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

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Fire Design

- Fire Design
- Building Types
- Fire Resistance
- Interior Finish
- Connections

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

**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>TABLE 602</th>
<th>FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUILDING ELEMENT</td>
<td>TYPE I</td>
</tr>
<tr>
<td>Primary structural frame</td>
<td>2h</td>
</tr>
<tr>
<td>Bearing walls</td>
<td>3h</td>
</tr>
<tr>
<td>Numbering walls and partitions</td>
<td>See Table 602</td>
</tr>
<tr>
<td>Floor construction and secondary members</td>
<td>See Section 602</td>
</tr>
<tr>
<td>Roof construction and secondary members</td>
<td>See Section 602</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 603</th>
<th>FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>TYPE I</td>
</tr>
<tr>
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<td>1h</td>
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<tr>
<td>Bearing walls</td>
<td>3h</td>
</tr>
<tr>
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<td>See Table 602</td>
</tr>
<tr>
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<td>See Section 602</td>
</tr>
<tr>
<td>Roof construction and secondary members</td>
<td>See Section 602</td>
</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.

Structural elements that can be CLT:
- Floor
- Roof
- Interior walls

<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</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>(see Section 2021)</td>
<td>2h</td>
<td>2h</td>
<td>1hr</td>
<td>1hr</td>
<td>1hr</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>3h</td>
<td>2</td>
<td>2h</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>4</td>
<td>4h</td>
<td>3</td>
<td>3h</td>
<td>3</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>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
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<tr>
<td>(see Section 2024)</td>
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<td>0</td>
<td>0</td>
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<td>Floor construction and secondary</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>members (see Section 2042)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Roof construction and secondary</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>members (see Section 2042)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type III** requires a 2hr fire rating at exterior walls for both protected and unprotected construction, 1hr rated most everywhere else for **IIIA** and no where else for **IIIB**.

**Type IV** are generally combustible with the exception of the exterior walls and requires that there are no concealed spaces.

Structural elements that can be CLT:
- Floor
- Roof
- Interior walls

Fire and Life Safety - Building Types

**Type IV** are generally combustible with the exception of the exterior walls that can be CLT or FRT when the rating is 2hr or less.

Structural elements that can be CLT under 2015 IBC:
- Floor
- Roof
- Interior walls
- Exterior walls
Fire and Life Safety - Building Types

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

---

**TABLE 609**

<table>
<thead>
<tr>
<th>PRIMARY STRUCTURAL MEMBER</th>
<th>TYPE A</th>
<th>TYPE B</th>
<th>TYPE C</th>
<th>TYPE D</th>
<th>TYPE E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior of Building</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Interior of Building</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exterior of Building</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Interior of Building</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

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**BUSINESS**

**Occupancy**

NFPA 13 Sprinklers IBC 903.3.1.1

**Modifications**

6 stories

85 feet

135,000 sq. ft./floor max

405,000 sq. ft. total max.

No Fire walls

---

**RESIDENTIAL**

**Occupancy**

NFPA 13 Sprinklers IBC 903.3.1.1

**Modifications**

5 stories

85 feet

76,875 sq. ft./floor max

230,625 sq. ft. total max.

No Fire walls

---

[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 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 and Life Safety - AMMR

[A] 104.11.2 Tests. Whenever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the building official shall have the authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test standards. In the absence of recognized and accepted test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.

[A] 104.11.1 Research reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from approved sources.

Fire Resistance

Fire protection based on
- ASTM E119 test performed by AWC or test reports from FPInnovations, OR...
- Calculate fire resistance per NDS Ch. 16

ASTM E119 Fire Endurance Test

- 5-Ply CLT (approx. 7” thick)
- 5/8” Type X GWB each side
- Sought 2 hour rating
- **RESULTS:** 3 hours 6 minutes

Fire Resistance Testing

Full Scale E119 Testing was done to prove min 2hr resistance to allow CLT as an exception in Type IV construction.

