Part 4: Principles of Fire Resistance Design, Protection of Connections and Special Inspections

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Description

Changes to the 2021 International Building Code allow for construction of mass timber buildings with larger heights and areas than is currently permitted in Types III, IV, and V construction. This presentation will provide an overview of fire design of mass timber building elements and assemblies, and protection of connections. New code provisions for special inspection of tall mass timber structures will also be discussed. Additional options for acoustics and energy performance will be presented.

Learning Objectives

• Understand principles of fire design provisions for mass timber building elements and assemblies for new construction Types IV-A, IV-B, and IV-C.
• Learn how to design fire protection for mass timber connections.
• Recognize new code provisions for special inspection of tall mass timber structures.
• Evaluate options for acoustics and energy performance.
Mass Timber Series

- **Module 1** Introduction to Mass Timber Products
- **Module 2** What’s New in 2015/2018 IBC for Mass Timber Construction?
- **Modules 3-6** Tall Mass Timber Construction per 2021 IBC
  - **Module 3** Part 1: Background and Overview
  - **Module 4** Part 2: Heights & Areas and Construction Fire Safety
  - **Module 5** Part 3: Fire Safety
  - **Module 6** Part 4: Fire and Connection Design and Special Inspection

Outline

- Principles of Fire-resistance Design for New Construction Types IV-A, IV-B, and IV-C
- Design of Fire Protection for Mass Timber Connections
- Special Inspection of Tall Mass Timber Structures
- Acoustics and Energy Performance
Mass Timber Fire-Resistance Design

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

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary structural frame \textsuperscript{f} (see Section 202)</td>
<td>A\textsuperscript{0} B 2a 2a 0 0 0 0 2a 2a</td>
<td>A 0 0 0 2 1b 2a 2b 1b 2b</td>
<td>A 0 0 0 2 1b 2a 2b 1b 2b</td>
<td>A 0 0 0 2 1b 2a 2b 1b 2b</td>
<td>HT 1b 0 0 0 1b 0 0 1b 0</td>
</tr>
<tr>
<td>Bearing walls</td>
<td>3 3a 1 1 0 0 1 1</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>1/HTg 1 1 0 0 1b 0 0 1b 0</td>
</tr>
<tr>
<td>Exterior \textsuperscript{g}</td>
<td>3 3a 1 1 0 0 1 1</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>1/HTg 1 1 0 0 1b 0 0 1b 0</td>
</tr>
<tr>
<td>Interior</td>
<td>3 3a 1 1 0 0 1 1</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>3 2 2 2 1 1 0 1 0</td>
<td>1/HTg 1 1 0 0 1b 0 0 1b 0</td>
</tr>
<tr>
<td>Nonbearing walls and partitions – Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions – Interior \textsuperscript{d}</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td>See Section 2304.11.2 0 0</td>
</tr>
<tr>
<td>Floor construction and associated secondary structural members (see Section 202)</td>
<td>2 2 1 1 0 1 0</td>
<td>2 2 1 1 0 1 0</td>
<td>2 2 1 1 0 1 0</td>
<td>2 2 1 1 0 1 0</td>
<td>HT 1 1 0 0 1b 0 0 1b 0</td>
</tr>
<tr>
<td>Roof construction and associated secondary structural members (see Section 202)</td>
<td>1 3a 1 1 0 0 1 1</td>
<td>1 3a 1 1 0 0 1 1</td>
<td>1 3a 1 1 0 0 1 1</td>
<td>1 3a 1 1 0 0 1 1</td>
<td>HT 1 1 0 0 1b 0 0 1b 0</td>
</tr>
</tbody>
</table>

Mass Timber Fire-Resistance Design

Noncombustible

(703.5)

≠

Fire-resistant

(703.2 and 703.3)
Mass Timber Fire-Resistance Design

Heavy timber inherent fire resistance

minimum prescriptive dimensions

Noncombustible Time Contribution

703.1 Fire-resistance rating of mass timber. The required fire resistance of mass timber elements in Section 602.4 shall be determined in accordance with Section 703.2 or Section 703.3. The fire resistance rating of building elements shall be as required in Tables 601 and 602 and as specified elsewhere in this code. The fire-resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element added to the protection time of the noncombustible protection.
Noncombustible Time Contribution

Prescriptive Method

TABLE 722.7.1(1)
PROTECTION REQUIRED FROM NONCOMBUSTIBLE COVERING MATERIAL

<table>
<thead>
<tr>
<th>Required Fire-Resistance Rating of Building Element per Tables 601 and 705.5 (hours)</th>
<th>Minimum Protection Required 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>

