



# Early Design Decisions: Priming Mass Timber Projects for Success

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



# Course Description

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Mass timber is a unique, non-commodity building material and, to lay the groundwork for success, certain critical decisions must be made as early as possible. These decisions can have a big impact on cost and can either increase or limit opportunities later in design. There are many cases of project teams that want to realize the full benefits of mass timber, but, because they base their designs on traditional building practices instead of optimizing them for mass timber, end up with avoidable price premiums. This presentation will walk through early project decisions and design steps, focusing on how to optimize projects for mass timber and how one early decision can influence others. Topics will include construction types, fire ratings, column grids and beam/panel spans, acoustics and MEP integration. Completed mass timber projects will be used to illustrate the variety of viable options when navigating these key decisions.

# Learning Objectives

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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 that these ratings have on effective member spans and resulting grids.
3. Review code-compliance requirements for acoustics and primary frame connections, and provide solutions for meeting these requirements with tested mass timber assemblies.
4. Highlight effective methods of integrating MEP services in a mass timber building and discuss the relative impacts of each on cost, aesthetics, occupant comfort and future tenant renovations.



# Key Early Design Decisions

**What is the Single Most Important Early Design Decision on a Mass Timber Project? Is it:**

**Construction Type  
Fire-Resistance Ratings**

**Member Sizes**

**Grids & Spans**

**Exposed Timber (where & how much)**

**MEP Layout**

**Acoustics**

**Concealed Spaces**

**Connections**

**Penetrations**

**The Answer is...They All Need to Be Weighed (Plus Others)**

# Key Early Design Decisions

Significant Emphasis Placed on the Word **Early**

**Early** Because:

Avoids placing limitations due to construction norms or traditions that may not be efficient with mass timber

Allows greater integration of all building elements in 3D models, ultimately used throughout design, manufacturing and install



# Key Early Design Decisions

## Early = Efficient

Realize Efficiency in:

- Cost reduction
- Material use (optimize fiber use, minimize waste)
- Construction speed
- Trade coordination
- Minimize RFIs

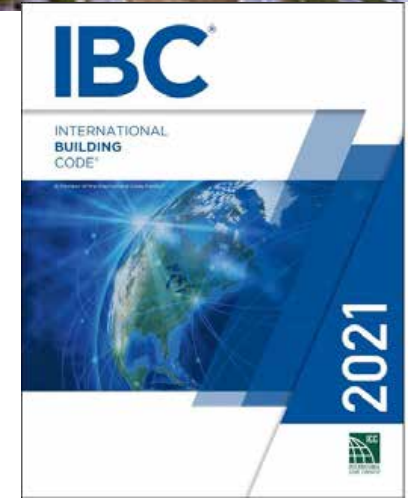
Commit to a mass timber design from the start



# Key Early Design Decisions

There are a number of project-specific factors that influence how these early decisions are made, and in some cases, the order in which the decisions are made:

- **Site** (size, orientation, zoning, cost)
- **Building needs** (size, occupancy(ies), layout, floor to floor, aesthetics, sustainability goals)
- Resulting **code options** & design implications





# Key Early Design Decisions

One *potential* design route:

1. Building size & occupancy informs construction type & grid
2. Construction type informs fire resistance ratings
3. Grid & fire resistance ratings inform timber member sizes & MEP layout

But that's not all...



Architects: The Miller Hull Partnership with  
Eng  
Con  
Ph

# Key Early Design Decisions

Other impactful decisions:

- **Acoustics** informs member sizes (and vice versa)
- Fire-resistance ratings inform **connections & penetrations**
- **MEP layout** informs use of concealed spaces





# Key Early Design Decisions

Other impactful decisions:

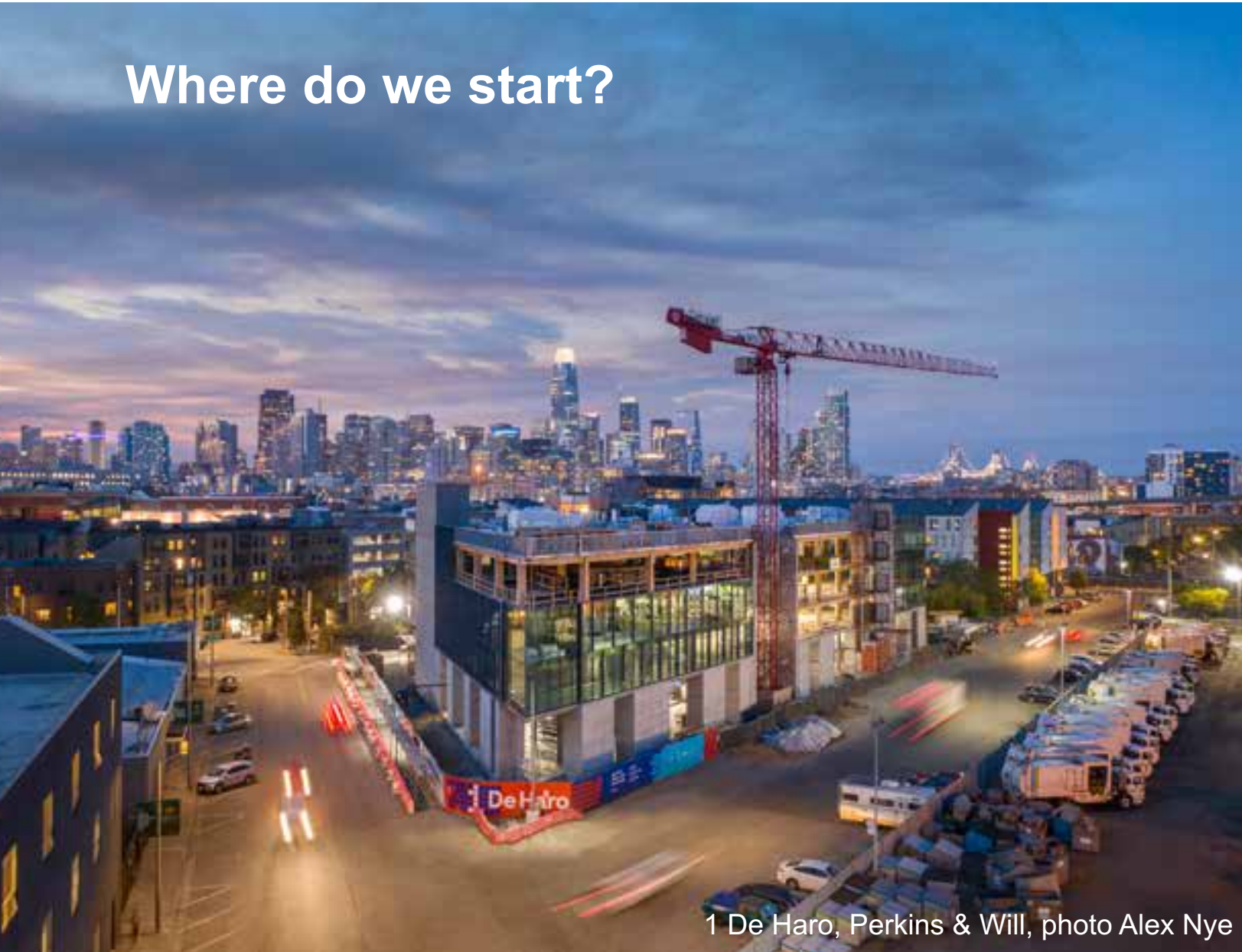
- **Grid** informs efficient spans, MEP layout
- **Manufacturer capabilities** inform member sizes, grids & connections
- **Lateral system** informs connections, construction sequencing

And more...



# Key Early Design Decisions

Where do we start?



1 De Haro, Perkins & Will, photo Alex Nye



# 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 <sup>2</sup> (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

# 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
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.								
R-2	18	12	8	5	5	5	4	3
	Allowable Area Factor (At) for SM, Feet <sup>2</sup> (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

# 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 <sup>f</sup> (see Section 202)	3 <sup>a, b</sup>	2 <sup>a, b, c</sup>	1 <sup>b, c</sup>	0 <sup>c</sup>	1 <sup>b, c</sup>	0	3 <sup>a</sup>	2 <sup>a</sup>	2 <sup>a</sup>	HT	1 <sup>b, c</sup>	0
Bearing walls												
Exterior <sup>a, f</sup>	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3 <sup>a</sup>	2 <sup>a</sup>	1	0	1	0	3	2	2	1/HT <sup>g</sup>	1	0
Nonbearing walls and partitions Exterior					See Table 705.5							
Nonbearing walls and partitions Interior <sup>d</sup>	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 <sup>b</sup>	1 <sup>b, c</sup>	1 <sup>b, c</sup>	0 <sup>c</sup>	1 <sup>b, c</sup>	0	1½	1	1	HT	1 <sup>b, c</sup>	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)

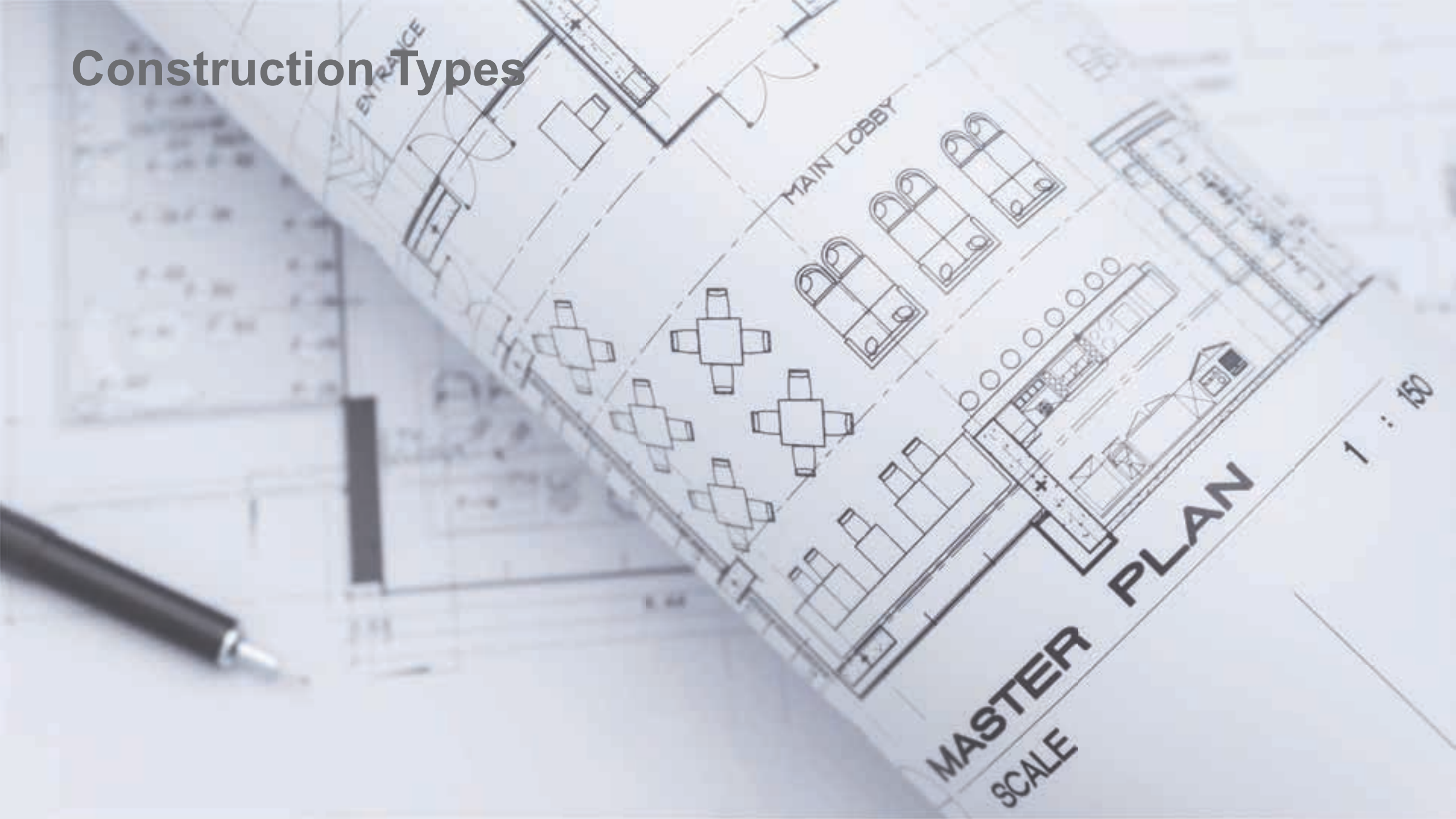
Panel	Example Floor Span Ranges
3-ply CLT (4-1/8" thick)	Up to 12 ft
5-ply CLT (6-7/8" thick)	14 to 17 ft
7-ply CLT (9-5/8")	17 to 21 ft
2x4 NLT	Up to 12 ft
2x6 NLT	10 to 17 ft
2x8 NLT	14 to 21 ft
5" MPP	10 to 15 ft



Credit: David Barber, ARUP



# 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?**

- Type IB & II: Roof Decking



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



Image: StructureCraft Builders



# Construction Types

All wood framed building options:

## Type III

Exterior walls non-combustible (may be FRTW)

Interior elements any allowed by code, including mass timber

## Type V

All building elements are any allowed by code, including mass timber

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

## Type IV (Heavy Timber)

Exterior walls non-combustible (may be FRTW OR CLT)

Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)

# 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)



# 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 <sup>3</sup> / <sub>4</sub> x 8 <sup>1</sup> / <sub>4</sub>	7 x 7 <sup>1</sup> / <sub>2</sub>
	Beams	6 x 10	5 x 10 <sup>1</sup> / <sub>2</sub>	5 <sup>1</sup> / <sub>4</sub> x 9 <sup>1</sup> / <sub>2</sub>
Roof	Columns	6 x 8	5 x 8 <sup>1</sup> / <sub>4</sub>	5 <sup>1</sup> / <sub>4</sub> x 7 <sup>1</sup> / <sub>2</sub>
	Beams*	4 x 6	3 X 6 <sup>7</sup> / <sub>8</sub>	3 <sup>1</sup> / <sub>2</sub> X 5 <sup>1</sup> / <sub>2</sub>

**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

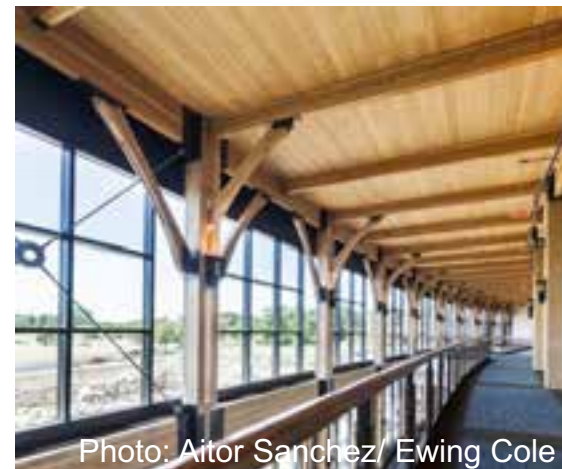


# Construction Types

## Type IV min. sizes:

### Floor Panels/Decking:

- 4" thick CLT (actual thickness)
- 4" NLT/DLT/GLT (nominal thickness)
- 3" thick (nominal) decking covered with: 1" decking or 15/32" WSP or 1/2" particleboard



# Construction Types

## Type IV min. sizes:

### Interior Walls:

- Laminated construction 4" thick
- Solid wood construction min. 2 layers of 1" matched boards
- Wood stud wall (1 hr min)
- Non-combustible (1 hr min)

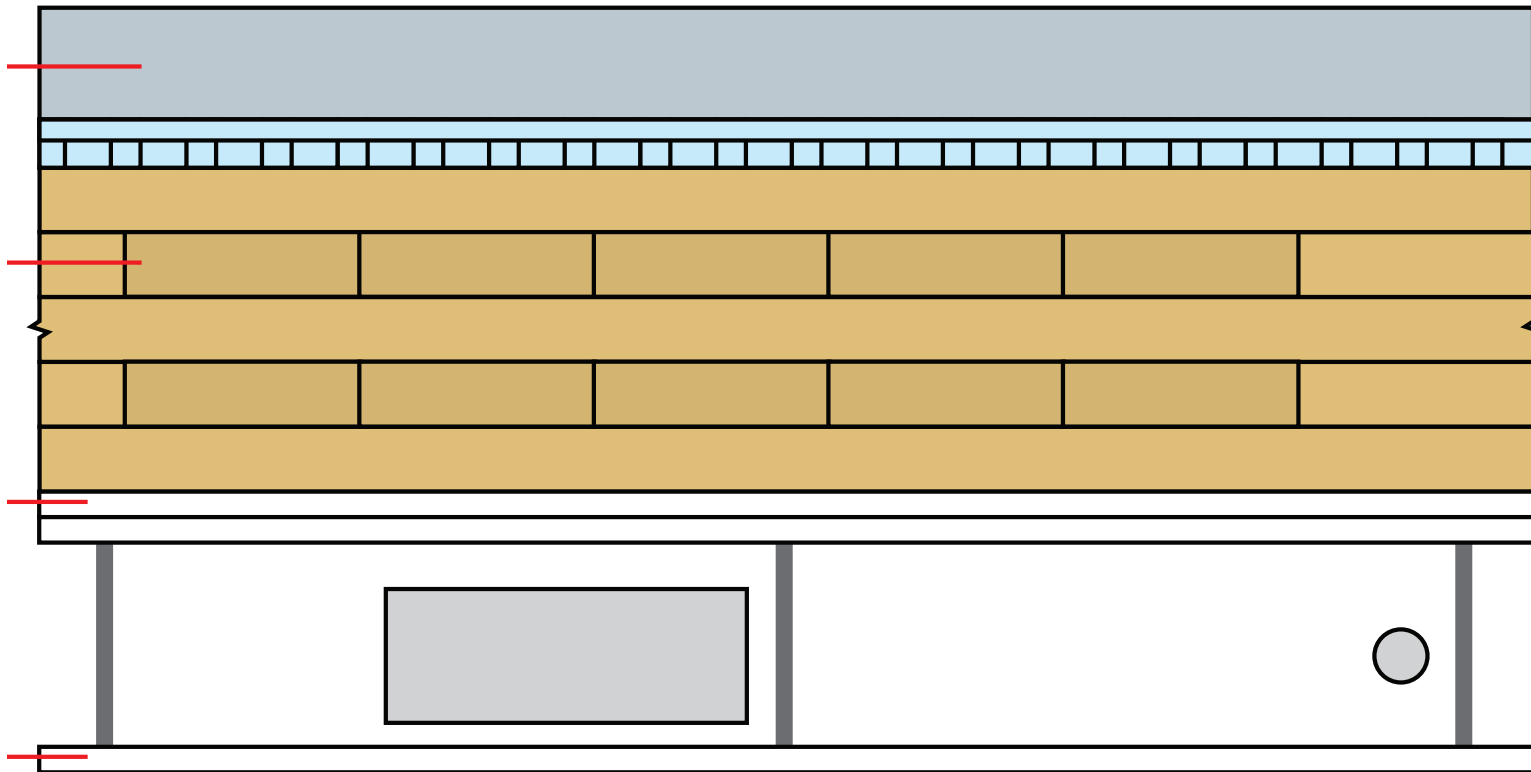
Verify other code requirements for FRR  
(eg. interior bearing wall; occupancy  
separation)



# Construction Types

## Type IV concealed spaces

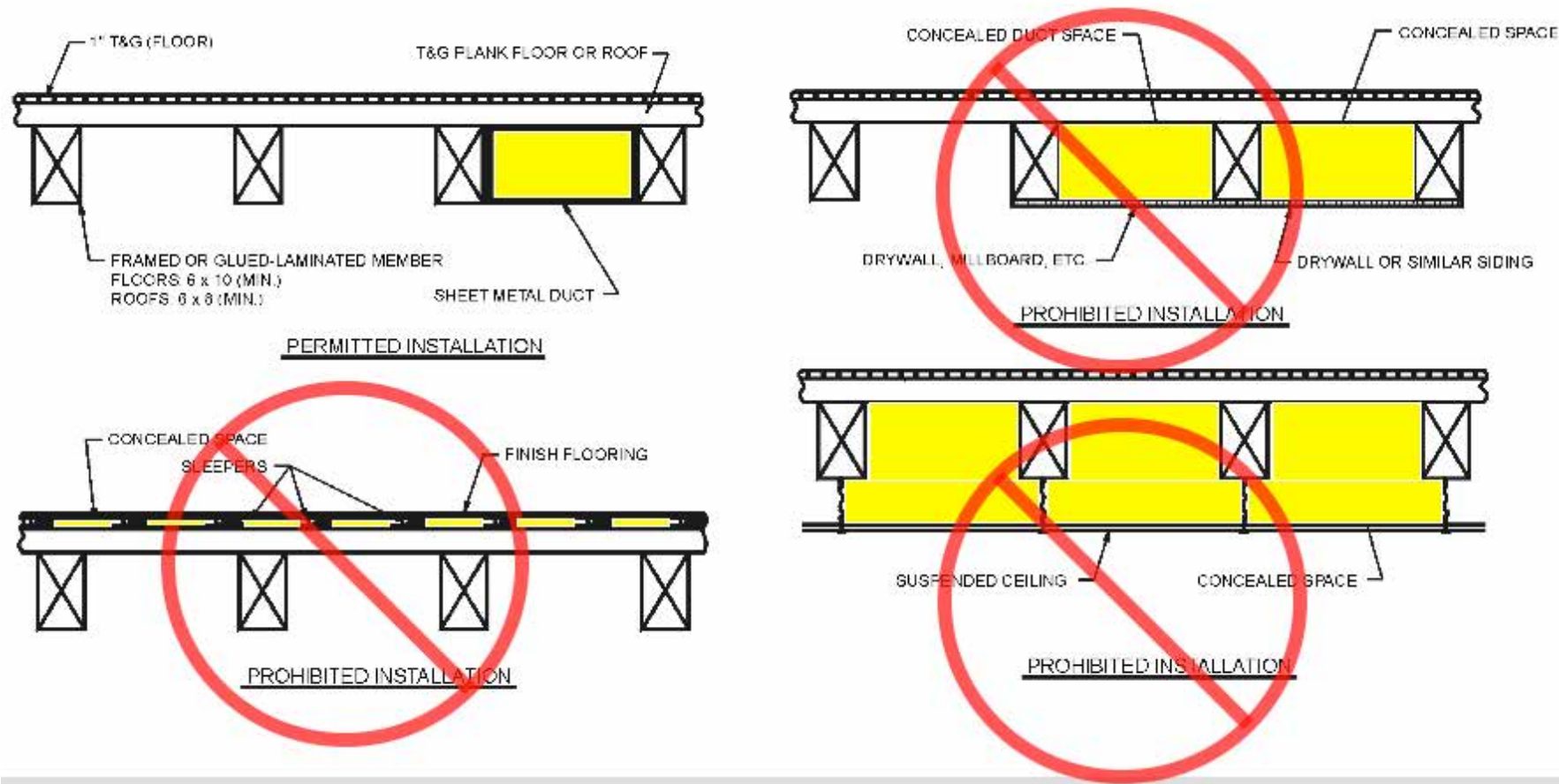
Can I have a dropped ceiling? Raised access floor?



# Construction Types

## Type IV concealed spaces

Until 2021 IBC, Type IV-HT provisions prohibited concealed spaces





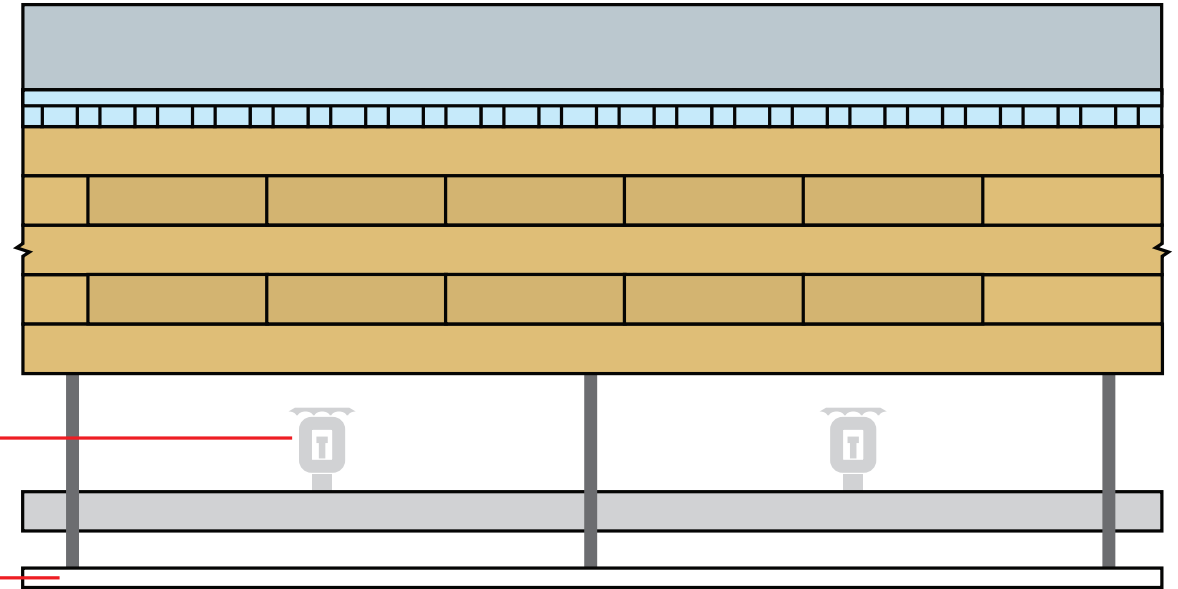
# Construction Types

## Type IV concealed space options within 2021 IBC

### Option 1:

Sprinklers in concealed spaces

Dropped ceiling



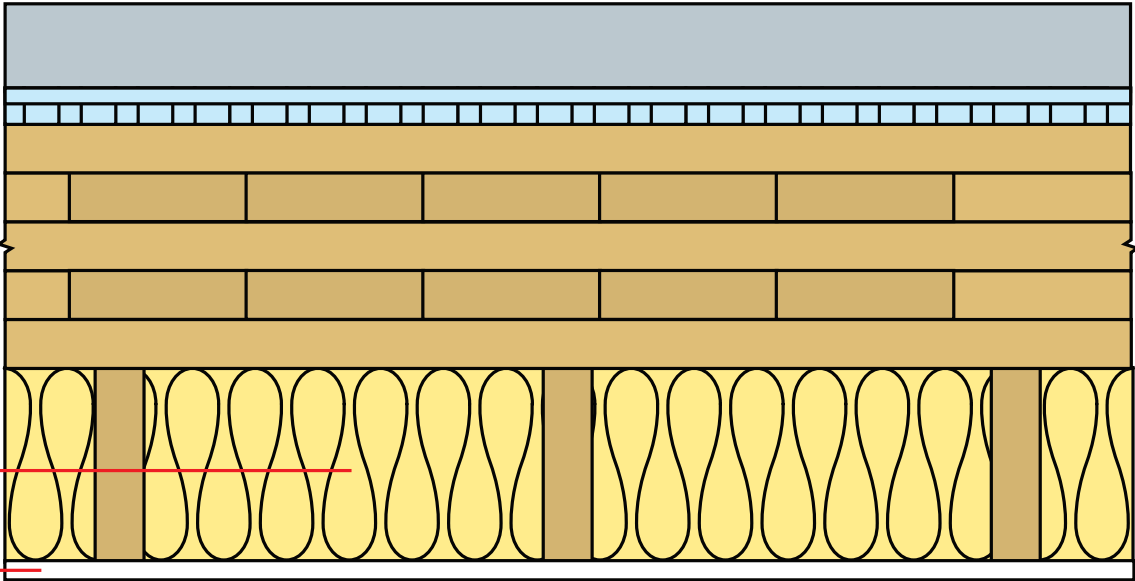
# Construction Types

## Type IV concealed space options within 2021 IBC

Option 2:

Noncombustible insulation

Dropped ceiling



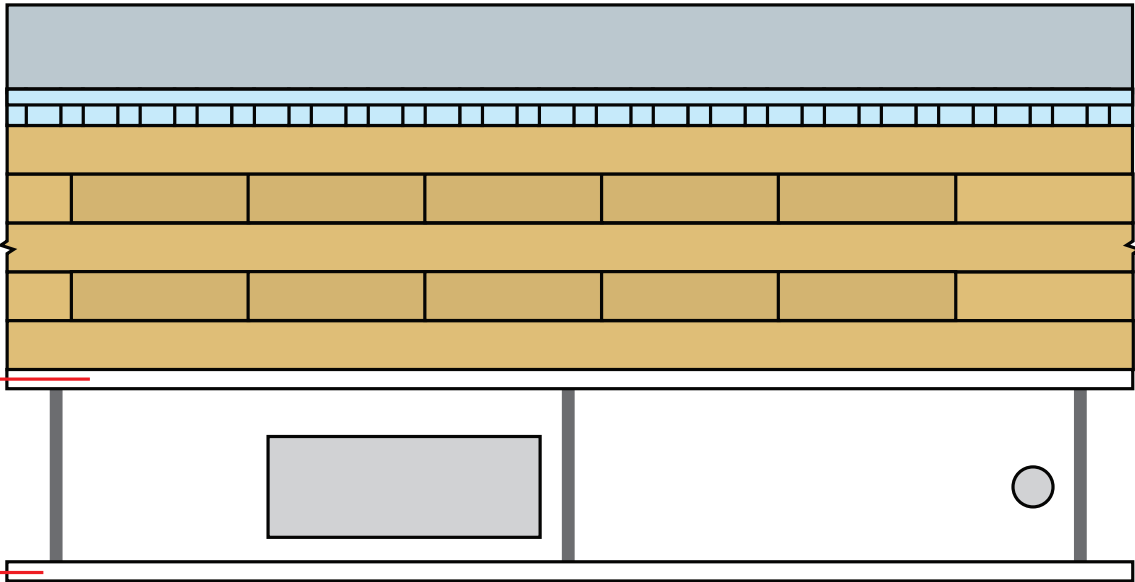
# Construction Types

## Type IV concealed space options within 2021 IBC

### Option 3:

5/8" Type X gypsum on all mass timber surfaces within concealed space

Dropped ceiling



# Construction Types

## Concealed spaces solutions paper



### Concealed Spaces in Mass Timber and Heavy Timber Structures

Concealed spaces, such as those created by a dropped ceiling in a floor/ceiling assembly or by a stud wall assembly, have unique requirements in the International Building Code (IBC) to address the potential of fire spread in non-visible areas of a building. Section 718 of the 2018 IBC includes prescriptive requirements for protection and/or compartmentalization of concealed spaces through the use of draft stopping, fire blocking, sprinklers and other means. For information on these requirements, see the WoodWorks Q&A, *Are sprinklers required in concealed spaces such as floor and roof cavities in multi-family wood-frame buildings?*

For mass timber building elements, the choice of construction type can have a significant impact on concealed space requirements. Because mass timber products such as cross-laminated timber (CLT) are prescriptively recognized for Type IV construction, there is a common misperception that exposed mass timber building elements cannot be used or exposed in other construction types. This is not the case.

