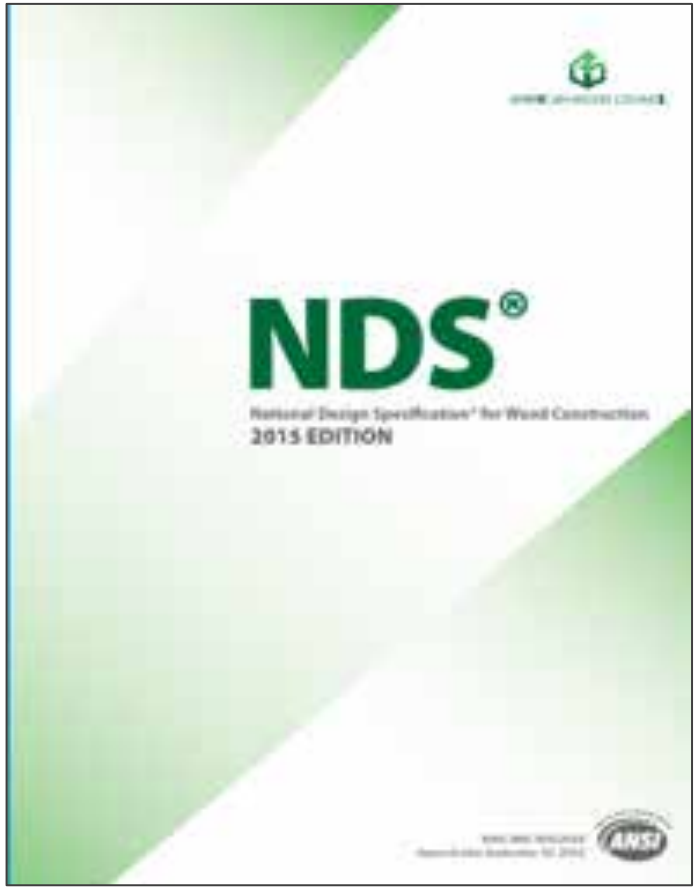
Similar to heavy timber, mass timber products have inherent fire resistance properties

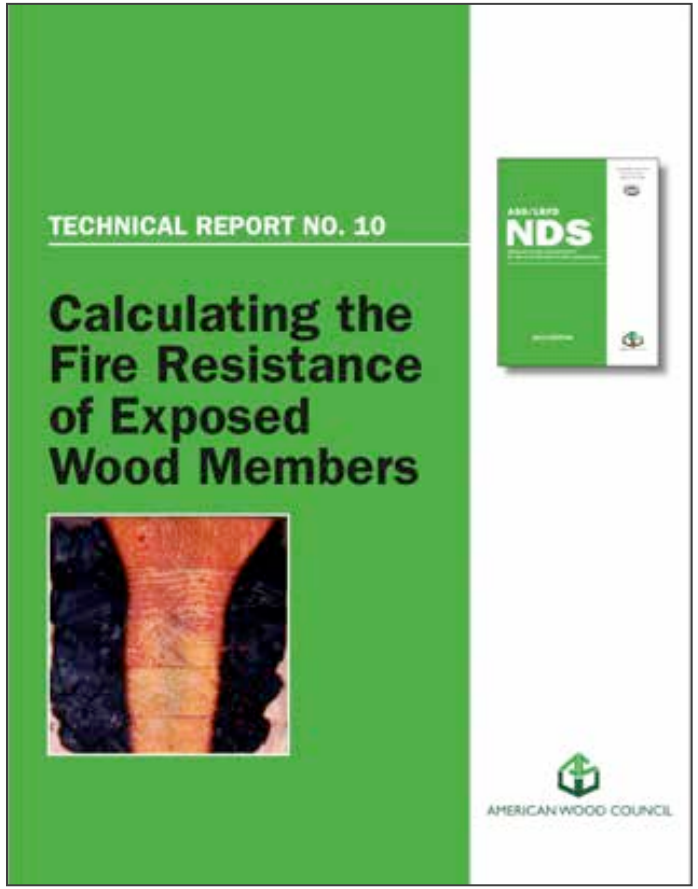


Source: AWC's TR 10

Mass Timber Fire Resistance

For Exposed Wood Members: IBC 722.1 References AWC's NDS Chapter 16 (AWC's TR 10 is a design aid to NDS Chapter 16)





