Mid-Rise Multi-Family: Exploring Light-Frame and Mass Timber Solutions

February 15, 2024

Presented by
Kate Carrigg, PE, WoodWorks
Chelsea Drenick, SE, WoodWorks
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Get to Know Us
<table>
<thead>
<tr>
<th>Building Systems</th>
<th>Building Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-Frame</td>
<td>Multi-Family / Mixed Use</td>
</tr>
<tr>
<td>Mass Timber / CLT</td>
<td>Education</td>
</tr>
<tr>
<td>Off-Site / Panelized Construction</td>
<td>Office</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Commercial Low-Rise</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
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<td></td>
<td>Civic / Recreational</td>
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<tr>
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<td>Institutional / Healthcare</td>
</tr>
</tbody>
</table>

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WoodWorks Innovation Network
Discover mass timber projects across the US and connect with their teams.
Acoustics and Mass Timber: Room-to-Room Noise Control
This paper covers key aspects of mass timber acoustical design, including rules of thumb for optimal design, common assemblies, detailing strategies, and flanking paths. Companion to the Inventory of Mass Timber Acoustical Assemblies.

Expert Tips

Impact of Wall Stud Size and Spacing on Fire and Acoustic Performance
Interior wall partitions in a wood-frame building—such as unit demising and corridor walls in a multi-family project—must meet several design objectives simultaneously. Two primary functions are fire resistance and acoustical separation. Having to cite two tested wall assemblies, one for fire-resistance endurance results and another for acoustic results, is common.

Award Winner

Firehouse 12
The continuous plywood shell that creates varying acoustic conditions within the performance space forms the exterior of the auditorium.

Acoustical Considerations for Mixed-Use Wood-Frame Buildings
This paper will help you understand the effects of acoustics in the context of other performance areas, enabling you to more easily navigate the decisions and trade-offs required when evaluating assembly options.

Solution Papers

Holes and Penetrations in Mass Timber Floor and Roof Panels
Guidance for the design of mass timber floor and roof panels with openings, including structural, fire resistance, and acoustic impacts, and tips for reinforcement.

Expert Tips
Who are you looking for?

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Funding Partners
Attendee Notes

1. To receive a certificate of completion, stay on for the duration of the webinar.

2. The PDF of today’s presentation can be found on WoodWorks.org under the Events tab—then Presentation Archives.
## Agenda

### Mid-Rise Multi-Family: Exploring Light-Frame and Mass Timber Solutions

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00 - 11:40 am</td>
<td>Welcome, Introduction to Mid-Rise (Chelsea Drenick)</td>
</tr>
<tr>
<td>11:40 – 11:45 am</td>
<td>5-minute Break</td>
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<tr>
<td>11:45 am – 12:45 pm</td>
<td>Design Considerations (Kate Carrigg)</td>
</tr>
<tr>
<td>12:45 -12:50 pm</td>
<td>5-minute Break</td>
</tr>
<tr>
<td>12:50-1:10 pm</td>
<td>Case Studies and Design Example (Chelsea Drenick)</td>
</tr>
<tr>
<td>1:10-1:30 pm</td>
<td>Q&amp;A (Chelsea Drenick &amp; Kate Carrigg)</td>
</tr>
</tbody>
</table>
“The Wood Products Council” is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

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This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.
Course Description

This presentation will help designers understand the breadth of considerations associated with mid-rise multi-family buildings for both light-frame wood and mass timber construction. It will begin with a review of occupancies and construction types, emphasizing opportunities for wood use in Types III, IV and V construction. Methods for optimizing the design of mid-rise wood buildings will also be explored, including how to maximize a project’s height and area using sprinklers, open frontage, sloping sites, podiums, and mezzanines. Essential detailing practices for multi-family construction, including detailing for fire-resistance ratings, acoustical performance, and shrinkage, will also be reviewed for both light frame and mass timber.
Learning Objectives

1. Discuss allowable construction types, occupancies, and building heights and areas for wood-frame mid-rise construction per the International Building Code (IBC).
2. Identify potential modifications to the IBC’s base tabular heights and areas based on building frontage, sprinklers, sloping sites, podiums, and mezzanines.
3. Review code requirements unique to mass timber and light-frame housing projects and emphasize solutions for criteria such as construction type, fire-resistance ratings, and acoustics design.
4. Discuss wood’s shrinkage potential and causes, identify shrinkage effects on structural and non-structural components, and review detailing best practices to minimize shrinkage effects.
Outline

» Introduction to Mid-Rise Construction
  Terminology
  Construction Types
  Maximizing Heights and Areas

» Design Considerations
  Lateral System Options
  Acoustics
  Fire Resistance Ratings
  Shaft Walls
  Exterior Walls
  Moisture and Shrinkage

» Case Studies and Design Example
Light-Frame Wood
Photo: WoodWorks

Heavy Timber
Photo: Benjamin Benschneider

Mass Timber
Photo: John Stamets
Glue Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo: StructureCraft
Photo: LendLease
Photo: Freres Lumber
Dowel-Laminated Timber (DLT)

Nail-Laminated Timber (NLT)

Glue-Laminated Timber (GLT)

Plank orientation
What is CLT?

3+ layers of laminations

**Solid Sawn or Structural Composite Lumber Laminations**

Cross-Laminated Layup

Glued with Structural Adhesives

*All dimensions are approximate. Consult with manufacturers*
Cross-Laminated Timber (CLT) in the Code

CLT is defined in Chapter 2 Definitions:

[BS] 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.
Common CLT Layups

Most Designs
Least $/sf

3-ply 3-layer
5-ply 5-layer
7-ply 7-layer
9-ply 9-layer

Most Common for Multi-Family
Framing Options for Mass Timber Multi-Family

Mass Timber Floors & Roofs on LWF Bearing Walls
Credit: KL&A Engineers & Builders

Mass Timber Floors & Roofs on Mass Timber Bearing Walls
Credit: Grey Organschi Architecture and Spiritos Properties
Framing Options for Mass Timber Multi-Family

Mass Timber Floors & Roofs on Post & Beam Framing

Mass Timber Floors & Roofs on Posts (Flat Plate)

Credit: ADX Creative and Engberg Anderson

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

AKA Components, Sub-Assemblies
Typically, just structure and sheathing:

• Wall panels – wall framing and sheathing.
• Floor and roof cassettes – floor/roof framing and sheathing.
Panelized Construction

Shear wall hold downs and panel-to-panel stitching installed in field.

Image: Entekra
Floor and Roof Cassettes

Typically fabricated in single-bay lengths, 8’-12’ widths.
Modular Construction (aka Volumetric Modular)

Multi-Family Units:
» Hotel Rooms
» Apartments
» Condos
» Workforce Housing
» Student Housing
Modular Construction (aka Volumetric Modular)

Significant Differences from Prefabricated Construction.
Volumetric Shipping & Erection Foundation Requirements.
Mid-Rise Construction

» Senior Living
» Apartments/Condos
» Mixed Use
» Student Housing
» Affordable Housing
» Hotels

Where **wood** is a viable option, it’s likely the most appropriate choice.

The Gibson, Hummel Architects, KPFF Consulting Engineers, photo Leo A. Geis
Why Wood?

Using wood helps reduce environmental impact
Wood products play significant role in modern economy

- Wood Costs Less
- Wood is Versatile
- Wood Meets Code
- Wood is Durable
- Wood is Renewable

Photo courtesy OFRI

The Gibson, Hummel Architects, KPFF Consulting Engineers, photo Leo A. Geis
Carbon Case Study

AvalonBay Stadium - Anaheim, CA

WoodWorks Resources
https://www.woodworks.org/why-wood/sustainability/

Whole Building Life Cycle Assessment (WBLCA)
» Introduction to Whole Building Life Cycle Assessment: The Basics
» Worksheet for Structural WBLCA of Mass Timber Buildings
» WBLCAs of Built Projects

Expert articles on topics such as:
» Biogenic Carbon in LCA Tools
» Long-Term Biogenic Carbon Storage
» What Net Zero Means in Building Construction
» Environmental Product Declarations (EPDs)

Volume of wood used:
5,200 cubic meters / 183,600 cubic feet of lumber and sheathing

U.S. and Canadian forests grow this much wood in:
15 minutes

Carbon stored in the wood:
3,970 metric tons of CO₂

Avoided greenhouse gas emissions:
8,440 metric tons of CO₂

TOTAL POTENTIAL CARBON BENEFIT:
12,410 metric tons of CO₂

EQUIVALENT TO:
2,370 cars off the road for a year
Energy to operate a home for 1,050 years