Fire Resistance Calculation

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

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


Fire Resistance

Chapter 16 NDS
- Charring Rate and Char Depth

SECTION 721
CALCULATED FIRE RESISTANCE
721.1 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 concrete, masonry and clay masonry assemblies shall be permitted in accordance with ACI 216/ASCE 36. The calculated fire resistance of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 39. The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/ASCE National Design Specification for Wood Construction (NDS).

Net section properties

Plan

Typical one foot section

Section
Interior Finish

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

### Classification in Codes are:

<table>
<thead>
<tr>
<th>Class</th>
<th>Flame Spread Range</th>
<th>Example Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>I or A</td>
<td>0-25</td>
<td>Enclosed vertical exits</td>
</tr>
<tr>
<td>II or B</td>
<td>26-75</td>
<td>Exit access corridors</td>
</tr>
<tr>
<td>III or C</td>
<td>76-200</td>
<td>Other rooms and areas</td>
</tr>
</tbody>
</table>

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### Connections

Structural requirements and......

- HT doesn’t identify specific protection requirements
- connection protection must be equivalent to construction type requirements

**Metal Connectors**
- strength compromised
- Reduced capacity in heated zone
- Thermal conductivity of connector itself
Figure 12
Examples of connections seen in CLT platform construction

Figure 13
Examples of connections seen in CLT balloon construction

Figure 14
 Concealed metal plates

Figure 9
CLT panel-to-panel half-lapped joint detail
Connections

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

Type IV Construction does not have fire ratings for connections.

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

Frequently Asked Questions:

1. What Building Type should I specify?
2. How tall can I go with CLT?
3. Can I expose CLT?
4. Are there approved fire rated assemblies?

Frequently Asked Questions:

1. What Building Type should I specify?
   - This will depend on the height and area you require and if your threshold for fire walls.
   - Types III, IV and V will all allow CLT to some degree.
   - The 2015 IBC holds an opportunity for expanded use that may be accessed by utilizing 104.10
2. How tall can I go with CLT?
3. Can I expose CLT?
4. Are there approved fire rated assemblies?
Frequently Asked Questions:

1. What Building Type should I specify?
2. How tall can I go with CLT?
   - Depends on occupancy, use of sprinklers and structural design parameters
   - 6 Story Office Type IV or III
   - 6 Story S-2 (parking) - Type IV
   - 5 Story Retail & Residential - Type IV or III
   - Possibly taller with performance based design
3. Can I expose CLT?
4. Are there approved fire rated assemblies?

Frequently Asked Questions:

1. What Building Type should I specify?
2. How tall can I go with CLT?
3. Can I expose CLT?
   - Additional sacrificial laminations may be required to accommodate required fire resistance rating.
   - Most exposed CLT will have a Class B or C finish rating.
   - Type IV members are not subject to interior finish requirements.
4. Are there approved fire rated assemblies?

Frequently Asked Questions:

1. What Building Type should I specify?
2. How tall can I go with CLT?
3. Can I expose CLT?
4. Are there approved fire rated assemblies?

Lateral Design

- A calculated method has been established for fire ratings of Cross Laminated Timber.
- The calculated method has been justified with full scale E119 fire tests.
- Not having set approved fire assemblies gives designers more flexibility with their assemblies but may require more explanation with a building dept.
CLT in Lateral Force Resisting Systems

CLT Panels can be used as structural diaphragms and shear walls.

Source: A Ceccotti in the US CLT Handbook

CLT in Lateral Force Resisting Systems

CLT Panels have a very high in-plane shear strength.