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
WOOD PRODUCTS COUNCIL

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
5-ply CLT (154mm 6.063 in.)	Nordic	SPF 1650 Fb 1.5 E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 54% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.134 in.)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 73% Moment Capacity	1	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Splines	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 1 1/4" [illegible]	Topside Splines	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 Splines	1/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 30% Moment Capacity	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Splines	1/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 30% Moment Capacity	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X Gyp under Resilient Channel under 1 7/8" I-Joists with 1 1/2" Mineral Wool between 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 Splines	1-1/2" Maxxon CrypGrete 2800 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 Splines	2" gypcrete topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1/#2 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 19% 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 100% Moment Capacity	2	1 (Test 4)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced 100% 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 (175mm 6.875")	KLH	CV SM1	None	Half-Lap & [illegible]	None	Loaded, See Manufacturer	1	18	SwRI

Credit: WoodWorks

MT Fire Resistance Ratings (FRR)

WoodWorks
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Fire-Resistive Design of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

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

Mass Timber Fire Design Resource

- **Code compliance options for demonstrating FRR**
- **Construction type considerations**
- **Free download at woodworks.org**

Credit: WoodWorks

New Tall Mass Timber Types

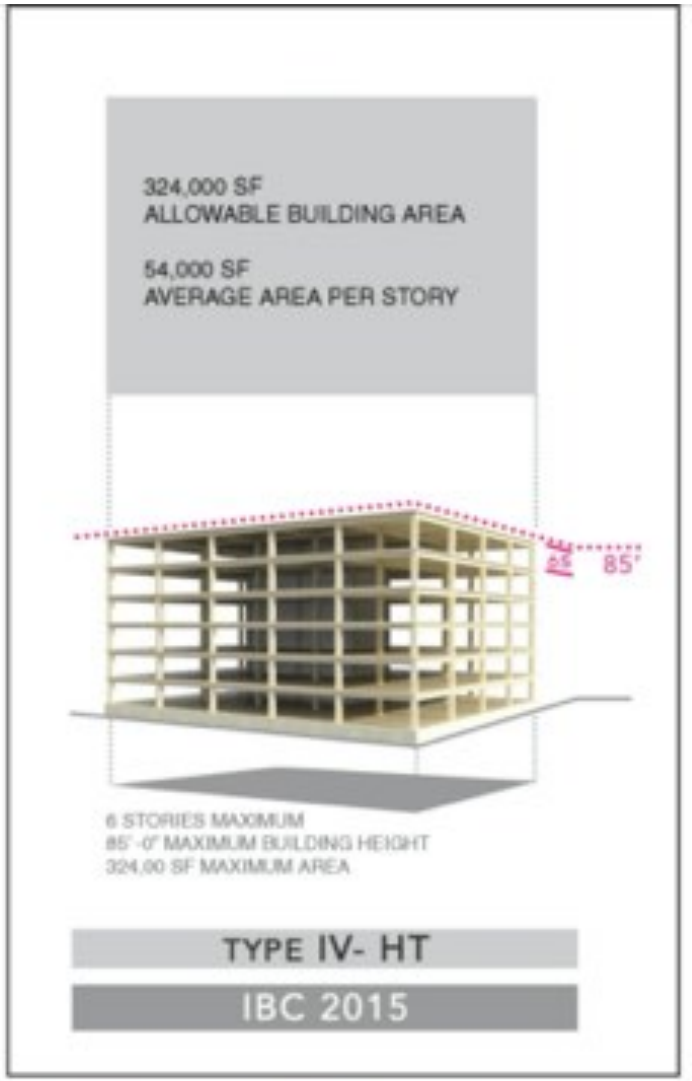
18 STORIES
BUILDING HEIGHT 270'
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000SF

12 STORIES
BUILDING HEIGHT 180 FT
ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000SF

9 STORIES
BUILDING HEIGHT 85'
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

TYPE IV-A | TYPE IV-B | TYPE IV-C

IBC 2021



TYPE IV- HT

IBC 2015

BUSINESS OCCUPANCY [GROUP B]

*BUILDING FLOOR-TO-FLOOR HEIGHTS ARE SHOWN AT 12'-0" FOR ALL EXAMPLES FOR CLARITY IN COMPARISON BETWEEN 2015 TO 2021 IBC CODES.

