Early Design Decisions: Priming Mass Timber Projects for Success

Presented by Mark Bartlett, WoodWorks
March 23, 2022

Photo Credit: Sarah Campbell Foundation Center for Conservation / Lake|Flato Architects / photo Peter Molick
Designing a wood building?
Ask us anything.

FREE PROJECT SUPPORT / EDUCATION / RESOURCES

Nationwide support for the code-compliant design, engineering and construction of non-residential and multi-family wood buildings.

- Allowable Heights/Areas
- Construction Types
- Structural Detailing
- Wood-Framed & Hybrid Systems
- Fire/Acoustic Assemblies
- Lateral System Design
- Alternate Means of Compliance
- Energy-Efficient Detailing
- Building Systems & Technologies

woodworks.org/project-assistance | help@woodworks.org
New WOOD SOLUTION PAPER

CLT Diaphragm Design for Wind and Seismic Resistance
Using SDPWS 2021 and ASCE 7-22

New CASE STUDIES

Adidas East Village Expansion
Innovative mass timber designs meet ambitious construction timeline

Thomas Logan
Wood-frame urban podium project fills need for affordable downtown housing

INTERNATIONAL MASS TIMBER CONFERENCE
April 12 – April 14

Common Challenges in Wood Lateral System Layouts | May 3
1.5 AIA/CES HSW LUs, 1.5 PDH credits, 0.15 ICC credits

Lateral Design for Mass Timber Structures: How to Do It, How It’s Been Done | May 5
1.5 AIA/CES HSW LUs, 1.5 PDH credits, 0.15 ICC credits

Virtual International Mass Timber Conference | May 12

Visit woodworks.org/publications-media

Visit woodworks.org/events
Mass Timber Competition: Building to Net Zero
New for GCs and installers:

Download free at woodworks.org
Meet the Help Desk

Need technical assistance on a project?

Email: help@woodworks.org
Current State of Mass Timber Projects

As of December 2021, in the US, **1,303** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.

* This total includes modern mass timber and post-and-beam structures built since 2013

Source: WoodWorks, December 31, 2021

Watch the Chat Window, Ask Questions through the Q&A Box

» During today’s event will be sending links, files and other pertinent information through the Chat window, located at the bottom of your screen.

» Submit questions in the Q&A box at the bottom of your screen as they come up in the presentations. We will get to as many questions as possible.
“The Wood Products Council” is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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

1. Identify construction types within the International Building Code where a mass timber structure is permitted.
2. Discuss the impacts of construction type on required fire-resistance ratings of structural elements, noting the impacts that these ratings have on effective member spans and resulting grids.
3. Review code-compliance requirements for acoustics and primary frame connections, and provide solutions for meeting these requirements with tested mass timber assemblies.
4. Highlight effective methods of integrating MEP services in a mass timber building and discuss the relative impacts of each on cost, aesthetics, occupant comfort and future tenant renovations.
Key Early Design Decisions

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

- MEP Layout
- Acoustics
- Concealed Spaces
- Connections
- Penetrations
- Construction Type
- Fire-Resistance Ratings
- Member Sizes
- Grids & Spans
- Exposed Timber (where & how much)

The Answer is…They All Need to Be Weighed (Plus Others)
Key Early Design Decisions

Significant Emphasis Placed on the Word Early

Early Because:

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

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

Early = Efficient

Realize Efficiency in:
• Cost reduction
• Material use (optimize fiber use, minimize waste)
• Construction speed
• Trade coordination
• Minimize RFIs

Commit to a mass timber design from the start
Key Early Design Decisions

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

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

One *potential* design route:

1. Building size & occupancy informs construction type & grid

2. Construction type informs fire resistance ratings

3. Grid & fire resistance ratings inform timber member sizes & MEP layout

But that’s not all…
Key Early Design Decisions

Other impactful decisions:

• **Acoustics** informs member sizes (and vice versa)

• Fire-resistance ratings inform connections & penetrations

• **MEP layout** informs use of concealed spaces
Key Early Design Decisions

Other impactful decisions:

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

• **Manufacturer capabilities** inform member sizes, grids & connections

• **Lateral system** informs connections, construction sequencing

And more…
Key Early Design Decisions

Where do we start?

