Early Design Decisions: Priming Mass Timber Projects for Success

Presented by
Chelsea Drenick and Mike Romanowski, WoodWorks
March 16, 2022
HEAVY TIMBER
Federal Center South, Seattle, WA
Photo: Benjamin Benschneider

MASS TIMBER
Bullitt Center, Seattle, WA
Photo: John Stamets
Mass Timber Building Options

Post & Beam  Flat Plate  Honeycomb
Mass Timber Building Options

Hybrid: Light-Frame Wood

Hybrid: Steel
Glue-Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations (MPP)

Dowel-Laminated Timber (DLT)

Nail-Laminated Timber (NLT)

Glue-Laminated Timber (GLT)
Plank orientation

Photo: Freres Lumber
Photo: StructureCraft
Photo: Think Wood
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 installation
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 height, 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…
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 choice** 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**

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)</th>
<th>Allowable Number of Stories above Grade Plane (IBC Table 505.4)</th>
<th>Allowable Area Factor (At) for SM, Feet² (IBC Table 506.2)</th>
</tr>
</thead>
</table>
Key Early Design Decisions

**Construction Type – Primarily based on building size & occupancy**

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, R</td>
<td>270 180 85 85 85 85 70 60</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>Allowable Area Factor (At) for SM, Feet$^2$ (IBC Table 506.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2, A-3, A-4</td>
<td>135,000 90,000 56,250 45,000 42,000 28,500 34,500 18,000</td>
</tr>
<tr>
<td>B</td>
<td>324,000 216,000 135,000 108,000 85,500 57,000 54,000 27,000</td>
</tr>
<tr>
<td>R-2</td>
<td>184,500 123,000 76,875 61,500 72,000 48,000 36,000 21,000</td>
</tr>
</tbody>
</table>

2021 IBC/2019 CBC Supplement
Key Early Design Decisions

Fire-Resistance Ratings

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

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions Interior&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary structural members (see Section 202)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary structural members (see Section 202)</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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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)

<table>
<thead>
<tr>
<th>Panel</th>
<th>Example Floor Span Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (4-1/8&quot; thick)</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>5-ply CLT (6-7/8&quot; thick)</td>
<td>14 to 17 ft</td>
</tr>
<tr>
<td>7-ply CLT (9-5/8&quot;)</td>
<td>17 to 21 ft</td>
</tr>
<tr>
<td>2x4 NLT</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>2x6 NLT</td>
<td>10 to 17 ft</td>
</tr>
<tr>
<td>2x8 NLT</td>
<td>14 to 21 ft</td>
</tr>
<tr>
<td>5&quot; MPP</td>
<td>10 to 15 ft</td>
</tr>
</tbody>
</table>

Credit: David Barber, ARUP
Construction Types

When does the code allow mass timber to be used?

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

Permitted anywhere that combustible materials and heavy timber are allowed, plus more.
IBC/CBC 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, IIA & IIB**: Roof Construction (ref. Table 601, footnote c)
Construction Types

All wood framed building options:

**Type III**
Exterior walls non-combustible (may be FRTW)
Interior elements anything allowed by code, including mass timber

**Type V**
All building elements are anything allowed by code, including mass timber

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

**Type IV-HT (Heavy Timber)**
Exterior walls non-combustible (may be FRTW or CLT)
Interior elements must qualify as Heavy Timber (min. sizes, no concealed spaces for 2018 IBC or earlier)
Construction Types

Where does the code allow MT to be used?

- **Type III**: Interior elements (floors, roofs, walls) and exterior walls if FRT
Construction Types

Where does the code allow MT to be used?

