Early Design Decisions: Priming Mass Timber Projects for Success

Presented by
Mike Romanowski, S.E., WoodWorks
June 9, 2023
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 (IBC) 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 meetings 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.
HEAVY TIMBER
Federal Center South, Seattle, WA
Photo: Benjamin Benschneider

MASS TIMBER
Bullitt Center, Seattle, WA
Photo: John Stamets
Mass Timber Gravity Framing Systems

Post & Beam  Flat Plate  Honeycomb
Mass Timber Gravity Framing Systems

Hybrid: Light-Frame Wood

Hybrid: Steel
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
- Beam & Column (Grid) Layout
- 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 is 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

One potential design route:

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

But these are not the only decisions that have to be made…
Key Early Design Decisions

Other impactful decisions:

- **Acoustics** can influence member sizes (and vice versa)
- Fire-resistance ratings influence connections & penetrations
- **MEP layout** influences the use of concealed spaces
Key Early Design Decisions

Other impactful decisions:

• **Grid** layout influences efficient spans, MEP layout

• **Manufacturer capabilities** influences member sizes, grid layout & connections

• **Lateral system choice** influences connections, construction sequencing
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>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
<th>III-A</th>
<th>III-B</th>
<th>V-A</th>
<th>V-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, R</td>
<td>270</td>
<td>180</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

#### Allowable Building Height above Grade Plane, Feet (IBC/CBC Table 504.3)

#### Allowable Number of Stories above Grade Plane (IBC/CBC Table 505.4)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>A-2, A-3, A-4</th>
<th>B</th>
<th>R-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2, A-3, A-4</td>
<td>18, 12, 6, 4, 4, 3, 3</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>18, 12, 9, 6, 6, 4, 4</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>R-2</td>
<td>18, 12, 8, 5, 5, 4, 3</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

#### Allowable Area Factor ($A_t$) for SM, Feet$^2$ (IBC/CBC Table 506.2)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>A-2, A-3, A-4</th>
<th>B</th>
<th>R-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>
<td>324,000, 216,000, 135,000, 108,000, 85,500, 57,000, 54,000, 27,000</td>
<td>184,500, 123,000, 76,875, 61,500, 72,000, 48,000, 36,000, 21,000</td>
</tr>
</tbody>
</table>
Key Early Design Decisions

Fire-Resistance Ratings (FRR)

- Driven primarily by construction type
- Rating achieved through timber alone or non-combustible membrane protection (or both)?

<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></td>
<td></td>
<td>A B</td>
<td>A B</td>
<td></td>
</tr>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>$3^{a,b}$</td>
<td>$2^{a,b,c}$</td>
<td>$1^{b,c}$</td>
<td>$0^{c}$</td>
<td></td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td>A B</td>
<td>A B C</td>
<td>HT</td>
</tr>
<tr>
<td>Exterior</td>
<td>$3^{a}$</td>
<td>$2^{a}$</td>
<td>$1^{b,c}$</td>
<td>$0^{c}$</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>$3^{a}$</td>
<td>$2^{a}$</td>
<td>$1^{b,c}$</td>
<td>$0^{c}$</td>
<td></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>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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>Interior</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>$2^{a,b}$</td>
<td>$1^{b,c}$</td>
<td>$1^{b,c}$</td>
<td>$0^{c}$</td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary structural members (see Section 202)</td>
<td>$1^{1/2}$</td>
<td>$1^{b,c}$</td>
<td>$1^{b,c}$</td>
<td>$0^{c}$</td>
<td></td>
</tr>
</tbody>
</table>
Key Early Design Decisions

Fire-Resistance Ratings (FRR)

- Thinner panels (i.e. 3-ply CLT) generally have difficulty achieving a 1+ hour FRR
- 5-ply CLT or 2x6 NLT & DLT panels can usually achieve a 1- or 2-hour FRR
- Construction Type | FRR | Member Size | Grid Layout (each impacts the other)

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

Construction Types I & II:
All elements required to be non-combustible materials (with a few exceptions)
Construction Types

