Cross Laminated Timber Solutions

Part 2: Addressing Common Design Challenges for Use Today

Presented By: Jeff Peters, P.E.
April 5th 2018
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. Consider the acoustic and moisture performance of CLT assemblies and how they inform the design of a project.
Outline

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

- Fire Design
  - Building Types
  - Fire Resistance
  - Connections
In 2015 IBC, CLT is now defined in Chapter 2 Definitions:

[B.S] CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.

And is referenced in Chapter 23:

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.
# Allowable Uses of CLT in Types III, IV, & V

<table>
<thead>
<tr>
<th>Allowable CLT Applications</th>
<th>Permitted in Floors</th>
<th>Permitted in Roofs</th>
<th>Permitted in Interior Walls</th>
<th>Permitted in Exterior Walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type III</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Type IV&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Yes, min. 4”</td>
<td>Yes, min. 3”</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Yes w/covering</td>
</tr>
<tr>
<td>Type V</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Footnotes**

*<sup>a</sup> – Concealed spaces are not permitted in type IV construction per IBC 2015 602.4.6 & 602.4.7*

*<sup>b</sup> – Interior walls in type IV construction shall meet the minimum sizes in IBC 2015 602.4.8.1*

*<sup>c</sup> – Required exterior covering on CLT used in exterior walls is FRT sheathing (15/32” min.), gypsum board (1/2” min.), or a noncombustible material*
Fire & Life Safety – Bldg Types 2015 IBC

- **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
Concealed Space Limitations on HT

Type IV Construction requires that interior elements be without concealed spaces:

• Concealed spaces include dropped ceilings, attics, chases, others

Concealed space requirement does not apply to any other construction type. If using heavy timber elements in non type IV construction, concealed spaces are permitted but may be required to be sprinklered

Source: US CLT Handbook
Fire and Life Safety – Building Types

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

Source: 2015 IBC

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<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A²</td>
<td>B</td>
<td>HT</td>
</tr>
<tr>
<td>Primary structural frame</td>
<td>3ʳ</td>
<td>2⁴</td>
<td>1</td>
<td>0</td>
<td>HT</td>
</tr>
<tr>
<td>(see Section 202)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<td>2⁴</td>
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<tr>
<td>Nonbearing walls and partitions</td>
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</tr>
<tr>
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<td>Floor construction and secondary members</td>
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<td>Roof construction and secondary members</td>
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<tr>
<td>(see Section 202)</td>
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<td></td>
</tr>
</tbody>
</table>
### INSTITUTIONAL (TYPE IV)
Institutional Occupancy
NFPA 13 Sprinklers IBC 903.3.1.1

**Modifications**
- 4 or 5 stories
- 65 or 85 feet
- 67,500 sq. ft./floor max
- 202,500 sq. ft. total max
- No Fire walls

### INSTITUTIONAL (TYPE VA)
Institutional Occupancy
NFPA 13 Sprinklers IBC 903.3.1.1

**Modifications**
- 3 or 4 stories
- 50 or 70 feet
- 39,375 sq. ft./floor max (w/frontage)
- 118,125 sq. ft. total max (w/frontage)
- No Fire walls

### INSTITUTIONAL (TYPE VB)
Institutional Occupancy
NFPA 13 Sprinklers IBC 903.3.1.1

**Modifications**
- 2 or 3 stories
- 40 or 60 feet
- 16,875 sq. ft./floor max (w/frontage)
- 50,625 sq. ft. total max (w/frontage)
- No Fire walls
Fire and Life Safety – Construction Type III

- **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
Fire and Life Safety – Construction Type V

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

All structural elements can be combustible construction including CLT:
- Exterior walls
- Floor
- Roof
- Interior walls
Fire and Life Safety – Building Types

- **Types IIIA & VA are** protected construction and require a 1hr rating for all structural elements with some exceptions for roofs (2 hrs for ext. walls in type III – CLT cannot be used in ext. walls of type III)
- CLT may be used with calculated fire resistance per NDS Chapter 16 referenced in IBC 722.1

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I A</th>
<th>TYPE I B</th>
<th>TYPE II A</th>
<th>TYPE II B</th>
<th>TYPE III A</th>
<th>TYPE III B</th>
<th>TYPE IV HT</th>
<th>TYPE V A</th>
<th>TYPE V B</th>
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<tbody>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>3a</td>
<td>2a</td>
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<td>0</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
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<td>1hc</td>
<td>1hc</td>
<td>0c</td>
<td>1hc</td>
<td>0</td>
<td>HT</td>
<td>1hc</td>
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<tr>
<td>(see Section 202)</td>
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<td></td>
<td></td>
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<tr>
<td>Roof construction and associated secondary members</td>
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<td>1hc</td>
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<td>(see Section 202)</td>
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</tbody>
</table>