- **Type IV-HT**: Exposed interior elements (floors, roofs, walls) and exterior walls if CLT or FRT; must meet min. sizes. Could be concealed space limitations (varies by code version)
## Construction Types

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

<table>
<thead>
<tr>
<th>Framing</th>
<th>Solid Sawn (nominal)</th>
<th>Glulam (actual)</th>
<th>SCL (actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columns</td>
<td>8 x 8</td>
<td>6(^3/4) x 8¼</td>
<td>7 x 7½</td>
</tr>
<tr>
<td>Beams</td>
<td>6 x 10</td>
<td>5 x 10½</td>
<td>5¼ x 9½</td>
</tr>
<tr>
<td>Roof</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columns</td>
<td>6 x 8</td>
<td>5 x 8¼</td>
<td>5¼ x 7½</td>
</tr>
<tr>
<td>Beams*</td>
<td>4 x 6</td>
<td>3 X 6(^7/8)</td>
<td>3½ X 5½</td>
</tr>
</tbody>
</table>

Minimum width by depth in inches
See IBC/CBC Sec. 602.4 & 2304.11 for details

*3” nominal width allowed where sprinklered
Construction Types

Type IV-HT concealed spaces

Prior to the 2021 IBC/2019 CBC Supplement, Type IV-HT provisions prohibited concealed spaces
Construction Types

Type IV-HT concealed space options under the 2021 IBC/2019 CBC Supplement

Option 1:

Sprinklers in concealed spaces
Dropped ceiling
Construction Types

Type IV-HT concealed space options under the 2021 IBC/2019 CBC Supplement

Option 2:

Noncombustible insulation
Dropped ceiling
Construction Types

Type IV-HT concealed space options under the 2021 IBC/2019 CBC Supplement

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

In addition to Type I buildings, structural mass timber elements including CTFs (glue laminated timber boards), high performance timber (HPT), and heavy timber trusses (HSS) can be used in the following construction types, ensuring a high level of resistance and rigidity.

- Type III: Floors, roofs, and interior walls may be any material except concrete or masonry, including mass timber, exterior walls are required to be noncombustible on the exterior-oriented side.

- Type V: Floors, roofs, interior walls, and exterior walls are required to be noncombustible, including mass timber.

- Type II A: Mass timber may be used in select environments such as exposed environments, maintaining the primary theme in the 2024 IBC - i.e., Type II A.

- Type II B: Mass timber exterior columns and walls when 20 feet or more in height are required to be noncombustible, doors, and windows.

Construction Types

Where does the code allow MT to be used?

- **Type V:** Interior elements (floors, roofs, walls) and exterior walls
Construction Types

Type IIIA: 6 stories
Type IIIB: 4 stories

Type IV-HT: 6 stories

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

Type VA: 4 stories
Type VB: 3 stories

Credit: Ema Peter
Credit: Christian Columbres Photography
Construction Types

New Options in the 2021 IBC/2019 CBC Supplement
Allowable mass timber building size for group B occupancy with NFPA 13 sprinklers
Fire Design

Construction type influences FRR

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>A 3^a</td>
<td>B 2^a</td>
<td>A 1</td>
<td>B 0</td>
<td>A 1</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>A 3</td>
<td>B 2</td>
<td>A 1</td>
<td>B 0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>A 3^a</td>
<td>B 2^a</td>
<td>A 1</td>
<td>B 0</td>
<td>1</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Table 602</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>A 0</td>
<td>B 0</td>
<td>A 0</td>
<td>B 0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Section 602.4.6</td>
</tr>
<tr>
<td>Floor construction and associated secondary members (see Section 202)</td>
<td>A 2</td>
<td>B 2</td>
<td>A 1</td>
<td>B 0</td>
<td>1</td>
</tr>
<tr>
<td>Roof construction and associated secondary members (see Section 202)</td>
<td>$1\frac{1}{2}^b$</td>
<td>$1^b_{ce}$</td>
<td>$1^b_{ce}$</td>
<td>0^c</td>
<td>$1^b_{ce}$</td>
</tr>
</tbody>
</table>

2018 IBC/2019 CBC
Fire Design

Construction type influences FRR

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
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<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Primary structural frame$^d$ (see Section 202)</td>
<td>$3^b$</td>
<td>$2^b, c$</td>
<td>$1^b, e$</td>
<td>$0^c$</td>
<td></td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior$^e, f$</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>$3^b$</td>
<td>$2^a$</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
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<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior$^d$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary structural members (see Section 202)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary structural members (see Section 202)</td>
<td>$1^{1/2}_b$</td>
<td>$1^{b, e}$</td>
<td>$1^{b, e}$</td>
<td>$0^c$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2021 IBC/2019 CBC Supplement
Fire Design

