The Case for Cross Laminated Timber: Part 2
Opportunities and Challenges for a New Class of Timber Product

Learning Objectives

1. Review answers to common questions regarding the design and construction of CLT structures, including those related to cost and designing for exposed conditions.
2. Evaluate the fire characteristics of CLT, including the benefits of charring, effects of lamination, flame spread and more.
3. Discuss current seismic approaches that can be used for CLT buildings as well as the future of seismic testing.
4. Consider the acoustic and moisture performance of CLT assemblies and how they inform the design of a project.

Outline

- CLT Design
  - Fire
  - Lateral
  - Acoustic
  - Building Enclosure
- Including....
  - Information available in the CLT Handbook
  - Information from additional resources
  - Answers to Frequently Asked Questions

Fire and Life Safety – Building Types

- Type V are generally combustible such as wood although V permits any material permitted by code

All structural elements can be combustible construction:
  - Exterior walls
  - Floor
  - Roof
  - Interior walls

Fire Design

- Building Types
  - Fire Resistance
  - Interior Finish
  - Connections

Fire and Life Safety – Building Types

- Type VB is unprotected construction and requires no fire rating on any building elements.
**Type VA** is protected construction and requires a 1hr rating for all structural elements with some exceptions for roofs.

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
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<td>P</td>
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<tr>
<td>Roofs</td>
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</tr>
</tbody>
</table>

Fire and Life Safety – Building Types

**Type III** is noncombustible exterior and combustible interior. Fire-retardant-treated wood framing is permitted in the exterior walls.

- **Floor**
- **Roof**
- **Interior walls**

**Type IV** - Fire resistance requirements do NOT apply to HT Construction except at the Exterior Walls

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<td>Roofs</td>
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</tbody>
</table>

**BUSINESS**

- **Occupancy**
- **Sprinkler IBC 903.3.1.1**
- **Modifications**
- **Stories**
- **105 sq. ft./floor max**
- **No Fire walls**

**RESIDENTIAL**

- **Occupancy**
- **NFP A 13 Sprinklers IBC 903.3.1.1**
- **Modifications**
- **Stories**
- **5 ft.**
- **770 sq. ft./floor max**
- **No Fire walls**
Fire and Life Safety - AMMR

[A] 104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Fire Resistance & AMMR

Fire protection based on

• ASTM E119 test performed by AWC or test reports from FPInnovations, OR...

ASTM E119 Fire Resistance Test

• 5-Ply CLT (approx. 7” thick)
• 5/8” Type X GWB each side
• RESULTS: 3 hours 6 minutes

Fire Resistance Calculation under AMMR

Full Scale E119 Testing was done to prove the calculation methods.

The advantage to a calculated method is versatility (not relying on assembly tests to include your exact assembly).

Fire Resistance

Using AMMR

• Charring Rate and Char Depth
### Fire Resistance

Net section properties

![Typical one foot section](image)

### Interior Finishes

Wood Interior Finish – Flame spread
- Building occupancy
- Location of the material in the building
- Sprinklers or no sprinklers

ASTM E84 or UL 723 Test Method

#### IBC 803.1.1

<table>
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<tr>
<th>Class</th>
<th>Flame Spread Index</th>
<th>Smoke Development Index</th>
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<tr>
<td>A</td>
<td>0-25</td>
<td>0-400</td>
</tr>
<tr>
<td>B</td>
<td>26-75</td>
<td>0-400</td>
</tr>
<tr>
<td>C</td>
<td>76-200</td>
<td>0-400</td>
</tr>
</tbody>
</table>

#### Connections

Structural requirements and......
- WCD 5 by AWC has recommendations for HT connections
- Connections in protected construction require protection also using wood, gypsum or other approved material
- HT doesn’t identify specific protection requirements

#### Metal Connectors
- strength compromised
- Reduced capacity in heated zone
- Thermal conductivity of connector itself

#### Connections

Examples of connections seen in CLT platform construction

![Figure 12](image)

Examples of connections seen in CLT bullpen construction

![Figure 13](image)
Connections

Fire ratings for connections are established by the fire rating of the system.

Type IV Construction provide fire resistance, but is not rated.

