A New Path Forward for Tall Wood Construction: Code Provisions and Design

Prepared by:
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Fire-Resistant Design for Wood Construction

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The American Wood Council (AWC) provides wood design and construction information to assist building industry professionals, develops structural and fire performance data on a wide range of traditional and engineered wood products, and engages in long-term research.

AWC is an ANSI accredited standards developer.
Code Change Process

Project Scope

In December 2015, the ICC Board established the ICC Ad Hoc Committee on Tall Wood Buildings noting the purpose of the ad hoc committee is to

1. explore the building science of tall wood buildings
2. investigate the feasibility, and
3. take action on developing code changes for tall wood buildings.

This scope will require further refinement by the committee.
The Board has determined that the effort is to be undertaken by the newly formed Ad Hoc Committee on Tall Wood Buildings (AH-TWB). In making the committee appointments, the Board recognized the need to have a consensus committee comprised of the necessary balance of stakeholders including:

- Representatives from building construction material industries
- Building and Fire Officials
- Architects and engineers
- Fire protection experts
- Other construction related stakeholders
TWB Committee

• 4 Work Groups appointed
  • Definitions and Standards
  • Fire
  • Structural
  • Codes
• 82 major issues identified, assigned to specific work groups, and investigated
• Hundreds of reports reviewed and collected via ICC TWB webpage
• Performance Objectives discussed and listed
TWB Ad Hoc Objectives

TWB identified performance objectives to be met:

- No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered
- No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios
- No unusual response from typical radiation exposure from adjacent properties to present a risk of ignition of the subject building under reasonably severe fire scenarios
TWB Ad Hoc Objectives (cont’d)

TWB identified performance objectives to be met:

- No unusual fire department access issues
- Egress systems designed to protect building occupants during design escape time, plus a factor of safety
- Highly reliable fire suppression systems to reduce risk of failure during reasonably expected fire scenarios. Degree of reliability proportional to evacuation time (height) and risk of collapse.

The TWB has determined that its comprehensive package of proposals meet these performance objectives
Alternate Means outside of scope TWB:

SOM Timber Research Project

18 Story High-rise inside of scope:
Shrinkage must be accounted for in platform construction:

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

Detailing to address shrinkage...
Most Asked Question:

Why are there three new Types of Construction?

Three Main Categories:

1. Noncombustible (Types I & II)
2. Combustible Lt-Frame (Types III & V)
3. Mass Timber (Type IV)

IBC TABLE 601

<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>
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<td>A</td>
<td>B</td>
<td>A</td>
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</tbody>
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Three Main Categories:

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<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

ICC TALL WOOD AD HOC COMMITTEE
Fire Behavior Depends on:

Fire behavior depends in part on:

- Amount of exposed wood
- Arrangement of exposed wood
- Thermal performance of adhesive

Behavior of Fire and Materials

Protection of mass timber construction:
Non-combustible protection (for MT)

FRR of mass timber element =
time assigned to the wood
without protection + time
assigned to the added NC
protection (usually gypsum)

Non-combustible protection

FS5-18
IBC: 703.8 (New)
Proponent: Stephen DiGiovanni, representing ICC Ad Hoc Committee on Tall Wood Buildings (TWB)

703.8 Determination of noncombustible protection time contribution. The time, in minutes, contributed to
the fire resistance rating by the noncombustible protection of mass timber building elements, components, or
assemblies, shall be established through a comparison of assemblies tested using procedures set forth in ASTM E 119
or UL 263. The test assemblies shall be identical in construction, loading, and materials, other than the noncombustible
protection. The two test assemblies shall be tested to the same criteria of structural failure.

1. Test Assembly 1 shall be without protection.
2. Test Assembly 2 shall include the representative noncombustible protection. The protection shall be
   fully defined in terms of configuration details, attachment details, joint sealing details, accessories
   and all other relevant details.