In addition to Type IV buildings, structural mass timber elements—including CLT, glue-laminated timber (glulam), nail-laminated timber (NLT), structural composite lumber (SCL), and tongue-and-groove (T&G) decking—can be utilized and exposed in the following construction types, whether or not a fire-resistance rating is required:

- **Type III** – Floors, roofs and interior walls may be any material permitted by code, including mass timber; exterior walls are required to be noncombustible or fire retardant-treated wood.
- **Type V** – Floors, roofs, interior walls and exterior walls (i.e., the entire structure) may be constructed of mass timber.
- **Types I and II** – Mass timber may be used in select circumstances such as roof construction—including the primary frame in the 2021 IBC—in Types I-B, II-A or II-B; exterior columns and arches when 20 feet or more of horizontal separation is provided; and balconies, canopies and similar projections.



[https://www.woodworks.org/wp-content/uploads/wood\\_solution\\_paper-Concealed\\_Spaces\\_Timber\\_Structures.pdf](https://www.woodworks.org/wp-content/uploads/wood_solution_paper-Concealed_Spaces_Timber_Structures.pdf)



# Construction Types

**Where does the code allow MT to be used?**

- Type V: All interior elements, roofs & exterior walls



Image: Christian Columbres Photography

# Construction Types



Type III: 6 stories

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



Credit: Ema Peter

Type IV: 6 stories

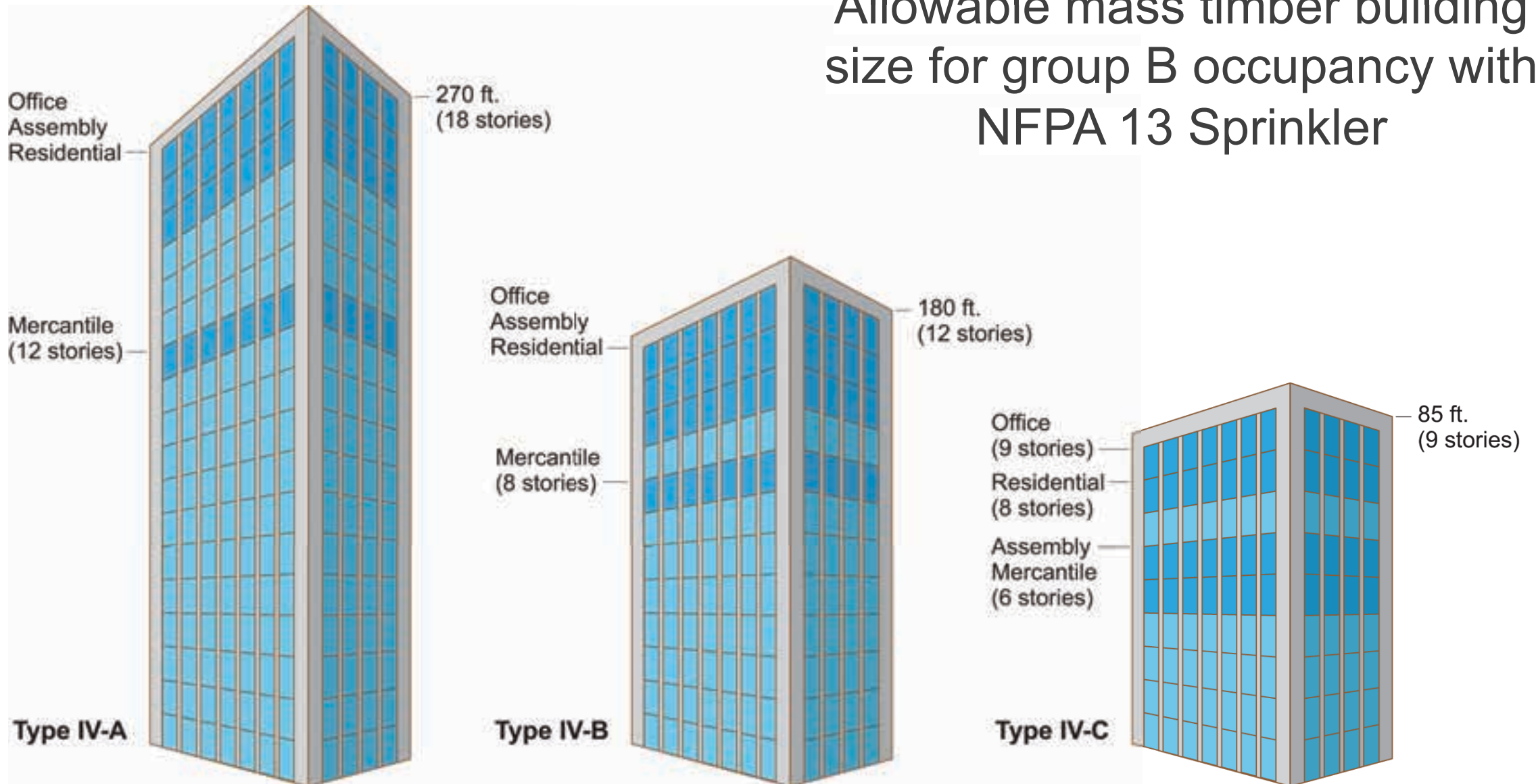


Credit: Christian Columbres Photography

Type V: 4 stories

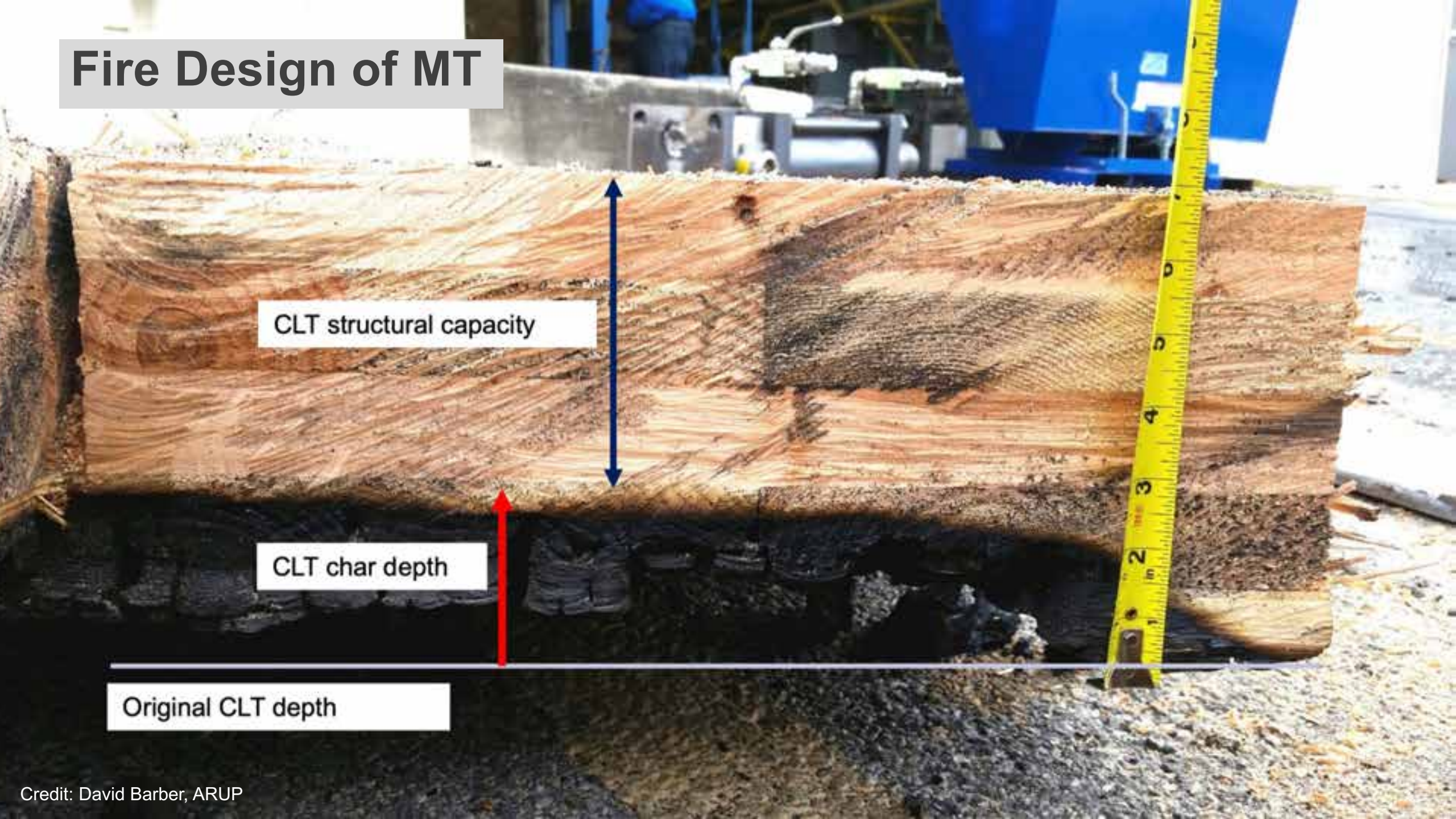
# Construction Types

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





# Fire Design of MT



CLT structural capacity

CLT char depth

Original CLT depth



# 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	HT	A	B
Primary structural frame <sup>f</sup> (see Section 202)	3 <sup>a</sup>	2 <sup>a</sup>	1	0	1	0	HT	1	0
Bearing walls									
Exterior <sup>e, f</sup>	3	2	1	0	2	2	2	1	0
Interior	3 <sup>a</sup>	2 <sup>a</sup>	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions									
Exterior	See Table 602								
Nonbearing walls and partitions									
Interior <sup>d</sup>	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1 <sup>1/2</sup> <sup>b</sup>	1 <sup>b, c</sup>	1 <sup>b, c</sup>	0 <sup>e</sup>	1 <sup>b, c</sup>	0	HT	1 <sup>b, c</sup>	0

Source: 2018 IBC

# 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 <sup>f</sup> (see Section 202)	3 <sup>a, b</sup>	2 <sup>a, b, c</sup>	1 <sup>b, c</sup>	0 <sup>c</sup>	1 <sup>b, c</sup>	0	3 <sup>a</sup>	2 <sup>a</sup>	2 <sup>a</sup>	HT	1 <sup>b, c</sup>	0
Bearing walls												
Exterior <sup>e, f</sup>	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3 <sup>a</sup>	2 <sup>a</sup>	1	0	1	0	3	2	2	1/HT <sup>g</sup>	1	0
Nonbearing walls and partitions Exterior					See Table 705.5							
Nonbearing walls and partitions Interior <sup>d</sup>	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 <sup>1/2</sup> <sup>b</sup>	1 <sup>b, c</sup>	1 <sup>b, c</sup>	0 <sup>c</sup>	1 <sup>b, c</sup>	0	1 <sup>1/2</sup>	1	1	HT	1 <sup>b, c</sup>	0

Source: 2021 IBC

# Key Early Design Decisions

Construction type influences FRR

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

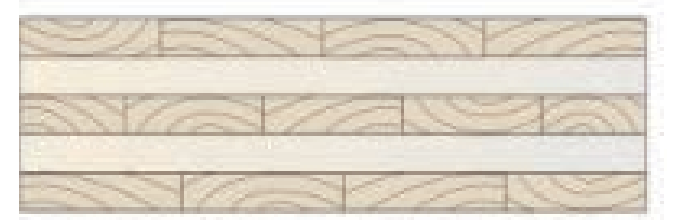
Method of demonstrating FRR (calculations or testing)  
can impact member sizing



# Key Early Design Decisions

## Member Sizes

- Impact of FRR on sizing
- Impact of sizing on efficient spans
- Consider connections – can drive member sizing



Credit: ARUP



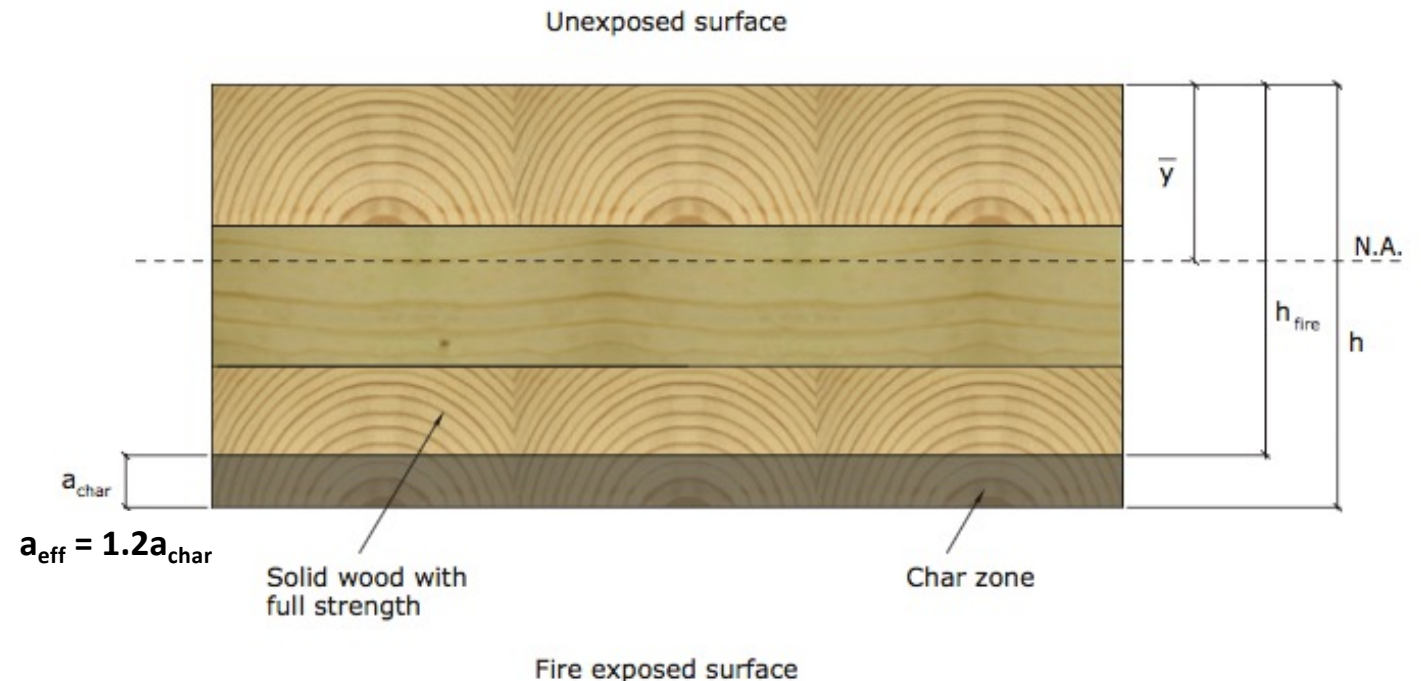
Credit: Kaiser+Path



# Key Early Design Decisions

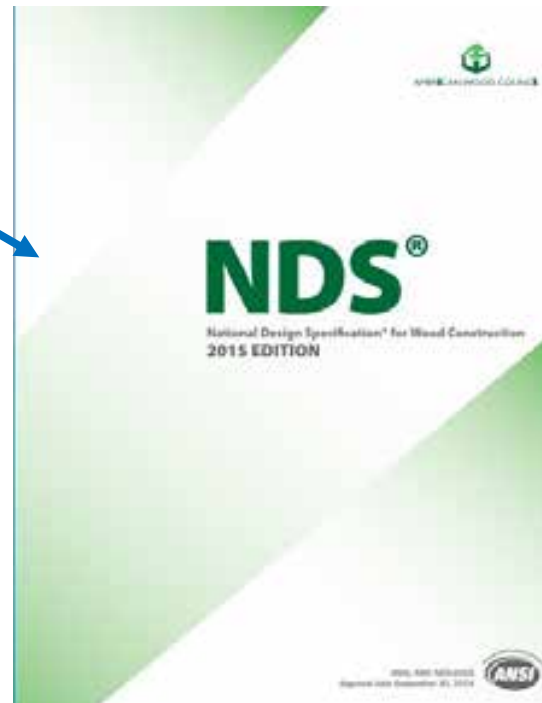
## Which Method of Demonstrating FRR of MT is Being Used?

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



### 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)**"

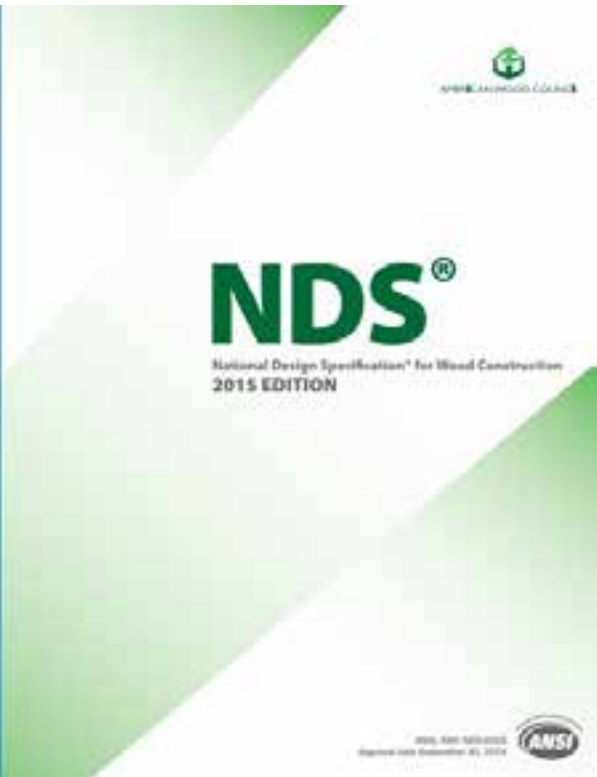


### NDS Chapter 16

#### 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



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  $\beta_n=1.5\text{in./hr.}$ )**

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

Nominal char rate of 1.5"/HR is recognized in NDS. Effective char depth calculated to account for duration, structural reduction in heat-affected zone



Credit: ARUP

**Table 16.2.1A Char Depth and Effective Char Depth (for  $\beta_n = 1.5$  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  $\beta_n=1.5$ in./hr.)**

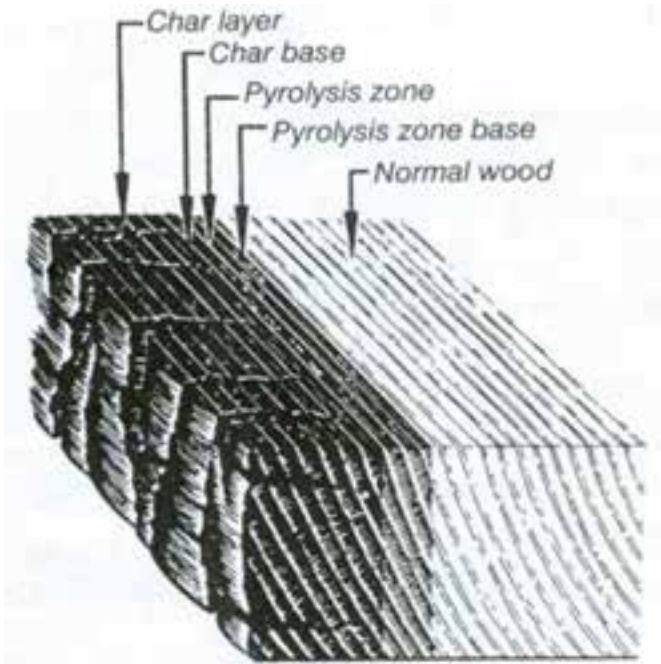
Required Fire Endurance (hr.)	Effective Char Depths, $a_{char}$ (in.)								
	lamination thicknesses, $h_{lam}$ (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6



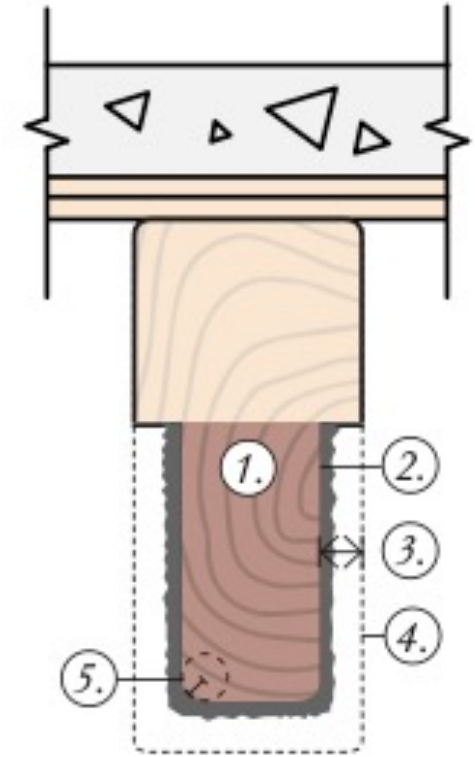
# FRR Design of MT

Two structural capacity checks performed:

1. On entire cross section neglecting fire effects
2. On post-fire remaining section, with stress increases



Credit: Forest Products Laboratory



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

Solid Sawn, Glulam, SCL

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

CLT

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

Effective Char Depth

# FRR Design of MT

NDS Table 16.2.2 Design stress adjustment factors applied to adjust to average ultimate strength under fire design conditions

**Table 16.2.2 Adjustment Factors for Fire Design<sup>1</sup>**

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

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.

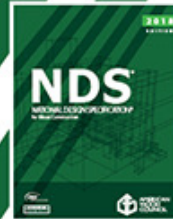
2. Factor shall be based on initial cross-section dimensions.

3. Factor shall be based on reduced cross-section dimensions.

Source: AWC's NDS

# FRR Design of MT

AWC's TR10 is a technical design guide, aids in the use of NDS  
Chapter 16 calculations



Calculating the  
Fire Resistance of  
Wood Members  
and Assemblies

Technical Report No. 10



## Example 5: Exposed CLT Floor - Allowable Stress Design

Simply-supported cross-laminated timber (CLT) floor spanning  $L=18$  ft in the strong-axis direction. The design loads are  $q_{live}=80$  psf and  $q_{dead}=30$  psf including estimated self-weight of the CLT panel. Floor decking, nailed to the unexposed face of CLT panel, is spaced to restrict hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a 1-hour structural fire resistance time when subjected to an ASTM E119 fire exposure.

For the structural design of the CLT panel, calculate the maximum induced moment.

Calculate panel load (per foot of width):

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

Calculate maximum induced moment (per foot of width):

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

From PRG 320, select a 5-ply CLT floor panel made from 1-3/8 in x 3-1/2 in. lumber boards (CLT thickness of 6-7/8 inches). For CLT grade V2, tabulated properties are:

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

Calculate the allowable design moment (assuming  $C_D=1.0$ ;  $C_M=1.0$ ;  $C_t=1.0$ ;  $C_L=1.0$ )

$$M_s' = F_b(S_{eff})(C_D)(C_M)(C_t)(C_L) = 4,675 (1.0)(1.0)(1.0) = 4,675 \text{ ft-lb/ft of width} \quad (\text{NDS 10.3.1})$$

$$\text{Structural Check:} \quad M_s' \geq M_{max} \quad 4,675 \text{ ft-lb/ft} > 4,455 \text{ ft-lb/ft} \quad \checkmark$$

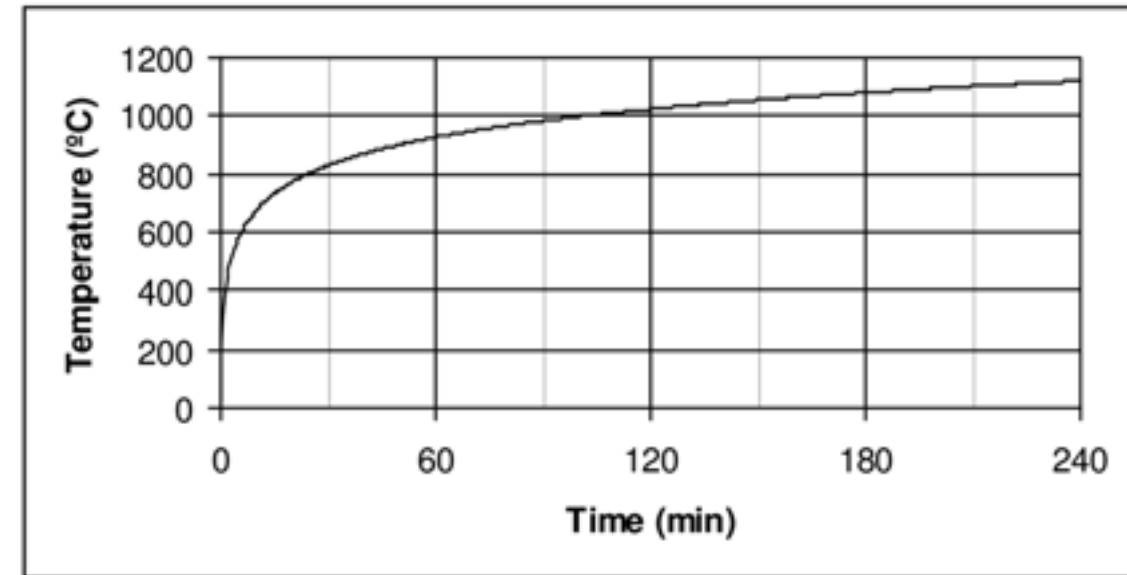
(note: serviceability check is not performed to simplify the design example, but should be done in typical structural design).

# FRR Design of MT

## Tested FRR of Exposed MT:

- IBC 703.2 notes the acceptance of FRR demonstration via testing in accordance with ASTM E119

**703.2 Fire-resistance ratings.** The *fire-resistance rating* of building elements, components or assemblies shall be determined in accordance with the test procedures set forth in ASTM E119 or UL 263 or in accordance with Section 703.3. The *fire-resistance rating* of penetrations and *fire-resistant joint systems* shall be determined in accordance Sections 714 and 715, respectively.



Standard ASTM E119 test time-temperature curve



# FRR Design of MT

## Tested FRR of Exposed MT:

- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers

 **Fire Testing Laboratory** 

**TEST REPORT** Page 1 of 53  
for  
**American Wood Council**  
222 Calocin 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-1080  
Assignment No. X-1089  
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)  
Test Date: October 4, 2012  
Report Date: October 16, 2012

Prepared by:   
Michael J. Pilon  
Test Engineer

Reviewed by:   
Robert J. Marchetti  
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.  
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The laboratory is not liable for any consequences or losses product modification, approval or endorsement by this laboratory.