All wood-framed building options:

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

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

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

**Type IV-HT (Heavy Timber)**
Exterior walls must be non-combustible (may be FRTW or CLT)
Interior elements must qualify as Heavy Timber (min. prescriptive sizes, no concealed spaces for 2018 IBC or earlier)
**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>Columns</td>
<td>8 x 8</td>
<td>6 3/4 x 8 3/4</td>
</tr>
<tr>
<td></td>
<td>Beams</td>
<td>6 x 10</td>
<td>5 x 10 1/2</td>
</tr>
<tr>
<td>Roof</td>
<td>Columns</td>
<td>6 x 8</td>
<td>5 x 8 3/4</td>
</tr>
<tr>
<td></td>
<td>Beams*</td>
<td>4 x 6</td>
<td>3 x 6 7/8</td>
</tr>
</tbody>
</table>

Minimum width by depth in inches
See IBC 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, Type IV-HT provisions prohibited concealed spaces

Credit: IBC
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 for fire spread in non-visible areas of a building. Section 718 of the 2018 IBC includes prescriptive requirements for protection and 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: fire sprinklers required in concealed spaces such as floor and roof cavities in multifamily wood-frame buildings.

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

In addition to Type V-B 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, interior walls and exterior walls for the entire structure may be constructed of mass timber.
- **Types I and II**: Most timber may be used in certain circumstances such as roof construction—including the primary frame in the 2021 IBC—in Type I-B, I-A, or II-B exterior walls as long as 29 feet or more of horizontal separation is provided, and balconies, canopies and similar projections.

Construction Types

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

Type IV-A
- Office Assembly Residential
- Mercantile (12 stories)
- 270 ft. (18 stories)

Type IV-B
- Office Assembly Residential
- Mercantile (8 stories)
- 180 ft. (12 stories)

Type IV-C
- Office (9 stories)
- Residential (8 stories)
- Assembly Mercantile (6 stories)
- 85 ft. (9 stories)
Fire Design

Construction Type influences FRR requirements

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

Method of demonstrating FRR can impact member sizing
Fire Design

What are the methods for demonstrating FRR of MT?
1. Calculations in accordance with IBC Sec. 703.2.2 & 722 → NDS Chapter 16
2. Tests in accordance with ASTM E119

Credit: Urban One
Fire Design (NDS Chapter 16)

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

Solid Sawn, Glulam, SCL

CLT

Effective Char Depth

Credit: Forest Products Laboratory
Fire Design (NDS Chapter 16)

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 $q_{dow}=80$ psf and $q_{new}=30$ 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):

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

Calculate maximum induced moment (per foot of width):

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

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

Bending moment, $F_{b,\text{tab}} = 4,675 \text{ ft-lb/ft of width}$

(PRG 320 Annex A, Table A2)

Calculate the allowable design moment (assuming $C_o=1.0$, $C_w=1.0$, $C_i=1.0$, $C_L=1.0$)

$$M_* = F_b(S_{ax})(C_o)(C_w)(C_i)(C_L) = 4,675 (1.0)(1.0)(1.0) = 4,675 \text{ ft-lb/ft of width}$$

(NDS 10.3.1)

Structural Check:

$$M_* \geq M_{max}$$

$4,675 \text{ ft-lb/ft} > 4,455 \text{ ft-lb/ft}$

(√)

(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 Assemblies)

- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers
<table>
<thead>
<tr>
<th>Mass Timber Panel</th>
<th>Manufacturer</th>
<th>CLT Grade or Timber Grade</th>
<th>Ceiling Protection</th>
<th>Panel Connection</th>
<th>Floor Topping</th>
<th>Load Rating</th>
<th>Fire Resistance Achieved (Hours)</th>
<th>Source</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (114mm 4.488 in) Nordic</td>
<td>SPF 1650 Fb 1.5E MSR x SPF #5</td>
<td>2 layers 1/2&quot; Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 36% Moment Capacity</td>
<td>1</td>
<td>(Test 1)</td>
<td>NRC Fire Laboratory</td>
<td></td>
</tr>
<tr>
<td>3-ply CLT (105mm 4.133 in) Structural</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 5/8&quot; Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 75% Moment Capacity</td>
<td>1</td>
<td>(Test 5)</td>
<td>NRC Fire Laboratory</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>NRC Fire Laboratory March 2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>5</td>
<td>NRC Fire Laboratory Nov 2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>3/4&quot; proprietary gypsum over Maxxom acoustic mat</td>
<td>Reduced 50% Moment Capacity</td>
<td>1.5</td>
<td>3</td>
<td>Interim 8/24/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>3/4&quot; proprietary gypsum over Maxxom acoustic mat or proprietary sound board</td>
<td>Reduced 50% Moment Capacity</td>
<td>2</td>
<td>4</td>
<td>UL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>1-1/2&quot; Maxxon Cyp-Greene 2000 over Maxxon Reinforcing Mesh</td>
<td>Loaded, See Manufacturer</td>
<td>2.5</td>
<td>6</td>
<td>Interim 2/22/2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) DR Johnson V1</td>
<td>None</td>
<td>Half-Lap &amp; Topside Spline</td>
<td>2&quot; gypsum topping</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>7</td>
<td>SwRI (May 2016)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Nordic</td>
<td>SPF 1950 Fb MSR x SPF #3</td>
<td>None</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 59% Moment Capacity</td>
<td>1.5</td>
<td>(Test 3)</td>
<td>NRC Fire Laboratory</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT (175mm 6.875&quot;) Structural</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 5/8&quot; Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 101% Moment Capacity</td>
<td>2</td>
<td>(Test 6)</td>
<td>NRC Fire Laboratory</td>
<td></td>
</tr>
<tr>
<td>7-ply CLT (245mm 9.65&quot;) Structural</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>None</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 101% Moment Capacity</td>
<td>2.5</td>
<td>(Test 7)</td>
<td>NRC Fire Laboratory</td>
<td></td>
</tr>
</tbody>
</table>
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
- **NDS Chapter 16 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 orientation
• Need for future tenant reconfiguration
• Impact on fire & structural design: concealed spaces, penetrations
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
Raised access floor (RAF) above MT
• Aesthetics (minimal exposed MEP)
• More efficient MEP system
• Impact on head height
• Concealed space code provisions apply
Structural Grid
Structural Grid

Column & Beam Layout

• Consider Efficient Layouts
• Repetition & Scale
• Manufacturer Panel Width, Length & Thickness
Structural Grid

Column & Beam Layout

• Consider Efficient Layouts
• Repetition & Scale
• Manufacturer Panel Width, Length & Thickness

24’-6” 26’-2” 24’-6” 40’-0”

14’-0”

26’-0”

26’-0”
Structural Grid

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

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

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

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
Why so much focus on panel thickness?
Panels are the biggest part of the biggest piece of the cost pie.

Source: Swinerton
Structural Grid

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><strong>$65/SF</strong></td>
<td><strong>$53/SF</strong></td>
</tr>
</tbody>
</table>

Source: PCL Construction
Connections

Connection design considerations:
- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost

Credit: Alex Schreyer
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
MASS TIMBER CONNECTIONS INDEX
A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load-carrying capacity.
Penetrations & Firestopping