Source: The Cross Laminated Timber Design Guide from Structurlam

Connections Determine Lateral Strength

Similar to Wood Structural Panel Shear Walls

Source: Nordic CLT Guide

Source: SDPWS 2008
Connections Determine Lateral Strength

Similar to Wood Structural Panel Shear Walls

2 brackets
2S

3 brackets
3S

4 brackets
4S

CLT Shear Strength Depends on Connections

Source: US CLT Handbook

Frequently Asked Questions:

1. How do you design connections for CLT?

CLT connections should adhere to the National Design Specification® for Wood Construction (NDS ®) just like other wood connections. The NDS has specific provisions for commodity fasteners, which can be found in Appendix K – L. The NDS does not yet include information on how to apply its dowel bearing equations regarding grain direction to CLT. However, the existing NDS design provisions can be applied with some modification, assuming that the CLT dowel bearing strength is based on the species-specific gravity of the face ply and the loading direction relative to the grain angle of the face ply.

Table 1: Allowable Stress Design Values – CLT Panel Connection

<table>
<thead>
<tr>
<th>Model</th>
<th>D</th>
<th>F</th>
<th>H</th>
<th>V</th>
<th>L</th>
<th>1F</th>
<th>2F</th>
<th>3F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Commercial Products

Figure 1: ARB09 – CLT Panel Connection

Figure 2: AE116 – CLT to Concrete

Table 1: Allowable Stress Design Values – CLT Panel Connection

<table>
<thead>
<tr>
<th>Model</th>
<th>D</th>
<th>F</th>
<th>H</th>
<th>V</th>
<th>L</th>
<th>1F</th>
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</tr>
</tbody>
</table>

Fasteners and Brackets

- Bracket A
- Bracket B
- Bracket C
- Bracket D
**Frequently Asked Questions:**

1. **What type of connections are recommended/approved for CLT?**
   - 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**

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

**Wind Design**

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

**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
CLT Handbook - Chapter 4

- Shear wall Performance
  - Prescribed vs. principles of mechanics
  - Based on connection design - fasteners should yield
- Seismic design
  - Coefficients (R, Ω, Cd)
  - Performance Based Design Pathways
- Literature review
- Numerical modeling
- Examples -
  - allowable capacity
  - system simulation
- R=2 conservative recommendation

Acoustic Design

Perceivable sound pressure differential is 3dB

Important rule for the development of cost-effective solutions!

Acoustics

Essential Knowledge – Principle for Good Sound Insulation Design
- Sufficient mass
- Soft surface of floor finishing
- Floating topping and finishing
- Suspended drywall ceiling
- Decouple
Acoustics

Sound Insulation of Bare CLT Floors and Walls

<table>
<thead>
<tr>
<th>Number of layers</th>
<th>Thickness (in.)</th>
<th>Assembly type</th>
<th>STC</th>
<th>IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3-3/4 to 4-1/2</td>
<td>Wall</td>
<td>32-34</td>
<td>N.A.</td>
</tr>
<tr>
<td>5</td>
<td>5-1/3</td>
<td>Floor</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>5-3/4</td>
<td>Floor</td>
<td>39</td>
<td>24</td>
</tr>
</tbody>
</table>

Measured on field bare CLT wall and floor

<table>
<thead>
<tr>
<th>Number of layers</th>
<th>Thickness in.</th>
<th>Assembly type</th>
<th>FSTC</th>
<th>FIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4-1/8</td>
<td>Wall</td>
<td>28</td>
<td>N.A.</td>
</tr>
<tr>
<td>7</td>
<td>8-1/5</td>
<td>Floor</td>
<td>N.A.</td>
<td>25-30</td>
</tr>
</tbody>
</table>

Design Examples for >50 STC Walls

- STC 50:
  1 and 3 = 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 7 = 5/8 in. gypsum boards
  3 and 5 = 2 in. by 3 in. wood studs at least 16 in. o.c.
  2 and 6 = 2.5 in. mineral wool
  4 = 4-1/2 in. CLT

