Designing Tall Timber for Code Compliance: Fire Resistance, Acoustics and Connection Detailing

Ricky McLain, PE, SE, Senior Technical Director – Tall Wood, WoodWorks – Wood Products Council

Photo: Kaiser+Path
Questions we’ll answer:
• How much timber can be exposed
• How do you design for fire-resistance (exposed & protected)
• What do I need to know about acoustics in tall timber?
• What do the connections & details look like (and how does fire impact them)
Type IV-C Protection vs. Exposed

All Mass Timber surfaces may be exposed

Exceptions: Shafts, concealed spaces, outside face of exterior walls
Type IV-B

12 STORIES
BUILDING HEIGHT 180 FT
ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000 SF

Credit: Susan Jones, atelierjones

Credit: LEVER Architecture
Type IV-B Protection vs. Exposed

NC protection on all surfaces of Mass Timber except limited exposed areas

~20% of Ceiling or ~40% of Wall can be exposed, see code for requirements

Credit: Susan Jones, atelierjones
Limited Exposed MT allowed in Type IV-B for:

- MT beams and columns which are not integral part of walls or ceilings, no area limitation applies
- MT ceilings and beams up to 20% of floor area in dwelling unit or fire area, or
- MT walls and columns up to 40% of floor area in dwelling unit or fire area, or
- Combination of ceilings/beams and walls/columns, calculated as follows:
Mixed unprotected areas, exposing both ceilings and walls:

- In each dwelling unit or fire area, max. unprotected area =
  \[
  \frac{U_{tc}}{U_{ac}} + \frac{U_{tw}}{U_{aw}} \leq 1.0
  \]
- \( U_{tc} \) = Total unprotected MT ceiling areas
- \( U_{ac} \) = Allowable unprotected MT ceiling areas
- \( U_{tw} \) = Total unprotected MT wall areas
- \( U_{aw} \) = Allowable unprotected MT wall areas
Design Example: Mixing unprotected MT walls & ceilings

800 SF dwelling unit
- \( U_{ac} = (800 \text{ SF}) \times (0.20) = 160 \text{ SF} \)
- \( U_{aw} = (800 \text{ SF}) \times (0.40) = 320 \text{ SF} \)
- Could expose 160 SF of MT ceiling, OR 320 SF of MT Wall, OR
- If desire to expose 100 SF of MT ceiling in Living Room, determine max. area of MT walls that can be exposed

Credit: AWC
Design Example: Mixing unprotected MT walls & ceilings

\[
\frac{U_t}{U_a} + \frac{U_{tw}}{U_{aw}} \leq 1.0
\]

\[
\frac{100}{160} + \frac{U_{tw}}{320} \leq 1.0
\]

\(U_{tw} = 120\ SF\)

- Can expose 120 SF of MT walls in dwelling unit in combination with exposing 100 SF of MT ceiling

Credit: AWC
Type IV-B Protection vs. Exposed

Credit: AWC
Type IV-B Protection vs. Exposed

Credit: AWC
Horizontal separation of unprotected areas:

• Unprotected portions of mass timber walls and ceilings shall be not less than 15 feet from unprotected portions of other walls and ceilings, measured horizontally along the ceiling and from other unprotected portions of walls measured horizontally along the floor.
Type IV-B Protection vs. Exposed

Credit: AWC
Type IV-A

18 STORIES
BUILDING HEIGHT 270'
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000SF

Credit: Susan Jones, atelierjones

Photos: Structurlam, naturally:wood, Fast + Epp, Urban One
Type IV-A Protection vs. Exposed

100% NC protection on all surfaces of Mass Timber

Credit: Susan Jones, atelierjones
602.4 Type IV. Type IV construction is that type of construction in which the building elements are mass timber or noncombustible materials and have fire resistance ratings in accordance with Table 601. Mass timber elements shall meet the fire resistance rating requirements of this section based on either the fire resistance rating of the noncombustible protection, the mass timber, or a combination of both and shall be determined in accordance with Section 703.2 or 703.3. The minimum dimensions and permitted materials for building elements shall comply with the provisions of this section and Section 2304.11. Mass timber exterior load-bearing walls and nonload-bearing walls shall be mass timber construction, or shall be of noncombustible construction.