See Table 602
Fire and Life Safety – Building Types

- **Types IIIB & VB** are unprotected construction and requires no fire rating on any building elements.
- Use CLT without requirement for calculated fire resistance (size for structural loads only)
- Min HT Sizes in IBC 602.4 do not need to be met

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**TABLE 601**

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Bearing walls</td>
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<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
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<td></td>
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<td></td>
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<tr>
<td>Exterior</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary members (see Section 202)</td>
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<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof construction and associated secondary members (see Section 202)</td>
<td>1&lt;sup&gt;1/2&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
**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 concrete, concrete masonry and clay masonry assemblies shall be permitted in accordance with ACI 216.1/TMS 0216. The calculated fire resistance of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 29. The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA National Design Specification for Wood Construction (NDS).
In a variety of ways the building code does recognize the ability for Heavy Timber to resist fires through charring.
Strength Loss – Wood vs Steel

Average fire temperature: 1,300°F 1,800°F

@ 450°F steel starts to weaken

@ 1400°F Steel retains 10% of strength; Wood retains 75%

Results from test sponsored by National Forest Products Association at the Southwest Research Institute.
CLT’s Fire Resistance Capabilities

Similar to heavy timber, CLT as a mass timber product has inherent fire resistance capabilities.
NDS Chapter 16 for CLT Fire Resistance

2015 NDS is the 1st Edition to Include Calculation of CLT Fire Resistance

$$\beta_{\text{eff}} = \frac{1.2\beta_n}{t^{0.187}}$$

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

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr.)</th>
<th>Effective Char Depths, $a_{\text{char}}$ (in.)</th>
<th>lamination thicknesses, $h_{\text{lam}}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>2.2, 2.2, 2.1, 2.0, 2.0, 1.9, 1.8, 1.8, 1.8</td>
<td>5/8, 3/4, 7/8, 1, 1-1/4, 1-3/8, 1-1/2, 1-3/4, 2</td>
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<tr>
<td>1½-Hour</td>
<td>3.4, 3.2, 3.1, 3.0, 2.9, 2.8, 2.8, 2.8, 2.6</td>
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<tr>
<td>2-Hour</td>
<td>4.4, 4.3, 4.1, 4.0, 3.9, 3.8, 3.6, 3.6, 3.6</td>
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</tr>
</tbody>
</table>
Design Aid for CLT Fire Resistance

AWC’s Technical Report 10 includes discussion of CLT fire tests and design examples

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

For the structural design of the CLT panel, calculate the maximum induced moment. Calculate panel load (per foot of width):

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

Calculate maximum induced moment (per foot of width):

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

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

Bending moment, $F_bS_{eff,0} = 4,675 \text{ ft-lb/ft of width}$ (PRG 320 Annex A, Table A2)
Fire and Life Safety – AMMR

If a project is under IBC 2012 or older, AMMR can be used to justify CLT’s use

[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 (6-7/8” thick)
- 5/8” Type X GWB each side
- Goal: Min. 2 hour fire resistance
- RESULTS: 3 hours 6 minutes

Free download at awc.org
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 Protection of Connections

**16.3 Wood Connections**

Where fire endurance is required, connectors and fasteners shall be protected from fire exposure by wood, fire-rated gypsum board, or any coating approved for the required endurance time.

Connections must be appropriately designed for structural requirements and......

- Connections in protected construction require protection also using wood, gypsum or other approved material

Considerations of Exposed Metal Connectors in Fire Situations:

- Strength compromised
- Reduced capacity in heated zone
- Thermal conductivity of connector itself
Connections

Figure 12
Examples of connections seen in CLT platform construction
Connections

*Figure 13*
Examples of connections seen in CLT balloon construction
Connections

Figure 14
Concealed metal plates
Connections

Figure 9
CLT panel-to-panel half-flapped joint detail
• Fire ratings for connections are established by the fire rating of the system.
• Type IV Construction provide fire resistance, but is not rated.
Interior Finishes – Exposed CLT

