MASS CHANGE WITH MASS TIMBER
BUILDING CODE IMPLICATIONS FOR ARCHITECTS AND DESIGNERS

JULY 10, 2019  AIA SEATTLE

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SESSION OUTLINE

• Why Tall Timber + Code Change Proposals Process
• The Code Changes
• Structural Implications
• General Case Studies + Conceptual Case Study Type IV-B
• Question + Answer session
Why Washington and Tall Timber?

Legislation ESB 5450

Forest Health Crisis:
Management Practices
Remove Fuels
Prevent Fires
Increase Dialogue
Sustainable Harvest

Establish
Manufacturing Base:
Hi-tech CNC Machining
Prefabication/Modularization
Modernize Construction

Rural Jobs
New Industry
Economic Growth

Local/Renewable Material
State-wide CLT Coalition:
Submitted state-wide code change proposal based directly from ICC TWB Committee work
TAG and SBCC Process
ESB 5450 was vital
Public Hearings

Outcome:
Tall wood provisions adopted for 2015 WA State Building Code (effective July 1, 2019) and 2018 WA State Building Code (effective July 1, 2020)
Pre-adopts 2021 IBC provisions
SBCC interpretations necessary to incorporate IBC changes made in 2019
TWB:
Formed by ICC
Board of Directors
Broad Industry Representation and Participation
Open Meetings
Science + Judgment
<table>
<thead>
<tr>
<th>TWB Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>No collapse after complete burn-out of fuel without automatic sprinkler protection</td>
</tr>
<tr>
<td>No unusual risk (radiation/fire exposure) to adjoining properties</td>
</tr>
<tr>
<td>No unusual risk (radiation/fire exposure) of adjoining properties to mass timber building</td>
</tr>
<tr>
<td>No unusual fire department access issues</td>
</tr>
<tr>
<td>Egress systems designed to protect building occupants during the design escape time, plus a factor of safety</td>
</tr>
<tr>
<td>Highly reliable fire suppression systems to reduce the risk of failure during reasonably expected fire scenarios</td>
</tr>
<tr>
<td>The degree of reliability should be proportional to evacuation time (height) and the risk of collapse</td>
</tr>
</tbody>
</table>
TWB Fire Tests

Compartment Tests

Type IV-A & IV-B survived complete burn-out

Type IV-C tested with sprinkler activation, not complete burn-out

CLT manufactured with non-heat delaminating adhesives as required in PRG-320 2018
Status of Tall Wood Proposals

**2021 IBC & IFC**

13 proposals
Passed as proposed by TWB
ICC membership voting:
  • 977 votes cast (> any other)
  • 71% in favor, 29% against

**2021 IBC Group B Proposals (2019)**

3 TWB proposals approved by ICC Committees
2 competing proposals disapproved
The Code Changes
2021 IBC: 11 Code Change Proposals (Group A)

- Tables 504.3 & 504.4: Allowable Height/Stories
- Table 506.2: Allowable Area
- 508/509: Fire Barriers
- 602.4: Type of Construction
- 703.8: Performance Method
- 703.9 & 1705.19: Sealants at Edges
- 718.2.1: Fireblocking Materials
- 722.7: Fire-Resistance Ratings
- IFC 3308.4: Fire Safety During Construction
Section 202: New Definition

MASS TIMBER

Structural elements of Type IV construction primarily of solid, built-up, panelized or engineered wood products that meet minimum cross section dimensions of Type IV construction.

Light-frame wood construction not allowed!

NOTES:
Heavy Timber minimum dimensions in IBC 2018 moved to section 2301.11
For WA 2015 amended IBC, minimum dimensions remain in Chapter 6
Types of Type IV

**IBC Defines Minimum Sectional Dimensions:**

- Solid Sawn
- Glued-Laminated Timber (GLT)
- Structural Composite (LVL, PSL, LSL, OSL)
- Nail-Laminated Timber (NLT)
- Cross-Laminated Timber (CLT)

**Other:**

- Dowel-Laminated Timber (DLT)
- Mass Plywood Panel (MPP)
IBC Section 602.4 Type IV

