Mass Timber Construction: Products, Performance and Design

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WoodWorks / Wood Products Council

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Photo: Corey Gaffer courtesy Perkins + Will
Mass timber

- What is it – products
- Why use it – appeal
- How does it work – design
Mass timber is a category of framing styles often using small wood members formed into large panelized solid wood construction including CLT, NLT or glulam panels for floor, roof and wall framing.
Mass Timber Framing Systems

- Post & Beam
- Two-Way Panel Deck
- Hybrid Light-Frame & Mass Timber
- “Honeycomb”
5 PLY CLT PANELS, 2-WAY SPAN
~9’X13’ GRID OF COLUMNS

Two-Way Panels

Brock Commons
Vancouver, BC
Images: acton ostry architects
What’s in a mass timber building?

Products used
Mass Timber Framing Systems

Framing Styles

- Post & Beam
- Two-Way Panel Deck
- Hybrid Light-Frame & Mass Timber
- “Honeycomb”

Vertical framing – columns & beams - is commonly glulam
Mass timber products

Glulam = a structural composite of lumber and adhesives

- Recognized in IBC 2303.1.3 using ANSI/AITC A 190.1 and ASTM D 3737
- Can be used for floor, roof purlins, beams, arches, columns
Mass timber products

Glulam specs:

**Typical Widths:**
3-1/8”, 3-1/2”, 5-1/8”, 5-1/2”, 6-3/4”, 8-3/4”, 10-3/4”, 12-1/4”

**Typical Depths:**
Increments per # of lams from 6” to 60”+
western species lams are typically 1-1/2” thick
Southern pine lams are typically 1-3/8” thick

**Typical Species:**
Douglas-Fir, Southern Pine, Spruce
### Glulam design values

#### Bending About X-X Axis

(Loaded Perpendicular to Wide Faces of Laminations)

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<th>$F_{c,Lx}$ (psi)</th>
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Source: nds supplement table 5a
Mass timber products

Glulam specs:
Pt readily available
FRT may be available, varies by manufacturer & treater
Can be cambered, curved & tapered

Different Appearance Grades available
Mass timber products

glulam

Images: American Laminators

Glulam appearance grades

- Framing Grade
- Industrial Grade
- Architectural Grade
- Premium Grade
Mass timber products

Glulam layup:
Vary strength of laminations
• Higher strength lams at top and bottom - tension and compression stresses are high
• Lower strength lams in center plies

Image: Apa
Flexibility of spans and shapes

Richmond Olympic Oval, Richmond, BC, Canada
Design Team: Cannon Design Architecture, Fast + Epp, Glotman Simpson
Photo Credit: Stephanie Tracey, Craig Carmichael, Jon Pesochin, KK Law Creative, Ziggy Welsch
104’ Span Glulam Arches
Glulam purlins @ 4’ o.
First Tech Credit Union

Hillsboro, OR

5 stories
156,000 sf
First Tech Credit Union
Hillsboro, OR

ARCHITECT: HACKER
IMAGE CREDIT: StructurLam
Mass Timber Framing Systems

Framing Styles

- Post & Beam
- Two-Way Panel Deck
- Hybrid Light-Frame & Mass Timber
- “Honeycomb”

Horizontal panels – & vertical panels in “honeycomb” - many options
Mass Timber Products

- Glue Laminated Timber (GLT)
- Laminated Veneer Lumber (LVL)
- Parallel Strand Lumber (PSL)
- Laminated Strand Lumber (LSL)
- Cross Laminated Timber (CLT)
- Nail Laminated Timber (NLT)
- Timber-Concrete Composite (TCC)
- Dowel Laminated Timber (DLT)
- Mass Plywood Panel (MPP)

Photo credit: StructureCraft Builders/Freres Lumber
Nail Laminated Timber

Photo credit: structurecraft Builders
What is it?

Nail-laminated timber (NLT) is mechanically laminated to create a solid timber panel. NLT is created by placing dimension lumber (nominal 2x, 3x, or 4x thickness and 4 in. to 12 in. width) on edge and fastening the individual laminations together with nails.
When does the code allow it to be used?