**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

**TEST REPORT**

**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 Floor/Ceiling Assembly for compliance with the applicable requirements of the following criteria: ASTM E119-16a, Standard Test Methods for Fire Tests of Building Construction and Materials, CAN/ULC S-594, Standard Methods of Fire Tests of Building Construction and Materials.**

**FPInnovations**   
**NRC-CNRC**

Project No. 301006155  
Final Report 2012/13

**Preliminary CLT Fire Resistance Testing Report.**

by  
Lindsay Osborne, M.A.Sc.  
Christian Dagenais, Eng., M.Sc.  
Scientists  
Advanced Building Systems – Serviceability and Fire Group

and  
Nourddine Benichou, Ph.D.  
Senior Research Officer  
National Research Council of Canada – Fire Research Resource Centre

July 2012

# FRR Design of MT

## WoodWorks Inventory of Fire Tested MT Assemblies

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 4.49 in)	Nordic	SPF 1650 Fb 1.3 E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 30% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (101mm 4.01 in)	Structulam	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	EI	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	EI	1 layer of 5/8" Type X gypsum under J-channels and furring strips with 3.5/8" dimensional bolts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	3	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	EI	None	Topside Spline	3/4 in. proprietary gypsum over Maxon acoustical mat	Reduced 50% Moment Capacity	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	EI	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypsum over Maxon acoustical mat or proprietary sound board	Reduced 50% Moment Capacity	2	4	UL
3-ply CLT (175mm 6.875")	Nordic	EI	1 layer 5/8" Type X Gyp under Ruxton Channel under 7.5/8" L-bats with 3.1/2" Mineral Wool between bats	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structulam	E1 M5 MSR 2100 x SPF #2	None	Topside Spline	1.4-2" Maxon Cyp-Guts 2000 or Maxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	VI	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 50% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structulam	SPF #1/#2 x SPF #1/#2	1 layer 3/8" Type X gypsum	Half-Lap	None	Unloaded 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structulam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unloaded 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	VI	None	Half-Lap	nominal 1/2" plywood with 8d nails	Loaded, See Manufacturer	2	12 (Test 3)	Western Fire Center 10/28/2016
5-ply CLT (175mm 6.875")	DR Johnson	VI	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 (145mm 5.71")	KIH	CV3M1	None	Half-Lap & Topside Spline	None	Loaded, See Manufacturer	1	18	SwRI

# 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).
  - Seen as more acceptable by some building officials
- **Calculations:**
  - Can provide more design flexibility
  - Allows for project span and loading specific analysis



# FRR Design of MT



## Fire-Resistive Design of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

Richard MacLean, P.E., S.E. • Senior Technical Director • WoodWorks  
Scott Zimmerman, P.D., P.E., S.E. • 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 IV (IBC 602.3)** – Timber elements can be used in floors, roofs and interior walls. Fire-retardant-treated wood (FRTTW) 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 | Beth Architecture  
Munoz Structural Engineering

## Mass Timber Fire Design Resource

- Code compliance options for demonstrating FRR
- Free download at [woodworks.org](http://woodworks.org)

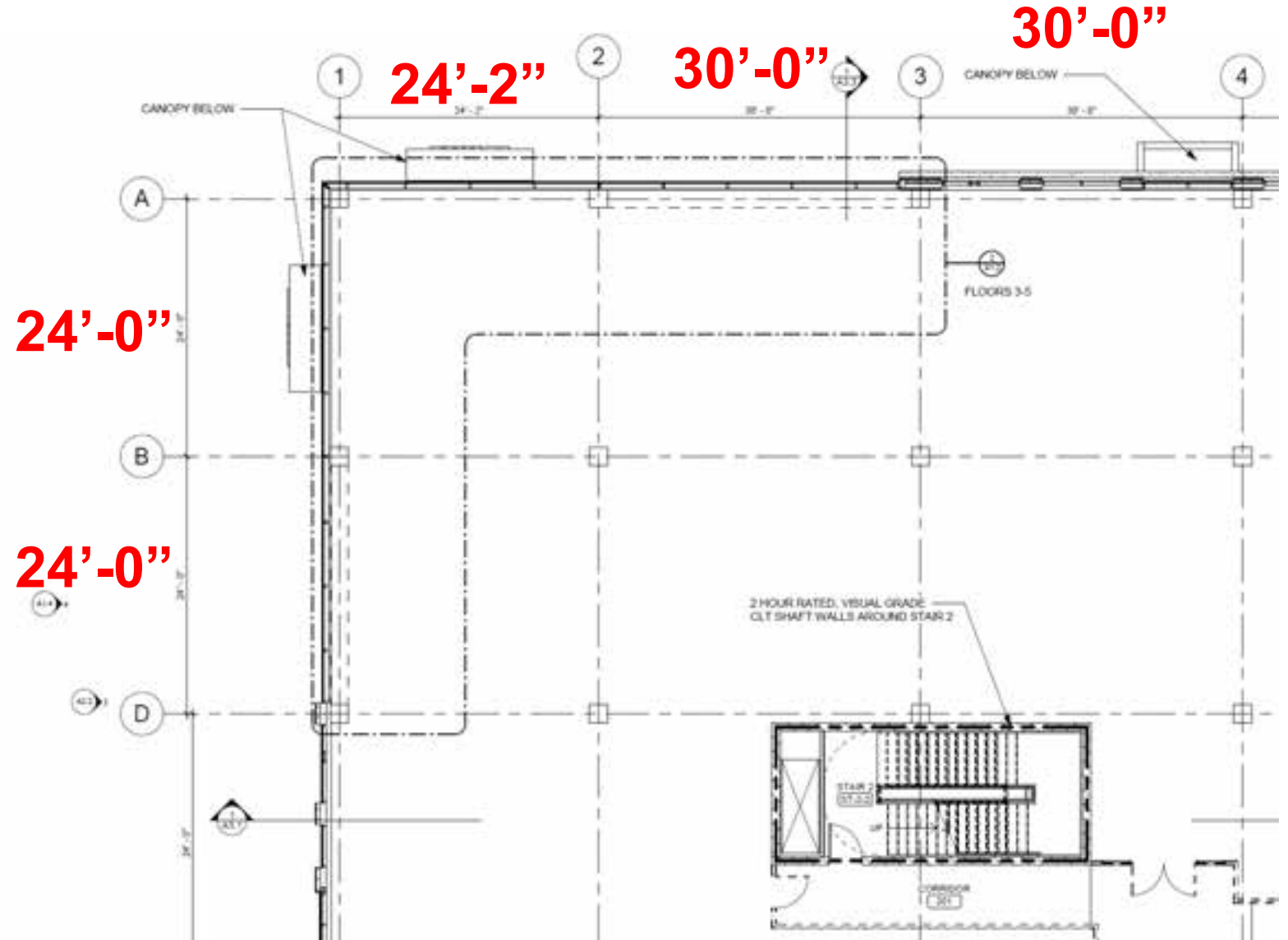
# Structural Grid



# Structural Grid

## Grids & Spans

- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation

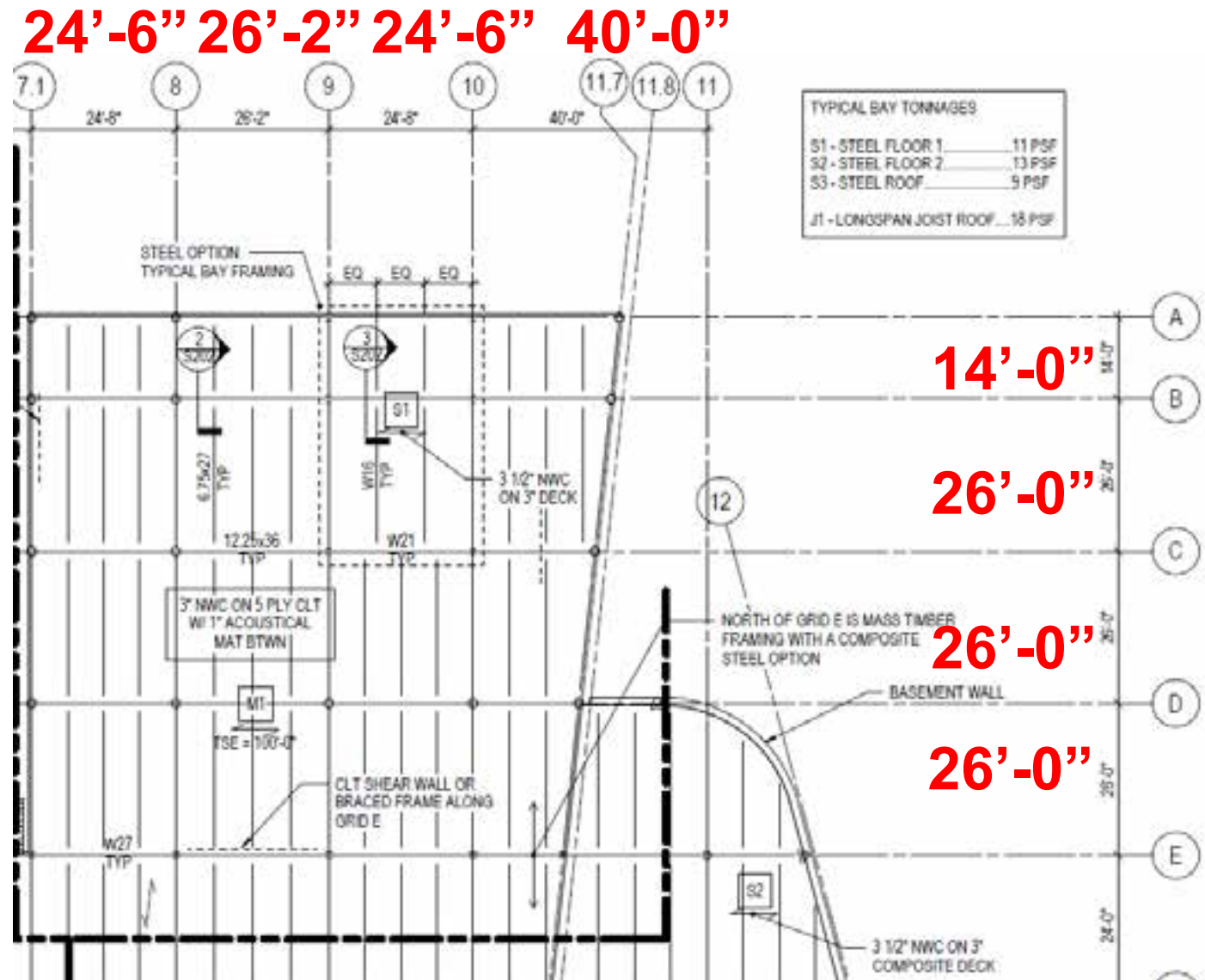




# Structural Grid

## Grids & Spans

- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation



# Structural Grid

## Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

## 0 HR FRR: Consider 3-ply Panel

- Efficient Spans of 10-12 ft
- Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

Albina Yard, Portland, OR  
20x20 Grid, 1 purlin per bay  
3-ply CLT  
Image: Lever Architecture



# Structural Grid

## Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

## 0 HR FRR: Consider 3-ply Panel

- Efficient Spans of 10-12 ft
- Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

Platte Fifteen, Denver, CO  
30x30 Grid, 2 purlins per bay  
3-ply CLT  
Image: JC Buck





# Structural Grid

## Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

## 1 or 2 HR FRR: Likely 5-ply Panel

- Efficient spans of 14-17 ft
- Grids of 15x30 (no purlins) to 30x30 (1 purlin) may be efficient

First Tech Credit Union, Hillsboro, OR  
12x32 Grid, One-Way Beams  
5-ply (5.5") CLT  
Image: Swinerton



# Structural Grid

## Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

## 1 or 2 HR FRR: Likely 5-ply Panel

- Efficient spans of 14-17 ft
- Grids of 15x30 (no purlins) to 30x30 (1 purlin) may be efficient

Clay Creative, Portland, OR  
30x30 Grid, 1 purlin per bay  
2x6 NLT  
Image: Mackenzie



# Key Early Design Decisions

## Construction Type Early Decision Example



### 7-story building on health campus

- Group B occupancy, NFPA 13 sprinklers throughout
- Floor plate = 22,300 SF
- Total Building Area = 156,100 SF

### MT Construction Type Options:

- **If Building is < 85 ft**
  - 7 stories of IV-C
  - 6 stories of IIIA or IV-HT over 1 story IA podium
- **If Building is > 85 ft**
  - 7 stories of IV-B



# Key Early Design Decisions

## Construction Type Early Decision Example



MT Construction Type Options:

- If Building is < 85 ft
  - 7 stories of IV-C
  - 6 stories of IIIA or IV-HT over 1 story IA
- If Building is > 85 ft
  - 7 stories of IV-B

**Implications of construction type choice in this example:**

- FRR (2 hr vs 1 hr vs min sizes)
- Efficient spans & grid
- Exposed timber limitations
- Concealed spaces
- Cost
- And more...

# Key Early Design Decisions

## Construction Type Early Decision Example

MT Construction Type Options:

- If Building is < 85 ft
  - **7 stories of IV-C**
  - 6 stories of IIIA or IV-HT over 1 story IA
- If Building is > 85 ft
  - 7 stories of IV-B

### Implications of Type IV-C:

- 2 hr FRR, all exposed floor panels, beams, columns
- Likely will need at least 5-ply CLT / 2x6 NLT/DLT
- Efficient spans in the 14-17 ft range
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required



# Key Early Design Decisions

## Construction Type Early Decision Example

MT Construction Type Options:

- If Building is < 85 ft
  - 7 stories of IV-C
  - **6 stories of IIIA or IV-HT over 1 story IA**
- If Building is > 85 ft
  - 7 stories of IV-B

### Implications of Type IIIA or IV-HT:

- 1 hr FRR or min. sizes
- Potential to use 3-ply or thin 5-ply CLT
- Efficient spans in the 10-12 ft range
- Efficient grids of that or multiples of that (i.e. 20x25, etc)
- 1 story Type IA podium required





# Key Early Design Decisions

## Construction Type Early Decision Example

MT Construction Type Options:

- If Building is < 85 ft
  - 7 stories of IV-C
  - 6 stories of IIIA or IV-HT over 1 story IA
- If Building is > 85 ft
  - **7 stories of IV-B**

### Implications of Type IV-B:

- 2 hr FRR, mostly protected floor panels, beams, columns
- Exposed areas: likely 5-ply / 2x6 NLT/DLT
- Protected areas: potential for thinner panels
- Choose 1 system throughout or multiple systems?
- Does grid vary or consistent throughout?
- No podium required



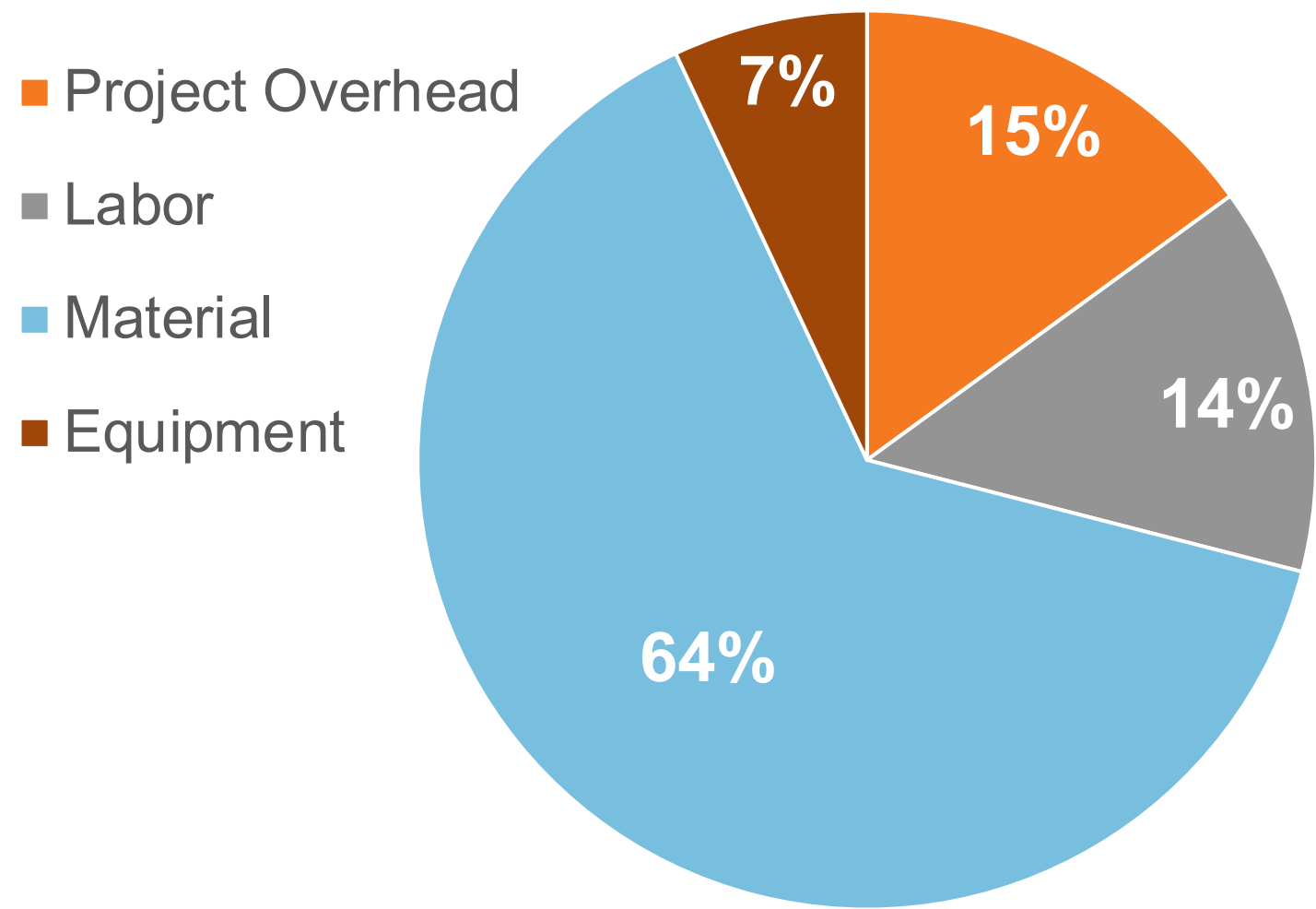
# Key Early Design Decisions

**Why so much focus on panel thickness?**



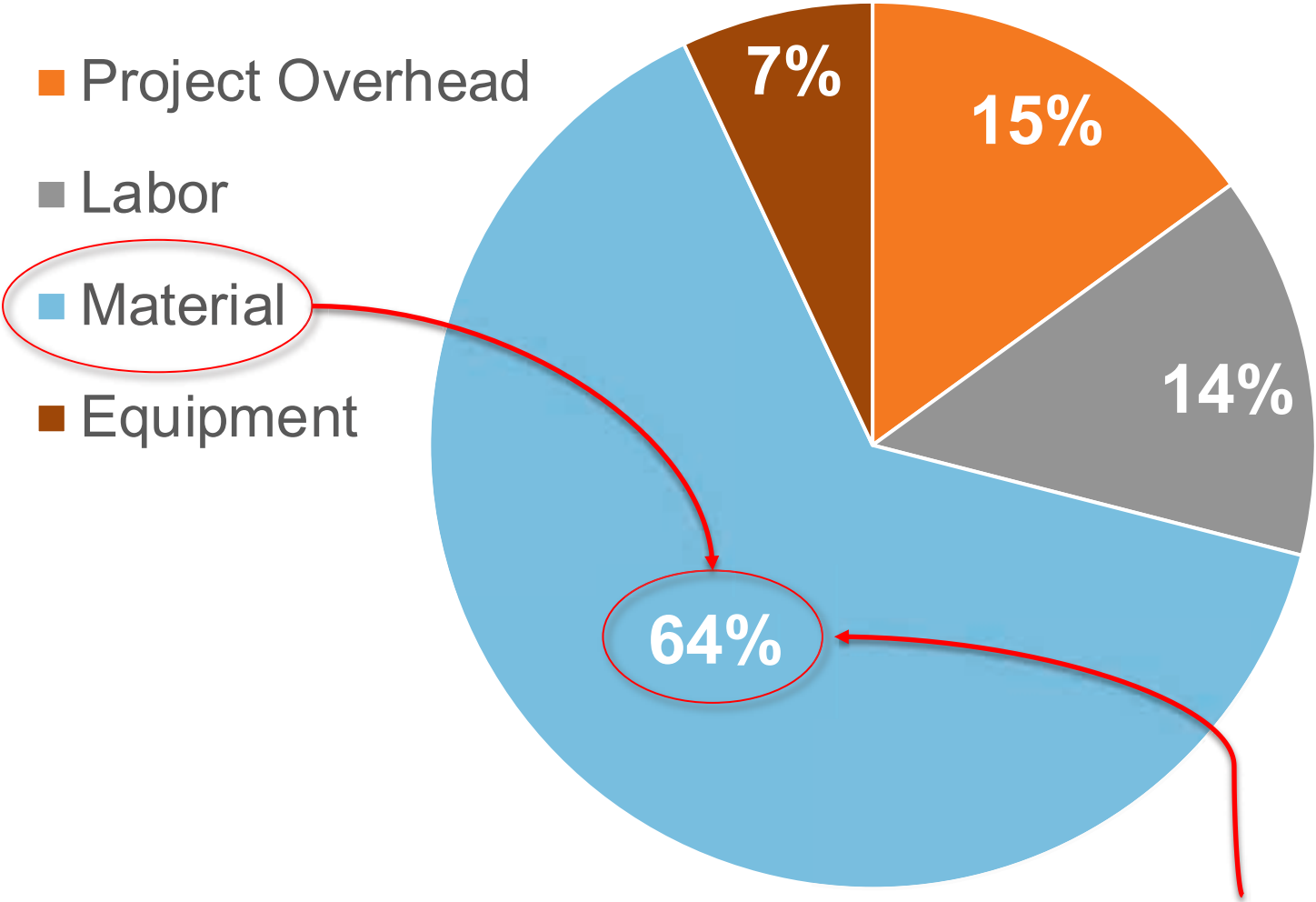
# Key Early Design Decisions

## Typical MT Package Costs





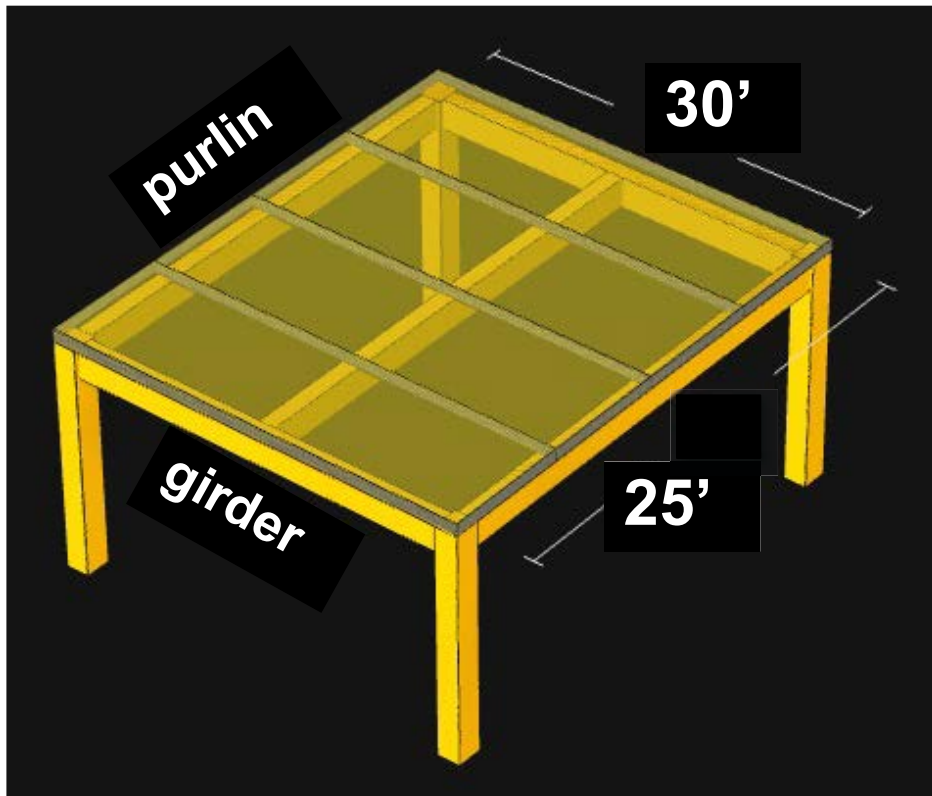
# Key Early Design Decisions



**Panels are the biggest part of the biggest piece of the cost pie**

# Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

## Type IIIA option 1

1-hr FRR

Purlin: 5.5"x28.5"

Girder: 8.75"x33"

Column: 10.5"x10.75"

Floor panel: 5-ply

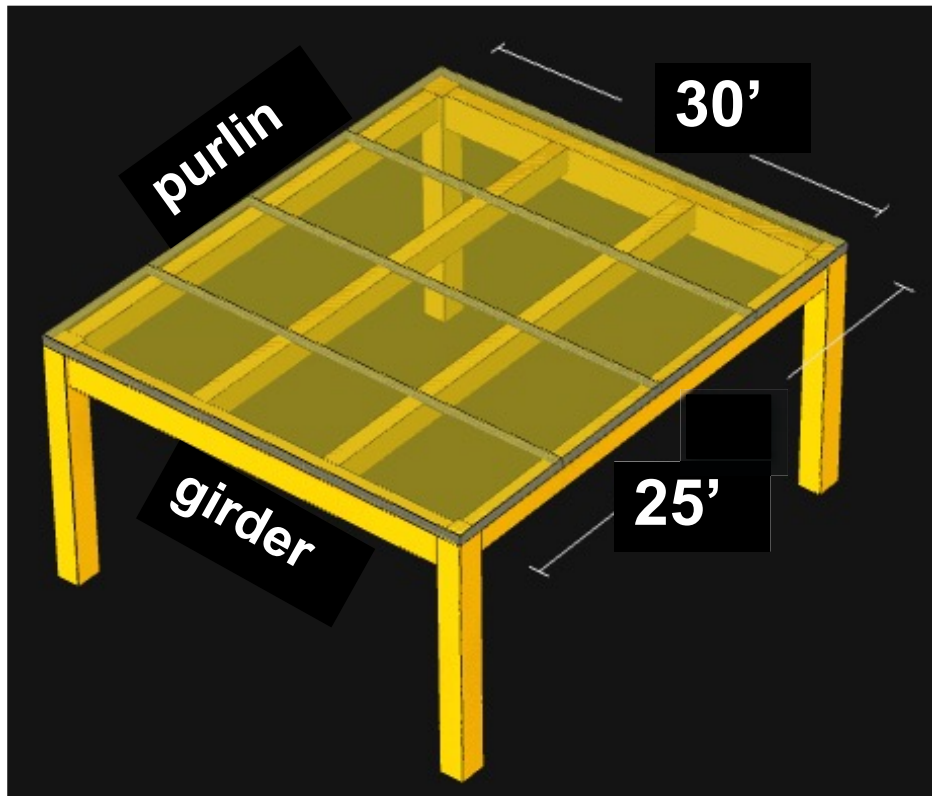
Glulam volume = 118 CF (22% of MT)

CLT volume = 430 CF (78% of MT)

Total volume = 0.73 CF / SF

# Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

## Type IIIA option 2

1-hr FRR

Purlin: 5.5"x24"

Girder: 8.75"x33"

Column: 10.5"x10.75"

Floor panel: 5-ply

Glulam volume = 123 CF (22% of MT)

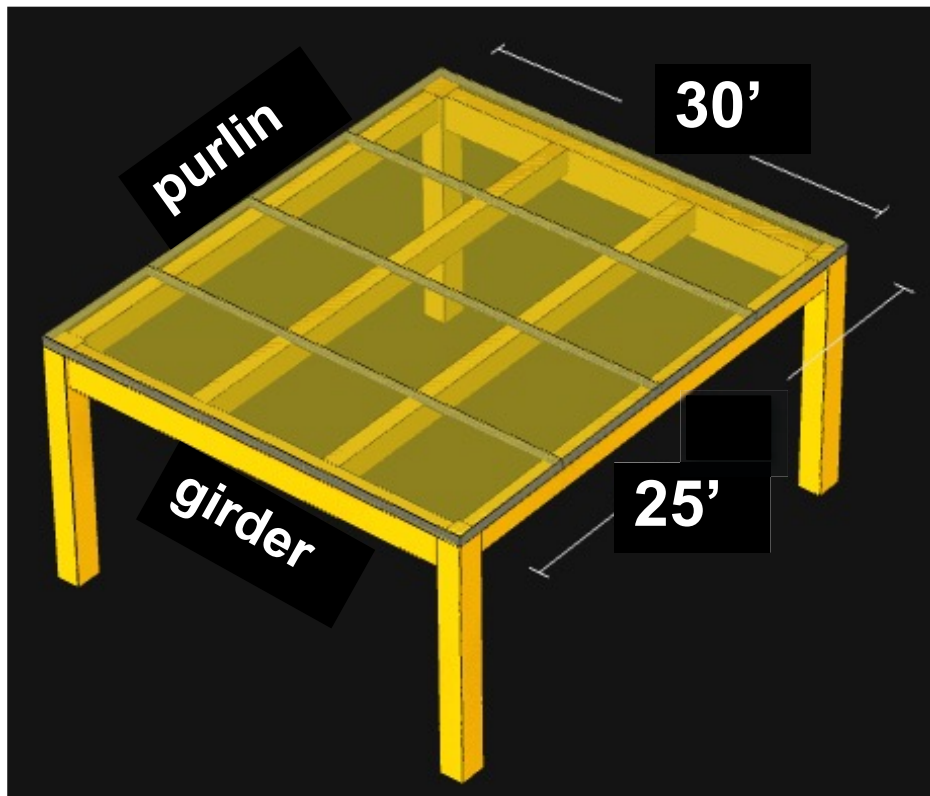
CLT volume = 430 CF (78% of MT)

Total volume = 0.74 CF / SF

Cost considerations: One additional beam (one additional erection pick), 2 more connections

# Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

## Type IV-HT

0-hr FRR (min sizes per IBC)

Purlin: 5.5"x24" (IBC min = 5"x10.5")

Girder: 8.75"x33" (IBC min = 5"x10.5")

Column: 10.5"x10.75" (IBC min = 6.75"x8.25")

Floor panel: 3-ply (IBC min = 4" CLT)

Glulam volume = 120 CF (32% of MT)

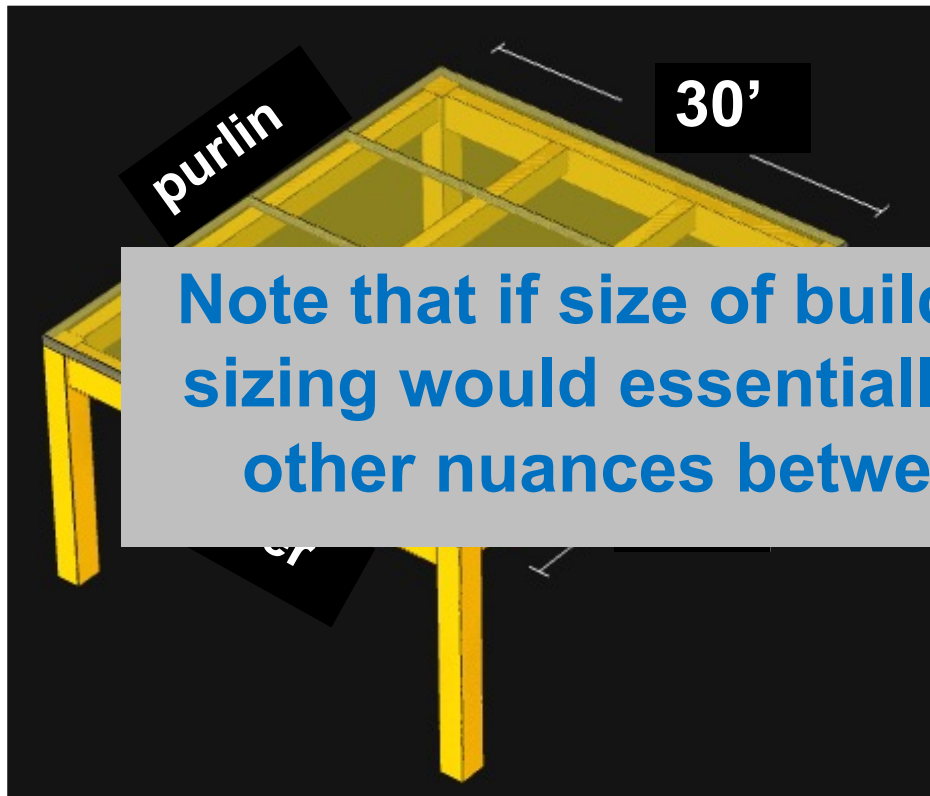
CLT volume = 258 CF (68% of MT)

Total volume = 0.51 CF / SF



# Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



## Type IV-HT

0-hr FRR (min sizes per IBC)

Purlin: 5.5"x24" (IBC min = 5"x10.5")

Note that if size of building had permitted Type IIIB, member sizing would essentially be the same as IV-HT. But there are other nuances between III and IV, we'll cover that later...