**Exception:** Type IV-HT Construction in accordance with Section 602.4.4.

The interior building elements, including nonload-bearing walls and partitions, shall be of mass timber construction or of noncombustible construction.

**Exception:** Type IV-HT Construction in accordance with Section 602.4.4.
Building Elements in Type IV Construction

Minimum sizes for existing Type IV (now IV-HT) apply to the new Type IV-A, IV-B and IV-C.

See
IBC 2018 2304.11
IBC 2015 602.4
# Tall Wood Fire Resistance Ratings (FRR)

## FRR Requirements for Tall Mass Timber Structures (hours)

<table>
<thead>
<tr>
<th>Building Element</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Frame</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Bearing Walls</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Interior Bearing Walls</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Roof Construction</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Primary Frame at Roof</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Floor Construction</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: 2021 IBC Table 601
Required Noncombustible Contribution to FRR

<table>
<thead>
<tr>
<th>FRR of Building Element (hours)</th>
<th>Minimum from Noncombustible Protection (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3 or more</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: 2021 IBC Section 722.7
# Noncombustible Protection (NC)

**Noncombustible Protection Required**

<table>
<thead>
<tr>
<th>Category</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof below Mass Timber</td>
<td>60 min</td>
<td>40 min*</td>
<td>Not Req.</td>
<td>Not Req.</td>
</tr>
<tr>
<td>Primary Frame @ Roof</td>
<td>80 min</td>
<td>40 min*</td>
<td>Not Req.</td>
<td>Not Req.</td>
</tr>
<tr>
<td>Primary Frame</td>
<td>120 min</td>
<td>80 min*</td>
<td>Not Req.</td>
<td>Not Req.</td>
</tr>
<tr>
<td>Below Mass Timber Floor</td>
<td>80 min</td>
<td>80 min*</td>
<td>Not Req.</td>
<td>Not Req.</td>
</tr>
<tr>
<td>Above Mass Timber Floor</td>
<td>1” Min NC Material</td>
<td>1” Min NC Material</td>
<td>Not Req.</td>
<td>Not Req.</td>
</tr>
</tbody>
</table>

Requirements Per new 602.4. * Some MT permitted to be exposed.
Noncombustible Protection (NC)

Prescriptive Noncombustible Contributions to FRR

<table>
<thead>
<tr>
<th>Type of Protection</th>
<th>Contribution per Layer (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot; Type X gypsum board</td>
<td>25</td>
</tr>
<tr>
<td>5/8&quot; Type X gypsum board</td>
<td>40</td>
</tr>
</tbody>
</table>

Source: 2021 IBC Section 722.7.1

Required Noncombustible Contribution to FRR

<table>
<thead>
<tr>
<th>FRR of Building Element (hours)</th>
<th>Minimum from Noncombustible Protection (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3 or more</td>
<td>120</td>
</tr>
</tbody>
</table>

1 layer 5/8 Type X
2 layers 5/8 Type X
3 layers 5/8 Type X

Source: 2021 IBC Section 722.7
In Type IV-A and IV-B, the floor assembly shall contain a noncombustible material not less than one inch in thickness above the mass timber.
Type IV-A Fire Resistance Ratings (FRR)

FRR Examples:

Primary Structural Frame (Beam, Column, Bearing Wall):

3 HR Required

NC protection = at least 120 min

• Use 3 layers of 5/8” type X Gypsum = 120 min (2 HR)
  Mass Timber FRR req’d = 3 HR – 2 HR = 1 HR
Type IV-A Fire Resistance Ratings (FRR)

FRR Examples:

Floor Panels:

2 HR Required
NC Protection = at least 80 min

- Use 2 layers of 5/8” type X Gypsum = 80 min (1.33 HR),
  plus:
  - Mass Timber FRR req’d = 2 HR – 1.33 HR = 0.67 HR,
  or
- Use 3 layers of 5/8” Type X Gypsum = 120 min (2 HR) and no FRR from MT req’d
Type IV-A Fire Resistance Ratings (FRR)

Primary Frame (3-hr) + Floor Panel Example (2-hr):

- Minimum 1" noncombustible material
- Mass timber floor panel
- 40 minutes of MT FRR
- Two layers 5/8" Type X gypsum
- Glulam beam (primary structural frame)
- 60 minutes of MT FRR
- Three layers 5/8" Type X gypsum
Type IV-B Fire Resistance Ratings (FRR)