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 803.11

<table>
<thead>
<tr>
<th>Class</th>
<th>Flame Spread Index</th>
<th>Smoke Development Index</th>
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<tbody>
<tr>
<td>A</td>
<td>0-25</td>
<td>0-450</td>
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<tr>
<td>B</td>
<td>26-75</td>
<td>0-450</td>
</tr>
<tr>
<td>C</td>
<td>76-200</td>
<td>0-450</td>
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</table>
## Interior Finishes – Exposed CLT

### TABLE 803.11
**INTERIOR WALL AND CEILING FINISH REQUIREMENTS BY OCCUPANCY**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SPRINKLERED</th>
<th>NONSPRINKLERED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interior exit stairways and ramps and exit passageways</td>
<td>Corridors and enclosure for exit access stairways and ramps</td>
</tr>
<tr>
<td>A-1 &amp; A-2</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>A-3(^f), A-4, A-5</td>
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<td>B</td>
</tr>
<tr>
<td>B, E, M, R-1</td>
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<td>C</td>
</tr>
<tr>
<td>R-4</td>
<td>B</td>
<td>C</td>
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<tr>
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<td>C</td>
<td>C</td>
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<td>B</td>
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<td>B</td>
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<tr>
<td>U</td>
<td>No restrictions</td>
<td>No restrictions</td>
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</table>

\(^a\) Includes accessory rooms.

\(^b\) Includes accessory rooms.

\(^c\) Includes accessory rooms.

\(^d\) Includes accessory rooms.

\(^e\) Includes accessory rooms.

\(^f\) Includes accessory rooms.

\(^g\) Includes accessory rooms.

\(^h\) Includes accessory rooms.

\(^i\) Includes accessory rooms.

\(^j\) Includes accessory rooms.
### Interior Finishes – Exposed CLT

AWC’s DCA 1 lists Flame Spread and Smoke Developed Indices for a number of softwood lumber species

<table>
<thead>
<tr>
<th>Species</th>
<th>Flame Spread Index</th>
<th>Flame Spread Class</th>
<th>Smoke Developed Index</th>
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<tbody>
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<td>Douglas-Fir</td>
<td>70</td>
<td>B</td>
<td>80</td>
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<tr>
<td>Hem-fir species group</td>
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<td>70</td>
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<tr>
<td>Pine, Eastern White</td>
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<td>110</td>
</tr>
<tr>
<td>Pine, Southern Yellow</td>
<td>70</td>
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<td>165</td>
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<tr>
<td>Spruce, Black (4” thick, 3 layers of cross laminations)</td>
<td>35</td>
<td>B</td>
<td>55</td>
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</table>

Gravity Design
Model Building Code Acceptance

ANSI/APA PRG 320-2011


2015 International Building Code

2015 International Building Code
CLT Product Standard

ANSI/APA PRG 320
- CLT Stress classes
- Quality Assurance testing
- Identification marking
## CLT Stress Grades

<table>
<thead>
<tr>
<th>Stress Grade</th>
<th>Major Strength Direction</th>
<th>Minor Strength Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>1950f-1.7E MSR SPF</td>
<td>#3 Spruce Pine Fir</td>
</tr>
<tr>
<td>E2</td>
<td>1650f-1.5E MSR DFL</td>
<td>#3 Doug Fir Larch</td>
</tr>
<tr>
<td>E3</td>
<td>1200f-1.2E MSR Misc</td>
<td>#3 Misc</td>
</tr>
<tr>
<td>E4</td>
<td>1950f-1.7E MSR SP</td>
<td>#3 Southern Pine</td>
</tr>
<tr>
<td>V1</td>
<td>#2 Doug Fir Larch</td>
<td>#3 Doug Fir Larch</td>
</tr>
<tr>
<td>V2</td>
<td>#1/#2 Spruce Pine Fir</td>
<td>#3 Spruce Pine Fir</td>
</tr>
<tr>
<td>V3</td>
<td>#2 Southern Pine</td>
<td>#3 Southern Pine</td>
</tr>
</tbody>
</table>