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
Fire Design

Which Method of Demonstrating FRR of MT is Being Used?
1. Calculations in Accordance with IBC/CBC Sec. 703.3 & 722 ➔ NDS Chapter 16
1. Tests in Accordance with ASTM E119
NDS Chapter 16 includes calculation of fire resistance for CLT, NLT, Glulam, Solid Sawn and SCL wood products.
Nominal char rate of 1.5”/HR is recognized in NDS. Effective char depth calculated to account for duration, structural strength reduction in heat-affected zone.
Fire Design

Two structural capacity checks performed:
1. On entire cross section neglecting fire effects
2. On post-fire remaining section, with stress increases

\[ a_{\text{char}} = \beta_t t^{0.813} \]
\[ a_{\text{char}} = n_{\text{lam}} h_{\text{lam}} + \beta_t \left( t - \left( n_{\text{lam}} t_{\text{gl}} \right) \right)^{0.813} \]
\[ a_{\text{eff}} = 1.2 a_{\text{char}} \]

Solid Sawn, Glulam, SCL
CLT
Effective Char Depth

Credit: Forest Products Laboratory
Fire Design

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

<table>
<thead>
<tr>
<th></th>
<th>ASD</th>
<th>Design Stress to Member Strength Factor</th>
<th>Site Factor</th>
<th>Volume Factor</th>
<th>Flat Use Factor</th>
<th>Beam Stability Factor</th>
<th>Column Stability Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Strength</td>
<td>$F_b$</td>
<td>$x$</td>
<td>2.85</td>
<td>$C_F$</td>
<td>$C_V$</td>
<td>$C_{hu}$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>Beam Buckling Strength</td>
<td>$F_{OE}$</td>
<td>$x$</td>
<td>2.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>$F_t$</td>
<td>$x$</td>
<td>2.85</td>
<td>$C_F$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>$F_c$</td>
<td>$x$</td>
<td>2.58</td>
<td>$C_F$</td>
<td>-</td>
<td>-</td>
<td>$C_P$</td>
</tr>
<tr>
<td>Column Buckling Strength</td>
<td>$F_{ce}$</td>
<td>$x$</td>
<td>2.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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
Fire Design

AWC’s TR 10 is a technical design guide, aids in the use of NDS Chapter 16 char 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 $q_{Load}=80$ psf and $q_{dead}=30$ psf including estimated self-weight of the CLT panel. Floor decking, nailed to the unexposed face of CLT panel, is spaced to restrict hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a 1-hour structural fire resistance time when subjected to an ASTM E119 fire exposure.

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

Calculate panel load (per foot of width):

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

Calculate maximum induced moment (per foot of width):

$M_{max} = W_{load} \cdot L^2 / 8 = (110)(18^2)/8 = 4,455$ ft-lbf/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:

- Bending moment: $f_{b,w2d} = 4,675$ ft-lbf/ft of width (PRG 320 Annex A, Table A2)

Calculate the allowable design moment (assuming $C_{v}=1.0; C_{w}=1.0; C_{t}=1.0; C_{h}=1.0$):

$M_{x} = f_{b}(S_{0}) (C_{v}) (C_{w}) (C_{t}) (C_{h}) = 4,675 \text{ ft-lbf} / \text{ft of width}$

(check: $M_{x} \geq M_{max}$)

$M_{x} = 4,675 > 4,455 \text{ ft-lbf} / \text{ft}$

Structural Check: $M_{x} \geq M_{max}$

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

Source: AWC's TR 10
Fire Design

Tested FRR of Exposed MT:
- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers
## Fire Design