Primary Frame (2-hr) + Floor Panel (2-hr)

Minimum 1" noncombustible material

Mass timber floor panel

40 minutes of MT FRR

2 layers 5/8" Type X gypsum

Glulam beam (primary structural frame)

40 minutes of MT FRR

Two layers 5/8" Type X gypsum
Type IV-B Fire Resistance Ratings (FRR)

Primary Frame (2-hr) + Floor Panel Example (2-hr)

Minimum 1" noncombustible material

Mass timber floor panel

2-hr of MT FRR; noncombustible material not required

Glulam beam (primary structural frame)

2-hr of MT FRR; noncombustible material not required
Primary Frame (2-hr) + Floor Panel Example (2-hr)

Noncombustible material not required

Mass timber floor panel

2-hr of MT FRR; noncombustible material not required

Glulam beam (primary structural frame)

2-hr of MT FRR; Noncombustible material not required
**MT Fire Resistance Ratings (FRR)**

IBC 722.7

The fire resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element (MT) added to the protection time of the noncombustible (NC) protection.

Credit: Urban One
MT Fire Resistance Ratings (FRR)

How do you determine FRR of MT?
2 Options:
1. Calculations in Accordance with IBC 722 → NDS Chapter 16
2. Tests in Accordance with ASTM E119

Credit: Urban One

Credit: US CLT Handbook
MT Fire Resistance Ratings (FRR)

NDS Chapter 16 includes calculation of fire resistance of NLT, CLT, Glulam, Solid Sawn and SCL wood products

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

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr.)</th>
<th>Effective Char Depths, $a_{\text{char}}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lamination thicknesses, $h_{\text{lam}}$ (in.)</td>
</tr>
<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>

Credit: FPInnovations
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.
MT Fire Resistance Ratings (FRR)

Structural capacity check performed on remaining section, with stress increases

Solid Sawn, Glulam, SCL

CLT

Effective Char Depth

Credit: Forest Products Laboratory
MT Fire Resistance Ratings (FRR)

Inventory of Fire Tested MT Assemblies

<table>
<thead>
<tr>
<th>Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLT Panel</strong></td>
</tr>
<tr>
<td>3-ply CLT (114mm, 4.49 in)</td>
</tr>
<tr>
<td>3-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>3-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>3-ply CLT (175mm, 6.89&quot;)</td>
</tr>
<tr>
<td>3-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>3-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
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<tr>
<td>3-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>5-ply CLT (175mm, 6.89&quot;)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>7-ply CLT (243mm, 9.56&quot;)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
<tr>
<td>5-ply CLT (155mm, 6.13 in)</td>
</tr>
</tbody>
</table>

Credit: WoodWorks
MT Fire Resistance Ratings (FRR)

Mass Timber Fire Design Resource
- Code compliance options for demonstrating FRR
- Updated as new tests are completed
- Free download at woodworks.org

Credit: WoodWorks
Concealed Spaces in Type IV

What if I have a dropped ceiling? Can I have a dropped ceiling?
• Impact on FRR, NC placement, sprinkler requirements
Concealed Spaces in Type IV

Previous Type IV (now IV-HT) provisions prohibited concealed spaces

Credit: IBC
CONCEALED SPACES: TYPE IV-HT

Option 1:

- Sprinklers in concealed spaces
- Dropped ceiling
CONCEALED SPACES: TYPE IV-HT

Option 2:

- Noncombustible insulation
- Dropped ceiling
CONCEALED SPACES: TYPE IV-HT

Option 3:

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

Dropped ceiling
Concealed Spaces in Type IV-A, IV-B

**Without Dropped Ceiling**

- Minimum 1" noncombustible material
- Mass timber floor panel
- Two layers 5/8" Type X gypsum*

*Applicable to most locations; limited exposed mass timber permitted in IV-B

**With Dropped Ceiling**

- Minimum 1" noncombustible material
- Mass timber floor panel
- Two layers 5/8" Type X gypsum
- Dropped ceiling
Concealed Spaces in Type IV-A, IV-B

