



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

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

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, layout, floor to floor, aesthetics, sustainability goals)
- Resulting **code options** & design implications

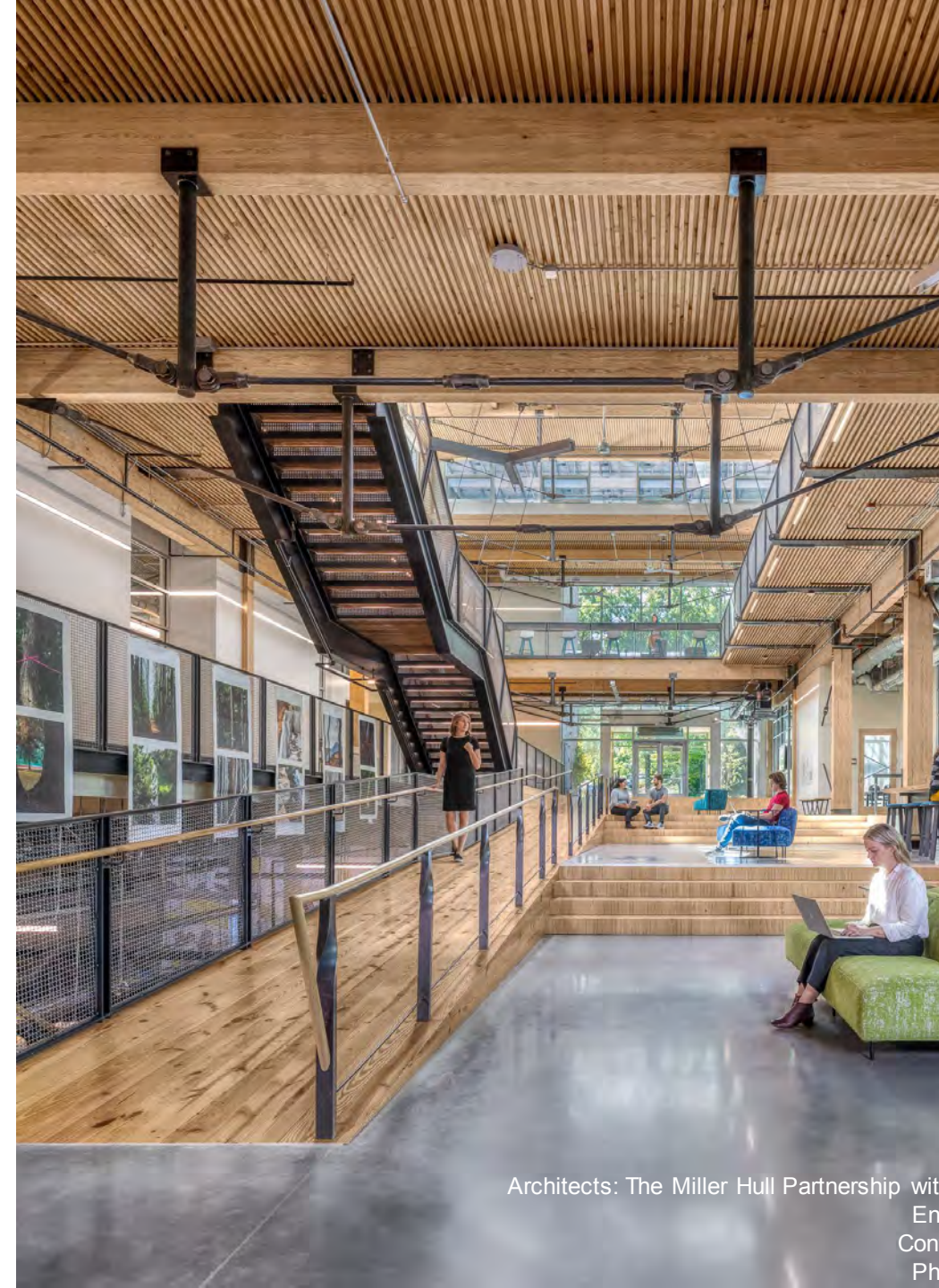


Key Early Design Decisions

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
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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:

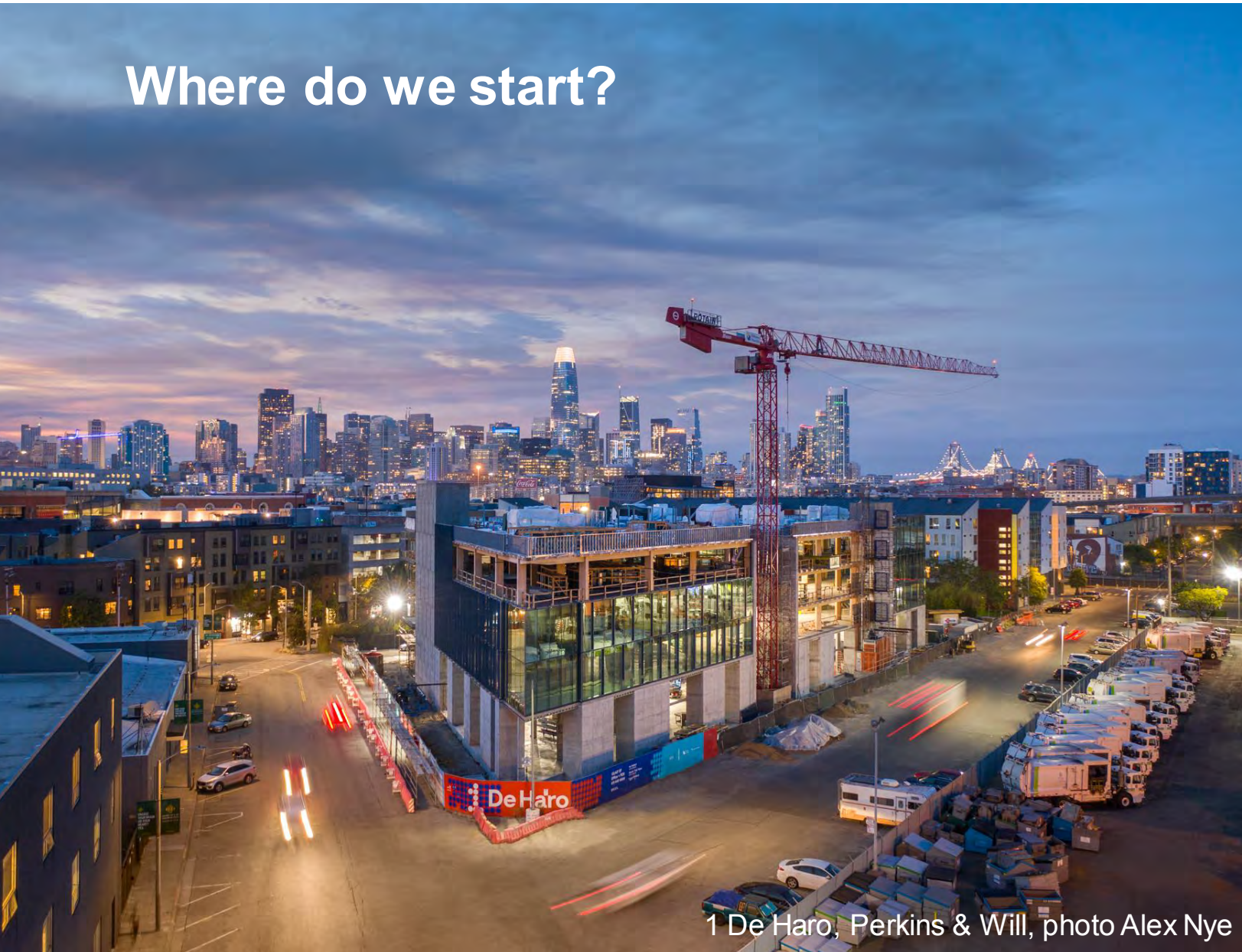
- **Grid** informs efficient spans, MEP layout
- **Manufacturer capabilities** inform member sizes, grids & connections
- **Lateral system** informs connections, construction sequencing

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 ² (IBC Table 506.2) | | | | | | | |
| A-2, A-3, A-4 | 135,000 | 90,000 | 56,250 | 45,000 | 42,000 | 28,500 | 34,500 | 18,000 |
| B | 324,000 | 216,000 | 135,000 | 108,000 | 85,500 | 57,000 | 54,000 | 27,000 |
| R-2 | 184,500 | 123,000 | 76,875 | 61,500 | 72,000 | 48,000 | 36,000 | 21,000 |

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 ² (IBC Table 506.2) | | | | | | | |
| A-2, A-3, A-4 | 135,000 | 90,000 | 56,250 | 45,000 | 42,000 | 28,500 | 34,500 | 18,000 |
| B | 324,000 | 216,000 | 135,000 | 108,000 | 85,500 | 57,000 | 54,000 | 27,000 |
| R-2 | 184,500 | 123,000 | 76,875 | 61,500 | 72,000 | 48,000 | 36,000 | 21,000 |

Key Early Design Decisions

Fire-Resistance Ratings

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

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

| BUILDING ELEMENT | TYPE I | | TYPE II | | TYPE III | | TYPE IV | | | | TYPE V | |
|---|-------------------|----------------------|-------------------|----------------|-------------------|---|----------------|----------------|----------------|-----------------------------|-------------------|---|
| | A | B | A | B | A | B | A | B | C | HT | A | B |
| Primary structural frame ^f (see Section 202) | 3 ^{a, b} | 2 ^{a, b, c} | 1 ^{b, c} | 0 ^c | 1 ^{b, c} | 0 | 3 ^a | 2 ^a | 2 ^a | HT | 1 ^{b, c} | 0 |
| Bearing walls | | | | | | | | | | | | |
| Exterior ^{a, f} | 3 | 2 | 1 | 0 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 0 |
| Interior | 3 ^a | 2 ^a | 1 | 0 | 1 | 0 | 3 | 2 | 2 | 1/HT ^g | 1 | 0 |
| Nonbearing walls and partitions Exterior | | | | | See Table 705.5 | | | | | | | |
| Nonbearing walls and partitions Interior ^d | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | See Section 2304.11.2 | 0 | 0 |
| Floor construction and associated secondary structural members (see Section 202) | 2 | 2 | 1 | 0 | 1 | 0 | 2 | 2 | 2 | HT | 1 | 0 |
| Roof construction and associated secondary structural members (see Section 202) | 1½ ^b | 1 ^{b, c} | 1 ^{b, c} | 0 ^c | 1 ^{b, c} | 0 | 1½ | 1 | 1 | HT | 1 ^{b, c} | 0 |

Key Early Design Decisions

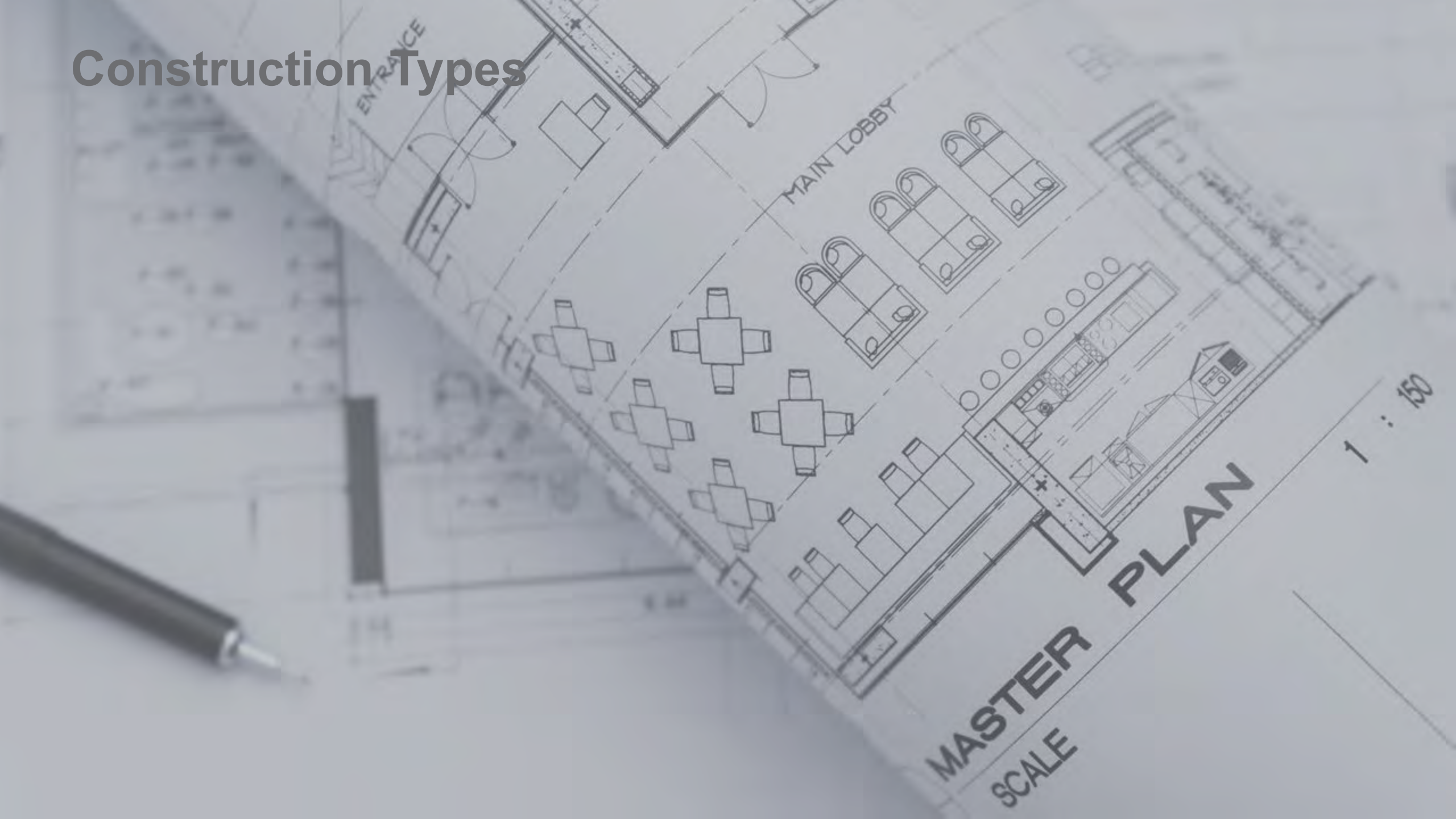
Fire-Resistance Ratings (FRR)

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

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



Construction Types



Construction Types

When does the code allow mass timber to be used?

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

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



Construction Types

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

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

However, there are exceptions including several for mass timber

Construction Types

Where does the code allow MT to be used?

- 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



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 ³ / ₄ x 8 ¹ / ₄ | 7 x 7 ¹ / ₂ |
| | Beams | 6 x 10 | 5 x 10 ¹ / ₂ | 5 ¹ / ₄ x 9 ¹ / ₂ |
| Roof | Columns | 6 x 8 | 5 x 8 ¹ / ₄ | 5 ¹ / ₄ x 7 ¹ / ₂ |
| | Beams* | 4 x 6 | 3 X 6 ⁷ / ₈ | 3 ¹ / ₂ X 5 ¹ / ₂ |

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

*3” nominal width allowed where sprinklered



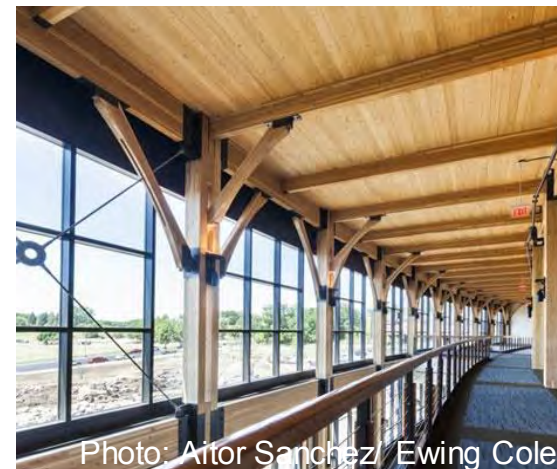
Photo: WoodWorks

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

Minimum 1" noncombustible material

oor panel

Type IV concealed spaces

Can I have a dropped ceiling? Raised access floor?

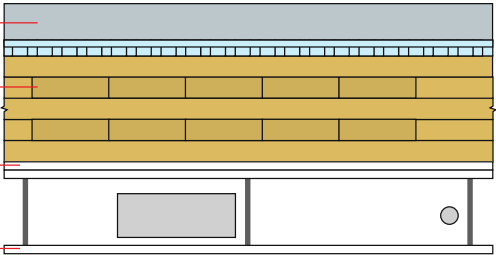
With Dropped ceiling

Minimum 1" noncombustible material

Mass timber floor panel

Two layers 5/8" Type X gypsum

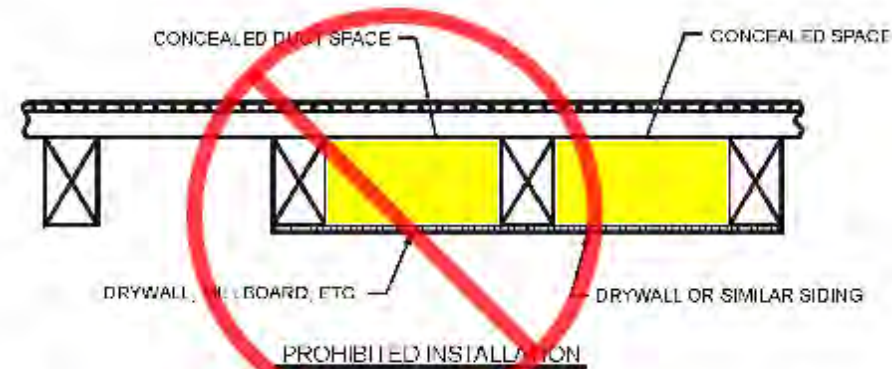
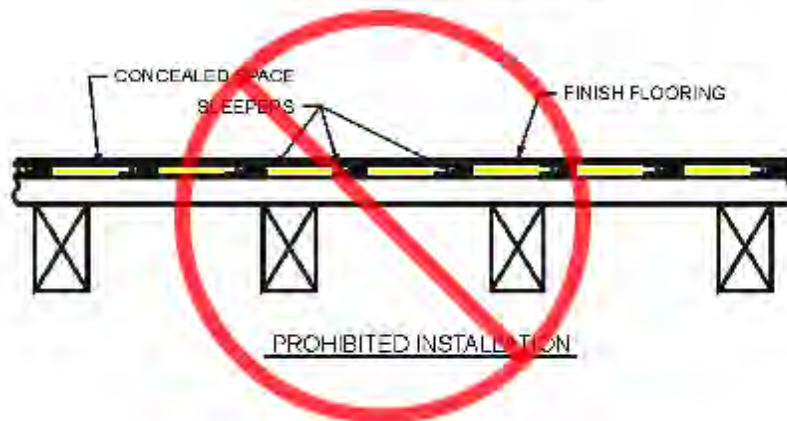
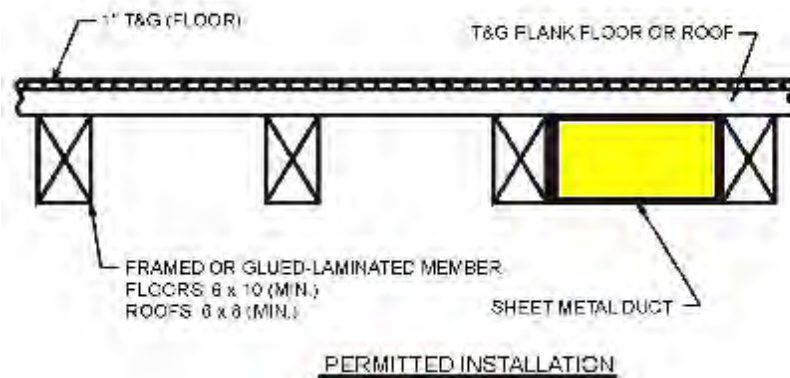
Dropped ceiling



Construction Types

Type IV concealed spaces

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



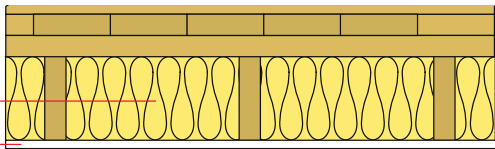
Construction Types

Type IV concealed space options within 2021 IBC

Dropped ceiling

Combustible insulation

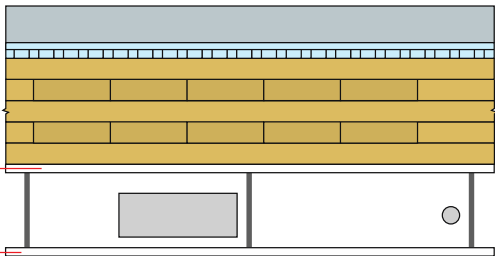
Dropped ceiling



Option 3:

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

Dropped ceiling



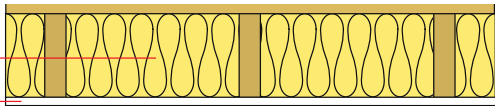
Construction Types

Type IV concealed space options within 2021 IBC

Dropped ceiling

Noncombustible insulation

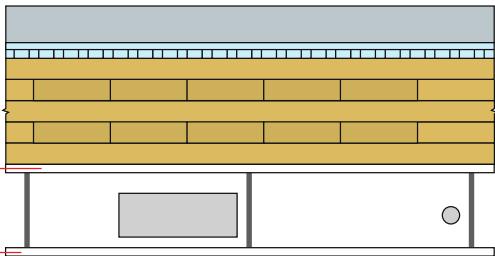
Dropped ceiling



Option 3:

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

Dropped ceiling



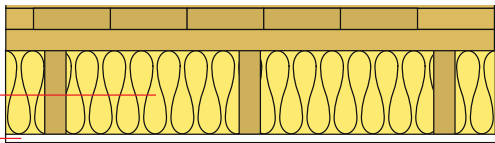
Construction Types

Type IV concealed space options within 2021 IBC

Dropped ceiling

Noncombustible insulation

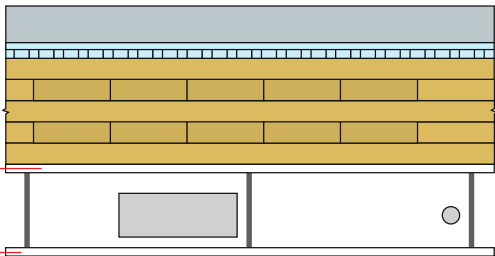
Dropped ceiling



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?*¹

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.



INTRO, Cleveland | Cleveland, Ohio
Harbor Bay Real Estate Advisors
HPA Architecture



The John W. Olver Design Building at UMass Amherst includes exposed wood structure in some areas and dropped ceilings in others. Architect: Leers Weinzapfel Associates

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



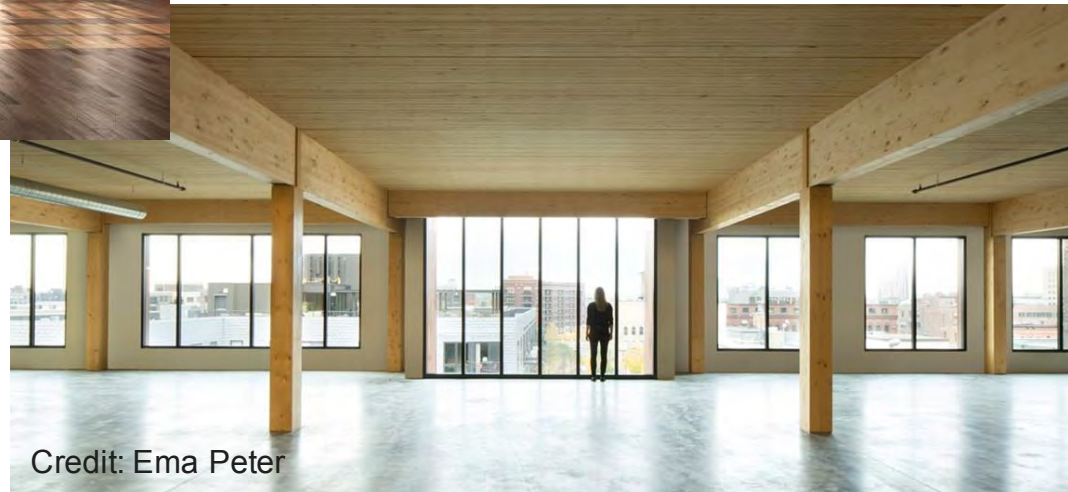
Image: Christian Columbres Photography

Construction Types



Type III: 6 stories

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



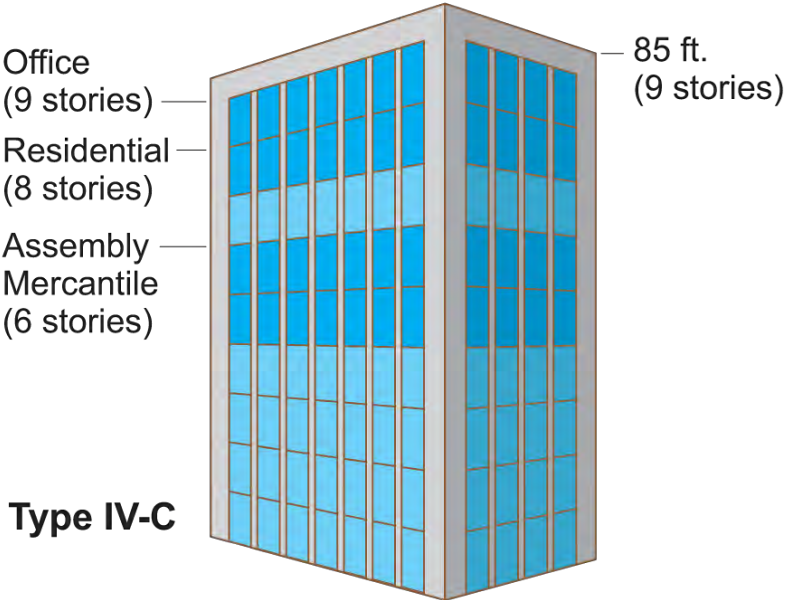
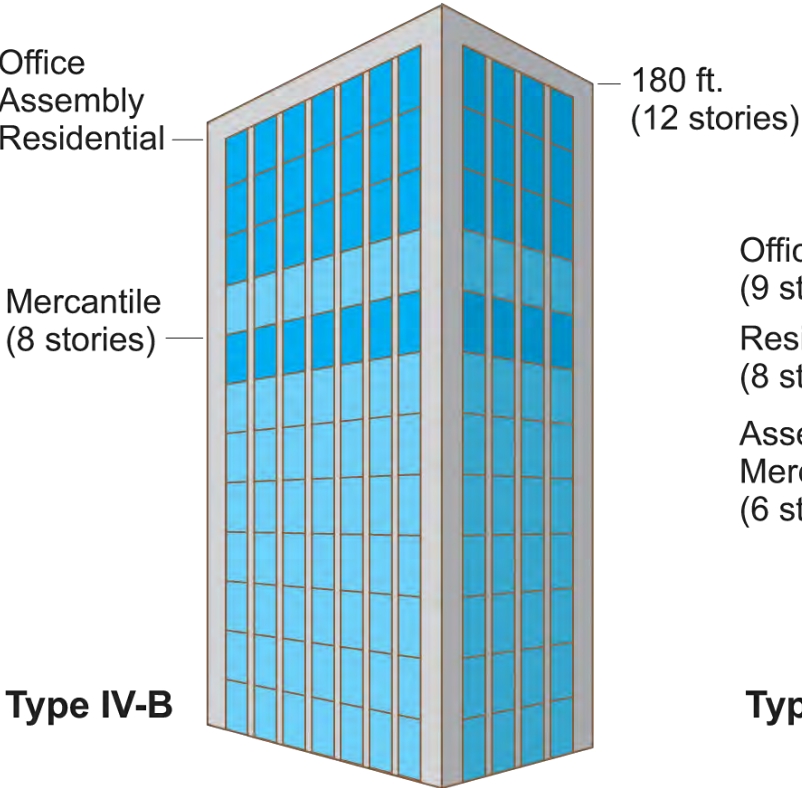
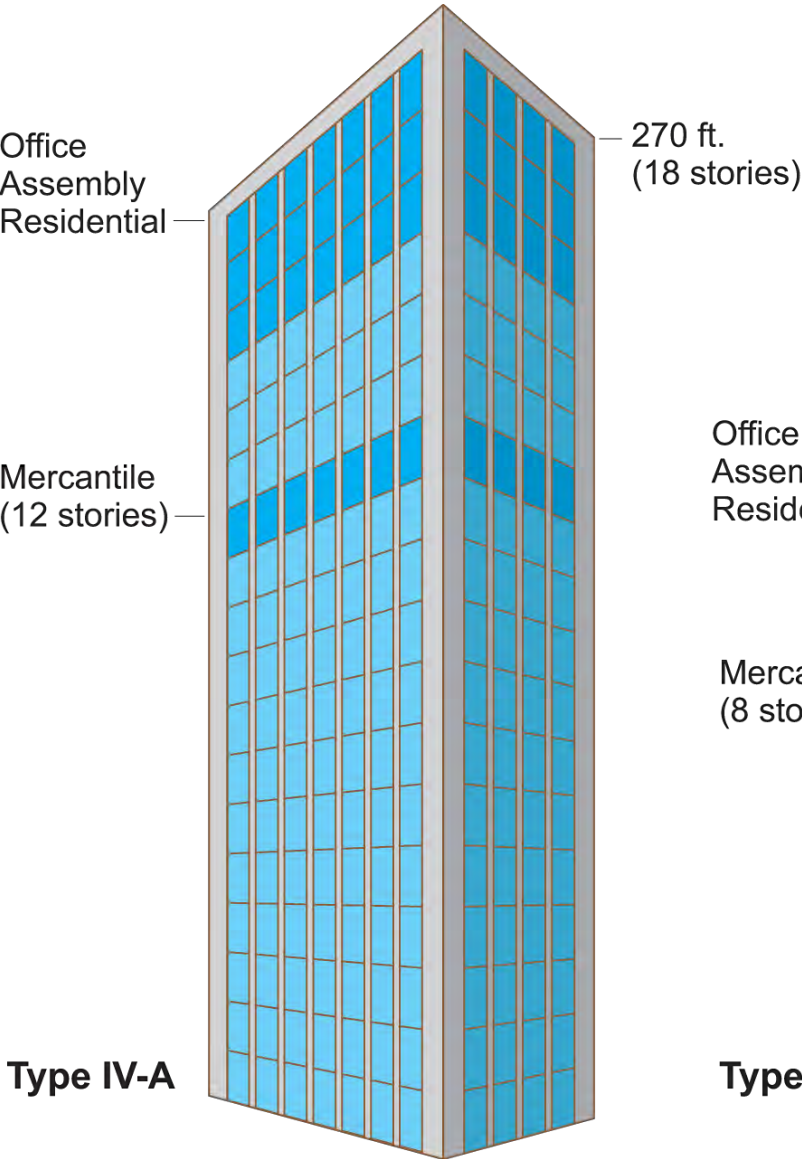
Type IV: 6 stories