The noncombustible protection time contribution shall be determined by subtracting the fire resistance time, in minutes,
of Test Assembly 1 from the fire resistance time, in minutes, of Test Assembly 2.
Testing of NC protection: Western Fire Center

Unprotected CLT (control test) | Single-Layer Protection | Triple-Layer Protection | Mineral Wool Protection
--- | --- | --- | ---
CLT type/grade | 5-Layer V4 (Smartlam) | | |
CLT panel size | Two 7’x18’ panels per test, joined together for an overall size of 14’x18’ | | |
Loading | 24 sand-filled barrels, uniformly-distributed for an applied load of 60 psf | | |
Span | 17’-10” | | |
Load Ratio | 75% of ASD moment (including self-weight) | | |
Noncombustible protection | None | 1 layer of 5/8” Type X gypsum wallboard | 3 layers of 5/8” Type X gypsum wallboard | 2” thick; 8 pcf mineral wool
GWB attachment | None | Type 5 screws @ 12” o.c. both directions. 1” penetration into CLT. 1.5” edge distance. | Type 5 screws @ 12” o.c. both directions, staggered 4” each layer. 1” penetration into CLT. 1.5” edge distance. | Type 5 screws and 1.5” fender washers at
Deflection at End of Test | 12.5” | 12.5” | 12.0” | 12.0”
Test duration | 149.4 minutes | 189.7 minutes | 276.8 minutes | 261.3 minutes
Noncombustible protection contribution | -- | 40.3 minutes | 127.4 minutes | 113 minutes
Time attributed to each layer | -- | 40.3 min/layer | 42.5 min/layer | 113 minutes

Other testing of NC protection:

Objective: Quantify contribution of other non-combustible protection in addition to gypsum on Mass Timber

<table>
<thead>
<tr>
<th></th>
<th>Unprotected CLT</th>
<th>Single-Layer Protection</th>
<th>Triple-Layer Protection</th>
<th>Mineral Wool Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT type/grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLT panel size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncombustible protection</td>
<td>None</td>
<td>1 layer of 5/8” Type X gypsum wallboard</td>
<td>3 layers of 5/8” Type X gypsum wallboard</td>
<td>2” thick; 8 pcf mineral wool</td>
</tr>
<tr>
<td>GWB attachment</td>
<td>None</td>
<td>Type 5 screws @ 12” o.c. both directions. 1” penetration into CLT. 1.5” edge distance.</td>
<td>Type 5 screws @ 12” o.c. both directions, staggered 4” each layer. 1” penetration into CLT. 1.5” edge distance.</td>
<td>Type 5 screws and 1.5” fender washers at</td>
</tr>
<tr>
<td>Deflection at End of Test</td>
<td>12.5”</td>
<td>12.5”</td>
<td>12.0”</td>
<td>12.0”</td>
</tr>
<tr>
<td>Test duration</td>
<td>149.4 minutes</td>
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<td>276.8 minutes</td>
<td>261.3 minutes</td>
</tr>
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<td>Noncombustible protection contribution</td>
<td>--</td>
<td>40.3 minutes</td>
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<td>113 minutes</td>
</tr>
<tr>
<td>Time attributed to each layer</td>
<td>--</td>
<td>40.3 min/layer</td>
<td>42.5 min/layer</td>
<td>113 minutes</td>
</tr>
</tbody>
</table>
MASS TIMBER FRR CHECKLIST:

- Mass timber material meets heavy timber minimum dimension requirements found in IBC 2304.11?
- Exposed MT meets limits for area and separation between exposed locations?
- NC Protection meets 2/3 FRR of Table 601 and other specific requirements?
- Overall FRR of building elements (either exposed or protected) meet the minimum FRR requirements of Table 601 (calculated or tested)?