**Without Dropped Ceiling**

Noncombustible material not required

Mass timber floor panel

Noncombustible material not required

**With Dropped Ceiling**

Noncombustible material not required

Mass timber floor panel

One layer 5/8" Type X gypsum covering all mass timber surfaces within concealed space

Dropped ceiling
Tall Wood Shaft Enclosures

• When can shaft enclosures be MT?
• What FRR requirements exist?
• If shaft enclosure is MT, is NC req’d?
Tall Wood Shaft Enclosures

Exit & Hoistway Enclosures

E&H Enclosures FRR

<table>
<thead>
<tr>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 12 Stories or 180 ft: MT protected with 2 layers 5/8” type X gyp (if 2 HR req’d) or 3 layers 5/8” type X gyp (if 3 HR req’d) both sides</td>
<td>NC or MT protected with 2 layers 5/8” type X gyp (IBC 2021 602.4.2.6) both sides</td>
<td>NC or MT protected with 1 layer 5/8” type X gyp (IBC 602.4.3.6) both sides</td>
</tr>
</tbody>
</table>

Above 12 Stories or 180 ft: Noncombustible shafts (IBC 2021 602.4)

2 HR (not less than FRR of floor assembly penetrated, IBC 713.4)
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
Acoustical Criteria
IBC 1207

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>
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
Acoustical Detailing

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

1. Add Mass
2. Add noise barriers
3. Add decouplers
Acoustical Detailing

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

1. Add Mass
2. Add noise barriers
3. Add decouplers
What does this look like in typical wood-frame construction:

1. Add Mass
2. Add noise barriers
3. Add decouplers
What does this look like in typical wood-frame construction:

1. Add Mass
2. Add noise barriers
3. Add decouplers
Mass Timber: Structure Often is Finish

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman | Architect: PATH Architecture
But by Itself, Not Adequate for Acoustics
# Mass Timber Acoustics

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

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

*Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks*
One of the main reasons is “mass”
Recall the three ways to increase acoustical performance:

1. Add Mass
2. Add noise barriers
3. Add decouplers
Concrete Slab:
6” Thick
80 PSF
STC 53

CLT Slab:
6-7/8” Thick
18 PSF
STC 41
There are three main ways to improve an assembly’s acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
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”+
Mass Timber Acoustics

Acoustical floor underlayments

Photo: AcoustiTECH™

Photo: Kinetics Noise Control, Inc.

Photo: Maxxon Corporation

Photo: Pilteq Inc.
Mass Timber Acoustics

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

Image credit: AcoustiTECH
Where can you find acoustically tested assemblies?

CLT Floors in CLT Handbook

<table>
<thead>
<tr>
<th>End view of cross-section</th>
<th>Floor detail</th>
<th>FSTC</th>
<th>FIIC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Carpet, or floating flooring about 2/5&quot; on 1/8&quot; resilient underlayment of 0.16 to 0.37 lb./ft.²</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 = At least 5.12 lb./ft.² dry topping, e.g. 0.8-1&quot; gypsum board, cement fibreboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 = Resilient underlayment, e.g. 2/5&quot; rubber mat of 0.84 lb./ft.², ¾&quot; texture felt of 0.27 lb./ft.², ½&quot; low density wood fibreboard of 0.73lb./ft.²</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 = 5-layer CLT of 6-7/8&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Replace the dry topping by wet topping, e.g. 1.5&quot; concrete of at least 15.6 lb./ft.²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mass Timber Acoustics
Mass Timber Acoustics

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

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

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

Mass Timber Assembly Options: Walls by Minimizing Flanking

Example Mass Timber Wall Assembly, STC 50

Acoustical Differences between Mass Timber Panel Options

Inventory of Tested Assemblies

Acoustically-Tested Mass Timber Assemblies

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

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<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$^1$</th>
<th>Source</th>
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<tr>
<td></td>
<td>Maxxon Acousti-Mat* 3/4</td>
<td>LVT on Acousti-Top®</td>
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<td>49$^2$</td>
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<td>CLT 5-ply (6.875&quot;)</td>
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<td>49$^3$</td>
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<td>45$^3$</td>
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</table>