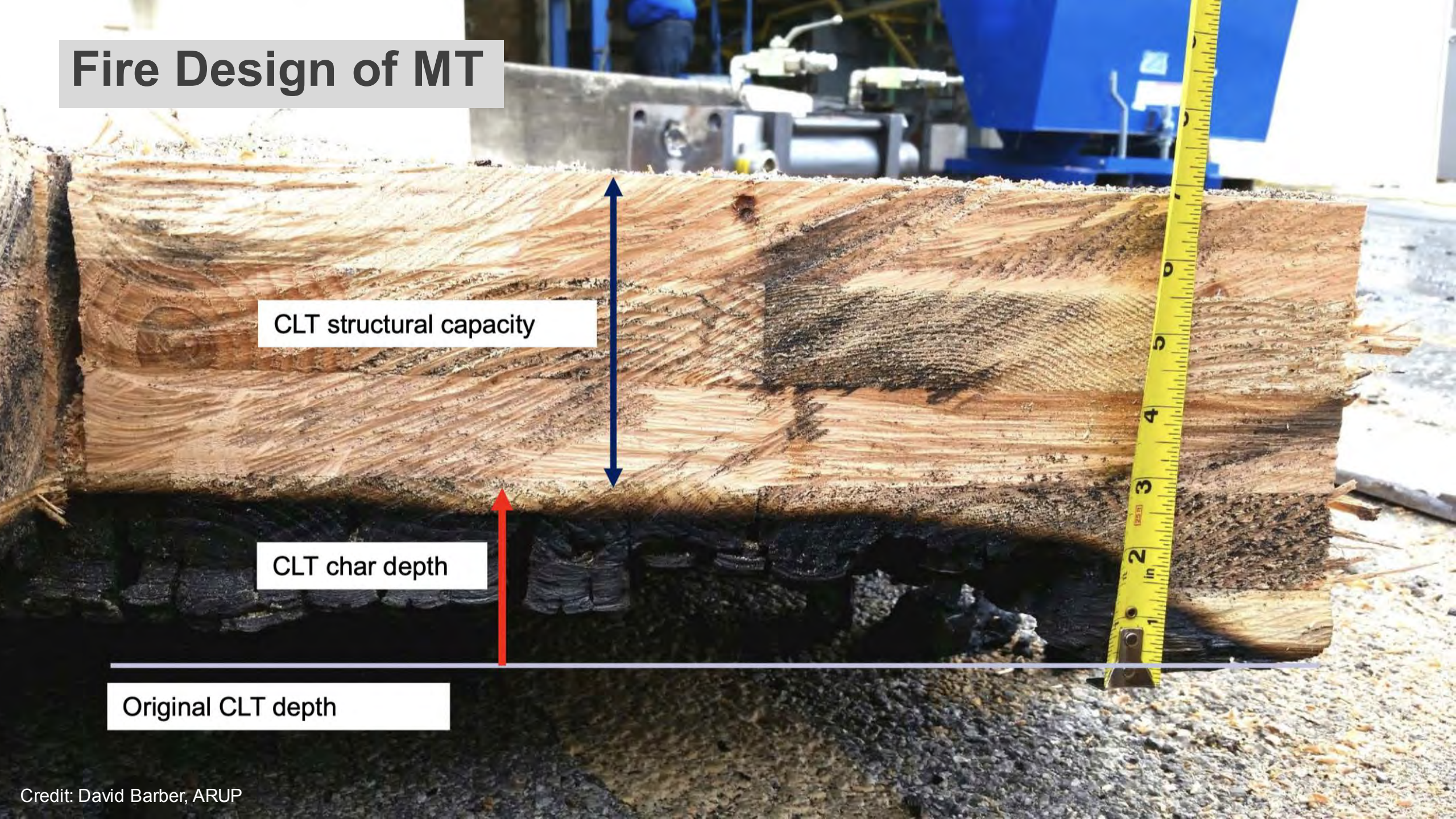
Type V: 4 stories

Construction Types

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



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 ^f (see Section 202) | 3 ^a | 2 ^a | 1 | 0 | 1 | 0 | HT | 1 | 0 |
| Bearing walls | | | | | | | | | |
| Exterior ^{e, f} | 3 | 2 | 1 | 0 | 2 | 2 | 2 | 1 | 0 |
| Interior | 3 ^a | 2 ^a | 1 | 0 | 1 | 0 | 1/HT | 1 | 0 |
| Nonbearing walls and partitions | See Table 602 | | | | | | | | |
| Exterior | | | | | | | | | |
| Nonbearing walls and partitions | | | | | | | See | | |
| Interior ^d | 0 | 0 | 0 | 0 | 0 | 0 | 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) | 1½ ^b | 1 ^{b, c} | 1 ^{b, c} | 0 ^c | 1 ^{b, c} | 0 | HT | 1 ^{b, c} | 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 ^f (see Section 202) | 3 ^{a, b} | 2 ^{a, b, c} | 1 ^{b, c} | 0 ^c | 1 ^{b, c} | 0 | 3 ^a | 2 ^a | 2 ^a | HT | 1 ^{b, c} | 0 |
| Bearing walls | | | | | | | | | | | | |
| Exterior ^{e, f} | 3 | 2 | 1 | 0 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 0 |
| Interior | 3 ^a | 2 ^a | 1 | 0 | 1 | 0 | 3 | 2 | 2 | 1/HT ^g | 1 | 0 |
| Nonbearing walls and partitions Exterior | | | | | See Table 705.5 | | | | | | | |
| Nonbearing walls and partitions Interior ^d | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | See Section 2304.11.2 | 0 | 0 |
| Floor construction and associated secondary structural members (see Section 202) | 2 | 2 | 1 | 0 | 1 | 0 | 2 | 2 | 2 | HT | 1 | 0 |
| Roof construction and associated secondary structural members (see Section 202) | 1 ^{1/2} ₂ | 1 ^{b, c} | 1 ^{b, c} | 0 ^c | 1 ^{b, c} | 0 | 1 ^{1/2} ₂ | 1 | 1 | HT | 1 ^{b, c} | 0 |

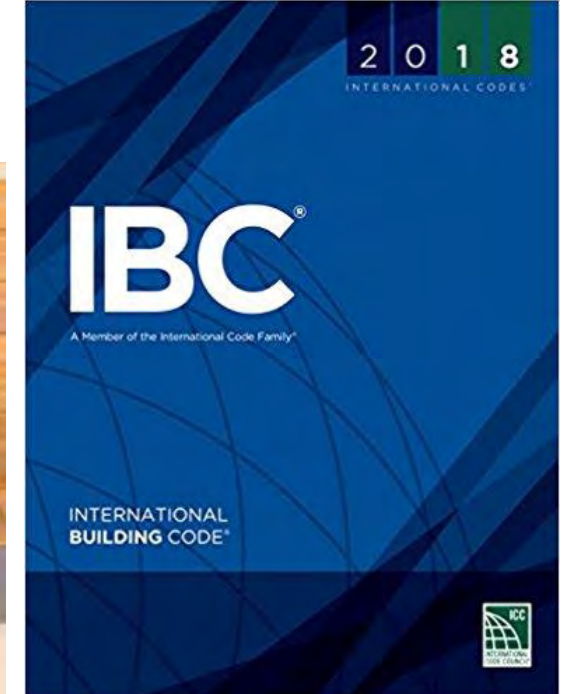
Source: 2021 IBC

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

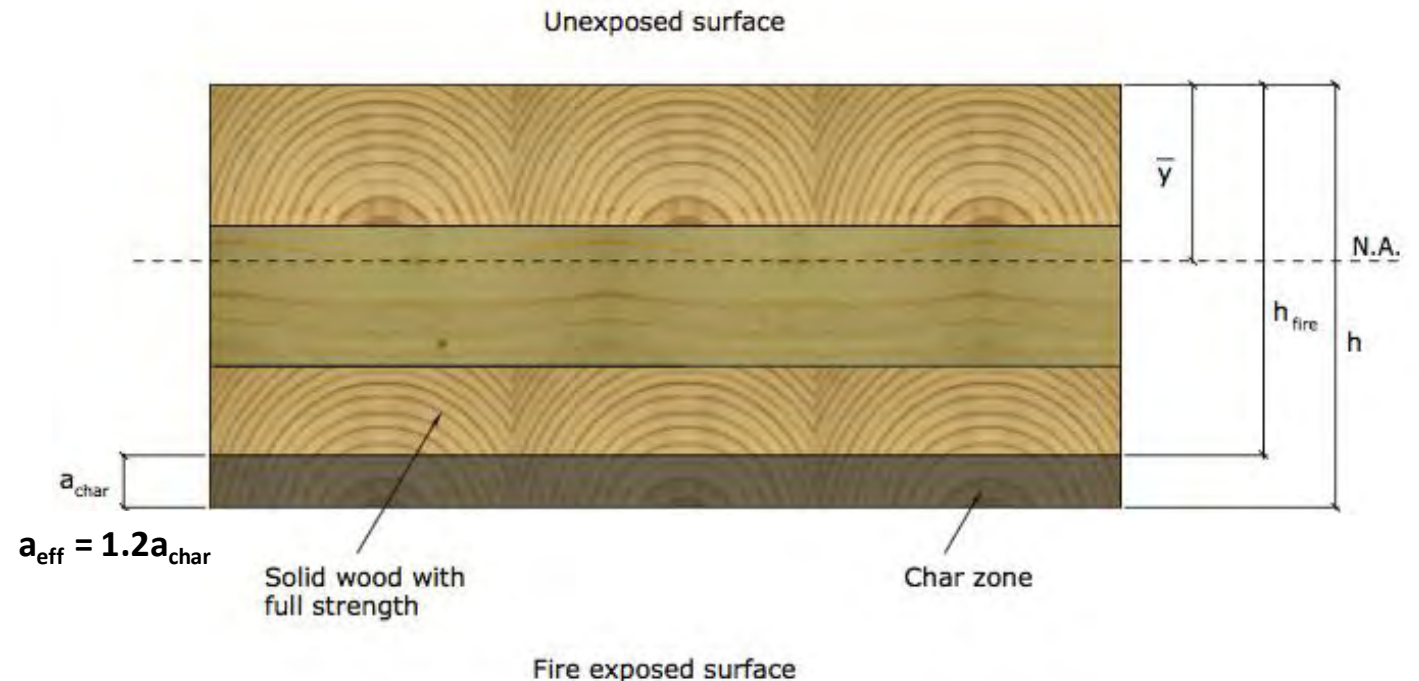


Credit: Kaiser+Path

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)**"

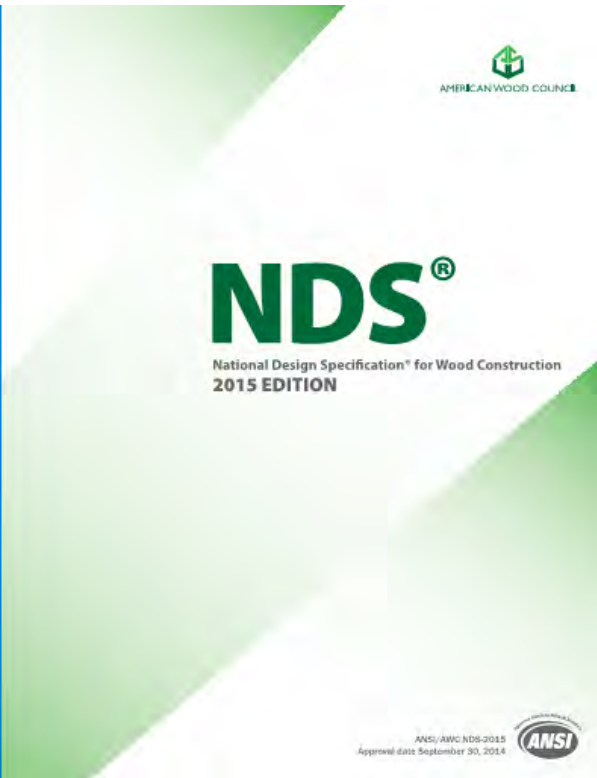


NDS Chapter 16

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 |



Credit: FPInnovations

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



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 |

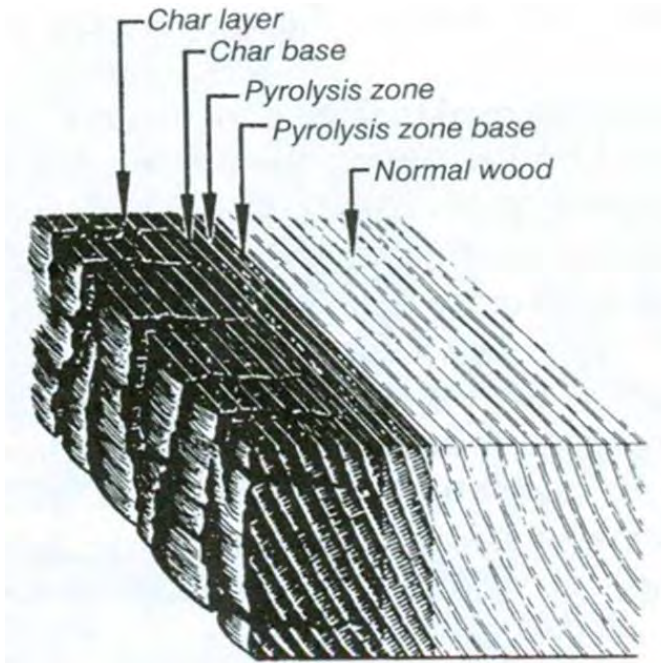
Table 16.2.1B Effective Char Depths (for CLT with $\beta_n=1.5$ in./hr.)

| 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 |

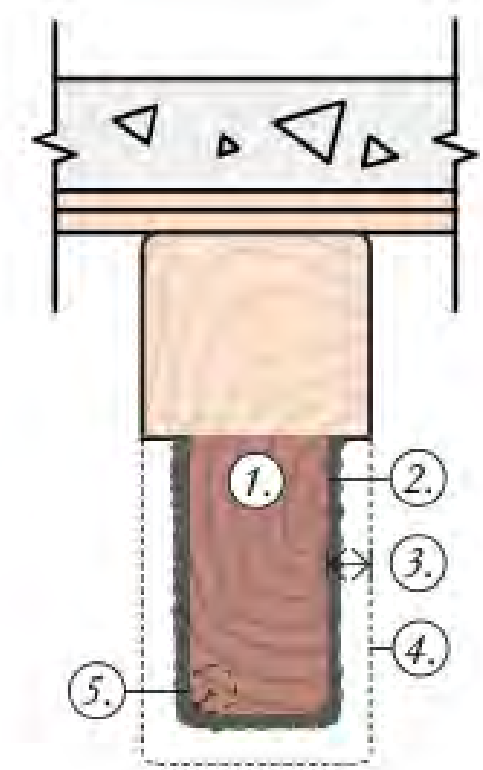
FRR Design of MT

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 Design¹

| | | | Design Stress to Member Strength Factor | ASD | | | | |
|--------------------------|-----------------|---|---|--------------------------|----------------------------|------------------------------|------------------------------------|--------------------------------------|
| | | | | Size Factor ² | Volume Factor ² | Flat Use Factor ² | Beam Stability Factor ³ | Column Stability Factor ³ |
| Bending Strength | F _b | x | 2.85 | C _F | C _V | C _{fu} | C _L | - |
| Beam Buckling Strength | F _{bE} | x | 2.03 | - | - | - | - | - |
| Tensile Strength | F _t | x | 2.85 | C _F | - | - | - | - |
| Compressive Strength | F _c | x | 2.58 | C _F | - | - | - | C _P |
| Column Buckling Strength | F _{cE} | x | 2.03 | - | - | - | - | - |

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

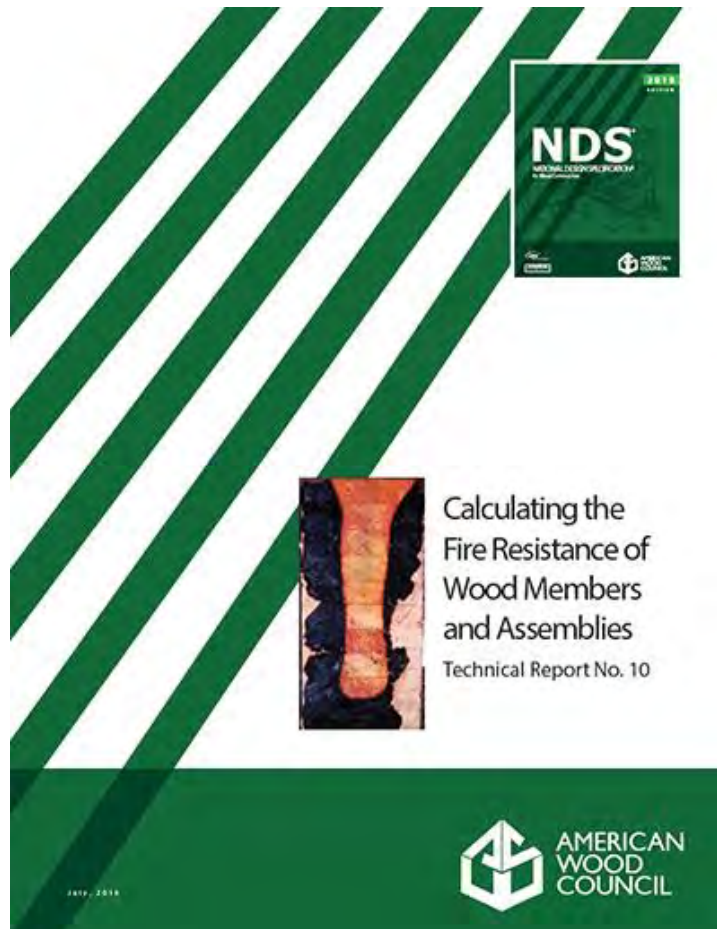
2. Factor shall be based on initial cross-section dimensions.

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



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 $q_{\text{live}}=80$ psf and $q_{\text{dead}}=30$ 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):

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

Calculate maximum induced moment (per foot of width):

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

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:

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

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

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

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

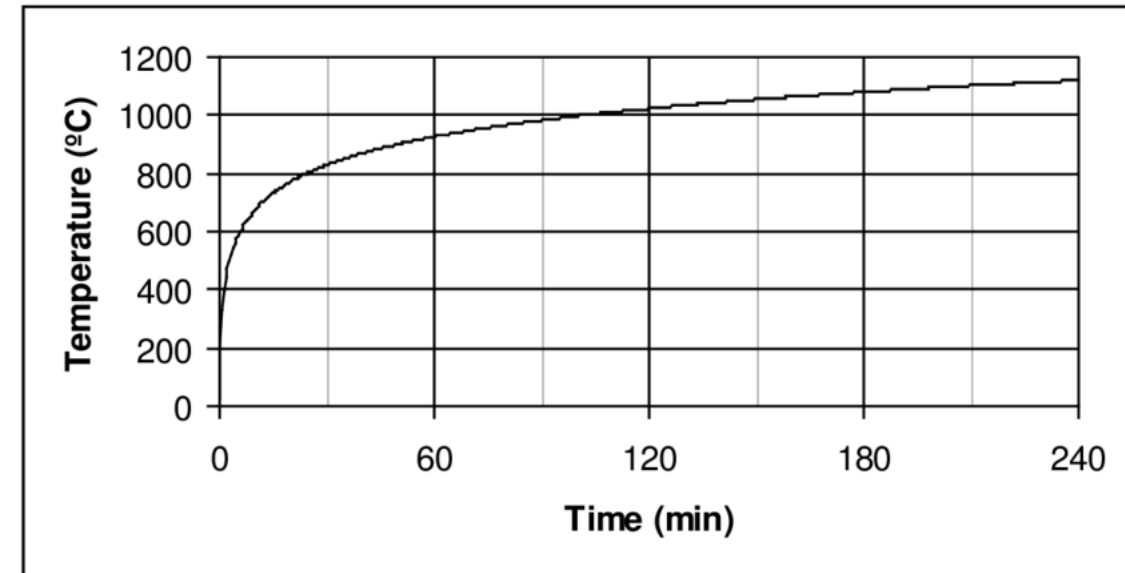
(note: serviceability check is not performed to simplify the design example, but should be done in typical structural design).

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



TEST REPORT
for
American Wood Council
222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

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


Page 1 of 53

Test Report No: WP-1950
Assignment No: K-1089
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)
Test Date: October 4, 2012
Report Date: October 15, 2012

Prepared by: 
Michael J. Rizzo
Test Engineer

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

The results reported in this document apply to specific samples submitted for measurement.
No responsibility is assumed for performance of any other specimen.
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The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by this laboratory.



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


EVALUATION CENTER
18015 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, and CAN/ULC S401, Standard Methods of Fire**



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
Noureddine Bénichou, 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 x 4.48 in) | Nordic | SPF 1650 Fb 1.3 EMSR x SPF #3 | 2 layers 1/2" Type X gypsum | Half-Lap | None | Reduced 36% Moment Capacity | 1 | 1 (Test 1) | NRC Fire Laboratory |
| 3-ply CLT (105mm x 4.13 in) | Structurlam | SPF #1/#2 x SPF #1/#2 | 1 layer 5/8" Type X gypsum | Half-Lap | None | Reduced 75% Moment Capacity | 1 | 1 (Test 3) | NRC Fire Laboratory |
| 5-ply CLT (173mm x 6.875") | Nordic | EI | None | Topside Splice | 2 staggered layers of 1/2" cement boards | Loaded. See Manufacturer | 2 | 2 | NRC Fire Laboratory March 2016 |
| 5-ply CLT (175mm x 6.875") | Nordic | EI | 1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3/5" fiberglass boards | Topside Splice | 2 staggered layers of 1/2" cement boards | Loaded. See Manufacturer | 2 | 5 | NRC Fire Laboratory Nov 2014 |
| 5-ply CLT (173mm x 6.875") | Nordic | EI | None | Topside Splice | 3/4 in. proprietary gyproc over Maxxon acoustical mat | Reduced 50% Moment Capacity | 1.5 | 3 | UL |
| 5-ply CLT (175mm x 6.875") | Nordic | EI | 1 layer 5/8" normal gypsum | Topside Splice | 3/4 in. proprietary gyproc over Maxxon acoustical mat or proprietary sound board | Reduced 50% Moment Capacity | 2 | 4 | UL |
| 5-ply CLT (175mm x 6.875") | Nordic | EI | 1 layer 5/8" Type X Gyp under Resilient Channel under 7/8" Joists with 3 1/2" Mineral Wool between joists | Half-Lap | None | Loaded. See Manufacturer | 2 | 21 | Intertek 8/24/2012 |
| 5-ply CLT (173mm x 6.875") | Structurlam | EI MS MSR 2100 x SPF #2 | None | Topside Splice | 1-1/2" Maxxon Cyp-Grete 2000 over Maxxon Reinforcing Mesh | Loaded. See Manufacturer | 2.5 | 6 | Intertek, 2/22/2016 |
| 5-ply CLT (175mm x 6.875") | DR Johnson | VI | None | Half-Lap & Topside Splice | 2" gypsum topping | Loaded. See Manufacturer | 2 | 7 | SwRI (May 2016) |
| 5-ply CLT (175mm x 6.875") | Nordic | SPF 1950 Fb MSR x SPF #3 | None | Half-Lap | None | Reduced 59% Moment Capacity | 1.5 | 1 (Test 3) | NRC Fire Laboratory |
| 5-ply CLT (175mm x 6.875") | Structurlam | SPF #1/#2 x SPF #1/#2 | 1 layer 5/8" Type X gypsum | Half-Lap | None | Unreduced 101% Moment Capacity | 2 | 1 (Test 6) | NRC Fire Laboratory |
| 7-ply CLT (245mm x 9.65") | Structurlam | SPF #1/#2 x SPF #1/#2 | None | Half-Lap | None | Unreduced 101% Moment Capacity | 2.5 | 1 (Test 7) | NRC Fire Laboratory |
| 5-ply CLT (173mm x 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 (173mm x 6.875") | SmartLam | VI | None | Half-Lap | nominal 1/2" plywood with 8d nails | Loaded. See Manufacturer | 2 | 12 (Test 5) | Western Fire Center 10/28/2016 |
| 5-ply CLT (175mm x 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 (114mm x 4.48 in) | KID | CV3M1 | None | Half-Lap & Topside Splice | 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 McLain, PE, SE • Senior Technical Director • WoodWorks
Scott Breneman, PhD, PE, SE • Senior Technical Director • WoodWorks

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

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

are leveraging to create innovative designs with a warm yet modern aesthetic, often for projects that go beyond traditional norms of wood design.