For information on the calculations in this chart, visit woodworks.org
Note: CO₂ on this chart refers to CO₂ equivalent.
Mid-Rise vs. High-Rise Definition – IBC 202

**IBC 202**: High-Rise Building: A building with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access.
Light-Frame Wood Mid-Rise Construction

6 stories for Offices,
5 stories for Residential
+ Mezzanine
+ Multi-Story Podium

Photo credit: Matt Todd & PB Architects
Walk-up / Tuck Under

First floor walk up units with private garage

Benefits:

» Eliminates need for S-2 parking garage
» Can be all wood
» Least expensive overall but lowest densification rates (20-35 units/acre)
Wrap-Around

Walk up units surround parking structure

Benefits:
» Enhanced security
» Centralized access to parking
» Visual appeal from street
» More expensive than walk/up tuck-under
» 5 story yields 60-80 units/acre
Podium

Multiple stories of wood over an elevated concrete deck

Benefits:

» Increased number of stories
» Accommodates mixed-use occupancies
» Most expensive but can allow increased density
» 4 stories over podium: 60-80 units/acre
» 5 stories over podium: 100-120 units/acre
» 5 stories with mezzanine + residential podium: 125-145 units/acre
Horizontal Building Separation – 510.2

Considered separate buildings above and below for purposes of area calculations if:

» Overall height is still limited to minimum of either building construction type
» 3hr rated horizontal assembly
» Building below is Type 1A with sprinklers
» Enclosures penetrating horizontal assembly are 2hr rated
» Occupancy above is A (occupant load <300), B, M, R or S
» Occupancy below is any except H
Parking Beneath Group R – IBC 510.4

Possibility of a **Type IV podium** where number of stories starts above parking when:

» Occupancy above is R and below is S-2

» Lower floor is open Type IV parking with grade entrance

» Horizontal assembly between 1st and 2nd floor shall be:
  » Type IV
  » Have 1 hr fire resistance rating when sprinklered
  » Have 2 hr fire resistance rating when not sprinklered

» Overall height is still limited to occupancy

Mid-Rise Construction Types

**Type V (70 ft, 4 stories residential)**
- All building elements are any allowed by code

**Type III (85 ft, 5 stories residential)**
- Exterior walls non-combustible (may be FRTW)
- Interior elements any allowed by code

Types III and V can be subdivided to A (protected) or B (unprotected)

**Type IV-HT (85 ft, 5 stories residential)**
- Exterior walls non-combustible (may be FRTW or CLT)
- Interior elements qualify as Heavy Timber
Construction Types

Where does the code allow mass timber to be used?

• **Type V**: All interior elements, roofs & exterior walls
Type III Construction

» Exterior walls are of noncombustible materials and **interior building elements are of any material**. Fire Retardant Treated (FRT) wood is permitted in exterior walls of 2hr fire rating or less.

- **Non-combustible**
  » Exterior walls

- **Fire Retardant Treated allowed**
  » Exterior walls if fire rating is 2hr or less

- **Untreated Lumber**
  » All interior elements
Construction Types

Where does the code allow mass timber to be used?
• **Type III**: Interior elements (floors, roofs, partitions/shafts)
2021 IBC: 3 New Tall Mass Timber Construction Types
602.4 Type IV. Type IV construction is that type of construction in which the building elements are mass timber or noncombustible materials and have fire resistance ratings in accordance with Table 601. Mass timber elements shall meet the fire resistance rating requirements of this section based on either the fire resistance rating of the noncombustible protection, the mass timber, or a combination of both and shall be determined in accordance with Section 703.2 or 703.3. The minimum dimensions and permitted materials for building elements shall comply with the provisions of this section and Section 2304.11. Mass timber

**Exception:** Type IV-HT Construction in accordance with Section 602.4.4.
Sprinkler Systems: 2021 IBC 903.2

In some cases, sprinklers are required by code depending on occupancy

» Most new Group R fire areas
» Group A, E, M, S-1, I fire areas exceeding 1-12k sf
Commercial Sprinkler Systems – IBC 903.3.1

» NFPA 13
Standard for Commercial Construction 903.3.1.1

» NFPA 13R
Residential Occupancies (One- and Two-Family or Low-Rise Multi-Family and Commercial, 4 stories max above grade) 903.3.1.2

» NFPA 13D
Standard for One- and Two-Family Residences (but allowed in a few commercial occupancies) 903.3.1.3
# NFPA 13 vs. NFPA 13R

<table>
<thead>
<tr>
<th>NFPA 13</th>
<th>NFPA 13R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal:</strong> Provide life safety and property protection</td>
<td><strong>Goal:</strong> Provide life safety only</td>
</tr>
<tr>
<td>Fully sprinklered system throughout entire building even in unoccupied spaces (closets, attics)</td>
<td>Partially sprinklered system; unoccupied spaces often don’t require sprinklers</td>
</tr>
<tr>
<td>Can cost more</td>
<td>Lower levels of water discharge, shorter water supply time can result in smaller pipe sizes, reduce need for storage &amp; pumps</td>
</tr>
<tr>
<td>Permitted for many occupancies, buildings of many sizes, allows greater building size increases</td>
<td>Limited applications, mainly for multi-family up to 4 stories, 60 feet</td>
</tr>
</tbody>
</table>
### Height – 2021 IBC Table 504.3

2021 IBC: Table 504.3 provides base & increased heights

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
<th>TYPE OF CONSTRUCTION</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
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<tr>
<td></td>
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<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
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<tr>
<td>NS&lt;sup&gt;d&lt;/sup&gt;</td>
<td>UL</td>
<td>160</td>
<td>65</td>
<td>55</td>
<td>65</td>
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<tr>
<td>S13D</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>S13R</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>S</td>
<td>UL</td>
<td>180</td>
<td>85</td>
<td>75</td>
<td>85</td>
<td>70</td>
</tr>
</tbody>
</table>

**NS** = Buildings not equipped throughout with an automatic sprinkler system

**S** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

**S13R** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

**S13D** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.3 (NFPA 13D)
## Stories–2021 IBC Table 504.4

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
<th>TYPE OF CONSTRUCTION</th>
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</thead>
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<tr>
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<td>See Footnotes</td>
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<tr>
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<td>Type I</td>
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<tr>
<td>R-2&quot;</td>
<td>NS&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>S13R</td>
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</table>

**NS** = Buildings not equipped throughout with an automatic sprinkler system  
**S13R** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)  
**S** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)
HEIGHT, BUILDING. The vertical distance from grade plane to the average height of the highest roof surface.

GRADE PLANE. A reference plane representing the average of finished ground level adjoining the building at exterior walls. Where the finished ground level slopes away from the exterior walls, the reference plane shall be established by the lowest points within the area between the building and the lot line or, where the lot line is more than 6 feet (1829 mm) from the building, between the building and a point 6 feet (1829 mm) from the building.
A basement is not included in the total allowable building area if it doesn’t exceed the area permitted for a building with no more than one story above grade plane.

“Basement” is defined as “not a story above grade plane” and has a finished floor surface:
• Less than 6 feet above grade plane; or
• Less than 12 feet above the finished ground level at any point
Mezzanines – 2021 IBC 505

Not counted toward building area* or number of stories if:

» Maximum 1/3 floor area of room or space where located

» Special egress provisions apply

» Must be open and unobstructed to room in which it’s located (walls ≤ 42” allowed)
  » Several exceptions

» Slightly different for equipment platforms

*Does count toward fire area with regard to fire protection in Chapter 9
### Area Factor – 2021 IBC 506.2

**TABLE 506.2**

**ALLOWABLE AREA FACTOR (A = NS, S1, S13R, or SM, as applicable) IN SQUARE FEET**

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
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<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>R-2°</td>
<td>NS&lt;sup&gt;2&lt;/sup&gt;</td>
<td>UL</td>
<td>UL</td>
<td>24,000</td>
<td>16,000</td>
<td>24,000</td>
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<td>64,000</td>
<td>96,000</td>
<td>64,000</td>
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<td></td>
<td>S1</td>
<td>UL</td>
<td>UL</td>
<td>72,000</td>
<td>48,000</td>
<td>72,000</td>
<td>48,000</td>
</tr>
</tbody>
</table>

**Can increase these areas by the Frontage Factor of Section 506.3**

**NS** = Buildings not equipped throughout with an automatic sprinkler system

**S1** = Buildings a maximum of one story above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

**S13R** = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

**SM** = Buildings two or more stories above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)
CALIFORNIA SPECIFIC: CBC Size Limits