Defines Three New Construction Types:
- Type IVA
- Type IVB
- Type IVC

**Type IV-HT:**
Legacy Type Heavy Timber
No Change

**Note:**
PRG-320 2018:
Heat De-lamination

NOTE: Heavy Timber minimum dimensions apply to new construction types and Type IV-HT
Type IVA

**INTERIOR:**
FULLY PROTECTED

Fully protected:
No exposed mass timber (walls, ceilings, roofs)

Not less than 80 minutes or 2/3 of the fire resistance rating from noncombustible protections

**EXTERIOR**

Minimum 40-minute noncombustible protection plus no combustible cladding or sub-framing

**FLOORS**

Minimum 1-inch thick non-combustible topping
Type IVB

**INTERIOR:**
**PARTIALLY PROTECTED**

- **Ceilings:** 20% exposed in dwelling unit/fire area
- **Walls:** 40% Exposed

**Combined Ceilings and Walls:** Formula Calculation + separate exposed ceilings and walls by minimum 15 feet

**EXTERIOR**
Minimum 40-minute noncombustible protection plus no combustible cladding or sub-framing

**FLOORS**
Minimum 1-inch thick non-combustible topping

**NOTE:** Mass timber buildings over 120’ require fire pump connections from two separate mains.
Type IVB
Type IVC

**INTERIOR**
No protection required

**EXTERIOR**
Minimum 40-minute noncombustible protection plus no combustible cladding or sub-framing

**FLOORS**
In accordance with 804

**TYPE IV-HT**
No change

**NOTES:** Concealed spaces and shafts require min. 40 minute protection inside and outside for Type IVC. Concealed spaces not permitted in Type IV-HT.
Fire Resistance Rating

Fire resistance ratings determined by rating of wood (tested or calculated) plus “noncombustible protection”

Noncombustible protection must provide 2/3 of required fire resistance rating for Type IV-A and IV-B

See Section 722 for noncombustible protection
Connections must be protected

SECTION 202
Building elements, **components** and assemblies to be fire-resistance rated

SECTION 722.1
Fire-resistance rating can be determined in **NDS Chapter 16 and AWC TR-10**:
Provide requirements to protect steel with wood, noncombustible protection or combination

SECTION 704.2 & 704.3
Primary frame to be protected

SECTION 2304.10.1
**GROUP B PROPOSAL**
Connection fire resistance to be determined by:
1. Testing
2. Analysis showing temp. rise is limited for all structural elements
Connections

EXAMPLE

Steel bucket connections with wood protective trim

3-4 layers of wood may be needed for 2 hour protection

Char contraction: manage temperature of steel <250°F to prevent extension of heated zone

Heat at steel can be a problem
## Connections

**FIRE TESTED CONNECTIONS (PROPRIETARY)**

Ricon
Knapp

<table>
<thead>
<tr>
<th>Test</th>
<th>Applied load at the connection</th>
<th>Connector design resistance with reduced amount of screws</th>
<th>Connector design resistance with full amount of screws</th>
<th>Fire test duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs [kN]</td>
<td>lbs [kN]</td>
<td>lbs [kN]</td>
<td>min</td>
</tr>
<tr>
<td>Single Ricon S VS 290x80</td>
<td>3,905 [17.4]</td>
<td>9,127 [40.6]</td>
<td>16,905 [75.2]</td>
<td>60</td>
</tr>
<tr>
<td>Double Ricon S VS 200x80</td>
<td>16,620 [73.9]</td>
<td>27,426 [122.0]</td>
<td>27,426 [122.0]</td>
<td>90</td>
</tr>
<tr>
<td>Megant 430x150</td>
<td>16,620 [73.9]</td>
<td>31,898 [141.9]</td>
<td>38,277 [170.5]</td>
<td>90</td>
</tr>
</tbody>
</table>

**NOTE:** Fire stopping requires special inspection

*Images: Myticon*
Noncombustible Protection (Prescriptive)

**TABLE 722.7.1 (1)**
Protection Required from Noncombustible Covering Material

<table>
<thead>
<tr>
<th>Required Fire Resistance of Building Elements per Tables 601 &amp; 602 (HOURS)</th>
<th>Minimum Protection Required from Noncombustible Protection (MINUTES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3 or more</td>
<td>120</td>
</tr>
</tbody>
</table>