**WoodWorks Inventory of Fire Tested MT Assemblies**

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Manufacturer</th>
<th>CLT Code or Size</th>
<th>Wood Species</th>
<th>Ceiling Protection</th>
<th>Panel Connections in Test</th>
<th>Fire Topping</th>
<th>Load Rating</th>
<th>Fire Resistance Achieved (Hours)</th>
<th>Issues</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 14”x10”</td>
<td>Dowell</td>
<td>SPF</td>
<td>704</td>
<td>2 layers 5/8” Type X gypsum</td>
<td>Half lay</td>
<td>None</td>
<td>Reduced</td>
<td>1 1/2</td>
<td>Fire Test 1</td>
<td></td>
</tr>
<tr>
<td>T3 14”x10”</td>
<td>Stoecklin</td>
<td>SPF</td>
<td>704</td>
<td>2 layers 5/8” Type X gypsum</td>
<td>Half lay</td>
<td>None</td>
<td>Reduced</td>
<td>1</td>
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<td>T3 14”x10”</td>
<td>Dowell</td>
<td>SPF</td>
<td>704</td>
<td>2 layers 5/8” Type X gypsum</td>
<td>Half lay</td>
<td>None</td>
<td>Reduced</td>
<td>1 1/2</td>
<td>Fire Test 1</td>
<td></td>
</tr>
<tr>
<td>T3 14”x10”</td>
<td>Stoecklin</td>
<td>SPF</td>
<td>704</td>
<td>2 layers 5/8” Type X gypsum</td>
<td>Half lay</td>
<td>None</td>
<td>Reduced</td>
<td>1 1/2</td>
<td>Fire Test 1</td>
<td></td>
</tr>
</tbody>
</table>

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

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
Fire Design

Mass Timber Fire Design Resource

- Code compliance options for demonstrating FRR
- Free download at woodworks.org
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
MEP Layout & Integration

Smaller grid bays at central core (more head height)
- Main MEP trunk lines around core, smaller branches in exterior bays
MEP Layout & Integration

One-way beam layout
- Columns/beams spaced at panel span limits in one direction
- Beam penetrations are minimized/eliminated

Recall typical panel span limits:

<table>
<thead>
<tr>
<th>Panel</th>
<th>Example Floor Span Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (4-1/8&quot; thick)</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>5-ply CLT (6-7/8&quot; thick)</td>
<td>14 to 17 ft</td>
</tr>
<tr>
<td>7-ply CLT (9-5/8&quot;)</td>
<td>17 to 21 ft</td>
</tr>
<tr>
<td>2x4 NLT</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>2x6 NLT</td>
<td>10 to 17 ft</td>
</tr>
<tr>
<td>2x8 NLT</td>
<td>14 to 21 ft</td>
</tr>
<tr>
<td>5&quot; MPP</td>
<td>10 to 15 ft</td>
</tr>
</tbody>
</table>
MEP Layout & Integration

Dropped below MT framing
- Can simplify coordination (fewer penetrations)
- Bigger impact on head height
MEP Layout & Integration

Penetrations through beams
- Requires more coordination (penetrations)
- Bigger impact on structural capacity of penetrated members
- Minimal impact on head height
MEP Layout & Integration

Chases above beams and below panels
- Fewer penetrations
- Bigger impact on head height (overall structure depth is greater)
- FRR impacts: top of beam exposure
Gaps between MT panels

- Fewer penetrations, can allow for easier modifications later
- Impact on acoustic performance
 MEP Layout & Integration

Gaps between MT panels
• Aesthetics: often uses ceiling panels to cover gaps
MEP Layout & Integration

Raised access floor (RAF) above MT
- Aesthetics (minimal exposed MEP)
- More efficient MEP system
MEP Layout & Integration

Raised access floor (RAF) above MT
• Impact on head height
• Concealed space code provisions
MEP Layout & Integration

Within 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

Concrete Shear Walls
• Typically at core
Lateral System Choices

Concrete Shear Walls
- Connection tolerances & adjustability
Lateral System Choices
Steel Braced/Moment Frames
Lateral System Choices

Steel Braced/Moment Frames
• Connection tolerances & adjustability
Lateral System Choices

Light-Frame Wood Shear Walls

Credit: KL&A Engineers & Builders
Lateral System Choices

Light-Frame Wood Shear Walls
- Standard of construction practice well known
- Limited to 65 ft shear wall height, 85 ft overall building height (Type IIIA & IV-HT construction)
Lateral System Choices
CLT Shear Walls (Conventional)
Lateral System Choices
CLT Rocking Shear Walls

