Optimization of Mass Timber Framing for Residential Towers (and other Project Typologies)

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Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
Innovation...

Traditional Project Team

Project Implementation

Gaps / Opportunities

...Exists in the Gaps
Mass timber has emerged as a competitive structural building technology that can offer several advantages for both residential and commercial building construction.

Why are we all talking about mass timber?

Mass timber has emerged as a competitive structural building technology that can offer several advantages for both residential and commercial building construction.
Case Study: INTRO Cleveland

LOCATION
Cleveland, OH

SIZE
500,000 SF

HEIGHT
9 Stories

SYSTEM
Mass Timber / Post-Tensioned Concrete

SECTOR
Residential Mixed-Use
Case Study: INTRO Cleveland

LOCATION
Cleveland, OH

SIZE
765,000 SF

HEIGHT
9 Stories

SYSTEM
Mass Timber / Post-Tensioned Concrete

SECTOR
Residential Mixed-Use
Feasibility Phase

Current Phase: Feasibility Phase

- Assemble Robust Team
- Code Limits
- Pertinent Information
- Structural Grid Impact
- Alignment with Project Goals
- Project Specifics
- Potential Outcomes
- Considerations

Up Next...

Optimization Phase
Establishing an Optimization Process

CREATE A FLEXIBLE OPTIMIZATION ENGINE
- Allow iteration across wide range of inputs
- Minimize member volume within preferred ranges
- Deploy either with parametric model or predetermined layout
- Customizable output and data collection

COLLECTIVELY ESTABLISH BOUNDS OF THE PROJECT OPTIMIZATION
- Collectively define acceptable search space
- Collectively define target criteria

RUN THE OPTIMIZATION AND SELECT PREFERRED SCHEMES
- Analyze results
- Select schemes for refinement
- Adjust bounds of the optimization
- Integrate new information
The Optimization Engine

Traditional Design Workflow

- Design Inputs
  - Panel Design
  - Timber Beam Design
  - Timber Column Design

Optimization Workflow

- Design Inputs
  - Panel Design
  - Timber Beam Design
  - Timber Column Design

  - Member Outputs
  - Optimal Member Output
Optimization Process

- Optimize Each Member
- Optimize Floor Systems
- Optimize Vertical Systems
- Apply Real World Constraints
- Collaborate
Member Optimization

Column Element

Beam Element

Panel Element
# Strength, Serviceability, Fire

## Beam Demand Capacity Ratio Envelope

<table>
<thead>
<tr>
<th>Serviceability Controlled</th>
<th>Bending Controlled</th>
<th>Shear Controlled</th>
<th>Fire Controlled</th>
<th>Minimum Area Section</th>
</tr>
</thead>
</table>

### Beam Demand Capacity Ratio Envelope

<table>
<thead>
<tr>
<th>Beam Width</th>
<th>Beam Depth</th>
<th>Serviceability Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 3</td>
<td>2 to 3</td>
<td>0.49</td>
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<tr>
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<td>6 to 7</td>
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<tr>
<td>7 to 8</td>
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<td>8 to 9</td>
<td>8 to 9</td>
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<tr>
<td>9 to 10</td>
<td>9 to 10</td>
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<td>10 to 11</td>
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<td>11 to 12</td>
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<tr>
<td>24 to 25</td>
<td>24 to 25</td>
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</table>
Impact of Beam Width

• 4 Million Optimized Beam Designs

• Deeper is better, unless...

• Fire chars both sides of the beam

Material Grade: 20F-1.5E
Required Fire Rating: 0 Hours
Span: 18'
Tributary Width: 20'
Loading: Residential
Minimum Area Beam Size: 3.125 X45
Impact of Beam Width

- 4 Million Optimized Beam Designs
- Deeper is better, unless...
- Fire chars both sides of the beam
Fire Rating and Taller Buildings

- Fire has large impact for lighter loaded columns
- As load increases, fire impact reduces

<table>
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<th>Story Number</th>
<th>Required Fire Rating</th>
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<tr>
<td></td>
<td>0 Hour</td>
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<tr>
<td>23</td>
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CLT Panel Evaluation

CLT DC Ratios (5 Ply)

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<tr>
<th>Span (ft)</th>
<th>Bending</th>
<th>Shear</th>
<th>Fire</th>
<th>LT Def</th>
<th>ST Def</th>
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<td>0.13</td>
<td>0.32</td>
<td>0.30</td>
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<td>0.24</td>
<td>1.07</td>
<td>1.41</td>
<td>0.92</td>
<td>1.17</td>
</tr>
</tbody>
</table>
System Optimization: Floor Framing

[Diagram showing floor framing with labels for CLT span direction, iterable overall building length, iterable overall building width, and iterable bay spacing.]
System Optimization: Floor Framing

<table>
<thead>
<tr>
<th>Ply Type</th>
<th>beam</th>
<th>column</th>
<th>panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Ply CLT</td>
<td>890 ft³ GLT Beam</td>
<td>508 ft³ GLT Column</td>
<td>5,835 ft³ CLT Panel</td>
</tr>
<tr>
<td></td>
<td>7,233 ft³ Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Ply CLT</td>
<td>820 ft³ GLT Beam</td>
<td>451 ft³ GLT Column</td>
<td>8,168 ft³ CLT Panel</td>
</tr>
<tr>
<td></td>
<td>9,439 ft³ Total</td>
<td></td>
<td></td>
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</tbody>
</table>