**TABLE 722.7.1 (2)**
Protection Provided by Noncombustible Covering Material

<table>
<thead>
<tr>
<th>Noncombustible Protection</th>
<th>Protection Contribution (MINUTES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2-inch Type X Gypsum Board</td>
<td>25</td>
</tr>
<tr>
<td>5/8-inch Type X Gypsum Board</td>
<td>40</td>
</tr>
</tbody>
</table>

NOTE: Testing procedure provided in Section 703.8 to determine time contribution of materials
**Table 601: Fire Resistance for Building Elements**

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Primary Structural Frame</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bearing Walls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Interior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Non-Bearing Walls &amp; Partitions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Floor Construction</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof Construction</td>
<td>1-1/2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
# Table 601: Fire Resistance for Building Elements

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<td></td>
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<td>A</td>
<td>B</td>
<td>A</td>
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<td>1</td>
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<td>3</td>
</tr>
<tr>
<td>Bearing Walls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HT</td>
</tr>
<tr>
<td>Exterior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Interior</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Non-Bearing Walls &amp; Partitions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-Bearing Walls &amp; Partitions:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(See Table 602)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor Construction</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof Construction</td>
<td>1-1/2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

**NOTE:** Reductions in fire resistance ratings allowed in hi-rise construction not allowed for mass timber.
**Table 506.2: Allowable Area**

<table>
<thead>
<tr>
<th>Occupancy Classification</th>
<th>Sprinklered</th>
<th>Type I</th>
<th>Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>S</td>
<td>UL</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>B</td>
<td>S</td>
<td>UL</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>S</td>
<td>UL</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>S</td>
<td>UL</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(S)</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>S</td>
<td>135,000</td>
<td>90,000</td>
<td>56,250</td>
<td>45,000</td>
<td></td>
<td></td>
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<tr>
<td>A-2</td>
<td>S</td>
<td>135,000</td>
<td>90,000</td>
<td>56,250</td>
<td>45,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-3</td>
<td>S</td>
<td>135,000</td>
<td>90,000</td>
<td>56,250</td>
<td>45,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>S</td>
<td>324,000</td>
<td>216,000</td>
<td>135,000</td>
<td>108,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>S</td>
<td>229,500</td>
<td>153,000</td>
<td>95,625</td>
<td>76,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>S</td>
<td>184,500</td>
<td>123,000</td>
<td>76,875</td>
<td>61,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-2</td>
<td>S</td>
<td>184,500</td>
<td>123,000</td>
<td>76,875</td>
<td>61,500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 503.4 & 504.4: Allowable Stories/Height Above Grade Plane

<table>
<thead>
<tr>
<th>Occupancy Classification</th>
<th>Sprinklered</th>
<th>TYPE OF CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(S)</td>
<td>A</td>
</tr>
<tr>
<td>A-2</td>
<td>S</td>
<td>UL/UL</td>
</tr>
<tr>
<td>A-3</td>
<td>S</td>
<td>UL/UL</td>
</tr>
<tr>
<td>B</td>
<td>S</td>
<td>UL/UL</td>
</tr>
<tr>
<td>M</td>
<td>S</td>
<td>UL/UL</td>
</tr>
<tr>
<td>R-2</td>
<td>S</td>
<td>UL/UL</td>
</tr>
</tbody>
</table>
Elevated temperature performance requirements in U.S. and Canada

- 6.3.1 - Adhesives must meet ANSI 405 (small scale qualification test)
- 6.3.3 - Adhesives must meet elevated temperature performance per Annex B (large-scale compartment test)

Intent to exclude premature failure of adhesives that permit CLT char layer fall-off before arriving at the glue-line, resulting in exposed fresh wood and fire regrowth / re-flashover in tests.