Credit: Susan Jones, atelierjones

WoodWorks Tall Wood Design Resource

http://www.woodworks.org/wp-content/uploads/wood_solution_paper-TALL-WOOD.pdf

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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.

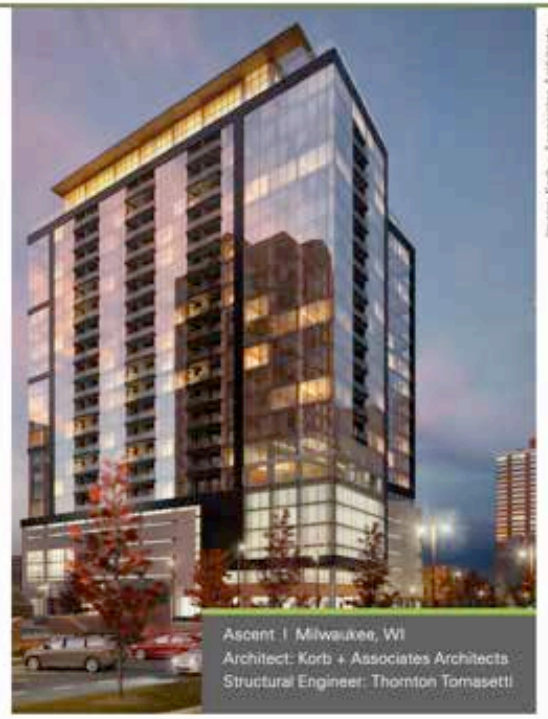


Image: Korb + Associates Architects

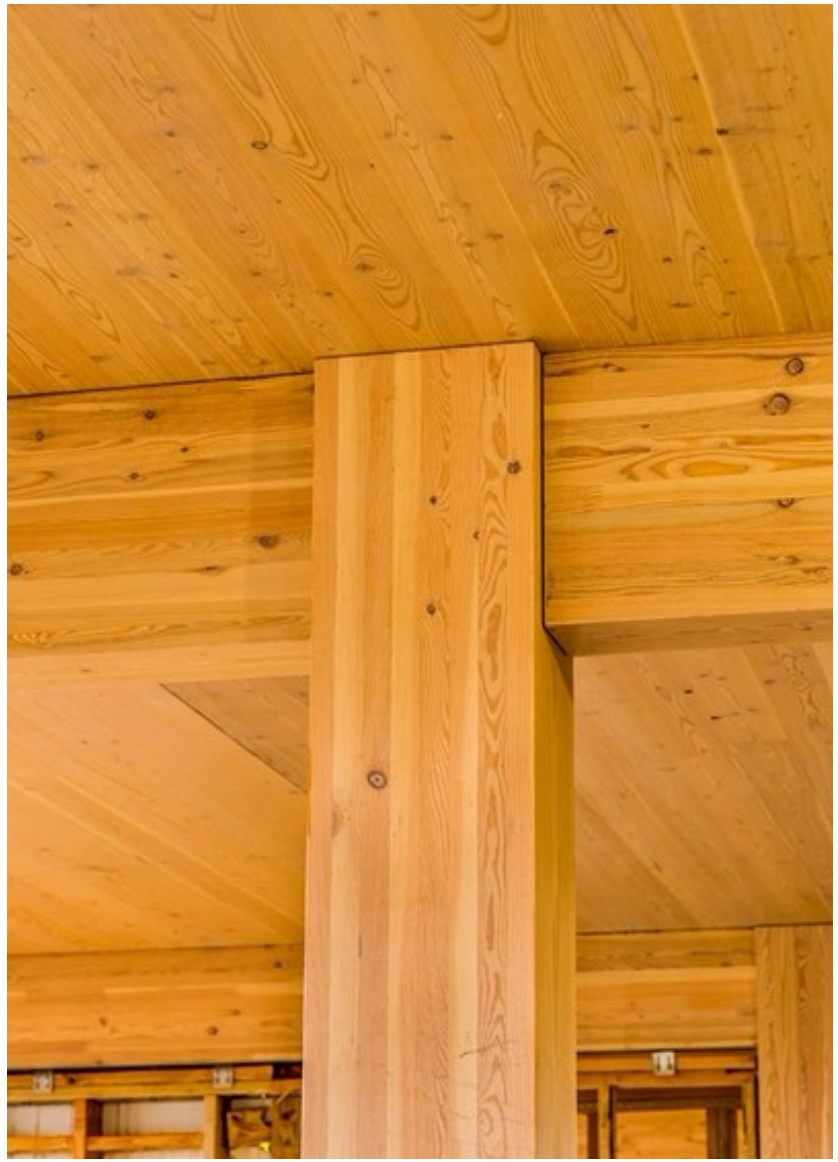
Ascent | Milwaukee, WI
Architect: Korb + Associates Architects
Structural Engineer: Thornton Tomasetti