Non-mandatory in PRG 320. Other stress grades including SCL permitted.
Strength

Photos Courtesy Structurlam
## CLT Panel Capacities

### ANSI/APA PRG 320

<table>
<thead>
<tr>
<th>CLT Grades</th>
<th>$F_{b,0}$ (psi)</th>
<th>$E_0$ ($10^6$ psi)</th>
<th>$F_{t,0}$ (psi)</th>
<th>$F_{c,0}$ (psi)</th>
<th>$F_{v,0}$ (psi)</th>
<th>$F_{s,0}$ (psi)</th>
<th>$F_{b,90}$ (psi)</th>
<th>$E_{90}$ ($10^6$ psi)</th>
<th>$F_{t,90}$ (psi)</th>
<th>$F_{c,90}$ (psi)</th>
<th>$F_{v,90}$ (psi)</th>
<th>$F_{s,90}$ (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>1,950</td>
<td>1.7</td>
<td>1,375</td>
<td>1,800</td>
<td>135</td>
<td>45</td>
<td>500</td>
<td>1.2</td>
<td>250</td>
<td>650</td>
<td>135</td>
<td>45</td>
</tr>
<tr>
<td>E2</td>
<td>1,650</td>
<td>1.5</td>
<td>1,020</td>
<td>1,700</td>
<td>180</td>
<td>60</td>
<td>525</td>
<td>1.4</td>
<td>325</td>
<td>775</td>
<td>180</td>
<td>60</td>
</tr>
<tr>
<td>E3</td>
<td>1,200</td>
<td>1.2</td>
<td>600</td>
<td>1,400</td>
<td>110</td>
<td>35</td>
<td>350</td>
<td>0.9</td>
<td>150</td>
<td>475</td>
<td>110</td>
<td>35</td>
</tr>
<tr>
<td>E4</td>
<td>1,950</td>
<td>1.7</td>
<td>1,375</td>
<td>1,800</td>
<td>175</td>
<td>55</td>
<td>575</td>
<td>1.4</td>
<td>325</td>
<td>825</td>
<td>175</td>
<td>55</td>
</tr>
<tr>
<td>V1</td>
<td>900</td>
<td>1.6</td>
<td>575</td>
<td>1,350</td>
<td>180</td>
<td>60</td>
<td>525</td>
<td>1.4</td>
<td>325</td>
<td>775</td>
<td>180</td>
<td>60</td>
</tr>
<tr>
<td>V2</td>
<td>875</td>
<td>1.4</td>
<td>450</td>
<td>1,150</td>
<td>135</td>
<td>45</td>
<td>500</td>
<td>1.2</td>
<td>250</td>
<td>650</td>
<td>135</td>
<td>45</td>
</tr>
<tr>
<td>V3</td>
<td>975</td>
<td>1.6</td>
<td>550</td>
<td>1,450</td>
<td>175</td>
<td>55</td>
<td>575</td>
<td>1.4</td>
<td>325</td>
<td>825</td>
<td>175</td>
<td>55</td>
</tr>
</tbody>
</table>

For SI: 1 psi = 0.006895 MPa

(a) See Section 4 for symbols.

(b) Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Table A2).

(c) Custom CLT grades that are not listed in this table shall be permitted in accordance with Section 7.2.1
## CLT Panel Capacities from Manufacturer

### CrossLam® Floor Panel Load Table (with 2” concrete topping)

<table>
<thead>
<tr>
<th>PANEL TYPE</th>
<th>SIZE (in)</th>
<th>MAX. SPAN (ft)</th>
<th>40 Residential</th>
<th>50 Office/Classroom</th>
<th>75 Mechanical Room</th>
<th>100 Assembly/Storage</th>
<th>150 Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>single span</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLT3</td>
<td>3.90</td>
<td>10.26</td>
<td>12.37</td>
<td>9.95</td>
<td>11.90</td>
<td>9.32</td>
<td>10.93</td>
</tr>
<tr>
<td>SLT5</td>
<td>6.66</td>
<td>15.90</td>
<td>19.28</td>
<td>15.48</td>
<td>18.31</td>
<td>14.60</td>
<td>16.41</td>
</tr>
<tr>
<td>SLT7</td>
<td>9.42</td>
<td>20.41</td>
<td>24.82</td>
<td>20.40</td>
<td>23.66</td>
<td>19.34</td>
<td>21.36</td>
</tr>
<tr>
<td>SLT9</td>
<td>12.18</td>
<td>24.31</td>
<td>30.05</td>
<td>24.31</td>
<td>28.73</td>
<td>23.94</td>
<td>26.08</td>
</tr>
<tr>
<td>double span</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLT3</td>
<td>3.90</td>
<td>11.50</td>
<td>12.98</td>
<td>11.50</td>
<td>12.28</td>
<td>10.93</td>
<td>10.93</td>
</tr>
<tr>
<td>SLT5</td>
<td>6.66</td>
<td>16.22</td>
<td>19.28</td>
<td>16.22</td>
<td>18.31</td>
<td>16.22</td>
<td>16.41</td>
</tr>
<tr>
<td>SLT7</td>
<td>9.42</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
</tr>
<tr>
<td>SLT9</td>
<td>12.18</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
<td>20.00**</td>
</tr>
</tbody>
</table>

*US CLT Handbook recommends L/300 for preliminary design.