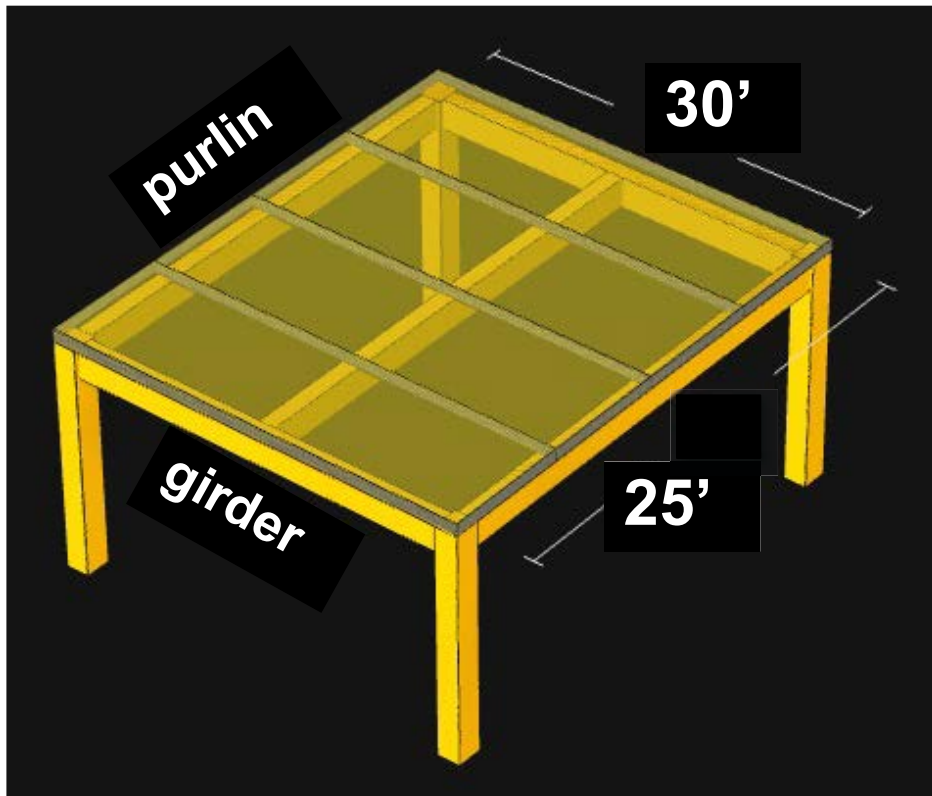
Glulam volume = 120 CF (32% of MT)

CLT volume = 258 CF (68% of MT)

Total volume = 0.51 CF / SF

# Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



## Type IV-C

2-hr FRR

Purlin: 8.75"x28.5"

Girder: 10.75"x33"

Column: 13.5"x21.5"

Floor panel: 5-ply

Glulam volume = 183 CF (30% of MT)

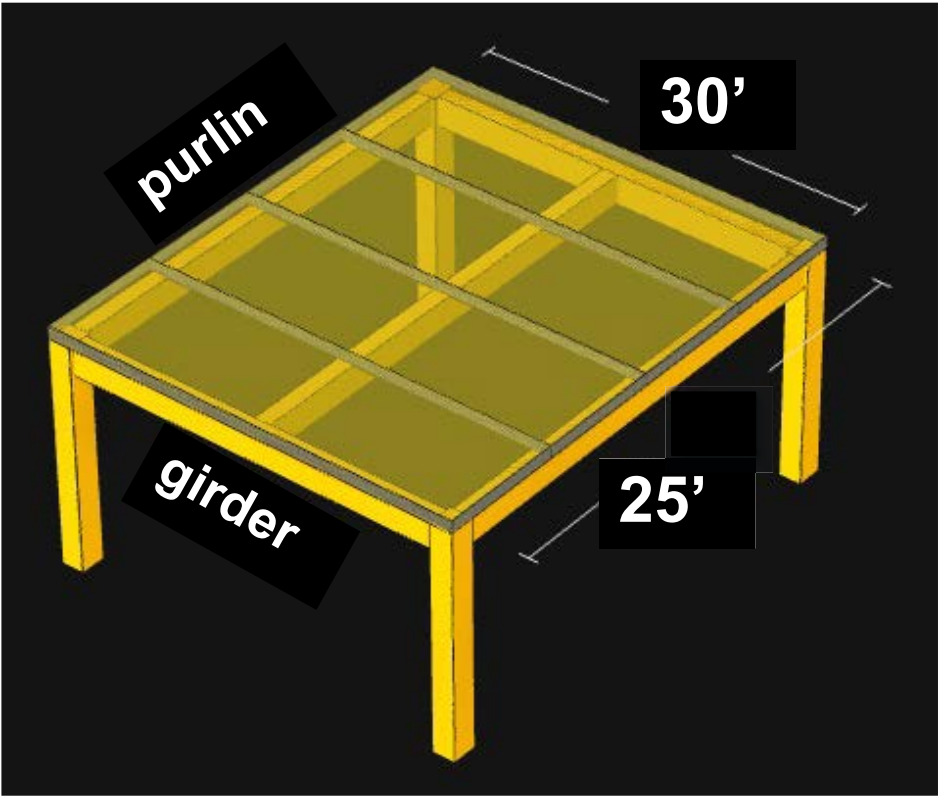
CLT volume = 430 CF (70% of MT)

Total volume = 0.82 CF / SF

Source: Fast + Epp, Timber Bay Design Tool

# Key Early Design Decisions

Which is the most efficient option?



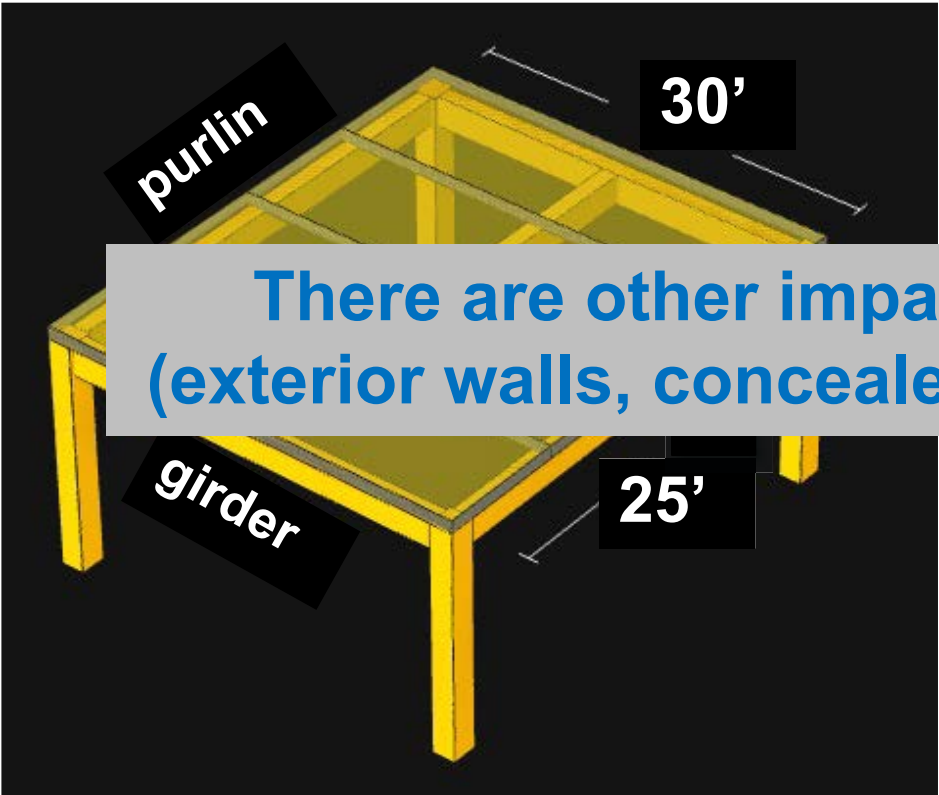
Source: Fast + Epp, Timber Bay Design Tool

	Timber Volume Ratio	Podium on 1 <sup>st</sup> Floor?
IIIA – Option 1	0.73 CF / SF	Yes
IIIA – Option 2	0.74 CF / SF	Yes
IV-HT	0.51 CF / SF	Yes
IV-C	0.82 CF / SF	No

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

# Key Early Design Decisions

Which is the most efficient option?



There are other impacts of construction type selection (exterior walls, concealed spaces) that should be considered

	Timber Volume Ratio	Podium on 1 <sup>st</sup> Floor?
IIIA – Option 1	0.73 CF / SF	Yes
IV-C	0.82 CF / SF	NO

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

Source: Fast + Epp, Timber Bay Design Tool



# Key Early Design Decisions

## Construction Type Early Decision Example



### 3-story building on college campus

- Mostly Group B occupancy, some assembly (events) space
- NFPA 13 sprinklers throughout
- Floor plate = 7,700 SF
- Total Building Area = 23,100 SF

### Impact of Assembly Occupancy Placement:

Owner originally desires events space on top (3<sup>rd</sup>) floor

- Requires Construction **Type IIIA**

If owner permits moving events space to 1<sup>st</sup> or 2<sup>nd</sup> floor

- Could use **Type IIIB**

# Key Early Design Decisions

## Construction Type Early Decision Example

3-story building on college campus

Cost Impact of Assembly Occupancy Placement:



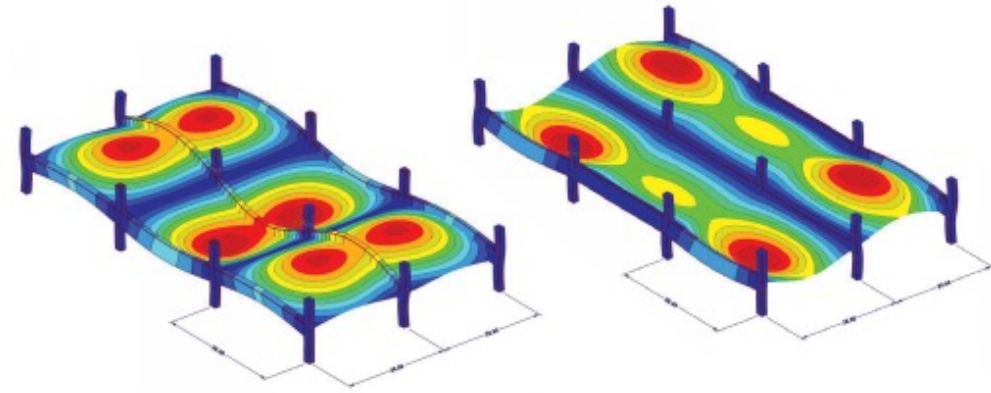
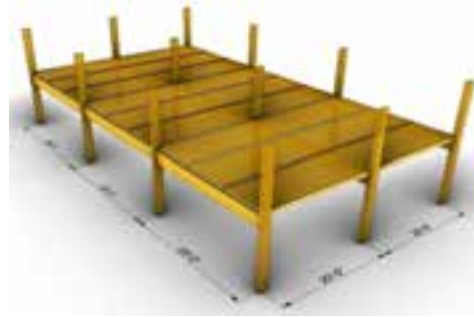
Location of Event Space	3 <sup>rd</sup> Floor	1 <sup>st</sup> Floor
Construction Type	III-A	III-B
Assembly Group	A-3	A-3
Fire Resistive Rating	1-Hr	0-Hr
Connections	Concealed	Exposed
CLT Panel Thickness	5-Ply	3-Ply
<u>Superstructure Cost/SF</u>	<u>\$65/SF</u>	<u>\$53/SF</u>



Source: PCL Construction

# Key Early Design Decisions

## NEW MASS TIMBER FLOOR VIBRATION DESIGN GUIDE



U.S. Mass Timber  
Floor Vibration

**D e s i g n   G u i d e**



**Worked office, lab  
and residential  
Examples**

***Covers simple and complex  
methods for bearing wall and  
frame supported floor systems***



# Connections





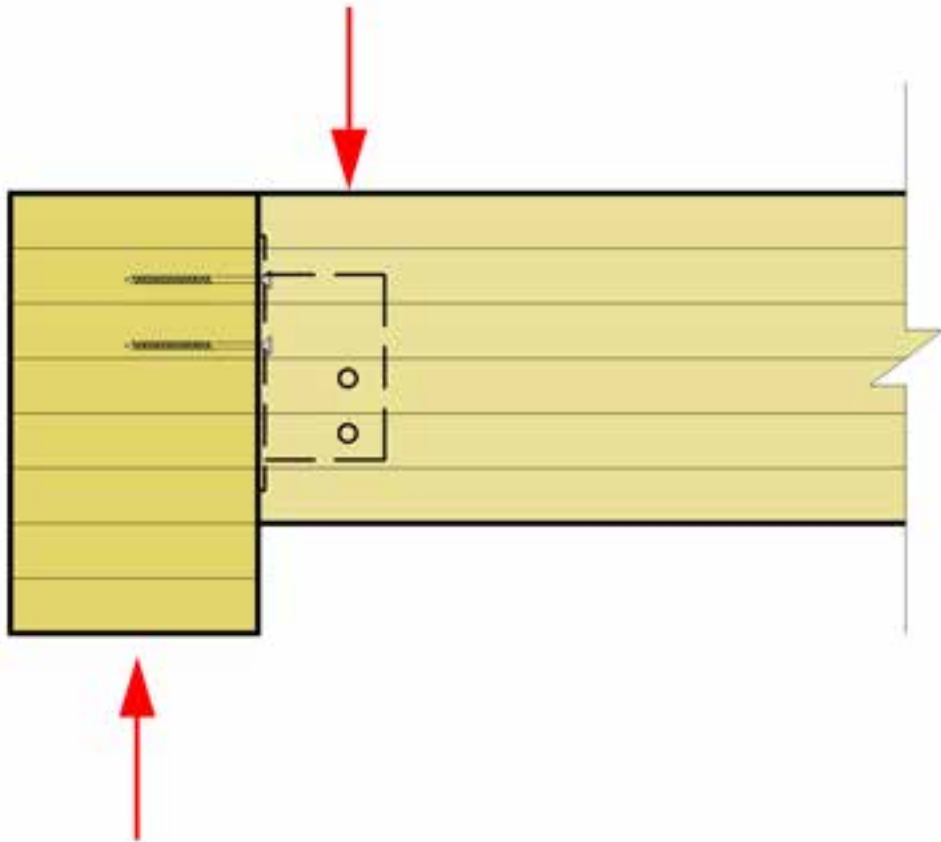
# Key Early Design Decisions

Many ways to demonstrate connection fire protection: calculations, prescriptive NC, test results, others as approved by AHJ



# Key Early Design Decisions

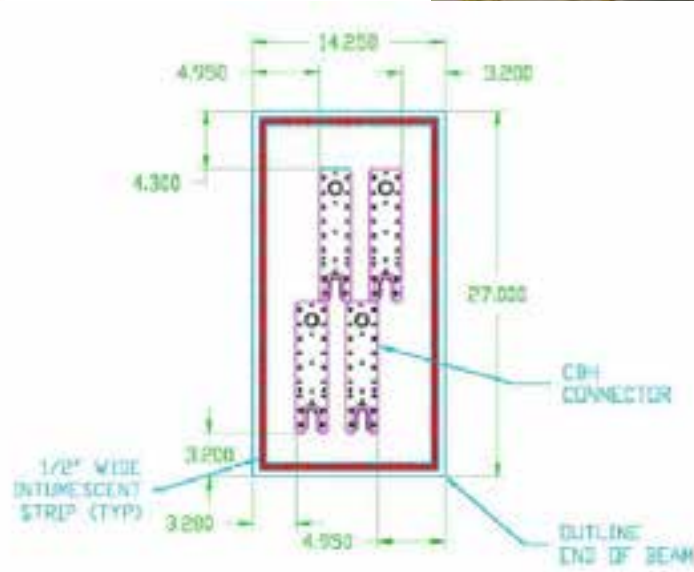
Steel hangers/hardware fully concealed within a timber-to-timber connection is a common method of fire protection





# Key Early Design Decisions

Connection FRR and beam reactions could impact required beam/column sizes





# Key Early Design Decisions

2017 Glulam Beam to Column Connection Fire Tests under standard ASTM E119 time-temperature exposure





# Key Early Design Decisions

## Fire Test Results

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

# Key Early Design Decisions

## Softwood Lumber Board Glulam Connection Fire Test Summary Report

Issue | June 5, 2017

Full Report Available at:

<https://www.thinkwood.com/wp-content/uploads/2018/01/reThink-Wood-Arup-SLB-Connection-Fire-Testing-Summary-web.pdf>



# Key Early Design Decisions

Member to member bearing also commonly used, can avoid some/all steel hardware at connection



# Key Early Design Decisions

Member to member bearing also commonly used, can avoid some/all steel hardware at connection



**Style of connection also impacts and is impacted by grid layout and MEP integration**





# Key Early Design Decisions



**KL&A**  
Engineers & Builders



ARCHITECTURE  
URBAN DESIGN  
INTERIOR DESIGN

**SWINERTON**  
MASS TIMBER

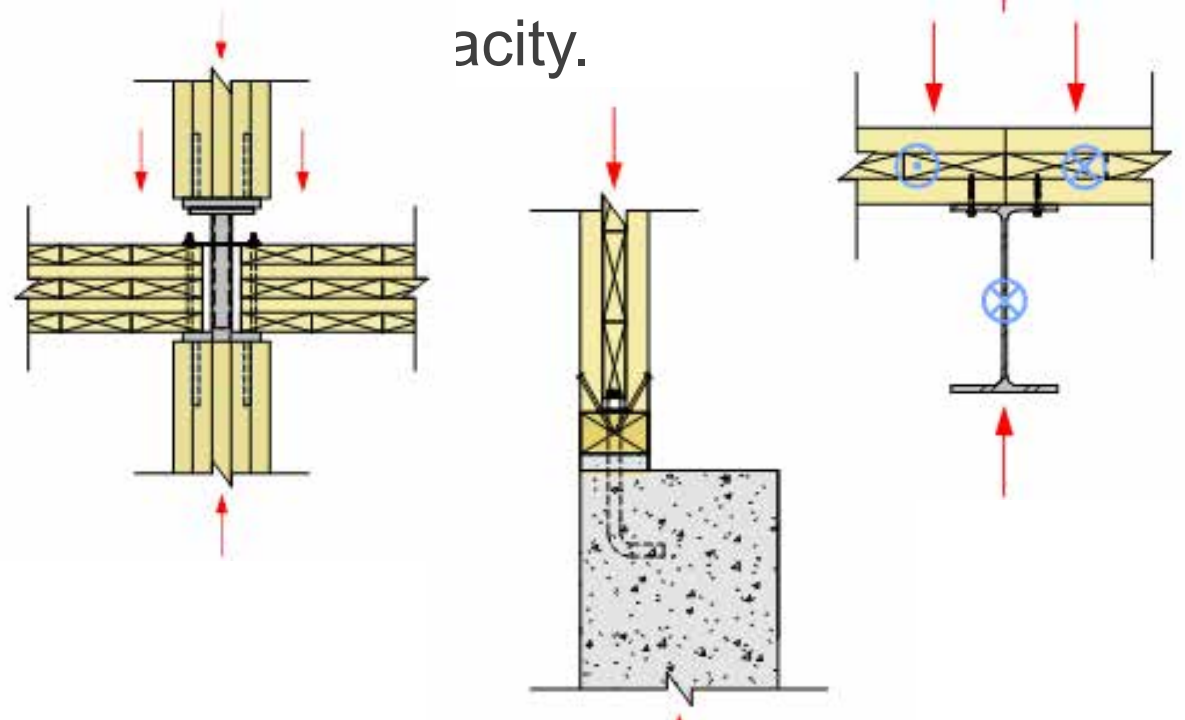


WoodWorks Index of  
Mass Timber Connections



## MASS TIMBER CONNECTIONS INDEX

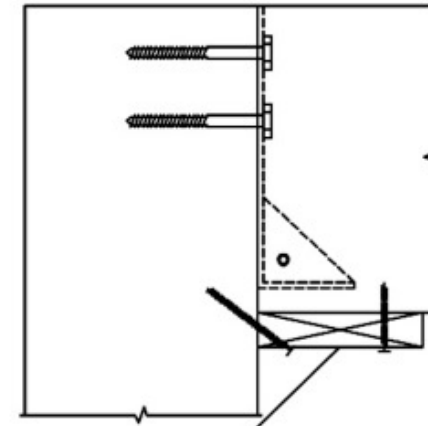
A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load capacity.



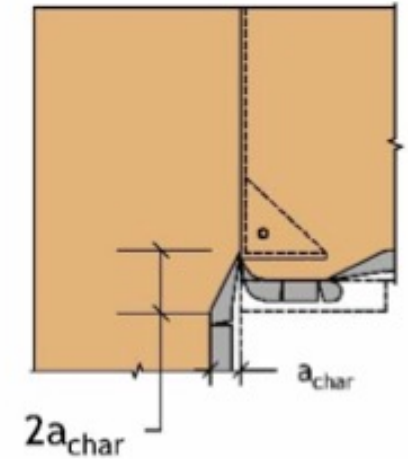
# Key Early Design Decisions

**2304.10.1 Connection fire resistance rating.** Fire resistance ratings in Type IV-A, IV-B, or IV-C construction shall be determined by one of the following:

1. Testing in accordance with Section 703.2 where the connection is part of the fire resistance test.
2. Engineering analysis that demonstrates that the temperature rise at any portion of the connection is limited to an average temperature rise of 250° F (139° C), and a maximum temperature rise of 325° F (181° C), for a time corresponding to the required fire resistance rating of the structural element being connected. For the purposes of this analysis, the connection includes connectors, fasteners, and portions of wood members included in the structural design of the connection.



Source: AWC's TR 10



# Connections

## Other connection design considerations:

- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost



Credit: Alex Schreyer



# Penetrations & Firestopping





# Penetrations & Firestopping

## Construction Type Impacts FRR | FRR impacts penetration firestopping requirements

**714.1.1 Ducts and air transfer openings.** Penetrations of fire-resistance-rated walls by ducts that are not protected with *dampers* shall comply with Sections 714.3 through 714.4.3. Penetrations of *horizontal assemblies* not protected with a shaft as permitted by Section 717.6, and not required to be protected with *fire dampers* by other sections of this code, shall comply with Sections 714.5 through 714.6.2. Ducts and air transfer openings that are protected with *dampers* shall comply with Section 717.

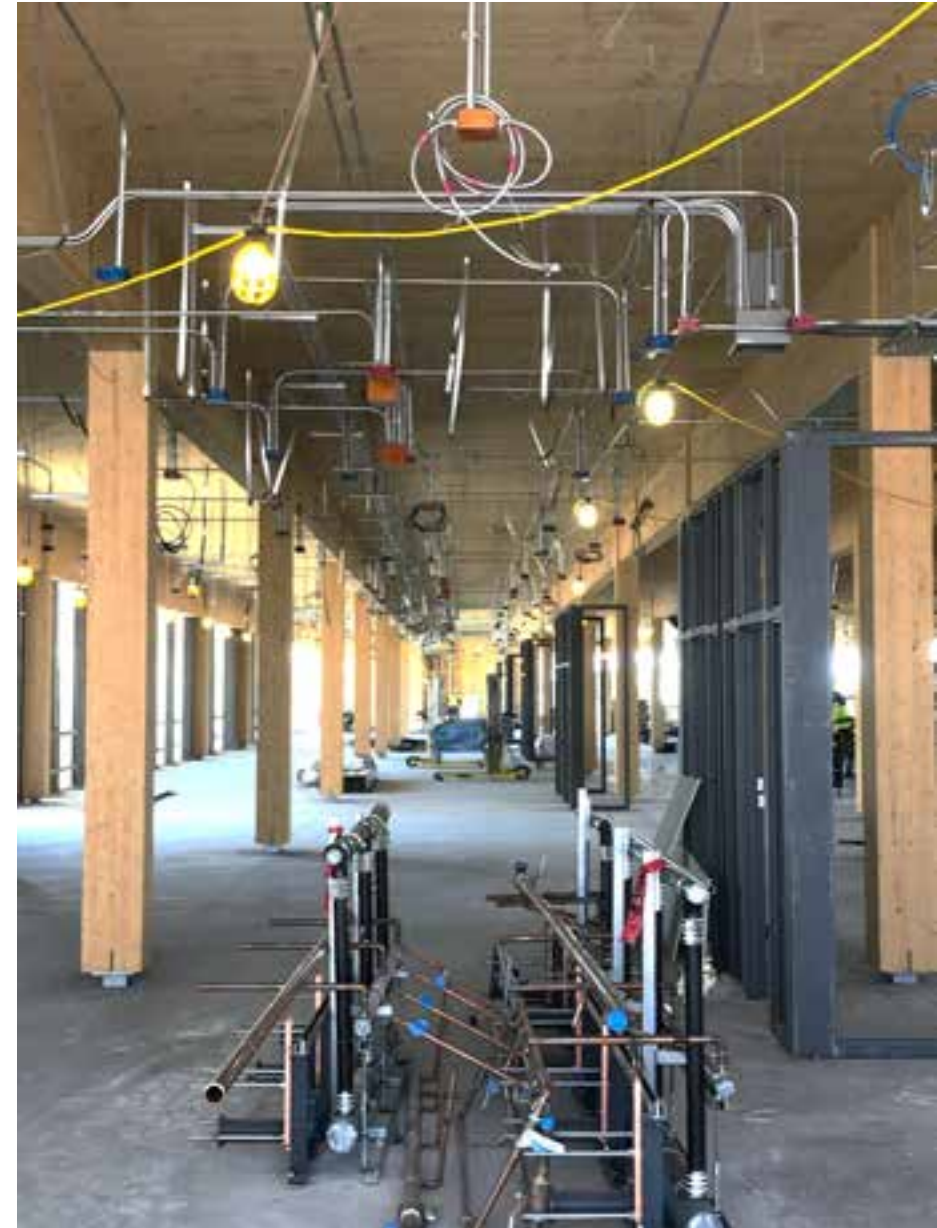


# Penetrations & Firestopping

## Code options for firestopping through penetrations

**714.4.1.1 Fire-resistance-rated assemblies.** *Through penetrations* shall be protected using systems installed as tested in the *approved* fire-resistance-rated assembly.

**714.4.1.2 Through-penetration firestop system.** *Through penetrations* shall be protected by an *approved penetration firestop* system installed as tested in accordance with ASTM E814 or UL 1479, with a minimum positive pressure differential of 0.01 inch (2.49 Pa) of water and shall have an *F rating* of not less than the required *fire-resistance rating* of the wall penetrated.





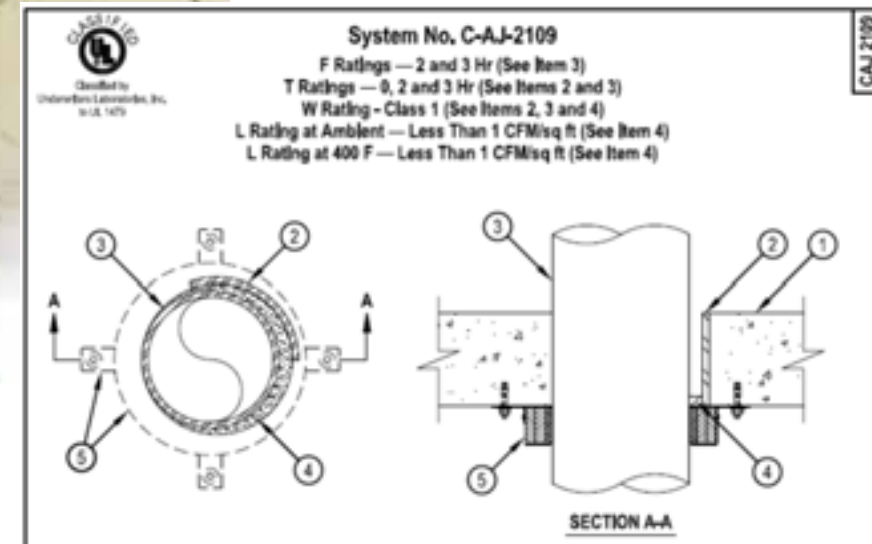
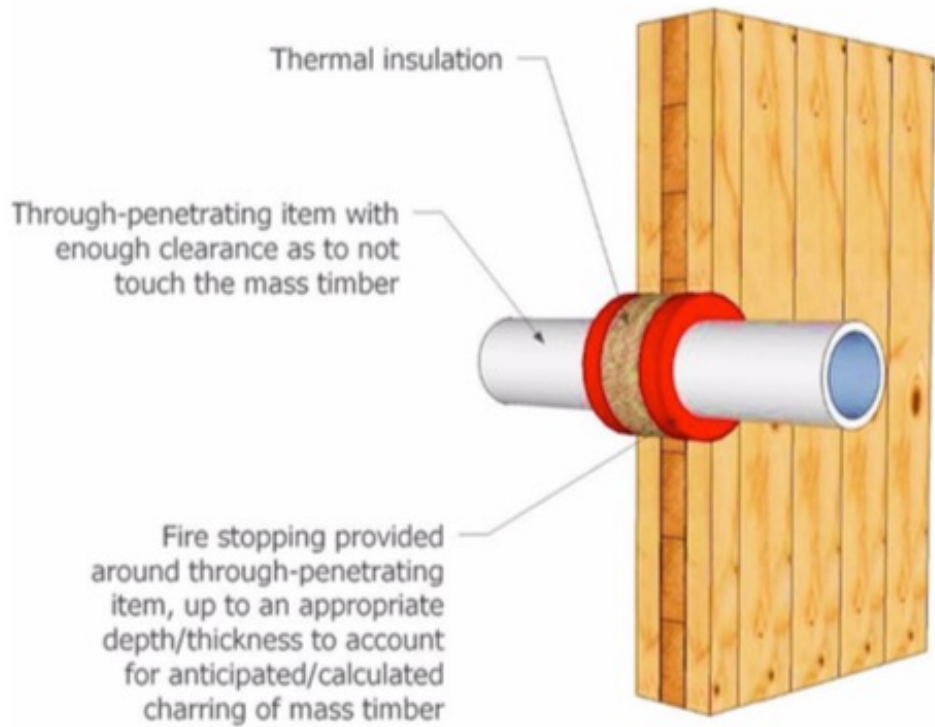
# Penetrations & Firestopping

Option 1: MT penetration firestopping via tested products



# Penetrations & Firestopping

Most firestopping systems include combination of fire safing (eg. noncombustible materials such as mineral wool insulation) plus fire caulk





# Penetrations & Firestopping

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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION

FIRE TECHNOLOGY DEPARTMENT  
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### FIRE RESISTANCE PERFORMANCE EVALUATION OF A PENETRATION FIRESTOP SYSTEM TESTED IN ACCORDANCE WITH ASTM E814-13A, STANDARD TEST METHOD FOR FIRE TESTS OF PENETRATION FIRESTOP SYSTEMS

**FINAL REPORT**  
Consisting of 18 Pages

SwRI® Project No. 01.21428.01.001a  
Test Date: September 30, 2015  
Report Date: October 22, 2015

Prepared for:

American Wood Council  
222 Catoctin Circle SE  
Leesburg, VA 20175

## FIRE PERFORMANCE OF FIRESTOPS, PENETRATIONS, AND FIRE DOORS IN MASS TIMBER ASSEMBLIES

Lindsay Ranger<sup>1</sup>, Christian Dagenais<sup>1</sup>, Conroy Lum<sup>1</sup>, Tony Thomas<sup>1</sup>

**ABSTRACT:** Integrity and continuity must be maintained for fire separations required to provide fire resistance to prevent passage of hot gases or increased temperature on the unexposed side. Vulnerable locations, where penetrations are introduced into mass timber systems, are susceptible to fire spread. Service and closure penetrations in mass timber fire separation have been investigated. Many of the fire stop systems were able to achieve 1-2 hr fire resistance in accordance with CAN/ULC-S115, which would be required for 2-hr fire resistance rated assemblies, in tall wood buildings. Construction details are outlined which ensure adequate fire performance of these penetrations.

**KEYWORDS:** Firestop, through-penetrations, fire rated door, mass timber, cross-laminated timber, tall wood buildings, fire resistance

### 1 INTRODUCTION

Many tall wood buildings using mass timber are planned or are currently being designed for construction around the world. A few have been built in Canada, including an 18 storey cross-laminated timber (CLT) and glulam building in British Columbia. The prescriptive requirements in the National Building Code of Canada (NBCC) [1] do not (yet) permit the construction of wood buildings taller than six stories, however an alternative solutions approach can be used to demonstrate equivalent performance to prescriptive acceptable solutions, requiring non-combustible construction. The

construction, as well as in several alternative building designs.