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

Mass Timber: Structure Often is Finish



Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman | Architect: PATH Architecture

But by Itself, Not Adequate for Acoustics

Mass Timber Acoustics

One of the main reasons is “mass”
Recall the three ways to increase acoustical performance:

1. Add Mass
2. Add noise barriers
3. Add decouplers


Image credit: Christian Columbres

Mass Timber Acoustics

TABLE 1:

Examples of Acoustically-Tested Mass Timber Panels

Mass Timber Panel	Thickness	STC Rating	IIC Rating
3-ply CLT wall[4]	3.07"	33	N/A
5-ply CLT wall[4]	6.875"	38	N/A
5-ply CLT floor[5]	5.1875"	39	22
5-ply CLT floor[4]	6.875"	41	25
7-ply CLT floor[4]	9.65"	44	30
2x4 NLT wall[6]	3-1/2" bare NLT 4-1/4" with 3/4" plywood	24 bare NLT 29 with 3/4" plywood	N/A
2x6 NLT wall[6]	5-1/2" bare NLT 6-1/4" with 3/4" plywood	22 bare NLT 31 with 3/4" plywood	N/A
2x6 NLT floor + 1/2" plywood[2]	6" with 1/2" plywood	34	33

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks[7]

Mass Timber Acoustics

<u>Concrete Slab:</u>
6” Thick
80 PSF
STC 53

<u>CLT Slab:</u>
6-7/8” Thick
18 PSF
STC 41

Mass Timber Acoustics

There are three main ways to improve an assembly's acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers

Solutions Paper

Mass Timber Acoustics

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Acoustics and Mass Timber: Room-to-Room Noise Control

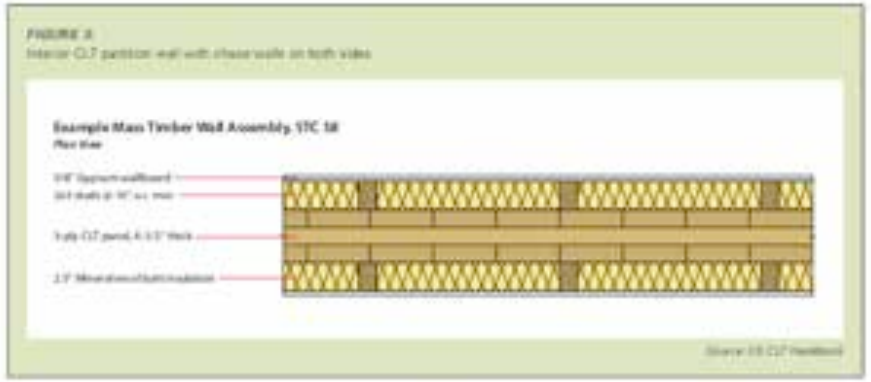
Richard McLain, PE, SE • Senior Technical Director • WoodWorks