TABLE 722.7.1(2)
PROTECTION PROVIDED BY NONCOMBUSTIBLE COVERING MATERIAL

<table>
<thead>
<tr>
<th>Noncombustible Protection</th>
<th>Protection Contribution (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 inch Type X Gypsum Board</td>
<td>25</td>
</tr>
<tr>
<td>1 inch Type X Gypsum Board</td>
<td>40</td>
</tr>
</tbody>
</table>

Mass Timber Fire-Resistance Design

Methods for establishing fire resistance (703)

1. Tested fire assembly (ASTM E119 or UL 263)
2. Fire-resistance designs documented in approved sources
3. Prescriptive assemblies using fire-resistance rated designs in Section 721
4. **Calculation of fire-resistance per Section 722**
5. Engineering analysis based on a comparison of building element, component or assembly designs that have been tested
6. Alternative protection methods per Section 104.11
7. Fire-resistance designs certified by an approved agency
Mass Timber Fire-Resistance Design

SECTION 722
CALCULATED FIRE RESISTANCE

722.1 General. The provisions of this section contain procedures by which the fire resistance of specific materials or combinations of materials is established by calculations. These procedures apply only to the information contained in this section and shall not be otherwise used. 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).
Mass Timber Fire-Resistance Design

NDS Section 16.2

- Fire design up to 2 hours
- Beams, columns, walls, floors/roofs

Products
- Sawn lumber
- Glulam (softwood)
- LVL
- PSL
- LSL
- CLT

Mass Timber and the IBC

Mass Timber Fire-Resistance Design

AWC Technical Report 10

- NDS Chapter 16 basis
  - Background
  - Commentary
  - Examples

Mass Timber and the IBC
Mass Timber Fire-Resistance Design

Wood at high temperature

- Low thermal conductivity
- Dimensionally stable
- Predictable char rate
- Inner portion remains cool
  - Does not lose strength
Mass Timber Fire-Resistance Design

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>1$\frac{1}{2}$-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>
Mass Timber Fire-Resistance Design

CLT: modified char depth model

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

<table>
<thead>
<tr>
<th>Required Fire Resistance (hr.)</th>
<th>Effective Char Depths, a_{eff} (in.) lamination thicknesses, h_{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>
Mass Timber Fire-Resistance Design

Determination of effective CLT residual cross-section

- Assume 5-layers @ 1.5” (total thickness is 7.5”)
- Determine thickness for 1-hr fire-resistance rating
- \( a_{\text{eff}} = 1.8” \) (NDS Table 16.2.1B)
- \( d = 7.5” - 1.8” = 5.7” \)
- Could conservatively assume 3-layer panel for design

Mass Timber Fire-Resistance Design

- Fire-resistance of exposed mass timber
  - Cross-sectional dimensions
  - Load ratio
Mass Timber Fire-Resistance Design

- Fire-resistance of protected mass timber
  - Cross-sectional dimensions
  - Load ratio
- plus -
  - Noncombustible protection

Mass Timber and Fire-Resistance Design

Mass Timber and the IBC

Waugh Thistleton Architects
(Stradthaus – Murry Grove)
Mass Timber Fire-Resistance Design

Nail-Laminated Timber (NLT)

- NDS 16.2.5. Timber Decks
- \( \geq 2" \) thick (actual)
- Clear-span between supports
- Assembly of wood beams
  - Exposed partially on sides
  - Exposed fully on one face
  - Char rate on sides reduced to 33% of effective char rate
  - Does not address thermal separation
  - Typically requires one layer of Type X gypsum
Glulam - Engineered Layups

Unbalanced Simple Spans
- No. 2D
- No. 2
- No. 3
- No. 2
- No. 1
- TL

Balanced Continuous Spans or Cantilevered
- TL
- No. 1
- No. 2
- No. 3
- No. 2
- No. 1
- TL

TL = Tension Lamination

Mass Timber and the IBC

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Glulam - Unbalanced Layup

- 2 - L2 Dense Grade Outer Compression Lams
- 1 - L2 Grade Inner Compression Lam
- 6 - L3 Grade Core Lams
- 1 - L2 Grade Inner Tension Lam
- 1 - L1 Grade Outer Tension Lams
- 1 - 302-24 Outer Tension Lams

- For 1-hr fire-rated beam
  - Substitute additional tension lam for core lam
- For 1-1/2 or 2-hr fire-rated beam
  - Substitute 2 additional tension lams for core lams