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

Mass Timber & Construction Type

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

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

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

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

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



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

Mass Timber Fire Design Resource

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

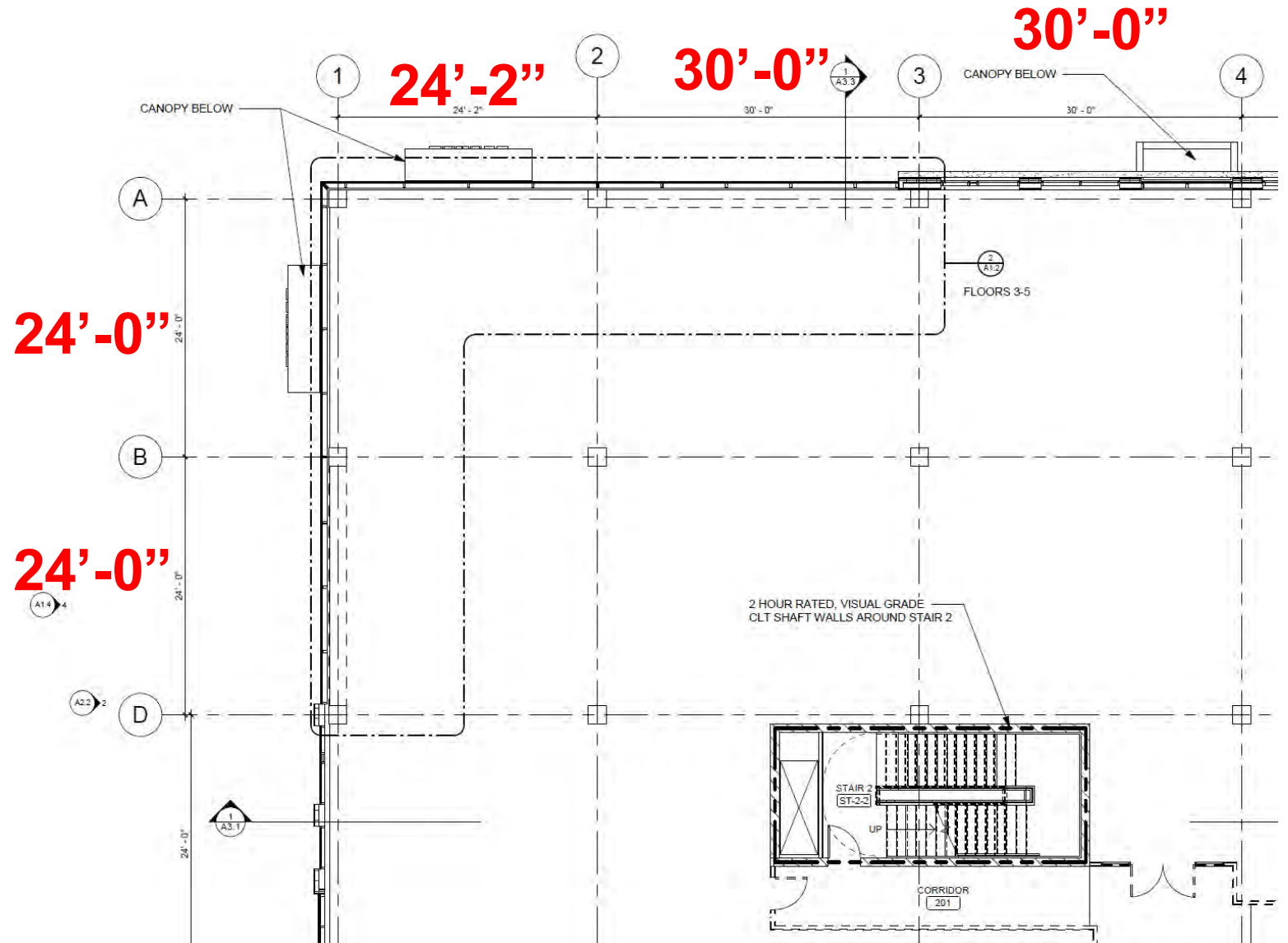
Structural Grid



Structural Grid

Grids & Spans

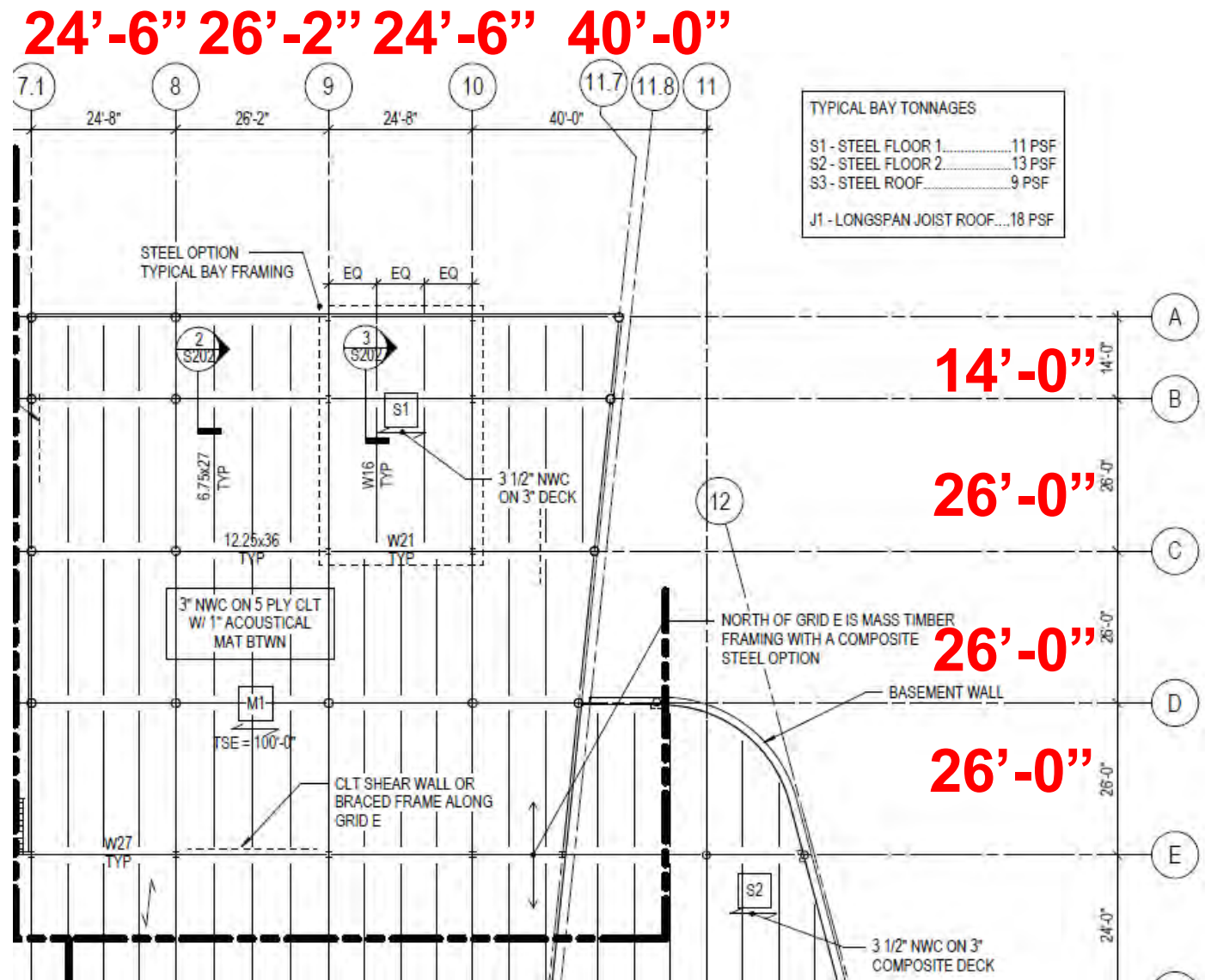
- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation



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



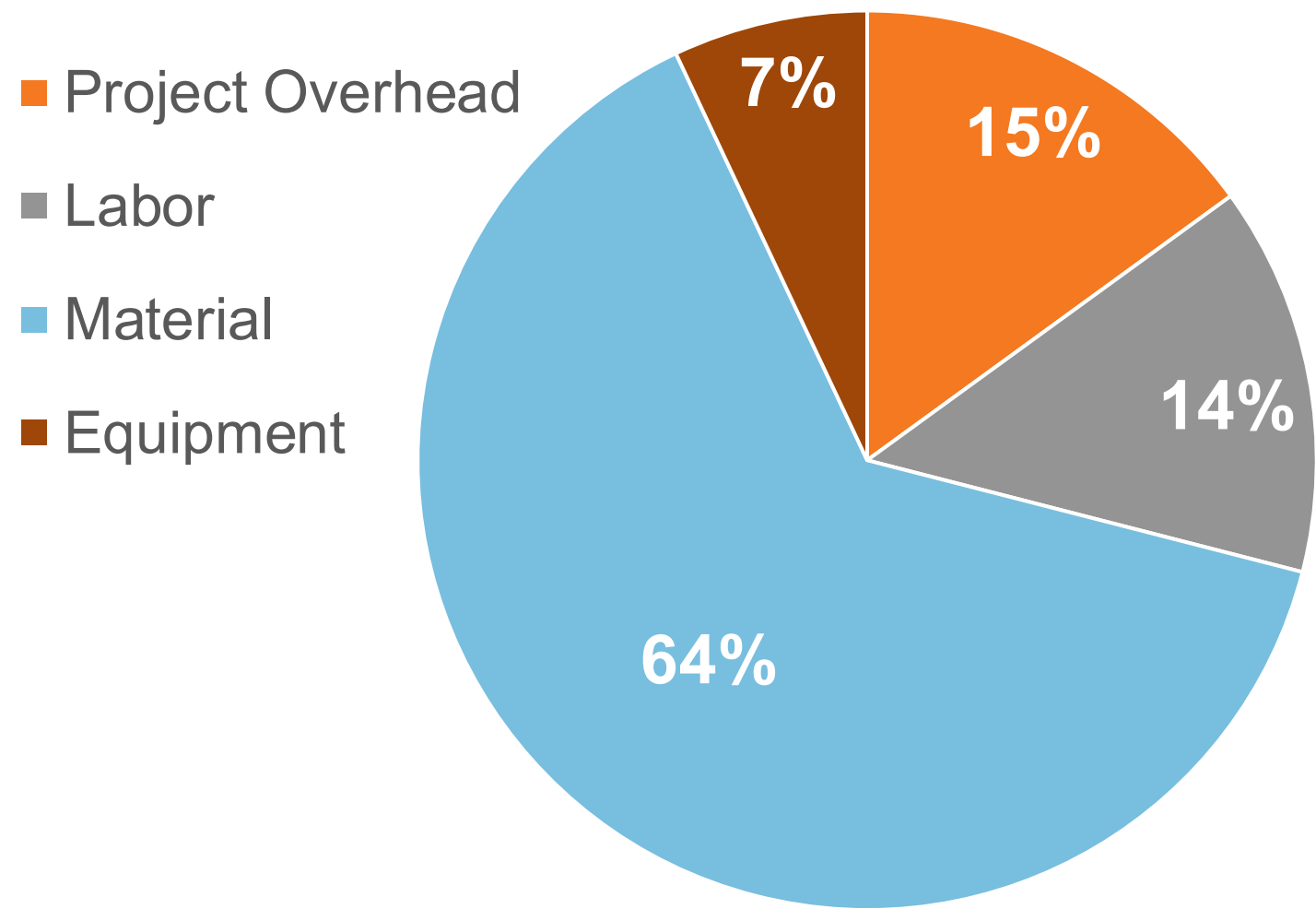
Key Early Design Decisions

Why so much focus on panel thickness?

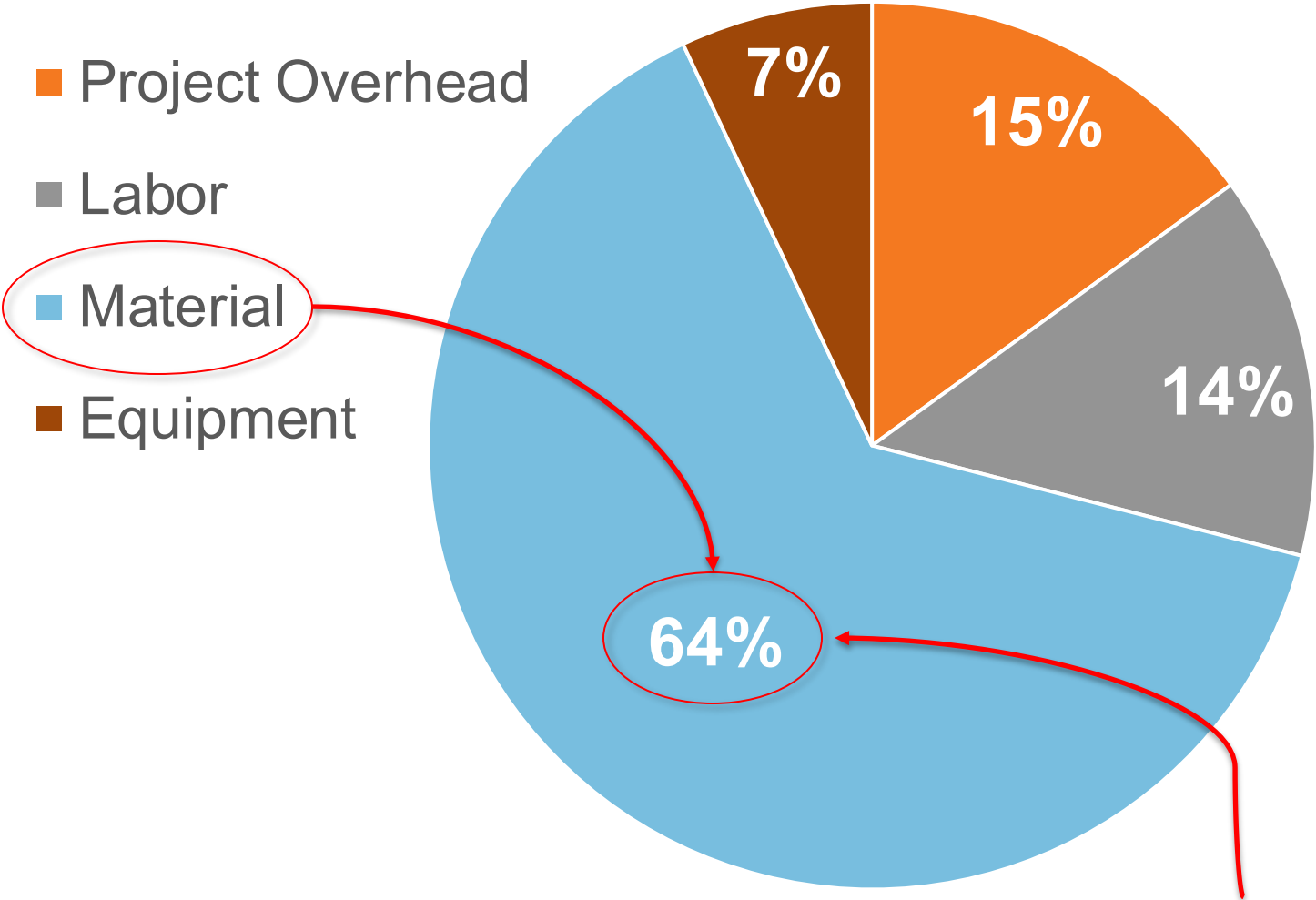


Key Early Design Decisions

Typical MT Package Costs



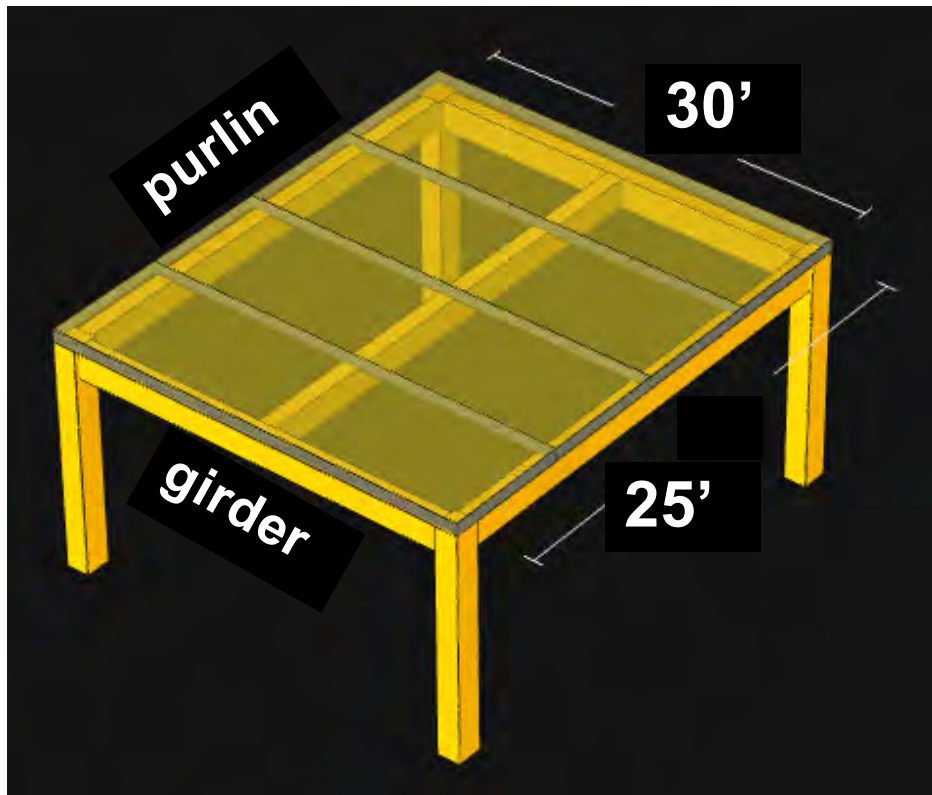
Key Early Design Decisions



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

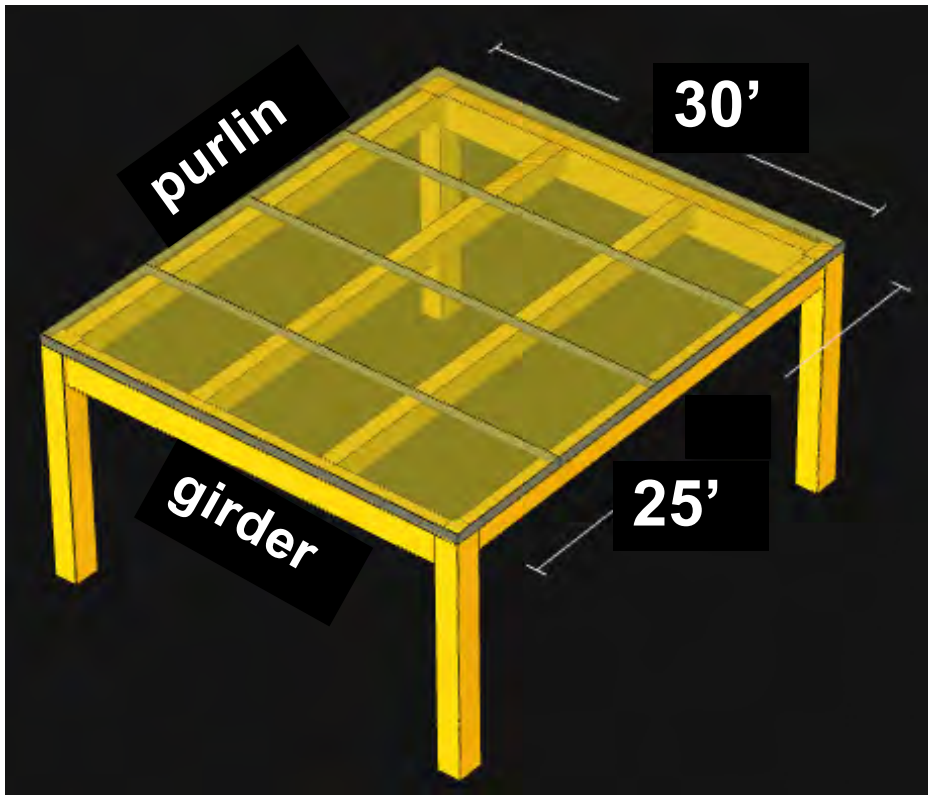
Glulam volume = 118 CF (22% of MT)

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)

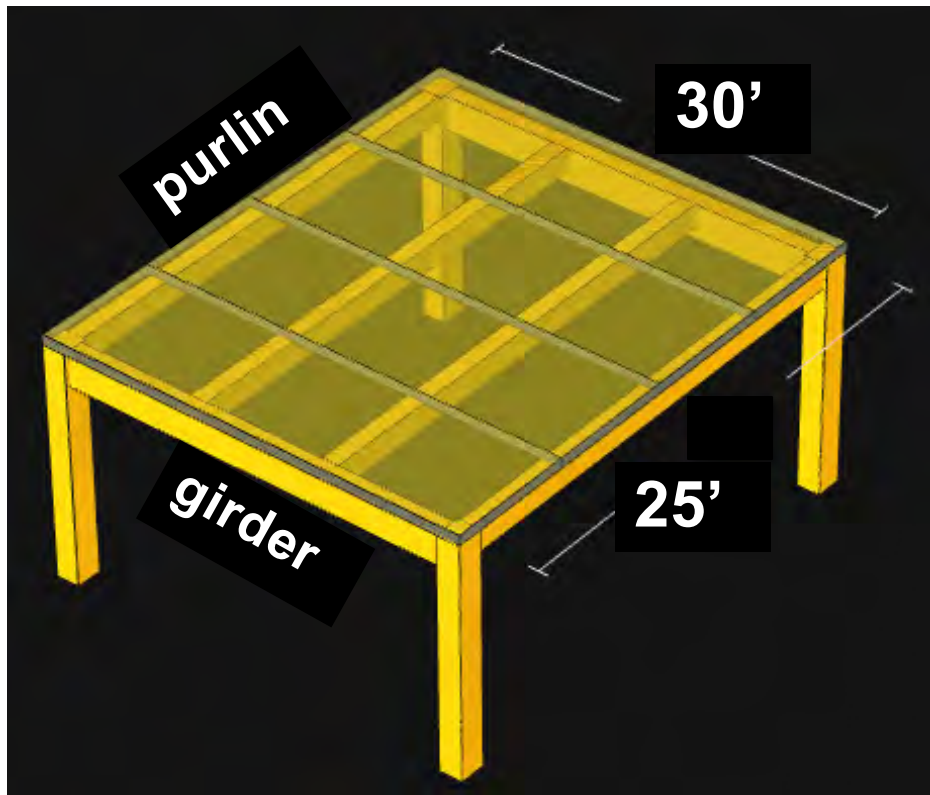
CLT volume = 430 CF (78% of MT)

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)

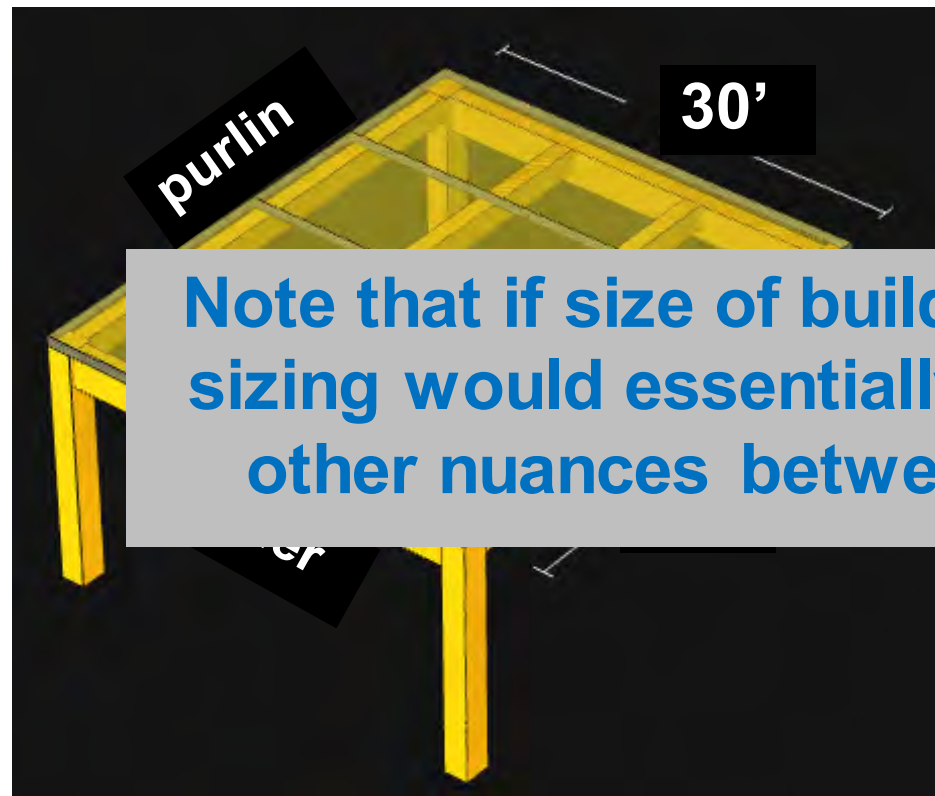
Glulam volume = 120 CF (32% of MT)

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...

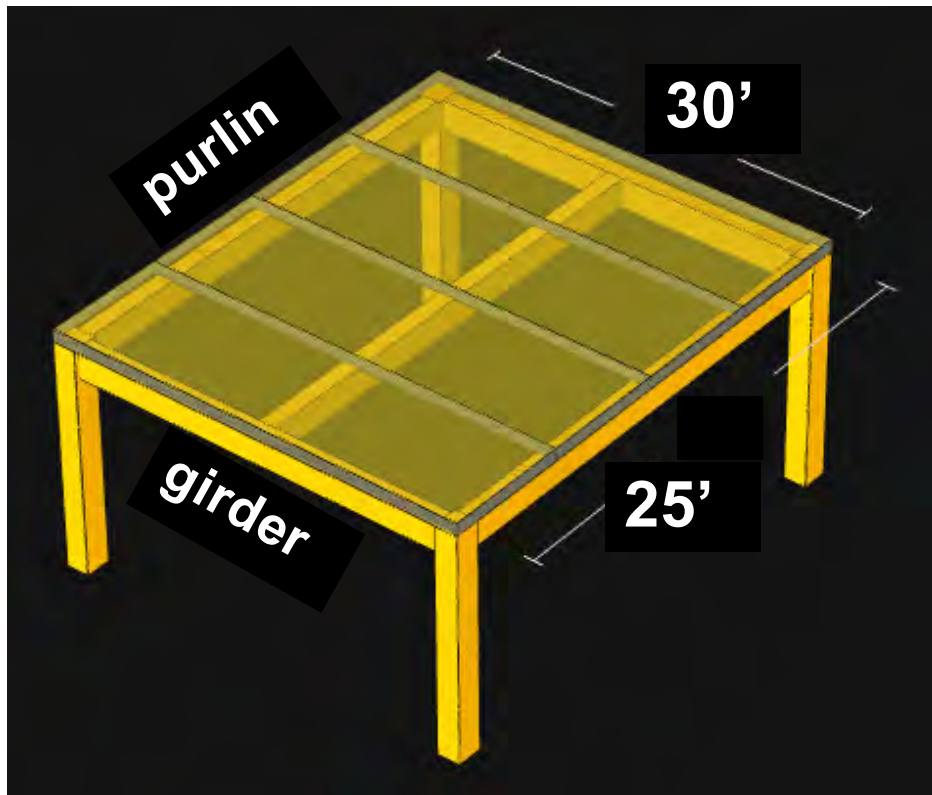
Glulam volume = 120 CF (32% of MT)

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)

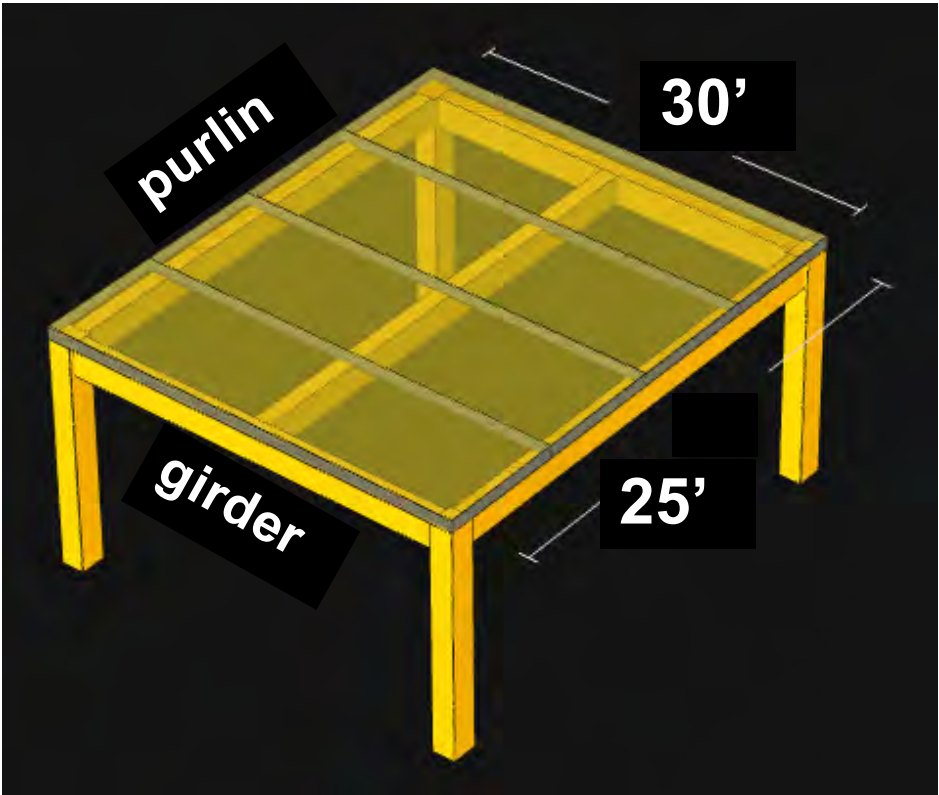
CLT volume = 430 CF (70% of MT)

Total volume = 0.82 CF / SF

Source: Fast + Epp, Timber Bay Design Tool

Key Early Design Decisions

Which is the most efficient option?



