Structural Mass Timber Design
The Engineer’s Role in Optimization

Presented by Greg Kingsley, PhD, PE

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

Dollar Cost of:

1. Elements
   (Panels, beams, and columns)

2. Bays
   (Timber, and steel/timber hybrid)

3. Timber Building Types
   (III-A, III-B, IV-HT, IV-C, IV-B, IV-A)

4. Building Archetypes
   (Timber, steel, and concrete)
MASS TIMBER ELEMENTS
MASS TIMBER ELEMENTS
CLT COST DEPENDS ON THE PRICE OF LUMBER
CLT COST DEPENDS ON SUPPLY

... and North American supply is increasing

North American Mass Timber Panel Manufacturing Capacity
CLT COST DEPENDS ON WOOD VOLUME!

3-ply 3-layer
(3.43” - 4.14”)

5-ply 5-layer
(5.47” - 6.90”)

7-ply 7-layer
(7.52” - 9.66”)

9-ply 9-layer
(9.57” - 12.42”)

7-ply 5-layer

9-ply 7-layer
CLT COST DEPENDS ON WOOD VOLUME!

CLT Thickness vs Span for Some North American Manufacturers

Dr K’s Generic CLT
CLT COST DEPENDS ON THE MANUFACTURER

Mass timber panels are not a commodity!

- Panel width
- Panel length
- Lamination thickness
- E-rated and V-rated
- Species
- Special finishes
Conceptual cost of Dr K’s Generic CLT is intended to include:

- CLT
- Shop fab
- Sanding
- Delivered
- Screws

but does not include:

- Finishes

CLT cost depends on number of plies and drop.
Glulam Beam and Column Cost

Glulam Beam and Column Cost as a function of width

Cost / Cubic Ft

$85

$80

$75

$70

$65

$60

$55

$50

$45

$40

Beam Width or Column Width (in)

Beam

Column
20 ft timber bents, no beams, CLT of varying span
Square bay, CLT with 2 equal (varying) spans
Wood Bay Study: 15x15 up to 30x30
Wood Bay Study: 15x15 up to 30x30
Wood Bay Study

WOOD STUDY E - 3-Ply CLT Timber Grid

Conceptual Cost/sf

Clear Height to Girder (ft)

- Concrete
- Wood Connections
- Wood
- Clear Ht

[Diagram showing cost variations and height measurements for different CLT timber grid configurations]
Steel beams and columns: Labor dominates cost

Timber beams and columns: Material volume dominates cost
WHAT DO MASS TIMBER CONNECTIONS COST?
Simple connections are economical

Panel to beam connections

Photo Credit: myticon
Connection Cost – Different Connection “Classes”
Connection Cost based on “Connection Class”

Cost for each class is based on …

- Connection material
- Screws and bolts
- Beam end fabrication
- Girder fabrication
- Field Installation

Cost increases with …

- Connection “Class”
  - Simple screws
    - Complex hidden custom connector
  - Reaction carried
PLATTE FIFTEEN
Office / Retail
Type III-B over IA Construction
2 floors concrete below grade
1 floor concrete above grade
3 floors + roof in mass timber
Concrete cores
30’ x 30’ grid
PLATTE 15

Office / Retail
Type III-B Construction
30’ x 30’ grid
Platte Fifteen Bay Study

Conceptual Comparison of Platte15 Structural Systems

Conceptual Cost $/SF

Clear Height to Girder (ft)

- Concrete
- Steel
- Connections
- Wood

Dimensions:
- 20x30, 7-ply, 2G, OB
- 30x30, 3-ply, 1G, Beam @ 10
- 30x30, 3-ply, strong, 1G, Beam @ 10
- 30x30, 3-ply, 2G, Beam @ 10
- 30x30, 3-ply, 2G cont, Beam @ 10
- 30x40, 3-ply, 3G cont, Beam @ 10
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
- 30x30, 3-ply, 2G Cont, Big conn
PLATTE 15

- DIFFERENT MATERIAL
- DIFFERENT TOLERANCE
- DESIGN FOR IT
PLATTE 15

CONNECTION DESIGN:

• CONNECTION MATERIAL

• CONSIDERATION OF MATERIAL INTERFACE

• TIME IS MONEY
PLATTE 15

50+ ft panels span five 10 ft bays

OZ Architecture  Adolfson & Peterson Construction  KL&A & Nordic
## Fire Resistance Requirements for Mass Timber Buildings

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Primary Structural Frame</th>
<th>Floor</th>
<th>Roof</th>
<th>Non-combustible Protection</th>
<th>Story Limit</th>
<th>Maximum Height (ft)</th>
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<tr>
<td>III-A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Not Required</td>
<td>6</td>
<td>85</td>
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<td>III-B</td>
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<td>0</td>
<td>0</td>
<td>Not Required</td>
<td>4</td>
<td>75</td>
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<td>IV-A</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
<td>Fully Covered</td>
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<td>270</td>
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<td>IV-B</td>
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<td>2</td>
<td>1</td>
<td>Partially Covered</td>
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<td>180</td>
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<tr>
<td>IV-C</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>Not Required</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>IV-HT</td>
<td>HT^a</td>
<td>HT^a</td>
<td>HT^a</td>
<td>Not Required</td>
<td>6</td>
<td>85</td>
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Effect of grid on cost/sf – Type IV-B