CBC has historically not allowed “double-dipping” for sprinkler increases of building area and height for occupancies A, E, H-4, H-5, I, R-1 and R-2

Also, for multi-story buildings that are occupancy group A, E, H, I, L or R, the total building area is equal to the allowable floor area multiplied by the number of stories not to exceed 2. In IBC, this value is not to exceed 3.
For example, if using sprinkler area increases, allowable height is **20 ft and 1 story less than IBC max limits** for occupancies A, E, H-4, H-5, I, R-1 and R-2

### TABLE 504.4—continued
**ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE**

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
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<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>R-2h</td>
<td>UL</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>NS1'</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>S13R</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>S (with height increase)</td>
<td>UL</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>S (with area increase)</td>
<td>UL</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

### TABLE 506.2a,b
**ALLOWABLE AREA FACTOR**

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
<th>TYPE OF CONSTRUCTION</th>
<th>A1, NS, S1, S13R, or SM, as applicable</th>
<th>IN SQUARE FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UL</td>
<td>24,000</td>
<td>16,000</td>
</tr>
<tr>
<td></td>
<td>UL</td>
<td>96,000</td>
<td>64,000</td>
</tr>
<tr>
<td></td>
<td>UL</td>
<td>72,000</td>
<td>48,000</td>
</tr>
<tr>
<td></td>
<td>SM (with area increase)</td>
<td>UL</td>
<td>24,000</td>
</tr>
<tr>
<td></td>
<td>SM (with area increase)</td>
<td>UL</td>
<td>24,000</td>
</tr>
</tbody>
</table>
Single Occupancy, 1 Story – 506.2.3

\[ A_a = A_t + [NS \times I_f] \]

(Equation 5-1)

- \( A_a \) = Allowable area per story (sq. ft.)
- \( A_t \) = Tabular allowable area per story per Table 506.2 for NS, S1 or S13R (sq. ft.)
- \( NS \) = Tabular allowable area per story per Table 506.2 for non-sprinklered building (sprinklered or not)
- \( I_f \) = Area increase factor due to frontage per 506.3
  \( I_{f, \text{max}} = 0.75 \)
The allowable area of a building is permitted to be increased when it has a certain amount of frontage on streets (public ways) or open spaces, since this provides access to the structure by fire service personnel, a temporary refuge area for occupants as they leave the building in a fire emergency and a reduced exposure to and from adjacent structures.
Frontage Increases – IBC 506.3.3

» 2021 IBC / 2022 CBC: Frontage increase calculation simplified

» Frontage increase is based on the smallest public way or open space that is >20’ and the percentage of the building perimeter having >20’ frontage (506.3.1 & 506.3.2).

» Area factor determined in accordance with table 506.3.3

<table>
<thead>
<tr>
<th>PERCENTAGE OF BUILDING PERIMETER</th>
<th>OPEN SPACE (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to less than 20</td>
</tr>
<tr>
<td>0 to less than 25</td>
<td>0</td>
</tr>
<tr>
<td>25 to less than 50</td>
<td>0</td>
</tr>
<tr>
<td>50 to less than 75</td>
<td>0</td>
</tr>
<tr>
<td>75 to 100</td>
<td>0</td>
</tr>
</tbody>
</table>

a. Interpolation is permitted.

TABLE 506.3.3
FRONTAGE INCREASE FACTOR*
Total Building Area – 2021 IBC 506.2.3

\[ A_a = [A_t + (NS \times I_f)] \times S_a \]

(Equation 5-2)

- \( A_a \) = Total allowable area more than 3 stories (sq. ft.)
- \( A_t \) = Tabular allowable area per story per Table 506.2 for NS, S1 or S13R (sq. ft.)
- \( NS \) = Tabular allowable area per story per Table 506.2 for non-sprinklered building (sprinklered or not)
- \( I_f \) = Area increase factor due to frontage per 506.3
  - \( I_f, \text{ max} = 0.75 \)
- \( S_a \) = Actual number of building stories above grade
  - \( S_{a, \text{ max}} = 3 \) for non-sprinklered buildings and those w/ NFPA13
  - \( S_{a, \text{ max}} = 4 \) for buildings w/ NFPA 13R
  - \( S_{a, \text{ max}} = 2 \) For Group A, E, H, I, L and R occupancies, high-rise buildings, regulated by the Office of the State Fire Marshal, actual number of building stories above grade plane, not to exceed two. (CALIFORNIA ONLY)
Mixed Occupancy, Multi-story


To simplify code analysis, this document provides logical, code-compliant steps for key elements of design—such as determining allowable building size, fire separation needs, detailing requirements and the application of special provisions.
Construction Type – Primarily based on building size & occupancy

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)</th>
<th>Allowable Number of Stories above Grade Plane (IBC Table 505.4)</th>
<th>Allowable Area Factor (At) for SM, Feet² (IBC Table 506.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>270</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>R-2</td>
<td>18</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>R-2</td>
<td>184,500</td>
<td>76,875</td>
<td>61,500</td>
</tr>
</tbody>
</table>
R-2 Occupancy, Type III-A vs Type IV-C

Type III-A

8 Stories
85 ft

Type I-A

Type IV-C

8 Stories
85 ft
Outline

» Introduction to Mid-Rise Construction
   Terminology
   Construction Types
   Maximizing Heights and Areas

» Design Considerations
   Lateral System Options
   Acoustics
   Fire Resistance Ratings
   Shaft Walls
   Exterior Walls
   Moisture and Shrinkage

» Case Studies and Design Example
What is being enforced in jurisdictions you are working in?
Lateral Systems

Prescriptive Code Compliance:

- Light Frame Wood Shear Walls (65 ft max)
- CLT Shear Walls (65 ft max) – Per 2021 SDPWS/ASCE 7-22
- Concrete Shear Walls
- Steel Braced Frames
- **CLT Rocking Walls** Currently in development!
CLT Walls – Platform Framed
R Values for CLT Shear Walls in SDPWS 2021

(Other)

CLT Shear Walls
not meeting Appendix B

\[ R = 1.5 \]
\[ C_d = 1.5 \quad \Omega_o = 2.5 \]
In SDPWS 2021 4.6.3

CLT Shear Walls
meeting SDPWS 2021 Appendix B

\[ R = 3.0^* \]
\[ C_d = 3.0 \quad \Omega_o = 3.0 \]

\[ R = 4.0^* \]
\[ C_d = 4.0 \quad \Omega_o = 3.0 \]

* ASCE 7-22

Panel aspect ratios
\[ 2 \leq h/b_s \leq 4 \]

Panel aspect ratios
\[ h/b_s = 4 \]
Panelized Construction

Shear wall hold downs and panel-to-panel stitching installed in field.
State of Oregon Statewide Alternative

Statewide Alternate Method
No. 15-01

Cross-laminated timber
Seismic force-resisting systems

Statewide Alternate Methods are approved by the division administrator in consultation with the appropriate advisory board. The advisory board’s review includes technical and scientific facts of the proposed alternate method. In addition:

- Building officials shall approve the use of any material, design or method of construction addressed in a statewide alternate method;
- The decision to use a statewide alternate method is at the discretion of the applicant; and
- Statewide alternate methods do not limit the authority of the building official to consider other proposed alternate methods encompassing the same subject matter.

Code/edition/section: 2022 Oregon Structural Specialty Code (OSSC)—Section 1613
American Society of Civil Engineers (ASCE) 7-2016 or ASCE 7-2022

Date: Issued—Jan. 15, 2015
Updated—Feb. 2, 2023

Subject: Cross-laminated timber (CLT)—Seismic force-resisting system

Background:
Cross-laminated timber (CLT) is a wood product with both residential and nonresidential applications. CLT is defined and recognized as a viable construction material subject to specific construction requirements within Chapters 2, 5, 6, 7, 17 and 23 of the 2022 OSSC. Building Codes Division has prepared this statewide alternate method to recognize CLT shear walls as a seismic force-resisting system (SFRS) for the application of ASCE 7-16 or ASCE 7-22, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Section 12.2, utilizing prescriptive design procedures.

Structures exceeding the prescriptive design procedures contained in this statewide alternate method will need to follow the performance-based procedures as outlined in OSSC Section 104.10 and ASCE 7-16 Section 1.3.1.3.