A Few Notes About the Inventory

MT Acoustics Inventory

<table>
<thead>
<tr>
<th>Material</th>
<th>STC(^1)</th>
<th>IIC(^1)</th>
<th>Source</th>
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<tr>
<td>Concrete/Gypsum Topping</td>
<td>47(^2) ASTC</td>
<td>47(^2) AIC</td>
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<tr>
<td>CLT Panel</td>
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<td>49(^2) AIC</td>
<td></td>
</tr>
<tr>
<td>Acoustical Mat Product</td>
<td>-</td>
<td>75(^2) AIC</td>
<td></td>
</tr>
<tr>
<td>No direct applied or hung ceiling</td>
<td>-</td>
<td>52(^2) AIC</td>
<td></td>
</tr>
<tr>
<td>Finish Floor if Applicable</td>
<td>-</td>
<td>51(^2) AIC</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Notes:

1. All STC tests performed in accordance with ASTM E 90 unless otherwise noted below. All IIC tests performed in accordance with ASTM E 492 unless otherwise noted below. See end of document for sources and referenced test reports.
2. ASTC field tests performed in accordance with ASTM E 336. AIC field tests performed in accordance with ASTM E 1007.
3. IIC tests not performed in accordance with a singular test standard. Test measurement method used a combination of ASTM E492 and ASTM 1007 per acoustical mat product manufacturer.
4. FSTC field test performed in accordance with ASTM E 336. AIC field test not performed in accordance with ASTM E 1007 (inadequate number of measurements).
5. STC and IIC noted is a prediction based on the ISO 15712-1 prediction method as noted in the referenced test report.
6. STC and IIC noted is based on floor zone testing procedures that are modifications of ASTM E90 and E492 test and do not fully conform with these test standards per acoustical mat product manufacturer and as noted in the referenced test report.
7. Actual thickness of CLT in this test was 6.3” (160 mm)
8. Assemblies included in the 1st edition of the CLT Handbook are included herein due to their legacy use. However, the testing standards used for these assemblies are European and direct correlation to IBC-referenced ASTM standards is not currently available.
9. STC and IIC noted is based on the ISO 12354 model as noted in the referenced manufacturer’s literature.
1206.2 Airborne sound. Walls, partitions and floor-ceiling assemblies separating *dwelling units* and *sleeping units* from each other or from public or service areas shall have a sound transmission class of not less than 50, or not less than 45 if field tested, for airborne noise where tested in accordance with ASTM E90. Alternatively, the sound transmission class of walls, partitions and floor-ceiling assemblies shall be established by engineering analysis based on a comparison of walls, partitions and floor-ceiling assemblies having sound transmission class ratings as determined by the test procedures set forth in ASTM E90. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. This requirement shall not apply to entrance doors; however, such doors shall be tight fitting to the frame and sill.
1206.3 Structure-borne sound. Floor-ceiling assemblies between *dwelling units* and *sleeping units* or between a *dwelling unit* or *sleeping unit* and a public or service area within the structure shall have an impact insulation class rating of not less than 50, or not less than 45 if field tested, where tested in accordance with ASTM E492. Alternatively, the impact insulation class of floor-ceiling assemblies shall be established by engineering analysis based on a comparison of floor-ceiling assemblies having impact insulation class ratings as determined by the test procedures in ASTM E492.
MT Acoustics Inventory

86 Tested 5-Ply (6.875”) CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed
5-Ply (6.875”) CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed

86 Tests Completed. Of these:
- 32 Have STC & IIC 50 or greater
- 7 Have STC & IIC 55 or greater
Topping Thickness Effect on 5-Ply (6.875”) CLT Floor Assemblies

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

32 Have STC & IIC 50 or greater
7 Include 1.5” Gypsum Topping
10 Include 2” Gypsum Topping
6 Include 2.5” Gypsum Topping
1 Includes 3” Concrete Topping
8 Include 4” Concrete Topping
MT Acoustics Inventory

Topping Thickness Effect on 5-Ply (6.875”) CLT Floor Assemblies

1. Includes 4” Concrete Topping
2. Include 2.5” Gypsum Topping
3. No direct applied or hung ceiling

- 7 Have STC & IIC 55 or greater

- 6 Include 2.5” Gypsum Topping
- 1 Includes 4” Concrete Topping
Tall Timber Assemblies

1” Bare Gypsum (no finish floor)