WA code change adopts PRG-320 2018 for Type IV-A/B/C

NOTE: IBC 2303.1.4 requires CLT to be manufacturer in accordance with PRG-320. For WA IBC 2015, only new Type IV-A/B/C require PRG-320 2018.
Adhesive Qualification Tests

Qualification Tests Performed on Other Adhesives

- Fire regrowth observed with PUR
- No fire regrowth observed with: Melamine Formaldehyde Resin, Improved PUR
- Test identifies acceptable performance
- Performance similar to solid wood
SECTION 403.3.2
Water Supply to Required Fire Pumps
Type IV buildings over 120-feet require fire pumps from two separate connections (non-combustible = 420-feet)

SECTIONS 508.4.4.1 & 509.4.1.1
Thermal Barrier
In Type IVB and IVC – Thermal barrier required for horizontal assemblies and when a fire barrier between separated occupancies and incidental uses is required
Special Inspections of Mass Timber Construction

2021 IBC TWB Proposals
Group B

3rd-Party Agency
WABO developing certifications

Required for Erection
Similar to precast concrete
Panel labeling, placement, structural connections
State interpretation required to update WA 2015 code

Connection Fire Protection
Handled by Building Inspector
Examples of Protection During Construction for Mass Timber Buildings Greater than Six Stories Above Grade Plane

Prior to placement of mass timber floor panels, all building elements more than 4 floors below the level of active mass timber construction shall be protected as required by this section.

Floor level of active mass timber construction.

Noncombustible floor covering required at this level and all lower floor levels.

Heavy bold lines indicate elements one layer of noncombustible protection on building elements of mass timber when required by Section 604.2.

Shading indicates where exterior wallcovering is required.
Nail-Laminated Timber “Gotcha”

Water During Construction
Difficult to dry-out between lamination joints
Provide expansion joints due to potential swelling of laminations
Design for moisture induced movement
Plan 1.25” swelling / 20’
Leave out (1) lamination every 20’
Stair, Hoistway and Shaft Construction “Gotchas”

Type IV-A/B/C Stairs and Hoistways

Exposed timber not allowed, including Type IV-C
GWB protected mass timber allowed up to 12 stories/180 feet

Non-combustible construction required above 12 stories/180 feet

Mass timber shafts must be protected with GWB

SOURCE: US FPL, USDA
Concealed Spaces “Gotchas”

Concealed spaces allowed in new construction types

• Limited combustibles
• Mass timber lined inside and outside with GWB
• Level of protection in concealed space:
  Rating dependent, 2-3 layers

Concealed spaces not allowed in Type IV-HT

NOTE: Type IV-A/B - 2/3rds of required fire protection must come from non-combustible protection inside and outside.
Type IV-C - Minimum 40 minute non-combustible protection inside and outside

SOURCE: US FPL, USDA
Exterior Wall “Gotchas”

Type IV-A/B/C
• GWB on outside face of mass timber
• No combustibles outboard of mass timber

Energy Code Notes
• Continuous insulation only per Prescriptive Path
• Mineral wool is non-combustible
• Performance path is available
• Confirm R-values of wood with local jurisdiction ahead of time

2 hr fire resistant rating required for Exterior (load-bearing and non-load bearing) and Interior bearing walls

Exterior noncombustible protection. All material outboard of mass timber must be non-combustible (except weather barrier)
Acoustic & Fire Assemblies

CLT Handbook:
Provides limited acoustically tested floor and wall assemblies

WoodWorks Document:
Provides larger and growing compendium of wall and floor assemblies
Includes CLT, NLT, GLT assemblies


SOURCE: CLT HANDBOOK
SOURCE: WOODWORKS
STRUCTURAL SYSTEMS
Type IV Seismic Systems - Up to 3-Stories

**Vertical Systems**
- CLT shear walls - not codified (low R-factor)
- Steel frames
- Concrete frames or shear walls

**Horizontal Systems**
- CLT diaphragm (using alternate means and methods)
- Plywood/OSB sheathing at NLT/DLT
- Reinforced concrete topping
CLT Shear Walls

Currently not in the US building code

Lacks seismic parameters for design (Response Modification Factor)

Current Research:

• FEMA P695 process to develop Seismic Design Parameters for CLT Shear Walls
• NEHRI Tall Wood Research Project to develop rocking CLT wall systems for tall buildings