T3 Minneapolis
Architect: MGA | Michael Green Architecture, DLR Group
Structural Engineer: Magnusson Klemencic Associates
Design Assist + Build: StructureCraft

The growing availability and code acceptance 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 has given designers a low-carbon alternative to steel, concrete, and masonry for many applications. However, the use of mass timber in multi-family and commercial buildings presents unique acoustic challenges.

While laboratory measurements of the impact and airborne sound isolation of traditional building assemblies such as light wood-frame, steel and concrete are widely available, fewer resources exist that quantify the acoustic performance of mass timber assemblies. Additionally, one of the most desired aspects of mass timber construction is the ability to leave a building's structure exposed as finish, which creates the need for asymmetric assemblies. With careful design and detailing, mass timber buildings can meet the acoustic performance expectations of most building types.

http://www.woodworks.org/wp-content/uploads/wood_solution_paper-MASS-TIMBER-ACOUSTICS.pdf



Mass Timber Assembly Options: Walls

Mass timber panels can also be used for interior and exterior walls—both bearing and non-bearing. For interior walls, the need to conceal services such as electrical and plumbing is an added consideration. Common approaches include building a chase wall in front of the mass timber wall or installing gypsum wallboard on resilient channels that are attached to the mass timber wall. As with bare mass timber floor panels, bare mass timber walls don't typically provide adequate noise control, and chase walls also function as acoustical improvements. For example, a 3-ply CLT wall panel with a thickness of 3.07" has an STC rating of 33.* In contrast, Figure 3 shows an interior CLT partition wall with chase walls on both sides. This assembly achieves an STC rating of 58, exceeding the IBC's acoustical requirements for multi-family construction. Other examples are included in the inventory of tested assemblies noted above.

Acoustical Differences between Mass Timber Panel Options

The majority of acoustically-tested mass timber assemblies include CLT. However, tests have also been done on other mass timber panel options such as NLT and dowel-laminated timber (DLT), as well as traditional heavy timber options such as tongue and groove decking. Most tests have concluded that CLT acoustical performance is slightly better than that of other mass timber options, largely because the cross-orientation of laminations in a CLT panel limits sound flanking.

For those interested in comparing similar assemblies and mass timber panel types and thicknesses, the inventory noted above contains tested assemblies using CLT, NLT, glued-laminated timber panels (GLT), and tongue and groove decking.

Improving Performance by Minimizing Flanking

Even when the assemblies in a building are carefully designed and installed for high acoustical performance, consideration of flanking paths—in areas such as assembly intersections, beam-to-column/wall connections, and MEP penetrations—is necessary for a building to meet overall acoustical performance objectives.

One way to minimize flanking paths at these connections and interfaces is to use resilient connection isolation and sealant strips. These products are capable of resisting structural loads in compression between structural members and connections while providing isolation and breaking hard, direct connections between members. In the context of the three methods for improving acoustical performance noted above, these strips act as decouplers. With airtight connections, interfaces and penetrations, there is a much greater chance that the acoustic performance of a mass timber building will meet expectations.

Inventory of Tested Assemblies

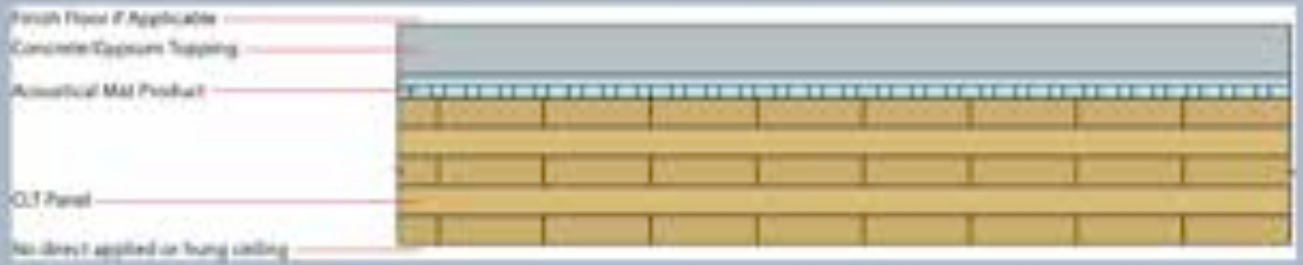
Acoustically-Tested Mass Timber Assemblies