Mass Timber and the IBC
Tension Lams - Unbalanced
3-sided Exposure Only (protected compression side)

Tension Lams - Balanced
3- or 4-Sided Exposure
Outline

- Principles of Fire-resistance Design for New Construction Types IV-A, IV-B, and IV-C
- Design of Fire Protection for Mass Timber Connections
- Special Inspection of Tall Mass Timber Structures
- Acoustics and Energy Performance

Fire-Resistive Connection Protection

2304.10.1 Connection fire-resistance rating.

Fire-resistance ratings for connections in Type IV-A, IV-B or IV-C shall be determined by one of the following:

1. **Testing** in accordance with Section 703.2 where the connection is a 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, and a maximum temperature rise of 325°F, 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.
Fire-Resistive Connection Protection

But we can't test every connection!

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

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

2. Engineering analysis that demonstrates . . .

Where fire resistance is required, connectors and fasteners shall be protected from fire exposure

- Additional wood cover
- Fire-rated gypsum board
- Other approved materials like coatings or insulation (approved for required endurance time)
- OR a combination thereof
Fire-Resistive Connection Protection

**AWC Technical Report 10**

- NDS Chapter 16 basis
  - Protecting connections
    - Background
    - Commentary
    - Examples

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Fire-Resistive Connection Protection

**AWC Technical Report 10**

- Thermal protection (separation)
- Example details
- Common fasteners and connectors

**AWC TR10 Figures**
Fire-Resistive Connection Protection

- Thermal Separation – limit avg temp rise ≤ 250°F
  
- 2-hr Example
  - 3 inches of wood protection
  - $t_p = 60 \left( \frac{3.0}{1.5} \right)^{1.23} = 141 \text{ minutes}$
  
- Wood protecting a connection
- 0.85 x (calculated protection time)
- $0.85 \times t_p = (0.85) 141 \text{ minutes} = 120 \text{ minutes}$

- 1-hr Example
  
- Gypsum Board
  - 0.5 x (NC Protection Time)
  - 5/8” Type X GB = 40 minutes (IBC Table 722.7.2(2))
  - $0.5 \times t_p = (0.5) 40 \text{ minutes} = 20 \text{ minutes}$ NG
Fire-Resistive Connection Protection

- Thermal Separation – limit avg temp rise ≤ 250°F
- Multiple layers of protection
  - Reduction factor only applies to layer adjacent to connection
- 1-hr Example
  - 2 layers of 5/8” Type X GB
    - Layer adjacent to connection = 40 (0.5) = 20 minutes
    - Second layer = 40 minutes
    - Total thermal separation = 40 + 20 = 60 minutes

Fire-Resistive Connection Protection

- Char contraction
  - Abutting edges
  - Char layer < char depth
  - Wedge-shaped gap
  - Additional wood cover protects abutting edges
  - Fasteners attaching cover do not require protection
Fire-Resistive Connection Protection

- Char contraction
  - Abutting edges
  - Char layer < char depth
  - Wedge-shaped gap
- Additional wood cover or blocking to protect abutting edges
- Fasteners attaching cover do not require protection

AWC TR10 Figure 8-3. Char pattern with wood strip added

110.3.5 Type IV-A, IV-B and IV-C connection protection inspection. In buildings of Type IV-A, IV-B and IV-C Construction, where connection fire-resistance ratings are provided by wood cover calculated to meet the requirements of Section 2304.10.1, inspection of the wood cover shall be made after the cover is installed, but before any other coverings or finishes are installed.
Outline

- Principles of Fire-resistance Design for New Construction Types IV-A, IV-B, and IV-C
- Design of Fire Protection for Mass Timber Connections
- Special Inspection of Tall Mass Timber Structures
- Acoustics and Energy Performance

Special Inspection

- New Section 1705.5.3 on Tall Mass Timber Construction
- New Table 1705.5.3
  - Required special inspections for new mass timber construction types
    - IV-A, IV-B & IV-C
- NOT Type IV-HT

Mass Timber and the IBC
**Special Inspection**

**TABLE 1709.5.3**

<table>
<thead>
<tr>
<th>Type</th>
<th>Continuous Special Inspection</th>
<th>Periodic Special Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inspection of anchorage and connections of mass timber construction to timber deep foundation systems.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2. Inspection of mass timber construction</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Inspection of connections where installation methods are required to meet design loads.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.1. Threaded fasteners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.1. Verify use of proper installation equipment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.2. Verify use of pre-drilled holes where required.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.3. Inspect screws, including diameter, length, head type, spacing, installation angle, and depth.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2. Adhesive anchors installed in horizontal or upwardly inclined orientation to resist sustained tension loads</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3.3. Adhesive anchors not defined in 3.2.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3.4. Bolted connections</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3.5. Concealed connections</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Special Inspection**

