Mass Timber Cost Optimization: How the Details Influence the Big Picture

Bruce Lindsey, Regional Director, WoodWorks – Wood Products Council

Photo: Texas Timber Frames
WHAT’S UNIQUE ABOUT MASS TIMBER?
IT’S (RELATIVELY) NEW
STRUCTURE = FINISH = FIRE PROTECTION
COST OPTIMIZATION MUST ACCOUNT FOR MORE THAN COST (OF TIMBER)
Mass Timber Construction Types
3-4 Story Building Options
# Mass Timber Construction Types

## 3-4 Story Building Options

<table>
<thead>
<tr>
<th></th>
<th>Type IIIB</th>
<th>Type VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Building Height</td>
<td>4 stories / 75 ft</td>
<td>4 stories / 70 ft</td>
</tr>
<tr>
<td>Allowable Area</td>
<td>57k SF / 171k SF</td>
<td>54k SF / 162k SF</td>
</tr>
<tr>
<td>Interior FRR</td>
<td>0 HR</td>
<td>1 HR</td>
</tr>
<tr>
<td>Interior materials</td>
<td>Any material</td>
<td>Any material</td>
</tr>
<tr>
<td>Interior partitions</td>
<td>0 HR non-brng</td>
<td>0 HR non-brng</td>
</tr>
<tr>
<td>Exterior Bearing Walls</td>
<td>FRTW or Non-com, 2 HR</td>
<td>Any material, 1 HR</td>
</tr>
<tr>
<td>Concealed Spaces</td>
<td>Permitted</td>
<td>Permitted</td>
</tr>
</tbody>
</table>

- **3-ply Floors**
  - No CLT ext. walls
  - Connections/Penetrations not rated

- **5-ply Floors**
  - CLT ext. walls
  - Connections/Penetrations rated
20x25 Grid No Intermediate Beams
5-ply CLT
VA or IIIB

20x20 Grid w/1 Intermediate Beam per Bay
3-ply CLT
IIIB

Photos: WoodWorks
Non-rated Connections
IIIB

Rated Connections
VA or IIIB

Photos: WoodWorks
Mass Timber Fire Design Resource
• Code compliance options for demonstrating FRR
• Construction type considerations
• Free download at woodworks.org
# MT Fire Resistance Ratings (FRR)

## Inventory of Fire Tested MT Assemblies

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Manufacturer</th>
<th>CLT Grade or Major x Minor Grade</th>
<th>Ceiling Protection</th>
<th>Panel Connection in Test</th>
<th>Floor Topping</th>
<th>Load Rating</th>
<th>Fire Resistance Achieved (Hours)</th>
<th>Source</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (144 mm x 4.88 in)</td>
<td>Nordic</td>
<td>SPF 16.50 lb. 1.5 EMSP x SPF 2</td>
<td>1 layer 1/2&quot; Type X Gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 90% Moment Capacity</td>
<td>1</td>
<td>Test 1</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>3-ply CLT (165 mm x 4.13 in)</td>
<td>Structalam</td>
<td>SPF #102 x SPF #102</td>
<td>1 layer 5/8&quot; Type X Gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 75% Moment Capacity</td>
<td>1</td>
<td>Test 5</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>EI</td>
<td>None</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; x 2&quot; cement boards</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>NRC Fire Laboratory March 2016</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer of 1 1/2&quot; Type X Gypsum under Z-Channel and Strips x 3 5/8&quot;</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; x 2&quot; cement boards</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>5</td>
<td>NRC Fire Laboratory Nov 2014</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>EI</td>
<td>None</td>
<td>Topside Spline</td>
<td>3/4 in proprietary gypsum over mass on acoustical mat</td>
<td>Reduced 100% Moment Capacity</td>
<td>3</td>
<td>3</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer 5/8&quot; normal gypsum</td>
<td>Topside Spline</td>
<td>3/4 in proprietary gypsum over mass on acoustical mat or proprietary sound board</td>
<td>Reduced 100% Moment Capacity</td>
<td>4</td>
<td>4</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>EI</td>
<td>1 layer 8 1/2&quot; Type X Gypsum under 3/4&quot; x 2 1/4&quot; T-Channel</td>
<td>Topside Spline</td>
<td>3/4 in proprietary gypsum over mass on acoustical mat or proprietary sound board</td>
<td>Reduced 100% Moment Capacity</td>
<td>21</td>
<td>21</td>
<td>InterTek 8/24/2012</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Structalam</td>
<td>M2 2010 x SPF 2</td>
<td>None</td>
<td>Topside Spline</td>
<td>1/2&quot; Masonite Gypsum 2000 over Masonite Reinforcing Mesh</td>
<td>Laminated, See Manufacturer</td>
<td>23</td>
<td>23</td>
<td>InterTek, 2/22/2016</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>DR Johnson</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap &amp; Topside Spline</td>
<td>2&quot; gypsum</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>SwRI (May 2016)</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Nordic</td>
<td>SPF 1910 Fb MIS x SPF 2</td>
<td>None</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 100% Moment Capacity</td>
<td>3</td>
<td>3</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>7-ply CLT (244 mm x 6.35&quot;)</td>
<td>Structalam</td>
<td>SPF #102 x SPF #102</td>
<td>1 layer 5/8&quot; Type X Gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced 100% Moment Capacity</td>
<td>4</td>
<td>4</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Smartlam</td>
<td>SV/4</td>
<td>None</td>
<td>Half-Lap</td>
<td>nominal 1/2&quot; plywood w/ 8d nails</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>Western Fire Center 10/26/2016</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>Smartlam</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap</td>
<td>nominal 1/2&quot; plywood w/ 8d nails</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>Western Fire Center 10/28/2016</td>
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<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>DR Johnson</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap</td>
<td>nominal 1/2&quot; plywood w/ 8d nails</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>Western Fire Center 11/01/2016</td>
</tr>
<tr>
<td>5-ply CLT (175 mm x 6.75&quot;)</td>
<td>KLI</td>
<td>CV/3M1</td>
<td>None</td>
<td>Half-Lap &amp; Topside Spline</td>
<td>None</td>
<td>Laminated, See Manufacturer</td>
<td>2</td>
<td>2</td>
<td>SwRI</td>
</tr>
</tbody>
</table>