1 De Haro, Perkins & Will, photo Alex Nye
## Key Early Design Decisions

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

<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>
<tbody>
<tr>
<td></td>
<td>R-2: 18</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>A-2, A-3, A-4: 135,000</td>
<td>B: 324,000</td>
<td>216,000</td>
</tr>
<tr>
<td></td>
<td>R-2: 184,500</td>
<td>123,000</td>
<td>76,875</td>
</tr>
</tbody>
</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>Allowable Area Factor (At) for SM, Feet² (IBC Table 506.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2, A-3, A-4</td>
</tr>
<tr>
<td>135,000, 90,000, 56,250, 45,000, 42,000, 28,500, 34,500, 18,000</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>324,000, 216,000, 135,000, 108,000, 85,500, 57,000, 54,000, 27,000</td>
</tr>
<tr>
<td>R-2</td>
</tr>
<tr>
<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

- Driven primarily by construction type
- Rating achieved through timber alone or non-com 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>3a, b</td>
<td>2a, b, c</td>
<td>1b, c</td>
<td>0c</td>
<td>1b, c</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3a</td>
<td>2a</td>
<td>1</td>
<td>0</td>
<td>1</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</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</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>1</td>
</tr>
<tr>
<td>Roof construction and associated secondary structural members (see Section 202)</td>
<td>11/2</td>
<td>1b, c</td>
<td>1b, c</td>
<td>0c</td>
<td>1b, c</td>
</tr>
</tbody>
</table>
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
Construction Types

When does the code allow mass timber to be used?

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

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

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

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

However, there are exceptions including several for mass timber
Construction Types

Where does the code allow MT to be used?

- **Type IB & II: Roof Decking**
Construction Types

All wood framed building options:

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

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

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

**Type IV (Heavy Timber)**
Exterior walls non-combustible (may be FRTW OR CLT)
Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)
Construction Types

Where does the code allow MT to be used?

• **Type III**: Interior elements (floors, roofs, partitions/shafts) and exterior walls if FRT
Construction Types

Where does the code allow MT to be used?

• **Type IV**: Any exposed interior elements & roofs, must meet min. sizes; exterior walls if CLT or FRT. Concealed space limitations (varies by code version)
## Type IV 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 1/4</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 2018 2304.11 or IBC 2015 602.4 for Details

*3” nominal width allowed where sprinklered
Construction Types

Type IV min. sizes:

**Floor Panels/Decking:**
- 4” thick CLT (actual thickness)
- 4” NLT/DLT/GLT (nominal thickness)
- 3” thick (nominal) decking covered with: 1” decking or 15/32” WSP or ½” particleboard
Construction Types

Type IV min. sizes:

**Interior Walls:**
- Laminated construction 4” thick
- Solid wood construction min. 2 layers of 1” matched boards
- Wood stud wall (1 hr min)
- Non-combustible (1 hr min)

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

Type IV concealed spaces

Can I have a dropped ceiling? Raised access floor?
Construction Types

Type IV concealed spaces

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

Credit: IBC
Construction Types

Type IV concealed space options within 2021 IBC

Option 1:

Sprinklers in concealed spaces
Dropped ceiling
Construction Types

Type IV concealed space options within 2021 IBC

Option 2:

Noncombustible insulation
Dropped ceiling
Construction Types

Type IV concealed space options within 2021 IBC

Option 3:

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

Dropped ceiling
Concealed Spaces in Mass Timber and Heavy Timber Structures

Concealed spaces, such as those created by a dropped ceiling in a floor/ceiling assembly or by a stud wall assembly, have unique requirements in the International Building Code (IBC) to address the potential for the 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. Are sprinklers required in concealed spaces such as floor and roof voids in multi-family wood-frame buildings?

For mass timber building elements, the choice of construction type can have a significant impact on concealed space requirements. Because mass timber products such as cross-laminated timber (CLT) are prescriptively recognized for Type IV construction, there is a common 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 IV buildings, structural mass timber elements—including CLT, glue-laminated timber (glulam), nail-laminated timber (NLT), structural composite lumber (SCL), and tongue and groove (T&G) decking—can be utilized and exposed in the following construction types, whether or not a fire-resistance rating is required:

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

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

Construction Types

Where does the code allow MT to be used?
• **Type V**: All interior elements, roofs & exterior walls
Construction Types

Type III: 6 stories

Type IV: 6 stories

Type V: 4 stories

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

Credits: Ema Peter, Christian Columbres Photography
Construction Types

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

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

- Type IV-B
  - Office Assembly Residential
  - Mercantile (8 stories)

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

CLT structural capacity

CLT char depth

Original CLT depth

Credit: David Barber, ARUP
### Key Early Design Decisions

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></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*a</td>
<td>2*a</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3*a</td>
<td>2*a</td>
<td>1</td>
<td>0</td>
<td>1</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</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary members (see Section 202)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof construction and associated secondary members (see Section 202)</td>
<td>$1^{1/2}$</td>
<td>$1^b$</td>
<td>$1^b$</td>
<td>$0^c$</td>
<td>$1^b$</td>
</tr>
</tbody>
</table>

Source: 2018 IBC
Key Early Design Decisions

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></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>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></td>
<td></td>
<td></td>
<td>1^{b,c}</td>
<td>0</td>
<td>3^{a}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2^{a}</td>
<td>2^{a}</td>
<td>HT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1^{b,c}</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bearing walls</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>3</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></td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td>1^{/HT}</td>
<td>1^{a}</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>structural members (see Section 202)</td>
<td></td>
<td></td>
<td>1^{0}</td>
<td>1^{1/2}</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HT</td>
<td>1^{b,c}</td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary</td>
<td>1^{1/2}</td>
<td>1^{b,c}</td>
<td>1^{b,c}</td>
<td>0^{c}</td>
<td></td>
</tr>
<tr>
<td>structural members (see Section 202)</td>
<td></td>
<td></td>
<td>0^{b,c}</td>
<td>0^{1/2}</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1^{1}</td>
<td>1^{b,c}</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HT</td>
<td>1^{b,c}</td>
<td></td>
</tr>
</tbody>
</table>