Although the general fire performance of mass timber is well documented, there are still several areas that warrant further investigation to ensure that safety levels are met and a number of solutions are available for designers to use. Generating generic assemblies will reduce the need for testing completed on an individual construction which will help ease the approvals process and encourage widespread adoption of tall wood building



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### FIRESTOPPING TEST WITNESS REPORT

for

**NORDIC STRUCTURES**

# Penetrations & Firestopping

## Inventory of Fire Tested Penetrations in MT Assemblies

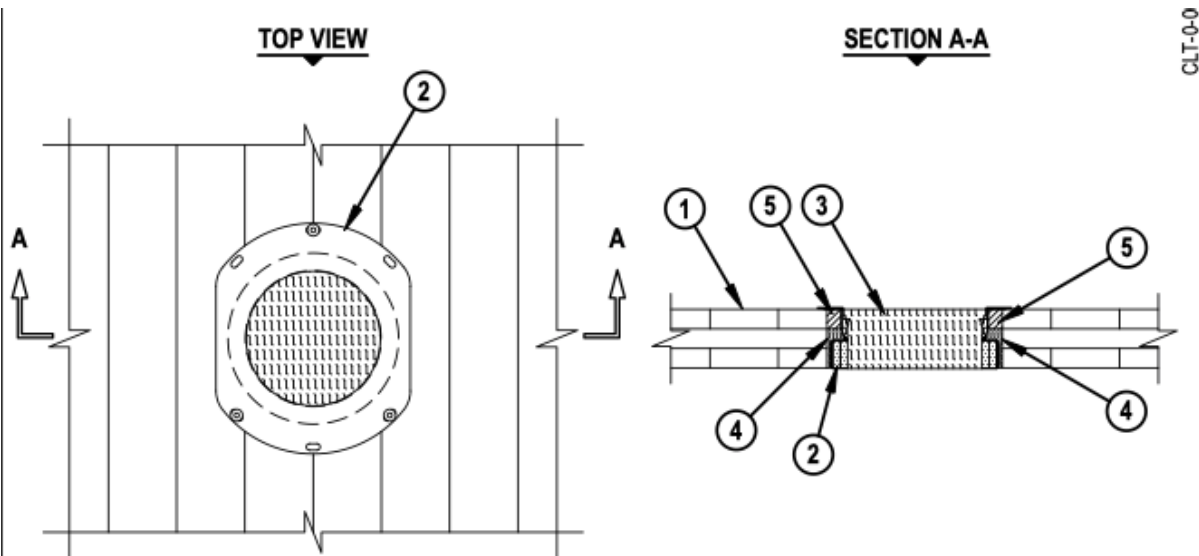


**Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies**

CLT Panel	Exposed Side Protection	Penetrating Item	Penetrant Centered or Offset in Hole	Firestopping System Description	F Rating	T Rating	Stated Test Protocol	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 1 in. annular space around the data cables to a total depth of approximately 2 – 5/64 in. The remaining 1 in. 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 – 5/64 in. The remaining 1 in. 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	NA.	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 – 5/64 in. The remaining 1 in. 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	NA.	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 1 in. annular space around the cast iron pipe to a total depth of approximately 2 – 5/64 in. The remaining 1 in. 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	NA.	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 – 1/4 in. annular space around the drop-in device to a total depth of approximately 1 – 7/64 in and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64 in. 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 (131 mm 5.16")	None	1.5" diameter data cable bunch	Centered	3.5" diameter hole. Mineral wool was installed in the 1 in. annular space around the data cables to a total depth of approximately 4 – 5/32 in. The remaining 1 in. 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 (131 mm 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 1 in. 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	NA.	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131 mm 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 1 in. 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
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5-ply CLT (131 mm 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 – 1/4 in. annular space around the drop-in device to a total depth of approximately 1 – 7/64 in and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64 in. 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

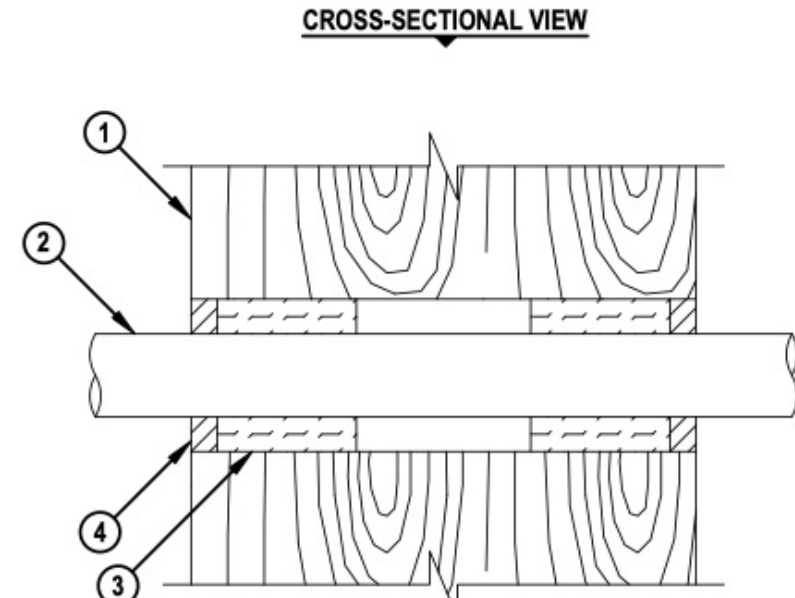
# Penetrations & Firestopping

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)



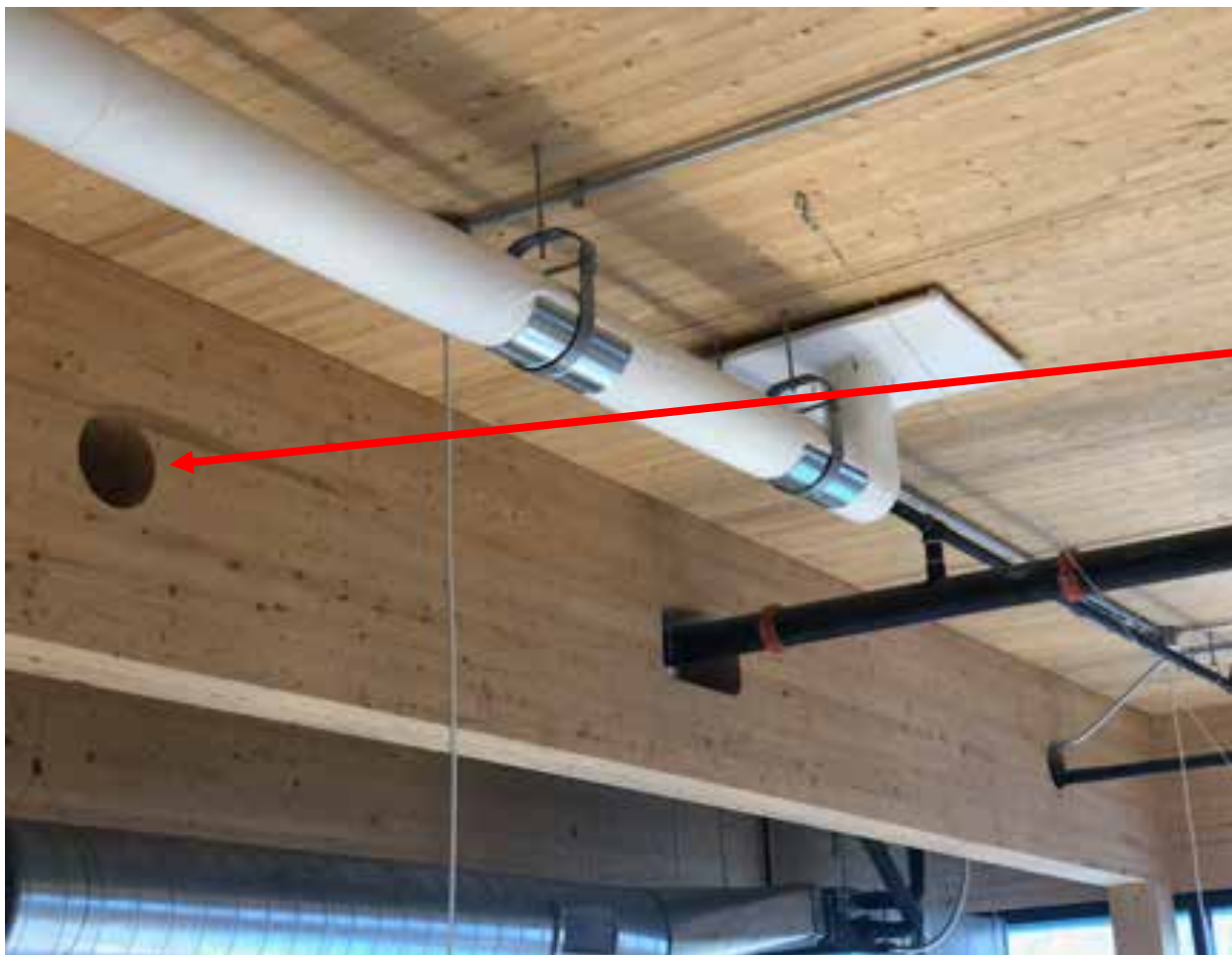
1. MASS TIMBER WALL ASSEMBLY (MINIMUM 12" THICK) (1-HR. OR 2-HR. FIRE-RATING).
2. MAXIMUM 2" NOMINAL DIAMETER PVC PLASTIC PIPE (SCH 40).
3. MINIMUM 4" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED AND RECESSED TO ACCOMMODATE SEALANT.
4. MINIMUM 3/4" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP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



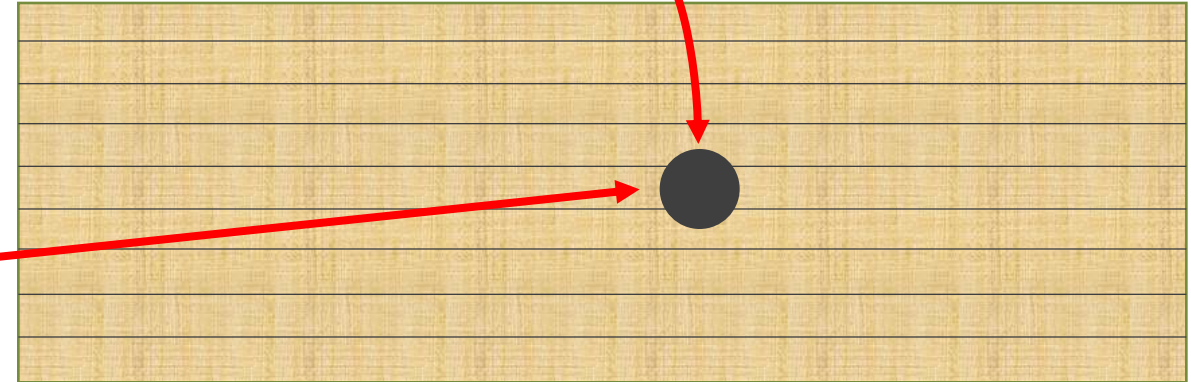
# Penetrations & Firestopping

Beam penetrations:

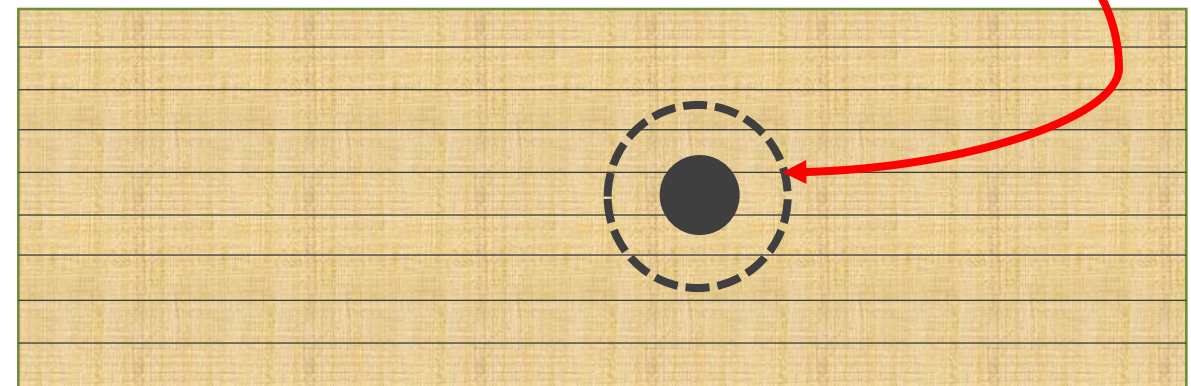
- If FRR = 0-hr, analyze structural impact of hole diameter only
- If FRR > 0-hr, account for charred hole diameter or firestop penetration



Hole diameter



Hole diameter after 1-hr char





# MEP Layout & Integration





# MEP Layout & Integration

Set Realistic Owner Expectations About Aesthetics

- MEP fully exposed with MT structure, or limited exposure?



# MEP Layout & Integration

## Key considerations:

- Level of exposure desired
- Floor to floor, structure depth & desired head height
- Building occupancy and configuration (i.e. central core vs. double loaded corridor)
- Grid layout and beam orientations
- Need for future tenant reconfiguration
- Impact on fire & structural design: concealed spaces, penetrations



Credit: WoodWorks



# MEP Layout & Integration

Smaller grid bays at central core (more head height)

- Main MEP trunk lines around core, smaller branches in exterior bays



Credit: Blaine Brownell

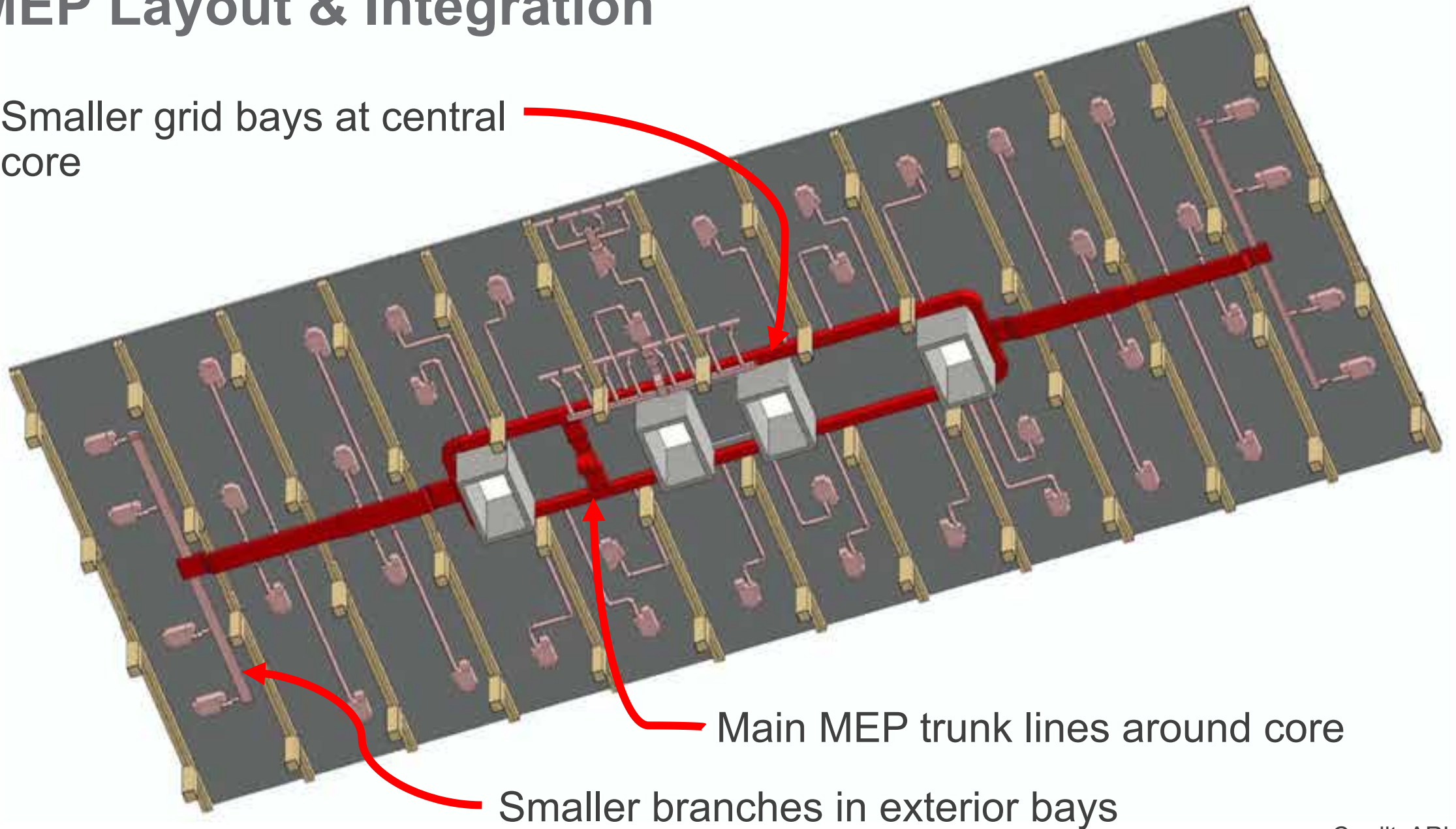


Credit: WoodWorks



# MEP Layout & Integration

Smaller grid bays at central core



Main MEP trunk lines around core

Smaller branches in exterior bays

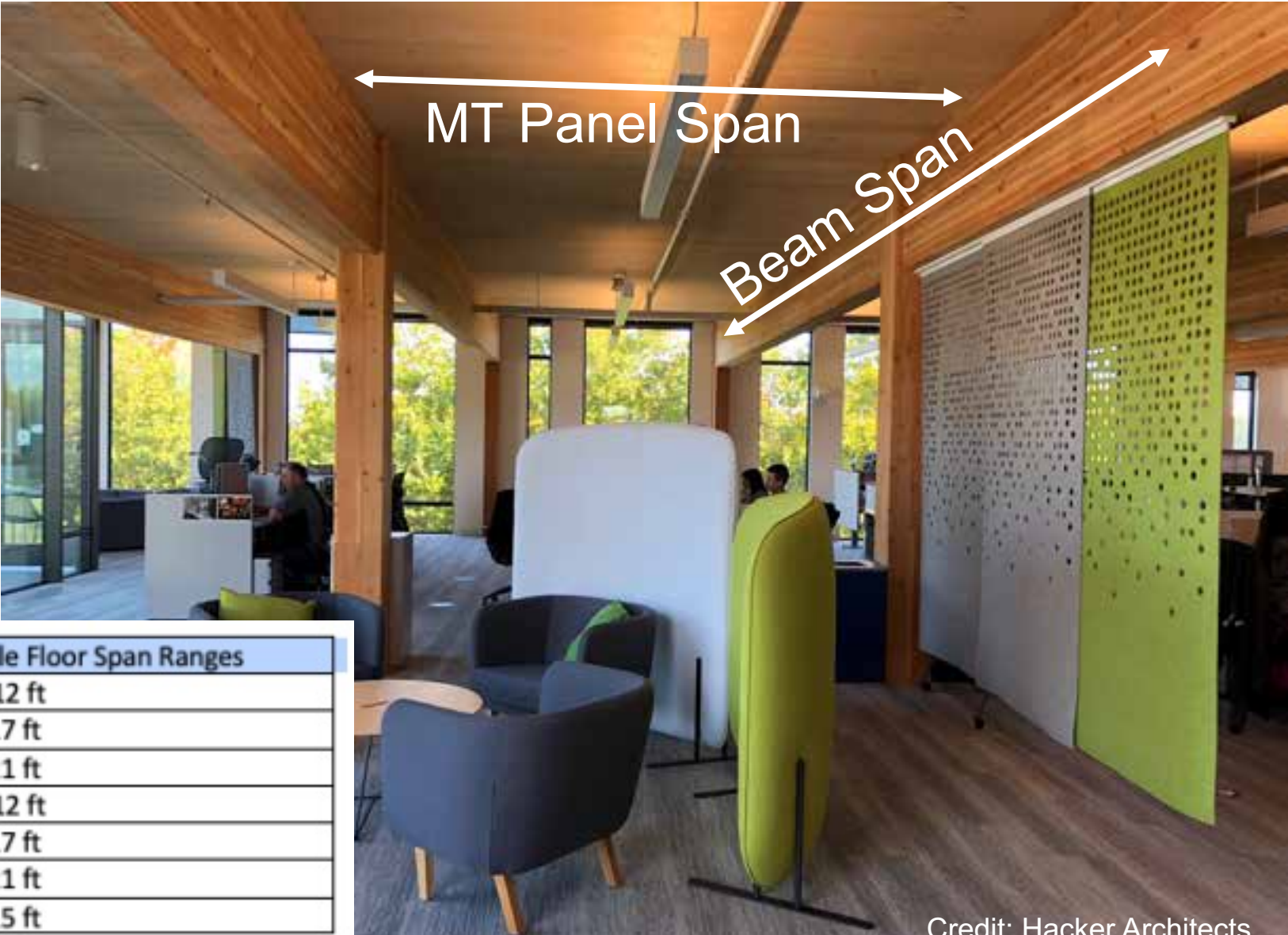
# MEP Layout & Integration

Grid impact: Relies on one-way beam layout. Columns/beams spaced at panel span limits in one direction.

Beam penetrations are minimized/eliminated

Recall typical panel span limits:

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





# MEP Layout & Integration

Dropped below MT framing

- Can simplify coordination (fewer penetrations)
- Bigger impact on head height





# MEP Layout & Integration

Grid impact: Usually more efficient when using a square-ish grid with beams in two directions



Credit: SOM Timber Tower Report

# MEP Layout & Integration

In penetrations through MT framing

- Requires more coordination (penetrations)
- Bigger impact on structural capacity of penetrated members
- Minimal impact on head height



Credit: WoodWorks



Credit: WoodWorks



# MEP Layout & Integration

In chases above beams and below panels

- Fewer penetrations
- Bigger impact on head height (overall structure depth is greater)
- FRR impacts: top of beam exposure



Credit: JC Buck



Credit: KL&A Engineers & Builders



# MEP Layout & Integration

In chases above beams and below panels at Platte 15

- 30x30 grid, purlins at 10 ft, 3-ply CLT



Credit: JC Buck



# MEP Layout & Integration

In chases above beams and below panels at Catalyst

- 30x30 grid, 5-ply CLT ribbed beam system



Credit: Hans-Erik Blomgren





# MEP Layout & Integration

In gaps between MT panels

- Fewer penetrations, can allow for easier modifications later



Credit: Ema Peter/MGA



Credit: Hacker Architects



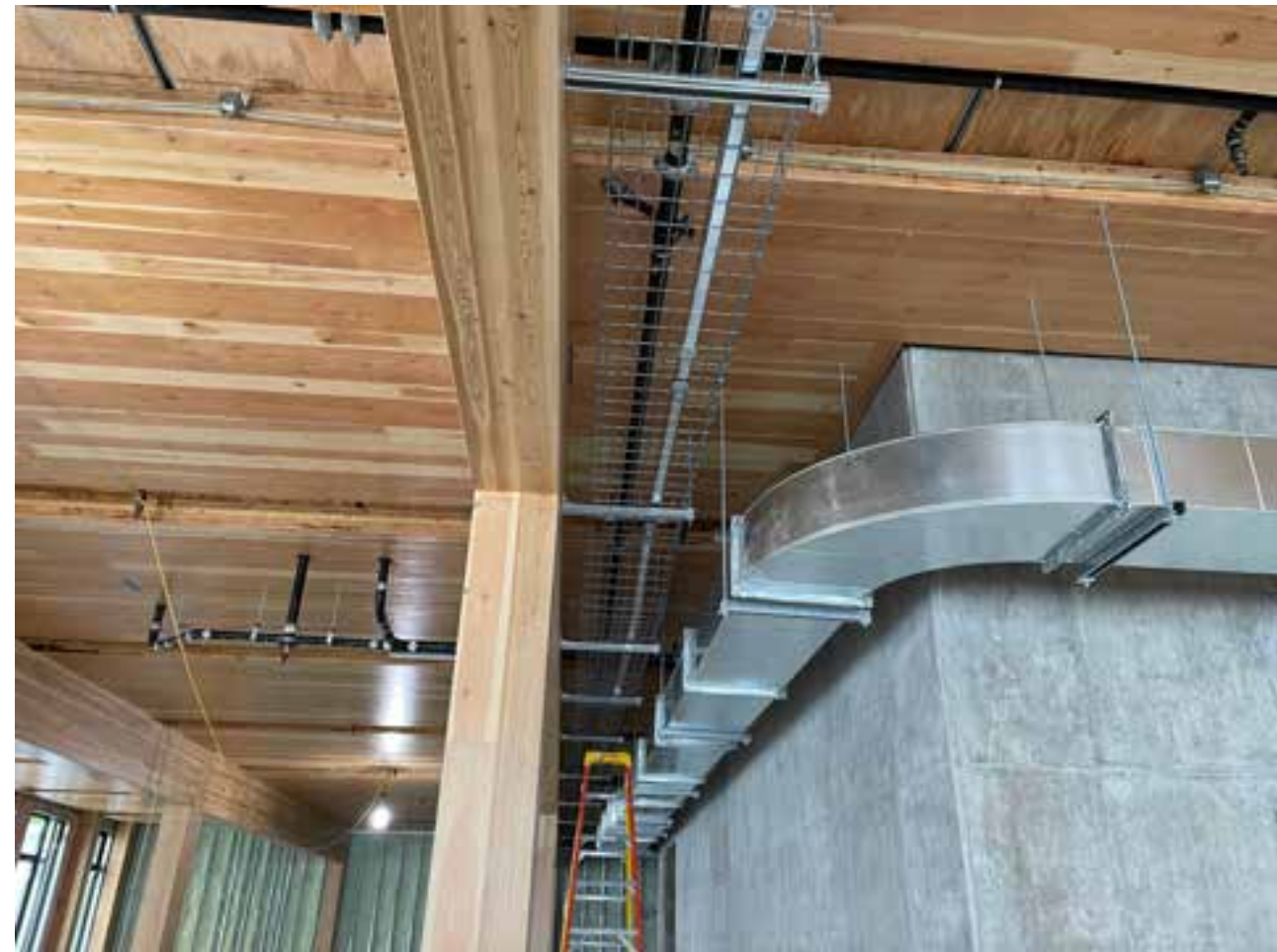
# MEP Layout & Integration

In gaps between MT panels

- FRR impacts: generally topping slab relied on for FRR



Credit: KPFF



# MEP Layout & Integration

In gaps between MT panels

- Impact on assembly acoustics performance





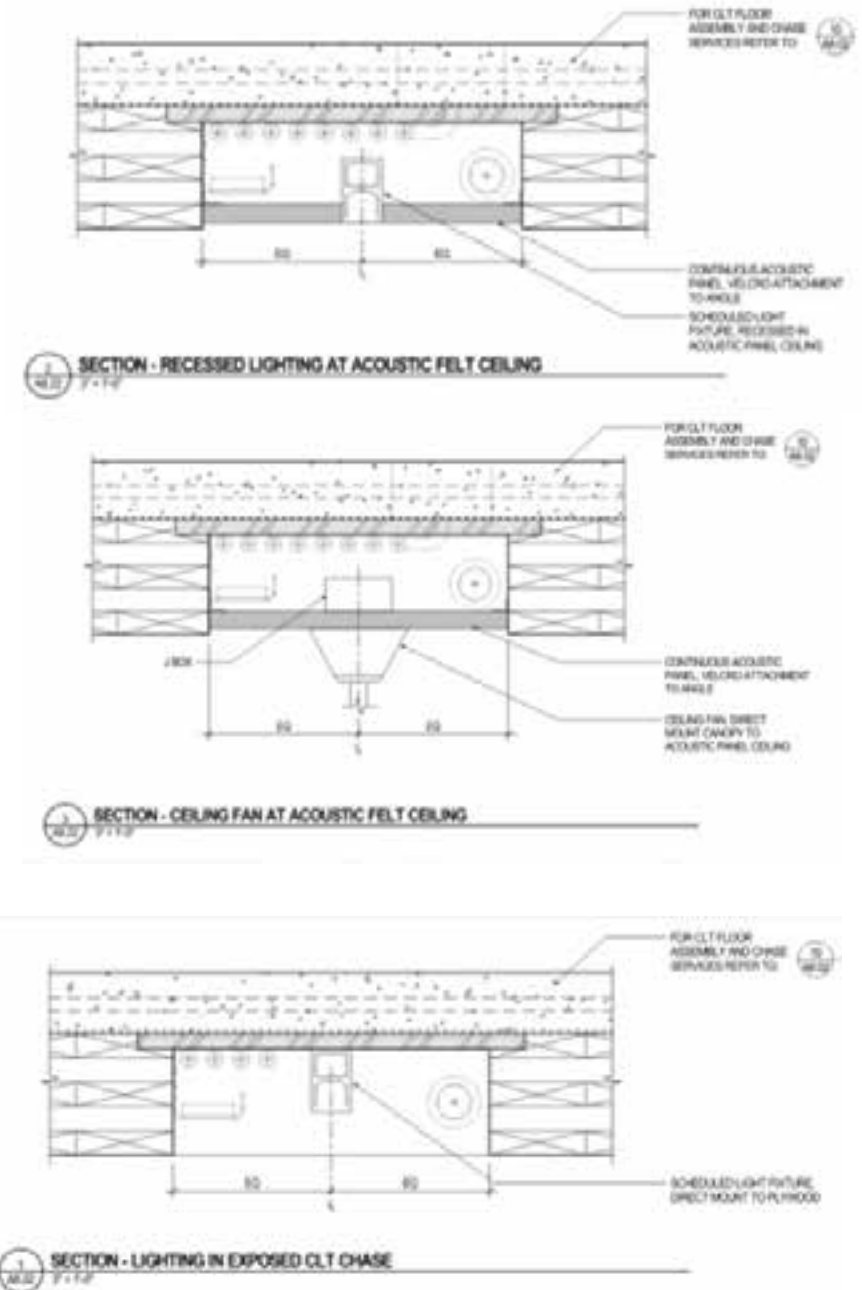
# MEP Layout & Integration

In gaps between MT panels

- Greater flexibility in MEP layout



Credit: WoodWorks



Credit: PAE Consulting Engineers



# MEP Layout & Integration

In gaps between MT panels

- Aesthetics: often uses ceiling panels to cover gaps



Credit: Ema Peter/MGA

# MEP Layout & Integration

- In raised access floor (RAF) above MT
- Aesthetics (minimal exposed MEP)



Credit: BOKA Powell

**RAF**



**NON RAF**



# MEP Layout & Integration

In raised access floor (RAF) above MT

- Impact on head height
- Concealed space code provisions



Credit: Global IFS





# MEP Layout & Integration

In topping slab above MT

- Greater need for coordination prior to slab pour
- Limitations on what can be placed (thickness of topping slab)
- No opportunity for renovations later





# Lateral System Choices & Impacts





# Lateral System Choices

## Concrete Shearwalls



Credit: Hacker Architects



# Lateral System Choices

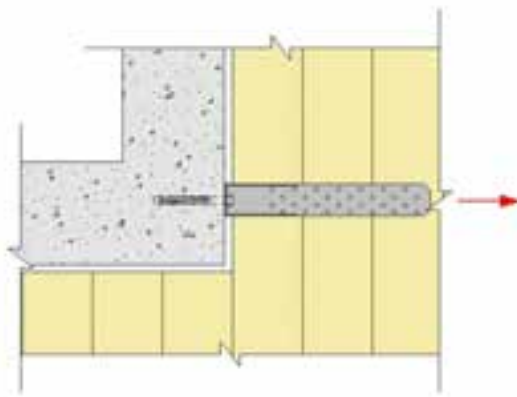
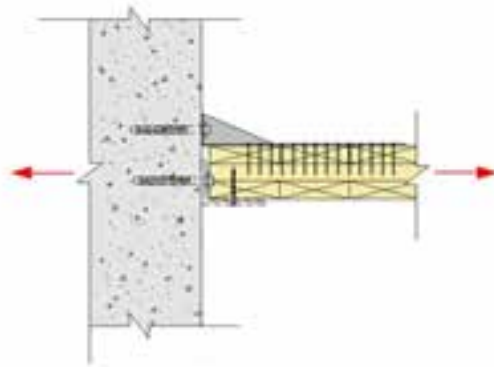
Connection to concrete core