Credit: WoodWorks
New Tall Mass Timber Types

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

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

9 STORIES
BUILDING HEIGHT 120 FT
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

6 STORIES MAXIMUM
85' MAXIMUM BUILDING HEIGHT
324,000 SF MAXIMUM AREA

IBC 2021

BUSINESS OCCUPANCY [GROUP B]

*BUILDING FLOOR-TO-FLOOR HEIGHTS ARE SHOWN AT 12'-0" FOR ALL EXAMPLES FOR CLARITY IN COMPARISON BETWEEN 2015 TO 2021 IBC CODES.

Credit: Susan Jones, atelierjones
Tall Wood Buildings in the 2021 IBC
Up to 18 Stories of Mass Timber

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

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

Background: ICC Tall Wood Building
Ad Hoc Committee
Over the past 10 years, there has been a growing interest in tall buildings constructed from mass timber materials (Breneman 2013, Timmers 2015). Around the world th
Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures

Richard McCain, PE, SE • Senior Technical Director • Tall Wood, WoodWorks

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

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

FRRs for the new construction types are similar to those required for Type I construction, which is primarily steel and concrete. (See Table 1.) They are found in IBC Table 211, which includes FRR requirements for all construction types and building elements. However, other code sections should be checked for overriding provisions (e.g., occupancy separation, shaft enclosures, etc.) that may alter the requirement.

### Table 1: FRR Requirements (Hours) for Tall Mass Timber Construction Types and Existing Type I

<table>
<thead>
<tr>
<th>Building Element</th>
<th>I-A Unlimited stories</th>
<th>IV-A 10 stories</th>
<th>IV-B Max 12 stories</th>
<th>IV-C Max 2 stories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior Bearing Walls</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Load-Bearing Walls</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Walls</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Mass Timber: Structure Often is Finish
But by Itself, Not Adequate for Acoustics
## Mass Timber Acoustics

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

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

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

One of the main reasons is “mass”
Recall the three ways to increase acoustical performance:

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

CLT Slab:
6-7/8” Thick
18 PSF
STC 41

Mass Timber Acoustics
There are three main ways to improve an assembly’s acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics and Mass Timber: Room-to-Room Noise Control

Richard McCullin, PE, ME • Senior Technical Director • WoodWorks

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

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

Inventory of Tested Assemblies

Acoustically-Tested Mass Timber Assemblies

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

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A Few Notes About the Inventory