Source: 2021 IBC
Key Early Design Decisions

Construction type influences FRR

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

Method of demonstrating FRR (calculations or testing) can impact member sizing
Key Early Design Decisions

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

Credit: ARUP

Credit: Kaiser+Path
Key Early Design Decisions

Which Method of Demonstrating FRR of MT is Being Used?
1. Calculations in Accordance with IBC 722 → NDS Chapter 16
2. Tests in Accordance with ASTM E119

Credit: Urban One
FRR Design of MT

Calculated FRR of Exposed MT: IBC to NDS code compliance path

IBC 703.3
Methods for determining fire resistance
- Prescriptive designs per IBC 721.1
- Calculations in accordance with IBC 722
- Fire-resistance designs documented in sources
- Engineering analysis based on a comparison
- Alternate protection methods as allowed by 104.11

IBC 722
Calculated Fire Resistance
*The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AWC National Design Specification for Wood Construction (NDS)*

NDS Chapter 16
Fire Design of Wood Members
- Limited to calculating fire resistance up to 2 hours
- Char depth varies based on exposure time (i.e., fire-resistance rating), product type and lamination thickness. Equations and tables are provided.
- TR 10 and NDS commentary are helpful in implementing permitted calculations.
NDS Chapter 16 includes calculation of fire resistance of NLT, CLT, Glulam, Solid Sawn and SCL wood products.
FRR Design of MT

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

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

<table>
<thead>
<tr>
<th>Required Fire Resistance (hr.)</th>
<th>Char Depth, $a_{\text{char}}$ (in.)</th>
<th>Effective Char Depth, $a_{\text{eff}}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>1½-Hour</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>2-Hour</td>
<td>2.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr.)</th>
<th>Effective Char Depths, $a_{\text{char}}$ (in.) lamination thicknesses, $h_{\text{lam}}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5/8</td>
</tr>
<tr>
<td>1-Hour</td>
<td>2.2</td>
</tr>
<tr>
<td>1½-Hour</td>
<td>3.4</td>
</tr>
<tr>
<td>2-Hour</td>
<td>4.4</td>
</tr>
</tbody>
</table>
FRR Design of MT

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

Solid Sawn, Glulam, SCL

CLT

Effective Char Depth

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

Credit: Forest Products Laboratory
FRR Design of MT

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

<table>
<thead>
<tr>
<th>Table 16.2.2 Adjustment Factors for Fire Design¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>ASD</strong></td>
</tr>
<tr>
<td>Design Stress to Member Strength Factor</td>
</tr>
<tr>
<td>Size Factor²</td>
</tr>
<tr>
<td>Volume Factor²</td>
</tr>
<tr>
<td>Flat Wise Factor²</td>
</tr>
<tr>
<td>Beam Stability Factor²</td>
</tr>
<tr>
<td>Column Stability Factor²</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Bending Strength</td>
</tr>
<tr>
<td>Beam Buckling Strength</td>
</tr>
<tr>
<td>Tensile Strength</td>
</tr>
<tr>
<td>Compressive Strength</td>
</tr>
<tr>
<td>Column Buckling Strength</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
FRR Design of MT

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

Example 5: Exposed CLT Floor - Allowable Stress Design

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

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

Calculate panel load (per foot of width):

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

Calculate maximum induced moment (per foot of width):

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

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

Bending moment, $F_0S_{eff,0} = 4,675 \text{ ft-lb/ft of width}$ (PRG 320 Annex A, Table A2)

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

$$ M'_a = F_0(S_{aw})(C_D)(C_M)(C_L) = 4,675 (1.0)(1.0)(1.0) = 4,675 \text{ ft-lb/ft of width} $$ (NDS 10.3.1)

Structural Check:

$$ M'_{a} \geq M_{max} $$

4,675 ft-lb/ft > 4,455 ft-lb/ft $\checkmark$

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

Source: AWC’s TR10
FRR Design of MT

Tested FRR of Exposed MT:
• IBC 703.2 notes the acceptance of FRR demonstration via testing in accordance with ASTM E119

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

Standard ASTM E119 test time-temperature curve
FRR Design of MT

Tested FRR of Exposed MT:

• Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers
## FRR Design of MT

**WoodWorks Inventory of Fire Tested MT Assemblies**

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Manufacturer</th>
<th>CLT Grade or Major x Minor Grade</th>
<th>Ceiling Protection</th>
<th>Panel Connection in Test</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 (150mm x 675mm)</td>
<td>Nordic</td>
<td>SPF 1650 Fb 13EMSR x SPF #3</td>
<td>2 layers 1/2” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 30% Moment Capacity</td>
<td>1</td>
<td>1 (Test 1)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>3-ply CLT (150mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #3/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 5% Moment Capacity</td>
<td>1</td>
<td>1 (Test 2)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EI</td>
<td>None</td>
<td>Topside Splice</td>
<td>2 staggered layers of 1/2” cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>NRC Fire Laboratory March 2016</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EI</td>
<td>None</td>
<td>Topside Splice</td>
<td>2 staggered layers of 1/2” cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>3</td>
<td>NRC Fire Laboratory Nov 2014</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EL</td>
<td>None</td>
<td>Topside Splice</td>
<td>3/4” proprietary gasket over mass on acoustical nailing</td>
<td>Reduced 50% Moment Capacity</td>
<td>1.5</td>
<td>3</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EL</td>
<td>None</td>
<td>Topside Splice</td>
<td>3/4” proprietary gasket over mass on acoustical nailing or proprietary sound board</td>
<td>Reduced 50% Moment Capacity</td>
<td>2</td>
<td>4</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer 3/8” normal gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 50% Moment Capacity</td>
<td>2</td>
<td>21</td>
<td>InterTek 8/24/2012</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer 3/8” normal gypsum under Rockland/Channel under 7/16” Laminated with 3/12” mineral/Wood between layers</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 50% Moment Capacity</td>
<td>2</td>
<td>8</td>
<td>InterTek, 2/22/2016</td>
</tr>
<tr>
<td>5-ply CLT (175mm x 675mm)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 50% Moment Capacity</td>
<td>1.5</td>
<td>1 (Test 4)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF 1510 Fb MSR x SPF #3</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2</td>
<td>1 (Test 8)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2.5</td>
<td>1 (Test 7)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2</td>
<td>12 (Test 7)</td>
<td>Western Fire Center 10/26/2016</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2</td>
<td>12 (Test 8)</td>
<td>Western Fire Center 10/28/2016</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2</td>
<td>12 (Test 8)</td>
<td>Western Fire Center 11/01/2016</td>
</tr>
<tr>
<td>5-ply CLT (25mm x 675mm)</td>
<td>Nordic</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>1 layer 3/8” Type X gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced 100% Moment Capacity</td>
<td>2</td>
<td>12 (Test 8)</td>
<td>Western Fire Center 11/01/2016</td>
</tr>
</tbody>
</table>
FRR Design of MT

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

Each has unique benefits:

- **Testing:**
  - Can result in higher FRR for some assemblies when compared to calculations (i.e. 2-hr FRR with 5-ply CLT panel).
  - Seen as more acceptable by some building officials

- **Calculations:**
  - Can provide more design flexibility
  - Allows for project span and loading specific analysis
Mass Timber Fire Design Resource

• Code compliance options for demonstrating FRR
• Free download at woodworks.org
Structural Grid
Structural Grid

Grids & Spans

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

- 24’-2”
- 30’-0”
- 30’-0”
- 24’-0”
- 24’-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”

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
Key Early Design Decisions

Construction Type Early Decision Example

7-story building on health campus
• Group B occupancy, NFPA 13 sprinklers throughout
• Floor plate = 22,300 SF
• Total Building Area = 156,100 SF

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA podium
• If Building is > 85 ft
  • 7 stories of IV-B
Key Early Design Decisions

Construction Type Early Decision Example

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA
• If Building is > 85 ft
  • 7 stories of IV-B

Implications of construction type choice in this example:
• FRR (2 hr vs 1 hr vs min sizes)
• Efficient spans & grid
• Exposed timber limitations
• Concealed spaces
• Cost
• And more…
Key Early Design Decisions

Construction Type Early Decision Example

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

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

Construction Type Early Decision Example

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

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

Construction Type Early Decision Example

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA
• If Building is > 85 ft
  • 7 stories of IV-B

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

Why so much focus on panel thickness?
Key Early Design Decisions

Typical MT Package Costs

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

Source: Swinerton
Panels are the biggest part of the biggest piece of the cost pie.
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IIIA option 1
1-hr FRR
Purlin: 5.5”x28.5”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

Glulam volume = 118 CF (22% of MT)
CLT volume = 430 CF (78% of MT)
Total volume = 0.73 CF / SF
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

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
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IV-HT
0-hr FRR (min sizes per IBC)
Purlin: 5.5”x24” (IBC min = 5”x10.5”)
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
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IV-HT
0-hr FRR (min sizes per IBC)
Purlin: 5.5”x24” (IBC min = 5”x10.5”)
Girder: 8.75”x33” (IBC min = 5”x10.5”)
Column: 10.5”x10.75” (IBC min = 6.75”x8.25”)

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 IIIIB, member sizing would essentially be the same as IV-HT. But there are other nuances between III and IV, we’ll cover that later…
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IV-C
2-hr FRR
Purlin: 8.75”x28.5”
Girder: 10.75”x33”
Column: 13.5”x21.5”
Floor panel: 5-ply

Glulam volume = 183 CF (30% of MT)
CLT volume = 430 CF (70% of MT)
Total volume = 0.82 CF / SF

Source: Fast + Epp, Timber Bay Design Tool
Key Early Design Decisions

Which is the most efficient option?