Following is a list of mass timber assemblies that have been acoustically tested as of January 23, 2019. Sources are noted at the end of this document. For free technical assistance on any questions related to the acoustical design of mass timber assemblies, or free technical assistance related to any aspect of the design, engineering or construction of a commercial or multi-family wood building in the U.S., email help@woodworks.org or contact the WoodWorks Regional Director nearest you: http://www.woodworks.org/project-assistance

Contents:

http://bit.ly/mass-timber-assemblies

Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed



CLT Panel	Concrete/Gypsum Topping	Acoustical Mat Product Between CLT and Topping	Finish Floor	STC[1]	IIC[1]	Source
CLT 5-ply (6.875")	1-1/2" Gyp-Crete®	Maxxon Acousti-Mat® 3/4	None	47[1] ASTC	47[1] AIIC	1
			LVT	-	49[1] AIIC	
			Carpet + Pad	-	75[1] AIIC	
			LVT on Acousti-Top®	-	52[1] AIIC	
			Eng Wood on Acousti-Top®	-	51[1] AIIC	
		Maxxon Acousti-Mat® N Premium	None	49[1] ASTC	45[1] AIIC	
			LVT	-	47[1] AIIC	
			LVT on Acousti-Top®	-	49[1] AIIC	
	1-1/2" Levelrock® Brand 2500	USG SAM N25 Ultra	None	45[3]	39[3]	15
			LVT	48[3]	47[3]	16
			LVT Plus	48[3]	49[3]	58
			Eng Wood	47[3]	47[3]	59
			Carpet + Pad	45[3]	67[3]	60
			Ceramic Tile	50[3]	46[3]	61
		Soprema® Insonomat	None	45[3]	42[3]	15
			LVT	48[3]	44[3]	16
			LVT Plus	48[3]	47[3]	58
			Eng Wood	47[3]	45[3]	59
			Carpet + Pad	45[3]	71[3]	60
			Ceramic Tile	50[3]	46[3]	61
		USG SAM N75 Ultra	None	45[3]	38[3]	15
			LVT	48[3]	47[3]	16
			LVT Plus	48[3]	49[3]	58
			Eng Wood	47[3]	49[3]	59