Photo: WoodWorks

Image: KPFF
Lateral System Choices

Timber Braced Frames
Lateral System Choices

**Prescriptive Code Compliance**
- Concrete Shear Walls
- Steel Braced/Moment Frames
- Light-Frame Wood Shear Walls
- CLT Shear Walls (Conventional)
- CLT Rocking Shear Walls
- Timber Braced Frames
Structural Grid
Structural Grid

Grids & Spans

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

24'-0"  24'-2"

24'-0"

30'-0"

30'-0"
Structural Grid

Grids & Spans

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

24’-6” 26’-2” 24’-6” 40’-0”

14’-0”

26’-0”

26’-0”
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
Structural Grid

Why so much focus on panel thickness?
Structural Grid

Typical MT Package Costs

- Project Overhead: 7%
- Labor: 14%
- Material: 64%
- Equipment: 15%

Source: Swinerton
Panels are the biggest part of the biggest piece of the cost pie
Structural Grid

Panel volume usually 65-80% of MT package volume

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

Source: Fast + Epp, Timber Bay Design Tool
Panel volume usually 65-80% of MT package volume

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

Source: Fast + Epp, Timber Bay Design Tool
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”)
- 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

Source: Fast + Epp, Timber Bay Design Tool
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”)
- 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

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.

Source: Fast + Epp, Timber Bay Design Tool
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
Which is the most efficient option – 7 story office building

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

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.
Which is the most efficient option?

<table>
<thead>
<tr>
<th></th>
<th>Timber Volume Ratio</th>
<th>Podium on 1st Floor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIIA – Option 1</td>
<td>0.73 CF / SF</td>
<td>Yes</td>
</tr>
<tr>
<td>IV-C</td>
<td>0.82 CF / SF</td>
<td>No</td>
</tr>
</tbody>
</table>

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

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.
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
Structural Grid

Construction Type Early Decision Example

3-story building on college campus

Cost Impact of Assembly Occupancy Placement:

<table>
<thead>
<tr>
<th>Location of Event Space</th>
<th>3rd Floor</th>
<th>1st Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Type</td>
<td>III-A</td>
<td>III-B</td>
</tr>
<tr>
<td>Assembly Group</td>
<td>A-3</td>
<td>A-3</td>
</tr>
<tr>
<td>Fire Resistive Rating</td>
<td>1-Hr</td>
<td>0-Hr</td>
</tr>
<tr>
<td>Connections</td>
<td>Concealed</td>
<td>Exposed</td>
</tr>
<tr>
<td>CLT Panel Thickness</td>
<td>5-Ply</td>
<td>3-Ply</td>
</tr>
<tr>
<td><strong>Superstructure Cost/SF</strong></td>
<td>$65/SF</td>
<td>$53/SF</td>
</tr>
</tbody>
</table>

Source: PCL Construction
NEW 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

Credit: Structurlam
Connections

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

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

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

Softwood Lumber Board
Glulam Connection Fire Test
Summary Report

Issue | June 5, 2017

Full Report Available at:
Connections

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

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
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-acuity.
Connections

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

1. Testing in accordance with Section 703.2 where the connection is part of the fire resistance test.

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

Source: AWC’s TR 10
Connections

Other connection design considerations:
- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost

Credit: Alex Schreyer
Penetrations & Firestopping

Photo: Alex Schreyer
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

Photos: AWC/FPInnovations
Penetrations & Firestopping

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

Photos: AWC/FPInnovations/Hilti
## Inventory of Fire Tested Penetrations in MT Assemblies