<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>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.
Key Early Design Decisions

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.
Key Early Design Decisions

Construction Type Early Decision Example

3-story building on college campus
• Mostly Group B occupancy, some assembly (events) space
• NFPA 13 sprinklers throughout
• Floor plate = 7,700 SF
• Total Building Area = 23,100 SF

Impact of Assembly Occupancy Placement:

Owner originally desires events space on top (3rd) floor
• Requires Construction Type IIIA
If owner permits moving events space to 1st or 2nd floor
• Could use Type IIIB
## Key Early Design Decisions

### Construction Type Early Decision Example

3-story building on college campus

### Cost Impact of Assembly Occupancy Placement:

<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
Key Early Design Decisions

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
Key Early Design Decisions

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

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

Connection FRR and beam reactions could impact required beam/column sizes
Key Early Design Decisions

2017 Glulam Beam to Column Connection Fire Tests under standard ASTM E119 time-temperature exposure
# Key Early Design Decisions

## Fire Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Beam</th>
<th>Connector</th>
<th>Applied Load</th>
<th>FRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.75” x 18” (222mm x 457mm)</td>
<td>1 x Ricon S VS 290x80</td>
<td>3,905lbs (17.4kN)</td>
<td>1hr</td>
</tr>
<tr>
<td>2</td>
<td>10.75” x 24” (273mm x 610mm)</td>
<td>Staggered double Ricon S VS 200x80</td>
<td>16,620lbs (73.9kN)</td>
<td>1.5hrs</td>
</tr>
<tr>
<td>3</td>
<td>10.75” x 24” (273mm x 610mm)</td>
<td>1 x Megant 430</td>
<td>16,620lbs (73.9kN)</td>
<td>1.5hrs</td>
</tr>
</tbody>
</table>
Key Early Design Decisions

Softwood Lumber Board
Glulam Connection Fire Test
Summary Report

Issue | June 5, 2017

Full Report Available at:
Key Early Design Decisions

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

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

Style of connection also impacts and is impacted by grid layout and MEP integration
Key Early Design Decisions

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.

WoodWorks Index of Mass Timber 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.
Connections

Other connection design considerations:

- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost

Credit: Alex Schreyer
WoodWorks Online Event


1430 Q, The HR Group Architects, Buehler Engineering, Greg Folkins Photography.

T3 Minneapolis, MGA, DLR Group, Magnusson Klemencic Associates, StructureCraft, photo Ema Peter.
Penetrations & Firestopping
Penetrations & Firestopping

Construction Type Impacts FRR | FRR impacts penetration firestopping requirements

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

Code options for firestopping through penetrations

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

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

Option 1: MT penetration firestopping via tested products

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
Penetrations & Firestopping

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

FINAL REPORT
Consisting of 18 Pages

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

Prepared for:
American Wood Council
222 Catoctin Circle SE
Leesburg, VA 20175

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

Lindsay Ranger', Christian Dagenais', Conroy Lum', Tony Thomas'

ABSTRACT: Integrity and continuity must be maintained for fire separations required to provide the prevent passage of hot gases or increased temperature on the unexposed side. Vulnerable locations, where fire is introduced into mass timber systems, are susceptible to fire spread. Service and closure penetrations and timber fire separation have been investigated. Many of the fire stop systems were able to achieve 1½ hour according to CAN/ULC-S115, which would be required for 2-hr fire resistance rated assemblies, in tall wood buildings. Construction details are outlined which ensure adequate fire performance of these assemblies.

KEYWORDS: Firestop, through-penetrations, fire rated door, mass timber, cross-laminated timber (CLT) buildings, fire resistance