Option 1: Mass timber penetration firestopping via tested products

Photos: AWC/FPInnovations
## Penetrations & Firestopping

### 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>Penetrant Centered or Offset in Hole</th>
<th>Firestopping System Description</th>
<th>F Rating</th>
<th>T Rating</th>
<th>Test Protocol</th>
<th>Source</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply (78mm 3.07&quot;)</td>
<td>None</td>
<td>1.5&quot; diameter data cable bunch</td>
<td>Centred</td>
<td>3.5 in diameter hole. Mineral wool was installed in the 1x annular space around the data cables to a total depth of approximately 2 - 5/8 in. The remaining 1x annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max castling.</td>
<td>1 hour</td>
<td>0.5 hour</td>
<td>CAN/ULC-S115</td>
<td>26</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (78mm 3.07&quot;)</td>
<td>None</td>
<td>2&quot; copper pipe</td>
<td>Centred</td>
<td>6.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 2 - 5/8 in. The remaining 1x annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max castling.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CAN/ULC-S115</td>
<td>26</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (78mm 3.07&quot;)</td>
<td>None</td>
<td>2.5&quot; sched. 40 pipe</td>
<td>Centred</td>
<td>6.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 2 - 5/8 in. The remaining 1x annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max castling.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CAN/ULC-S115</td>
<td>26</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (78mm 3.07&quot;)</td>
<td>None</td>
<td>8&quot; cast iron pipe</td>
<td>Centred</td>
<td>8.35 in diameter hole. Mineral wool was installed in the 1x annular space around the cast iron pipe to a total depth of approximately 2 - 5/8 in. The remaining 1x annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max castling.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CAN/ULC-S115</td>
<td>26</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (78mm 3.07&quot;)</td>
<td>None</td>
<td>68&quot; Hilti 6 in drop-in device. System No.: F-B 2649</td>
<td>Centred</td>
<td>9.01&quot; diameter hole. Mineral wool was installed in the 1 - 1/4x annular space around the drop-in device to a total depth of approximately 1 - 7/8 in and the remaining 1x annular space from the top of the mineral wool to the top edge of the 9 - 1/4x hole in the CLT was filled with Hilti FS-One Max castling.</td>
<td>1 hour</td>
<td>0.75 hour</td>
<td>CAN/ULC-S115</td>
<td>26</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (100mm 3.94&quot;)</td>
<td>1layer 5/8&quot; Type X gypaum</td>
<td>4&quot; sched. 40 pipe</td>
<td>Centred or offset up to 9/16 in</td>
<td>Maximum 5 inch diameter opening. One stack of three layers STI BLU2 Winstead with SSWRD Collar secured to underside of floor or both sides of wall. 1/2 inch depth of SpecSeal® RCI Intumescent sealant on top of floor or both sides of wall with a 1/4 inch bead at point contact.</td>
<td>2 hours</td>
<td>0.75 hour</td>
<td>ASTM E313 and CAN/ULC-S115</td>
<td>45</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (100mm 3.94&quot;)</td>
<td>1layer 5/8&quot; Type X gypaum</td>
<td>AC Liner with mark 1 inch copper condenser, 3 inch insulating copper th 5/8 in in AR/PVC insulation, two No. 18 conductor coated wires</td>
<td>Centred or offset. Offset may range from 1/2 in to 3/4 in</td>
<td>Maximum 5 inch diameter opening. Aprx mineral wool packed to EE opening and recoated 3/4 inch from the top of the floor. 3/4 inch depth of SpecSeal® RCI Intumescent sealant on top of floor.</td>
<td>2 hours</td>
<td>0.25 hour</td>
<td>ASTM E313 and CAN/ULC-S115</td>
<td>45</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (100mm 3.94&quot;)</td>
<td>1layer 5/8&quot; Type X gypaum</td>
<td>Cable bundle</td>
<td>Centred or offset. Offset may range from 1/2 in to 1-1/2 in</td>
<td>Maximum 6 inch diameter opening. Aprx mineral wool packed to EE opening and recoated 3/4 inch from the top of the floor or both sides of the wall. 3/4 inch depth of SpecSeal® RCI Intumescent sealant on top of floor.</td>
<td>2 hours</td>
<td>0.5 hour</td>
<td>ASTM E313 and CAN/ULC-S115</td>
<td>45</td>
<td>InterTek March 30, 2016</td>
</tr>
<tr>
<td>3-ply (100mm 3.94&quot;)</td>
<td>1layer 5/8&quot; Type X gypaum</td>
<td>Cable bundle</td>
<td>Centred or offset. Offset may range from 1/2 in to 1-1/2 in</td>
<td>Maximum 6 inch diameter opening. Aprx mineral wool packed to EE opening and recoated 3/4 inch from the top of the floor or both sides of the wall. 3/4 inch depth of SpecSeal® RCI Intumescent sealant on top of floor.</td>
<td>2 hours</td>
<td>0.5 hour</td>
<td>ASTM E313 and CAN/ULC-S115</td>
<td>45</td>
<td>InterTek March 30, 2016</td>
</tr>
</tbody>
</table>
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
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