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

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Exposed Side Protection</th>
<th>Penetrating Item</th>
<th>Penetrate Castrated or Offset in Hole</th>
<th>Firestopping System Description</th>
<th>F Rating</th>
<th>T Rating</th>
<th>Stated Test Protocol</th>
<th>Source</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply (76mm 0.075&quot;)</td>
<td>None</td>
<td>1.5&quot; diameter data cable bush</td>
<td>Centrated</td>
<td>3.5 in diameter hole. Mineral wool was installed in the 1 in. annular space around the data cable to a total depth of approximately 2 – 5/4 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.</td>
<td>1 hour</td>
<td>0.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (76mm 0.075&quot;)</td>
<td>None</td>
<td>2&quot; copper pipe</td>
<td>Centered</td>
<td>4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 2 – 5/4 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.</td>
<td>1 hour</td>
<td>NA</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (76mm 0.075&quot;)</td>
<td>None</td>
<td>2.5&quot; schol. 40 pipe</td>
<td>Centered</td>
<td>4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 2 – 5/4 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.</td>
<td>1 hour</td>
<td>NA</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (76mm 0.075&quot;)</td>
<td>None</td>
<td>6&quot; cast iron pipe</td>
<td>Centered</td>
<td>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 – 5/4 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.</td>
<td>1 hour</td>
<td>NA</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (76mm 0.075&quot;)</td>
<td>None</td>
<td>Hilti 6 in drop in device System No. F-B-2049</td>
<td>Centered</td>
<td>9.01 in 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 – 7/8 in. and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 – 1/4 in. hole in the CLT was filled with Hilti FS-One Max caulking.</td>
<td>1 hour</td>
<td>0.75 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>1.5&quot; diameter data cable bush</td>
<td>Centrated</td>
<td>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 4 – 5/32 in. The remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 – 1/4 in. hole in the CLT was filled with Hilti FS-One Max caulking.</td>
<td>2 hours</td>
<td>1.5 hours</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>2&quot; copper pipe</td>
<td>Centered</td>
<td>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 pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.</td>
<td>2 hours</td>
<td>NA</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>2.5&quot; schol. 40 pipe</td>
<td>Centered</td>
<td>4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 4 – 5/32 in. The remaining 1 in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.</td>
<td>2 hours</td>
<td>0.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>6&quot; cast iron pipe</td>
<td>Centered</td>
<td>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.</td>
<td>2 hours</td>
<td>NA</td>
<td>CANULC S115</td>
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<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>Hilti 6 in drop in device System No. F-B-2049</td>
<td>Centered</td>
<td>9.01 in 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 – 7/8 in. and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 – 1/4 in. hole in the CLT was filled with Hilti FS-One Max caulking.</td>
<td>2 hours</td>
<td>1.5 hours</td>
<td>CANULC S115</td>
<td>26</td>
<td>Intertek March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm 5.16&quot;)</td>
<td>None</td>
<td>1&quot; nominal PVC pipe</td>
<td>Centrated</td>
<td>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 W 5/51-3/4 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 Royal Save Mineral wool leaving a 5/8 in deep void at the top of the assembly. Hilti FS-One Max Intumescence 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.</td>
<td>2 hours</td>
<td>2 hours</td>
<td>ASTM E8 14</td>
<td>24</td>
<td>QAI Laboratories March 3, 2017</td>
</tr>
</tbody>
</table>
Penetrations & Firestopping

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

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

1. 3-Ply Cross Laminated Timber Floor Assembly (Minimum 3" Thick) (1-Hr. Fire-Rating).
2. Hilti CFS-DID Firestop Drop-In Device Inserted into Opening (See Table Below) and Secured to Top Surface of Cross Laminated Timber Floor Assembly with Three 1/4" x 1" Long Steel Wood Screws with Washers.
5. Minimum 1" Depth Hilti FS-One Max Intumescent Firestop Sealant Between CFS-DID Firestop Drop in Device and Periphery of Opening.
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
Consider Impacts of:
• Timber & Topping Thickness
• Panel Layout
• Gapped Panels
• Connections & Penetrations
• MEP Layout & Type
Acoustics & Sound Control