- Connections for TMT can be designed with common connectors
  - Screws, bolts, etc.
  - Thus, periodic
- Continuous inspection
  - Adhesive anchors under sustained tension
  - Similar to precast
**Special Inspection**

**1705.19 Sealing of mass timber**

Periodic special inspections of sealants or adhesives shall be conducted where sealant or adhesive required by Section 703.9 is applied to mass timber building elements as designated in the approved construction documents.

Sealants shown. Adhesives used likely not visible.

**Special Inspection**

**703.9 Sealing of adjacent mass timber elements...**

- Sealants per ASTM C920
  or
- Adhesives per ASTM D3498

**Exception:** Sealants or adhesives need not be provided where they are not a required component of a tested fire-resistance-rated assembly.
Special Inspection

Fabricated items exempt from on-site special inspection
- IBC 1704.2.5 – fabricator approved via QC/QA and third-party audit
  - CLT
  - SCL
  - Glulam
  - Sawn Timber

Structural Observation

1704.6.1 Structural observations for structures. Structural observations shall be provided for those structures where one or more of the following conditions exist:

1. The structure is classified as Risk Category III or IV.
2. The structure is a high-rise building.
3. The structure is assigned to Seismic Design Category E and is greater than two stories above the grade plane.
4. Such observation is required by the registered design professional responsible for the structural design.
5. Such observation is specifically required by the building official.

Not Specific to Tall Mass Timber

>75’
Fire Dept Access
Outline

- Principles of Fire-resistance Design for New Construction Types IV-A, IV-B, and IV-C
- Design of Fire Protection for Mass Timber Connections
- Special Inspection of Tall Mass Timber Structures
- Acoustics and Energy Performance

Acoustics

- IBC 1206
  - Airborne sound – STC
  - Structure-borne sound – IIC
Acoustics

- Multi-family
  - STC minimum = 50
  - IIC minimum = 50
  - Field-test = 45

Sound Transmission Ratings of Selected 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”</td>
<td>33</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT wall</td>
<td>5 3/4”</td>
<td>38</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT floor</td>
<td>5 1/4”</td>
<td>39</td>
<td>22</td>
</tr>
<tr>
<td>7-ply CLT floor</td>
<td>6 3/4”</td>
<td>41</td>
<td>25</td>
</tr>
<tr>
<td>7-ply CLT floor</td>
<td>9 3/4”</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>2x4 NLT wall</td>
<td>3-1/2” bare NLT</td>
<td>24</td>
<td>N/A</td>
</tr>
<tr>
<td>2x4 NLT wall</td>
<td>3-1/2” with 3/4” plywood</td>
<td>29 with 3/4” plywood</td>
<td>N/A</td>
</tr>
<tr>
<td>2x6 NLT wall</td>
<td>5-1/2” bare NLT</td>
<td>22</td>
<td>N/A</td>
</tr>
<tr>
<td>2x6 NLT wall</td>
<td>5-1/2” with 3/4” plywood</td>
<td>31 with 3/4” plywood</td>
<td>N/A</td>
</tr>
<tr>
<td>2x6 NLT floor + 1/2” plywood</td>
<td>5-1/2” with 1/2” plywood</td>
<td>34</td>
<td>33</td>
</tr>
</tbody>
</table>

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

- Example – floor with exposed mass timber

Acoustics

- Example – floor with exposed mass timber
Acoustics

- Examples – floors with ceiling concealed

[Diagram showing the components of a floor with ceiling concealed: Top Side Products, Timber Base, Batt Insulation, Sound Isolation Clips, Furring Channel, 2 Layers of Gypsum Board]

Acoustics

- Example – walls

[Diagram showing the components of a wall: 5/8" Gypsum Wallboard, 2x3 Studs @16" o.c. min, 3-ply CLT Panel, 4-17" thick, 2-5" Mineral Wool Batt Insulation]
Acoustics

- Example – flanking control

Energy Performance

- Exterior walls
  - Mass timber panels (e.g. CLT)
  - Curtain walls

- IBC Chapter 13
  - IECC compliance paths
    - ANSI/ASHRAE/IES Standard 90.1
    - Prescriptive design per IECC C402 through C405
    - Performance design per IECC C407
Energy Performance