IBC 722.6.3.3 - 1hr of protection = 1-1/2” wood covering

Chapter 8 - Fire

- IBC Height and Areas
- ASTM E119 Test
- ASTM E84 Test
- Design Examples

CLT in Lateral Force Resisting Systems

CLT Panels can be used as structural diaphragms and shear walls provided AMMR process is utilized.
Connections Determine Lateral Strength

Similar to Wood Structural Panel Shear Walls

<table>
<thead>
<tr>
<th>Connections</th>
<th>2 brackets</th>
<th>3 brackets</th>
<th>4 brackets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2S</td>
<td>3S</td>
<td>4S</td>
</tr>
</tbody>
</table>

CLT Shear Strength Depends on Connections

Source: US CLT Handbook

Fasteners and Brackets

Commercial Products & AMMR

<table>
<thead>
<tr>
<th>Commercial Products</th>
<th>AMMR</th>
</tr>
</thead>
</table>

Table 1: Shear Strength Design Values – CLT Panel Connection

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>F2, F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Transform Used in CLT Construction

Wind Design

- Wind design uses linear-elastic analysis methods
- Design resistance can be derived using standard methods
- Design is fairly straightforward

Seismic Design

To provide ductile seismic resistance, CLT connections in seismic force resisting systems should be governed by fastener yielding and wood crushing NOT brittle failures.

CLT Questions

- Self-tapping screws will likely be the most common connector used in CLT construction. These are proprietary connectors and design values and requirements would be specified by the manufacturer. The manufacturer will be responsible for providing lateral and withdrawal connection values and any information needed to explain how to use provisions of the NDS (e.g. dowel bearing strength adjustments, dowel bending strengths of the self-tapping screws, and specific application of the NDS yield equations).
- Design values for proprietary fasteners and information on their approved use are available in Evaluation Reports or the manufacturer’s literature.
Seismic Design

Available design approaches:
- Alternative Means until CLT system code recognized.
  - ELF Seismic Performance Factors; R, Omega, Cd.
  - (under development)
  - (CLT handbook provides values considered to be conservative)
- Performance Based Seismic Design

Acoustic Design

Acoustic Design

Acoustics – Non HT systems

Essential Knowledge – Principle for Good Sound Insulation Design

- Sufficient mass
- Soft surface of floor finishing
- Floating topping and finishing
- Suspended drywall ceiling
- Decouple

Acoustics – Non HT Systems

Sound Insulation of Bare CLT Floors and Walls

<table>
<thead>
<tr>
<th>Sound Insulation</th>
<th>CLT</th>
<th>STC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3/8 x 4-1/2</td>
<td>Wall 32-34 N.A.</td>
</tr>
<tr>
<td>4</td>
<td>1-1/2</td>
<td>Floor 26 26</td>
</tr>
<tr>
<td>5</td>
<td>2-3/4</td>
<td>Floor 26 26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Layers</th>
<th>Thickness in.</th>
<th>Assembly Type</th>
<th>PSTC</th>
<th>FRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1-1/4</td>
<td>Wall 20 N.A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1-1/4</td>
<td>Floor 32.4 29.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Perceivable sound pressure differential is 3dB

Important rule for the development of cost-effective solutions!

Acoustics Examples for >50 STC Walls

- STC 50: 1 and 2 = 4-1/2 in. CLT, 2=1-1/8 in. Mineral wool in the gap
- STC 55: Adding 5/8 in. gypsum board directly to both sides
- STC 60: with the gypsum boards and double the thickness of the gap and mineral wool
- STC 58: 1 and 2 = 5/8 in. gypsum boards
  2 and 3 = 2 by 2 in. wood studs at least 16 in. o.c.
  2 and 6 = 2.5 in. mineral wool
  4 = 4-1/2 in. CLT
Recommendations for meeting IBC requirements

**STC and IIC rated assemblies**

**Acoustics**

### Design Examples for >45 FSTC Walls

<table>
<thead>
<tr>
<th>Top view of cross-section</th>
<th>FSTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &amp; 5 = 5/8&quot; Gypsum board</td>
<td>46</td>
</tr>
<tr>
<td>2 &amp; 4 = Resilient channels at 24&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td>3, 5-layer CLT of 7-1/4&quot;</td>
<td></td>
</tr>
<tr>
<td>1 &amp; 7 = 5/8&quot; Gypsum board</td>
<td>47</td>
</tr>
<tr>
<td>2 &amp; 5 = Resilient channels at 24&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td>3 &amp; 8 = 3-layer CLT of 5/16&quot;</td>
<td></td>
</tr>
<tr>
<td>4 = 1&quot; air gap filled with mineral wool</td>
<td></td>
</tr>
</tbody>
</table>