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

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

<table>
<thead>
<tr>
<th>Mass Timber Panel</th>
<th>Thickness</th>
<th>STC Rating</th>
<th>IIC Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT wall</td>
<td>3.07&quot;</td>
<td>33</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT wall</td>
<td>6.875&quot;</td>
<td>38</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT floor</td>
<td>5.1875&quot;</td>
<td>39</td>
<td>22</td>
</tr>
<tr>
<td>5-ply CLT floor</td>
<td>6.875&quot;</td>
<td>41</td>
<td>25</td>
</tr>
<tr>
<td>7-ply CLT floor</td>
<td>9.65&quot;</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>2x4 NLT wall</td>
<td>3-1/2&quot; bare NLT</td>
<td>24 bare NLT</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>4-1/4&quot; with 3/4&quot; plywood</td>
<td>29 with 3/4&quot; plywood</td>
<td></td>
</tr>
<tr>
<td>2x6 NLT wall</td>
<td>5-1/2&quot; bare NLT</td>
<td>22 bare NLT</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>6-1/4&quot; with 3/4&quot; plywood</td>
<td>31 with 3/4&quot; plywood</td>
<td></td>
</tr>
<tr>
<td>2x6 NLT floor + 1/2&quot; plywood</td>
<td>6&quot; with 1/2&quot; plywood</td>
<td>34</td>
<td>33</td>
</tr>
</tbody>
</table>

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

Mass timber has relatively low “mass”

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

Acoustical Mat:

- Typically roll out or board products
- Thicknesses vary: Usually ¼” to 1”+
Acoustics & Sound Control

Acoustical floor underlayments

Photo: AcoustiTECH™

Photo: Kinetics Noise Control, Inc.

Photo: Maxxon Corporation

Photo: Pittaq Inc.
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 and Mass Timber: Room-to-Room Noise Control

The growing availability and cost-acceptance of mass timber—engineered wood products such as cross-laminated timber (CLT) and panelized wood structures—has driven a new interest in using wood as a primary structural material. The advantages of mass timber include its inherent acoustic properties, which can help to reduce noise transmission between rooms in buildings. This paper explores the acoustic performance of mass timber as an alternative to traditional building materials.

Mass Timber Assembly Options: Walls

Mass timber panels can be used in walls of various types, including load-bearing and non-load-bearing walls, to enhance acoustic performance. A well-designed mass timber wall assembly can significantly reduce sound transmission between rooms.

Acoustical Differences Between Mass Timber Panel Options

The majority of acoustically tested mass timber assemblies include CLT core panels, whereas other mass timber panel options such as LVL and stud-framed construction may offer different acoustic properties. The selection of panel options should be based on the specific acoustic requirements of the building.

Improving Performance by Minimizing Flanking

Even when the assembly in a building is well-insulated, sound transmission can occur through various paths, such as through structural members or connections. Minimizing flanking sound can significantly improve the overall acoustic performance of a mass timber building.
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

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# Inventory of Tested Assemblies

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

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Concrete/Gypsum Topping</th>
<th>Acoustical Mat Product Between CLT and Topping</th>
<th>Finish Floor</th>
<th>STC (^2)</th>
<th>IIC (^3)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT 5-ply (6.875(^{\circ}))</td>
<td>None</td>
<td>Maxson Acousti-Mat (^{\circ}) 3/4</td>
<td>None</td>
<td>47(^{\circ}) ASTC</td>
<td>47(^{\circ}) AIC</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>LVT</td>
<td>49(^{\circ}) AIC</td>
<td>49(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carpet Pad</td>
<td></td>
<td>Carpet Pad</td>
<td>75(^{\circ}) AIC</td>
<td>75(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT on Acousti-Top(^{\circ})</td>
<td></td>
<td>LVT on Acousti-Top(^{\circ})</td>
<td>52(^{\circ}) AIC</td>
<td>52(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eng Wood on Acousti-Top(^{\circ})</td>
<td></td>
<td>Eng Wood on Acousti-Top(^{\circ})</td>
<td>51(^{\circ}) AIC</td>
<td>51(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>Maxson Acousti-Mat (^{\circ}) % Premium</td>
<td>None</td>
<td>49(^{\circ}) AIC</td>
<td>49(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>LVT</td>
<td>47(^{\circ}) AIC</td>
<td>47(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT on Acousti-Top(^{\circ})</td>
<td></td>
<td>LVT on Acousti-Top(^{\circ})</td>
<td>49(^{\circ}) AIC</td>
<td>49(^{\circ}) AIC</td>
<td></td>
</tr>
<tr>
<td>1-1/2(^{\circ}) Gyp-Crete(^{\circ})</td>
<td>USG SAM N25 Ultra</td>
<td></td>
<td>None</td>
<td>45(^{\circ})</td>
<td>39(^{\circ})</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>LVT</td>
<td>48(^{\circ})</td>
<td>47(^{\circ})</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>LVT Plus</td>
<td></td>
<td>LVT Plus</td>
<td>48(^{\circ})</td>
<td>49(^{\circ})</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Eng Wood</td>
<td></td>
<td>Eng Wood</td>
<td>47(^{\circ})</td>
<td>47(^{\circ})</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Carpet + Pad</td>
<td></td>
<td>Carpet + Pad</td>
<td>45(^{\circ})</td>
<td>46(^{\circ})</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Ceramic Tile</td>
<td></td>
<td>Ceramic Tile</td>
<td>50(^{\circ})</td>
<td>46(^{\circ})</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
<td>None</td>
<td>45(^{\circ})</td>
<td>42(^{\circ})</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>LVT</td>
<td>48(^{\circ})</td>
<td>48(^{\circ})</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>LVT Plus</td>
<td></td>
<td>LVT Plus</td>
<td>48(^{\circ})</td>
<td>49(^{\circ})</td>
<td>58</td>
</tr>
</tbody>
</table>