**Mass Timber Assemblies**

**Effect of Timber Thickness**

**Without Dropped Ceiling**

- Minimum 1" noncombustible material
- Mass timber floor panel

3-ply CLT
- STC 53
- IIC 48

5-ply CLT
- STC 53
- IIC 52

**With Dropped Ceiling**

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

Dropped ceiling

- STC 53
- IIC 48

LVT on 2” Concrete
**Mass Timber Assemblies**

**Without Dropped Ceiling**

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

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

**With Dropped Ceiling**

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

**Effect of Gypsum Ceiling**

- STC 51
- IIC 43
- STC 52
- IIC 48
- STC 63
- IIC 63
MASS TIMBER WHY’S

- Innovation and Aesthetic Appeal
- Speed of Construction
- Construction Site Constraints – Urban Infill
- Labor Shortages
- Structural Performance - Lightweight
- Business Case for Healthy Buildings
KNOW YOUR WHY

COST

VALUE

Cost

Value
<table>
<thead>
<tr>
<th>Potential Benefits</th>
<th>Project Goal</th>
<th>Value Add</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast construction</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aesthetic Value (Leasing velocity/ premiums)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy Building / Biophilia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightweight structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor shortage solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• small crews</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• entry level workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just-in-time delivery (ideal for dense urban sites)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmentally friendly (low carbon footprint)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy forests/ wildfire resiliency &amp; support rural economies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reduce Risk
Optimize Costs

- For the entire project team, not just builders
- Lots of reference documents

Mass Timber Cost and Design Optimization Checklists

WoodWorks has developed the following checklists to assist in the design and cost optimization of mass timber projects. The design optimization checklists are intended for building designers (architects and engineers), but many of the topics should also be discussed with the fabricators and builders. The cost optimization checklists will help guide coordination between designers and builders (general contractors, construction managers, estimators, fabricators, installers, etc.) as they are estimating and making cost-related decisions on a mass timber project.

Most resources listed in this paper can be found on the WoodWorks website. Please see the end notes for URLs.
Is Mass Timber Cost Competitive?
Risk: Cost Analysis of Structure Only

Source: GBD Architects
Seattle Mass Timber Tower: Detailed Cost Comparison

Fast Construction

- Textbook example done by industry experts
- Mass timber vs. PT conc
- Detailed cost, material takeoff & schedule comparisons

“The initial advantage of Mass Timber office projects in Seattle will come through the leasing velocity that developers will experience.”
- Connor Mclain, Colliers

Download Case Study:
Seattle Mass Timber Tower
Fast Construction

Construction Schedule:

Source: Tall With Timber
A Seattle Mass Timber Tower Case Study by DLR Group
# Seattle Mass Timber Tower

Faster Construction + Higher Material Costs = Cost Competitive

<table>
<thead>
<tr>
<th>System</th>
<th>Mass Timber Design</th>
<th>PT Concrete Design</th>
<th>Mass Timber Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Cost of Work</td>
<td>$86,997,136</td>
<td>$85,105,091</td>
<td>2.2%</td>
</tr>
<tr>
<td>Project Overhead</td>
<td>$ 9,393,750</td>
<td>$11,768,750</td>
<td>-20.2%</td>
</tr>
<tr>
<td>Add-Ons</td>
<td>$ 8,387,345</td>
<td>$ 8,429,368</td>
<td>-0.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$104,778,231</strong></td>
<td><strong>$105,303,209</strong></td>
<td><strong>-0.5%</strong></td>
</tr>
</tbody>
</table>

Source: DLR Group | Fast + Epp | Swinerton Builders
Compressing the Typical Schedule

- **Fast Construction**

  - Below-grade foundations + soils
    - Less soil remediation + smaller foundations
      - for sites with problematic soils

  - Mass timber structure
    - Faster erection (prefabricated + precise)
    - If prefabricated, savings in enclosure time

  - Building envelope/exteriors
    - Earlier start*

  - MEP
    - MEP fully coordinated in design phase & therefore installed faster
    - Earlier start*

  - Interior finishes
    - Less finishes with exposed wood structure
    - Earlier start*

  - Overall mass timber construction schedule

  - Up to 25% schedule savings
    - = Less carrying costs
    - + Less GC overhead
    - + Ability to lease/occupy sooner

*Earlier start for follow-up trades; no waiting for cure times

Source: Mass Timber Cost & Design Optimization, WoodWorks²
Schedule Savings for Rough-In Trades
Fast Construction

NO curing (mass timber)

Curing & maze of shores (concrete)
Keys to Mass Timber Success:

Know Your WHY

Design it as Mass Timber From the Start

Leverage Manufacturer Capabilities

Understand Supply Chain

Optimize Grid

Take Advantage of Prefabrication & Coordination

Expose the Timber

Discuss Early with AHJ

Work with Experienced People

Let WoodWorks Help for Free

Create Your Market Distinction
QUESTIONS?
This concludes The American Institute of Architects Continuing Education Systems Course

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