*Jefferson Elementary School CLT Portable Additions | Image credit: John Gilson & Paula Saurez, Walsh Construction Co.*
CLT Shear Wall Construction

**CLT Panel**
- High-strength & stiffness values
- Tested strength & stiffness values from manufacturer

**Angle Brackets**
- Transfer shear
- Capacity from NDS dowel bearing equations

**Holdowns**
- Resist overturning
- CLT panel acts as a rigid body

---

**CLT Wall Components**
Source: Shahnewaz, Building Journal, August 2018.

**Diaphragm Connection Detail**
Source: CLT Handbook

**CLT Wall Overturning**
Source: Lukacs, Science Direct, October 2018
CLT Shear Wall Construction

- CLT Panels
- Generic angle bracket connections to the diaphragm
- Generic shear connectors between panels for energy dissipation
- Performed experiments with various CLT Panel aspect ratios (height:width)

Source: Omar Amini, PhD Student, Colorado State University
Type IV Seismic Systems - Greater Than 3-Stories

**Vertical Systems**
- Concrete frames or shear walls
- Steel frames
- CLT rocking walls (not codified)

**Horizontal Systems**
- CLT diaphragm (using alternate means and methods)
- Reinforced concrete topping

Source: naturallywood.com
Source: Lever Architecture
Source: Ema Peter
Rocking CLT Wall Implementation: Framework

Deformed shape of u-shaped flexural plates "fuse" of system dissipating energy
NHERI Tall Wood Research Project

**Goal:** Design method for seismically-resilient tall wood buildings

**Validation:** Shake table tests at University of San Diego California

*Intercollegiate project with industry involvement lead by Shiling Pei at Colorado School of Mines*

*Shake Table Test on a 2-story Rocking Wall Building (2017)  Shake Table Test on a 10-story Rocking Wall Building (2021)*
Mass Timber Assemblies

CLT Floor Panels with Wood Bearing Walls
Lowrise Structures up to 85 feet or 6 stories (Type III & V)

- 3-5 ply CLT panel with acoustical topping
- Glulam beams where needed
- Wood stud bearing walls
- Plywood shear walls
- CLT walls up to 3 stories max
- CLT approximate span:
  - 17 ft residential, 12 ft office/retail
Mass Timber Assemblies

CLT Floor Panels with Mass Timber Columns
Lowrise & Highrise Residential/Hospitality
Type III; Type IV-A, -B, -C, -HT; & Type V

- 5-Ply CLT panel
- Heavy timber columns
- CLT shear walls, concrete shear walls, steel frames
- Approx. 8'x13' column grid
- May need panel span testing
Mass Timber Assemblies

CLT or DLT Panels with Mass Timber Girders
Low-To-Highrise All Occupancies
Type III; Type IV-A, -B, -C, -HT; & Type V

- CLT or DLT panels with acoustical topping
- Glulam girders
- Heavy timber columns
- CLT shear walls, concrete shear walls, steel frames
- Approx. 20’x25’ column grid
- Optional beams spanning between girders to downsize panels
Mass Timber Assemblies

CLT or DLT Panels with Steel Wide Flange Beams
Low-To-Highrise Office/Industrial
Type III; Type IV-A, -B, -C, -HT; & Type V

- CLT or DLT panel with concrete topping
- Steel girders
- Steel columns
- Approx. 30'x40' column grid
- Optional beams spanning between girders to downsize panels
Mass Timber Assemblies

**CLT or DLT Panels with Pre-Cast Concrete Girders**
Low-To-Highrise Office/Industrial
Type III; Type IV-A, -B, -C, -HT; & Type V

- CLT or DLT panel with concrete topping
- Precast concrete girders
- Precast concrete columns
- Concrete shear walls or moment frames
- Approx. 30'x40' column grid
Timber Concrete Composite

- Mechanically join mass timber panel or glulam beam to concrete topping
- Various attachment methods (inclined screws shown)
- Increases strength and stiffness resulting in longer spans and relatively smaller framing members
Propriety Products - Screws