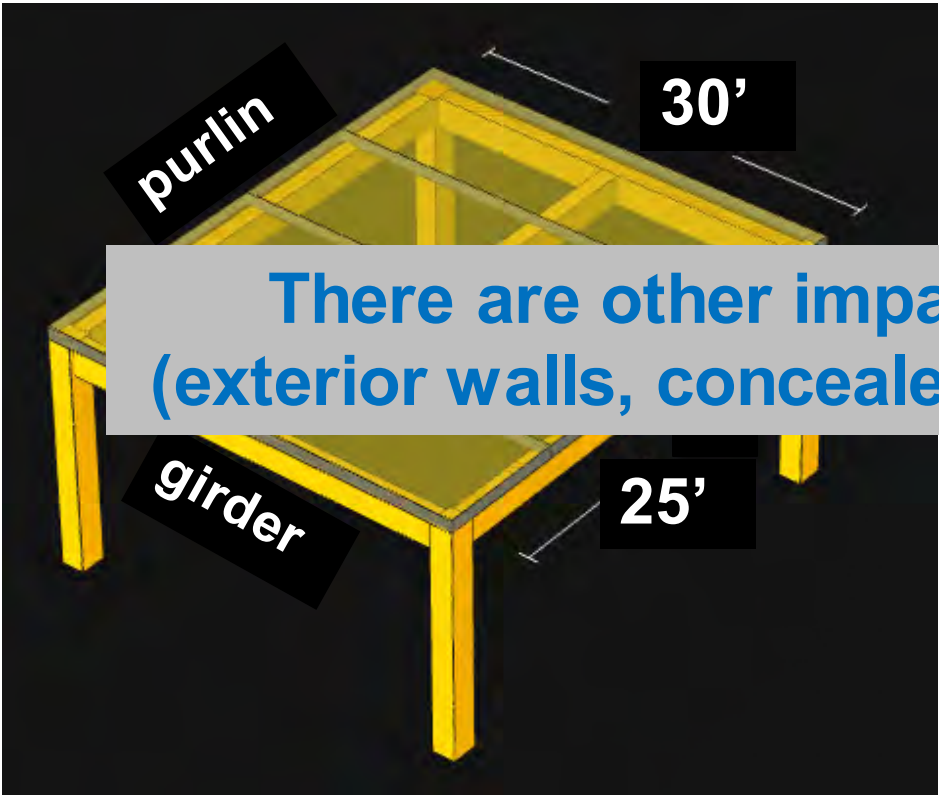
Source: Fast + Epp, Timber Bay Design Tool

| | Timber Volume Ratio | Podium on 1 st 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 constriction type selection (exterior walls, concealed spaces) that should be considered

| | Timber Volume Ratio | Podium on 1 st 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 (3rd) floor

- Requires Construction **Type IIIA**

If owner permits moving events space to 1st or 2nd 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:



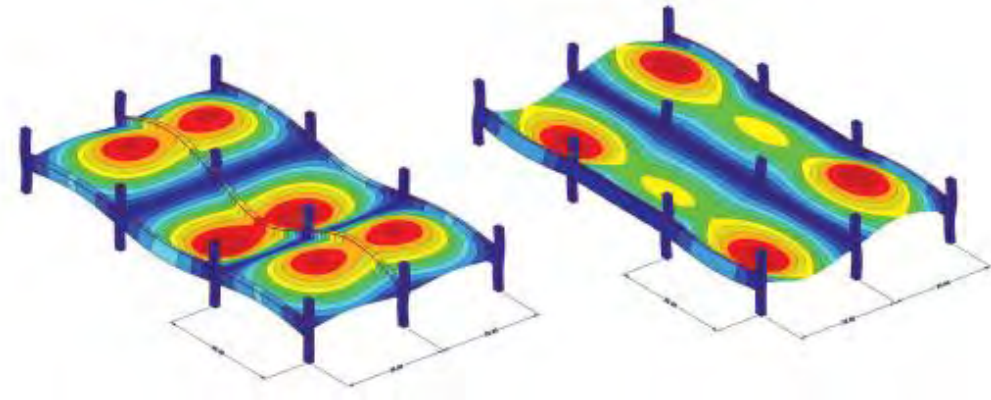
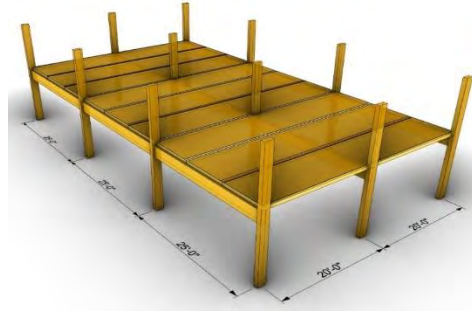
| Location of Event Space | 3 rd Floor | 1 st Floor |
|-------------------------------|-----------------------|-----------------------|
| Construction Type | III-A | III-B |
| Assembly Group | A-3 | A-3 |
| Fire Resistive Rating | 1-Hr | 0-Hr |
| Connections | Concealed | Exposed |
| CLT Panel Thickness | 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

Design Guide



**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



Photo: John Stamets



Photo: Josh Partee



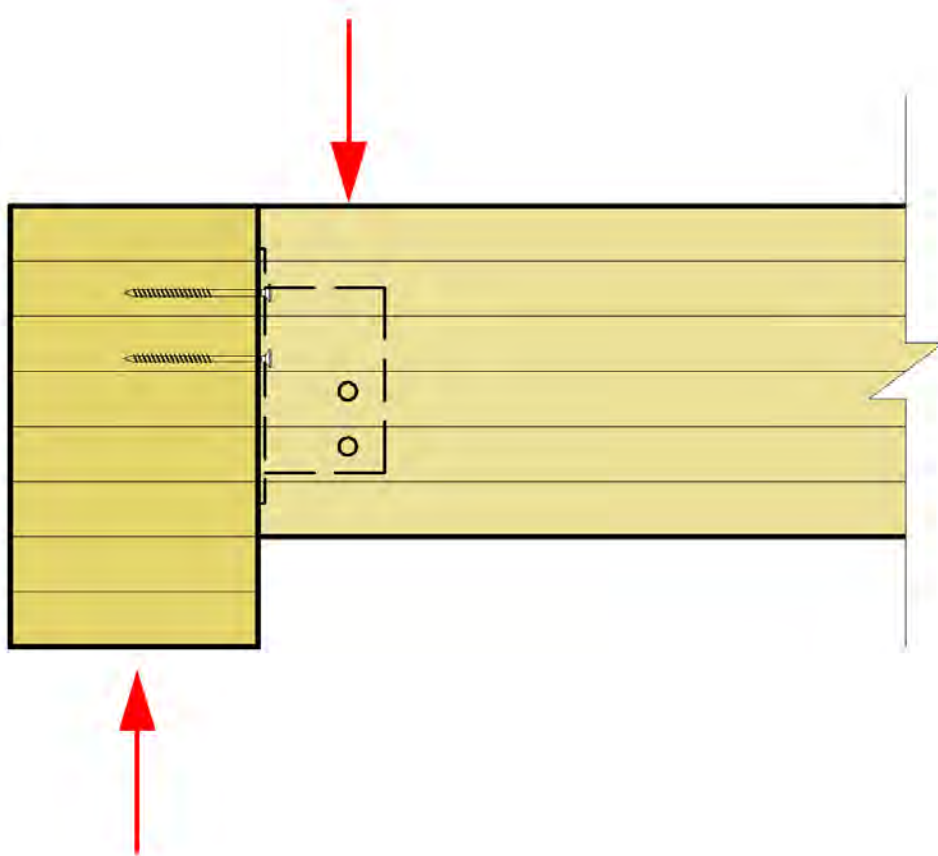
Photo: Christian Columbres



Photo: Blaine Brownell

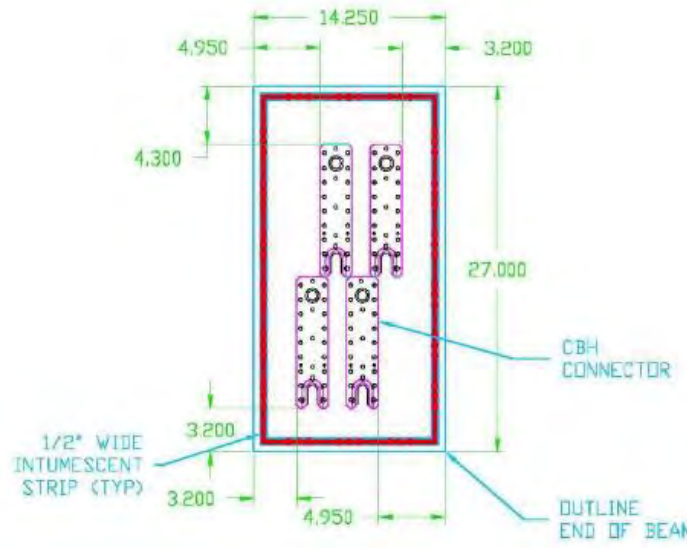
Key Early Design Decisions

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



Photos: Simpson Strong-Tie

Photo: LEVER Architecture

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 |

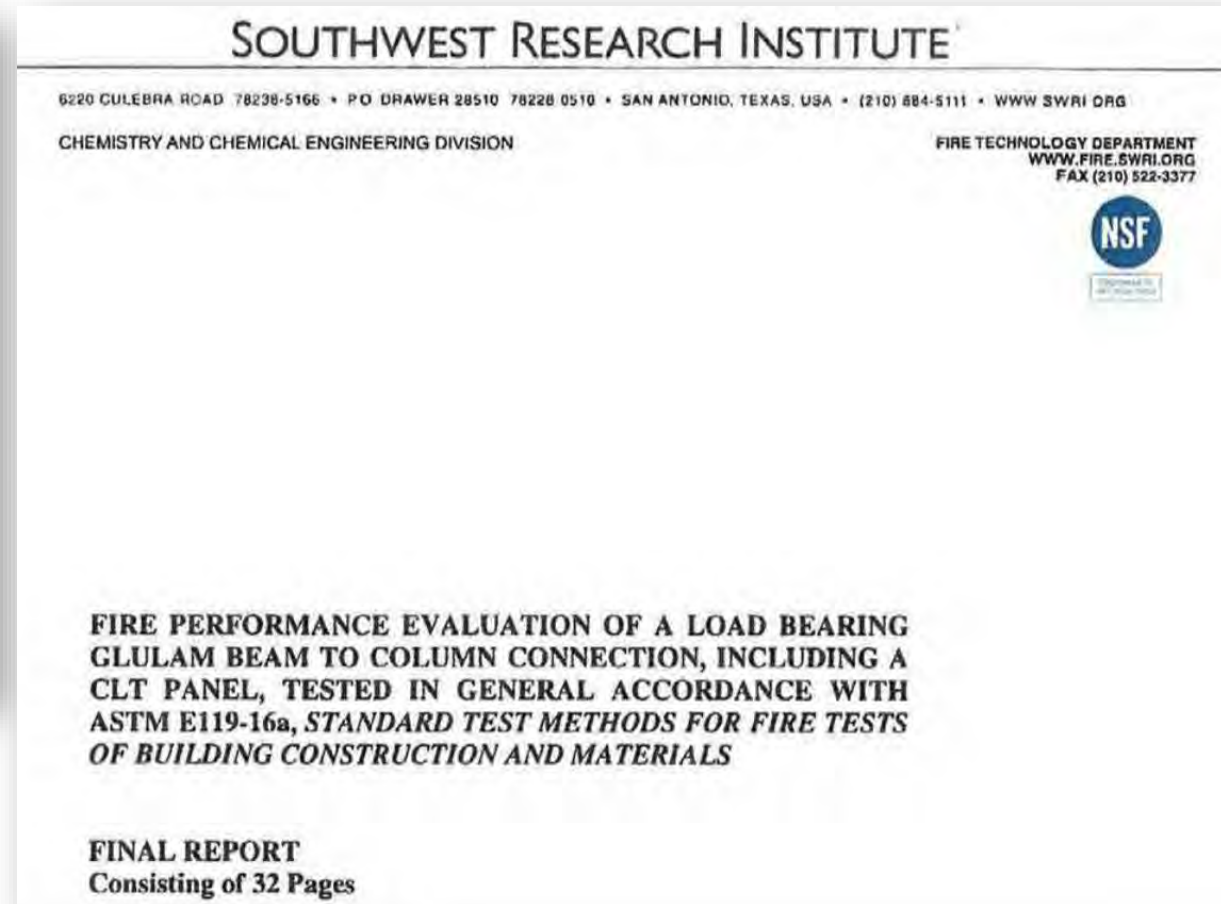
Key Early Design Decisions

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>



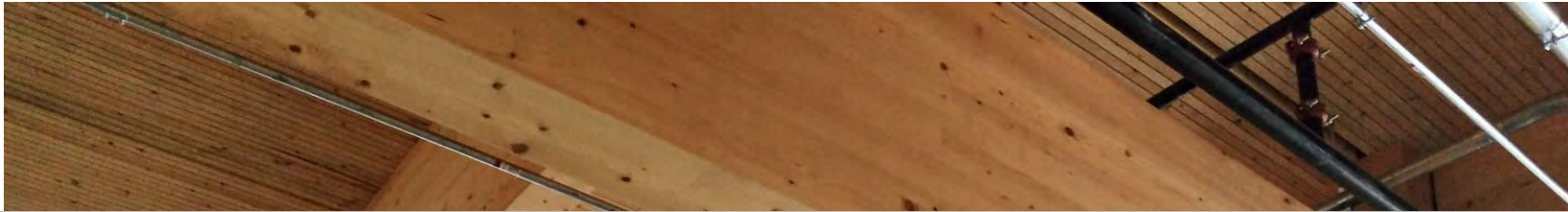
Key Early Design Decisions

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



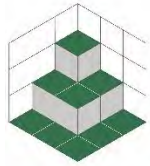
Style of connection also impacts and is impacted by grid layout and MEP integration





ARCHITECTURE
URBAN DESIGN
INTERIOR DESIGN

gn Decisions



KL&A
Engineers & Builders

SWINERTON
MASS TIMBER

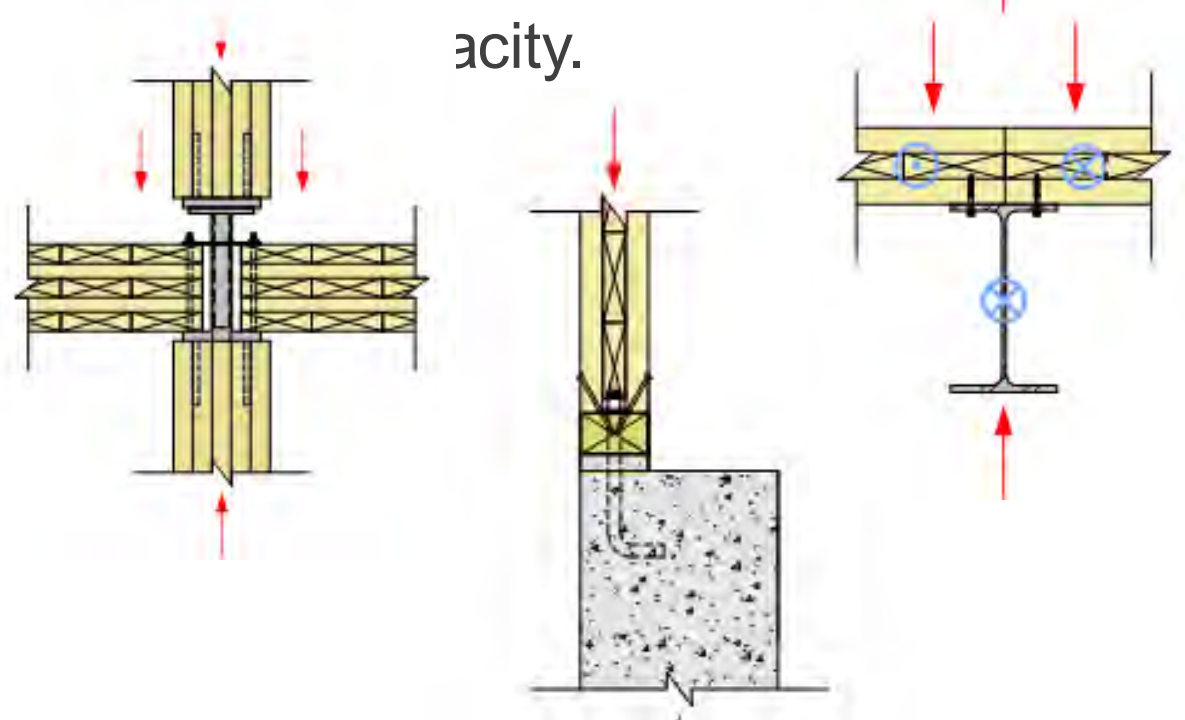


WoodWorks Index of Mass Timber Connections



MASS TIMBER CONNECTIONS INDEX

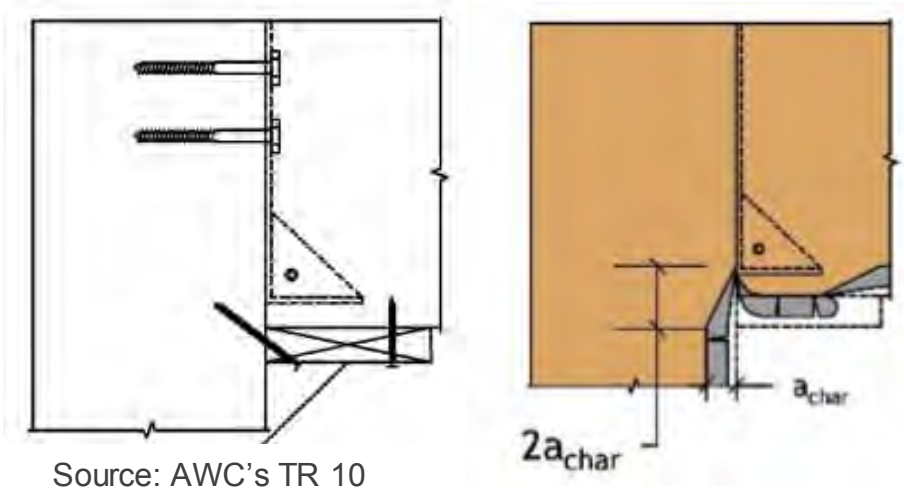
A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load capacity.



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.



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.

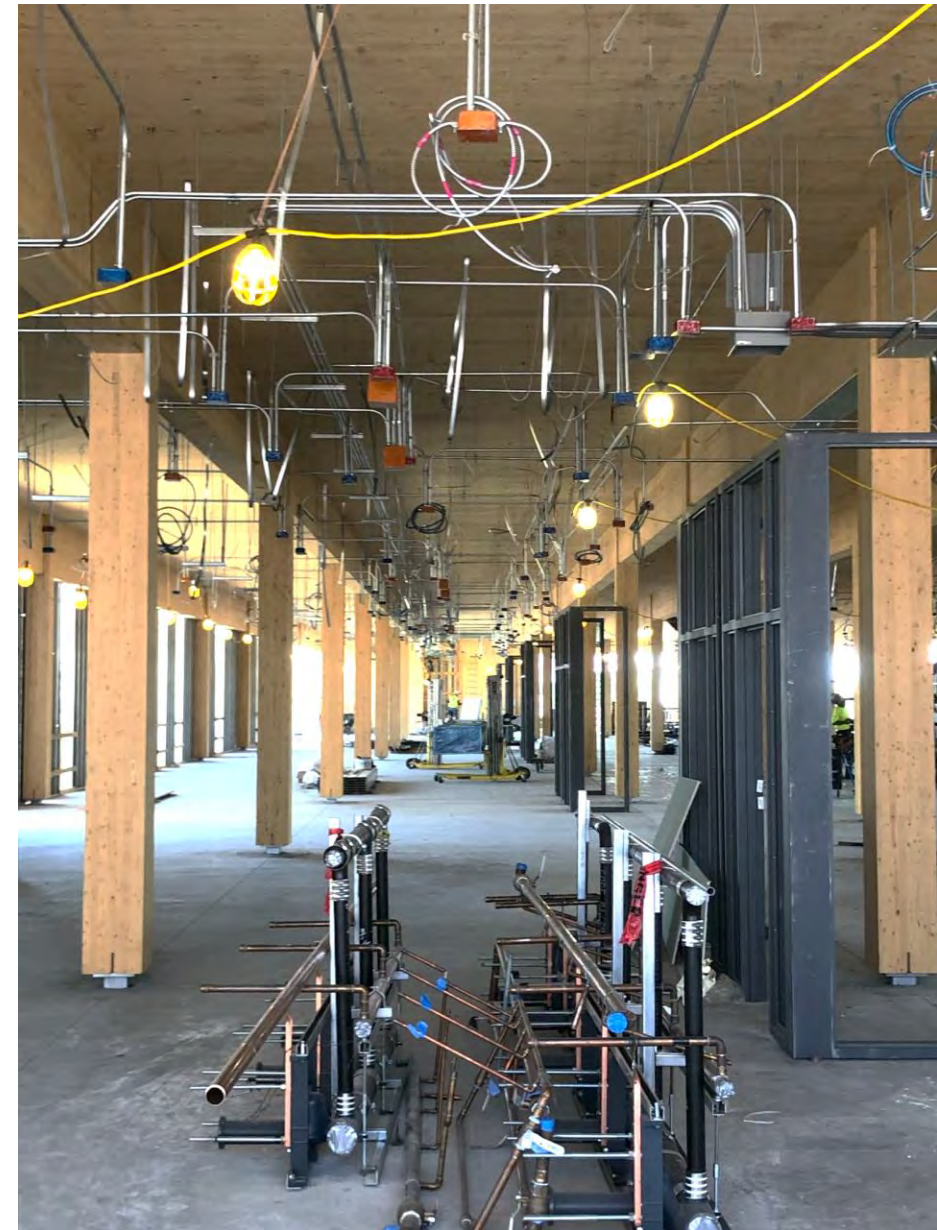


Penetrations & Firestopping

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.*



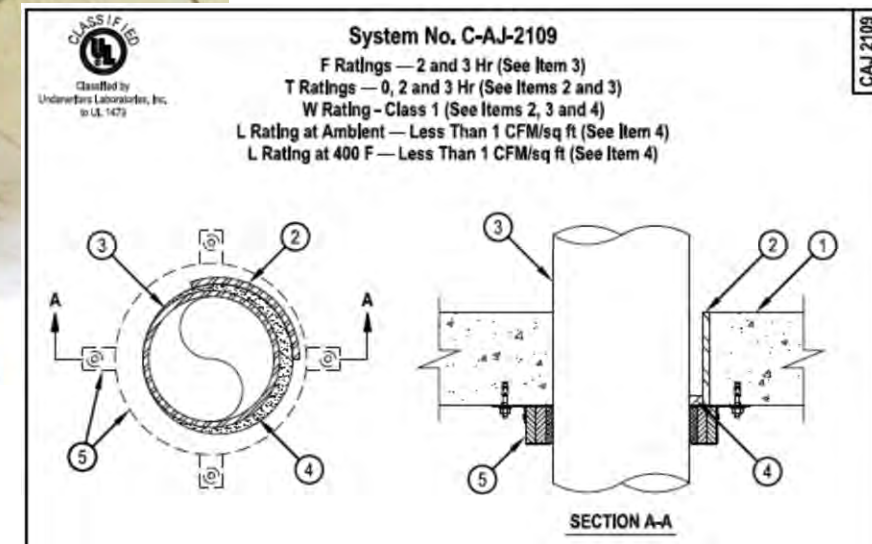
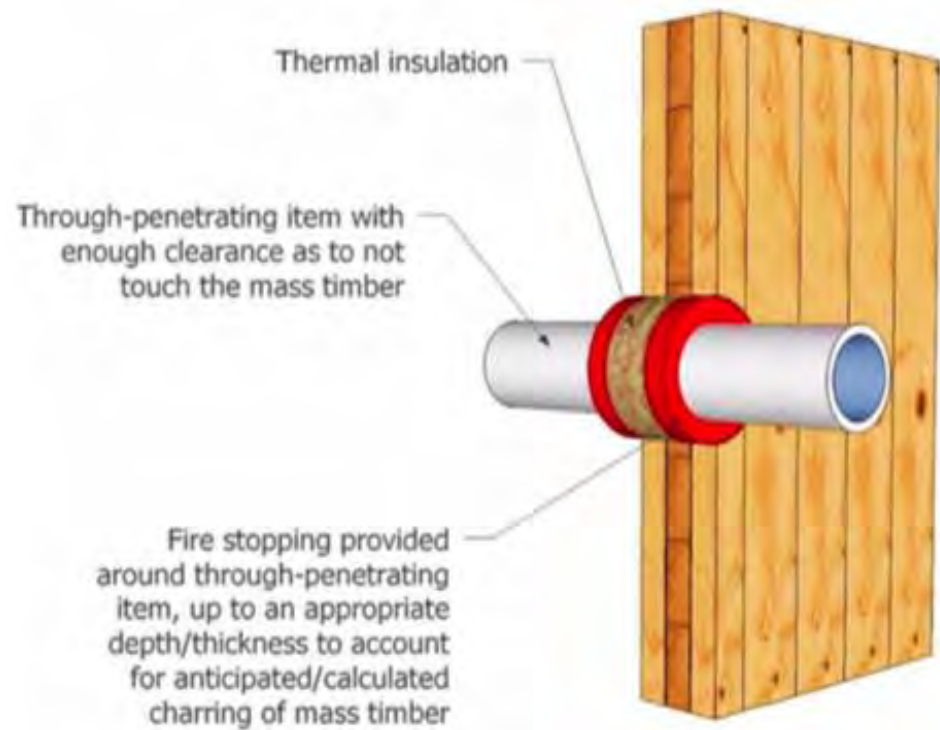
Penetrations & Firestopping

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 Ranger¹, Christian Dagenais¹, Conroy Lum¹, Tony Thomas¹

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 1-1/2 hr fire resistance in accordance with CAN/ULC-S115, which would be required for 2-hr fire resistance rated assemblies, such as 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 noncombustible 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 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

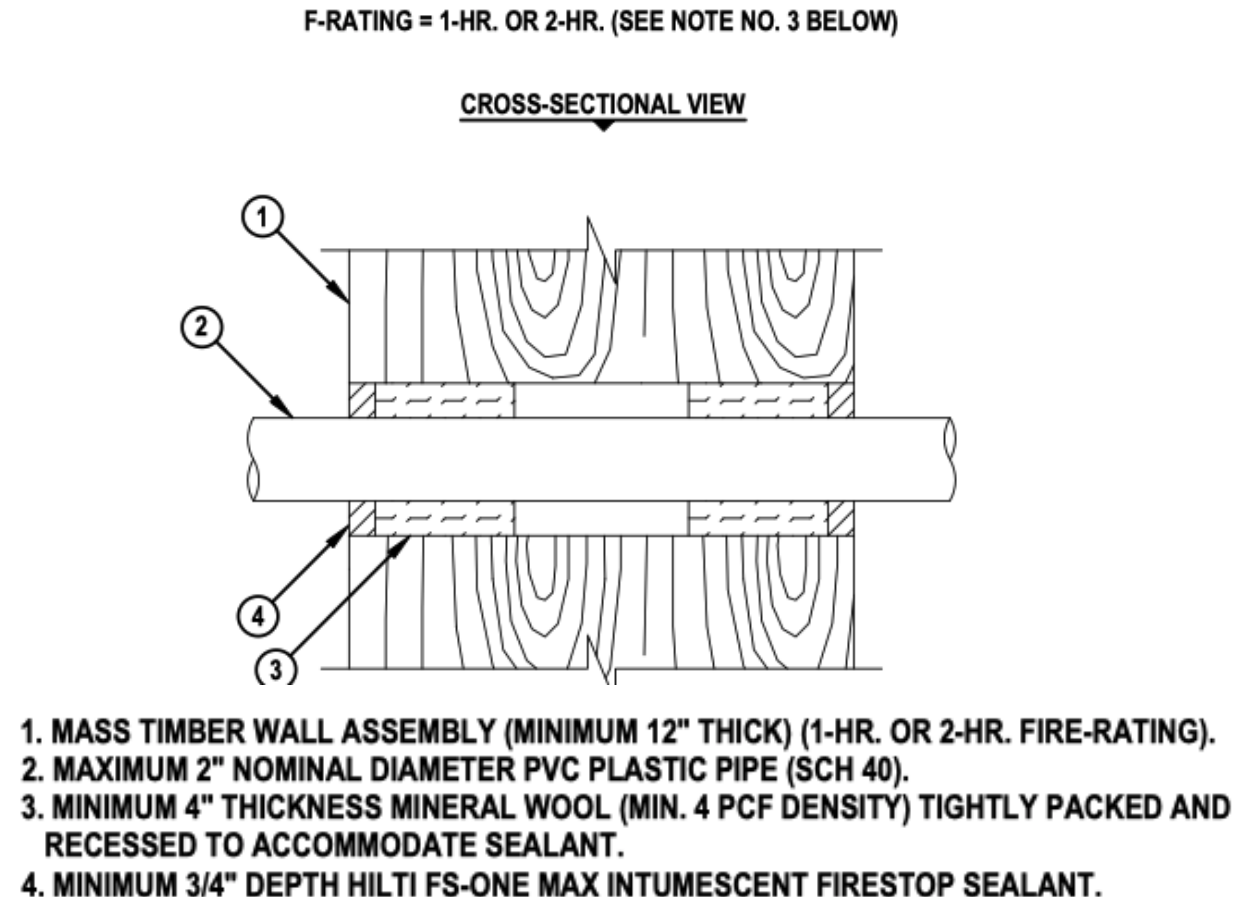
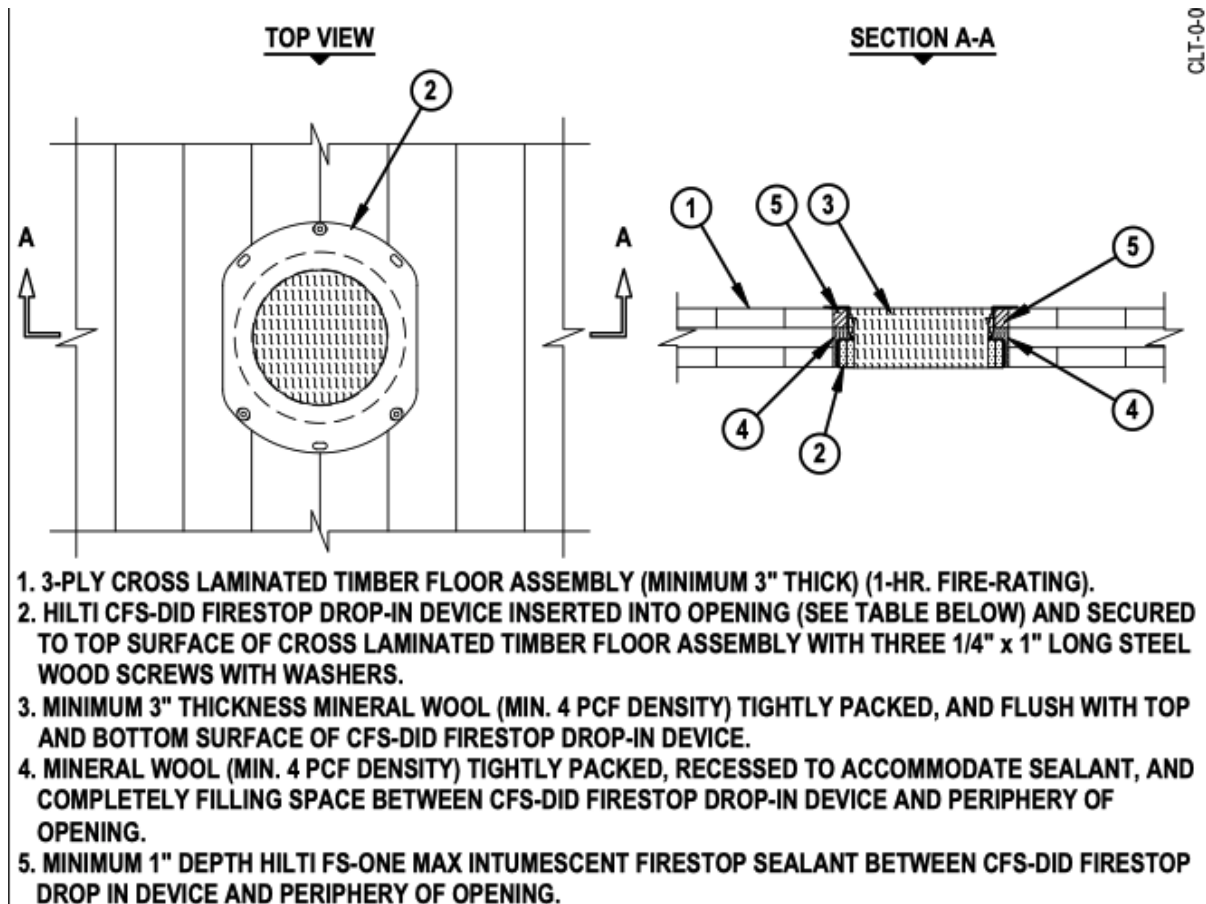


Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies

| 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 | N.A. | CANULC S115 | 26 | Intertek March 30, 2016 |
| 3-ply (78mm 3.07") | None | 2.5" sched. 40 pipe | Centered | 4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 2 – 5/64 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 | N.A. | CANULC S115 | 26 | Intertek March 30, 2016 |
| 3-ply (78mm 3.07") | None | 6" cast iron pipe | Centered | 8.35 in diameter hole. Mineral wool was installed in the 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 | N.A. | CANULC S115 | 26 | Intertek March 30, 2016 |
| 3-ply (78mm 3.07") | None | Hilti 6 in drop in device System No.: F-B-2049 | Centered | 9.01" diameter hole. Mineral wool was installed in the 1 – 1/4 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 (131mm 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 (131mm 5.16") | None | 2" copper pipe | Centered | 4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 4 – 5/32 in. The remaining 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 | N.A. | CANULC S115 | 26 | Intertek March 30, 2016 |
| 5-ply CLT (131mm 5.16") | None | 2.5" sched. 40 pipe | Centered | 8.92 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 |
| 5-ply CLT (131mm 5.16") | 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 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 | N.A. | CANULC S115 | 26 | Intertek March 30, 2016 |
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| 5-ply (178mm 6.97") | 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 W4 5/16" x 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 30, 2017 |

Penetrations & Firestopping

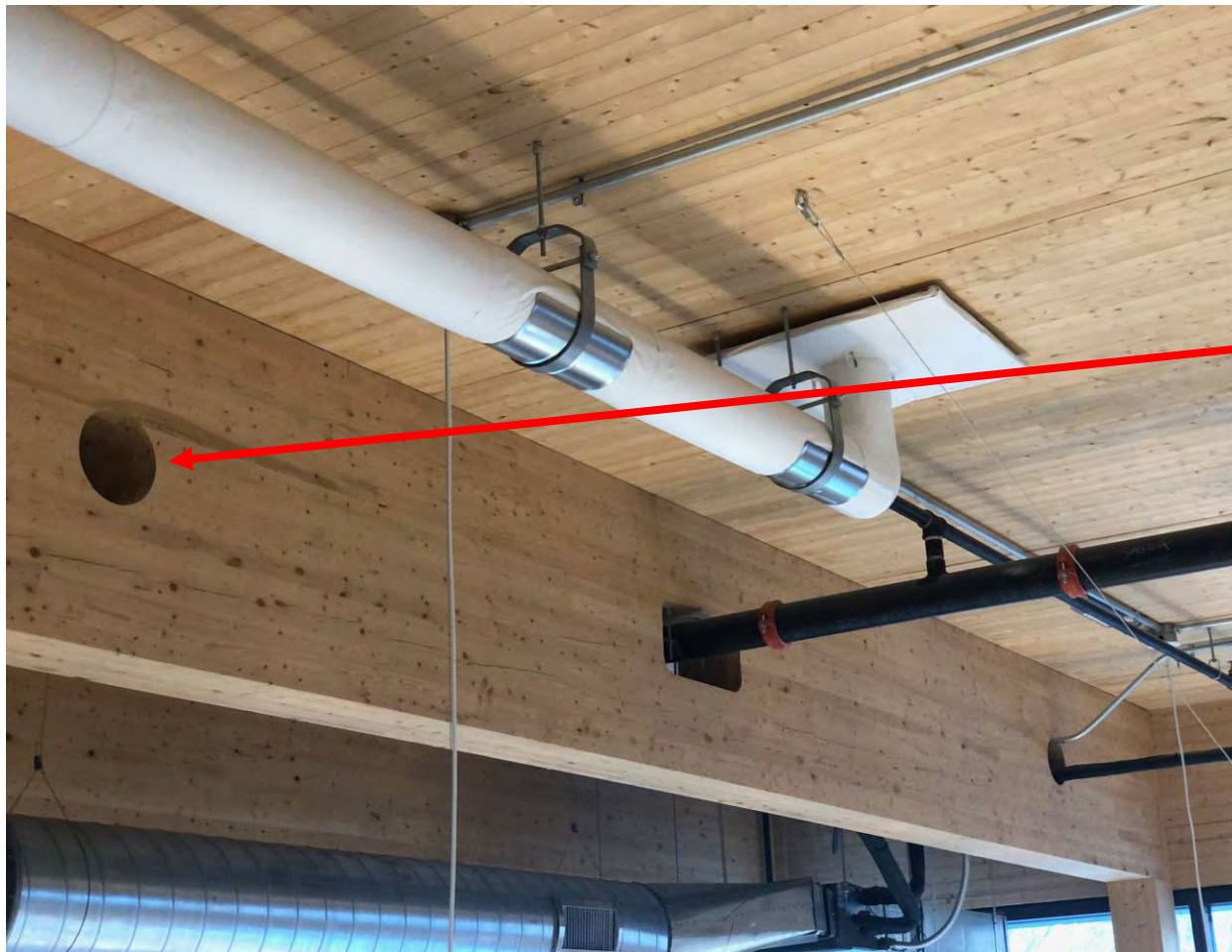
Option 2: MT penetration firestopping of penetrations via engineering judgement details (contact firestop manufacturer)



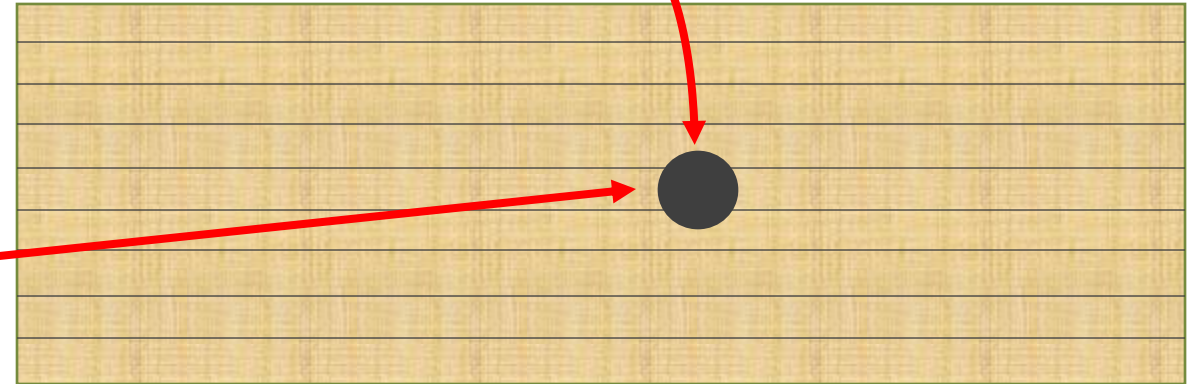
Penetrations & Firestopping

Beam penetrations:

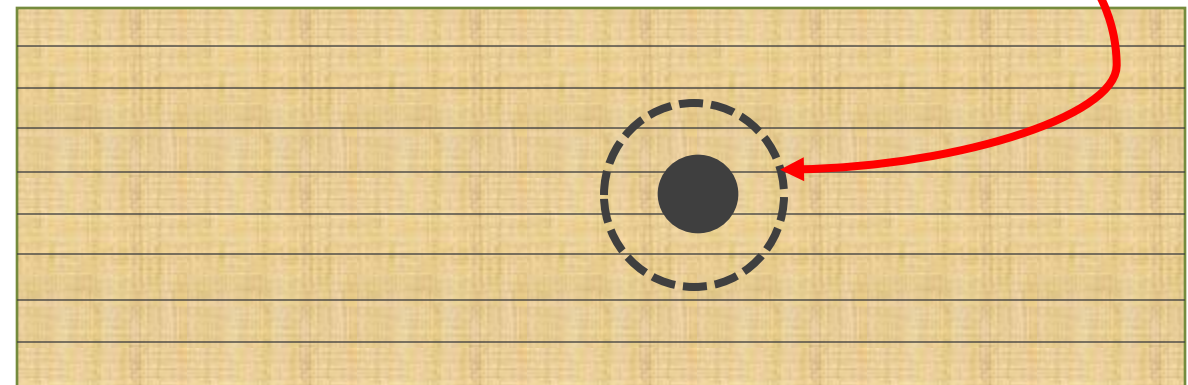
- If FRR = 0-hr, analyze structural impact of hole diameter only
- If FRR > 0-hr, account for charred hole diameter or firestop penetration



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



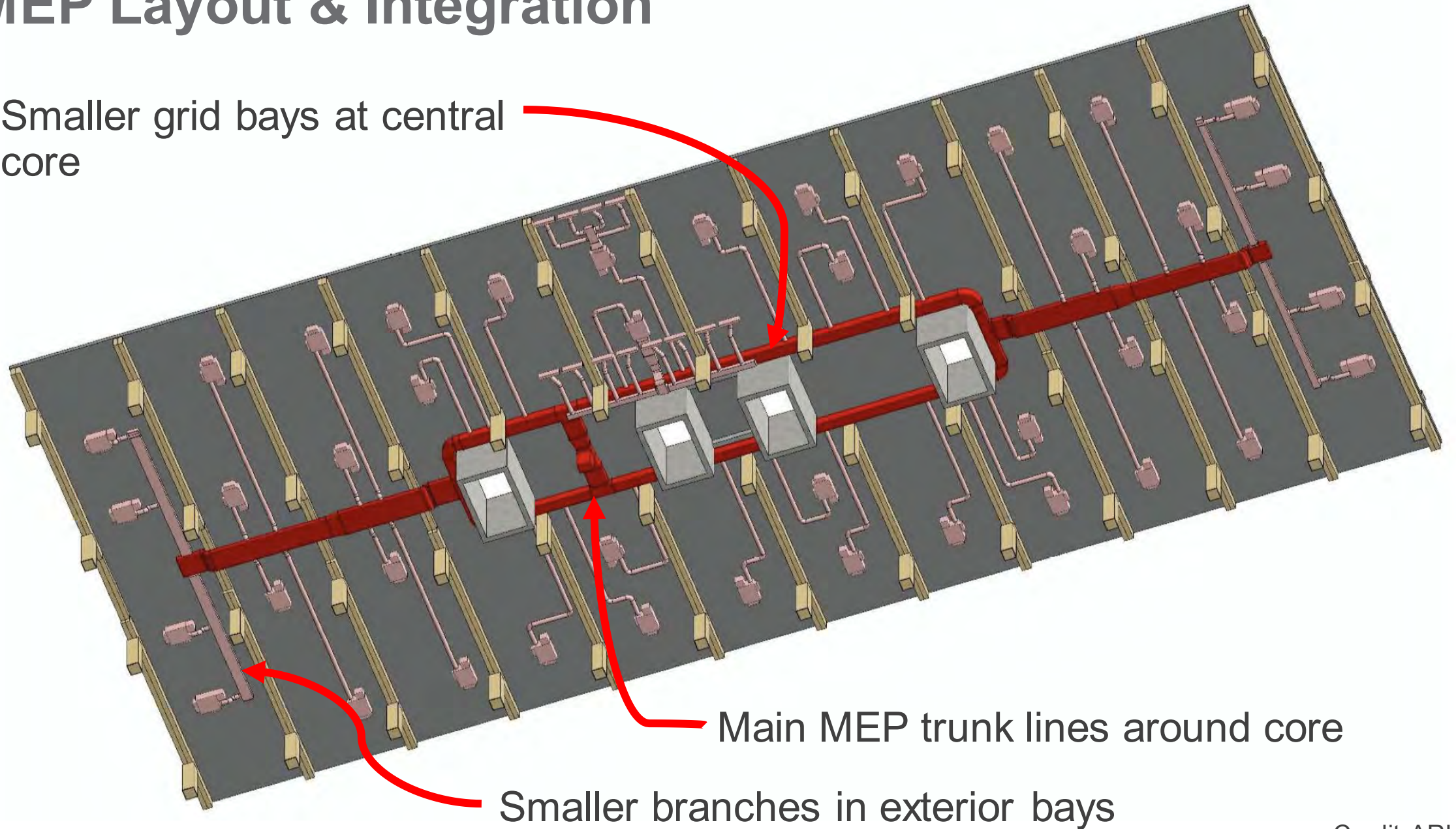
Credit: Blaine Brownell



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 |



Credit: Hacker Architects

MEP Layout & Integration

Dropped below MT framing

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



Credit: Alex Schreyer



Credit: WoodWorks

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



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



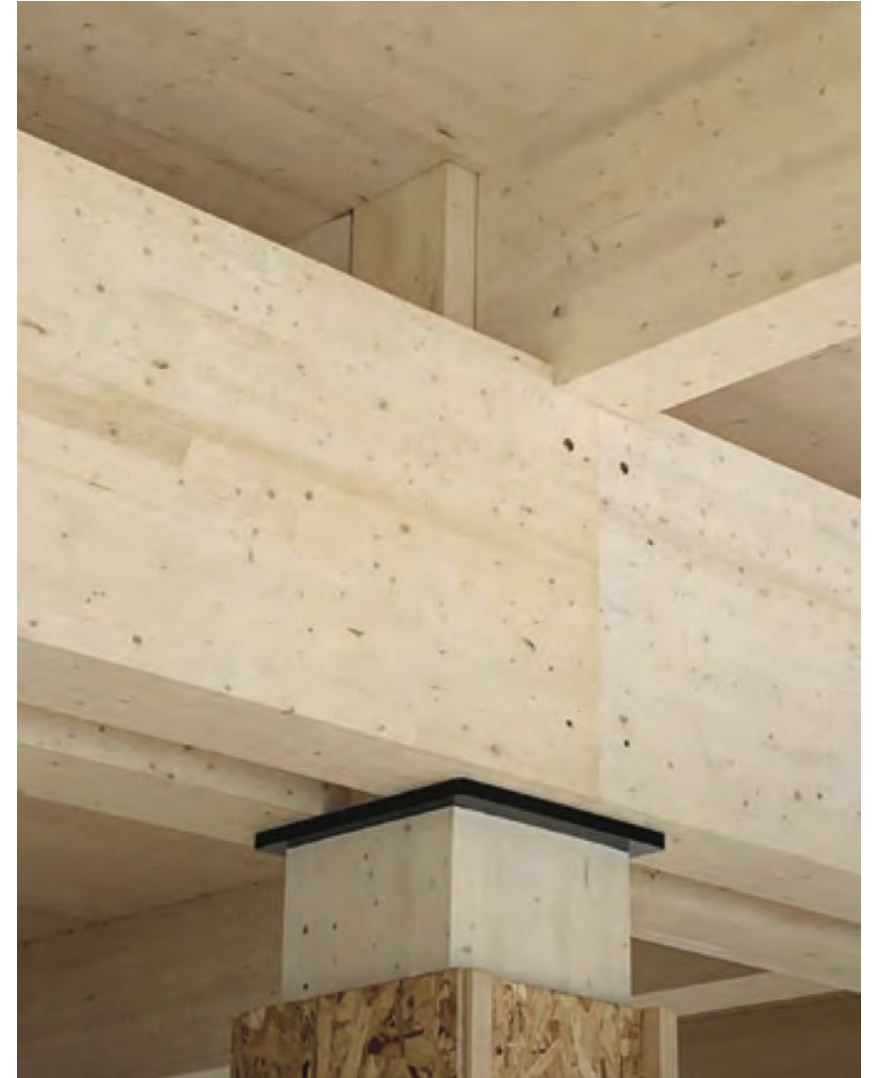
Credit: KL&A Engineers & Builders

MEP Layout & Integration

- In chases above beams and below panels at Platte 15
- 30x30 grid, purlins at 10 ft, 3-ply CLT

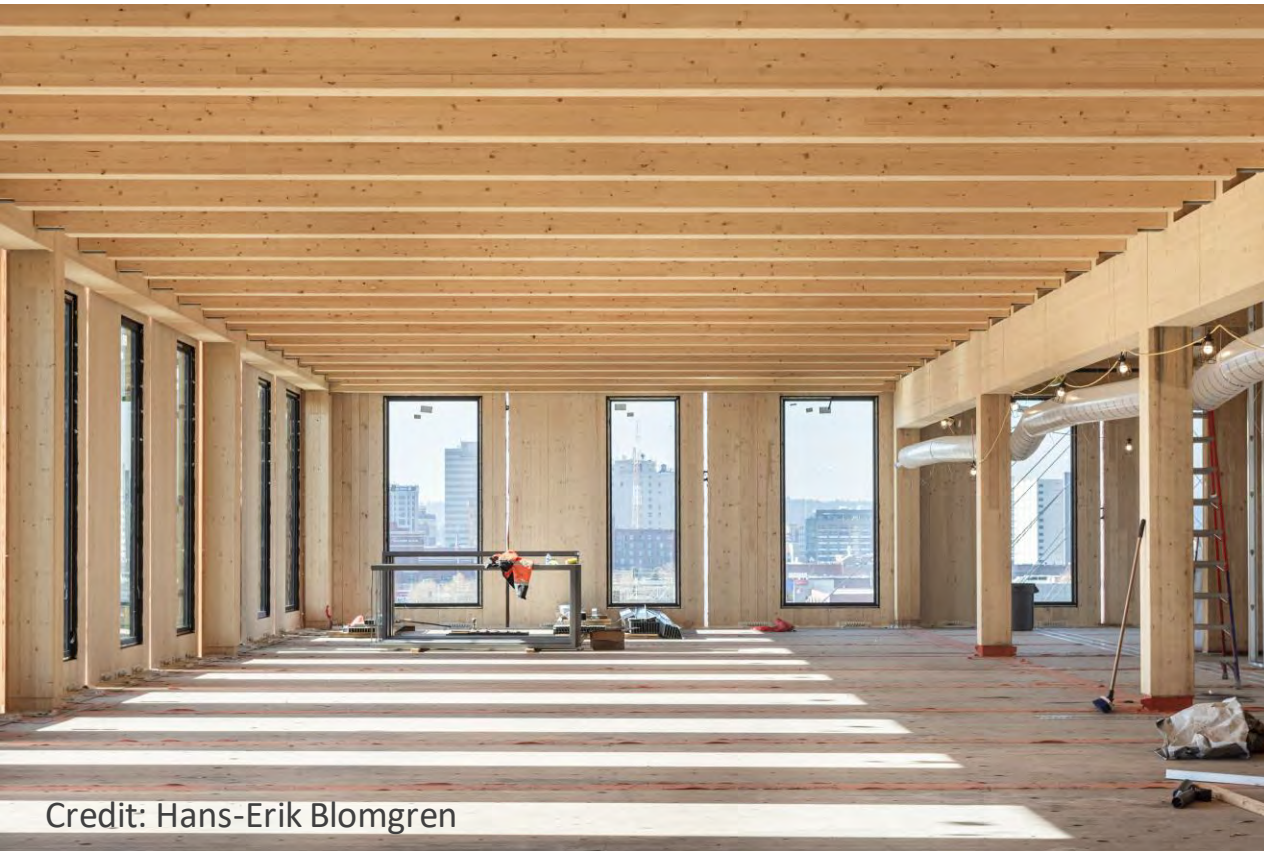


Credit: JC Buck



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



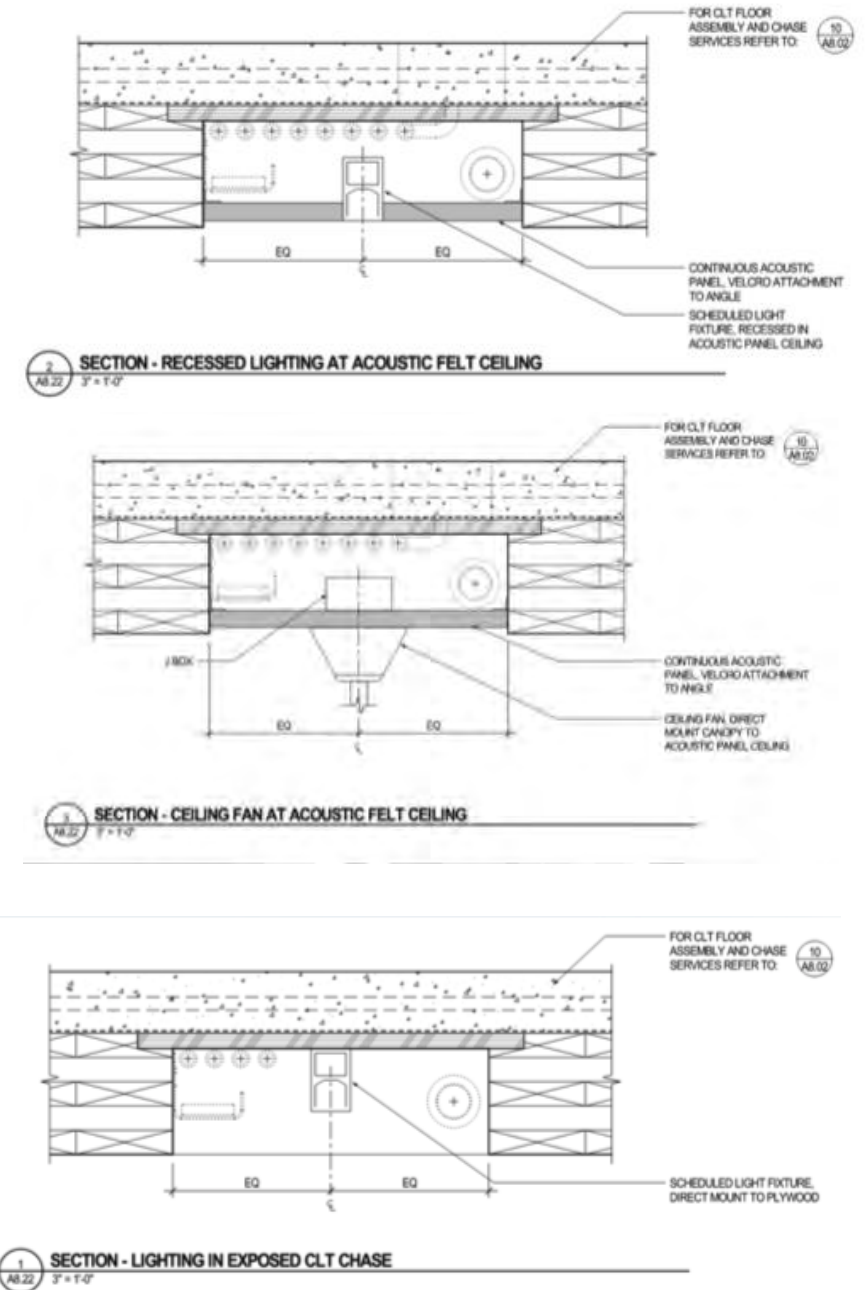
MEP Layout & Integration

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

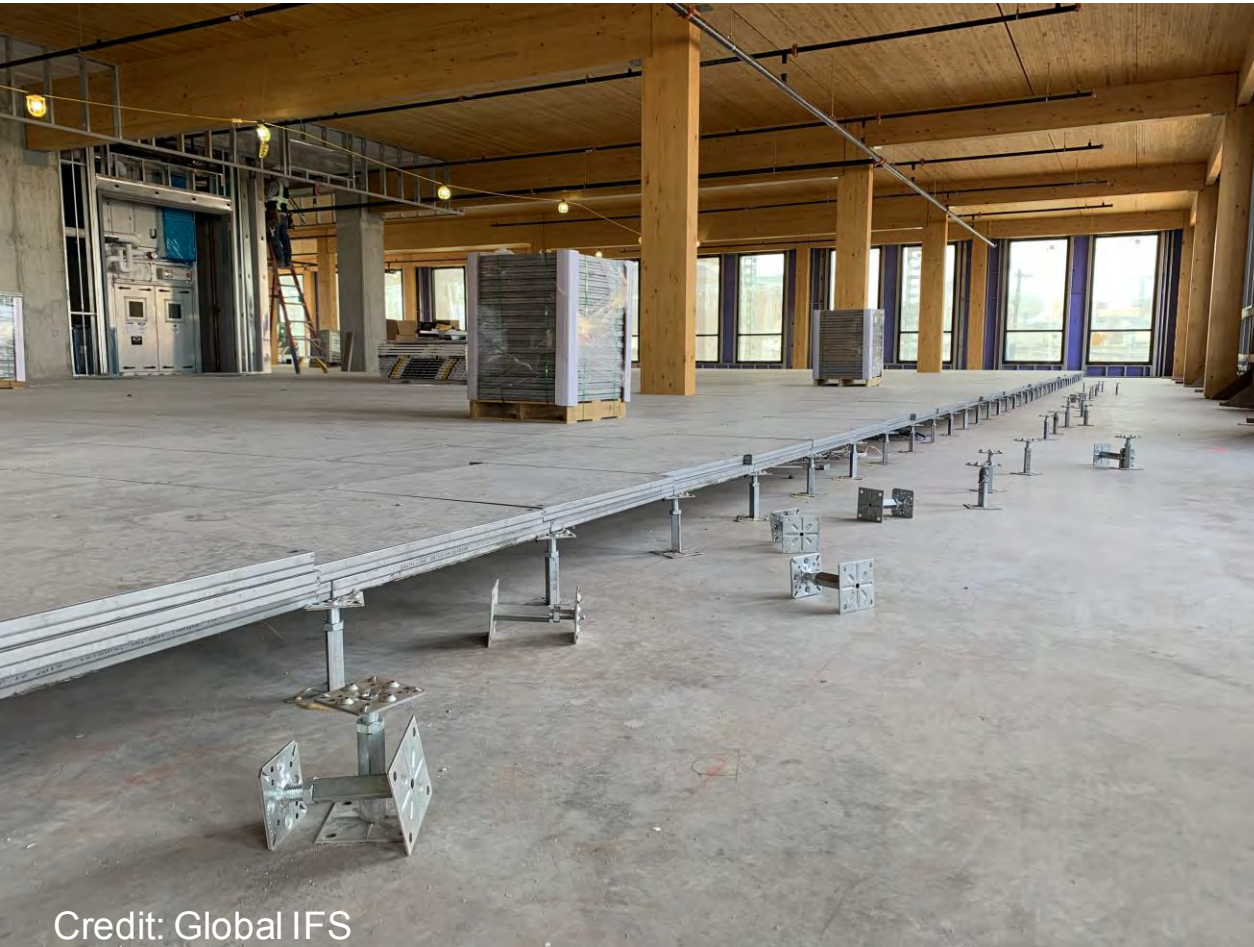
- In raised access floor (RAF) above MT
- Aesthetics (minimal exposed MEP)



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

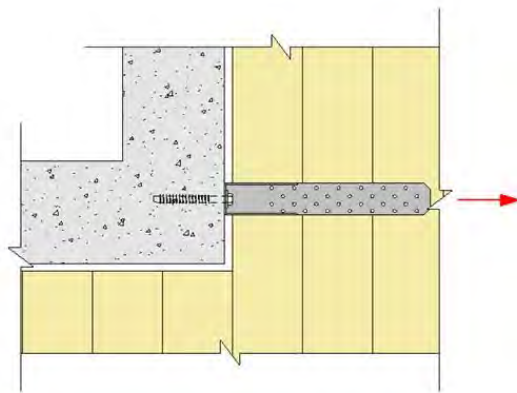
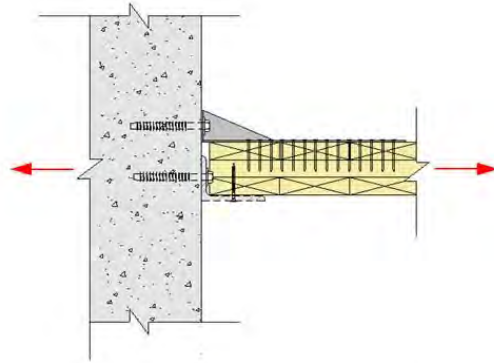
Connection to concrete core