Discussion:
ASCE 7-16 is the standard referenced in OSSC Section 1613 for the development of seismic design loads and associated criteria for structures. ASCE 7-16 Chapter 12 establishes seismic design coefficients and factors for various types of structures, including CLT buildings.
CLT Walls – Balloon Framed

Photo Credit: Alex Schreyer
Acoustics & Sound Control

Code requirements only address residential occupancies:

For unit to unit or unit to public or service areas:

Min. Sound Transmission Class (STC) of 50 (45 if field tested):
• Walls, Partitions, and Floor/Ceiling Assemblies

Min. Impact Insulation Class (IIC) of 50 (45 if field tested) for:
• Floor/Ceiling Assemblies
## Acoustical Criteria

### Acoustical Isolation Between Units – Airborne (STC) / Impact (IIC)

<table>
<thead>
<tr>
<th>Class Designation</th>
<th>Airborne Sound Isolation (STC)</th>
<th>Floor Ceiling Impact Isolation (IIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry level</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Market rate</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Luxury</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>
Choosing Acoustically Rated Assemblies

Common tested assemblies:

**STC:** ASTM E90, per IBC 1206.2
**IIC:** ASTM E492, per IBC 1206.3

- Manufacturers (proprietary tests)
- UL Listings
- Industry associations: Gypsum Catalog, AWC, APA, others
- Reach out to **WoodWorks**!

Alternate Method: IBC 1206.2 & 1206.3

- Both STC and IIC may be “established by engineering analysis based on a comparison of floor-ceiling assemblies having [STC/IIC] ratings as determined by the test procedures.”
Acoustics & Sound Control

There are **3 effective methods** of improving acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
There are 3 effective methods of improving acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
There are **3 effective methods** of improving acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
# 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[^4]</td>
<td>3.07&quot;</td>
<td>33</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT wall[^4]</td>
<td>6.875&quot;</td>
<td>38</td>
<td>N/A</td>
</tr>
<tr>
<td>5-ply CLT floor[^5]</td>
<td>5.1875&quot;</td>
<td>39</td>
<td>22</td>
</tr>
</tbody>
</table>

There are **3 effective methods** of improving acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers
Acoustics & Sound Control
### Choosing Mass Timber Assemblies

#### Inventory of Tested Assemblies

**Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed**

<table>
<thead>
<tr>
<th>CLT Panel</th>
<th>Concrete/Gypsum Topping</th>
<th>Acoustical Mat Product Between CLT and Topping</th>
<th>Finish Floor</th>
<th>STC</th>
<th>IIC</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT Panel</td>
<td>Maxxon Acousti-Mat® 3/4</td>
<td></td>
<td>None</td>
<td>47° ASTC</td>
<td>47° AIIC</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>-</td>
<td>-</td>
<td>49° AIIIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carpet + Pad</td>
<td></td>
<td>-</td>
<td>-</td>
<td>75° AIIIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT on Acousti-Top®</td>
<td></td>
<td>-</td>
<td>-</td>
<td>52° AIIIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eng Wood on Acousti-Top®</td>
<td></td>
<td>-</td>
<td>-</td>
<td>51° AIIIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
<td>49° ASTC</td>
<td>49° AIIIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT</td>
<td></td>
<td>-</td>
<td>47° AIIIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT on Acousti-Top®</td>
<td></td>
<td>-</td>
<td>49° AIIIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLT 5-ply</td>
<td>Maxxon Acousti-Mat® % Premium</td>
<td></td>
<td>None</td>
<td>49° ASTC</td>
<td>49° AIIIC</td>
<td></td>
</tr>
<tr>
<td>(6.875&quot;)</td>
<td>LVT</td>
<td></td>
<td>-</td>
<td>47° AIIIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT on Acousti-Top®</td>
<td></td>
<td>-</td>
<td>49° AIIIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLT 5-ply</td>
<td>USG SAM N25 Ultra</td>
<td></td>
<td>None</td>
<td>45°</td>
<td>39°</td>
<td>15</td>
</tr>
<tr>
<td>(6.875&quot;)</td>
<td>LVT</td>
<td></td>
<td>48°</td>
<td>47°</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVT Plus</td>
<td></td>
<td>48°</td>
<td>49°</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eng Wood</td>
<td></td>
<td>47°</td>
<td>47°</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carpet + Pad</td>
<td></td>
<td>45°</td>
<td>67°</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ceramic Tile</td>
<td></td>
<td>50°</td>
<td>46°</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

---

Note: The table above provides a detailed inventory of tested mass timber assemblies, including various combinations of CLT panels, concrete/gypsum toppings, and acoustical mat products. The table lists the specific materials used and their corresponding sound transmission class (STC) and airborne isolation class (IIC) ratings, along with a reference source for each entry.
### Impact of Ceiling Gypsum

#### Table 2: Impact of Direct Applied Ceiling Gypsum and Dropped Ceiling on Mass Timber Floor Panels

<table>
<thead>
<tr>
<th>Base Assembly (top to bottom)</th>
<th>Base assembly plus 2 layers direct applied 5/8” gyp on underside of mass timber</th>
<th>Base assembly plus 2 layers direct applied gyp plus dropped ceiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” poured gypsum, acoustical mat, 5-ply CLT</td>
<td>STC 50 IIC 40</td>
<td>STC 63 IIC 60</td>
</tr>
<tr>
<td>LVT, 1” poured gypsum, acoustical mat, 5-ply CLT</td>
<td>STC 51 IIC 43</td>
<td>STC 63 IIC 63</td>
</tr>
<tr>
<td>2” concrete, acoustical mat, 5-ply CLT</td>
<td>STC 52 IIC 46</td>
<td>Not tested</td>
</tr>
<tr>
<td>LVT, 2” concrete, acoustical mat, 5-ply CLT</td>
<td>STC 53 IIC 52</td>
<td>Not tested</td>
</tr>
</tbody>
</table>

**Base Assembly Exposed Timber**

**With Direct Applied Ceiling Gyp**

**With Direct Applied Ceiling Gyp & Dropped Ceiling**
Stud Wall Types

Can generally group interior wall types into these 3 categories:

- Single Stud Wall
- Staggered Stud Wall
- Double Stud Wall
Acoustics & Sound Control

Good Detailing + Good Installation = Good Performance

Open leg should be up on walls
Acoustically Rated Wall Assemblies
Can I add wood structural panels to an acoustically tested wall?

Yes, but placement is very important!
WSP placement in double stud walls – big impact on STC
Acoustics & Sound Control

Staggered stud wall condition:

• Blocking bridges finish on one side of wall to studs on opposite side, defeats purpose.

• Solution: use flat blocking in wall (wide face against WSP)
## Mass Timber Acoustic Wall Assemblies

<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.png) | 1 = 3-layer CLT ~ 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 |
| ![Top view of cross-section](image2.png) | 1 & 9 = 5/8” gypsum board  
2 & 7 = 2” by 3” wood studs at 16” o.c.  
4 & 6 = 1/2” air gap  
5 = 3-layer CLT of 4-1/8” | 50 |

Credit: US CLT Handbook
Acoustic Resources

» Free resources at woodworks.org

https://www.woodworks.org/resources/acoustical-considerations-for-mixed-use-wood-frame-buildings/

Combustibility

Fire Resistance

Fire Protection Systems

Flame Spread Classification
Fire Resistance Ratings (FRR)

**Fire-Resistance Rating**: The period of time a building element, component or assembly maintains the ability to:

- Support Structural Loads
- Provide Fire Confinement
Bearing vs. Non-Bearing Walls

*IBC Chapter 2 definition:*

**LOAD BEARING WALL:** Any metal or wood stud wall that supports more than 100 pounds per linear foot of vertical load in addition to its own weight.

**NON-LOAD BEARING WALL:** Any wall that is not a load-bearing wall
Fire Resistance Ratings (FRR)

<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></td>
</tr>
<tr>
<td>Primary structural frame (see Section 202)</td>
<td>3&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a,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></td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></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></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></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary structural</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>structural members (see Section 202)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary structural</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></td>
</tr>
<tr>
<td>structural members (see Section 202)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Driven primarily by construction type.
Supporting Structure – IBC 704.1

Structural members, that support a rated assembly must be fire-resistance rated to not less than the rating of the supported assembly.