1 INTRODUCTION

Many tall wood buildings using mass timber are planned or are currently being designed for construction around the world. A few have been built in Canada, including an 18 storey cross-laminated timber (CLT) and glulam building in British Columbia. The prescriptive requirements in the National Building Code of Canada (NBCC) [1] do not (yet) permit the construction of wood buildings taller than six stories, however an alternative solutions approach can be used to demonstrate equivalent performance to prescriptive acceptable solutions, rendering nonprohibitively expensive. Construction...
### 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>Centred 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>5-ply (78mm) 67&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 1 in. annular space around the data cable to a total depth of approximately 2 - 5/64 in. The remaining 1 in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.</td>
<td>1 hour</td>
<td>0.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply (78mm) 67&quot;</td>
<td>None</td>
<td>2&quot; copper pipe</td>
<td>Centred</td>
<td>4.375 in diameter hole. Pipe wrap was wrapped around the copper pipe to a total depth of approximately 2 - 5/64 in.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply (78mm) 67&quot;</td>
<td>None</td>
<td>2.5&quot; sch. 40 pipe</td>
<td>Centred</td>
<td>4.92 in diameter hole. Pipe wrap was wrapped around the schedule 40 pipe to a total depth of approximately 2 - 5/64 in.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply (78mm) 67&quot;</td>
<td>None</td>
<td>6&quot; cast iron pipe</td>
<td>Centred</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 - 5/64 in.</td>
<td>1 hour</td>
<td>N.A.</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply (78mm) 67&quot;</td>
<td>None</td>
<td>H16.6 in deep in device System No. F-1-2049</td>
<td>Centred</td>
<td>9.01&quot; diameter hole. Mineral wool was installed in the 1 - 1/4 in. annular space around the drop-in device to a total depth of approximately 1 - 7/64 in and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 - 1/4 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>Inertak 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 bunch</td>
<td>Centred</td>
<td>3.5&quot; diameter hole. Mineral wool was installed in the 1 in. annular space around the data cable to a total depth of approximately 4 - 5/32 in.</td>
<td>2 hours</td>
<td>1.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak 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>Centred</td>
<td>4.375 in diameter hole. Pipe wrap was wrapped around the copper pipe to a total depth of approximately 4 - 5/32 in.</td>
<td>2 hours</td>
<td>N.A.</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm) 5.16&quot;</td>
<td>None</td>
<td>2.5&quot; sch. 40 pipe</td>
<td>Centred</td>
<td>4.92 in diameter hole. Pipe wrap was wrapped around the schedule 40 pipe to a total depth of approximately 4 - 5/32 in.</td>
<td>2 hours</td>
<td>0.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak 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>Centred</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.</td>
<td>2 hours</td>
<td>N.A.</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (151 mm) 5.16&quot;</td>
<td>None</td>
<td>H16.6 in deep in device System No. F-1-2049</td>
<td>Centred</td>
<td>9.01&quot; diameter hole. Mineral wool was installed in the 1 - 1/4 in. annular space around the drop-in device to a total depth of approximately 1 - 7/64 in and the remaining 1 in. annular space from the top of the mineral wool to the top edge of the 9 - 1/4 in. hole in the CLT was filled with Hilti FS-One Max caulking.</td>
<td>2 hours</td>
<td>1.5 hour</td>
<td>CANULC S115</td>
<td>26</td>
<td>Inertak March 30, 2016</td>
</tr>
<tr>
<td>5-ply CLT (137 mm) 5.16&quot;</td>
<td>None</td>
<td>1&quot; nominal PVC pipe</td>
<td>Centred</td>
<td>4.21 in diameter at 3/4 in plywood reducer flush with the top of the slab. The layer of the slab was 40 cm thick, which extended from the top of the slab. The first location was with the bottom of the pipe flush with the bottom of the steel sleeve and the second location was with the top of the pipe flush with the steel sleeve. The void between the steel sleeve and the CLT and between the steel sleeve and Overlay was filled with Royal 855Sk mineral wool leaving a 3/4 in deep void at the top of the assembly. Hilti FS-One Max Intumescent Firestop System was applied to a depth of 9/16 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 E814</td>
<td>24</td>
<td>QA Laboratory March 3, 2017</td>
</tr>
</tbody>
</table>
Penetrations & Firestopping

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

1. 3-Ply Cross Laminated Timber Floor Assembly (Minimum 3" Thick) (1-Hr. Fire-Rating).
2. Hilti CFS-DID Firestop Drop-In Device Inserted into Opening (See Table Below) and Secured to Top Surface of Cross Laminated Timber Floor Assembly with Three 1/4" x 1" Long Steel Wood Screws with Washers.
5. Minimum 1" Depth Hilti FS-One Max Intumescent Firestop Sealant Between CFS-DID Firestop Drop in Device and Periphery of Opening.

F-Rating = 1-Hr. or 2-Hr. (See Note No. 3 Below)

1. Mass Timber Wall Assembly (Minimum 12" Thick) (1-Hr. or 2-Hr. Fire-Rating).
2. Maximum 2" Nominal Diameter PVC Plastic Pipe (Sch 40).
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
MEP Layout & Integration
MEP Layout & Integration

Set Realistic Owner Expectations About Aesthetics
- MEP fully exposed with MT structure, or limited exposure?
MEP Layout & Integration

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

Smaller grid bays at central core

Main MEP trunk lines around core

Smaller branches in exterior bays

Credit: ARUP
MEP Layout & Integration

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

Beam penetrations are minimized/eliminated

Recall typical panel span limits:

<table>
<thead>
<tr>
<th>Panel</th>
<th>Example Floor Span Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (4-1/8” thick)</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>5-ply CLT (6-7/8” thick)</td>
<td>14 to 17 ft</td>
</tr>
<tr>
<td>7-ply CLT (9-5/8”)</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” 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