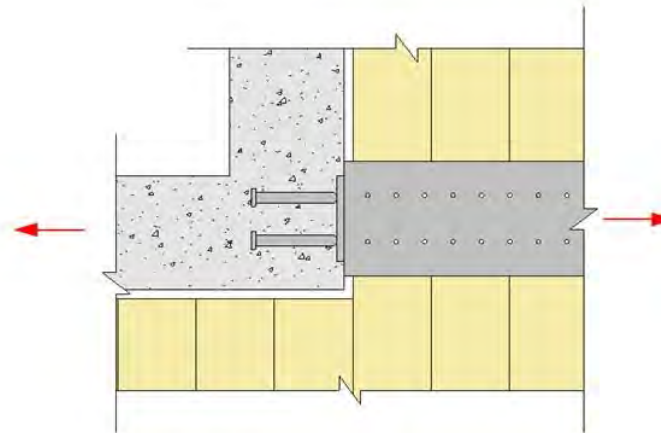
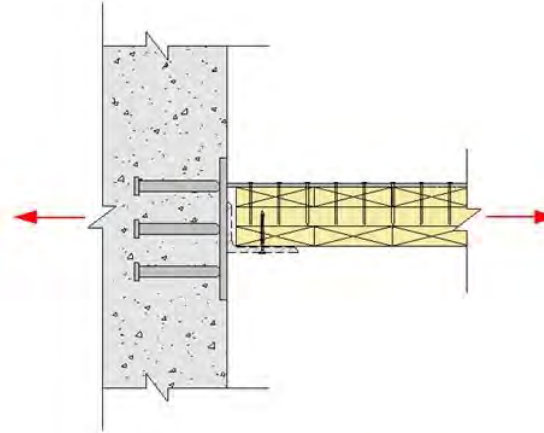
Lateral System Choices

Connections to concrete core

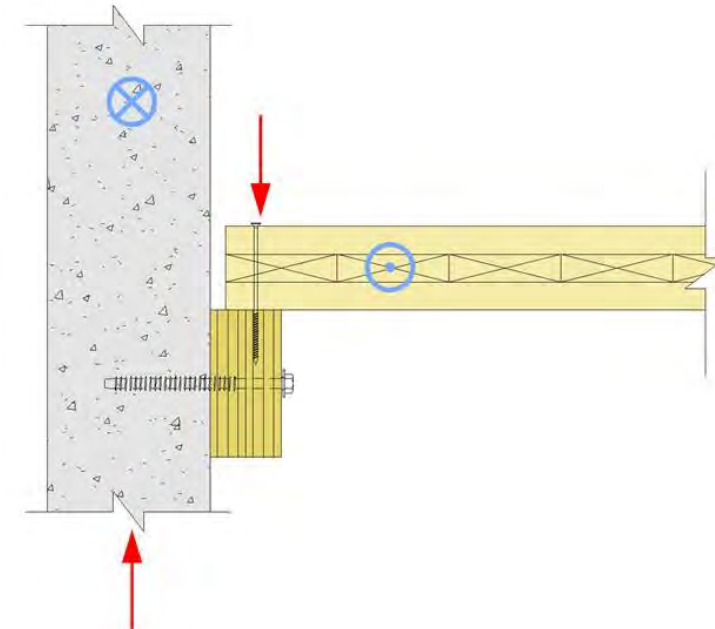
- Tolerances & adjustability
- Drag/collector forces



PLAN VIEW



PLAN VIEW



Lateral System Choices

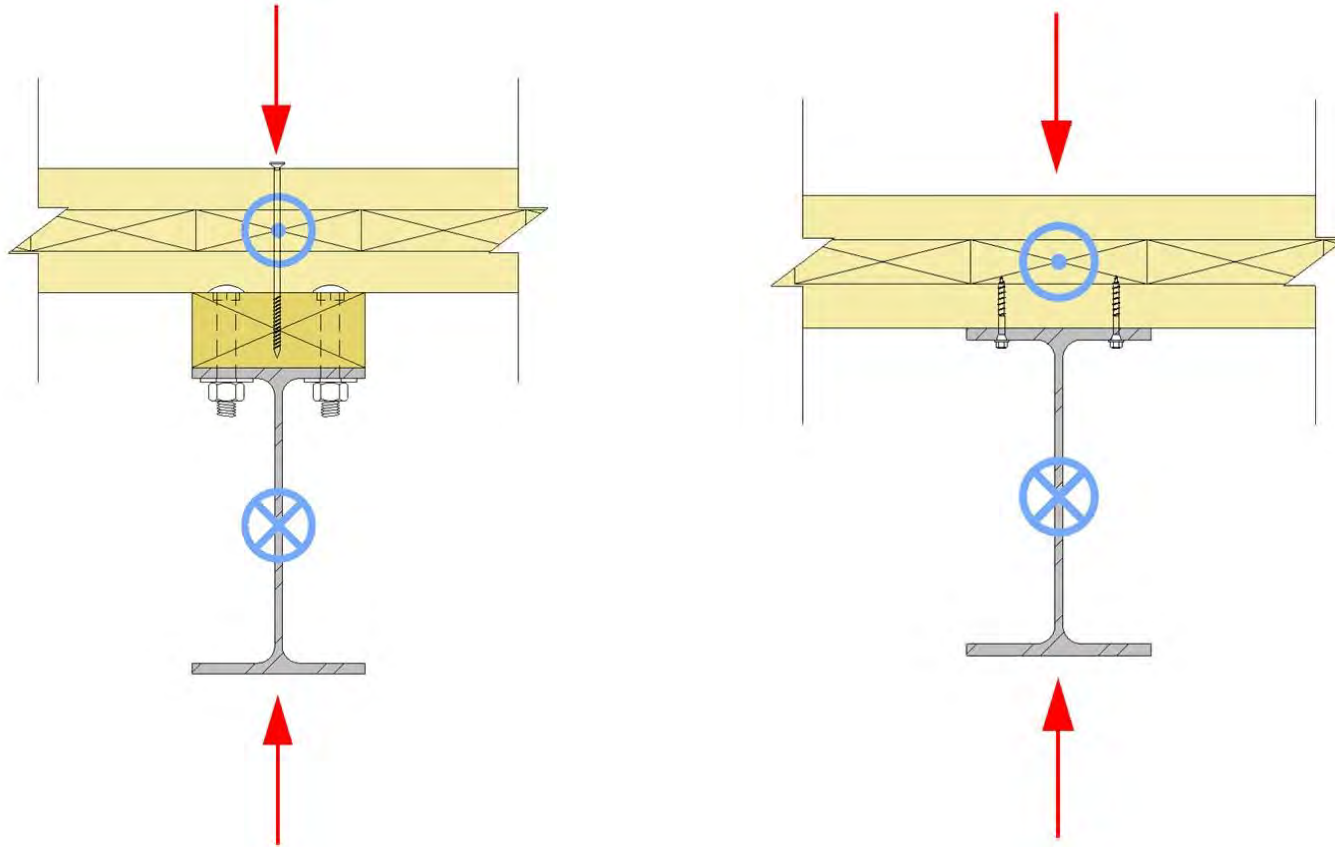
Steel Braced Frame



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)



Lateral System Choices

MT Shearwalls



Photo: Alex Schreyer



Lateral System Choices

MT Rocking Shearwalls



Photo: WoodWorks

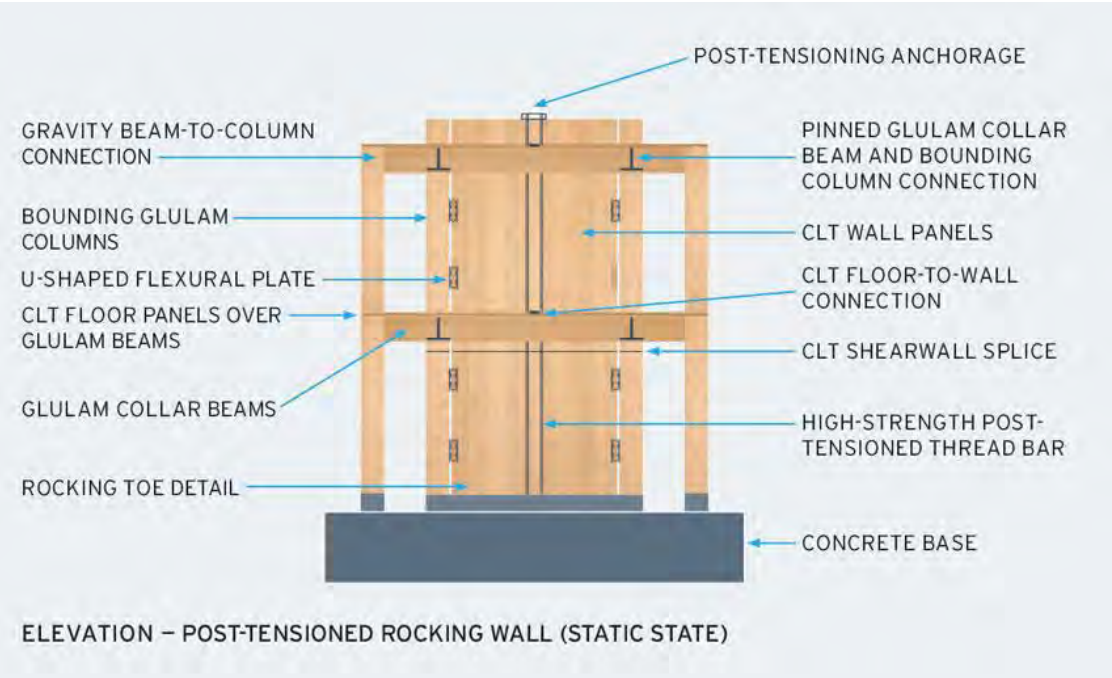


Image: KPFF

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**

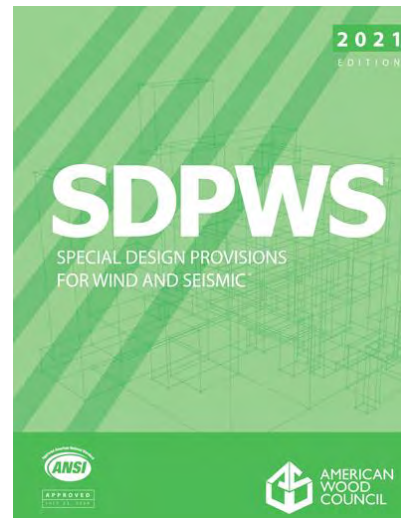


Photo: WoodWorks



Acoustics & Sound Control



Acoustics & Sound Control

Consider Impacts of:

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



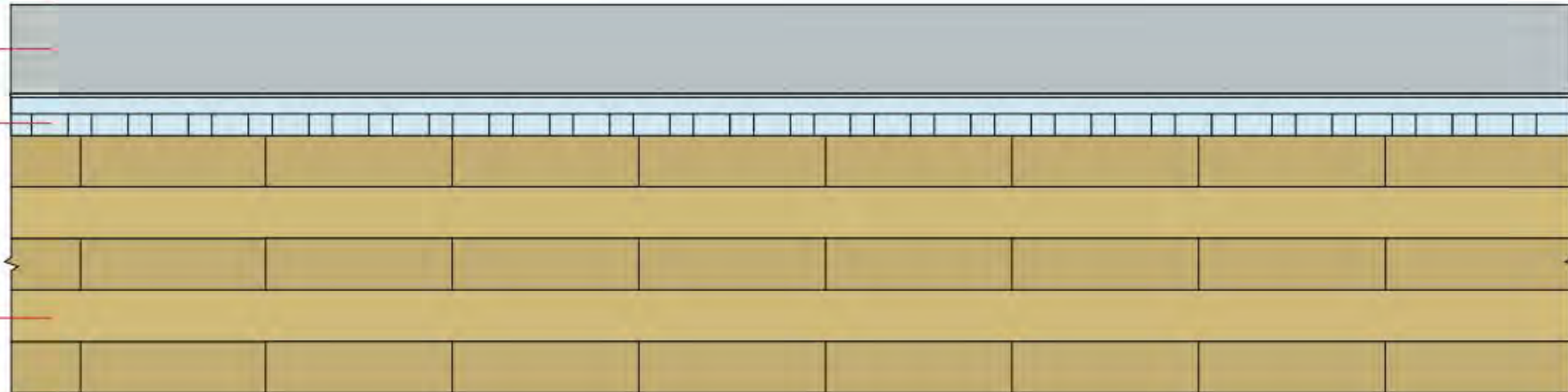
Credit: Rothoblaas

Acoustics & Sound Control



Images: Maxxon

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

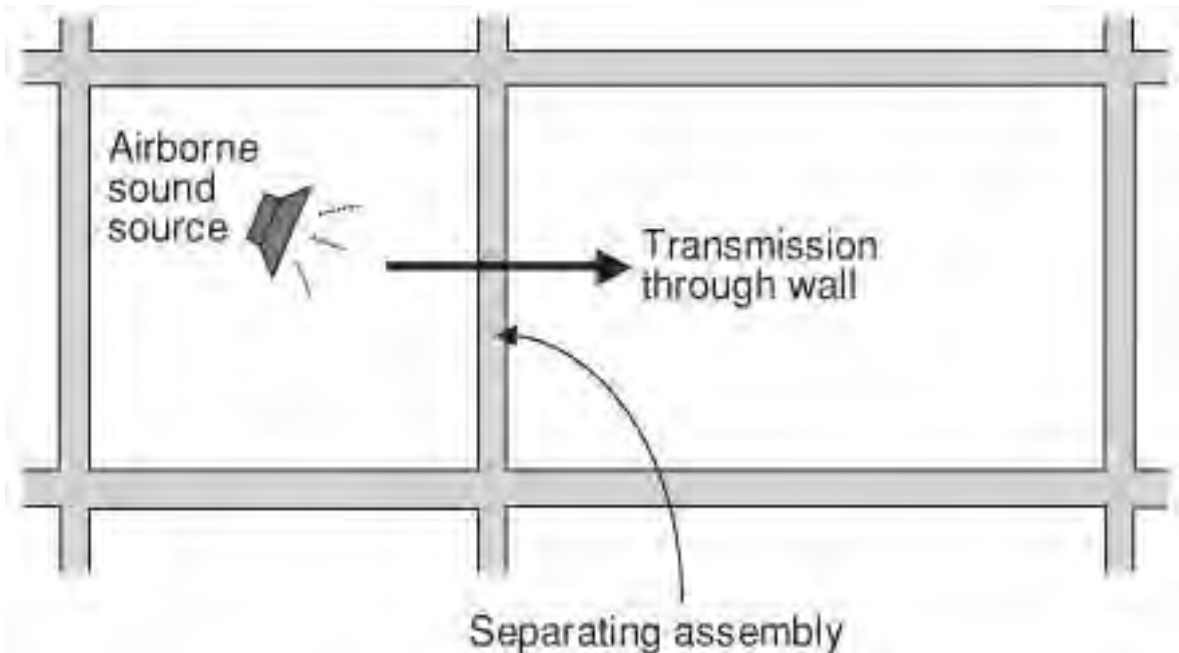


Acoustics & Sound Control

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

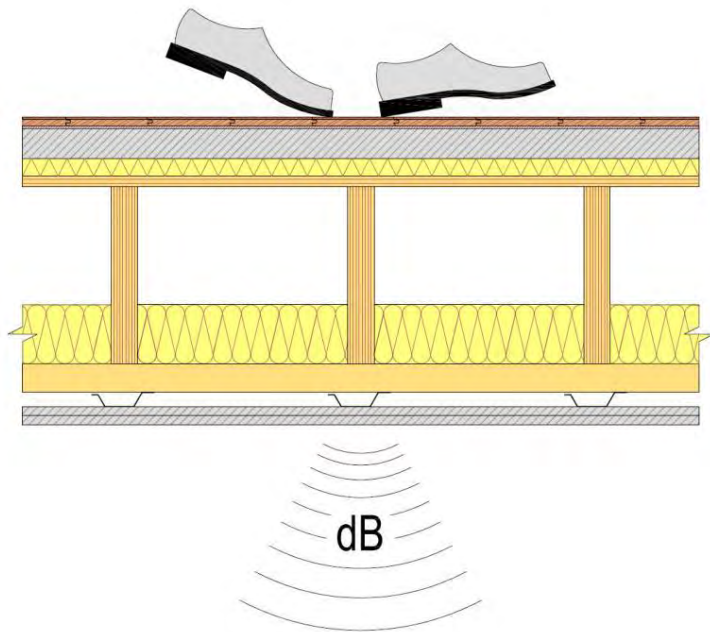


Acoustics & Sound Control

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:

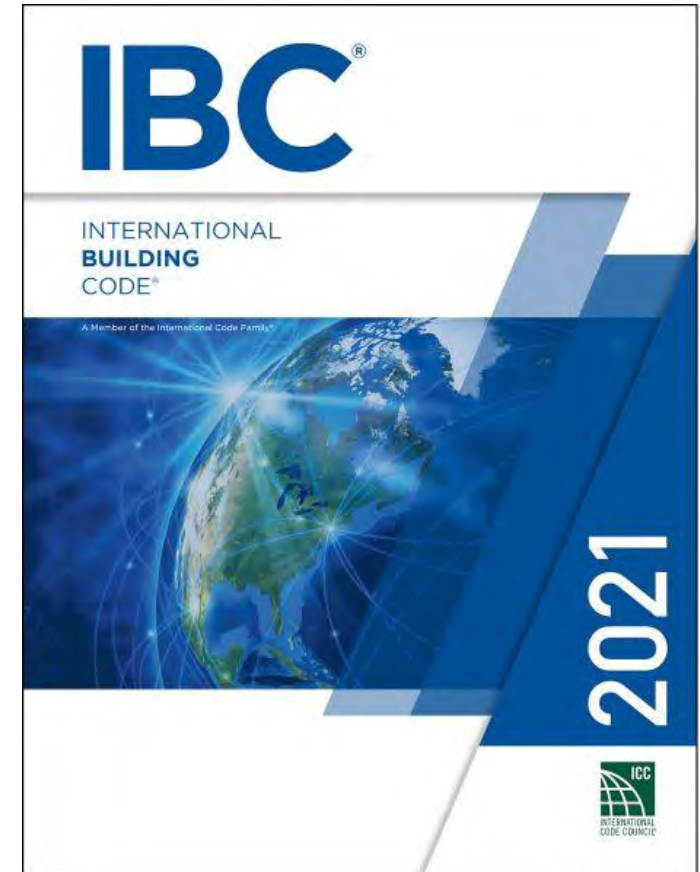
For unit to unit or unit to public or service areas:

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

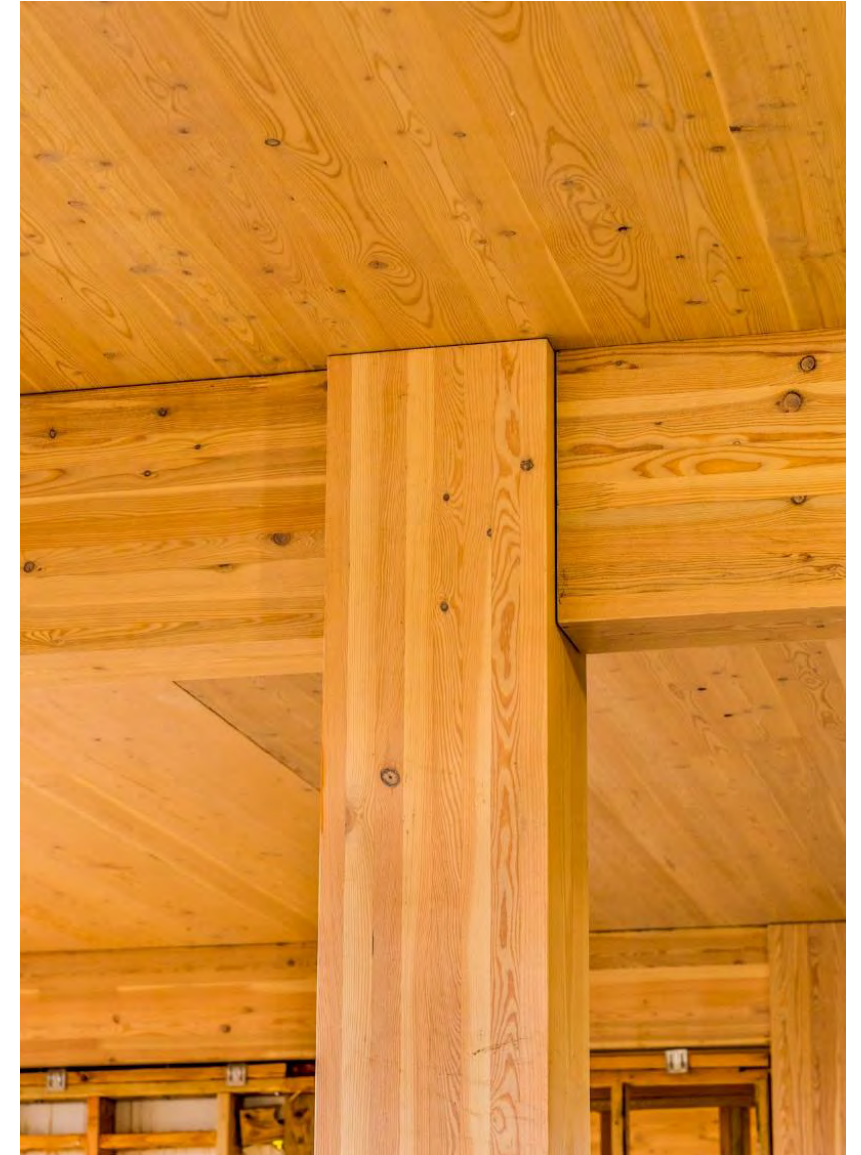


Acoustics & Sound Control

| 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



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

Acoustics & Sound Control

TABLE 1:
Examples of Acoustically-Tested Mass Timber Panels

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

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks⁷

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

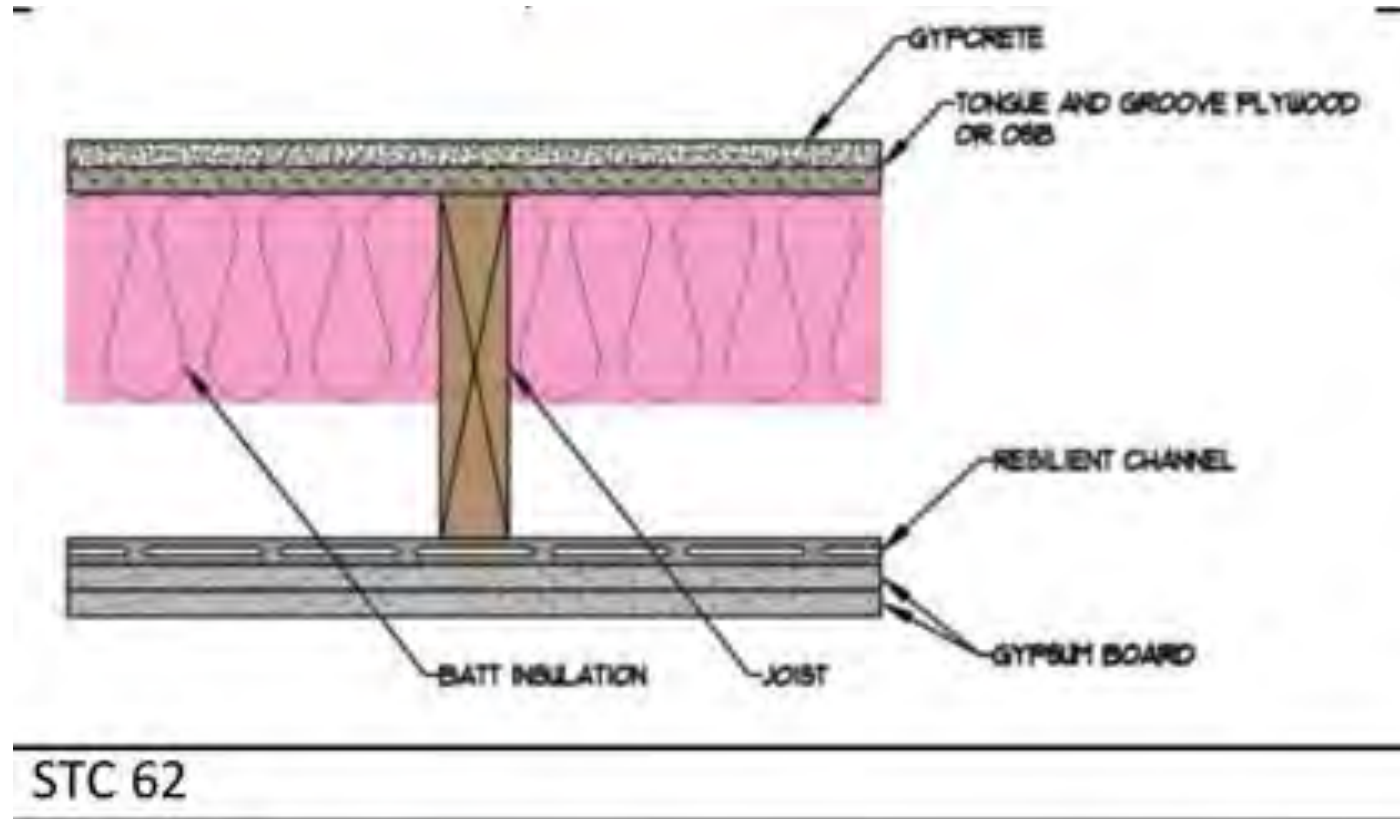


Image credit: Christian Columbres

Acoustics & Sound Control

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

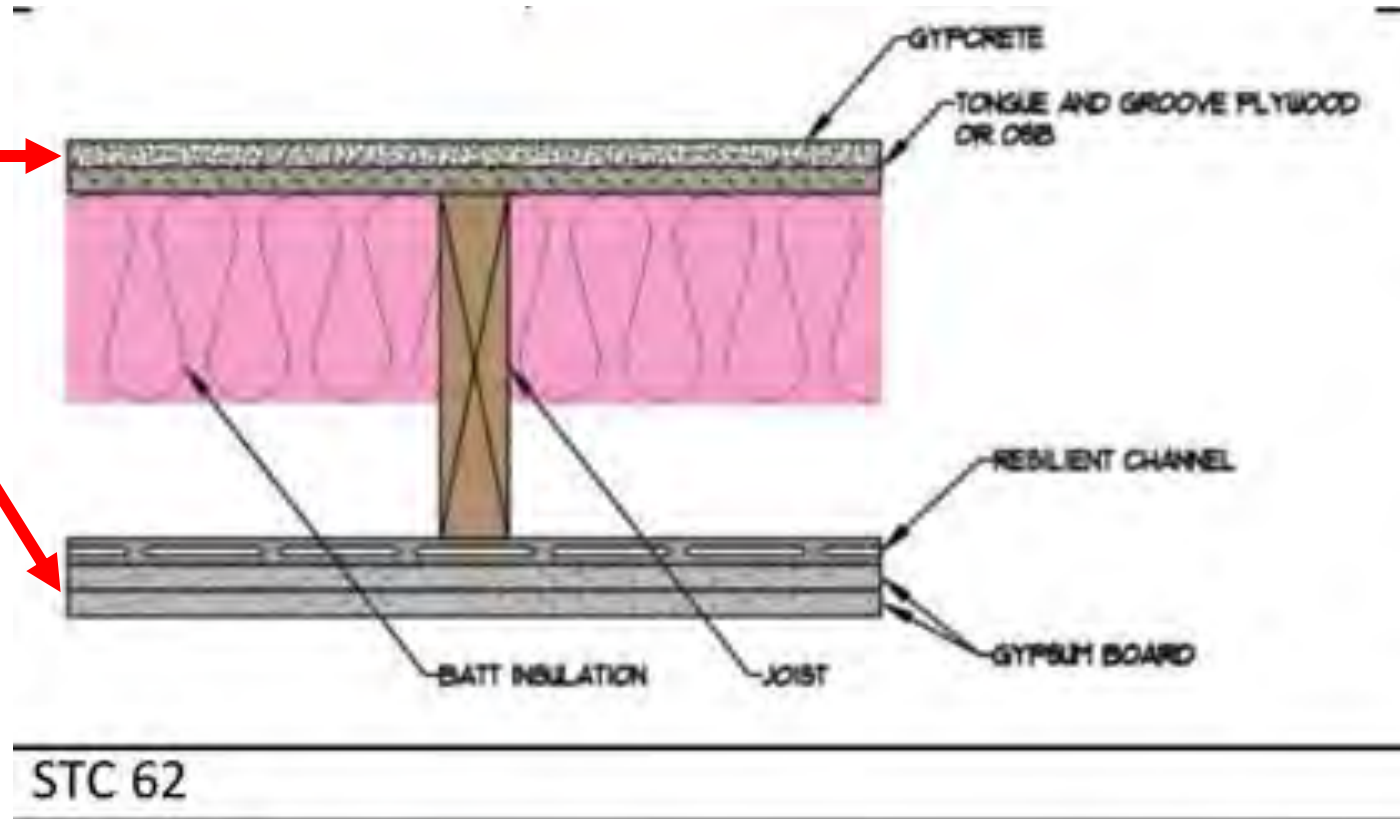
1. Add mass
2. Add noise barriers
3. Add decouplers