http://bit.ly/mass-timber-assemblies

LVT on 2” Concrete

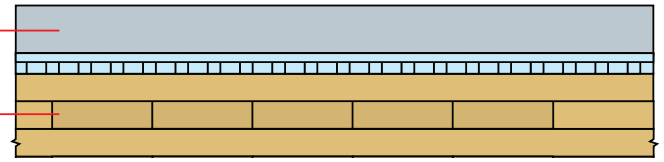
Mass Timber Assemblies

Effect of Timber Thickness

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel



3-ply CLT

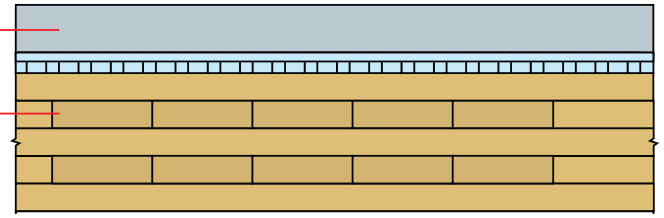
STC 53

IIC 48

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel



5-ply CLT

STC 53

IIC 52

LVT on 1” Gypsum

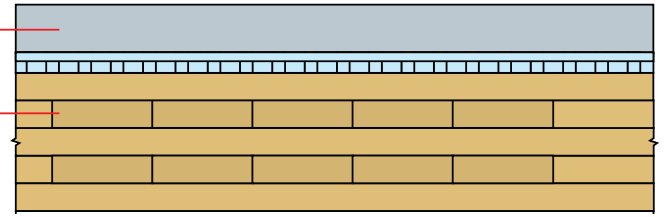
Mass Timber Assemblies

Effect of Gypsum Ceiling

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel



STC 51

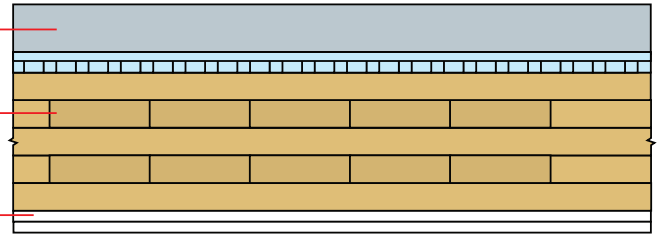
IIC 43

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel

Two layers 5/8" Type X gypsum*



STC 52

IIC 48

**Applicable to most locations; limited exposed mass timber permitted in IV-B*

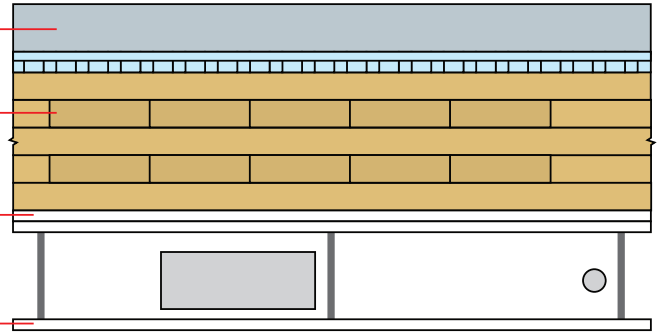
With Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel

Two layers 5/8" Type X gypsum

Dropped ceiling



STC 63

IIC 63

KNOW YOUR WHY

“Eventually we stopped focusing only on costs and instead began to focus on creating value.”
- Bart Whatley, AIA; Delineate Studio

MASS TIMBER WHY'S

- Innovation and Aesthetic Appeal
- Speed of Construction
- Construction Site Constraints – Urban Infill
- Labor Shortages
- Structural Performance - Lightweight
- Business Case for Healthy Buildings

Tremblay Laliberté Building, Structure Fusion, Photo Stephane Groleau

Keys to Mass Timber Success:

- Know Your WHY
- Design it as Mass Timber From the Start
- Leverage Manufacturer Capabilities
- Understand Supply Chain
- Optimize Grid
- Take Advantage of Prefabrication & Coordination
- Expose the Timber
- Discuss Early with AHJ
- Work with Experienced People
- Let WoodWorks Help for Free
- Create Your Market Distinction
- Are the owner and GC on board with Mass Timber?