(Exceptions: 707.5, 707.8, 709.4, 711.2)
IBC 711.2.4 - Fire resistance shall not be less than that required for:

» Separating mixed occupancies – 508.4
» Separating fire areas – 707.3.10
» Separating Dwelling units – not less than 1hr
  » Except for IIB, IIIB, VB with NFPA 13 sprinklers is ½-hr
» Separating smoke compartments – 709
» Separating incidental uses – 509
Fire Resistance Ratings – IBC 703.2

Fire resistance of elements, components or assemblies shall be based on testing (ASTM E119):

- UL Listings
- Gypsum Catalog
- Proprietary Manufacturer Tests
- Industry Documents: such as AWC’s DCA3

OR...
Methods for determining fire resistance:
» Prescriptive designs per IBC 721.1
Fire Resistance Ratings – IBC 703.2.2

Methods for determining fire resistance:

» Prescriptive designs per IBC 721.1
» Calculated Fire Resistance per IBC 722
"The addition of up to 16-3/4 inches of 0.5 pcf glass fiber insulation (R-40), either batt or loose-fill, to any 1- or 2-hour fire resistance rated floor-ceiling or roof-ceiling system having a cavity deep enough to accept the insulation is permitted provided that one additional layer of either 1/2 inch or 5/8 inch type X gypsum board is applied to the ceiling..."
Fire Resistance Ratings – IBC 703.2.2

Methods for determining fire resistance:

» Prescriptive designs per IBC 721.1
» Calculated Fire Resistance per IBC 722.6
» Calculated Fire Resistance per IBC 722.1 + NDS Chapter 16

<table>
<thead>
<tr>
<th>Required Fire Resistance (hr.)</th>
<th>Char Depth, $a_{char}$ (in.)</th>
<th>Effective Char Depth, $a_{eff}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>1½-Hour</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>2-Hour</td>
<td>2.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Calculated Fire Resistance of Wood

For Exposed Wood Members: IBC 722.1 References AWC’s NDS Chapter 16
(AWC’s TR 10 is a design aid to NDS Chapter 16)
Fire Resistance Ratings – NDS Ch. 16

Two structural capacity checks are performed:
1. On entire cross section neglecting fire effects
2. On post-fire remaining section, with stress increases

Solid Sawn, Glulam, SCL

CLT

Effective Char Depth

Credit: Forest Products Laboratory
FRR Design of Mass Timber

- Thinner panels (i.e. 3-ply) generally difficult to achieve a 1+ hour FRR
- 5-ply CLT panels can usually achieve a 1- or 2-hour FRR
- Construction Type >> FRR >> Member Size >> Grid

<table>
<thead>
<tr>
<th>Panel</th>
<th>Example Floor Span Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply CLT (4-1/8&quot; thick)</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>5-ply CLT (6-7/8&quot; thick)</td>
<td>14 to 17 ft</td>
</tr>
<tr>
<td>7-ply CLT (9-5/8&quot;&quot;)</td>
<td>17 to 21 ft</td>
</tr>
<tr>
<td>2x4 NLT</td>
<td>Up to 12 ft</td>
</tr>
<tr>
<td>2x6 NLT</td>
<td>10 to 17 ft</td>
</tr>
<tr>
<td>2x8 NLT</td>
<td>14 to 21 ft</td>
</tr>
<tr>
<td>5” MPP</td>
<td>10 to 15 ft</td>
</tr>
</tbody>
</table>

5-ply – 1 hour rating

1.9”

6.875”
FRR Design of Mass Timber

WoodWorks Inventory of Fire Tested MT Assemblies

Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof 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</td>
<td>Nordic</td>
<td>SPF 16/50 Ft 1.5 E/MSR x SPF #3</td>
<td>1 layer 1/2&quot; Type X Gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced</td>
<td>36% Moment Capacity</td>
<td>1</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>3-ply CLT</td>
<td>Structurlam</td>
<td>SPF 4/32 x SPF #1/8</td>
<td>1 layer 3/8&quot; Type X Gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Reduced</td>
<td>75% Moment Capacity</td>
<td>1</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>NRC Fire Laboratory March 2016</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>2 staggered layers of 1/2&quot; cement boards</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>NRC Fire Laboratory Nov 2014</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>3/4&quot; proprietary gypsum over Masson acoustical mat</td>
<td>Reduced</td>
<td>50% Moment Capacity</td>
<td>1</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Topside Spline</td>
<td>3/4&quot; proprietary gypsum over Masson acoustical mat or proprietary sound board</td>
<td>Reduced</td>
<td>50% Moment Capacity</td>
<td>2</td>
<td>UL</td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Nordic</td>
<td>E1</td>
<td>1 layer 5/8&quot; normal gypsum</td>
<td>Half-Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>Intertek 8/24/2012</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Structurlam</td>
<td>EI 85 MSR 2100 x SPF #2</td>
<td>None</td>
<td>Topside Spline</td>
<td>1-1/2&quot; Masson Gypsum, 2000 over Masson Reinforcing Mesh</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>Intertek, 2/22/2016</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>DR Johnson</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap &amp; Topside Spline</td>
<td>2&quot; gypsum topping</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>SwRI (May 2016)</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Structurlam</td>
<td>SPF 6/32 x SPF #3</td>
<td>None</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced</td>
<td>101% Moment Capacity</td>
<td>2</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Structurlam</td>
<td>SPF #1/2 x SPF #1/2</td>
<td>None</td>
<td>Half-Lap</td>
<td>None</td>
<td>Unreduced</td>
<td>101% Moment Capacity</td>
<td>2</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Smartlam</td>
<td>SL-V4</td>
<td>None</td>
<td>Half-Lap</td>
<td>normal 1/2&quot; plywood with 8d nails.</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>Western Fire Center 10/26/2016</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>Smartlam</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap</td>
<td>normal 1/2&quot; plywood with 8d nails.</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>Western Fire Center 10/28/2016</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>DR Johnson</td>
<td>V1</td>
<td>None</td>
<td>Half-Lap</td>
<td>normal 1/2&quot; plywood with 8d nails.</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>Western Fire Center 11/01/2016</td>
<td></td>
</tr>
<tr>
<td>5-ply CLT</td>
<td>KJH</td>
<td>CVI/31</td>
<td>None</td>
<td>Half-Lap &amp; Topside Spline</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>1</td>
<td>SwRI</td>
<td></td>
</tr>
</tbody>
</table>
2021 IBC 703.9 Sealing of adjacent mass timber elements. In buildings of Type IVA, IVB, and IVC construction, sealant or adhesive shall be provided to resist the passage of air.

Exception: Sealants or adhesives need not be provided where they are not a required component of a fire resistance-rated assembly.
Mass Timber or Non-combustible (NC)

Mass Timber, exterior surface protected with 1 layer 5/8” type X gyp
Permitted, requires NC protection on MT surfaces

All MT is protected
3 HR: 3 layers 5/8” type X gyp
2 HR or less: 2 layers 5/8” type X gyp

Same as IV-A for protected MT. Limited exposed MT permitted, FRR still applies

All MT permitted may be exposed except as noted

Tall Mass Timber – Materials and Protection

Structural Materials
Exterior Walls
Concealed Spaces
NC Gypsum Protection
FRR Design of Mass Timber

**IBC 722.7**
The fire resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element (MT) added to the protection time of the noncombustible (NC) protection.

Credit: Urban One
FRR Design of Tall Mass Timber

Where timber is required to be protected, NC must contribute at least 2/3 FRR

Required Noncombustible Contribution to FRR

<table>
<thead>
<tr>
<th>FRR of Building Element (hours)</th>
<th>Minimum from Noncombustible Protection (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3 or more</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: 2021 IBC Section 722.7
Mass Timber
Fire Design
Resources

» Free resources at woodworks.org


There are four basic types of fire-resistance rated wall assemblies:

1. Exterior Walls (IBC 705)
2. Fire Walls (IBC 706)
3. Fire Barriers (IBC 707)
4. Fire Partitions (IBC 708)
# Interior Fire-Rated Walls: Differences

<table>
<thead>
<tr>
<th>Fire walls</th>
<th>Fire Barrier</th>
<th>Fire Partition:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building Separation</td>
<td>• Shafts; Occupancy Separation</td>
<td>• Dwelling Unit Separation; Corridors</td>
</tr>
<tr>
<td>• Openings are protected and limited</td>
<td>• Openings are protected and limited</td>
<td>• Openings are protected</td>
</tr>
<tr>
<td>• Continuous from foundation to/through roof and exterior wall to/through exterior wall</td>
<td>• Continuous from floor through concealed space at each level</td>
<td>• May terminate at a fire rated floor/ceiling/roof assembly</td>
</tr>
<tr>
<td>• Structural stability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shaft Walls

Code requirements for shaft enclosures contained in IBC Section 713:

» **IBC 713.1:** The provisions of this section shall apply to shafts required to protect opening and penetrations through floor ceilings and roof assemblies. Interior exit stair-ways and ramps shall be enclosed in accordance with Section 1023.