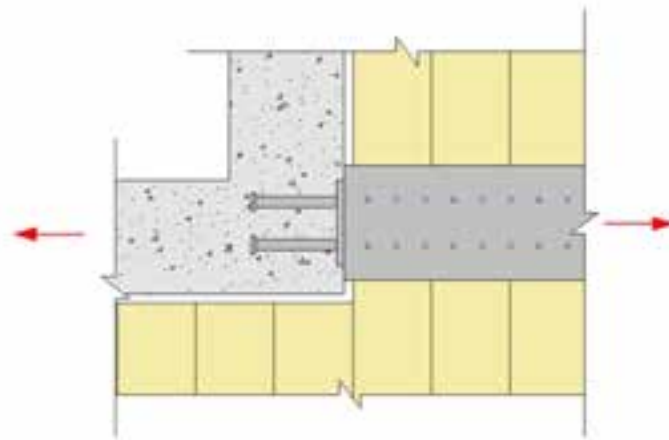
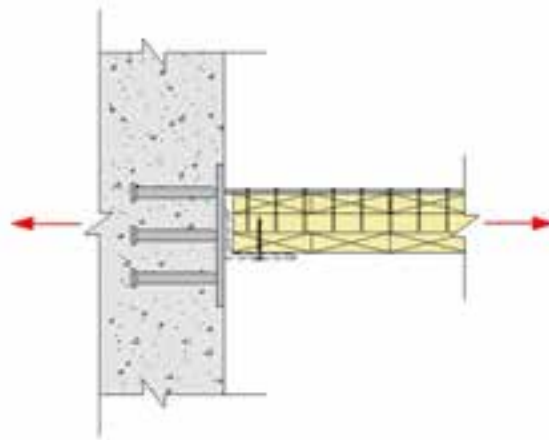
# Lateral System Choices

Connections to concrete core

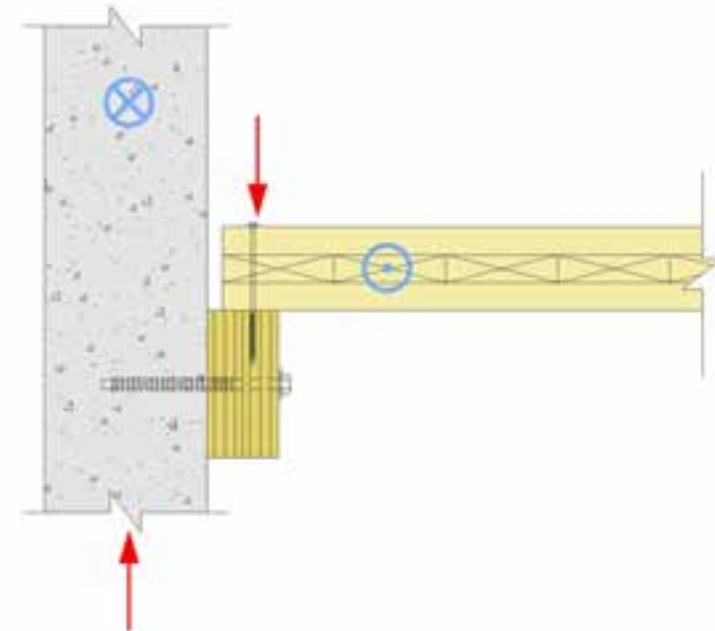
- Tolerances & adjustability
- Drag/collector forces



PLAN VIEW



PLAN VIEW





# Lateral System Choices

## Steel Braced Frame

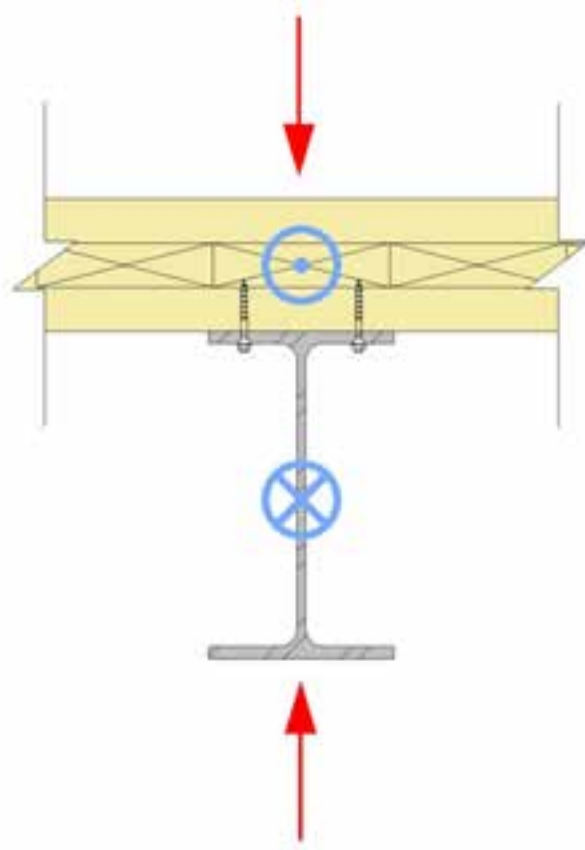
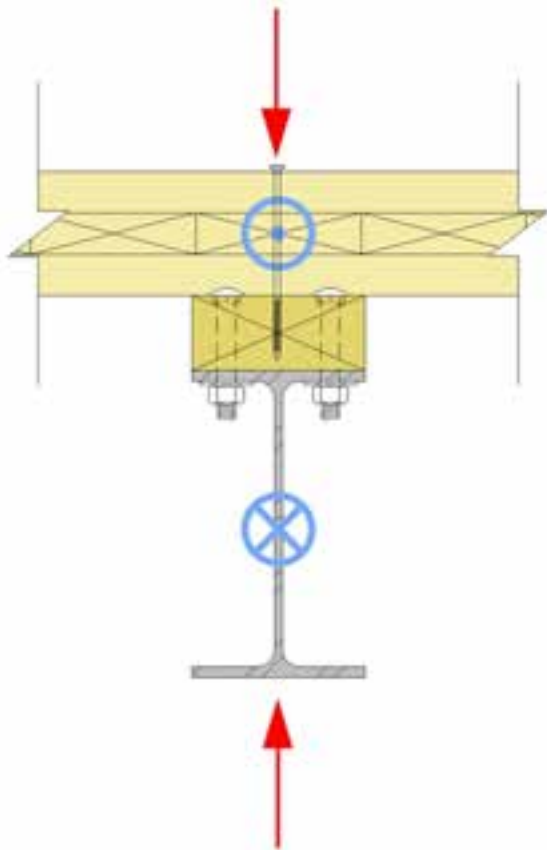




# Lateral System Choices

Connections to steel frame

- Tolerances & adjustability
- Consider temperature fluctuations
- Ease of installation



Photos: Marcus Kauffmann, ODF

# Lateral System Choices

## Wood-Frame Shearwalls



Credit: KL&A Engineers & Builders



# Lateral System Choices

## Wood-frame Shearwalls:

- Code compliance
- Standard of construction practice well known
- Limited to 65 ft shearwall height, 85 ft overall building height (Type IIIA construction)



Credit: Jeremy Bittermann & Kaiser + Path





# Lateral System Choices

## MT Shearwalls



Photo: Alex Schreyer



# Lateral System Choices

## MT Rocking Shearwalls



Photo: WoodWorks

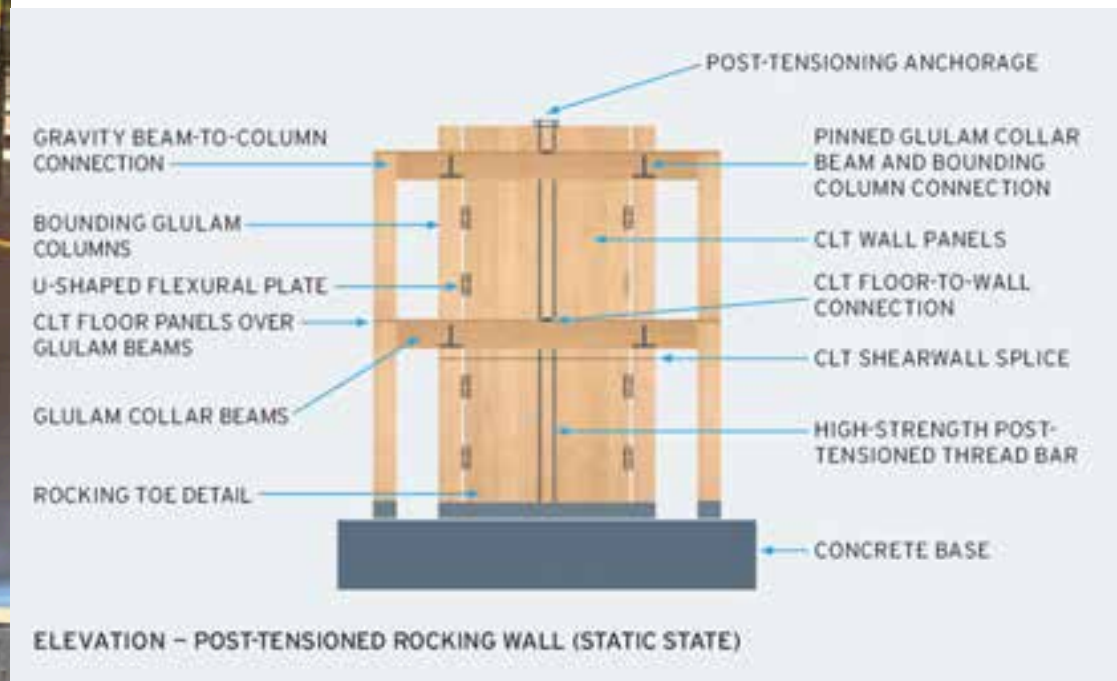


Image: KPFF



# Lateral System Choices

## Timber Braced Frame



Credit: Alex Schreyer



# Lateral System Choices

## Prescriptive Code Compliance

Concrete Shearwalls

Steel Braced Frames

Light Wood-Frame Shearwalls

CLT Shearwalls

CLT Rocking Walls

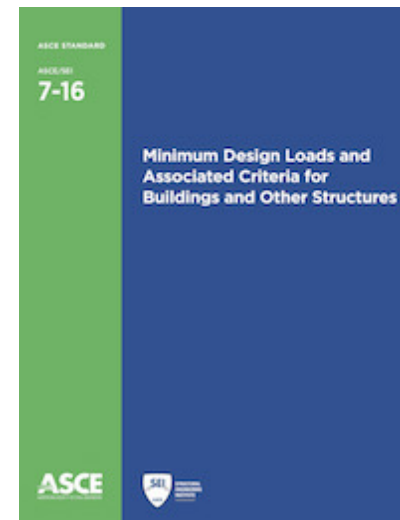
Timber Braced Frames



**2021 SDPWS  
ASCE 7-22**



Photo: WoodWorks



# Acoustics & Sound Control



# Acoustics & Sound Control

Consider Impacts of:

- Timber & Topping Thickness
- Panel Layout
- Gapped Panels
- Connections & Penetrations
- MEP Layout & Type



Credit: Rothoblaas

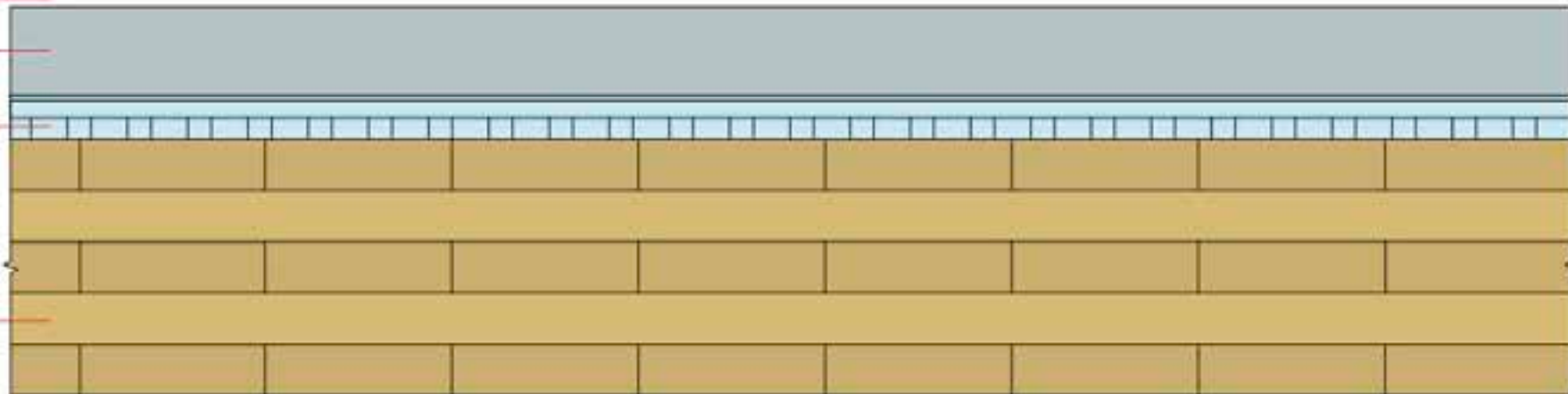


# Acoustics & Sound Control



Images: Maxxon

- Finish Floor if Applicable
- Concrete/Gypsum Topping
- Acoustical Mat Product
- CLT Panel
- No direct applied or hung ceiling

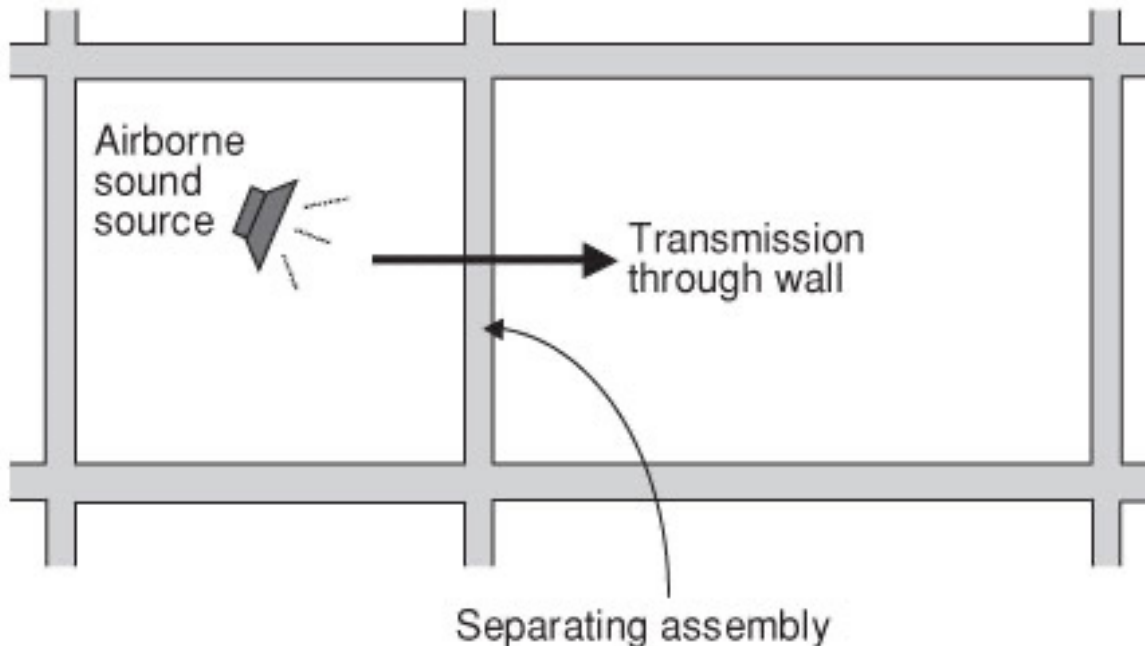


# Acoustics & Sound Control

## Air-Borne Sound:

### Sound Transmission Class (STC)

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies

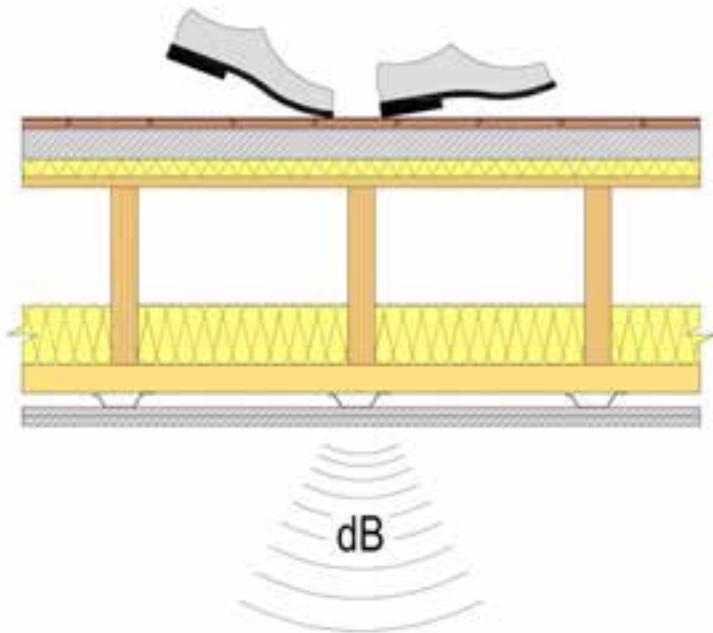


# Acoustics & Sound Control

## Structure-borne sound:

### Impact Insulation Class (IIC)

- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies





# Acoustics & Sound Control

Code requirements only address residential occupancies:

For unit to unit or unit to public or service areas:

**Min. STC of 50 (45 if field tested):**

- Walls, Partitions, and Floor/Ceiling Assemblies

**Min. IIC of 50 (45 if field tested) for:**

- Floor/Ceiling Assemblies

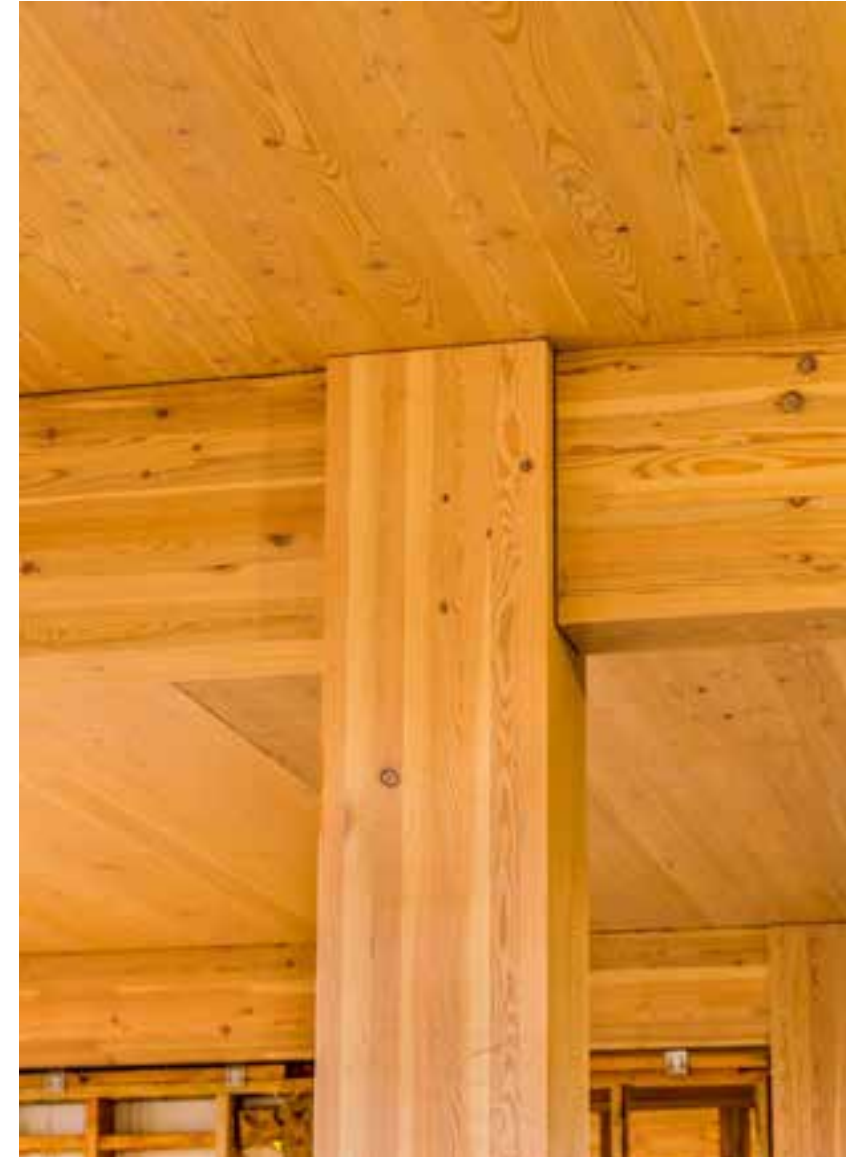


# Acoustics & Sound Control

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

# Acoustics & Sound Control

MT: Structure Often is Finish



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



# Acoustics & Sound Control

But by Itself, Not Adequate for Acoustics



# Acoustics & Sound Control

**TABLE 1:**  
**Examples of Acoustically-Tested Mass Timber Panels**

Mass Timber Panel	Thickness	STC Rating	IIC Rating
3-ply CLT wall <sup>4</sup>	3.07"	33	N/A
5-ply CLT wall <sup>4</sup>	6.875"	38	N/A
5-ply CLT floor <sup>5</sup>	5.1875"	39	22
5-ply CLT floor <sup>4</sup>	6.875"	41	25
7-ply CLT floor <sup>4</sup>	9.65"	44	30
2x4 NLT wall <sup>6</sup>	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 <sup>6</sup>	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 <sup>2</sup>	6" with 1/2" plywood	34	33

# Acoustics & Sound Control

**Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:**

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



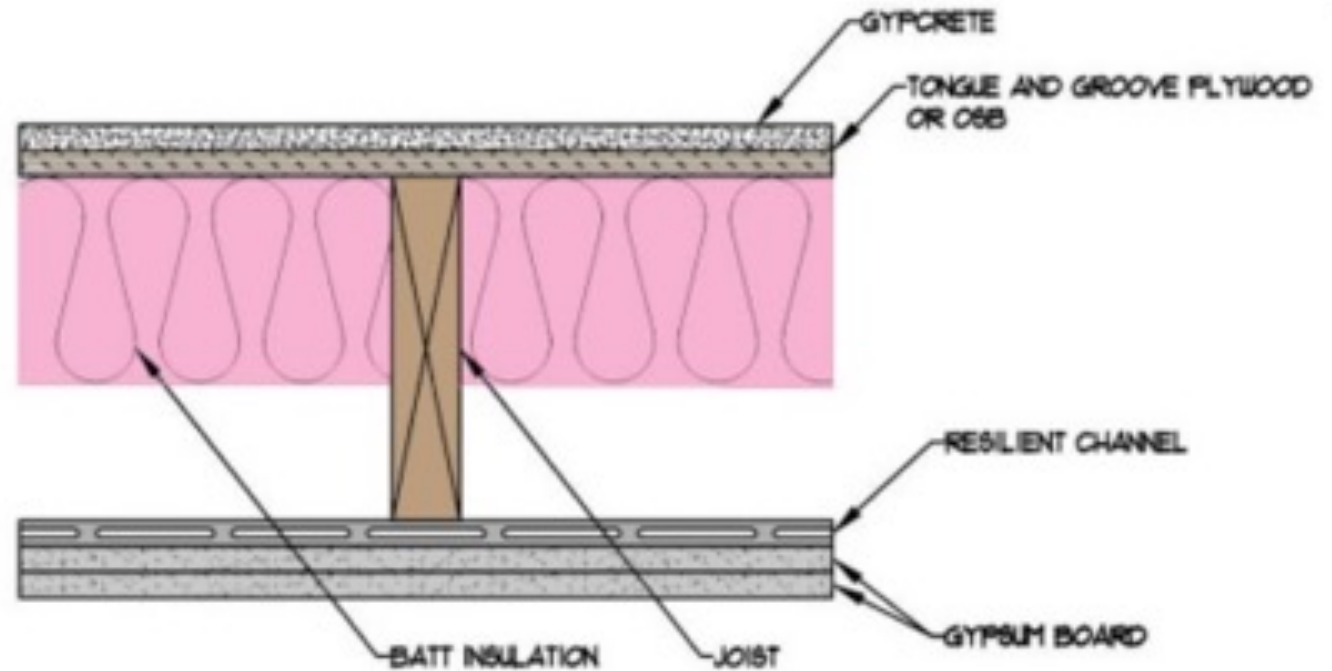
Image credit: Christian Columbres



# Acoustics & Sound Control

**What does this look like in typical wood-frame construction:**

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



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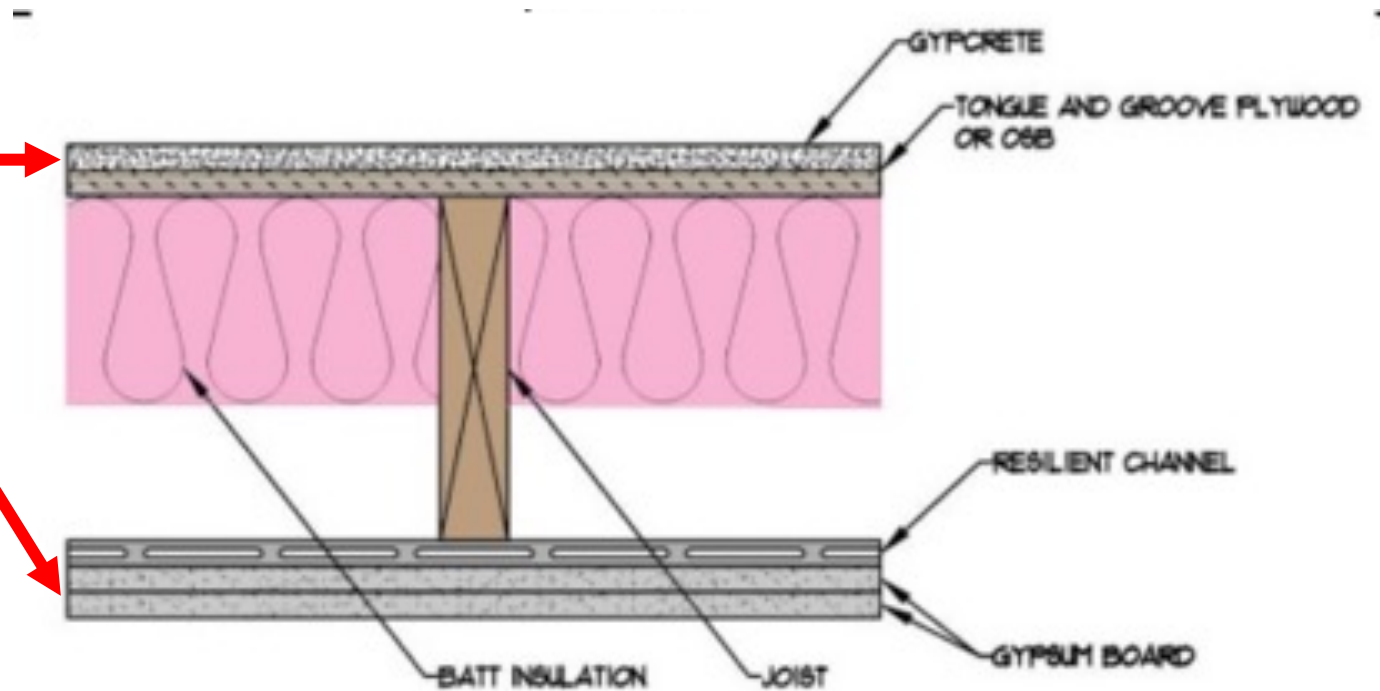
STC 62

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# Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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

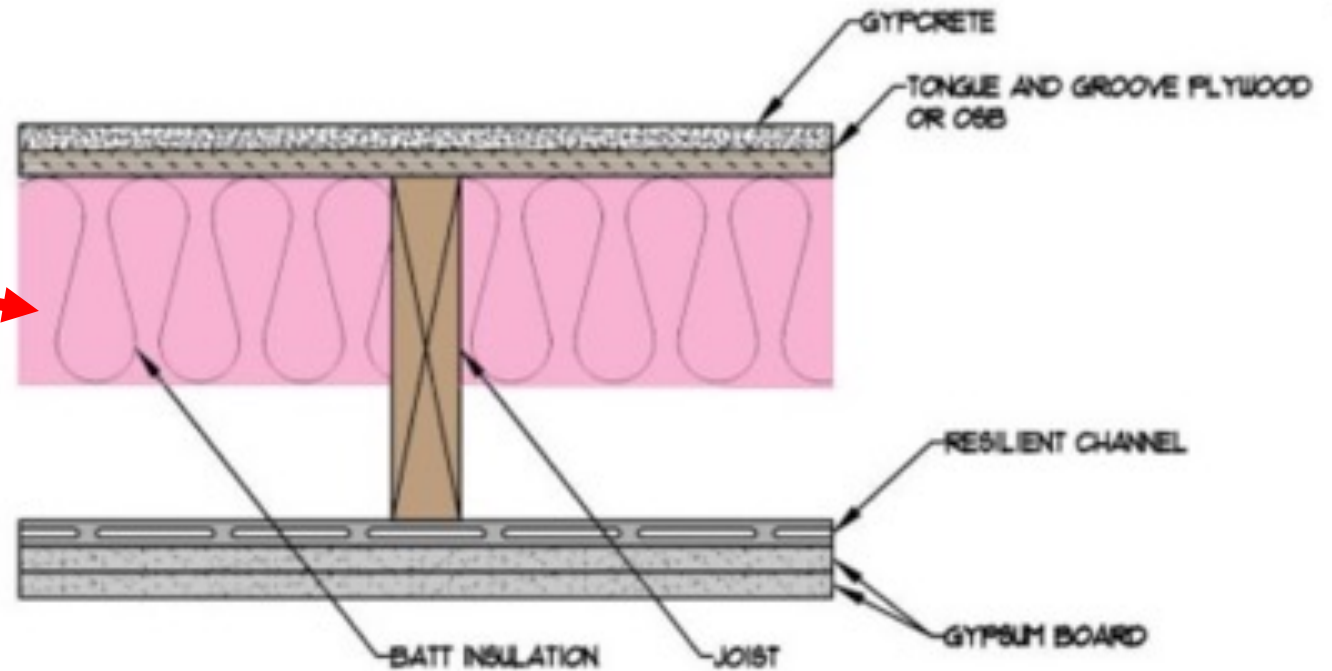


STC 62

# Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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