30% Volume Increase
# System Optimization: Vertical Framing

## 3 Bays
- 21,736 ft³ GLT Beam
- 33,177 ft³ GLT Column
- 140,030 ft³ CLT Panel
- **Total**: 194,943 ft³

## 5 Bays
- 14,478 ft³ GLT Beam
- 39,339 ft³ GLT Column
- 140,030 ft³ CLT Panel
- **Total**: 193,847 ft³

*2% Framing Volume Decrease + Shallow Corridor*
Project Optimization

• Early iteration and collaboration is key

• Architectural and site requirements influence layout options

• Establish collective goals
Analyzing Data

Standard Deviation (SD)
Fitness Values
SD Value Trendline
Mean Value Trendline
Establish Optimization Criteria

**Lowest Volume**
- Total Volume
  - Rank: 0 / 2500
  - Fitness Value: 54291
- Generation 39 // Ind. 5
- System Depth
  - Rank: 156 / 2500
  - Fitness Value: 16
- Corridor Depth
  - Rank: 1197 / 2500
  - Fitness Value: 16
- 5 Ply Span
  - Rank: 2346 / 2500
  - Fitness Value: 19.548427

**Lowest Member Count**
- Member Count
  - Rank: 0 / 2500
  - Fitness Value: 65776
- Generation 38 // Ind. 5
- System Depth
  - Rank: 1527 / 2500
  - Fitness Value: 24
- Corridor Depth
  - Rank: 221 / 2500
  - Fitness Value: 11.875
- 5 Ply Span
  - Rank: 2469 / 2500
  - Fitness Value: 19.548427

**Lowest Depth**
- System Depth
  - Rank: 0 / 2500
  - Fitness Value: 62237
- Generation 41 // Ind. 7
- Total Volume
  - Rank: 1458 / 2500
  - Fitness Value: 3825
- Member Count
  - Rank: 2372 / 2500
  - Fitness Value: 14
- System Depth
  - Rank: 697 / 2500
  - Fitness Value: 14
- Corridor Depth
  - Rank: 896 / 2500
  - Fitness Value: 17.155

**High Member Count**

**High Volume**

**Highest Member Count**
Explore Options
Filter Results

Parallel Coordinate Plot

72928  4029  24  24  19.55

54291  2142  14  10.5  15.16

Volume  Count  SystemD  CorridorD  Span

Increasing Fitness
Documentation and Pricing

TYPICAL TOWER FRAMING PLAN
SCALE: 3/32" = 1'-0"

LEGEND:

- Indicates BBS 125 200 AB CLT Panel (1/2" Thickness) with 3/8" Acoustic Mat and 2.15 Min Normal Weight Concrete Topping Reinforced with 3.0 Pct of Eucal Chemicals Tuf-Strand SF Fibers.
- Indicates Glulam Timber Beam size in inches / mm. See Quantity Information for total volume and piece count.

| Pricing Information |
|---------------------|-----------------|-----------------|-----------------|
| Member Type         | Column          | Beam            | Panel           |
| Material            | GL30n           | GL50h           | CLT BBS 125 200 |
| Piece Count         | 1151            | 973             |                 |
| Quantity            | 50,600 ft²      | 867 m²          | 43,900 ft²      | 1243 m²         |
|                     | 347,620 ft²     | 32,295 m²       |                 |
Pre-Construction Phase

Current Phase: Precon Phase
Construction Arc

- GENERAL CONTRACTING TEAM
- PASS TIMBER TEAM
- PARTNERED BIDS
- SOLE SERVICE BT BIDS
- RELATED TRADES

- PLANNING
- BIDDING AND TEAM SELECTION
- DESIGN INPUT
- TIMBER SYSTEM INPUT
- BID DOCUMENTS
- POTENTIAL VV
- INTEGRATE TRADES INTO BIM PROCESS
- FINAL BIM MODEL

- SCHEMATIC DESIGN
- DESIGN DEVELOPMENT
- CONSTRUCTION DOCUMENTS
- DESIGN TEAM
- DESIGN REFINEMENT
- DESIGN COMPLETION

Current Phase: Precon Phase
Design Arc

Up Next...
Common Challenges

• MEP Penetrations
• Trade Coordination
Common Challenges

• Large Duct Banks
• Beam Penetrations
Window Wall / Curtain Wall Attachment
Connection Efficiency
Construction Phase
Schedule Impact

- Erection Logistics
- Off Site Fabrication
Schedule Impact: Connection Considerations

Simple Bearing Connections

Trade Ready Connections
Schedule Impact: Connection Considerations

Custom Connections
Logistics Considerations

- Mockups
- Rigging
- Laydown Areas
- Temporary Water Protection

Tower Crains and Mobile Rigging
Logistics Considerations

- Mockups
- Rigging
- Laydown Areas
- Temporary Water Protection
Lessons Learned...

• Further Prefabrication
• Trade Mentality
• Embrace Technology

...Opportunities
Lessons Learned...

- Prefabrication
- Trade Mentality
- Embrace Technology

(Rig like and ironworker, handle like a carpenter)

...Opportunities
Lessons Learned...

• Prefabrication
• Trade Mentality
• Embrace Technology

...Opportunities
Lessons Learned...

- Prefabrication
- Trade Mentality
- Embrace Technology

...Opportunities
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