» **IBC 713.2:** Shaft Walls shall be constructed as **Fire Barriers** (per IBC 707)
Shaft Wall Hourly Rating

Section 713: Shaft Enclosures

713.4: Fire-Resistance Rating

- 2 hours - when connecting 4 stories or more
- 1 hour - when connecting less than 4 stories
  - Number of connected stories includes basement but not mezzanine
- Not less than floor assembly penetrated, but need not exceed 2 hours
Shaft Wall Hourly Rating

2021 IBC 510.2:

4. Interior exit stairways located within the Type IA building are permitted to be of combustible materials where the following requirements are met...

4.2. The stairway located in the Type IA building is enclosed by 3-hour fire-resistance-rated construction with opening protectives in accordance with Section 716.
Stair/Elevator Shaft Wall Materials

Photo: WoodWorks

Photo: Quality Contractors
Shaft Wall Materials – Mass Timber

» Cost?

» Construction Schedule?

» Material Compatibility (movement & lateral load resistance)?

» Fire Performance

» Aesthetics
Shaft Enclosures in Tall Timber

<table>
<thead>
<tr>
<th>Exit &amp; Hoistway Enclosures</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV-A</td>
</tr>
<tr>
<td>Up to 12 Stories or 180 ft: MT protected with 2 layers 5/8” type X gyp (if 2 HR req’d) or 3 layers 5/8” type X gyp (if 3 HR req’d) both sides</td>
</tr>
<tr>
<td>Above 12 Stories or 180 ft: Noncombustible shafts (IBC 2021 602.4)</td>
</tr>
</tbody>
</table>
Shaft Wall Resources

» Free resources at woodworks.org

https://www.woodworks.org/resources/shaft-wall-solutions-for-wood-frame-buildings/
https://www.woodworks.org/resources/shaft-wall-requirements-in-tall-mass-timber-buildings/
There are four basic types of fire-resistance rated wall assemblies:

1. Exterior Walls (IBC 705)
2. Fire Walls (IBC 706)
3. Fire Barriers (IBC 707)
4. Fire Partitions (IBC 708)
Exterior Walls – FRT Allowance

Type III Construction - IBC Section 602.3:
Fire-retardant-treated wood framing and sheathing complying with Section 2303.2 shall be permitted within exterior wall assemblies of a 2-hour rating or less.
NDS 2.3.4 Fire Retardant Treatment

The effects of fire-retardant chemical treatment on strength shall be accounted for in the design. Adjusted design values, including adjusted connection design values, for lumber and structural glued laminated timber pressure-treated with fire retardant chemicals shall be obtained from the company providing the treatment and redrying service.

*Shear wall capacity reduction typically handled by increasing sheathing thickness per FRT manufacturer recommendations – or can reduce shearwall capacity by applying connector reduction factors.
Exterior Wall Fire Resistance – 705.5

**TABLE 602**

<table>
<thead>
<tr>
<th>FIRE SEPARATION DISTANCE = X (feet)</th>
<th>TYPE OF CONSTRUCTION</th>
<th>OCCUPANCY GROUP H^a</th>
<th>OCCUPANCY GROUP F-1, M, S-1^f</th>
<th>OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U^h</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &lt; 5^b</td>
<td>All</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5 ≤ X &lt; 10</td>
<td>IA, Others</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>IA, IB</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>IIB, VB</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>X ≥ 30</td>
<td>All</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(2018 IBC)

**TABLE 705.5**

<table>
<thead>
<tr>
<th>FIRE SEPARATION DISTANCE = X (feet)</th>
<th>TYPE OF CONSTRUCTION</th>
<th>OCCUPANCY GROUP H^a</th>
<th>OCCUPANCY GROUP F-1, M, S-1^f</th>
<th>OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U^h</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &lt; 5^b</td>
<td>All</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5 ≤ X &lt; 10</td>
<td>IA, IVA</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>IA, IB, IVA, IVB</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>IIB, VB</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>X ≥ 30</td>
<td>All</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(2021 IBC)
Exterior Wall Fire Resistance - IBC 705

Basic assumption is that fires begin at the interior and rated wall assemblies are not required from the exterior unless close to another structure.

*CBC 705.5 requires exposure from both sides for Group R occupancies!
Exterior Walls – Fire Separation Distance

**705.5 Fire Resistance Ratings:** The required fire-resistance rating of exterior walls with a fire separation distance of less than or equal to 10 feet shall be rated for exposure to fire from both sides.

Table 601 & 602
Exterior Walls – 2-hr Int; 0-hr Ext

Design No. U349
August 21, 2013
Bearing Wall Rating — 2 Hr
(EXPOSED TO FIRE ON INTERIOR FACE ONLY)
For Wood Studs, Finish Rating — 55 min

Design No. V314
March 13, 2020
Bearing Wall Rating - 1 Hr Rating Exposed to Fire on Exterior Face (See Item 8)
Bearing Wall Rating - 2 Hr Rating Exposed to Fire on Interior Face
Finish Rating — 42 min (Exposed to Fire on Interior Face)
Loaded Per 2012 NDS Supplement, ASD Method, Wall Braced Mid-Height

Examples, ONLY! Use current listings from UL.
Many options are available for fire resistance tested floor assemblies and wall assemblies.

No tested intersection details exist.

We must understand the intent of the code, provide a rationale that meets the code’s intent, and utilize available information and testing results.
IBC 2024: Exterior Floor to Wall Intersections

Two key changes are included in the 2024 IBC which clarify platform framed floor to wall intersection details

Code Change #1:

**New section 705.6** - Clarifies fire-resistance continuity requirements for exterior walls

*Previous section 705.6 Structural Stability moves to 705.7*

---

705.6 Continuity.

The fire-resistance rating of exterior walls shall extend from the top of the foundation or floor/ceiling assembly below to one of the following:

1. The underside of the floor sheathing, roof sheathing, deck or slab above.
2. The underside of a floor/ceiling or roof/ceiling assembly having a fire-resistance rating equal to or greater than the exterior wall and the fire separation distance is greater than 10 feet.

Parapets shall be provided as required by Section 705.12.
Code Change #2:

**New Section 705.7.1**

- Clarifies how to achieve fire-resistance protection of floor supporting members.
- Clarifies material requirements for floor construction at exterior walls intersections (i.e. do floor sheathing, joists, and rim boards at exterior walls in Type III Construction need to be FRTW?)

In Type III construction where a floor assembly supports gravity loads from an exterior wall, the fire-resistance rating of the portion of the floor assembly that supports the exterior wall shall be not less than the fire-resistance rating required for the exterior wall in Table 601. The fire-resistance rating provided by the portion of the floor assembly supporting and within the plane of the exterior wall shall be permitted to include the contribution of the ceiling membrane when considering exposure to fire from the inside. Where a floor assembly supports gravity loads from an exterior wall, the building elements of the floor construction within the plane of the exterior wall, including but not limited to rim joists, rim boards and blocking, shall be in accordance with the requirements for interior building elements of Type III construction.
...floor construction within the plane of the exterior wall, including but not limited to rim joists, rim boards, and blocking shall be in accordance with the requirements for interior building elements of Type III Construction.

Interior building elements (floor construction) in Type III are not required to be FRTW
IBC 2024: Exterior Floor to Wall Intersections

705.7.1 Floor assemblies in Type III construction.

In Type III construction where a floor assembly supports gravity loads from an exterior wall, the fire-resistance rating of the portion of the floor assembly that supports the exterior wall shall be not less than the fire-resistance rating required for the exterior wall in Table 601. The fire-resistance rating provided by the portion of the floor assembly supporting and within the plane of the exterior wall shall be permitted to include the contribution of the ceiling membrane when considering exposure to fire from the inside. Where a floor assembly supports gravity loads from an exterior wall, the building elements of the floor construction within the plane of the exterior wall, including but not limited to rim joists, rim boards and blocking, shall be in accordance with the requirements for interior building elements of Type III construction.

“...the portion of the floor assembly that supports the exterior wall shall be not less than the fire-resistance rating ... shall be permitted to include the contribution of the ceiling membrane when considering exposure to fire from the inside.”