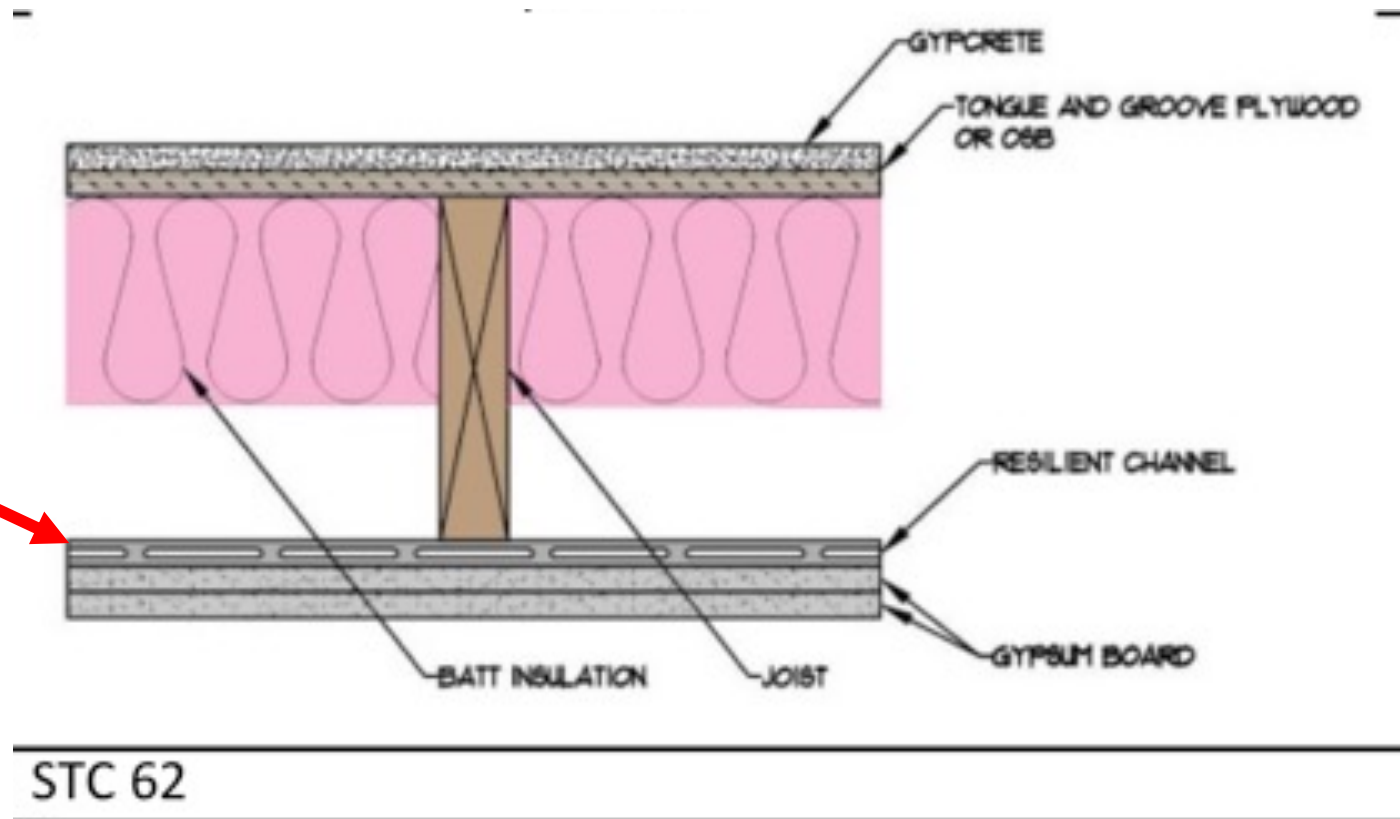
STC 62



# Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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



# Acoustics & Sound Control

**Mass timber has relatively low “mass”**

**Recall the three ways to increase acoustical performance:**

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



Credit: Christian Columbres

# Acoustics & Sound Control



Concrete Slab:

6" Thick

80 PSF

STC 53



CLT Slab:

6-7/8" Thick

18 PSF

STC 41





# Acoustics & Sound Control

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

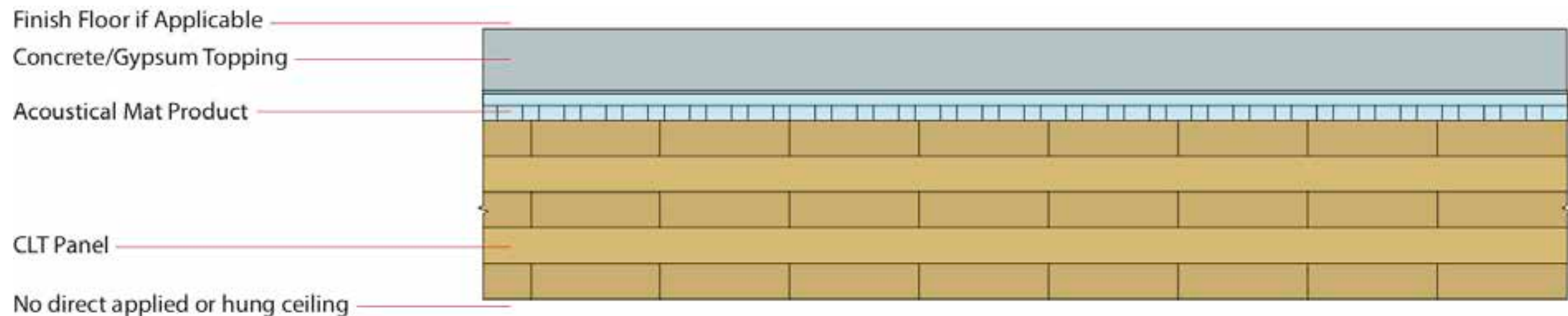


1. Add mass



2. Add noise barriers

3. Add decouplers



# Acoustics & Sound Control

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

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



## Acoustical Mat:

- Typically roll out or board products
- Thicknesses vary: Usually  $\frac{1}{4}$ " to 1"+



Credit: Maxxon

# Acoustics & Sound Control

Acoustical floor underlayments



Photo: AcoustiTECH<sup>10</sup>

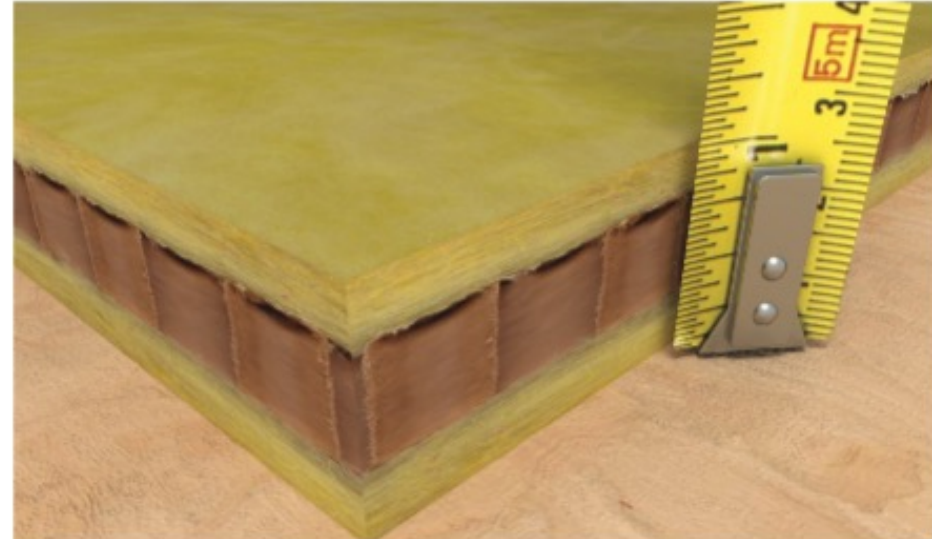


Photo: Kinetics Noise Control, Inc.,<sup>11</sup>



Photo: Maxxon Corporation

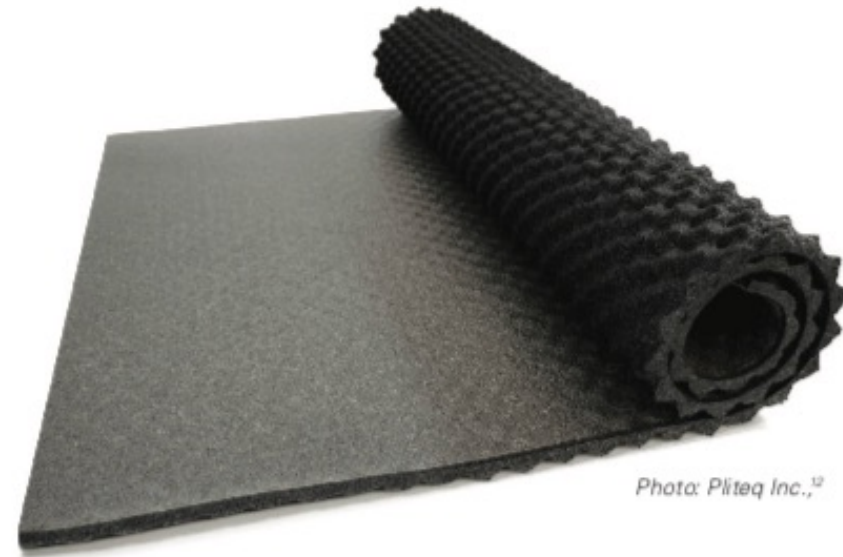


Photo: Pliteq Inc.,<sup>12</sup>



# Acoustics & Sound Control

## Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5" to 4" thick concrete/gypcrete topping
- Acoustical mat
- WSP (if applicable)
- Mass timber floor panels



# Acoustics & Sound Control

## Solutions Paper



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

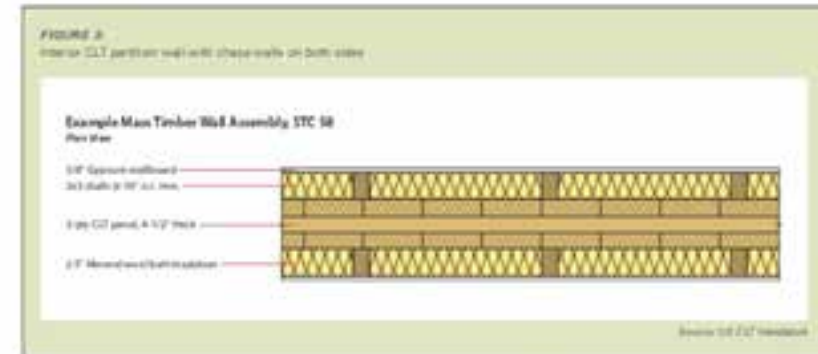
Nicholas McCann, P.E. • Senior Technical Director • WoodWorks



12 Minnesota  
Architect: MGA Architects/Interior Architecture, LLC  
Structural Engineer: Magnusson Karmelien Architects  
Image: Photo: © Matt Thompson/CIAD

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.



#### 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\"

#### 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 nail-laminated timber (NLT), 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 inter-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 preventing rotation and breaking flange, 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.



Acoustical connection strips

Photo: WoodWorks

# Acoustics & Sound Control



**ARC-CIRC CONSTRUCTION**

Acoustic Testing of CLT and Assemblies

Nordic Engineered Wood  
Report No. A1-000253.1  
19 August 2016

National Research Council Canada / Conseil national de recherches Canada

NATIONAL RESEARCH COUNCIL CANADA

**REPORT TO RESEARCH CONSORTIUM  
FOR WOOD AND WOOD-HYBRID  
MID-RISE BUILDINGS**

**CLT (CROSS LAMINATED TIMBER)**

ST	Condition	Number Tested	Lab	No. Testing Points	Sound Red.	Spec. Location	Sound Rating			Minimum STC Rating
							STC	W	Test Number	
1	10' Lab	No	University of Alberta	3/4"	Boundary	ST	48.00	W	11.0 (11.0/11.0)	41.0
						Spec. Wall	48.00	W	11.0 (11.0/11.0)	
						ST	48.00	W	11.0 (11.0/11.0)	
2	10' Lab	No	University of Alberta	3/4"	Boundary	ST	48.00	W	11.0 (11.0/11.0)	41.0
						Spec. Wall	48.00	W	11.0 (11.0/11.0)	

**Summary -  
Acoustical Performance Test Report**

A1-000253.1

19 August 2016

Rendered to:  
**PLTSQ INC.**

Series/Model: Vantage Floor Wood Flooring on Piling GradeMat™ ESTER over Insulation System - Piling GradeMat™ ESTER Rubber Underlayment

Specimen Type: Cross Laminated Timber - 119 mm (4.7")

Overall Size: 603 mm by 603 mm (23.7" by 23.7")

STC 48  
RC 49

**Test Specimen Identification:**  
Floor Topping: 119 mm (4.7") Vantage Floor Wood Flooring  
Floor Underlayment: 1 mm (0.04") Piling GradeMat™ ESTER Rubber Underlayment  
Subfloor Topping: 119 mm (4.7") Vantage Floor Wood Flooring  
Subfloor Underlayment (Top Layer): 119 mm (4.7") Piling GradeMat™ ESTER Rubber Underlayment  
Subfloor Underlayment (Bottom Layer): 119 mm (4.7") Piling GradeMat™ ESTER Rubber Underlayment  
Floor Size: 119 mm (4.7") Nordic Wood Products NLM Cross Laminated Timber

Reference should be made to Intertek-ATC Report E1996-11-113-01 for complete test specimen descriptions. This page shows test & complete report.

2400 Steeles East  
Unit 10, Scarborough, Ontario M1V 5P6  
www.intertek.com  
www.intertek.com/building  
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**KINETICS NOISE CONTROL, INC.**  
**ACOUSTICAL PERFORMANCE TEST REPORT**

**SCOPE OF WORK:**  
ASTM E914 AND ASTM E915 TESTING ON UFG STRUCTURAL PANELS CONCRETE SUBSTRATE WITH NFM-4.2-34 SYSTEM OVER STRUCTURE ON AFT UNIT

**SPECIMEN TYPE:**  
NFM-4.2-34 System

**REPORT NUMBER:**  
KNC-19-113-01

**TEST DATE:**  
10/13/19

**ISSUE DATE:** 11/19/19 **REVISED DATE:** 11/19/19

**RECORD RETENTION END:**  
10/13/20

**PAGES:**  
10

**DOCUMENT CONTROL:**  
ASTM E914 AND E915  
ASTM E914 AND E915  
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# Acoustics & Sound Control

## 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](mailto:help@woodworks.org) or contact the WoodWorks Regional Director nearest you: <http://www.woodworks.org/project-assistance>

#### Contents:

Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed .....	2
Table 2: CLT Floor Assemblies without Concrete/Gypsum Topping, Ceiling Side Exposed.....	7
Table 3: CLT Floor Assemblies without Concrete/Gypsum Topping, with Wood Sleepers, Ceiling Side Exposed .....	9
Table 4: NLT, GLT & T&G Decking Floor Assemblies, Ceiling Side Exposed.....	11
Table 5: Mass Timber Floor Assemblies with Ceiling Side Concealed.....	14
Table 6: Single CLT Wall .....	21
Table 7: Single NLT Wall .....	26
Table 8: Double CLT Wall .....	29
Sources.....	32
Disclaimer .....	34

# Acoustics & Sound Control

## Inventory of Tested 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 <sup>1</sup>	IIC <sup>1</sup>	Source
CLT 5-ply (6.875")	1-1/2" Gyp-Crete®	Maxxon Acousti-Mat® 3/4	None	47 <sup>2</sup> ASTC	47 <sup>2</sup> AIIC	1
			LVT	-	49 <sup>2</sup> AIIC	
			Carpet + Pad	-	75 <sup>2</sup> AIIC	
			LVT on Acousti-Top®	-	52 <sup>2</sup> AIIC	
			Eng Wood on Acousti-Top®	-	51 <sup>2</sup> AIIC	
		Maxxon Acousti-Mat® ¾ Premium	None	49 <sup>2</sup> ASTC	45 <sup>2</sup> AIIC	
			LVT	-	47 <sup>2</sup> AIIC	
	1-1/2" Levelrock®	USG SAM N25 Ultra	LVT on Acousti-Top®	-	49 <sup>2</sup> AIIC	
			None	45 <sup>6</sup>	39 <sup>6</sup>	15
			LVT	48 <sup>6</sup>	47 <sup>6</sup>	16
			LVT Plus	48 <sup>6</sup>	49 <sup>6</sup>	58
			Eng Wood	47 <sup>6</sup>	47 <sup>6</sup>	59
			Carpet + Pad	45 <sup>6</sup>	67 <sup>6</sup>	60
			Ceramic Tile	50 <sup>6</sup>	46 <sup>6</sup>	61
		USG SAM N25 Ultra	None	45 <sup>6</sup>	42 <sup>6</sup>	15
			LVT	48 <sup>6</sup>	44 <sup>6</sup>	16

# Key Early Design Decisions

## Early Design Decision Example

### **7-story, 84 ft tall multi-family building**

- Parking & Retail on 1<sup>st</sup> floor, residential units on floors 2-7
- NFPA 13 sprinklers throughout
- Floor plate = 18,000 SF
- Total Building Area = 126,000 SF

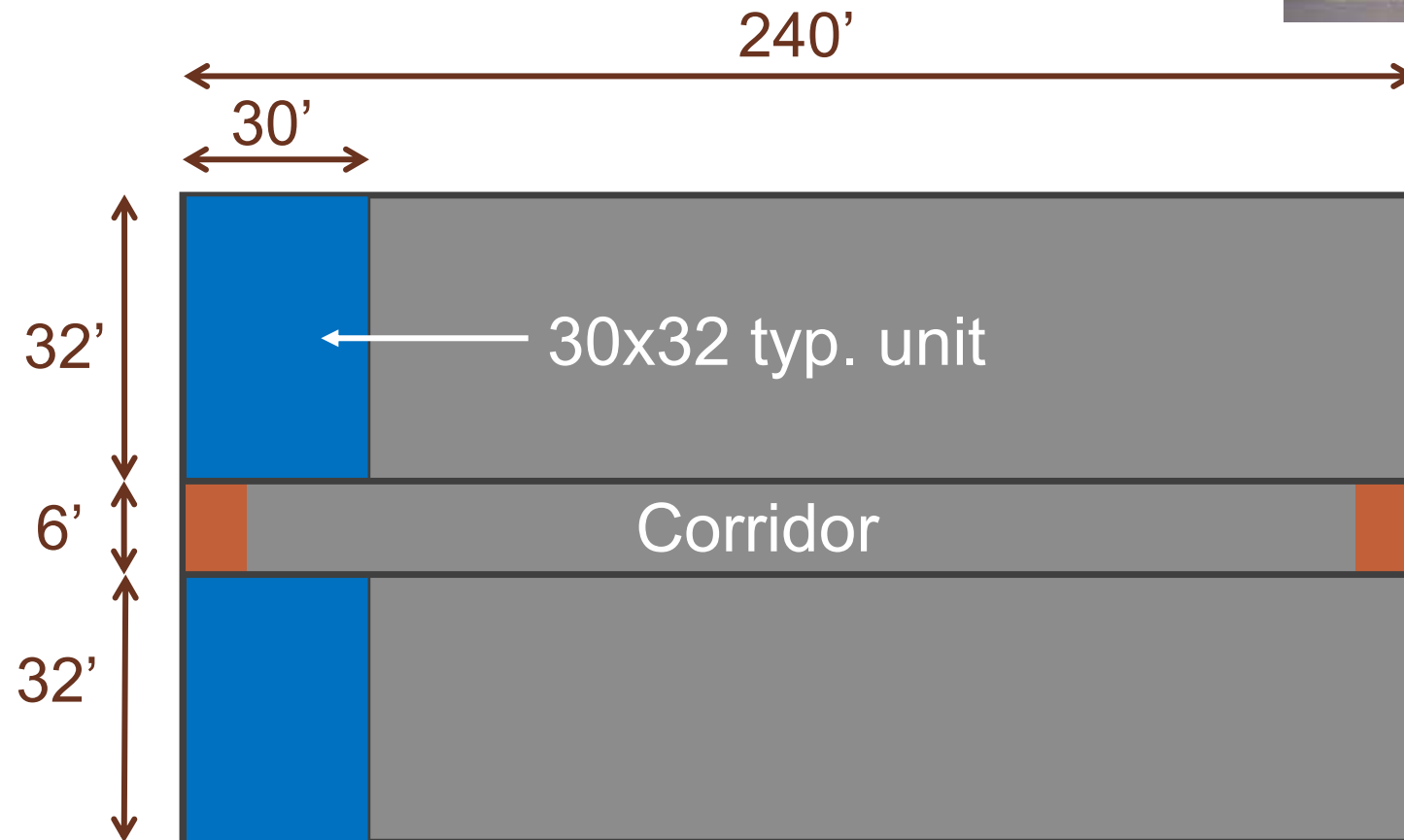




# Key Early Design Decisions

## Early Design Decision Example

7-story, multi-family building, typ. floor plan:

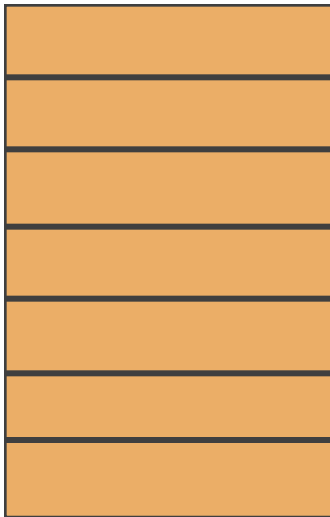


# Key Early Design Decisions

## Early Design Decision Example

### MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium



# Key Early Design Decisions

## Early Design Decision Example

### MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

### Implications of Type IV-C:

- 2 hr FRR, all exposed floor panels, beams, columns
- Likely will need at least 5-ply CLT / 2x6 NLT/DLT
- Efficient spans in the 14-17 ft range
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
- CLT exterior walls permitted