Acoustics & Sound Control

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

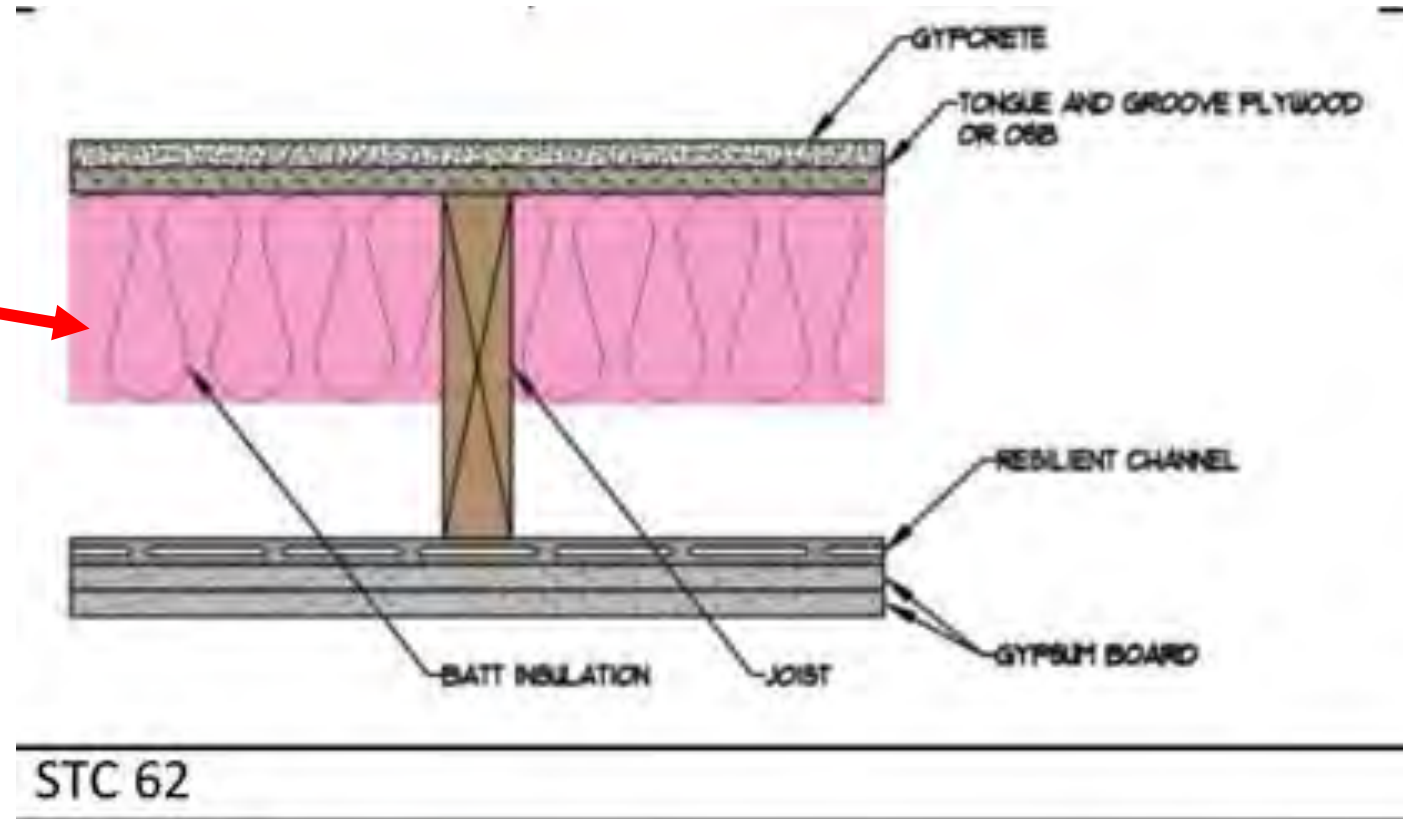
1. Add mass
2. Add noise barriers
3. Add decouplers



Acoustics & Sound Control

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

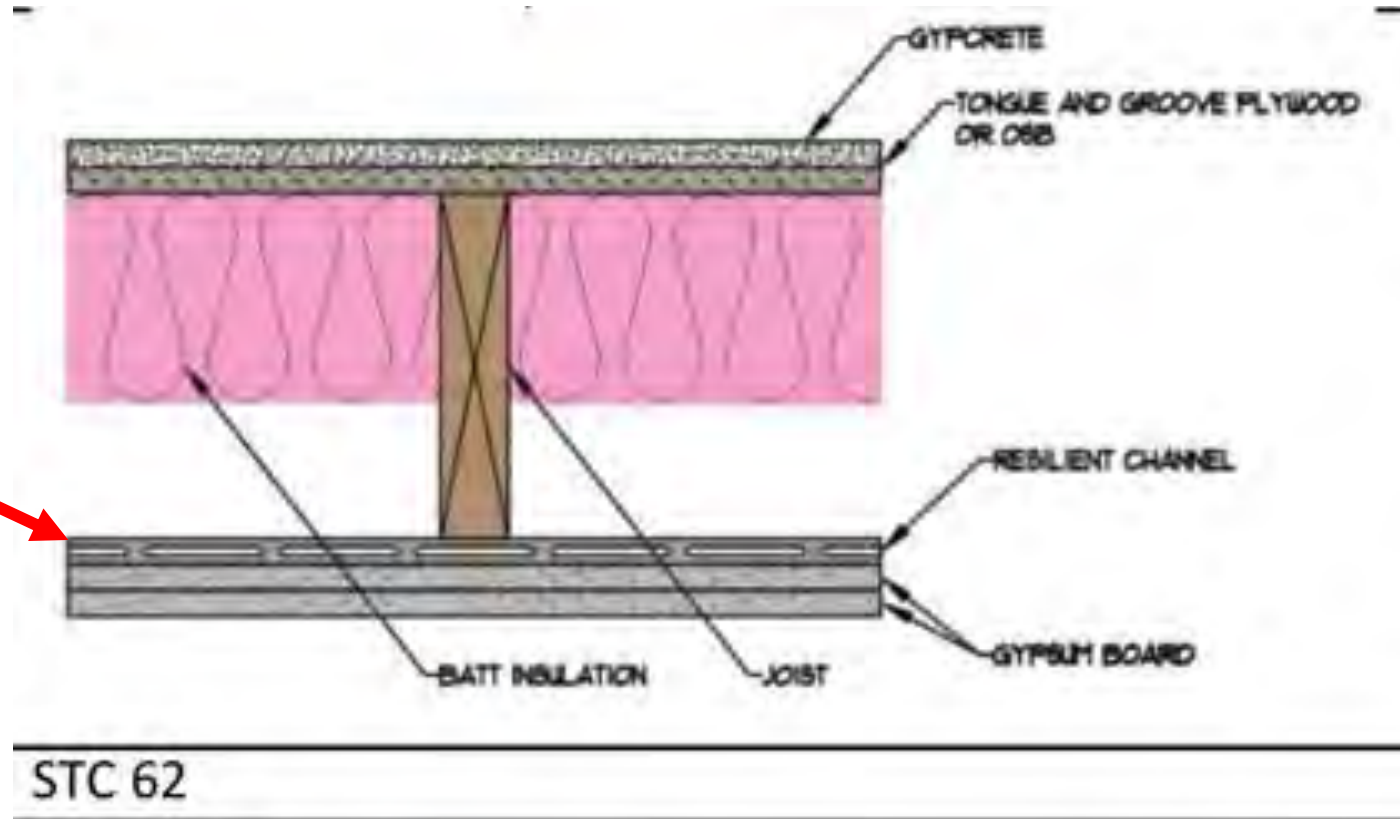
1. Add mass
2. Add noise barriers
3. Add decouplers



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

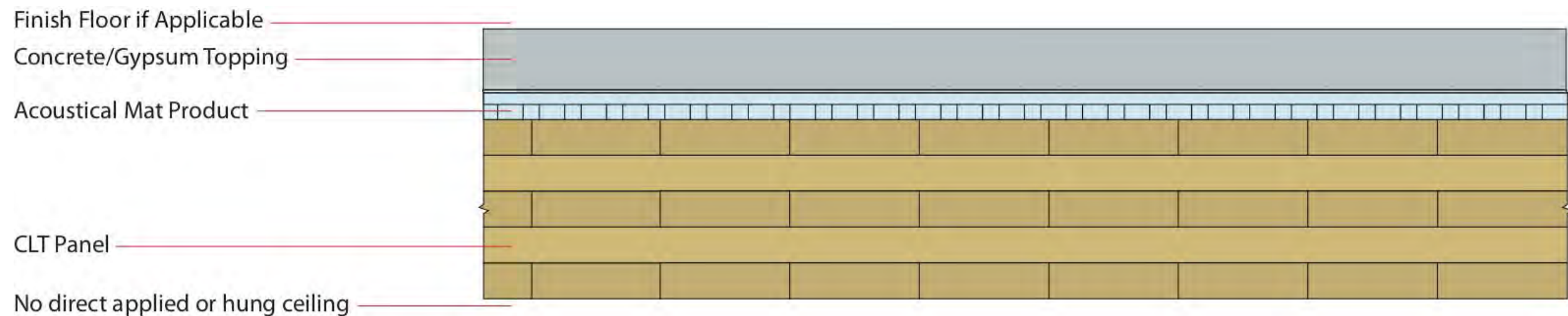
STC 41



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: AcoustiTECH¹⁰

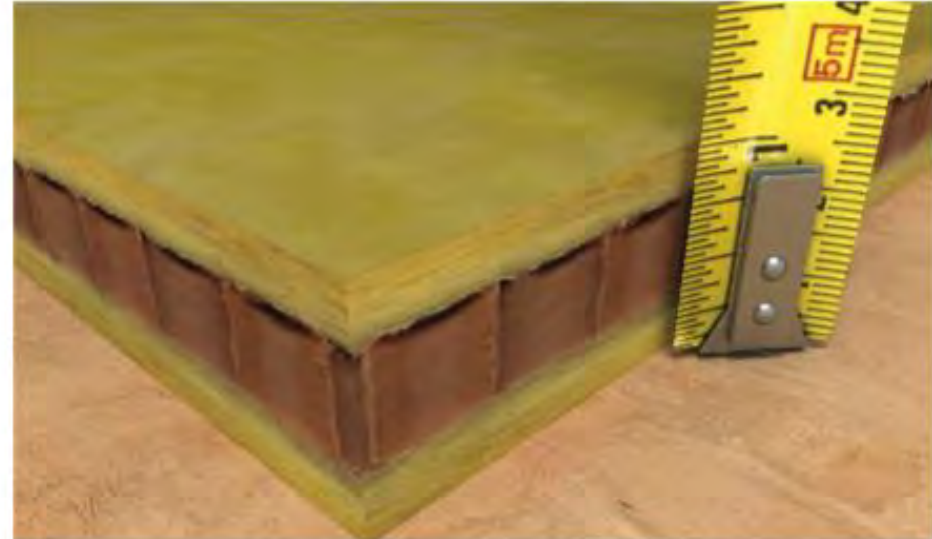


Photo: Kinetics Noise Control, Inc.,¹¹



Photo: Maxxon Corporation

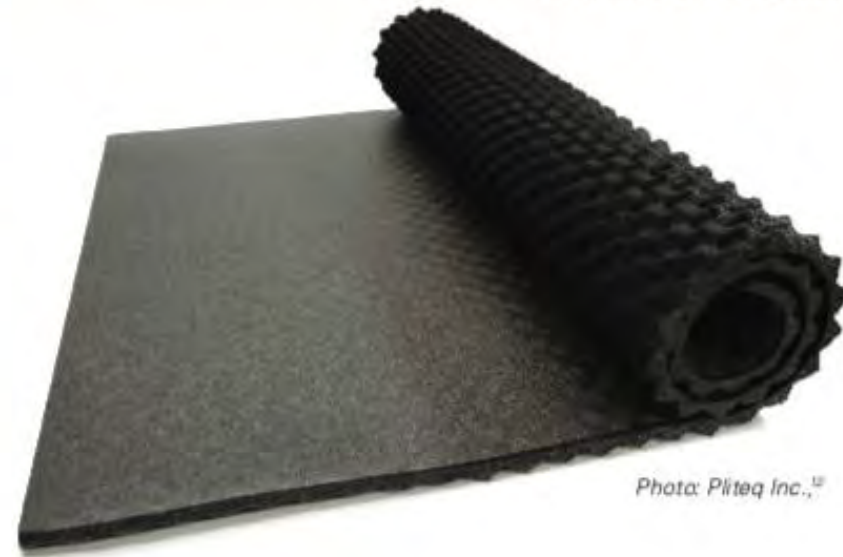


Photo: Pliteq Inc.,¹²

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

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

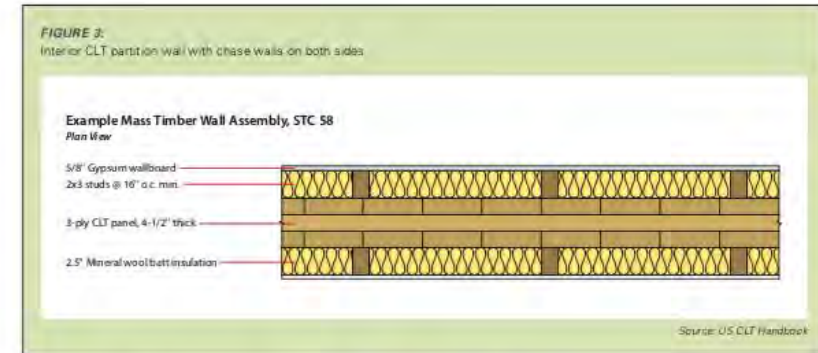


Photo: Corey Geller, Courtesy: Perini + Hill

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

The growing availability and code acceptance of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction has given designers a low-carbon alternative to steel, concrete, and masonry for many applications. However, the use of mass timber in multi-family and commercial buildings presents unique acoustic challenges.

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



Mass Timber Assembly Options: Walls

Mass timber panels can also be used for interior and exterior walls—both bearing and non-bearing. For interior walls, the need to conceal services such as electrical and plumbing is an added consideration. Common approaches include building a chase wall in front of the mass timber wall or installing gypsum wallboard on resilient channels that are attached to the mass timber wall. As with bare mass timber floor panels, bare mass timber walls don't typically provide adequate noise control, and chase walls also function as acoustical improvements. For example, a 3-ply CLT wall panel with a thickness of 3.07" has an STC rating of 33.⁴ In contrast, Figure 3 shows an interior CLT partition wall with chase walls on both sides. This assembly achieves an STC rating of 58, exceeding the IBC's acoustical requirements for multi-family construction. Other examples are included in the inventory of tested assemblies noted above.

Acoustical Differences between Mass Timber Panel Options

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

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

Improving Performance by Minimizing Flanking

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

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



Acoustical isolation strips

Photo: Perini+Hill

 National Research
Council Canada



Summary –

14

Conseil national
recherches Canada

| | |
|-----|----|
| STC | 58 |
| HC | 59 |

| | | |
|---|-------------------------|-----------------|
| 130 Derry Court New York, NY 10017 Tel: 212 693 6600 www.architect.com | www.martek.com/building | p. 717/764 7700 |
|---|-------------------------|-----------------|

DOCUMENT CONTROL
ATI 00629 (03/21/18)
RTTDS-R-AMER-Test-2844
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CLT (CROSS LAMINATED TIMBER)

| CLT | Insulation | Resilient Channel | Ceiling | Min. Topping Depth | Sound Mat | Floor Covering | Sound Rating | | | Maximum U _F Path Rating |
|-----|-----------------------------------|-------------------|-----------------------------------|--------------------|------------|----------------|--------------|-----|------------------|------------------------------------|
| | | | | | | | STC | IRC | Test Number | |
| 7" | 3" R ¹⁸ Bat Insulation | Yes | Suspended Ceiling w/ 5/8" Drywall | 3/4" | Acoustical | DT | 54 FRC | | F117 17-22-20-16 | R513 |
| | | | | | | Carpet and Pad | 54 FRC | | F117 22-20-16 | |
| | | | | | | DT | 54 FRC | | F117-23-20-16 | |
| | | | | | | Carpet and Pad | 74 FRC | | F117 24-20-16 | |

| Part | Resilient | Min. Topping | Sound Mat | Floor Covering | Sound Rating | | | Max. U.I. Rating |
|----------|-----------|--------------|--------------|----------------|--------------|------|-------------|------------------|
| Material | Thickness | Depth | | | STC | W.C. | Test Number | |
| | | 3/4" | Acoust-A-Mat | None | 45 FRC | | TP 11000000 | 110 |
| | | | | None | 38 FRC | | TP 11000000 | |

| wall | Min. Topping Depth | Sound Mat | Floor Covering | Sound Rating | | | Maximum Ulf Rating |
|------|--------------------|-----------|----------------|--------------|---------|-------------|--------------------|
| | | | | STC | IRC | Test Number | |
| a | None | No | None | 39 FSTC | 22 FIRC | 410100-055 | (90) |

of this guide. For assistance determining the right system for your project, contact your Mission Regional Representative at (800) 354-7887.

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 or contact the WoodWorks Regional Director nearest you: <http://www.woodworks.org/project-assistance>

Contents:

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

Key Early Design Decisions

Early Design Decision Example

7-story, 84 ft tall multi-family building

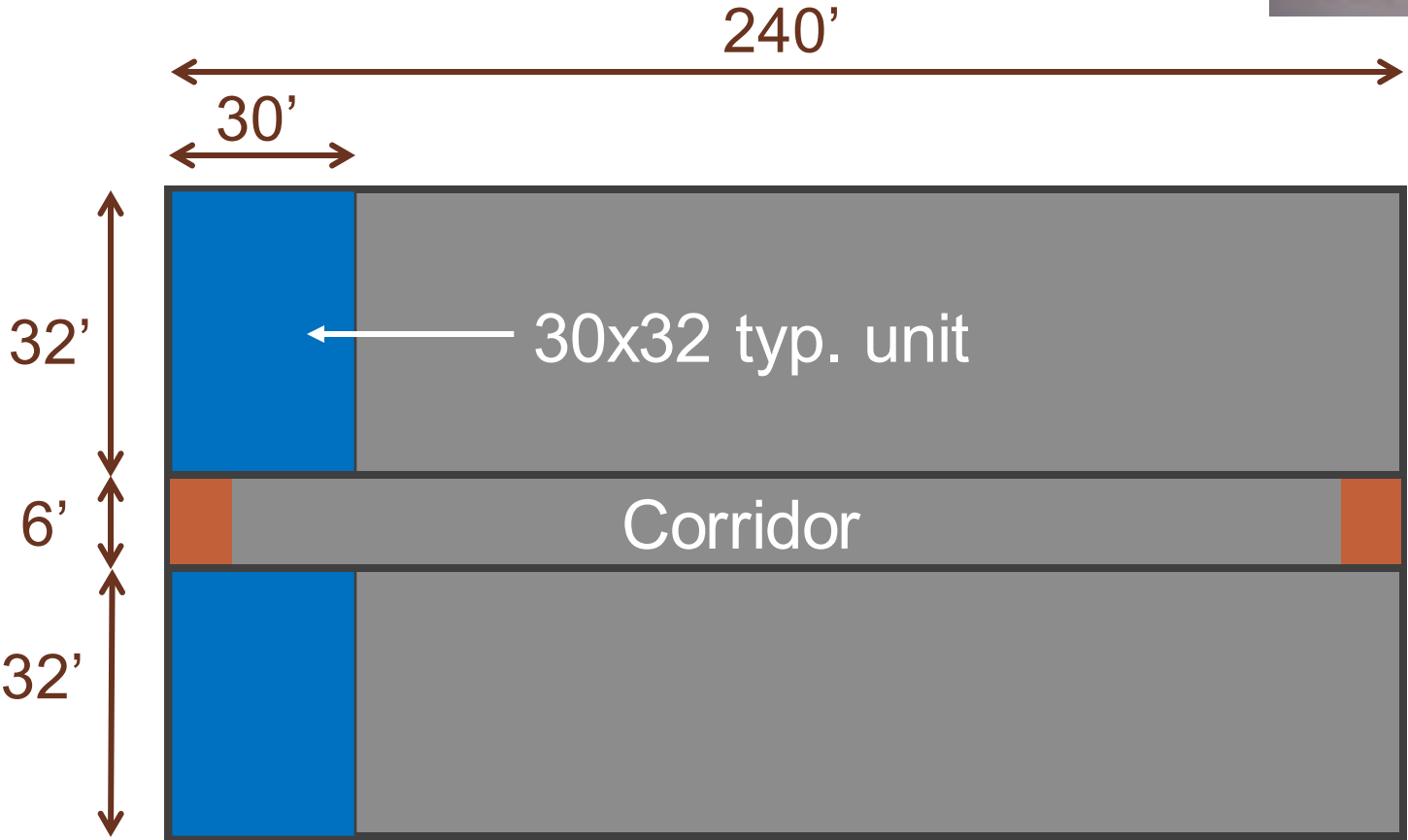
- Parking & Retail on 1st floor, residential units on floors 2-7
- NFPA 13 sprinklers throughout
- Floor plate = 18,000 SF
- Total Building Area = 126,000 SF