**IECC TABLE C402.1.4**

**OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, U-FACTOR METHOD**

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 EXCEPT MARINE</th>
<th>5 AND MARINE 4</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>All other</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
</tr>
<tr>
<td>Group R</td>
<td>0.151</td>
<td>0.151</td>
<td>0.151</td>
<td>0.123</td>
<td>0.104</td>
<td>0.104</td>
<td>0.090</td>
<td>0.090</td>
</tr>
<tr>
<td>Group R</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
<td>0.064</td>
</tr>
<tr>
<td>Mass Timber</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
</tr>
<tr>
<td>Wood framed</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
</tr>
<tr>
<td>and other</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
<td>U-</td>
</tr>
</tbody>
</table>

**Energy Performance**

- Does a CLT wall qualify as a “mass” wall?
  - Assume 1-3/8” lamination thickness
    - 3 layers = 4.125”
    - 5 layers = 6.875”
    - 7 layers = 9.625”

- Exterior fire protection required
  - All new construction types

**Required Mass Timber Thickness for Minimum Heat Capacity of 5 Btu/ft²•˚F**

<table>
<thead>
<tr>
<th>Layers of 5/8” Type X Gypsum</th>
<th>Minimum Thickness of Mass Timber (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0¹</td>
<td>6.36 (5 layers)</td>
</tr>
<tr>
<td>1</td>
<td>5.53 (5 layers)</td>
</tr>
<tr>
<td>2</td>
<td>4.71 (5 layers)</td>
</tr>
<tr>
<td>3</td>
<td>3.88 (3 layers)</td>
</tr>
<tr>
<td>4</td>
<td>3.05 (3 layers)</td>
</tr>
</tbody>
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### Energy Performance

**Required Minimum Thickness of Mass Wall to Meet IECC U-Factors**

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**CLT**

- 3 layers = 4.125"  
- 5 layers = 6.875"  
- 7 layers = 9.625"

---

**Energy Performance**

**Additional Minimum R-value for a Mass 4-1/8-inch-thick Wall under IECC**

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<th>CZ</th>
<th>Req. U-Factor</th>
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**R-9 mineral wool works**
### Energy Performance

#### Additional Minimum R-value for a **Non-mass 4-1/8-inch-thick Wall** under IECC

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### Energy Performance

#### Additional Minimum R-value for a **Mass 6-7/8-inch-thick Wall** under IECC

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## Energy Performance

### Additional Minimum R-value for a Mass 6-7/8-inch-thick Wall Under IECC

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### Additional Minimum R-value for a Non-mass 4-1/8-inch-thick Wall Under IECC

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Seismic Design Options

- **ASCE 7 Minimum Design Loads for Buildings and Other Structures**
- **Response Modification Coefficient (R)**
  - CLT not recognized as vertical SFRS in ASCE 7-16
- **Options**
  - Performance-based design procedure per ASCE 7
  - Demonstrating equivalence to an existing ASCE 7 system
  - ASCE 7, FEMA P695, and FEMA P795 Quantification of Building Seismic Performance Factors; Component Equivalency Methodology
- **R-factor anticipated in ASCE 7-22**

Lateral Design Options

- **Horizontal diaphragm example**
  - Wood structural panels over CLT
  - Acceptable under current codes

*Photo courtesy of StructureCraft*
Current Research

- Colorado State University
  - CLT shear wall testing (P695) to determine seismic R factor
- Colorado School of Mines
  - NEES project on rocking CLT shear wall
- Arup
  - Heavy timber buckling-restrained braced frame system
- Oregon State University
  - CLT diaphragm testing

Current Standards

- 2021 Special Design Provisions for Wind and Seismic
  - Platform construction
  - CLT shear walls
  - Ductility via nailed metal connectors
  - Referenced in 2021 IBC
Conclusion

This concludes 2021 IBC Tall Mass Timber Principles of Fire-Resistance Design, Protection of Connections and Special Inspections. You should now be able to:

• Understand principles of fire design provisions for mass timber building elements and assemblies for new construction Types IV-A, IV-B, and IV-C.
• Learn how to design fire protection for mass timber connections.
• Recognize new code provisions for special inspection of tall mass timber structures.
• Evaluate options for acoustics and energy performance.

2021 & Beyond
Repeat: May/June 6-part series on Mass Timber & IBC!
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