**Span is governed by maximum panel length of 40 ft - design as simple span using table values above.

---

### L/360, LL DEFLECTION CRITERIA - Panel thickness (in.)

<table>
<thead>
<tr>
<th>LL (psf)</th>
<th>10 ft</th>
<th>12 ft</th>
<th>14 ft</th>
<th>16 ft</th>
<th>18 ft</th>
<th>20 ft</th>
<th>22 ft</th>
<th>10 ft</th>
<th>12 ft</th>
<th>14 ft</th>
<th>16 ft</th>
<th>18 ft</th>
<th>20 ft</th>
<th>22 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>3 1/8</td>
<td>4 1/8</td>
<td>4 1/8</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>6 7/8</td>
<td>3 1/8</td>
<td>4 1/8</td>
<td>4 1/8</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>6 7/8</td>
</tr>
<tr>
<td>50</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>8 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>8 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
</tr>
<tr>
<td>100</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>8 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
<td>4 1/8</td>
<td>5 1/8</td>
<td>6 7/8</td>
<td>8 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
<td>9 5/8</td>
</tr>
</tbody>
</table>

Source: Nordic X-Lam, Stress Grade E1

Source: Structurelam, Stress Grade V2
CLT in NDS 2015 – Panel Strength

New Chapter 10 covering Adjustment Factors for CLT

Table 10.3.1  Applicability of Adjustment Factors for Cross-Laminated Timber

<table>
<thead>
<tr>
<th>Factor</th>
<th>ASD Only</th>
<th>ASD and LRFD</th>
<th>LRFD Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_b(S_{cr})'$ = $F_b(S_{cr})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_b(A_{parallel})'$ = $F_b(A_{parallel})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_T$</td>
</tr>
<tr>
<td>$F_\gamma(t_\gamma)' = F_\gamma(t_\gamma)$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_T$</td>
</tr>
<tr>
<td>$F_d(Ib/Q)<em>{eff}' = F_d(Ib/Q)</em>{eff}$</td>
<td>$C_M$</td>
<td>$C_T$</td>
<td>-</td>
</tr>
<tr>
<td>$F_c(A_{parallel})'$ = $F_c(A_{parallel})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_T$</td>
</tr>
<tr>
<td>$F_c(A)' = F_c(A)$</td>
<td>$C_M$</td>
<td>$C_T$</td>
<td>-</td>
</tr>
<tr>
<td>$(EI)<em>{app}' = (EI)</em>{app}$</td>
<td>$C_M$</td>
<td>$C_T$</td>
<td>-</td>
</tr>
<tr>
<td>$(EI)<em>{app-min}' = (EI)</em>{app-min}$</td>
<td>$C_M$</td>
<td>$C_T$</td>
<td>-</td>
</tr>
</tbody>
</table>
Floors & Roofs
Stiffness & Deflection

Major Axis Stiffness

Minor Axis Stiffness

$EI_{eff,0}$

$GA_{eff,0}$

$EI_{eff,90}$

$GA_{eff,90}$
### Structural Section Properties

<table>
<thead>
<tr>
<th></th>
<th>Major Axis</th>
<th>Minor Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flexural Strength:</strong></td>
<td>$F_{bS_{eff,0}}$</td>
<td>$F_{bS_{eff,90}}$</td>
</tr>
<tr>
<td><strong>Flexural Stiffness:</strong></td>
<td>$E_{I_{eff,0}}$</td>
<td>$E_{I_{eff,90}}$</td>
</tr>
<tr>
<td><strong>Shear Strength:</strong></td>
<td>$V_{s,0}$</td>
<td>$V_{s,90}$</td>
</tr>
<tr>
<td><strong>Shear Stiffness:</strong></td>
<td>$G_{A_{eff,0}}$</td>
<td>$G_{A_{eff,90}}$</td>
</tr>
</tbody>
</table>

Values in **RED** provided by CLT manufacturer

*Reference: PRG 320 and CLT Product Reports*
A State of the Art Review of Cross-Laminated Timber Floor Systems