**SWG**
- VS Plus shown 1/4"-1/2" DIA
- ICC Report # ESR 3179 - ASSY 3.0 (partially threaded)
- ESR 3178 - VG Plus (fully threaded)

**GRK**
- RSS shown 1/4"-3/8" DIA
- ICC Report # ESR 2442

**Simpson**
- Strong-drive shown up to 0.22" DIA
- EUS Report #192

**Rothoblaas**
- TBS shown ~ 1/4"-1/2" DIA
- No known U.S. testing
Propriety Products - Beam Hangers

Capacity up to 75,000lb (LRFD)

- Multiple hangers can be used on same beam to increase capacity

Successful full scale ASTM E119 fire testing

ICC approval pending
Conventional Hangers

Kerf Plate Connections

Bucket Type Connection
DLT/NLT Spline Connection

Typical DLT Decking Spline

- Acoustic mat per arch'l (where occurs)
- Concrete topping & reinf. per plan
- DLT decking per plan
- Gap per DLT mfr. for wood expansion (3/4" max.)
- 1/2" x 6" plywood spline @ 10d @ 8"oc ea. side of joint
CLT Spline Connections

**Surface Spline**

- CONT. 1⅜"x6" PLYWOOD
- CTRD. ON JOINT
- ⅛" MAX. OVERCUT EA. SIDE

**Half-Lap**

- 1⅛" MIN TYP.

TYPICAL END SPLINE

TYPICAL SIDE SPLINE
Panel Connection to Framing Member

- DLT Decking Spline Over Steel Beam
- DLT Decking Over Wood Beam
- DLT Decking Spline Over Wood Beam
Achieving fire rating does not necessarily require an increase in member size.

Adjustment factor \((K)\) applied to capacity per section 16.2.2.

Example (3-sided exposure):

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>MOMENT DEMAND (K-FT)</th>
<th>SIZE (NO FIRE RATING)</th>
<th>SIZE (1-HR FIRE RATING)</th>
<th>SIZE (2-HR FIRE RATING)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PURLIN</td>
<td>40 K-FT</td>
<td>GL 5-1/8&quot; x 16-1/2&quot;</td>
<td>GL 5-1/8&quot; x <strong>19-1/2&quot;</strong></td>
<td>GL 8-3/4&quot; x <strong>18&quot;</strong></td>
</tr>
<tr>
<td>GIRDER</td>
<td>230 K-FT</td>
<td>GL 10-3/4&quot; x 28-1/2&quot;</td>
<td>GL 10-3/4&quot; x <strong>22-1/2&quot;</strong></td>
<td>GL 10-3/4&quot; x <strong>28-1/2&quot;</strong></td>
</tr>
</tbody>
</table>

*Analysis considers loss of charred wood material but utilized ultimate strength of wood (vs allowable capacity derived from 5% exclusion value)*
Fire Design per NDS Ch. 16 (Cont.)

Table 16.2.2 Adjustment Factors for Fire Design

<table>
<thead>
<tr>
<th>Member Stress</th>
<th>ASD Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Strength</td>
<td>$F_{kx}$</td>
</tr>
<tr>
<td>Beam Buckling Strength</td>
<td>$F_{kx}$</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>$F_{kx}$</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>$F_{kx}$</td>
</tr>
<tr>
<td>Column Buckling Strength</td>
<td>$F_{kx}$</td>
</tr>
</tbody>
</table>

K-Factor

Effective Char Depth ($A_{char}$)

Relative Net Section Loss is MORE SIGNIFICANT in SMALLER MEMBERS

"Smaller" Member

Effective Char Depth ($A_{char}$)

Relative Net Section Loss is LESS SIGNIFICANT in LARGER MEMBERS

"Larger" Member
Timber Concrete Composite - Field Inspections

- Fastener type and size
- Spacing, edge distance
- Embedment depth
- Installation angle
Vibration/Acoustics

- Vibration performance requirements are determined for projects based on owners desired serviceability needs. Not driven by code.
- Typically, panel spans are limited by vibration, not strength.
- Acoustic assemblies typically require cementitious topping.
- There is a lot of current testing/research ongoing into predicting acoustic and vibration performance.
Supply Chain