How do we practically implement this? The details in AWC’s DCA 3 illustrate options
AWC’s DCA3 provides floor to wall intersection detailing options

Addresses both continuity provisions and requirements for FRT elements in exterior wall plane
Exterior Walls – Intersecting Floors (AWC’s DCA3)

Figure 1A: Example detail for Type III-A exterior wall-floor intersection with rim board and blocking
Exterior Walls – Intersecting Floors

**Methodology:**

**Fire-resistance for exposure from interior side:**

- **Case A:** Minimum $1\frac{1}{8}$-inch-thick inner rim board plus two layers of minimum $\frac{5}{8}$ in. Type X GWB in the ceiling membrane provides 2 hours of protection to the outer rim board, based on the NDS-calculated time for the char depth to reach the inner rim board / outer rim board interface plus 40 minutes for each layer of $\frac{5}{8}$ in. Type X GWB (per IBC Table 722.6.2(1)).

- **Case B:** Minimum $1\frac{3}{4}$-inch-thick inner rim board plus two layers of minimum $\frac{1}{2}$ in. Type X GWB in the ceiling membrane provides 2 hours of protection to the outer rim board, based on the NDS-calculated time for the char depth to reach the inner rim board / outer rim board interface plus 25 minutes for each layer of $\frac{1}{2}$ in. Type X GWB (per IBC Table 722.6.2(1)).

- **Case C:** Minimum $1\frac{5}{8}$-inch-thick inner rim board plus one layer of minimum $\frac{5}{8}$ in. Type X GWB in the ceiling membrane plus minimum $1\frac{1}{2}$-inch-thick, 2.5 pcf (nominal) mineral wool batt insulation provides 2 hours of protection to the outer rim board, based on the NDS-calculated time for the char depth to reach the inner rim board / outer rim board interface, plus 40 minutes for the $\frac{5}{8}$ in. Type X GWB (per IBC Table 722.6.2(1)), plus 15 minutes for the mineral wool insulation.

  The outer rim board must be designed to support the load from the wall above.

**Fire-resistance for exposure from exterior side** (where required per IBC Section 705.5): A combination of exterior fire protection, FRTW sheathing, and minimum $1\frac{1}{8}$-inch-thick outer rim board is used to provide two hours of protection to the inner rim board. Layers to the exterior of the outer rim board (e.g., exterior fire protection, FRTW sheathing, etc.) must be sufficient to provide at least 80 minutes of protection to the outer rim board. The inner rim board must be designed to support the load from the wall above.
Exterior Walls – Intersecting Floors

Floor Joist Options:
- Solid Sawn
- Trusses
- I-Joists

Floor sheathing

Joist hanger

Blocking

FRT sheathing
Shaft Walls / Fire Barriers – IBC 707

**707.5: Continuity.** Fire barriers shall extend from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, slab or deck above and shall be securely attached thereto. Such fire barriers shall be continuous through concealed space, such as the space above a suspended ceiling.

**707.5.1 Supporting Construction.** The supporting construction for a fire barrier shall be protected to afford the required fire-resistance rating of the fire barrier supported. Hollow vertical spaces within a fire barrier shall be fire blocked in accordance with Section 718.2 at every floor level.
Floor to Shaft Wall Detailing

This is now a joint!

This floor is now supporting construction
Floor to Shaft Wall Detailing
2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed...
Shrinkage Calculations

Three variables influence amount of shrinkage:

1. Installed moisture content (MC)
2. In-service equilibrium moisture content (EMC)
3. Cumulative thickness of cross-grain wood contributing to shrinkage

Wood species has relatively little impact since most species used in commercial construction have similar shrinkage properties.
Wood Science - Moisture Content

Wood’s MC vary during a year, it can vary drastically during construction.
Wood Science

Wood is orthotropic:

**Longitudinal** (L), **Radial** (R), and **Tangential** (T)

» Longitudinal shrinkage is negligible

» Assume avg. of radial & tangential or assume all tangential
Species-Specific Method:

\[ S = C \times D_i \times (M_F - M_i) \]

**Shrinkage Calculations – Running the Numbers**

- \( S \): shrinkage (inches)
- \( D_i \): initial dimension (shrinkage zone)
- \( C = C_T \) or \( C_R \): dimension change coefficient, tangential or radial direction
- \( C_T \) values:
  - 0.00263 for Douglas Fir-Larch
  - 0.00245 for Hem-Fir
  - 0.00234 for Spruce-Pine-Fir
  - 0.00263 for Southern Pine
- \( M_F \): final moisture content (%)
- \( M_i \): initial moisture content (%)

Wood Handbook: [www.fpl.fs.fed.us](http://www.fpl.fs.fed.us)
Minimizing Shrinkage – Detailing

Platform Framing

2x SILL PLATE
2x BLOCKING
2x JOISTS

SHRINKAGE ZONE:
2x SILL PLATE
2x12 FLOOR JOIST
(2) 2x TOP PLATE
15 3/4" TOTAL

(2) 2x TOP PLATE

Semi-Balloon Framing

STUD WALL, SEE SCHEDULE (TYP)

FLOOR SHEATHING

WALL SHEATHING, AS REQUIRED

SHRINKAGE ZONE:
2x SILL PLATE
(2) 2x TOP PLATE
4 1/2" TOTAL

FLOOR TRUSS
TOP FLANGE HANGER

Images: Schaefer
## Minimizing Shrinkage – Detailing

<table>
<thead>
<tr>
<th>Platform Detail:</th>
<th>Semi-Balloon Detail:</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.75” Shrinkage Zone</td>
<td>4.5” Shrinkage Zone</td>
</tr>
<tr>
<td>19% MC Initial</td>
<td>19% MC Initial</td>
</tr>
<tr>
<td>12% EMC</td>
<td>12% EMC</td>
</tr>
</tbody>
</table>

\[
S = (0.0025)(15.75”)(12-19) = 0.28”
\]

5-story building: **1.4” total**

\[
S = (0.0025)(4.5”)(12-19) = 0.08”
\]

5-story building: **0.4” total**
Differential Movement

Consider differential movement between wood frame elements and other materials that...

» Expand due to moisture or thermal changes
» Do not change with moisture but do change with thermal fluctuations
» Shrink much less than wood
Differential Movement – Veneer Opening Example

NOTE: SIZE OF CAULK JOINT SHALL BE TWICE THE ANTICIPATED DIFFERENTIAL MOVEMENT BETWEEN THE VENEER AND WOOD STRUCTURE

WINDOW, SEE ARCH
SEALANT & BACKER ROD, SEE ARCH
SILL, SEE ARCH
WEATHER RESISTANT BARRIER & FLASHING, SEE ARCH
BRICK VENEER, SEE ARCH
EXTERIOR WALL SHEATHING
2x STUD

Images: Schaefer
» Vertically slotted holes in studs allow differential movement
» Verify structural adequacy of studs

Note: Engineer shall review loading conditions on wall for allowable size of penetration.
Vertical Stacks – Compensation Devices
Tall Mass Timber Differential Vertical Movements
Non-Structural Components

- Interior Partitions
- Exterior Cladding
- Mechanical Equipment
- Roof Drainage
Shrinkage

Resources


Minimizing Shrinkage – Detailing

The same concepts apply to post & beam wood-frame structures

Photos: StructureCraft
Planning for Environmental Exposures

- Plan Early
- Risk Evaluation
- Develop Construction Phase Plan
- Execute the Design and Moisture Management Plan
- Monitor

RDH Moisture Management Guide 1st Ed
Outline

» Introduction to Mid-Rise Construction
  Terminology
  Construction Types
  Maximizing Heights and Areas

» Design Considerations
  Lateral System Options
  Acoustics
  Fire Resistance Ratings
  Shaft Walls
  Exterior Walls
  Moisture and Shrinkage

» Case Studies and Design Example
Mid-Rise Design Example

7-story, 84 ft tall multi-family building
• Parking & Retail on 1st floor, residential units on floors 2-7
• NFPA 13 sprinklers throughout
• Floor plate = 18,000 SF
• Total Building Area = 126,000 SF
Construction Type Options:
- 7 stories of IV-C (mass timber)
- 5 stories of IIIA over 2 stories of IA podium (mass timber or light-frame)
- 5 stories of IV-HT over 2 stories of IA podium (mass timber)
**Timber Construction Type Options:**
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

**Implications of Type IV-C:**
- 2 hr FRR, all exposed floor panels, beams, columns (+min sizes)
- Likely will need at least 5-ply CLT (maybe 7-ply)
- Efficient spans in the 14-17 ft range (5 ply)
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
- CLT exterior walls permitted
- Exposed CLT ceilings – aesthetic value
- Materials are mass timber or non-combustible (no light-frame wood permitted!)
- Lateral System: likely steel or concrete
Mid-Rise Design Example