IBC defines NLT as mechanically laminated decking per IBC 2304.9.3

Permitted anywhere that combustible materials and heavy timber are allowed, plus more
When is it used?
NLT is typically used for floor and roof panels. Plywood/OSB added to one face can provide in-plane shear capacity, allowing the product to be used as a diaphragm. Can also be used for walls, shafts.
Mass timber products

Nail-laminated timber (NLT) panels

often exposed on underside
Structure is finish

Photo credit: woodworks
Mass timber products

Content includes:

- Nail-laminated timber (NLT) panels
- Architecture
- Fire
- Structure
- Enclosure
- Supply and Fabrication
- Construction and Installation
- Erection engineering

Free download at www.thinkwood.com/nltguide
NLT panels can be built on-site/in-place or pre-fabricated offsite.
Type IV Construction
7 stories (6 Timber on 1 Concrete)
234,000 sf
2x8 NLT Floor Panels w/3” Concrete Topping
Glulam Beam and Column Frame
20’x25’ Grid
t3 minneapolis
Minneapolis, mn

Image Credit: Ema Peter
320 & 360 Wythe Ave.
New York, NY

3 story & 5 story buildings
Mostly office, some apartments
NLT & Glulam
Mass timber products

Dowel-Laminated Timber (DLT)

Photo credit: StructureCraft Builders
Mass timber products

Dowel-laminated timber (DLT) panels

- Similar to NLT – Nails Connecting Lams replaced with hardwood dowels
- Common in Europe – often referred to as Brettstapel
- Not currently recognized as prescriptively permitted material in IBC
- Timber Framers Guild

Photo credit: StructureCraft Builders
Dowel Laminated Timber: Similar to NLT – But lams are usually finger jointed in DLT so joint layups not a concern

credit: Structurecraft Builders
Various profile options

Mass timber products

Photo credit: StructureCraft Builders
111 East Grand
Des Moines, IA

4 story, 66,800 SF Spec office building
Credit: StructureCraft Builders
Mass timber products

Glue-laminated timber (gLT) panels

Photo credit: unalam
Mass timber products

Glue-laminated timber (gLT) panels

Glulam decking:

• Similar to deep glulam beams laid on their side
• Same code references and manufacturing standards as glulam beams and columns
• Be careful of design stresses and layups used – spec uniform layup (all lams same species & grade)
Mass timber products

Glue-laminated timber (gLT)

Same shrinkage and diaphragm considerations as nlt:

- Gap panels to allow movement
- Cover with wood structural panel for diaphragm
- Available in variety of lamination options
Tongue and groove decking:
2x, 3x or 4x solid or laminated wood decking laid flat with interlocking tongue and groove on narrow (side) face
• Recognized in IBC 2304.8 (lumber decking)
• 2x usually has a single t&G; 3x and 4x usually have a double t&g
• 6” and 8” are common widths
Ice block I
Sacramento, CA

135,000 sf of retail and restaurant space
Glulam frame, 3x T&G Decking
Mass timber products

Cross-laminated timber (cLT)
Mass timber products

Cross-laminated timber (cLT)

What is clt?
Solid wood panel
3 layers min. of solid sawn lams
90 deg. cross-lams
Similar to plywood sheathing
Common clt layups

3-ply 3-layer

5-ply 5-layer

7-ply 7-layer

9-ply 9-layer

Cross-laminated timber (cLT)

7-ply 5-layer

9-ply 7-layer
Mass timber products

Cross-laminated timber (cLT)

Clt prefabrication

• Finished panels are planed, sanded, cut to size. Then openings are cut with precise CNC routers.
• Third party inspection at factory
• Custom engineered for material efficiency
• Custom designed for project
• Each panel numbered, delivered & installed in predetermined sequence
4 stories
16,000 sf
Green Roof

ARCHITECT: Lever Architecture
IMAGE CREDIT: Lever Architecture
Candlewood suites
Redstone arsenal, AL

Image Credit: IHG® Army Hotels, Lendlease
Candlewood Suites
Redstone Arsenal, AL

- 62,600 sf, 4 story hotel, 92 private rooms
- CLT utilized for walls, roof panels, and floor panels
- 1,557 CLT Panels; Typical floor panel is 8’x50’ & weighs 8,000 lbs
- Completed Late 2015

Credit: Lend Lease & Schaefer
### Savings on this CLT project compared to typical light gauge steel construction