What is the current status of the NW supply chain?

a. Structurlam Penticton, B.C.
b. SmartLam Columbia Falls, MT
c. DR Johnson Lumber Riddle, OR
d. Katerra Spokane, WA
e. Vaagen Timbers Colville, WA
f. StructureCraft Abbotsford, B.C.
Efficient Mass Timber Structures

Characteristics of Efficient Mass Timber Structures

• Beam-Girder-Column Configuration
• Minimized Floor & Roof Panel Thicknesses
• Designed for Modular Fabrication
• Column Spacing Between 20 and 25 Feet
• Non-rated Construction, if possible (III-B, IV-HT, V-B)
• Bolted Steel Lateral Frames
• Light-weight Floor Toppings
• Minimal Facade Undulation
• Timber-Concrete Composite for Long Spans
BROCK COMMONS  Vancouver, BC

- Building Height:  **190 ft | 57.9 m**
- Use:  **Residential Apartments**
- Stories:  **18**
- Square Footage:  **162,697 ft² | 15,115 m²**
- Owner:  **University of British Columbia**
- Architects:  **Acton Ostry Architects, Inc.**
- Structural:  **Fast+Epp - Design**
  **RJC Engineers | Merz Kley Partner**
BROCK COMMONS Vancouver, BC

Acton Ostry Architects & University of British Columbia

- CLT floor slabs with glulam columns and steel connectors
- Partial encapsulation during construction
- Completed construction condition
- Encapsulated structure final condition

Template for TYPE IV-A

Hybrid mass timber + concrete structure
BROCK COMMONS Vancouver, BC

exposed wood structure at student amenity space

encapsulated wood structure at typical floor

cement structure and CLT canopy at base
BROCK COMMONS Vancouver, BC

Acton Ostry Architects
& University of British Columbia
FRAMeWORK Portland, OR

• Building Height: **148 ft**
• Use: **Office, Retail, Affordable Housing**
• Stories: **12**
• Square Footage: **90,000 ft²**
• Owner: **Home Forward + Beneficial State Bank**
• Architects: **Lever Architecture**
• Structural: **KPFF Consulting Engineers**
• More representative to Type IB
• Best planned project representing Type IV-B albeit the unique seismic system – design indicates more exposed wood than would be allowed
CLT wall panel structural testing at Oregon State University. Structural tests were taken well beyond actual building demands to observe failure mechanisms in the CLT panels.
CARBON 12 Portland, OR

- Building Height: 85 ft
- Use: Residential Condos + Commercial
- Stories: 8
- Square Footage: 42,000 ft²
- Owner: Kaiser Group
- Architects: Path Architecture
- Structural: Munzing Structural
  - exposed CLT with exposed Post + Beams (Portland Special)
  - protected concealed spaces, stairs and shafts
HINES T3 Minneapolis, MN

- Building Height: 85 ft
- Use: Commercial Office
- Stories: 7
- Square Footage: 180,000 ft²
- Owner: Hines
- Architects: Michael Green + DLR Group
- Structural: Magnusson Klemencic Associates + Structure Craft
tech office tenants seeking out **Mass Timber** Aesthetic

code compliant **TYPE IV - HT**

[Image of a building interior with wooden elements and a diagram of a cross-section of a building with wooden beams.]
• Building Height: **140 ft** (**180 max height**)
• Use: **Hotel (R1)**
• Stories: **12** (**max stories**)
• Square Footage: **135,000ft²** (**393,600 SF max area for R-1 Type IV-B site specific**)
• Architects: **Weber Thompson**
• Modular + Conceptual

This conceptual study explores details and function of Type IV-B construction under the lens of modular CLT construction to control costs through reducing on-site construction periods.
exploded module to module connection

Modular concept: 8.5’ - 13’ wide modules assembled on site. Mineral wool b/w modules - treatment of concealed spaces created out of redundancy of modular format (not a tested assembly)

PROJECT WHITTLE

conceptual TYPE IV-B
1-layer of 5/8” Type X Gypsum Sheathing + weather barrier at minimum attached to module to eliminate sequencing issues for protected exterior as floor assemblage exceeds 4 levels