Without Dropped Ceiling
- Minimum 1” noncombustible material
- Mass timber floor panel

With Dropped Ceiling
- Minimum 1” noncombustible material
- Mass timber floor panel
- Two layers 5/8” Type X gypsum

*Applicable to most locations; limited exposed mass timber permitted in IV-B

STC 50
IIC 40

STC 52
IIC 46

STC 63
IIC 60
**LVT on 1” Gypsum**

**Without Dropped Ceiling**

- Minimum 1” noncombustible material
- Mass timber floor panel

- Two layers 5/8” Type X gypsum

*Applicable to most locations; limited exposed mass timber permitted in IV-B

**With Dropped Ceiling**

- Minimum 1” noncombustible material
- Mass timber floor panel
- Two layers 5/8” Type X gypsum

- Dropped ceiling

**Tall Timber Assemblies**

**STC 51**

**IIC 43**

**STC 52**

**IIC 48**

**STC 63**

**IIC 63**
Without Dropped Ceiling

Minimum 1” noncombustible material
Mass timber floor panel
Two layers 5/8” Type X gypsum*

With Dropped Ceiling

Minimum 1” noncombustible material
Mass timber floor panel
Two layers 5/8” Type X gypsum
Dropped ceiling

*Applicable to most locations; limited exposed mass timber permitted in IV-B

Eng. Wood on 1” Gypsum

Tall Timber Assemblies

NA

STC 52
IIC 47

STC 64
IIC 62
CONNECTIONS IN TALL WOOD

Photo: Structurlam
In Construction Types IV-A, IV-B & IV-C, building elements are required to be FRR as specified in IBC Tables 601 and 602. Connections between these building elements must be able to maintain FRR no less than that required of the connected members.

16.3 Wood Connections

Wood connections, including connectors, fasteners, and portions of wood members included in the connection design, shall be protected from fire exposure for the required fire resistance time. Protection shall be provided by wood, fire-rated gypsum board, other approved materials, or a combination thereof.

Source: NDS
Connection Fire Protection

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

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

## Fire Test Results

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

Issue | June 5, 2017

Full Report Available at:
https://www.thinkwood.com/wp-content/uploads/2018/01/reThink-Wood-
Arup-SLB-Connection-Fire-Testing-Summary-web.pdf
PENETRATIONS IN TALL WOOD
Penetration Fire Protection

Although not a new code requirement or specific to tall wood, more testing & information is becoming available on firestopping of penetrations through MT assemblies.

Photos: AWC/FPInnovations
Penetration Fire Protection

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

Photos: AWC/FPInovations/Hilti
Penetration Fire Protection

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 1, Christian Dagenais 1, Conroy Lum 1, Tony Thomas 1

ABSTRACT: Integrity and continuity must be maintained for fire separations required to provide fire prevention passage of hot gases or increased temperature on the unexposed side. Vulnerable locations where are 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 1-hour fire resistance. There were some systems that were able to achieve 2-hour fire resistance.

KEYWORDS: Firestop, through-penetration, fire rated door, mass timber, cross-laminated timber, 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 approach involves the use of mass timber as an alternative construction, as well as in several after building designs.

Although the general fire performance is well documented, there are still several areas that need further investigation to ensure safety levels are met and a number of them are available for designers to use. Generating testing for generic assemblies will reduce the need to correlate on an individual construction.
## Penetration Fire Protection