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

Credit: SOM Timber Tower Report
MEP Layout & Integration

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

In chases above beams and below panels
  • Fewer penetrations
  • Bigger impact on head height (overall structure depth is greater)
  • FRR impacts: top of beam exposure
MEP Layout & Integration

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

In chases above beams and below panels at Catalyst
• 30x30 grid, 5-ply CLT ribbed beam system

Credit: KL&A Engineers & Builders
Credit: Hans-Erik Blomgren
MEP Layout & Integration

In gaps between MT panels
• Fewer penetrations, can allow for easier modifications later
MEP Layout & Integration

In gaps between MT panels
• FRR impacts: generally topping slab relied on for FRR
MEP Layout & Integration

In gaps between MT panels
• Impact on assembly acoustics performance
MEP Layout & Integration

In gaps between MT panels
• Greater flexibility in MEP layout

Credit: WoodWorks

Credit: PAE Consulting Engineers
MEP Layout & Integration

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

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

In raised access floor (RAF) above MT
- Impact on head height
- Concealed space code provisions
MEP Layout & Integration

In topping slab above MT

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

Concrete Shearwalls
Lateral System Choices

Connection to concrete core
Lateral System Choices

Connections to concrete core
• Tolerances & adjustability
• Drag/collector forces
Lateral System Choices

Steel Braced Frame

Photos: Marcus Kauffmann, ODF
Lateral System Choices

Connections to steel frame
- Tolerances & adjustability
- Consider temperature fluctuations
- Ease of installation

Photos: Marcus Kauffmann, ODF
Lateral System Choices

Wood-Frame Shearwalls

Credit: KL&A Engineers & Builders
Lateral System Choices

Wood-frame Shearwalls:
• Code compliance
• Standard of construction practice well known
• Limited to 65 ft shearwall height, 85 ft overall building height (Type IIIA construction)
Lateral System Choices
MT Shearwalls

Photo: Alex Schreyer
Lateral System Choices

MT Rocking Shearwalls
Lateral System Choices

Timber Braced Frame
Lateral System Choices

Prescriptive Code Compliance
- Concrete Shearwalls
- Steel Braced Frames
- Light Wood-Frame Shearwalls
- CLT Shearwalls
- CLT Rocking Walls
- Timber Braced Frames

Photo: WoodWorks

2021 SDPWS
ASCE 7-22
Acoustics & Sound Control

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

Images: Maxxon
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
<table>
<thead>
<tr>
<th>STC</th>
<th>What can be heard</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Normal speech can be understood quite easily and distinctly through wall</td>
</tr>
<tr>
<td>30</td>
<td>Loud speech can be understood fairly well, normal speech heard but not understood</td>
</tr>
<tr>
<td>35</td>
<td>Loud speech audible but not intelligible</td>
</tr>
<tr>
<td>40</td>
<td>Onset of &quot;privacy&quot;</td>
</tr>
<tr>
<td>42</td>
<td>Loud speech audible as a murmur</td>
</tr>
<tr>
<td>45</td>
<td>Loud speech not audible; 90% of statistical population not annoyed</td>
</tr>
<tr>
<td>50</td>
<td>Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.</td>
</tr>
<tr>
<td>60+</td>
<td>Superior soundproofing; most sounds inaudible</td>
</tr>
</tbody>
</table>
Acoustics & Sound Control

MT: Structure Often is Finish

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman   |   Architect: Kaiser + PATH
Acoustics & Sound Control

But by Itself, Not Adequate for Acoustics
# Acoustics & Sound Control

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

<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>2x6 NLT wall</td>
<td>5-1/2&quot; bare NLT</td>
<td>22 bare NLT</td>
<td>N/A</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
Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

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

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

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

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

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

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

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

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

Mass timber has relatively low “mass”
Recall the three ways to increase acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

Concrete Slab:
6” Thick
80 PSF
STC 53

CLT Slab:
6-7/8” Thick
18 PSF
STC 41
Acoustics & Sound Control

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

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control

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

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

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

Acoustical floor underlayments

Photo: AcoustiTECH

Photo: Kinetics Noise Control, Inc.

Photo: Maxxon Corporation

Photo: Pitaq Inc.
Acoustics & Sound Control

Common mass timber floor assembly:
• Finish floor (if applicable)
• Underlayment (if finish floor)
• 1.5” to 4” thick concrete/gypcrete topping
• Acoustical mat
• WSP (if applicable)
• Mass timber floor panels
Acoustics and Mass Timber: Room-to-Room Noise Control

Richard Sisco, PE, SE A senior technical specialist at WoodWorks

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

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

Mass Timber Assembly Options: Walls
Mass timber panels can also be used for interior and exterior walls—both bearing and non-bearing. For interior walls, the need for contact services such as electrical and plumbing is an added consideration. Common approaches include building a chase wall in front of the mass timber wall or installing gusset wallboard on resilient channels that are attached to the mass timber wall. As with base mass timber floor panels, base mass timber walls don’t typically provide adequate noise control, and chase walls also function as acoustical improvements. For example, a 5-ply CLT wall panel with a thickness of 3 3/4” has an STC rating of 55. In contrast, Figure 2 shows an interior CLT partition wall with chase walls on both sides. This assembly achieves an STC rating of 69, exceeding the IBC’s acoustical requirements for multifamily construction. Other examples are included in the inventory of tested assemblies noted above.