Timber Construction Type Options:
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

Implications of Type IIIA:
- 1 hr FRR floors, interior bearing walls, 2 hr exterior bearing walls
- Light frame wood (joists, trusses, prefab option) OR 5-ply CLT
- 2 story Type IA podium required
- CLT exterior walls not permitted, non-combustible or FRT wood only
- Can use light-frame wood framing for interior walls
- Lateral System: If <65 feet for wood portion, light frame wood shear walls are an option
Mid-Rise Design Example

Timber Construction Type Options:
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

Implications of Type IV-HT:
- 1 hr FRR (dwelling separation) and min. sizes
- Likely 5-ply CLT (no light-frame floor, must meet min. sizes)
- 2 story Type IA podium required
- Essentially the same panel and grid options as IIIA
- CLT exterior walls permitted
- Exposed CLT ceilings – aesthetic value
- **All walls require 1-hr rating** (non-bearing included)
  (IBC/CBC Table 601 -> 2304.11.2)
- Lateral System: light frame wood permitted up to 65 ft, 1-hour minimum.
Construction Type Options:
• 7 stories of IV-C (mass timber)
• 5 stories of IIIA over 2 stories of IA podium (mass timber or light-frame)
• 5 stories of IV-HT over 2 stories of IA podium (mass timber)
THE KIND PROJECT, SACRAMENTO, CA

Credit: Kalesnikoff Mass Timber
THE DUKE, AUSTIN, TX
360 WYTHE AVENUE, BROOKLYN, NY
CANYONS, PORTLAND, OR

Credit: Jeremy Bittermann & Kaiser + Path
Mass Timber Business Case Studies: Value Creation Analysis

Development Overview
• Property Information
• Product Strategy
• Investment Highlights

Qualitative Discussion
• Challenges
• Lessons Learned
• Successes

Quantitative Overview
• Development Timeline
• Costs
• Rents
• Lease up

Comparative Return Analysis

<table>
<thead>
<tr>
<th></th>
<th>Market</th>
<th>Pro Forma</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield on cost</td>
<td>6.25%</td>
<td>7.00%</td>
<td>7.35%</td>
</tr>
<tr>
<td>Cap rate</td>
<td>4.75%</td>
<td>4.50%</td>
<td>TBD</td>
</tr>
<tr>
<td>Value/rentable SF</td>
<td>$550/ RSF</td>
<td>$717/ RSF</td>
<td>TBD ($800+/ RSF)</td>
</tr>
<tr>
<td>Leverage</td>
<td>65%</td>
<td>65%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Multifamily | Office | Industrial | Student Housing
Initial Findings: Residential

Residents respond to "look & feel"

• Aesthetics seem to be broadly appealing; wider target markets = better market demand
• Robust pre-leasing = lower costs & risks
  o More income sooner = lowers operating & interest budgets
  o Faster to stabilization = faster to refinance
• Tangible distinction = mitigates future supply risk
• Tangible realization of desired brand identities
Quantitative Overview

Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Total project cost</td>
<td>$32,000,000</td>
</tr>
<tr>
<td>Land: @ appraised value</td>
<td>$3,660,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Market Standard*</th>
<th>Pro Forma</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction costs (normalized wo/COVID)</td>
<td>$186 / GSF</td>
<td>$192 / GSF</td>
<td>$186 / GSF</td>
</tr>
<tr>
<td>Construction costs (w/COVID delays + adds)</td>
<td>N/A</td>
<td>N/A</td>
<td>$210 / GSF</td>
</tr>
</tbody>
</table>

NOI

<table>
<thead>
<tr>
<th>Item</th>
<th>Apartment Market</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rental rates (avg. of renovation + new addition)</td>
<td>Studio $1,500</td>
<td>$1,722</td>
</tr>
<tr>
<td>1-BR</td>
<td>$2,000</td>
<td>$2,924</td>
</tr>
<tr>
<td>2-BR</td>
<td>$2,500</td>
<td>$3,473</td>
</tr>
<tr>
<td>Occupancy after 13 months (stabilized)</td>
<td>80%</td>
<td>85%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Parking Revenue Market</th>
<th>Pro Forma</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>In addition to lease</td>
<td>$125</td>
<td>$130</td>
<td>$135</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Retail Market</th>
<th>Pro Forma</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail rental rates</td>
<td>$32 / RSF/YR</td>
<td>$32 / RSF/YR</td>
<td>$0 / COVID</td>
</tr>
<tr>
<td>Rent type (e.g., NNNN)</td>
<td>NNN</td>
<td>NNN</td>
<td>N/A</td>
</tr>
<tr>
<td>Tenant improvement allowance</td>
<td>$30/SF</td>
<td>$30/SF</td>
<td>N/A</td>
</tr>
<tr>
<td>Occupancy after 12 months</td>
<td>90%</td>
<td>90%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Return Performance (as of October 2021)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Market</th>
<th>Pro Forma</th>
<th>Realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield on cost – untrended</td>
<td>5.5%</td>
<td>5.7%</td>
<td>Lower</td>
</tr>
<tr>
<td>Cap rate (mkt vs. appraisal subject conclusion)</td>
<td>4.5%</td>
<td>4.5%</td>
<td>Not yet known</td>
</tr>
<tr>
<td>Value per unit</td>
<td>$435,000</td>
<td>$500,000</td>
<td>Not yet known</td>
</tr>
</tbody>
</table>

Leverage

<table>
<thead>
<tr>
<th>Item</th>
<th>Leverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td></td>
</tr>
</tbody>
</table>

Timeline

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Context/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of conception (first dollar spent)</td>
<td>January 2018</td>
<td></td>
</tr>
<tr>
<td>Date underwriting finalized (go/no-go decision)</td>
<td>December 2018</td>
<td>Equal</td>
</tr>
<tr>
<td>Date equity capital secured</td>
<td>October 2018</td>
<td>Equal</td>
</tr>
<tr>
<td>Permitting duration</td>
<td>11 months</td>
<td>Equal</td>
</tr>
<tr>
<td>GMP in place</td>
<td>January 2019</td>
<td></td>
</tr>
<tr>
<td>Construction start</td>
<td>February 27, 2019</td>
<td></td>
</tr>
<tr>
<td>Duration of construction (anticipated without COVID)</td>
<td>11 months</td>
<td>10% faster than normal</td>
</tr>
<tr>
<td>Duration of construction (realized w/COVID)</td>
<td>12 months</td>
<td>COVID slowed 1 month</td>
</tr>
<tr>
<td>Construction completed</td>
<td>September 2020</td>
<td></td>
</tr>
<tr>
<td>Date stabilized (80% occupancy, NOI, or at pro forma or refinanced)</td>
<td>Not yet stabilized (as of October 2021)</td>
<td>COVID impacted leasing</td>
</tr>
</tbody>
</table>

Interview with listing retail broker confirmed substantial pre-leasing occurred (60% of space). COVID 19 pandemic wiped out retail market in latter half of 2020 & all of 2021, forced all retail leased to abandon. Recent activity is positive with five local, design-oriented tenants proceeding to take majority of space.

*Market standard costs refer to normal cost to build for subject’s use, irrespective of structural approach

Disclaimer: Information herein was provided by the developer and verified for reasonableness by a third-party expert. Market data and figures have been reviewed by an independent third party utilizing industry standard resources. For additional sources and disclaimers, see the Basis of information page for this case study and the Disclosures, Disclaimers and Confidentiality page at the end of this case study package.
CARBON12
PORTLAND, OR

First Modern Tall Mass Timber Building in the US
8 stories
42,000 sqft
1st floor retail, 7 stories of condos above
Completed in 2017
11 E LENOX, BOSTON, MA

7 STORIES

70 FT, Passive House, Multi-Family

Credit: WoodWorks, Kure Creative
Heartwood
Seattle, WA

66,000 sf, 8 stories
Type IV-C
Workforce Housing
MT / CLT
Wood construction: 1 day per floor
Completed 2023

atelierjones LLC
DCI Engineers
Image: atelierjones LLC

Photos Mike Sinclair
MINNESOTA PLACES
PORTLAND, OR

8 stories total
7 stories of mass timber
Type IV-C
72 Affordable Housing Units
54,000 sqft
TIMBERVIEW
PORTLAND, OR

» 8 Stories
» Type IV-C
» 105 Affordable Housing Units
Questions? Ask us anything.

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