**Why Mass Timber?**

Architectural Warmth / Biophilia
Why Mass Timber?

Sustainability

Graphic courtesy of Lever Architecture

Why Mass Timber?

Rural Economic Development

Graphic courtesy of Lever Architecture

Why Mass Timber?

Prefabrication / Speed of Erection
WHAT IS MASS TIMBER?

HISTORIC PRECEDENCE

Mass Timber is NOT...
Design Considerations

Fire - Predictable Char Rates

<table>
<thead>
<tr>
<th>Fire Rating</th>
<th>Char Rate</th>
<th>Char Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>1.80 in/hour</td>
<td>1.8 in</td>
</tr>
<tr>
<td>1½ hour</td>
<td>1.68 in/hour</td>
<td>2.5 in</td>
</tr>
<tr>
<td>2 hour</td>
<td>1.58 in/hour</td>
<td>3.2 in</td>
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</tbody>
</table>

After fire scene. Shows a wood beam supporting twisted steel I-beams. (Forest Products Laboratory)

Design Considerations

Connections – Engineered Bearing Connections
Challenges, Limitations, & Opportunities

Acoustics & Floor Vibrations

Challenges, Limitations, & Opportunities

Supply Chain & Local Installer Capabilities

Challenges, Limitations, & Opportunities

Regulatory Challenges – LFRS
Challenges, Limitations, & Opportunities

Regulatory Challenges – Fire

Gravity Framing Options

- Steel Framing:
  30’x30’ Bays with Purlins

- Glulam Framing:
  20’x20’ Bays with Purlins
  16’x30’ Bays with CLT
  20’-22’x30’ Bays with TCC, DLT, NLT, MMP
  30’x30’ Bays with pre-fabricated rib panels

- Two-Way CLT Slabs:
  10’x16’ Bays
  20’x20’ Bays w/CLT Drop Caps

Performance-Based Fire
Challenges, Limitations, & Opportunities

MEP System Integration

OUR JOURNEY

Completed / Permitted CLT Projects
SUMMARY OF BUILDING TYPES

Mid-Rise (7-12 Stories)
- Office
- Residential / Hotels
- Mixed Use

Low-Rise
- Class 'A' Office Space
- Residential / Hotels
- Civic
- Higher Ed / K-12
- Parking Garages?

ALBINA YARD

LEVU ARCHITECTURE
FRAMEWORK
Owner:
- Home Forward
- Beneficial Bank

Project Team:
- project*
- LEVER ARCHITECTURE
- Walsh Construction / StructureCraft
- KPFF, ARUP, PAE

Project Facts:
- 12 Stories – 135 ft
- Mixed Use
- 90,000 Sq. ft.
- Type 1B Equivalent Construction

STRUCTURAL DESIGN

- Gravity System – Gypcrete & CLT Floor Panels spanning to Glulam Beams and Columns
- Lateral System – Resilient Post-tensioned Rocking CLT Walls
- Performance Based Design - Pursued for Fire Design and Seismic Design
FIRE DESIGN

Fire Assemblies / Testing
- 2 hour floor & wall assembly – DR Johnson
- Connections – Project specific
- Penetrations – Existing manufacture data

Performance Based Fire Modeling
- Proving equivalence
- Determining how much wood can be exposed

Structural Fire Design
- Floor Assembly – Tested
- Glulam beams & columns – Apply char depths
SEISMIC RESILIENCY & SUSTAINABILITY

Alternate Systems Considered
- Concrete Core
- Steel Braced Frames

Project Goals
- All Timber Solution
- Resilient Solution

System Chosen
- Post-Tension Rocking CLT Walls
  - Self-Centering
  - Resilient / Low Damage
  - Quickly / Easily Repairable

SEISMIC LATERAL SYSTEM

RIGID PANEL ROCKING BEHAVIOR
RESILIENT POST-TENSIONED ROCKING CLT WALLS

PERFORMANCE BASED DESIGN

Structural Design
- Post-Tensioned Rocking Walls
- Extensive Review of Existing Research
- Nonlinear Response History Analysis
- Project Specific Component Testing
- CLT Diaphragm
- Analytical Modeling
- Connections – Drift Compatibility / Fire Rating
- Project Specific Full-Scale Testing

Review
- Authority Having Jurisdiction
- Independent Peer Review Team
- Research Partners

DESIGN CRITERIA

Demonstrating Code-Equivalent Performance
1. Strength-Level Wind
2. Establish Minimum Seismic Strength
3. Deformation- and Force-Controlled Actions and Drift Verification at MCE

Opportunities for Enhanced Performance
1. Reparability Earthquake
2. Serviceability Wind
3. Serviceability Earthquake
**EFFECTIVE SHEAR MODULUS OF CLT**

**Concrete**
- $f'_c = 5000$psi (34.5 MPa)

**CLT DF No. 1**
- $EI_{eff} = 2025{}^{2}{}^4I_g$
- $GI_{eff} = 1850{}^{2}{}^4I_g$

**CLT / Concrete**
- $50\%$
- (35 to 75 ksi)$^4I_g$
- 2 to 5\%

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1. Cracked section modifiers for concrete taken as 0.5 for $EI_{eff}$ and 1.0 for $GI_{eff}$.
2. $EI_{eff}$ for CLT based on Flaig and Blaß (2013) and Brandner et al. (2015).

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**BARE WALL TESTING**

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International Building Code - 2021

Additional Heavy Timber Types