Continuous Insulation + non-combustible rain-screen assembled on-site

Corridor included as extension of hotel key module
PROJECT WHITTLE
module to module connection detail study
untested wall assembly (exposed timber + fully protected)

- 2 layer 5/8” GYP (2hr)
- 3 layer CLT (protected)
- +/- 4” mineral wool b/w modules
- 5 layer CLT exposed (allowed under type IV-B up to 40%)
- Concealed Metal plate - 1” concrete topping protected
- Protected L bracket

Assembly does not meet 2HR testing requirement
“mostly tested” wall assembly (exposed timber + fully protected)

- 2 layer 5/8” GYP–2hr
- 5 layer CLT (protected)
- +/– 4” mineral wool b/w modules
- 5 layer CLT exposed–2hr (allowed under type IV-B up to 40%)
- Concealed Metal plate – 1” concrete topping protected
- Protected L bracket

Redundant system as part of modular construction creates concealed spaces
wall assembly (exposed timber + fully protected)

- 2 layer 5/8” GYP (2hr)
- 5 layer CLT - 1 side exposed
  (allowed under type IV-B up to 40%)
- Sound isolation needed for STC
- Concealed Metal plate - 1”
  concrete topping protected

Detail eliminating redundancy and assuming componentized in lieu of modular construction
floor ceiling assembly – untested assembly

Economics of a modular system would require testing of assemblies

1” concrete topping

3 layer CLT

+/− 4” mineral wool (Fire stop gap b/w floor ceiling)

3 layer CLT

2 layers gyp
Component floor ceiling assembly - tested assembly

Detail eliminating redundancy and assuming on-site construction in lieu of modular

Sound isolation to meet STC

1" concrete topping

5 layer CLT

2 layers gyp
PROJECT WHITTLE

EXPOSED STRUCTURAL TIMBER TYPE IV-B CODE REALITY

VS

FRAMEWORK CASE STUDY – EXCEEDS LIMITATIONS OF TYPE IV-B EXPOSED STRUCTURAL TIMBER
PROJECT WHITTLE

EXPOSED STRUCTURAL TIMBER WALLS

Uw = total unprotected ceiling
Uaw = allowable unprotected wall (<40% total floor area) = 487 SF total floor area @ 40% = 195 SF
**PROJECT WHITTLE**

**EXPOSED STRUCTURAL TIMBER CEILING**

20% CEILING AREA

Utc = total unprotected ceiling

Uac = allowable unprotected ceiling (< 20% total floor area) = 487 SF total ceiling area @ 20% = 97.4 SF

**conceptual TYPE IV-B**
EXPOSED STRUCTURAL TIMBER CEILING + WALLS – Separate exposed ceilings and walls by minimum 15 FT, measure along the ceiling

\[(U_{tc} / U_{ac}) + (U_{w} / U_{aw}) \leq 1\]

- Utc = total unprotected ceiling = 58 SF
- Uac = allowable unprotected ceiling (< 20% total floor area) = 97.4 SF
- Uw = total unprotected wall = 77 SF
- Uaw = allowable unprotected wall (< 40% total floor area) = 195 SF

\[(58 \text{ SF} / 97.4 \text{ SF}) + (77 \text{ SF} / 195 \text{ SF}) = 0.99 \leq 1\]
RESOURCES

• 2021 IBC Code Change Proposals (Group A)
• US CLTHandbook
• Think Wood – https://www.thinkwood.com/
• American Wood Council (AWC) Tall Mass Timber – https://awc.org/tallmasstimber
• AWC TR 10 - Calculating the Fire Resistance of Wood Members and Assemblies
• National Design Specification® (NDS®) for Wood Construction – 2018
• FP Innovations: Acoustic performance of cross-laminated timber assemblies
• MiTiCon – http://www.my-ti-con.com/resources/topics/timber
• WoodWorks – http://www.woodworks.org/
MASS CHANGE WITH MASS TIMBER
BUILDING CODE IMPLICATIONS FOR
ARCHITECTS AND DESIGNERS

JULY 10, 2019  AIA SEATTLE

THANK YOU!

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