**Candlewood Suites at Redstone Arsenal, AL**
4 Stories, 62k SF

<table>
<thead>
<tr>
<th>PAL Portfolio</th>
<th>Typical New PAL Hotel (Actual*)</th>
<th>Redstone Arsenal (Actual)</th>
<th>Difference</th>
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<tbody>
<tr>
<td>Gross square feet (sf)</td>
<td>54,891</td>
<td>62,688</td>
<td>+14%</td>
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<tr>
<td>Average # of employees</td>
<td>18 (peak 26)</td>
<td>10 (peak 11)</td>
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<tr>
<td>Structural duration (days)</td>
<td>123</td>
<td>78</td>
<td>-37%</td>
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<tr>
<td>Structural person hours</td>
<td>14,735</td>
<td>8,203</td>
<td>-44%</td>
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<tr>
<td>Structural production rate/day</td>
<td>460 sf</td>
<td>803 sf</td>
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<tr>
<td>Overall schedule</td>
<td>15 months</td>
<td>12 months</td>
<td>-20%</td>
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</table>

* PAL New Build Hotel Historical Average

Source: Lendlease

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Image: Lendlease | Source: Lendlease
Mass timber products

Cross-laminated timber (clt)

In 2015 IBC, CLT is now 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.
NEW MASS TIMBER DESIGN MANUAL

80+ pages of mass timber technical resources, case studies and more. Links directly to many additional resources.

Jointly Produced By:

WOODWORKS™
WOOD PRODUCTS COUNCIL

THINK WOOD

https://info.thinkwood.com/masstimberdesignmanual
NEW MASS TIMBER FLOOR VIBRATION DESIGN GUIDE

Covers simple and complex methods for bearing wall and frame supported floor systems

Worked office, lab and residential Examples

Covers simple and complex methods for bearing wall and frame supported floor systems
NEW MASS TIMBER CONNECTIONS INDEX

A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load-carrying capacity.
Grid options and member sizes:
What’s been done
Bullitt center
Seattle, wa

11'-6” Beam Spacing
11'-6” column spacing at exterior
23'-0” Column Spacing at interior
2x6 NLT Floor Deck
• ~8’ finished floor to bottom of beam
• 25’x30’ at perimeter
• 30’x30’ bays at center
• 2x6 NLT Spans 15’
• Exterior steel moment frame keeps core area more versatile
25’x25’ Grid, 1 row
- Intermediate beams
- 15’-18’ floor to floor heights
- Composite floor: 2x4 and 2x6 NLT floor panels with 3 ½” reinforced concrete topping

Image Credit: Christian Columbres
t3 minneapolis
Minneapolis, mn

20’x25’ Grid
2x8 NLT Floor Panels span 20’ w/3”
Concrete Topping
Mass timber appeal
MARKET DRIVERS FOR MASS TIMBER

PRIMARY DRIVERS

» Construction Efficiency & Speed
» Construction site constraints – Urban Infill
» Innovation/Aesthetic

SECONDARY DRIVERS

» Carbon Reductions
» Structural Performance – lightweight

Image Credit: Structure Fusion
Mass timber appeal
Reduced construction time

1 Floor = 3 Days

17 Floors Erected in 9.5 Weeks

Brock Commons, Vancouver, BC
Source: naturally:wood⁵
Mass timber appeal

Material mass

75% lighter weight than concrete

Source: Structurlam®
Mass timber appeal

Completed in 2012
10 stories
~ 105 ft. tall, > 18.6 K sqft.
3 year investment in R&D
Poor soils required a much lighter building

Forte’, Victoria Harbor, Melbourne, Australia
Architect: LendLease | Source: Lendlease
Mass timber appeal
Reduced embodied carbon

Brock Commons,
Vancouver, BC

Source: Naturally:wood

Photo credit: acton ostry architects

ESTIMATED ENVIRONMENTAL IMPACT OF WOOD USE

Volume of wood products used: 2,233 cubic meters of CLT and Glulam

U.S. and Canadian forests grow this much wood in: 6 minutes

Carbon stored in the wood: 1,753 metric tons of CO₂

Avoided greenhouse gas emissions: 679 metric tons of CO₂

Total potential carbon benefit: 2,432 metric tons of CO₂

THE ABOVE GHG EMISSIONS ARE EQUIVALENT

511 cars off the road for a year

Energy to operate a home for 222 years


*CO₂ in this case study refers to CO₂ equivalent
Mass timber appeal

Minimal waste
Mass timber appeal

Mass timber elements fabricated to tight tolerances

Prefabricated and precise

Computer Numerically Controlled (CNC) connections

Photo credit: naturally:wood
Mass timber appeal
Energy efficient

CLT has an R-value of approximately 1.25 per inch of thickness. Source: US CLT Handbook\textsuperscript{10}