Scott Breneman, PhD, PE, SE, Senior Technical Director
WoodWorks – Wood Product Council

Abstract

Increased availability of cross-laminated timber (CLT) in North America combined with its successful use in projects worldwide has generated interest in its properties and performance within the U.S. design community. With the inclusion of CLT in the 2015 International Building Code and upcoming design standards, curiosity is evolving with a number of developers, architects and structural engineers looking to use CLT in upcoming projects. One application under frequent consideration is the use of CLT within horizontal floor and roof systems to create long-spanning structural decks. This paper is for engineers designing floor systems with CLT for the first time, who are unfamiliar with

Status in North America

In North America, the availability and acceptance of CLT is much newer than in Europe however the adoption is happening at a fast rate considering the speed at which material design standards and building code modifications occur. The ANSI approved product standard ANSI/APA PRG 320 Standard for Performance-Rated Cross-Laminated Timber provides a basis for standardization of CLT quality, manufacturing and structural properties (APA, 2012) in North America. With the availability of the PRG 320 Product Standard, CLT will be a code referenced building component in the 2015 International Building Code.

The sizes of panels available are limited by the size of the manufacturing equipment and shipping constraints. North American panels are manufactured up to 16 feet in length and typically range from 8 to 16 feet.
Connection Details

Source: Structurelam
Connectors for CLT in NDS 2015:
Dowel Type Fasteners, e.g. Lag Screws, Wood Screws and Nails
Unique Design Considerations due to alternating grain direction
Withdrawal

Lag screws loaded in end grain in narrow edge of CLT, regardless of grain orientation, shall have their capacity reduced by end grain factor = 0.75 (NDS 12.2.1.5)

Nails, wood screws and spikes shall not be loaded in withdrawal in CLT end grain (NDS 12.2.2.4 & 12.2.3.6)
Dowel Bearing Strength:

- *Panel face vs. panel edge*

12.3.3.5 Dowel bearing strengths, $F_e$, for dowel-type fasteners installed into the panel face of cross-laminated timber shall be based on the direction of loading with respect to the grain orientation of the cross-laminated timber ply at the shear plane.

12.3.3.6 Where dowel-type fasteners are installed in the narrow edge of cross-laminated timber panels, the dowel bearing strength shall be $F_{e,\perp}$ for $D \geq 1/4"$ and $F_e$ for $D < 1/4"$. 
Connector Design in CLT - NDS 2015

12.5.2 End Grain Factor, $C_{eg}$

12.5.2.2 Where dowel-type fasteners are inserted in the end grain of the main member, with the fastener axis parallel to the wood fibers, reference lateral design values, $Z$, shall be multiplied by the end grain factor, $C_{eg} = 0.67$.

12.5.2.3 Where dowel-type fasteners with $D \geq 1/4''$ are loaded laterally in the narrow edge of cross-laminated timber, the reference lateral design value, $Z$, shall be multiplied by the end grain factor, $C_{eg} = 0.67$, regardless of grain orientation.

**Lateral Design End Grain Factor:**

$D < ¼''$: $C_{eg} = 0.67$ (if in end grain only)

$D > ¼''$: $C_{eg} = 0.67$ (if in narrow face regardless of grain direction)
Dowel Bearing Length:

- *Adjusted with grain direction*

**12.3.5 Dowel Bearing Length**

12.3.5.1 Dowel bearing length in the side member(s) and main member, \( \ell_s \) and \( \ell_m \), shall be determined based on the length of dowel bearing perpendicular to the application of load.

12.3.5.2 For cross-laminated timber where the direction of loading relative to the grain orientation at the shear plane is parallel to grain, the dowel bearing length in the perpendicular plies shall be reduced by multiplying the bearing length of those plies by the ratio of dowel bearing strength perpendicular to grain to dowel bearing strength parallel to grain (\( F_{c\perp} / F_{c\parallel} \)).
Connector Design in CLT - NDS 2015

Example:

½" Bolt in SPF 3-ply CLT with 1-½" plies

\[ l_m = t_{1\|} + t_{2\perp} + t_{3\|} = 3(1.5) = 4.5" \]

\[ l_{m-adj} = t_{1\|} + t_{2\perp}(F_{e\perp}/F_{e\|}) + t_{3\|} \]

\[ = 1.5 + 1.5(2450/4700) + 1.5 = 3.8" \]
Connector Design in CLT - NDS 2015

End distance, edge distance and fastener spacing requirements in narrow edge

NDS Figure 12I
Connection Styles

Floor Panel to Floor Panel

- Interior Spline
- Single Surface Spline
- Double Surface Spline
- Half Lap
Connection Styles
Connections Determine Lateral Strength