Key Early Design Decisions

Early Design Decision Example

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

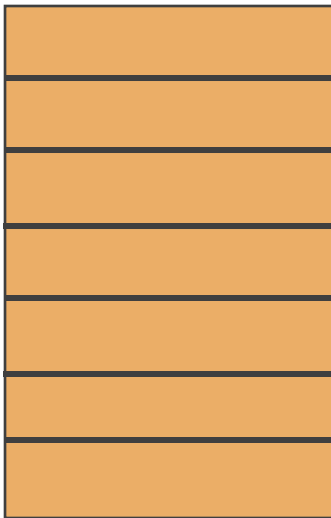


Key Early Design Decisions

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

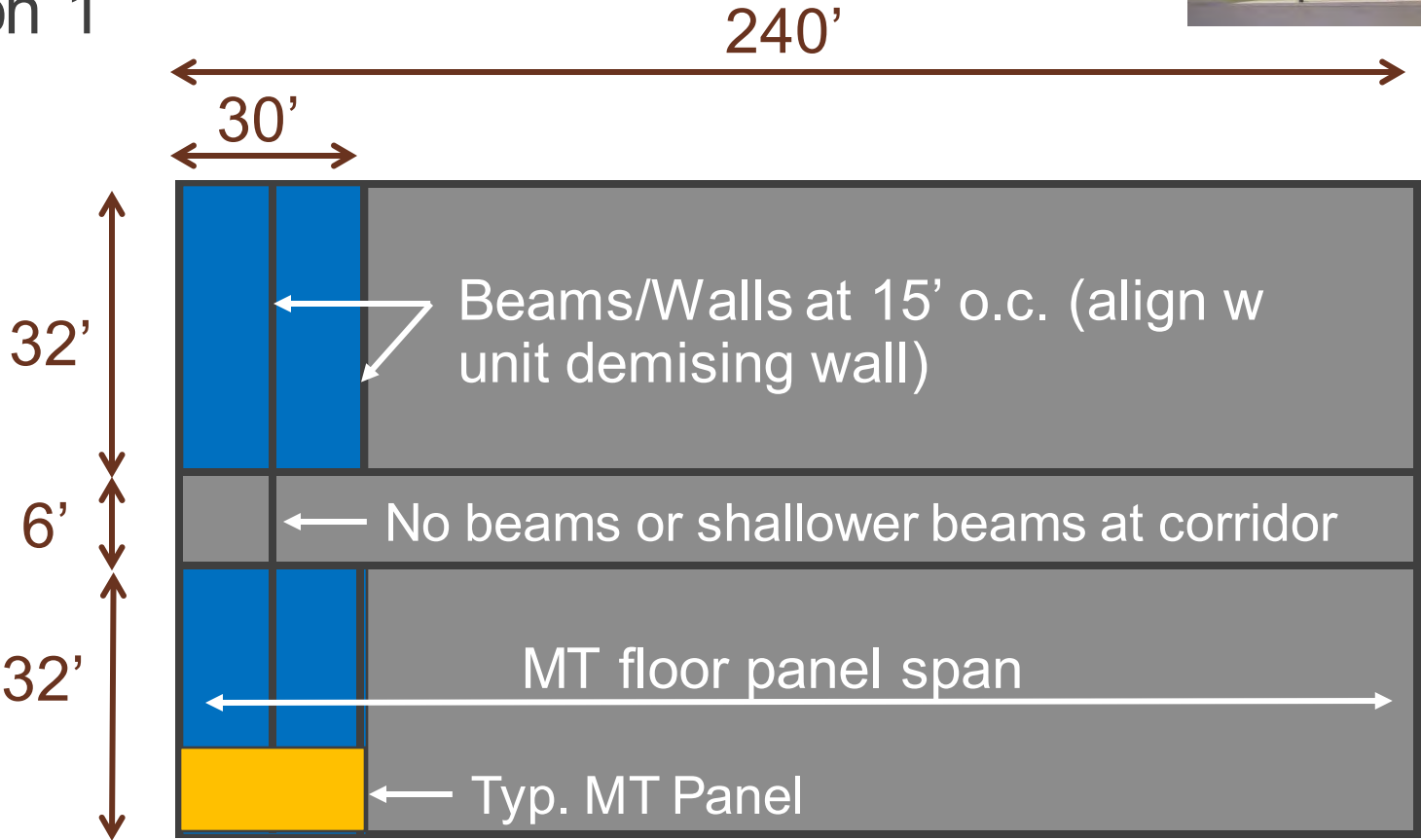


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

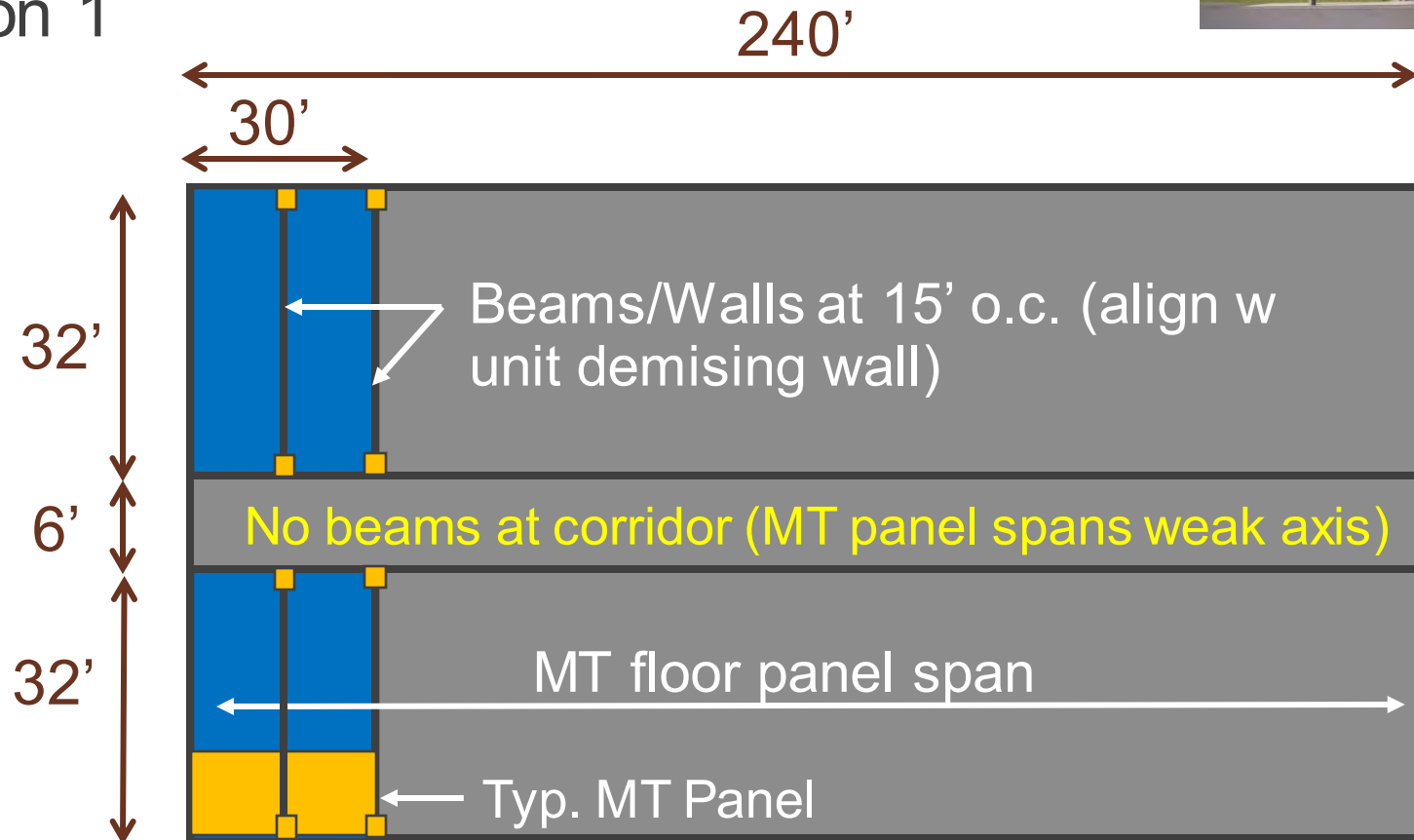


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

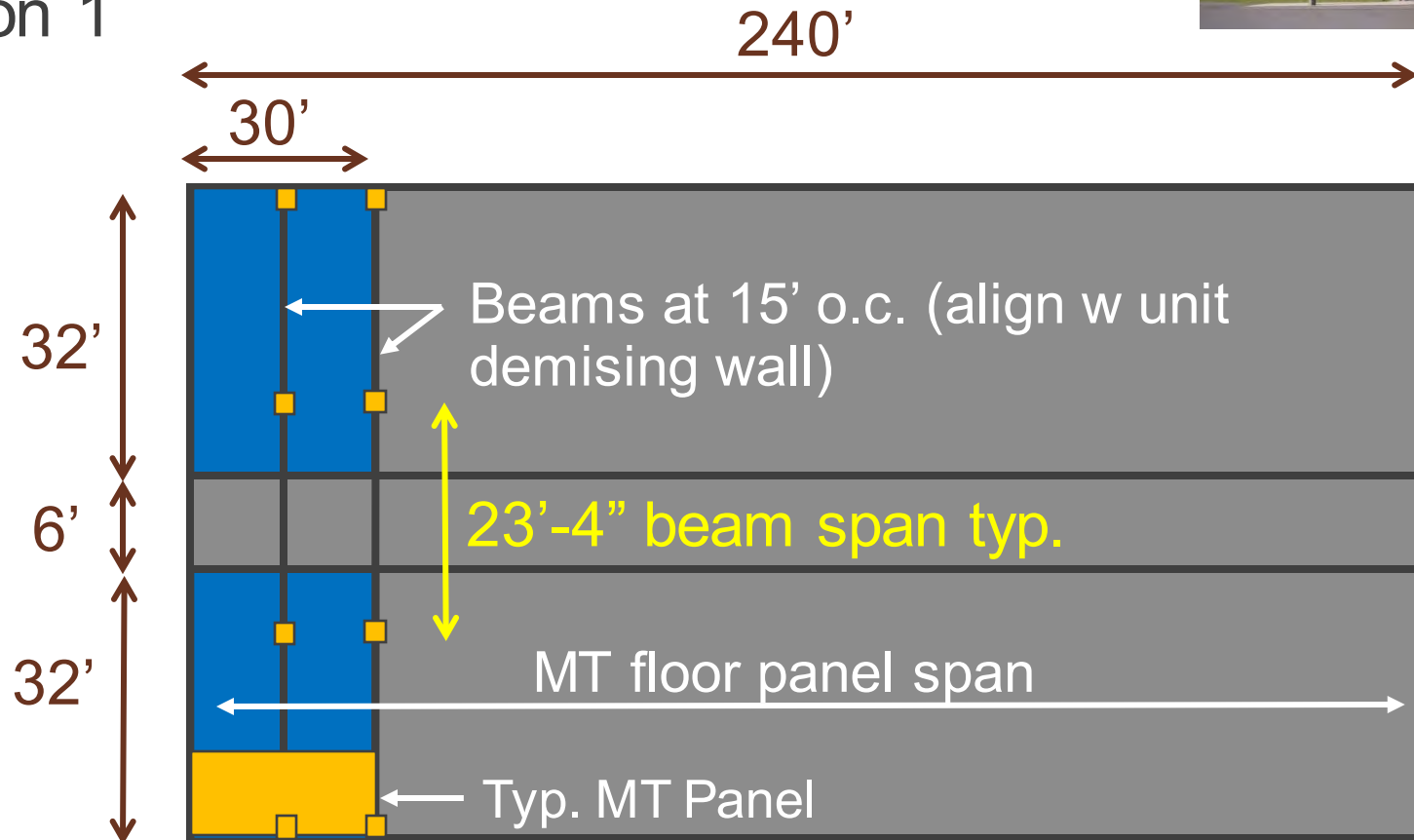


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

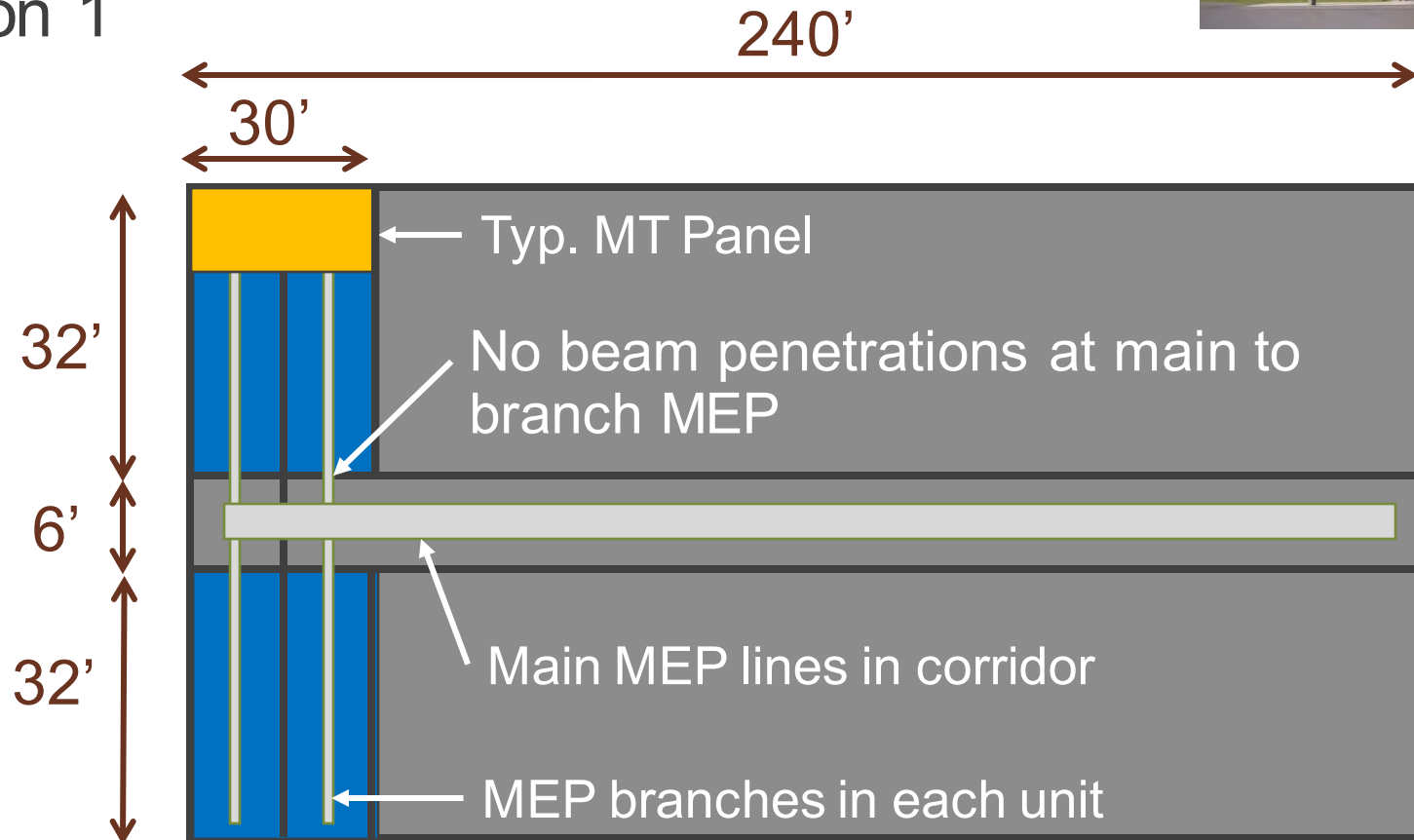


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

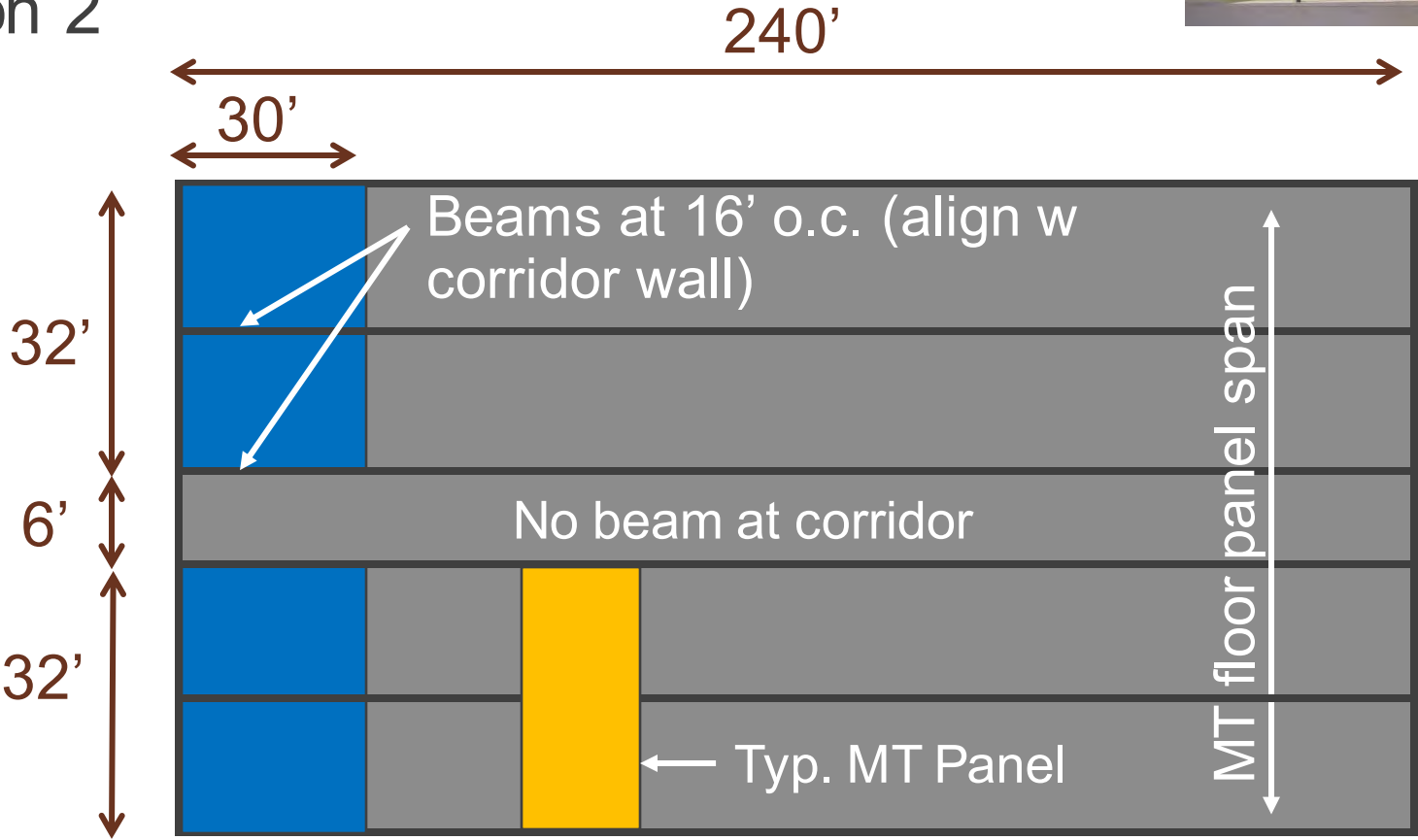


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2

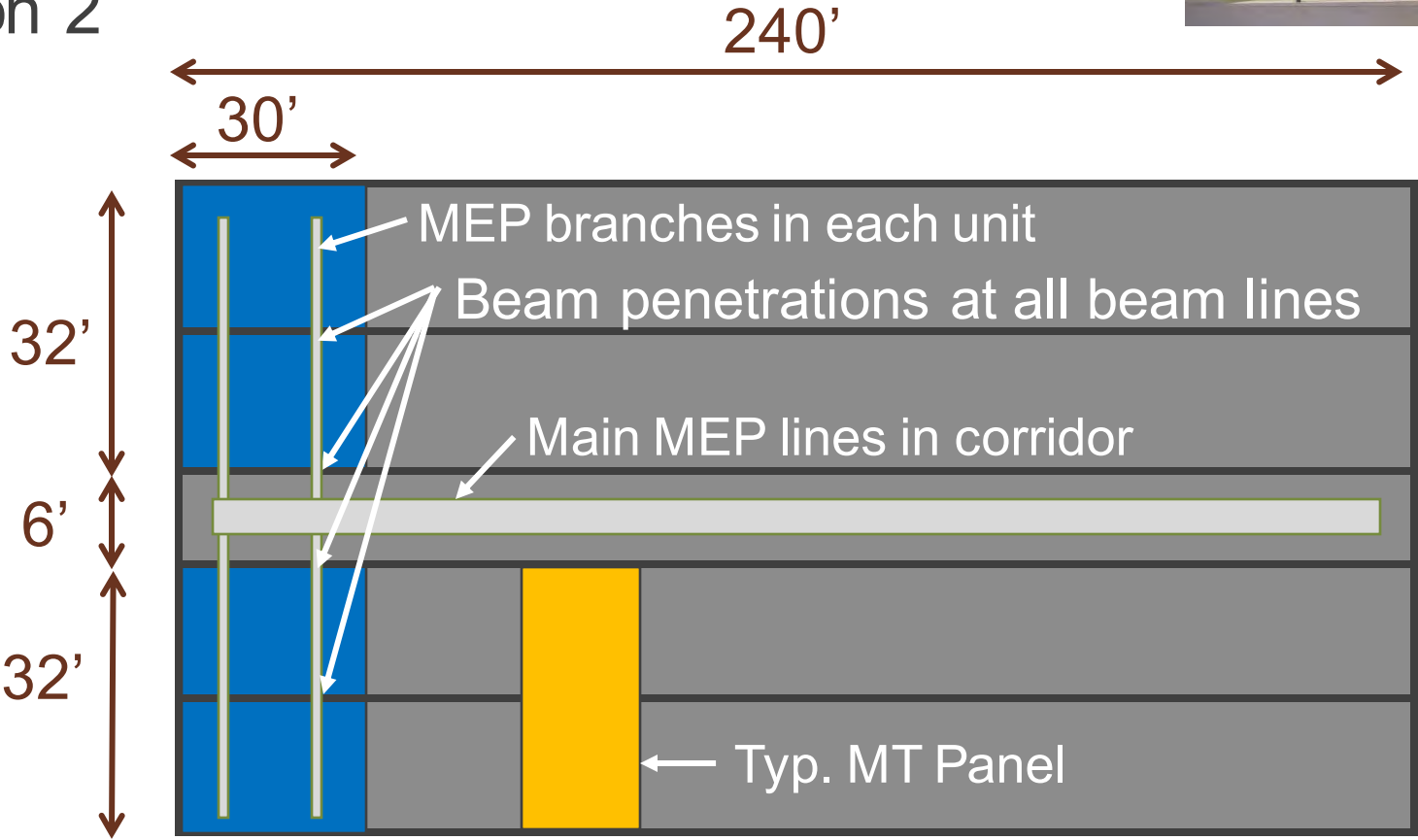


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2



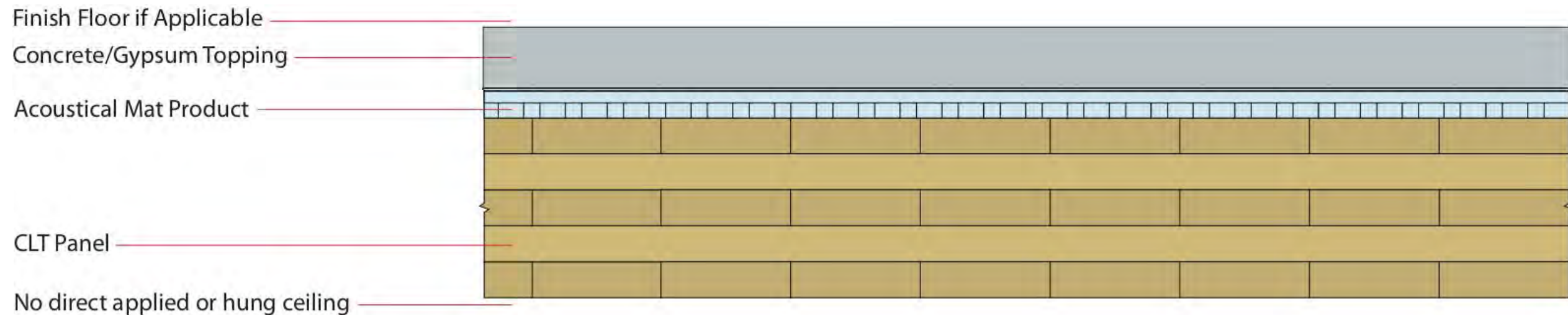
Key Early Design Decisions

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

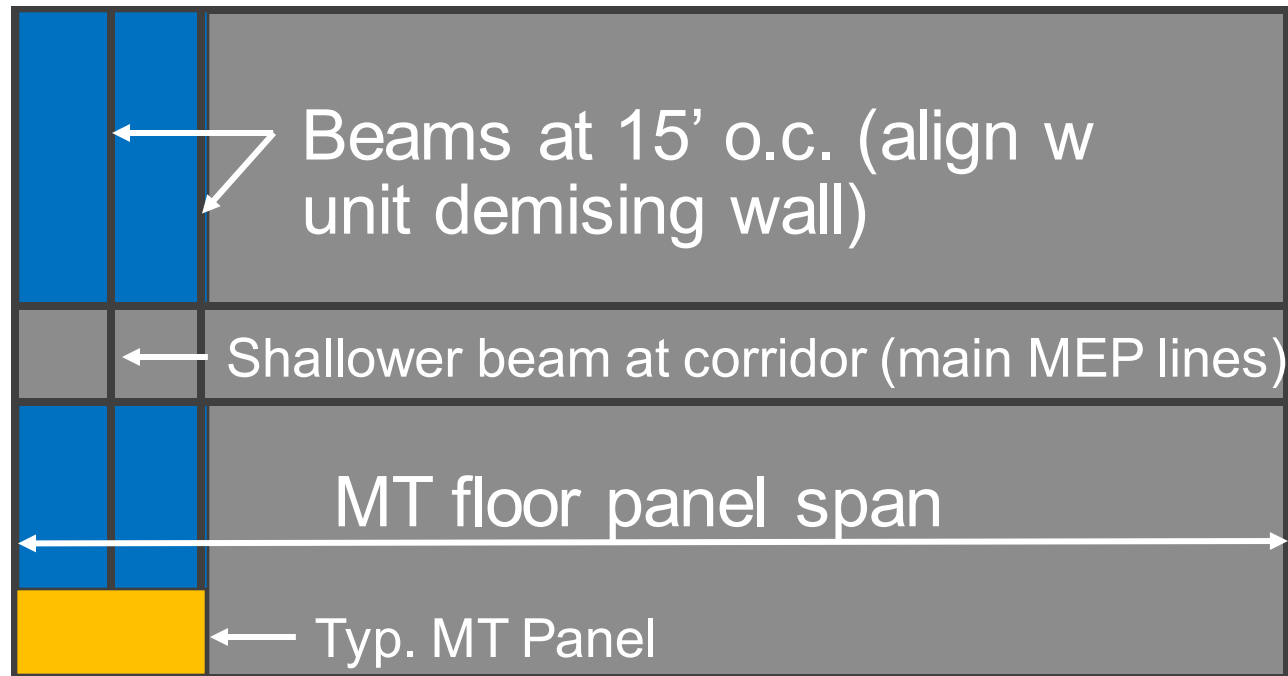
Early Design Decision Example

Type IIIA Grid Options

- Option 1



Credit: Monte French Design Studio



Key Early Design Decisions

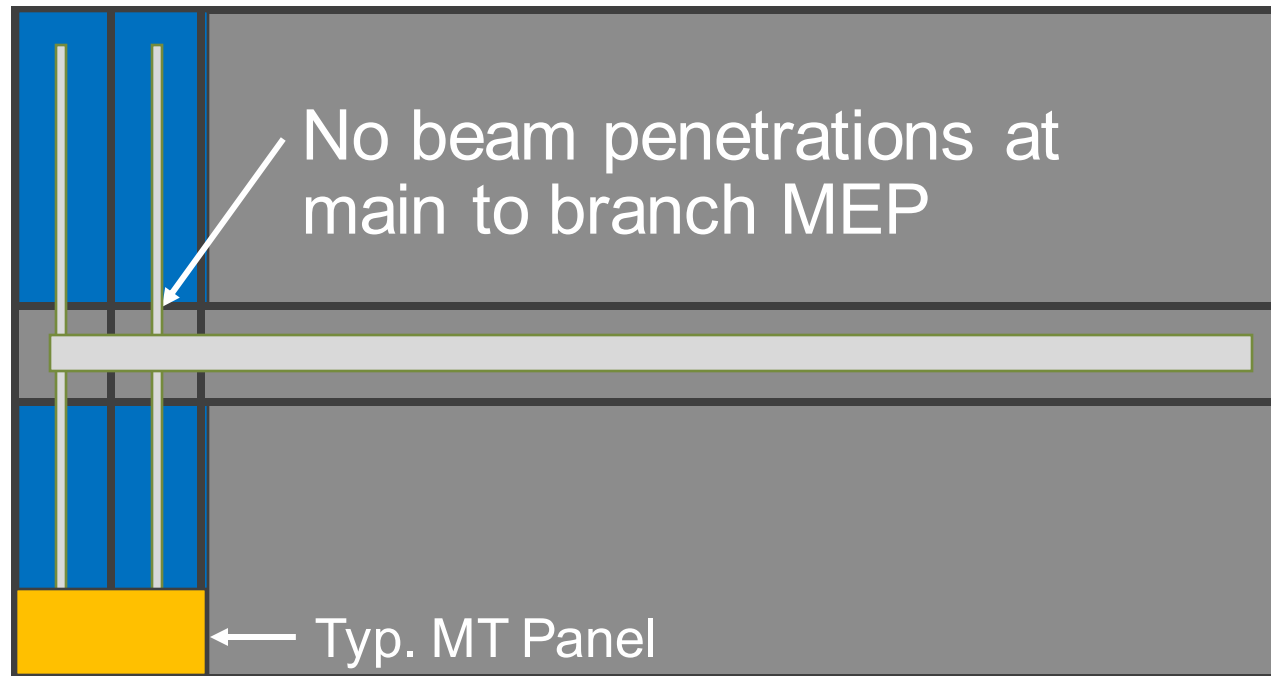
Early Design Decision Example

Type IIIA Grid Options

- Option 1



Credit: Monte French Design Studio

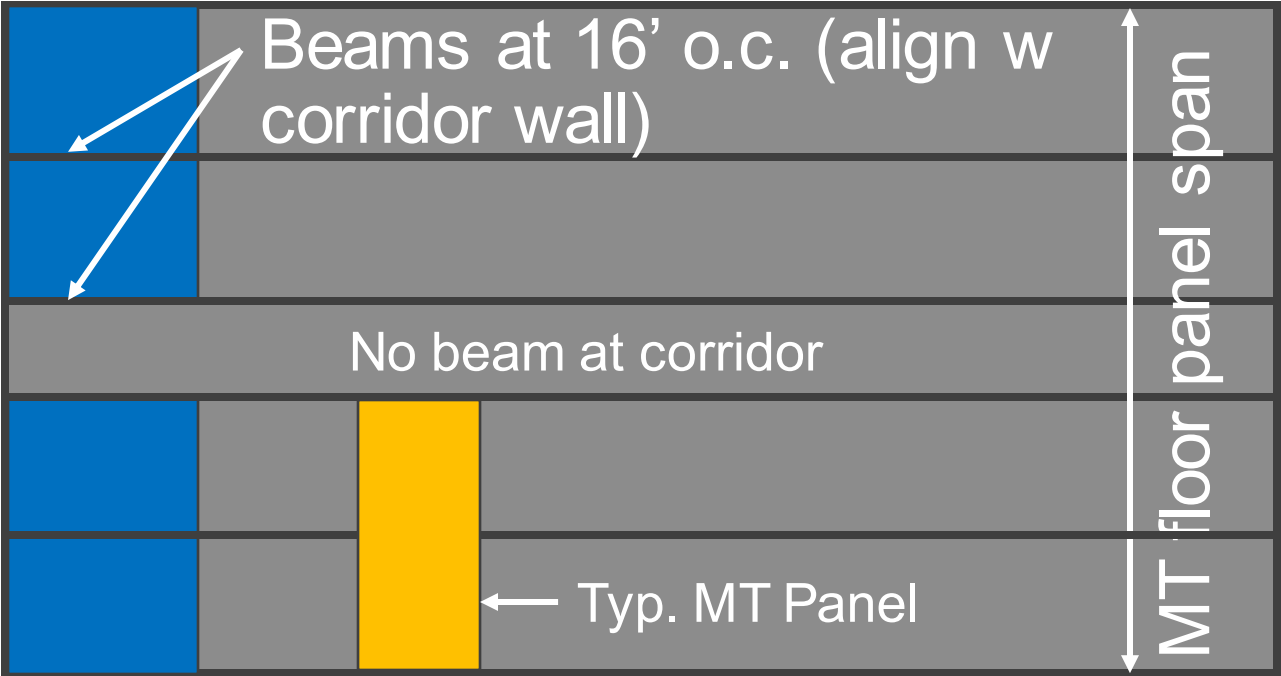


Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

- Option 2

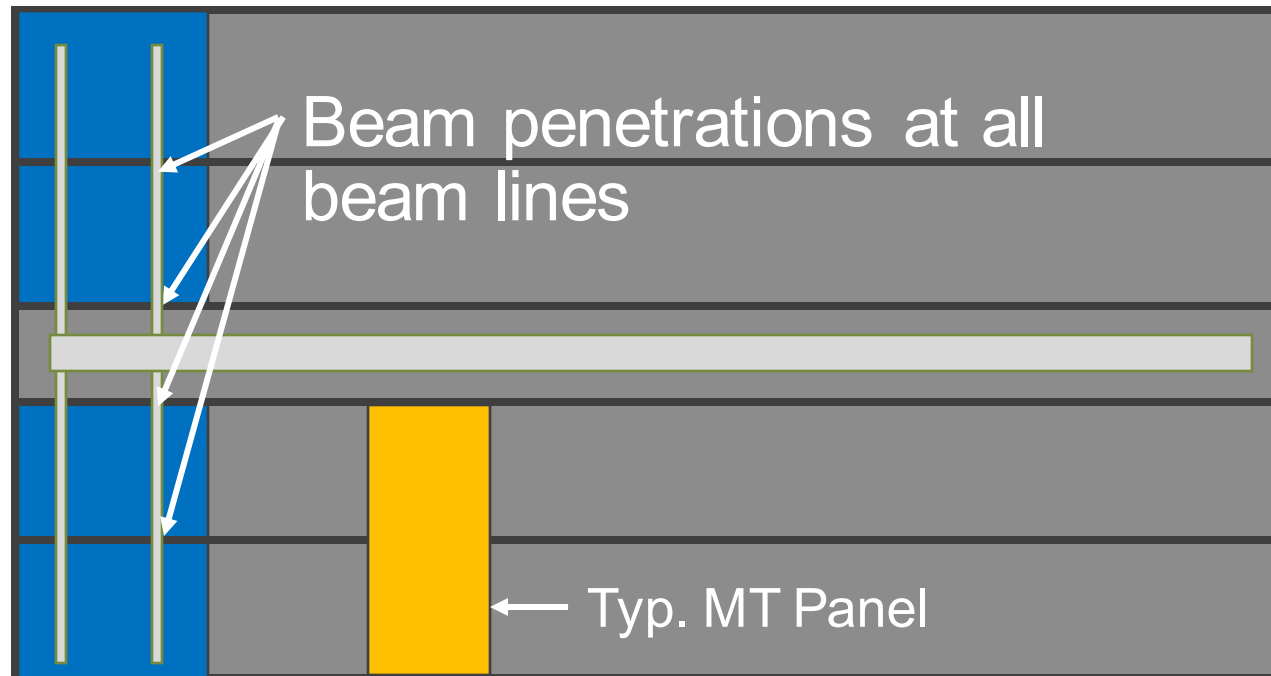


Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

- Option 2



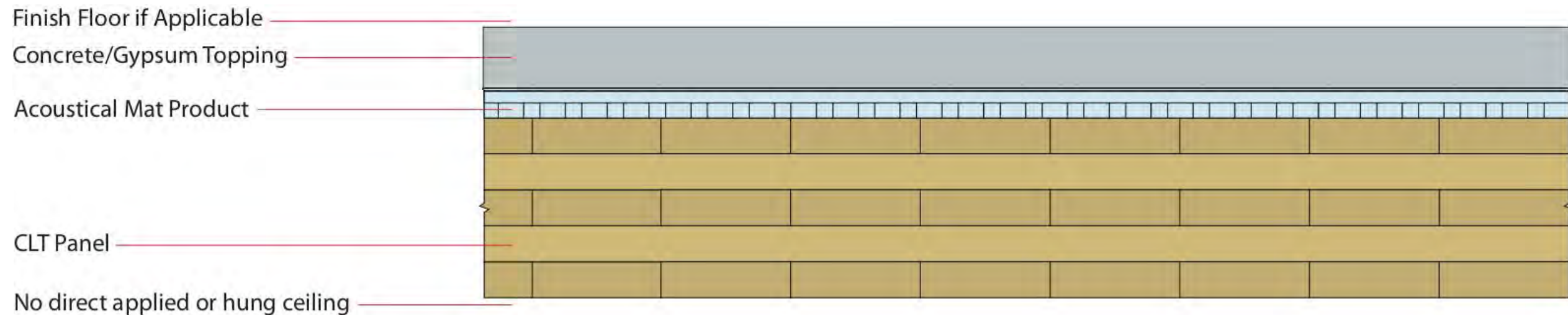
Key Early Design Decisions

Early Design Decision Example

Type IIIA Floor Assembly Options



Credit: Monte French Design Studio



- 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 –
Hillsboro, OR**

ARCHITECT:
Hacker

ENGINEERS:
Kramer Gehlen & Associates,
Equilibrium Consulting

CONTRACTOR:
Swinerton



Download Checklists at
www.woodworks.org

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? Ask me anything.



Jeff Peters, PE, CGC

Regional Director | FL, AL, LA

386.871.8808

Jeff.Peters@woodworks.org

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



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