<table>
<thead>
<tr>
<th>Thickness</th>
<th>1 in. (25 mm)</th>
<th>4 in. (100 mm)</th>
<th>6 in. (150 mm)</th>
<th>8 in. (200 mm)</th>
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<td>R-value (h·ft·°F·Btu\textsuperscript{-1})</td>
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<td>RSI (m\textsuperscript{2}·K·W\textsuperscript{-1})</td>
<td>0.22</td>
<td>0.88</td>
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WHERE DOES mass timber FIT IN IBC’S CONSTRUCTION TYPES?
IBC DEFINES 5 CONSTRUCTION TYPES: I, II, III, IV AND V
A BUILDING MUST BE CLASSIFIED AS ONE OF THESE

CONSTRUCTION Types I & II:
ALL ELEMENTS REQUIRED TO BE NON-COMBUSTIBLE MATERIALS

HOWEVER, THERE ARE EXCEPTIONS INCLUDING SEVERAL FOR MASS TIMBER
ALL WOOD FRAMED BUILDING OPTIONS:

Type III
Exterior walls non-combustible (may be FRTW)
Interior elements any allowed by code, INCLUDING MASS TIMBER

Type V
All building elements are any allowed by code, INCLUDING MASS TIMBER

Types III and V are subdivided to A (protected) and B (unprotected)

Type IV (Heavy Timber)
Exterior walls non-combustible (may be FRTW OR CLT)
Interior elements qualify as Heavy Timber (min. sizes, no concealed
CONCEALED SPACES

Type IV Construction requires that interior elements be without concealed spaces:

• Concealed spaces include dropped ceilings, attics, chases, others
• Concealed space restriction does not apply to any other construction type. If using mass timber elements in non type IV construction, concealed spaces are permitted but may be required to be sprinklered
• Ibc 602.4.6 permits 1 hour fire resistance rated construction for partitions

Example of concealed space created by dropped ceiling
Where does the code allow MT to be used?

- **Type V**: Interior elements, roofs & exterior walls
Construction types

Type III: 6 stories

Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler

Type IV: 6 stories

Type V: 4 stories
Fire resistance

Photo Credit: fPinnovations
Mass timber design

Fire resistance

![Image of comparative strength loss of wood versus steel](image)

**Comparative Strength Loss of Wood Versus Steel**

- **Wood**
  - 25% loss @ 30 minutes
  - 50% loss @ 1020°F

- **Steel**
  - 90% loss @ 30 minutes
  - 1380°F

*Results from test sponsored by National Forest Products Association at the Southwest Research Institute*

Source: Aitc
Mass timber design

Fire resistance

Similar to heavy timber, mass timber products have inherent fire resistance properties.

Source: AWC’s TR 10
Mass timber products

ACOUSTICS
Lightweight concrete topping or other similar materials can provide improved acoustical performance, increased durability.
Mass timber design
Acoustics

Acoustical mat - typically installed between subfloor and topping or flooring

Image credit: Pliteq
Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5” to 3” thick concrete/gypcrete topping
- Acoustical mat
- WSP (if applicable)
- Mass timber floor panels

Image credit: AcoustiTECH
Options without concrete topping:

- Gypsum/cement board (Fermacll, Permabase, etc.)
- Proprietary products
Mass timber construction costs vary with project location, size, spans, finish level and many other variables.

Product manufacturers are the best source of pricing information.
Questions?

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901 East Sixth, Thoughtbarn-Delineate Studio, Leap!Structures, photo Casey Dunn
Mass timber Costs

Factors relevant to the cost conversation:

- Cure time: mass timber has none. can be worked on immediately after being placed.
- Light-weight:
- Crane size: mass timber is lighter than traditional materials\(^7\). Smaller crane = potential savings.
- Smaller seismic forces & foundations = potential savings.
- Construction speed: estimated to be 25% faster\(^11\). Sooner completion = sooner occupancy = sooner revenue.
- Others: less construction traffic\(^11\), prefabricated & precise – goes together smoothly.
- Other items that affect cost: Shipping distance, sealers/sanding requirements, amount of custom cnc work.

Source 7: Structurlam
Source 11: Fast + Epp
Photo Credit: Structurlam
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