### Inventory of Fire Tested Penetrations in MT Assemblies

| Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies |
|-----------------------------------|-------------------------------|-----------------------------|---------|------------------|------------------|
| CLT Panel                        | Exposed Side Protection       | Penetration Item            | Penetrated Center of Object in Hole | Firestopping System Description | F Rating | T Rating | Standard Test Protocol | Source | Testing Lab |
|-----------------------------------|-------------------------------|-----------------------------|---------|------------------|------------------|
| 3-ply (7mm3.07”)                  | None                          | 1.5” diameter data cable bunch | Cenetered | 5.5 in diameter hole. Mineral wool was installed in the 1.5 in. small space around the data cables so the total depth of approximately 2 – 5/8 in. The remaining 1.5 in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 1 hour | 0.5 hour | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 3-ply (7mm3.07”)                  | None                          | 2” copper pipe             | Cenetered | 4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 2 – 5/8 in. The remaining 1.5 in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 1 hour | N.A. | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 3-ply (7mm3.07”)                  | None                          | 2.5” sch 40 pipe           | Cenetered | 4.82 in diameter hole. Pipe wrap was installed around the sch 40 pipe to a total depth of approximately 2 – 5/8 in. The remaining 1.5 in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 1 hour | N.A. | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 3-ply (7mm3.07”)                  | None                          | 6” cast iron pipe          | Cenetered | 5.35 in diameter hole. Mineral wool was installed in the 1.5 in. annular space around the cast iron pipe to a total depth of approximately 2 – 5/8 in. The remaining 1.5 in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 1 hour | N.A. | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 3-ply (7mm3.07”)                  | None                          | Hilti 6" drop in device System No: E-B-2049 | Cenetered | 9.81” 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 – 5/8 in. The remaining 3 in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 1 hour | 0.75 hour | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | 1.5” diameter data cable bunch | Cenetered | 3.5” diameter hole. Mineral wool was installed in the 1 in. annular space around the data cables so the total depth of approximately 4 – 5/32 in. The remaining 3 in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 2 hours | 1.5 hours | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | 2” copper pipe             | Cenetered | 4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 4 – 5/32 in. The remaining 3 in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 2 hours | N.A. | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | 2.5” sch 40 pipe           | Cenetered | 4.92 in diameter hole. Pipe wrap was installed around the sch 40 pipe to a total depth of approximately 4 – 5/32 in. The remaining 3 in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 2 hours | 0.5 hour | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | 6” cast iron pipe          | Cenetered | 5.35 in diameter hole. Mineral wool was installed in the 1.5 in. annular space around the cast iron pipe to a total depth of approximately 4 – 5/32 in. The remaining 3 in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 2 hours | N.A. | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | Hilti 6” drop in device System No: E-B-2049 | Cenetered | 9.81” 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 – 5/8 in. The remaining 3 in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking. | 2 hours | 1.5 hours | CANULC SI 15 26 | Inертак | March 30, 2016 |
| 5-ply CLT (131mm 5.16”)           | None                          | 1” nominal PVC pipe        | Cenetered | 4.21 in diameter hole. 2” x 4” in plywood reducer flush with the top of the slab reducing the opening to 2 1/2 in. Two wraps of Hilti CP-445 E 4W/3/1/4” Flexy wrap strip at two locations with a 50 gauge steel sleeve which extended from the top of the slab to 1 in. below the slab. The first location was at the bottom of the wrap strip flush with the bottom of the steel sleeve and the second was with the bottom of the wrap strip 1 in. from the bottom of the slab. The void between the steel sleeve and the CLT and between the steel sleeve and pipe was filled with Recol Silicofine mineral wool leaving a 3/4 in. deep void at the top of the assembly. Hilti FS-One Max intumescent Firestop Sealant was applied to depth of 3/4 in. on the top of the assembly between the plywood and steel sleeve as well as the steel sleeve and pipe. | 2 hours | 2 hours | ASTM E 814 24 | QAI Laboratories | March 3, 2017 |
Tall Wood Buildings in the 2021 IBC
Up to 18 Stories of Mass Timber

In January 2019, the International Code Council (ICC) approved a set of proposals to allow tall wood buildings as part of the 2021 International Building Code (IBC). Based on these proposals, the 2021 IBC will include three new construction types — Type IV-A, IV-B, and IV-C — allowing the use of mass timber or non-combustible materials. These new types are based on the previous Heavy Timber construction type (renamed Type IV-HT) but with additional fire-resistance ratings and levels of required noncombustible protection. The code will include provisions for up to 18 stories of Type IV-A construction for business and residential occupancies.

Based on information first published in the Structural Engineers Association of California (SEACO) 2018 Conference Proceedings, this paper summarizes the background to these proposals, technical research that supported their adoption, and resulting changes to the IBC and product-specific standards.