\(^2\) STC: Sound transmission class

\(^3\) IIC: Impact insulation class
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:

30x32 typ. unit
Corridor

Credit: Monte French Design Studio
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

Credit: Monte French Design Studio
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
- Materials are mass timber or non-combustible (no light-frame wood permitted!)
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

• Option 1

Beams/Walls at 15’ o.c. (align with unit demising wall)

No beams or shallower beams at corridor

MT floor panel span

Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

• Option 1

Beams/Walls at 15’ o.c. (align w unit demising wall)

No beams at corridor (MT panel spans weak axis)

MT floor panel span

Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

No beam penetrations at main to branch MEP

Main MEP lines in corridor

MEP branches in each unit
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options
• Option 1

- Beams at 15’ o.c. (align w unit demising wall)
- 23’-4” beam span typ.
- MT floor panel span
- Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2

Beams at 16’ o.c. (align with corridor wall)

No beam at corridor

Typ. MT Panel

MT floor panel span
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options
• Option 2

- Beam penetrations at all beam lines
- MEP branches in each unit
- Main MEP lines in corridor
- Typ. MT Panel

Credit: Monte French Design Studio
### Key Early Design Decisions

**Early Design Decision Example**

**Type IV-C Floor Assembly Options**

<table>
<thead>
<tr>
<th>Finish Floor if Applicable</th>
<th>Concrete/Gypsum Topping</th>
<th>Acoustical Mat Product</th>
<th>CLT Panel</th>
<th>No direct applied or hung ceiling</th>
</tr>
</thead>
</table>

- 2-hr FRR: 5-ply CLT or 7-ply CLT
- 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
Concealed Spaces in Type IV-C

**Without Dropped Ceiling**

- Noncombustible material not required
- Mass timber floor panel
- Noncombustible material not required

**With Dropped Ceiling**

- Noncombustible material not required
- Mass timber floor panel
- One layer 5/8" Type X gypsum covering all mass timber surfaces within concealed space
- Dropped ceiling
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
- 5-ply CLT, maybe thinner
- 1 story Type IA podium required
- CLT exterior walls not permitted, non-combustible or FRT wood only
- Can use light-frame wood framing for interior walls
- If <65 feet for wood portion, light frame wood shear walls are an option
Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

- Can use beams or bearing walls gravity support

![Diagram showing beams or bearing walls at 15' o.c. (align w unit demising wall), MT floor panel span, and Typ. MT Panel.](image)
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 are that or multiples of that span
- 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

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?

Chelsea Drenick, SE  
Regional Director N. CA, NV, UT  
303.588.1300
chelsea.drenick@woodworks.org

Mike Romanowski, SE  
Regional Director S. CA, AZ, NM  
619.206.6632
mike.romanowski@woodworks.org

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