Similar to Wood Structural Panel Shear Walls

CLT Shear Strength Depends on Connections

Source: US CLT Handbook
Connection Details

Simple connections with:
- Metal angles
- Self tapping Screws

Source: US CLT Handbook

Source: Structurelam
Fasteners and Brackets
Connection Published Capacities

Figure 1: ABR105 – CLT Panel Connection

Figure 2: AE116 – CLT to Concrete

Table 1: Allowable Stress Design Values – CLT Panel Connection

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Gauge</th>
<th>Dimensions (in.)</th>
<th>Fastener Schedule</th>
<th>Allowable Load (lbs.), C₀ = 1.60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>W₁, W₂, L</td>
<td>Horizontal Leg</td>
<td>Vertical Leg</td>
</tr>
<tr>
<td>ABR9020</td>
<td>14</td>
<td>3/₄₈, 3/₄₈</td>
<td>10 CNA4x60</td>
<td>10 CNA4x60</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>4/₄₈, 4/₄₈</td>
<td>10 SD10212</td>
<td>10 SD10212</td>
</tr>
<tr>
<td>ABR105</td>
<td>11</td>
<td>3/₄₈, 3/₄₈</td>
<td>10 CNA4x60</td>
<td>10 CNA4x60</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>4/₄₈, 4/₄₈</td>
<td>10 SD10212</td>
<td>10 SD10212</td>
</tr>
<tr>
<td>AE116</td>
<td>11</td>
<td>3/₄₈, 1/₄₈</td>
<td>7 CNA4x60</td>
<td>18 CNA4x60</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>4/₄₈, 4/₄₈</td>
<td>7 SD10212</td>
<td>18 SD10212</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm; 1 lbf = 4.45 N.
1. The allowable loads are based on the use of SPF Grade 2 Cross Laminated Timber (CLT) material conforming to APA PRG-320.
2. Installation and fastener schedule assume platform framing, i.e., install vertical leg at bottom edge of CLT wall panel, and horizontal leg on CLT floor panel with 3/₄ in. min. edge distance.
3. Allowable loads have been increased for wind or earthquake loading with no further increase allowed. Reduce for other load durations as required by code.
4. Nails: CNA4x60 = 4 mm diameter x 60 mm long proprietary ring-shank nail.
5. Screws: SD10212 = 0.162 in. shank diameter x 2.5 in. long Simpson Strong-Drive® wood screw.
Overturning Restraint Connections

Source: Timber Connect
Our aim for this white paper is to provide a practical design method to determine the strength of a Cross Laminated Timber horizontal diaphragm and deflection due to lateral wind or seismic loads.

CLT HORIZONTAL DIAPHRAGM DESIGN
The design approach is based on compliance with engineered design of CLT in accordance with the 2015 International Building Code, reference standards, and other published information including manufacturer's literature.

Applicable Building Code, reference standards, and other information sources:
- ICC, 2015 International Building Code
- ANSI/AWC NDS-2015 National Design Specification (NDS) for Wood Construction with Commentary
- AWC SDPWS-2015 Special Design Provisions for Wind and Seismic
- ASCE 7-10 Minimum Design Loads for Buildings and Other

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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
## 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>FIIC</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
## Acoustics

### 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>
</table>
| ![Top view of cross-section](image1) | 1 & 5 = 5/8” Gypsum board  
2 & 4 = Resilient channels at 24” o.c.  
3. 5-layer CLT of 7-1/4” | 46   |
| ![Top view of cross-section](image2) | 1 & 7 = 5/8” Gypsum board  
2 & 6 = Resilient channels at 24” o.c  
3 & 5 = 3-layer CLT of 3.07”  
4 = 1” air gap filled with mineral wool | 47   |
**Acoustics**

