Structural Mass Timber Design

The Engineer’s Role in Optimization

Presented by Chris Kendall, PE

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
The Engineer’s Role in Economy: OUTLINE

1. Mass timber panels and what they cost.


3. Bay studies
   A. Case Study: Boulder office

4. Mass timber connections and what they cost
   B. Case Study: Denver office

5. Steel beams and columns and what they cost

6. Office building systems and what they cost
WHAT DO MASS TIMBER PANELS COST?
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 THE MANUFACTURER

Mass timber panels are not a commodity!

- Panel width
- Panel length
- Lamination thickness
- E-rated and V-rated
- Species
- Special finishes
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
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
WHAT DOES GLUE LAMINATED TIMBER COST?
Dr K’s Glulam Beam Cost

Unit cost per cubic ft is a function of beam width

![Graph showing Glulam Beam Cost as a function of width](image)

Cost / Cubic Ft

Glulam Beam Cost as a function of width

Beam Width (in)

$50

$48

$46

$44

$42

$40

0 2 4 6 8 10 12 14 16
BAY STUDIES
Estimating the “Conceptual Cost” of a structural bay

- CLT Cost
- Wood Beams and Girders
- Wood Columns
- Wood connections
  - Beams, Girders, Columns
- Steel Beams and Girders
- Steel Columns
- Concrete (NC topping)

Conceptual cost estimates that follow are appropriate only for illustrating the relative difference between similar systems.

They are not accurate enough to compare steel vs concrete vs mass timber systems.
20 ft timber bents, no beams, CLT of varying span
Square bay w/ secondary beams, 3-ply CLT of varying span
Square bay, CLT with 2 equal (varying) spans
Wood Bay Study: 15x15 up to 30x30

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<th>15'</th>
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Wood Bay Study: 15x15 up to 30x30
BOULDER LOADING DOCK
BOULDER LOADING DOCK

- Type IV, Sprinklered Construction
- 2-story
- 2012 IBC
- 7-ply 5-layer CLT Floors
- 5-ply CLT roof
- 3-ply CLT shear walls
- Stora Enso and Ligna Terra
- 25 x 30 Grid
BOULDER LOADING DOCK

- 25 x 30 Grid
- 7-ply 5-layer CLT Floors
- 5-ply CLT roof
- 3-ply CLT shear walls
BOULDER LOADING DOCK
BOULDER LOADING DOCK
BOULDER LOADING DOCK

Simple connections
WHAT DO MASS TIMBER CONNECTIONS COST?
Mass timber design connections

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 15

- DIFFERENT MATERIAL
- DIFFERENT TOLERANCE
- DESIGN FOR IT
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
PLATTE 15
WHAT DOES STEEL FRAMING COST?
Steel Mill Base Price
Steel Pricing

Material Cost +
Detailing and Fabrication Cost +
Erection Cost

Total Cost

Approximately 2/3 of cost is labor and handling, not material
So ...

Fewer larger pieces are usually more economical than many small pieces

<table>
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<tr>
<th>Beam Size</th>
<th>Price per pc</th>
<th>Price per ton</th>
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<tr>
<td>W10x26 spanning 20 ft</td>
<td>$1,161 / pc</td>
<td>$4,255 / ton</td>
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<tr>
<td>W16x40 spanning 30 ft</td>
<td>$1,705 / pc</td>
<td>$2,707 / ton</td>
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<tr>
<td>W24x84 spanning 50 ft</td>
<td>$3,906 / pc</td>
<td>$1,771 / ton</td>
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Hybrid Bay Study: 15x15 up to 30x30
Hybrid vs Wood Grid

HYBRID E - 3-Ply CLT on Steel Grid

WOOD STUDY E - 3-Ply CLT Timber Grid

Conceptual Cost/$ft

Clear Height to Girdle (ft)

Concrete
Steel
Wood
Clear Ht
MULTI-STORY OFFICE ARCHETYPE STUDY

TYPE III A  6-STORY

CONCRETE  STEEL  MASS TIMBER
TYPE III A 6-STORY

MULTI-STORY OFFICE ARCHETYPE STUDY

Superstructure Cost Premium Over Concrete (%)

- **Pass 1**
  - Wood: 14.32%
  - Steel: 4.56%

- **Pass 2**
  - Wood: 7.01%
  - Steel: 2.65%

- **Pass 3**
  - Wood: 2.38%
  - Steel: 1.80%

- **Pass 4**
  - Wood: 1.19%
  - Steel: 1.59%

- **Pass 5**
  - Wood: 0.49%
  - Steel: 1.58%

**Raw material, installed**

**Includes general conditions (labor)**

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

**Include urban site logistics**

**Include finishes**
Some important design considerations that affect cost but not addressed here ...
Tall Wood requires design for fire rated assemblies

All case studies in this presentation were unrated construction
T3 - MEP

Photo courtesy of David Hanley
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