Background: ICC Tall Wood Building Ad Hoc Committee

Over the past 10 years, there has been a growing interest in tall buildings constructed from mass timber materials (Brennerman 2013, Timmers 2015). Around the world there

WoodWorks Tall Wood Design Resources
Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures

Changes to the 2021 International Building Code (IBC) have created opportunities for wood buildings that are much larger and taller than prescriptively allowed in past versions of the code. Occupant safety, and the need to ensure fire performance in particular, was a fundamental consideration as the changes were developed and approved. The result is three new construction types—Type IV-A, IV-B and IV-C—which are based on the previous Heavy Timber construction type (renamed Type IV-HT), but with additional fire protection requirements.

One of the main ways to demonstrate that a building will meet the required level of passive fire protection, regardless of structural materials, is through hourly fire-resistance ratings (FRRs) of its elements and assemblies. The IBC defines an FRR as the period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests, or the methods based on tests, prescribed in Section 703.

FRRs for the new construction types are similar to those required for Type I construction, which is primarily steel and concrete. (See Table 1.) They are found in IBC Table 601, which includes FRR requirements for all construction types and building elements; however, other code sections should be checked for overriding provisions e.g., occupancy separation, shaft enclosures, etc. that may alter the requirement.

<table>
<thead>
<tr>
<th>Table 1: FRR Requirements (Hours) for Tall Mass Timber Construction Types and Existing Type I</th>
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<tr>
<td>Building Element</td>
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<tr>
<td>------------------</td>
</tr>
<tr>
<td>Unlimited stories, Max. 10 stories, Max. 12 stories, Max. 32 stories, Max. 32 stories</td>
</tr>
<tr>
<td>Wall</td>
</tr>
<tr>
<td>Column</td>
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<tr>
<td>Beam</td>
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Shaft Wall Requirements in Tall Mass Timber Buildings

The 2021 International Building Code (IBC) introduced three new construction types—Type IV-A, IV-B and IV-C—which allow tall mass timber buildings. For details on the new types and their requirements, see the WoodWorks paper, Tall Wood Buildings in the 2021 IBC—Up to 18 Stories of Mass Timber.

This paper builds on that document with an in-depth look at the requirements for shaft walls, including when and where wood can be used.

Shaft Enclosure Requirements in the 2021 IBC

A shaft is defined in Section 202 of the 2021 IBC as "an enclosed space extending through one or more stories of a building, connecting vertical openings in successive floors, or floors and roof." Therefore, shaft enclosure requirements apply to stairs, elevators, and mechanical/electrical/plumbing (MEP) chases in multi-story buildings. While these applications may be similar in their fire design requirements, they tend to differ in terms of their assemblies, detailing, and construction constraints.

Shaft enclosures are specifically addressed in IBC Section 713. However, because shaft enclosure walls must be constructed as fire barriers per Section 713.2, many shaft wall requirements reference provisions for fire barriers found in Section 707.

Allowable Shaft Wall Materials

Provisions addressing materials permitted in shaft walls are relatively new. Wood products, mass timber can...
What is the current status of tall mass timber buildings in the building code?

Status as of January 1, 2020:

The first of two groups of proposed code changes regarding tall mass timber buildings has been approved for the 2021 International Building Code (IBC). The review and voting process for the second group of changes is underway and will be completed in the fall of 2019. Oregon has preemptively approved the first group of changes through a Statewide Alternative Method, allowing tall wood buildings today, and Washington will formalize similar prescriptive allowances in early July. Other jurisdictions are considering tall wood buildings through Alternate Methods and Materials Requests and/or allowing design teams to look ahead to the already-approved tall mass timber code language of the 2021 IBC, even though that version of the code has yet to be adopted in their jurisdiction.

Following is a more detailed summary of where things stand and how we arrived at this point:

The IBC is the model building code adopted in whole and/or with local amendments by most states and jurisdictions in the U.S. It is updated every three years to reflect advancements in products and technology while giving time to ensure that new additions provide adequate fire and life safety and structural performance and are fully vetted through a hearing, public comment and voting process. The current version is the 2018 IBC, and the 2021 IBC will be published in the fall of 2020.

In 2015, the board of the International Code Council (ICC), developer of the IBC, created the Ad Hoc Committee on Tall Wood Buildings (AHC-TWB) to assess the science behind mass timber high-rises and, if appropriate, propose changes to the code. After considerable review, the committee proposed two groups of changes—Group A and Group B—which are being reviewed and voted on annually. The committee is led by Forest Products Labs.
QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course.

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