Design Examples for >45 FSTC Walls

<table>
<thead>
<tr>
<th>Top view of cross-section</th>
<th>Wall detail</th>
<th>FSTC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 &amp; 5 = 5/8&quot; Gypsum board</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>2 &amp; 4 = Resilient channels at 24&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. 5-layer CLT of 7-1/4&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 &amp; 7 = 5/8&quot; Gypsum board</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>2 &amp; 6 = Resilient channels at 24&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 &amp; 5 = 3-layer CLT of 3.07&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 = 1&quot; air gap filled with mineral wool</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top view of cross-section</th>
<th>Wall detail</th>
<th>FSTC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = 3-layer CLT of 4-1/8&quot;</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>2 = 1/2&quot; air gap</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 = 2&quot; by 3&quot; wood studs at 16&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 = 2-1/2&quot; mineral wool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 = 5/8&quot; gypsum board</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top view of cross-section</th>
<th>Wall detail</th>
<th>FSTC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 &amp; 9 = 5/8&quot; gypsum board</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2 &amp; 7 = 2&quot; by 3&quot; wood studs at 16&quot; o.c.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 &amp; 8 = 2-1/2&quot; mineral wool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 &amp; 6 = 1/2&quot; air gap</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 = 3-layer CLT of 4-1/8&quot;</td>
<td></td>
</tr>
</tbody>
</table>
Acoustics

Design Examples for >45 FSTC and FIIC Floors

<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>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>~45</td>
<td>~45</td>
<td></td>
</tr>
<tr>
<td>2 = At least 5.12 lb./ft.² dry topping, e.g. 0.8-1&quot; gypsum board, cement fibreboard</td>
<td>~50</td>
<td>~50</td>
<td></td>
</tr>
<tr>
<td>3 = Resilient underlayment, e.g. 2/5&quot; rubber mat of 0.84 lb./ft.², 1/2&quot; low density wood fibreboard of 0.73 lb./ft.²</td>
<td>~53</td>
<td>~53</td>
<td></td>
</tr>
<tr>
<td>4 = 5-layer CLT of 6-7/8&quot;</td>
<td>~50</td>
<td>~50</td>
<td></td>
</tr>
</tbody>
</table>

- Replace the dry topping by wet topping, e.g. 1-3" concrete of at least 15.6 lb./ft.²

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

Fermacell can be replaced with cement -fiber board as long as it has the same or higher density (32kg/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
Moisture Management

- Water Resistive Barrier
  - Essential part
  - Properly overlapped in a shingle fashion
  - integrate with flashings
  - Sealed at all penetrations

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)

Energy Performance

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 (Housewraps)
**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.

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**Roof Assemblies**

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**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

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>Wood framing</th>
<th>Exterior insulation (R-value/Inch (Rg/In))</th>
<th>2 inches R-value (Rg)</th>
<th>4 inches R-value (Rg)</th>
<th>6 inches R-value (Rg)</th>
<th>8 inches R-value (Rg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2¼-inch thick CLT panels</td>
<td>2½-inch</td>
<td>17.2</td>
<td>20.9</td>
<td>24.4</td>
<td>27.9</td>
</tr>
<tr>
<td>2¼-inch</td>
<td>3.88/cm</td>
<td>15.0</td>
<td>17.7</td>
<td>22.8</td>
<td>27.9</td>
</tr>
<tr>
<td>R.80 inch</td>
<td>3.88/cm</td>
<td>19.8</td>
<td>24.4</td>
<td>28.7</td>
<td>32.9</td>
</tr>
<tr>
<td>R.5 inch</td>
<td>9.53/cm</td>
<td>19.8</td>
<td>24.4</td>
<td>28.7</td>
<td>32.9</td>
</tr>
<tr>
<td>R.22 inch</td>
<td>6.05/cm</td>
<td>19.8</td>
<td>24.4</td>
<td>28.7</td>
<td>32.9</td>
</tr>
</tbody>
</table>

Resources

WoodWorks - Portal to CLT Information
Questions?

[contact info]

Project Assistance also available at help@woodworks.org