Images: Korb & Associates

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Mark Bartlett, PE

Regional Director - WoodWorks

Mark.bartlett@woodworks.org

214-679-1874

Reduce Risk

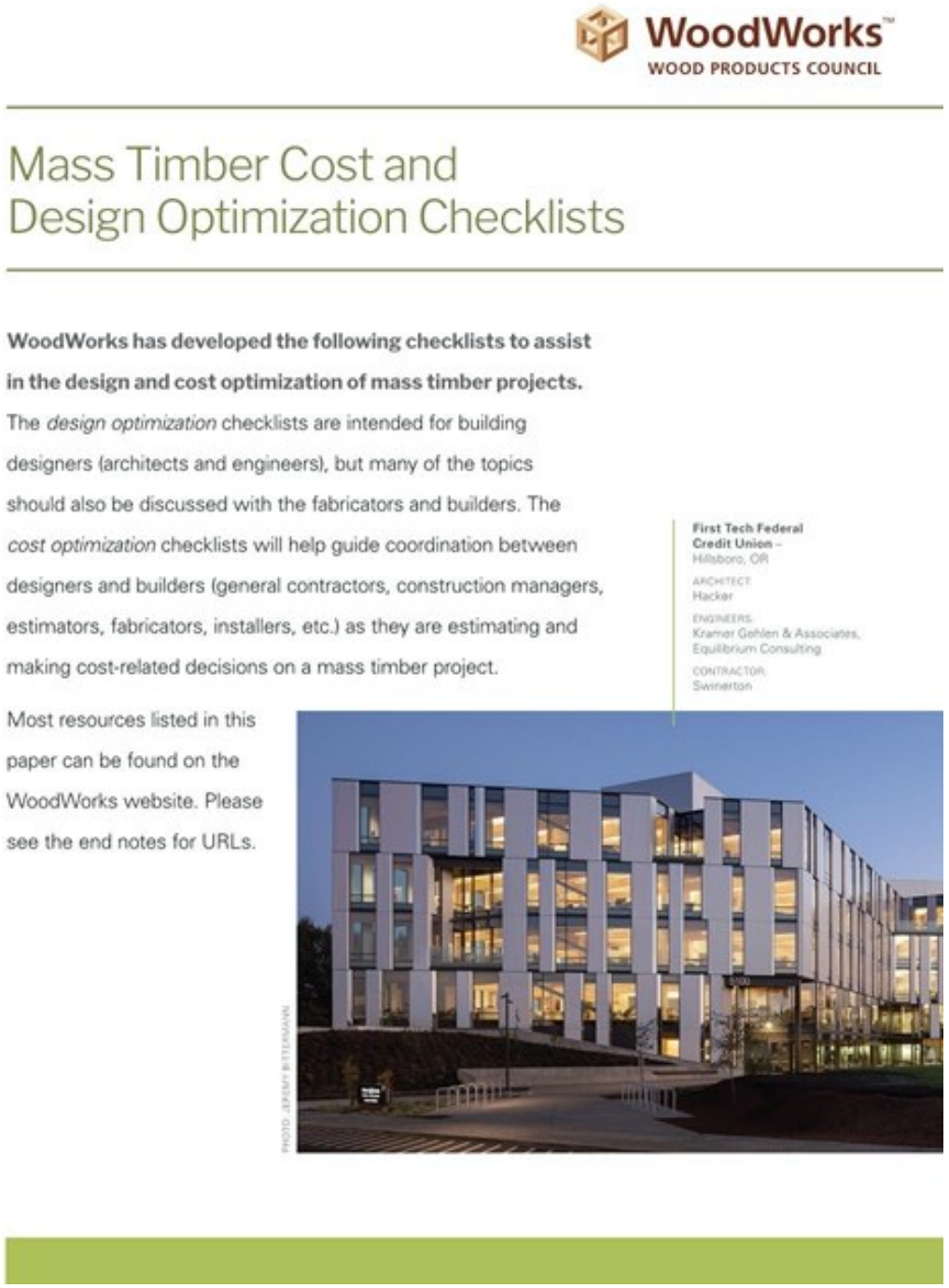
Optimize Costs

- For the entire project team, not just builders
- Lots of reference documents

Download Checklists at

www.woodworks.org

www.woodworks.org/wp-content/uploads/wood_solution_paper-Mass-Timber-Design-Cost-Optimization-Checklists.pdf



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Mass Timber Cost and Design Optimization Checklists

WoodWorks has developed the following checklists to assist in the design and cost optimization of mass timber projects.

The *design optimization* checklists are intended for building designers (architects and engineers), but many of the topics should also be discussed with the fabricators and builders. The *cost optimization* checklists will help guide coordination between designers and builders (general contractors, construction managers, estimators, fabricators, installers, etc.) as they are estimating and making cost-related decisions on a mass timber project.

Most resources listed in this paper can be found on the WoodWorks website. Please see the end notes for URLs.

First Tech Federal Credit Union –
Hillsboro, OR

ARCHITECT:
Hacker

ENGINEERS:
Kramer Gehlen & Associates,
Equilibrium Consulting

CONTRACTOR:
Swinerton

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