Acoustical Differences between Mass Timber Panel Options
The majority of acoustically tested mass timber assemblies include CLT. However, tests have also been done on other mass timber panel options such as NLT and dowel-laminated timber (DLT), as well as traditional heavy timber options such as tongue and groove decking. Most tests have concluded that CLT, large solid wood panels, is slightly better than that of other mass timber options, largely because of the cross-orientation of laminations in a CLT panel helps sound flanking.

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

Acoustics & Sound Control
Inventory of Tested Assemblies

Acoustically-Tested Mass Timber Assemblies

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

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

Sources ........................................................................................................................................................................... 32

Disclaimer ........................................................................................................................................................................ 34

### 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</th>
<th>IIC</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2” Gyp-Crete*</td>
<td>Maxson Acousti-Mat® 3/4</td>
<td>None</td>
<td>LVT</td>
<td>47* ASTC</td>
<td>47* AIC</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carpet + Pad</td>
<td>-</td>
<td>75* AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT on Acousti-Top*</td>
<td>-</td>
<td>52* AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maxson Acousti-Mat® % Premium</td>
<td>None</td>
<td>LVT</td>
<td>49* ASTC</td>
<td>45* AIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT on Acousti-Top*</td>
<td>-</td>
<td>51* AIC</td>
<td></td>
</tr>
<tr>
<td>CLT 5-ply (6.875”)</td>
<td>USG SAM N25 Ultra</td>
<td>None</td>
<td>LVT</td>
<td>45*</td>
<td>39*</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT Plus</td>
<td>48*</td>
<td>47*</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVT on Acousti-Top*</td>
<td>48*</td>
<td>49*</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carpet + Pad</td>
<td>45*</td>
<td>67*</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ceramic Tile</td>
<td>50*</td>
<td>64*</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>45*</td>
<td>42*</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ceramic Tile</td>
<td>48*</td>
<td>44*</td>
<td>16</td>
</tr>
</tbody>
</table>
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
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 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

Credit: Monte French Design Studio
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

Credit: Monte French Design Studio
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options
• Option 1

No beam penetrations at main to branch MEP

Typ. MT Panel

Main MEP lines in corridor

MEP branches in each unit
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

Credit: Monte French Design Studio
Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2

32’ Beam penetrations at all beam lines

6’ Main MEP lines in corridor

32’ MEP branches in each unit

Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IV-C Floor Assembly Options

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

Note: many other acoustic mat and topping options exist, one example shown here
Note: 5-ply is most efficient for the 15-16 ft panel spans shown
Key Early Design Decisions

Early Design Decision Example

MT Construction Type Options:

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

Implications of Type IIIA:

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

Early Design Decision Example

Type IIIA Grid Options
  • Option 1

- Beams at 15’ o.c. (align with unit demising wall)
- Shallower beam at corridor (main MEP lines)
- MT floor panel span
- Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options
- Option 1

No beam penetrations at main to branch MEP

Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options
• Option 2

- Beams at 16’ o.c. (align w corridor wall)
- No beam at corridor
- Typ. MT Panel
Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options
• Option 2
Key Early Design Decisions

Early Design Decision Example

Type IIIA Floor Assembly Options

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

Note: many other acoustic mat and topping options exist, one example shown here
Note: 5-ply is most efficient for the 15-16 ft panel spans shown
Key Early Design Decisions

Early Design Decision Example

MT Construction Type Options:
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

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

Ref. IBC 420.2, 420.3, 708.3, 711.2.4.3
Key Early Design Decisions

Early Design Decision Example

MT Construction Type Options:
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

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

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

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
Create Your Market Distinction
Questions? Ask us anything.

Mark Bartlett, PE
Regional Director | TX
(214) 679-1874
mark.bartlett@woodworks.org
Copyright Materials
This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of the speaker is prohibited.

© The Wood Products Council 2021

Disclaimer: The information in this presentation, including, without limitation, references to information contained in other publications or made available by other sources (collectively “information”) should not be used or relied upon for any application without competent professional examination and verification of its accuracy, suitability, code compliance and applicability by a licensed engineer, architect or other professional. Neither the Wood Products Council nor its employees, consultants, nor any other individuals or entities who contributed to the information make any warranty, representative or guarantee, expressed or implied, that the information is suitable for any general or particular use, that it is compliant with applicable law, codes or ordinances, or that it is free from infringement of any patent(s), nor do they assume any legal liability or responsibility for the use, application of and/or reference to the information. Anyone making use of the information in any manner assumes all liability arising from such use.