Longer spans = higher connection cost

CLT press length efficiency affects cost

<table>
<thead>
<tr>
<th>Stories</th>
<th>Grid</th>
<th>III-B</th>
<th>III-A (Gyp)</th>
<th>III-A (No Gyp)</th>
<th>IV-HT</th>
<th>IV-C</th>
<th>IV-B</th>
<th>IV-A</th>
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<td>4</td>
<td>21 x 20.5</td>
<td>30 x 27</td>
<td>24 x 22</td>
<td>20.5 x 20</td>
<td>24’x20’</td>
<td>24 x 24</td>
<td>24 x 22.5</td>
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<tr>
<td>Cost</td>
<td>$25.53</td>
<td>$32.70</td>
<td>$32.10</td>
<td>$30.14</td>
<td>$36.97</td>
<td>$45.49</td>
<td>$45.04</td>
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<tr>
<td>6</td>
<td>--</td>
<td>24 x 23.5</td>
<td>20 x 20</td>
<td>20.5 x 20</td>
<td>24 x 24.5</td>
<td>24 x 24</td>
<td>24 x 22</td>
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<tr>
<td>Cost</td>
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<td>$32.56</td>
<td>$33.33</td>
<td>$31.50</td>
<td>$38.47</td>
<td>$46.68</td>
<td>$46.72</td>
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<tr>
<td>9</td>
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<td>24 x 24.5</td>
<td>24 x 24</td>
<td>24 x 22.5</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
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<td>--</td>
<td>$39.16</td>
<td>$47.37</td>
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<td>24 x 24</td>
<td>24 x 22</td>
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<tr>
<td>Cost</td>
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<td>--</td>
<td>$49.44</td>
<td>$49.93</td>
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<td>--</td>
<td>--</td>
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<td>24 x 22</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
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<td>--</td>
<td>--</td>
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<td>--</td>
<td>$52.81</td>
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</table>

The most economical option for each building type for each number of stories. Bay size in feet. Most economical system at each height shaded in blue.
The cost of the most economical bay option for each viable building type for a given number of stories

BUILDING ARCHETYPES
MULTI-STORY OFFICE ARCHETYPE STUDY

TYPE III A  6-STORY

CONCRETE  STEEL  MASS TIMBER
TYPE III A 6-STORY

Superstructure Construction Time (months)

- **Concrete**: 6.38 months
- **Steel**: 6.18 months
- **Wood**: 3.14 months

3.24 Months savings
TYPE III A 6-STORY

Superstructure Cost Premium Over Concrete (%)

- **Wood**
- **Steel**

<table>
<thead>
<tr>
<th>Pass</th>
<th>Wood</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass 1</td>
<td>14.32%</td>
<td>4.56%</td>
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<tr>
<td>Pass 2</td>
<td>7.01%</td>
<td>2.65%</td>
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<tr>
<td>Pass 3</td>
<td>2.38%</td>
<td>1.80%</td>
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<tr>
<td>Pass 4</td>
<td>1.19%</td>
<td>1.59%</td>
</tr>
<tr>
<td>Pass 5</td>
<td>0.49%</td>
<td>1.58%</td>
</tr>
</tbody>
</table>

**Raw material, installed**

**Includes general conditions (labor)**

**Includes general requirements (equipment) and waste management**

**Include urban site logistics**

**Include finishes**
Whole Building Cost Premium Over Concrete (%)

- **Wood**
- **Steel**

<table>
<thead>
<tr>
<th>Pass</th>
<th>Wood Premium</th>
<th>Steel Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.68%</td>
<td>2.15%</td>
</tr>
<tr>
<td>2</td>
<td>1.05%</td>
<td>0.40%</td>
</tr>
<tr>
<td>3</td>
<td>0.36%</td>
<td>0.27%</td>
</tr>
<tr>
<td>4</td>
<td>0.18%</td>
<td>0.24%</td>
</tr>
<tr>
<td>5</td>
<td>0.07%</td>
<td>0.24%</td>
</tr>
</tbody>
</table>

Assuming Superstructure Cost = 15% of Whole Building Cost

- **Raw material, installed**
- **Includes general conditions (labor)**
- **Includes general requirements (equipment) and waste management**
- **Include urban site logistics**
- **Include finishes**

**TYPE III A 6-STORY**

MULTI-STORY OFFICE ARCHETYPE STUDY
Finally: MEP coordination. Consider it early to minimize cost
Some conclusions

• Don’t hammer square pegs into round holes
  • When establish grid, remember:
    – Timber: Wood volume is key      Cost usually goes up with span
    – Steel: Number of pieces is key    Cost usually goes down with span

• Collaboration and coordination is critical
  • Engage fabricators early!
  • Architects, engineers, contractors, fabricators, erectors all have a part to play in optimizing systems

• After grids are set, don’t forget other factors
  • Connection cost
  • Constructability
  • Interface with other materials
This concludes The American Institute of Architects Continuing Education Systems Course

QUESTIONS?

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