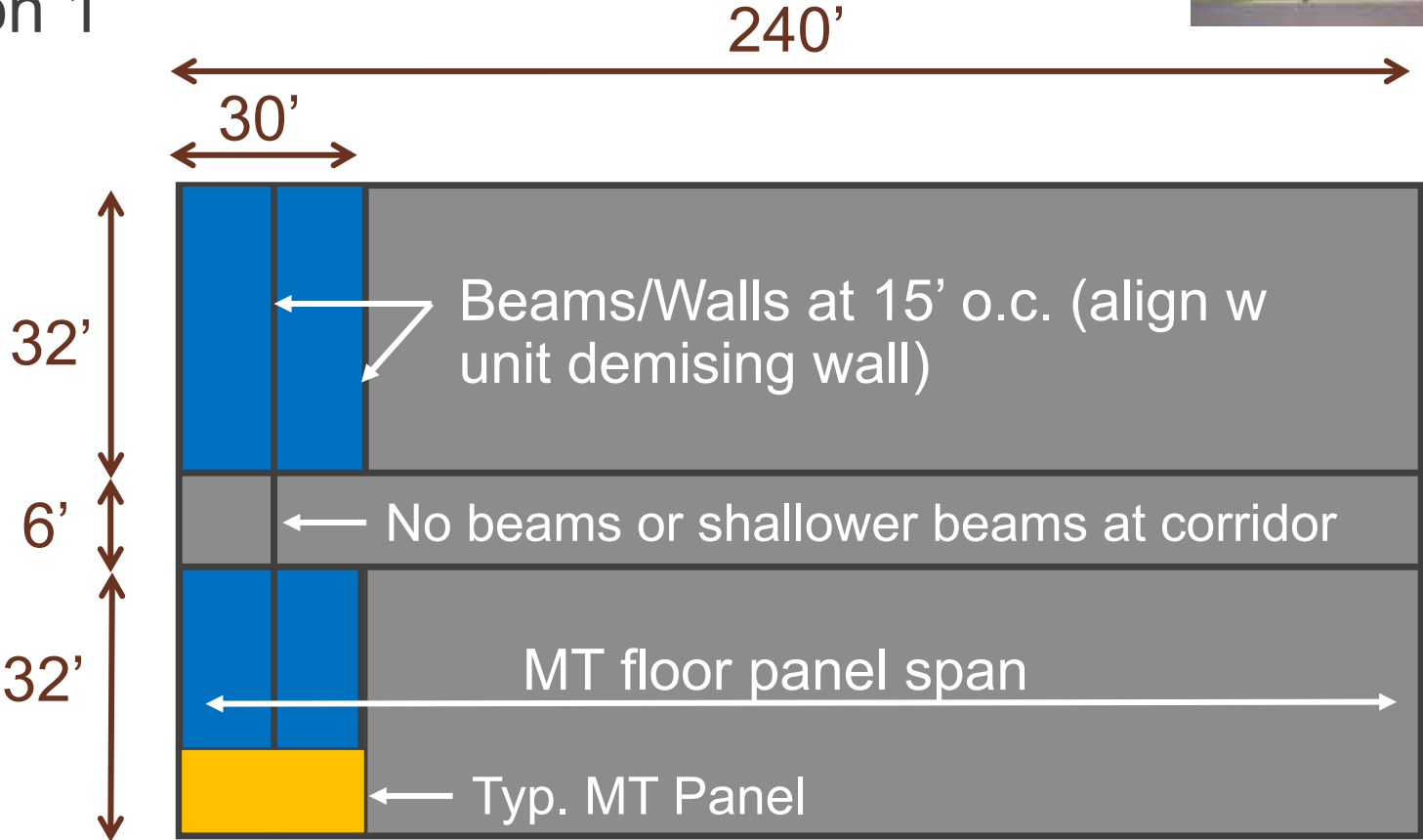


# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Grid Options

- Option 1

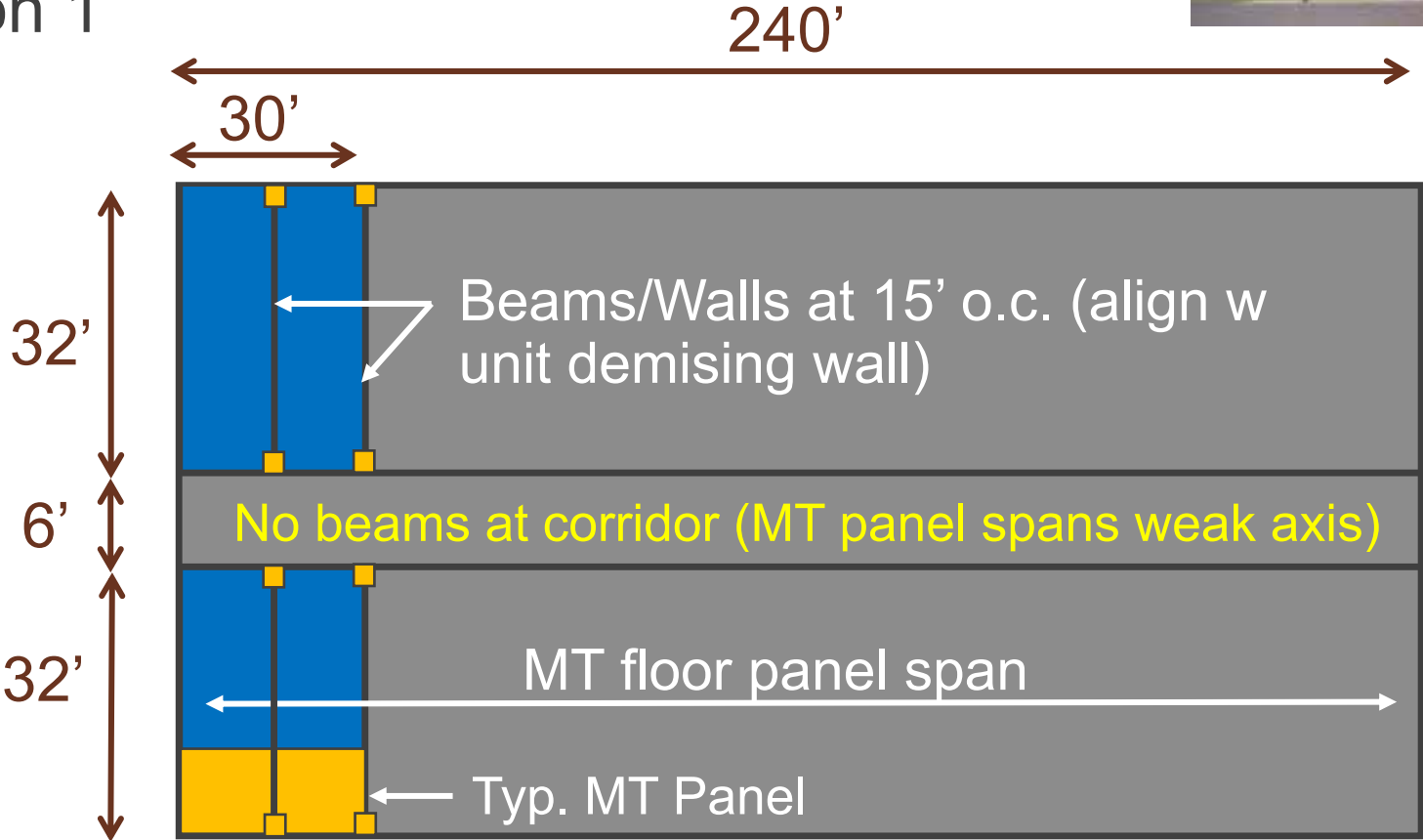


# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Grid Options

- Option 1

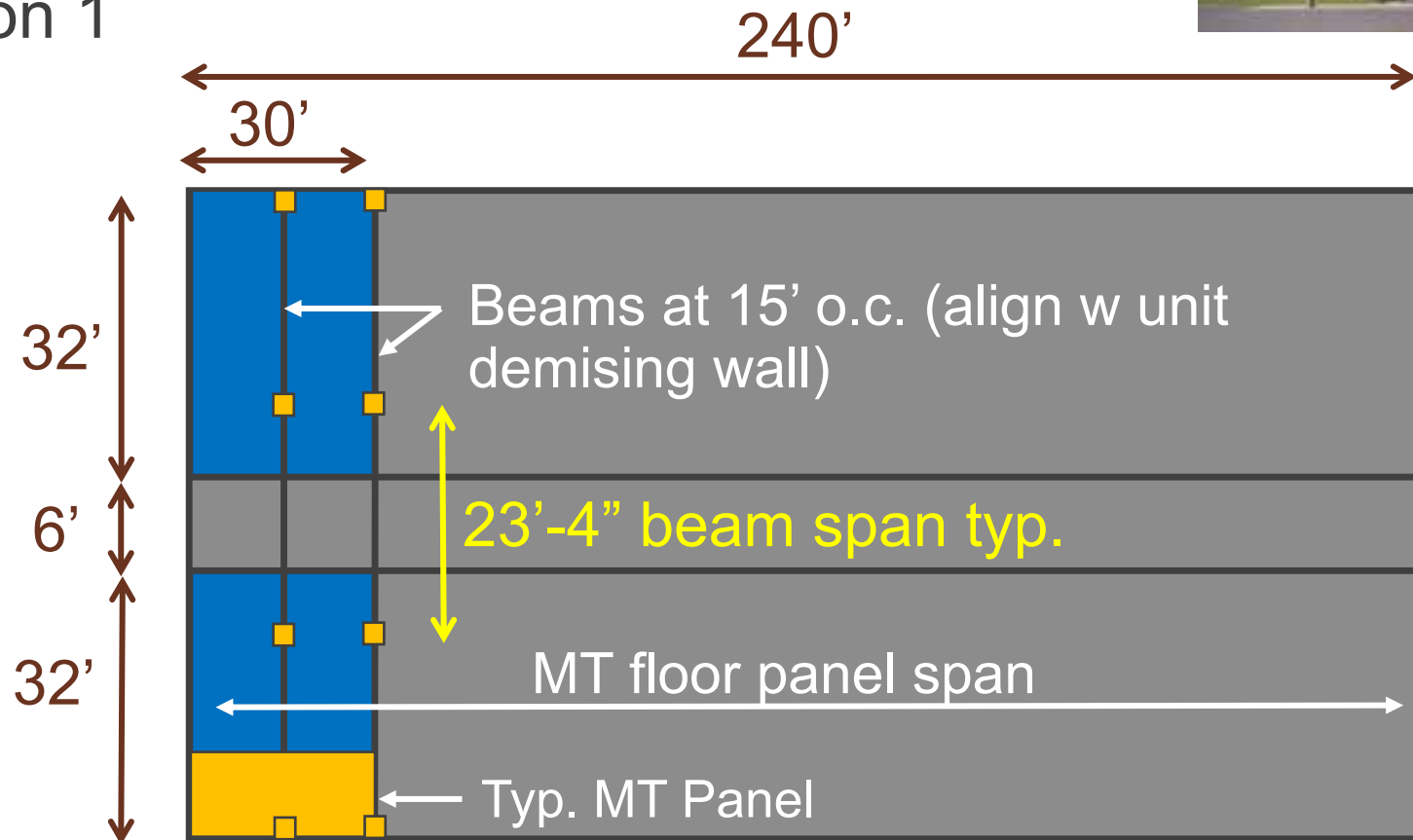


# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Grid Options

- Option 1



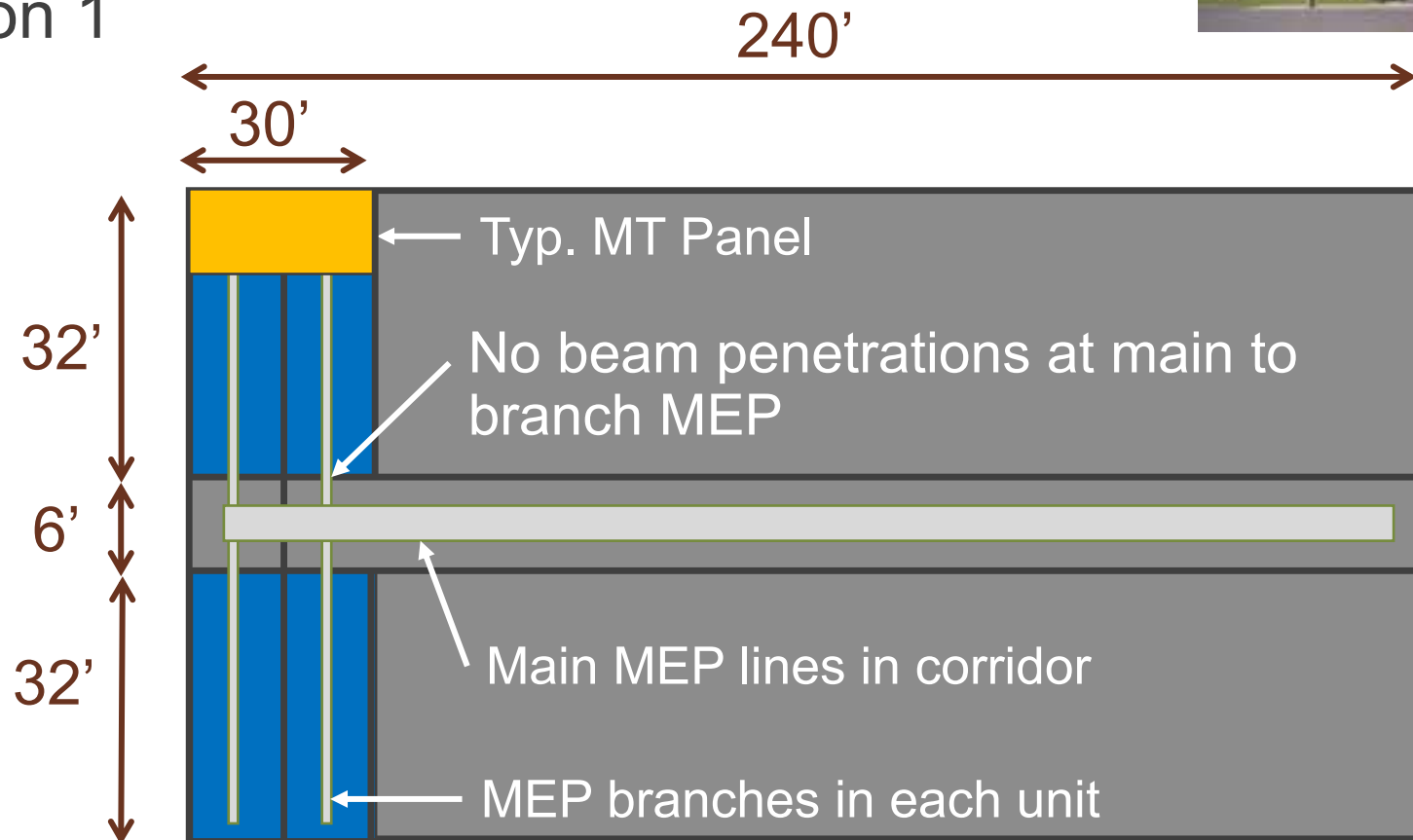


# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Grid Options

- Option 1



# Key Early Design Decisions

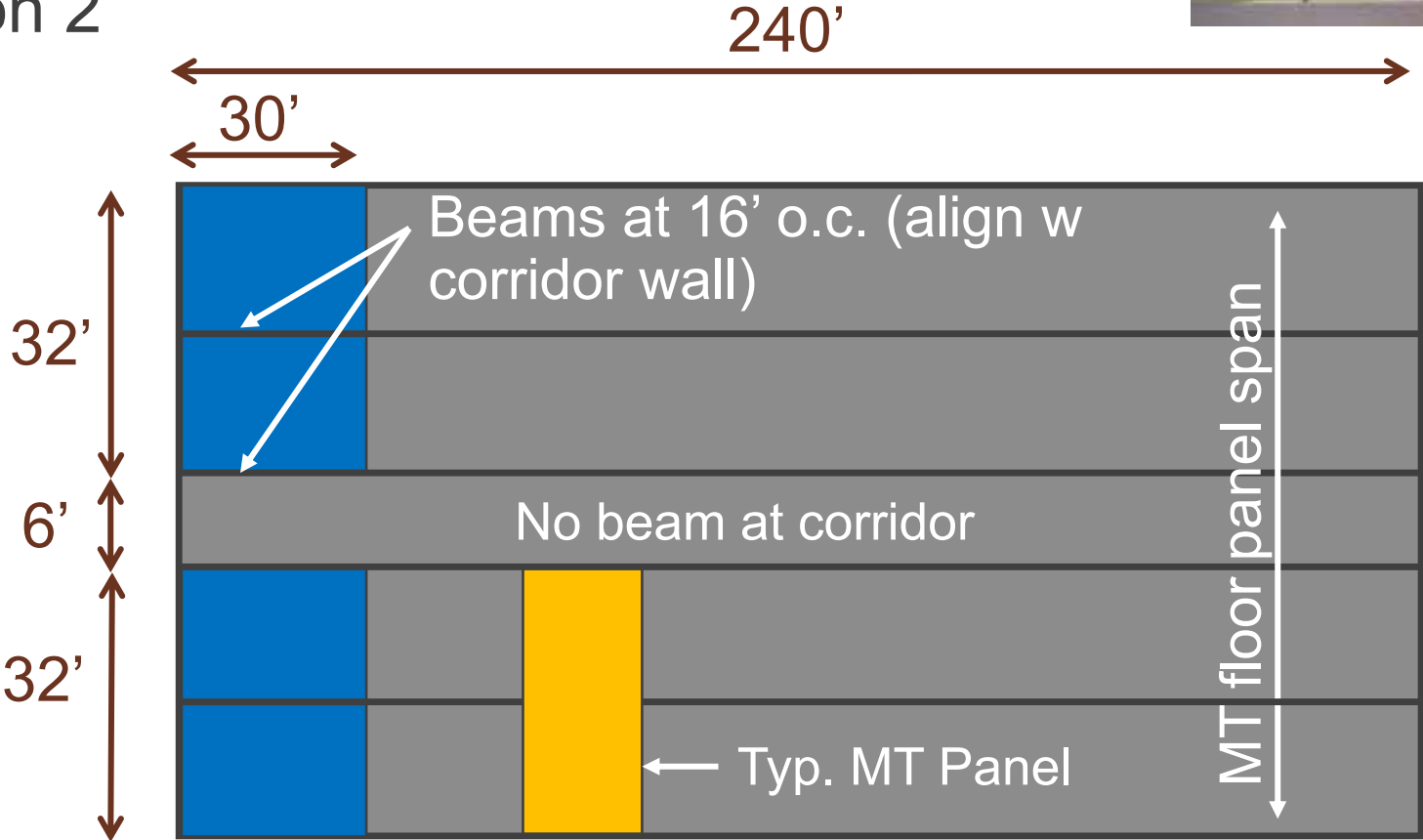
## Early Design Decision Example

### Type IV-C Grid Options

- Option 2



Credit: Monte French Design Studio

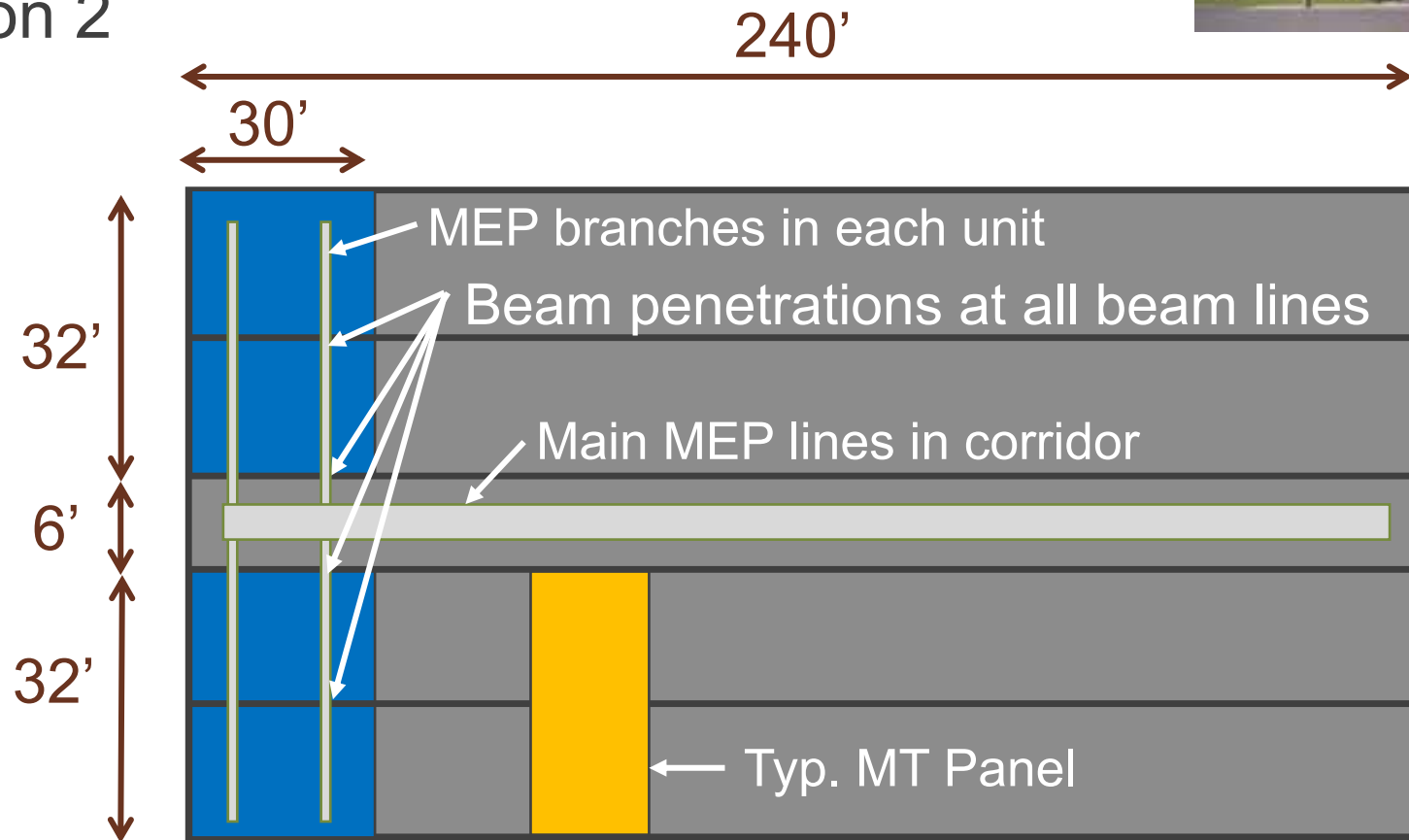


# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Grid Options

- Option 2





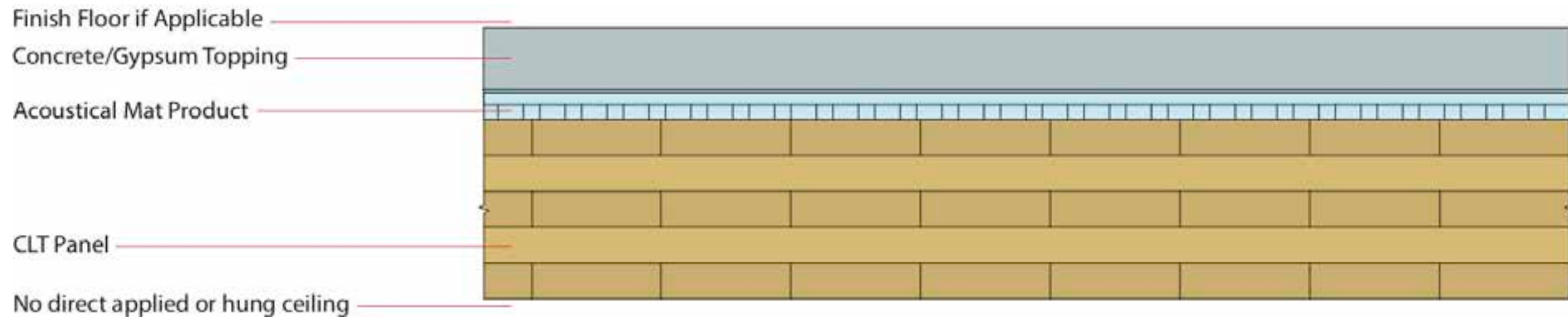
# Key Early Design Decisions

## Early Design Decision Example

### Type IV-C Floor Assembly Options



Credit: Monte French Design Studio



- 2-hr FRR: 5-ply CLT (tested assembly) or 7-ply CLT (char calculations)
- STC & IIC 50 min: 2" topping (5-ply CLT) or 1.5" topping (7-ply CLT)

Note: many other acoustic mat and topping options exist, one example shown here

Note: 5-ply is most efficient for the 15-16 ft panel spans shown

# Key Early Design Decisions

## Early Design Decision Example

### MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

### Implications of Type IIIA:

- 1 hr FRR
- Potential to use 3-ply or thin 5-ply CLT
- Efficient spans vary with panel thickness
- Efficient grids of that or multiples of that (i.e. 20x25, etc)
- 1 story Type IA podium required
- CLT exterior walls not permitted

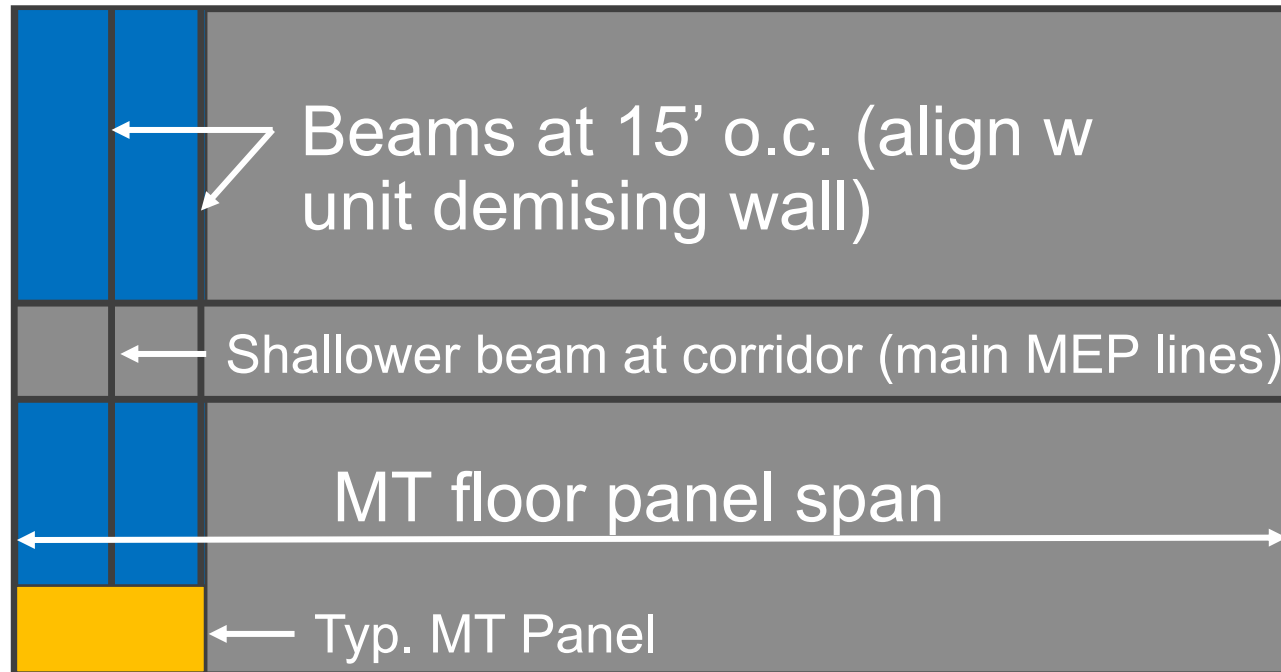


# Key Early Design Decisions

## Early Design Decision Example

### Type IIIA Grid Options

- Option 1



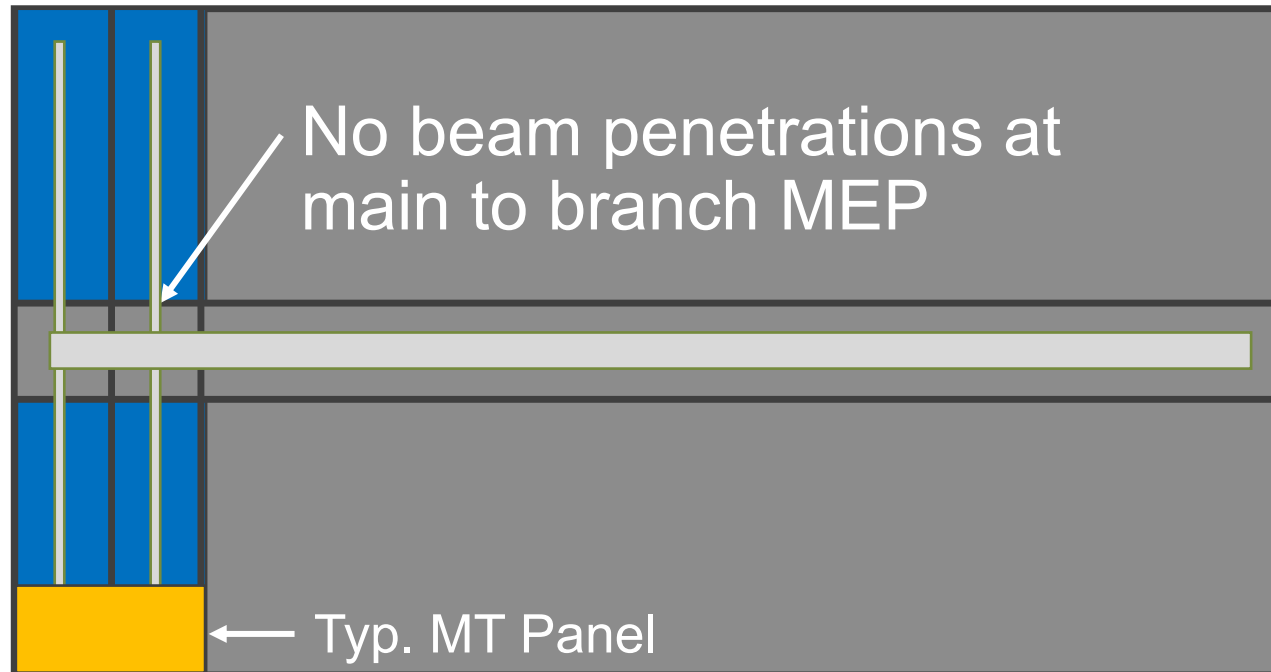


# Key Early Design Decisions

## Early Design Decision Example

### Type IIIA Grid Options

- Option 1

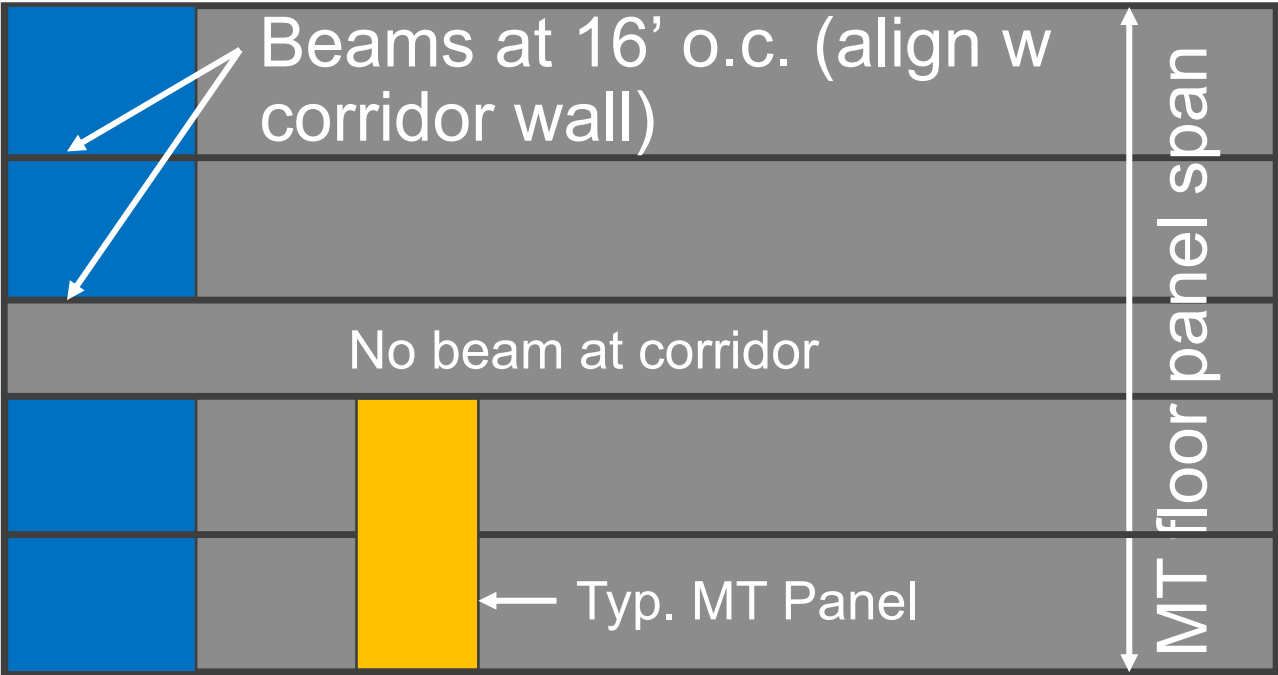


# Key Early Design Decisions

## Early Design Decision Example

### Type IIIA Grid Options

- Option 2

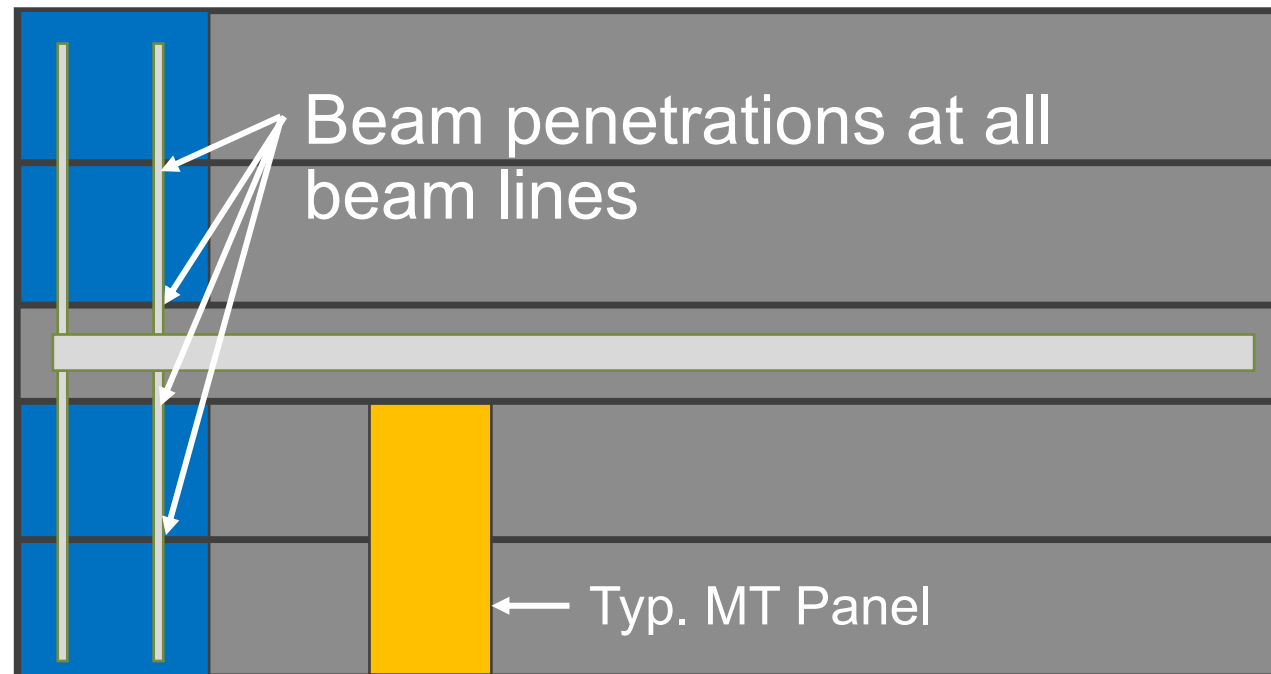


# Key Early Design Decisions

## Early Design Decision Example

### Type IIIA Grid Options

- Option 2

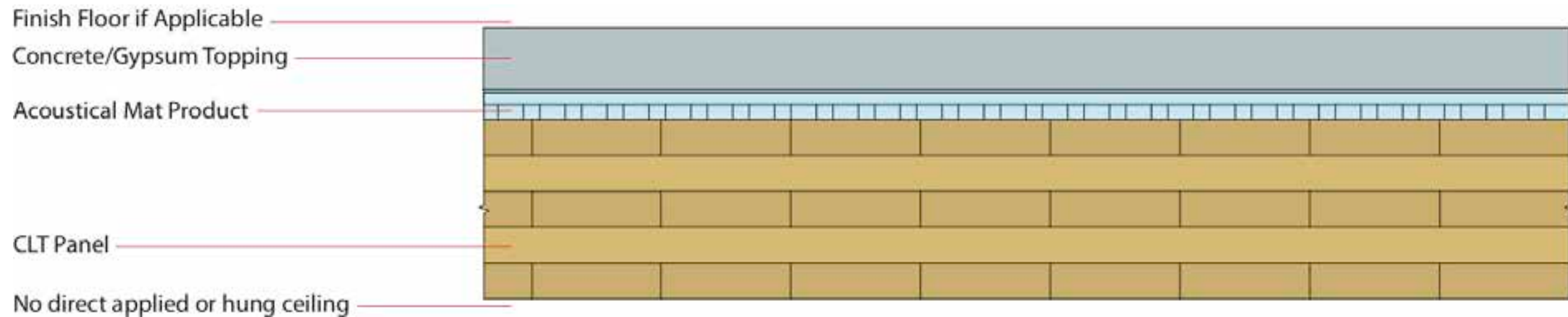




# Key Early Design Decisions

## Early Design Decision Example

### Type IIIA Floor Assembly Options



- 1-hr FRR: 5-ply CLT (tested assembly or char calculations)
- STC & IIC 50 min: 2" topping (5-ply CLT)

Note: many other acoustic mat and topping options exist, one example shown here

Note: 5-ply is most efficient for the 15-16 ft panel spans shown

# Key Early Design Decisions

## Early Design Decision Example

### MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

### Type IV-HT in Group R Occupancy:

- Separation walls (fire partitions) and horizontal separation (horizontal assemblies) between dwelling units require a 1-hour rating.
- Floor panels require a 1-hour rating in addition to minimum sizes
- Essentially the same panel and grid options as IIIA

Ref. IBC 420.2, 420.3, 708.3, 711.2.4.3



# Key Early Design Decisions

## Early Design Decision Example

### MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

### Implications of Type IV-HT:

- 1 hr FRR and min. sizes
- Potential to use 3-ply or thin 5-ply CLT
- Efficient spans vary with panel thickness
- Efficient grids of that or multiples of that (i.e. 20x25, etc)
- 1 story Type IA podium required
- CLT exterior walls permitted





# Reduce Risk

## Optimize Costs

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

## 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 -  
Mansfield, OH  
ARCHITECT  
Parker  
MECHANICAL  
Kemper Gensel & Associates  
Equilibrium Consulting  
CONTRACTOR  
Sommerville



**Download Checklists at**  
**[www.woodworks.org](http://www.woodworks.org)**

[www.woodworks.org/wp-content/uploads/wood\\_solution\\_paper-Mass-Timber-Design-Cost-Optimization-Checklists.pdf](http://www.woodworks.org/wp-content/uploads/wood_solution_paper-Mass-Timber-Design-Cost-Optimization-Checklists.pdf)



## 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



# Questions?



## Speaker Name

**Title**

Phone

email

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





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