### Design Examples for >45 FSTC Walls

<table>
<thead>
<tr>
<th>Top view of cross-section</th>
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</table>
| ![Cross-section 1](image1) | 1 = 3-layer CLT of 4-1/8”  
2 = 1/2” air gap  
3 = 2” by 3” wood studs at 16” o.c.  
4 = 2-1/2” mineral wool  
5 = 5/8” gypsum board | 47 |
| ![Cross-section 2](image2) | 1 & 9 = 5/8” gypsum board  
2 & 7 = 2” by 3” wood studs at 16” o.c.  
3 & 8 = 2-1/2” mineral wool  
4 & 6 = 1/2” air gap  
5 = 3-layer CLT of 4-1/8” | 50 |
# 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></td>
<td>1 = Carpet, or floating flooring about 2/5” on 1/8” resilient underlayment of 0.16 to 0.37 lb./ft.$^2$</td>
<td>~45</td>
<td>~45</td>
</tr>
<tr>
<td></td>
<td>2 = At least 5.12 lb./ft.$^2$ dry topping, e.g. 0.8-1” gypsum board, cement fibreboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 = Resilient underlayment, e.g. 2/5” rubber mat of 0.84 lb./ft.$^2$, ¾” texture felt of 0.27 lb./ft.$^2$, ½” low density wood fibreboard of 0.73 lb./ft.$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 = 5-layer CLT of 6-7/8”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Replace the dry topping by wet topping, e.g. 1.5” concrete of at least 15.6 lb./ft.$^2$
  
- Replace the dry topping by wet topping, e.g. 1.5” concrete of at least 15.6 lb./ft.$^2$
### Design Examples for >45 FSTC and FIIC Floors

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<td>2 = 1/8” resilient underlayment of 0.16 to 0.37 lb./ft.²</td>
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<td></td>
<td>3 = 5-layer CLT of 6-7/8”</td>
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</tr>
<tr>
<td></td>
<td>4 = Sound isolation clips of 4” high</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>5 = Metal hat channel at 16” o.c.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 = Sound absorption material (such as glass fibre) of 4”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 = Gypsum board of 5/8”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 = Gypsum board of 5/8”</td>
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</table>

**- Replace 1)** by hardwood flooring nailed to ¾” plywood

**- Replace 2)** by thick resilient underlayment, e.g. 2/5” rubber mat of 0.84 lb./ft.², ¾” texture felt of 0.27 lb./ft.², ½” low-density wood fibre board of 0.73 lb./ft.²

|                           | ~53  | ~53  |
|                           |      |      |

- Replace 1) by ceramic tile glued to ½” and ¾” plywood

- Replace 2) by thick resilient underlayment, e.g. 2/5” rubber mat of 0.84 lb./ft.², ¾” texture felt of 0.27 lb./ft.², ½” low-density wood fibreboard of 0.73 lb./ft.²

|                           | ~53  | ~53  |
|                           |      |      |

---

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

- **Floor detail**: 1 = Carpet, or flooring about 2/5”
  - 2 = 1/8” resilient underlayment of 0.16 to 0.37 lb./ft.²
  - 3 = 5-layer CLT of 6-7/8”
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  - 5 = Metal hat channel at 16” o.c.
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- **FSTC**: ~50
- **FIIC**: ~50

- **Floor detail**:
  - Replace 1) by hardwood flooring nailed to ¾” plywood
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- **FSTC**: ~53
- **FIIC**: ~53
Chapter 9 - Sound

- Acoustic properties of CLT
- STC and IIC rated assemblies
- FSTC and FIIC rated assemblies
- Recommendations for meeting IBC requirements
1. Are there any substitutions for more common acoustic assembly materials?

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?

   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
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

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.
Roof Assemblies
CLT Handbook - Chapter 10

- Properties of CLT
  - Water vapor absorption
  - 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 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 (RSI/cm)]</th>
<th>Exterior insulation thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 inches R-value (RSI)</td>
<td>4 inches R-value (RSI)</td>
</tr>
<tr>
<td>3½-inch-thick CLT panels</td>
<td>17.2 (3.0)</td>
<td>20.9 (3.7)</td>
</tr>
<tr>
<td>R-4/inch (0.28/cm)</td>
<td>19.8 (3.5)</td>
<td>24.4 (4.3)</td>
</tr>
<tr>
<td>R-5/inch (0.34/cm)</td>
<td>17.2 (3.0)</td>
<td>20.9 (3.7)</td>
</tr>
</tbody>
</table>
WoodWorks – Portal to CLT Information

Mass Timber/CLT

For more mass timber and CLT-related resources, visit www.rethinkwood.com/masstimber.

- Code-Related
  - APA Product Reports® – APA
  - Approved changes to the 2015 International Building Code – American Wood Council

- Research
  - Fire Test Report: Cross Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing) – American Wood Council
  - Timber Tower Research Project – Skidmore Owings Merrill
Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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386-871-8808

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