### Design Examples for >45 FSTC and FIIC Floors

<table>
<thead>
<tr>
<th>End view of cross-section</th>
<th>FSTC</th>
<th>FIIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = Carpet or floating flooring about 3/4&quot; in 1/8&quot; resilient underlayment of 0.16 to 0.27 lb/sf.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>2 = 3/8&quot; fiber or 1/2&quot; dry topping, e.g. 1/16&quot; wood fiber or 3/16&quot; Gypsum board, cement boards, or masonry.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>3 = Capillary curing of fiber or 1/2&quot; dry topping.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>4 = 1/8&quot; dry topping, e.g. 1/16&quot; wood fiber or 3/32&quot; Gypsum board, cement boards, or masonry.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>5 = 1/8&quot; dry topping, e.g. 1/16&quot; wood fiber or 3/32&quot; Gypsum board, cement boards, or masonry.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>6 = 1/8&quot; dry topping, e.g. 1/16&quot; wood fiber or 3/32&quot; Gypsum board, cement boards, or masonry.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>7 = 1/8&quot; dry topping, e.g. 1/16&quot; wood fiber or 3/32&quot; Gypsum board, cement boards, or masonry.</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

### Chapter 9 - Sound

- Acoustic properties of CLT
- STC and IIC rated assemblies
- FSTC and FIIC rated assemblies
- Recommendations for meeting IBC requirements

### Frequently Asked Question:

1. **Are there any substitutions for more common acoustic assembly materials?**

   **Yes**

   Fernacell can be replaced with cement–fiber board as long as it has the same or higher density (32 kg/m²).

   Isover is very similar to Roxul (Rock wool).
Frequently Asked Question:

1. Are there more tested assemblies available?

Yes

NRC has data on assemblies beyond those in the Handbook.
Additional assemblies may be tested.
Acousticians can estimate sound performance based on sound test data.

Building Enclosure Design

- CLT wall assemblies should be built "breathable".
- Prevent rain infiltrations.
- Wetting during transportation, construction and service should be minimized.
- Studies show that in heating climate that no vapor barrier will be required at interior.

Moisture Management

- Rain screen:
  - cavity directly behind the cladding.
  - allows improved drying.
  - Openings in cladding at top and bottom.
- Drained wall:
  - Requires WRB.
  - 1/16" air gap suggested.
  - Drainage wrap recommended with foam insulation.
  - OR groves cut in back side of foam insulation.

Energy Performance

- Exterior Insulation:
  - Provides continuity (no break at floors).
  - Shields CLT and air barrier from temp (less expansion and contraction).
  - Capitalizes more thermal mass benefit.
  - Keeps it warmer (in cold climates).
  - Lowers surface relative humidity.
  - Keeps it dryer (in hot humid).

Moisture Management

- Water Resistive Barrier:
  - Essential part.
  - Properly overlapped in a shingle fashion.
  - Integrate with flashings.
  - Sealed at all penetrations.
Energy Performance

- Rigid shear block type connection through insulation, cladding to vertical strapping.

Energy Performance

- Air-tight as a material, but not as a system.
- Recommend:
  - self-adhered sheet product air barrier membranes
  - or thick liquid applied membrane on exterior of panels (exterior air barrier approach)
- Not recommended:
  - loose-applied sheets (House-wraps)

Energy Performance

- Sealants, tapes, & membranes applied on either side can't address this type of airflow path through the CLT lumber gaps.
- Airflow path more convoluted – lower leakage rates, but still a consideration.

Energy Performance

- Roof Assemblies

- CLT Handbook - Chapter 10

- Properties of CLT
  - Water vapor sorption
  - Permeability
  - Liquid water absorption
  - Heat storage/transfer
  - Air permeability

- Approaches to exterior water management
- Recommended Assemblies
- Moisture Control During Construction
- Preservative Treatment
Resources

Buildings in Marine to Cold Climate Zones in North America


Resources

Buildings in Marine to Cold Climate Zones in North America

Chapter 3: Moisture, Air and Thermal Control
- Building as a System
- Climate Zones
- Interior Climate, HVAC Interaction
- Critical Barrier Concept
- Control of Rainwater Penetration
- Control of Air Flow
- Controlling Condensation
- Construction Moisture
- Controlling Heat Flow and Insulation
- Whole Building Energy Efficiency
- Computer Simulation Considerations for Wood-framed Enclosures

Resources

Buildings in Marine to Cold Climate Zones in North America

Chapter 4 – Energy Efficient Walls Exterior Insulated
- Material selection & guidance
- Control Functions
- Critical Barriers
- Effective R-value Tables

<table>
<thead>
<tr>
<th>Exterior Insulation Thickness</th>
<th>R-value (R/ft²·h·°F/inch) (R/vice·cm·°C)</th>
<th>R-value (R/ft²·h·°F/inch) (R/vice·cm·°C)</th>
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<tbody>
<tr>
<td>3 inches</td>
<td>1.1</td>
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<td>8 inches</td>
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Questions?

[contact info]

Project Assistance also available at help@woodworks.org

WoodWorks –Portal to CLT Information

[contact info]