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 wall⁴</td>
<td>3.07&quot;</td>
<td>33</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT wall⁴</td>
<td>6.875&quot;</td>
<td>38</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT floor⁴</td>
<td>5.1875&quot;</td>
<td>39</td>
<td>22</td>
</tr>
<tr>
<td>5-ply CLT floor⁴</td>
<td>6.875&quot;</td>
<td>41</td>
<td>25</td>
</tr>
<tr>
<td>7-ply CLT floor⁴</td>
<td>9.65&quot;</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>2x4 NLT wall⁶</td>
<td>3-1/2&quot; bare NLT 4-1/4&quot; with 3/4&quot; plywood</td>
<td>24 bare NLT 29 with 3/4&quot; plywood</td>
<td>N/A</td>
</tr>
<tr>
<td>2x6 NLT wall⁶</td>
<td>5-1/2&quot; bare NLT 6-1/4&quot; with 3/4&quot; plywood</td>
<td>22 bare NLT 31 with 3/4&quot; plywood</td>
<td>N/A</td>
</tr>
<tr>
<td>2x6 NLT floor + 1/2&quot; plywood³</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, WoodWorks⁷
### Acoustics & Sound Control

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Weight PSF</th>
<th>STC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Slab</td>
<td>6” Thick</td>
<td>80</td>
<td>53</td>
</tr>
<tr>
<td>CLT Slab</td>
<td>6-7/8” Thick</td>
<td>18</td>
<td>41</td>
</tr>
</tbody>
</table>
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

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

Credit: AcoustiTECH
### Inventory of Acoustically Tested MT 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 ¹</th>
<th>IIC ²</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT 3-ply (3.5&quot;)</td>
<td>3&quot; concrete</td>
<td>Maxxon Acousti-Mat® 3/4</td>
<td>None</td>
<td>53² ASTC</td>
<td>45² FIIIC</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT on GenieMat RST05</td>
<td>54</td>
<td>44</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eng Wood on GenieMat RST05</td>
<td>53</td>
<td>46</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carpet Tile</td>
<td>52</td>
<td>50</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>2&quot; concrete</td>
<td>Pliteq GenieMat™ FF25</td>
<td>None</td>
<td>57</td>
<td>45</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT</td>
<td>-</td>
<td>58</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 layers of ½&quot; USG Fiberock® on Kinetics®</td>
<td>55</td>
<td>55</td>
<td>106</td>
</tr>
</tbody>
</table>

¹ STC: Sound Transmission Class
² 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 = 16,800 SF
• Total Building Area = 117,600 SF
Key Early Design Decisions

Early Design Decision Example

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

- 30x32 typ. unit
- Corridor
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
- 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 at 15’ o.c. (align w/ unit demising wall)
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 at 15' o.c. (align w/ unit demising wall)

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

No beam penetrations at main to branch MEP

Main MEP lines in corridor below shallower beams

MEP branches in each unit

Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

Beams at 15' o.c. (align with 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 w/ corridor wall)

No beam at corridor

Typ. MT Panel

MT floor panel span

Credit: Monte French Design Studio
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

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
- 2-story Type IA podium required
- Can use light-frame wood for interior walls (FRT light-frame wood for exterior walls)
- If wood portion is ≤65 feet, 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 for gravity support

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

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
Reduce Risk
Optimize Costs

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

Download Checklists at
www.woodworks.org

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

Images: Korb & Associates
Questions?

Mike Romanowski, SE
Regional Director | CA-South, AZ, NM

619.206.6632
mike.romanowski@woodworks.org