Summary of tests:
“Non-Standard Fire” not in the code

![Typical “non-standard” TT curve](image)

### Compartment Temperature

#### Typical “non-standard” TT curve

---

### Mass Timber Fire Testing:

<table>
<thead>
<tr>
<th>Year</th>
<th>Test Sponsor and Location</th>
<th>Test Description</th>
<th>Fire Test Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>FPInnovations (FPI); National Research Council of Canada (NRC)</td>
<td>Protected Cross-Laminated Timber (CLT) Floor and Wall Tests,</td>
<td>E 119</td>
</tr>
<tr>
<td>2012</td>
<td>American Wood Council (AWC); NGC Testing Services</td>
<td>5 ply CLT wall with 8/00 PLF load protected with 1 layer of 5/8” type X gypsum wall board (GWB) each side</td>
<td>E 119</td>
</tr>
<tr>
<td>2014</td>
<td>AWC; Western Fire Center (WFC)</td>
<td>GWB-Protected Beam Tests, Protected Structural Composite Lumber (SCL) Tests</td>
<td>E 119</td>
</tr>
<tr>
<td>2015</td>
<td>AWC; Southwest Research Institute (SwRI)</td>
<td>Nail Laminated Timber (NLT) and CLT compartments; 2 hour FRR fire stops</td>
<td>Non-Standard; E 814</td>
</tr>
<tr>
<td>2016</td>
<td>LEVER Architecture, ARUP; SwRI</td>
<td>2 Hour exposed beam and column test with CLT deck</td>
<td>E 119</td>
</tr>
<tr>
<td>2017</td>
<td>FPFF; NRC; NIST National Fire Research Lab</td>
<td>CLT Compartment Fire Tests (w/ first generation PUR adhesive CLT)</td>
<td>Non-Standard</td>
</tr>
<tr>
<td>2017</td>
<td>US FPL, ICC Tall Wood Ad Hoc (TWB), AWC; ATF Lab</td>
<td>Compartment Fire Tests, Two Story Mass Timber Building</td>
<td>Non-Standard</td>
</tr>
<tr>
<td>2017</td>
<td>AWC; SwRI</td>
<td>Development of a Fire Performance Assessment Methodology for CLT Adhesives</td>
<td>New PRG 320, Annex B standard</td>
</tr>
<tr>
<td>2017</td>
<td>AWC; WFC</td>
<td>CLT Floor/Ceiling Assembly to establish the contribution of GWB to FRR</td>
<td>E 119</td>
</tr>
<tr>
<td>2018</td>
<td>NRC, CNRC</td>
<td>Fire Testing of Rooms with Exposed Second Generation PUR adhesive CLT</td>
<td>Non-Standard</td>
</tr>
</tbody>
</table>
3.7.1 NRC Protected CLT Floor and Wall Tests

As discussed in 2.8, in 2011, FPInnovations (FPI), in collaboration with the National Research Council of Canada (NRC), conducted a series of 8 full-scale fire resistance tests of CLT floors and walls [50]. All tests followed the ULC S101 time-temperature curve, a fire exposure comparable to the ASTM E119 time-temperature curve. Three of the CLT floors and one of the CLT walls were protected with GWB.

As reported in Section 2.8 for unprotected CLT floor and wall tests, loading of the floors and walls was based on Canadian standards. For purposes of this analysis, allowable stress design (ASD) values were determined by using relevant grades from the CLT product standard, PRG-320 [51]. Structural fire resistance was then calculated using NDS design provisions and appropriate ASD design values from PRG-320.

NRC Test #1 - Protected Floor:
NRC Test #2 - Protected Wall:
NRC Test #5 - Protected Floor:
NRC Test #6 - Protected Floor:

2012  American Wood Council (AWC); NGC Testing Services  5 ply CLT wall with 8700 PLF load protected with 1 layer of 5/8” type X gypsum wall board (GWB) each side  E 119
### 2014
**AWC; Western Fire Center (WFC)**

**GWB-Protected Beam Tests, Protected Structural Composite Lumber (SCL) Tests**

#### Table 3.6a Added Contribution of Gypsum Wallboard Protection

<table>
<thead>
<tr>
<th>Beam Description</th>
<th>Design Stress Ratio</th>
<th>Thickness (inches)</th>
<th>Layers</th>
<th>SCL Beam + GWB</th>
<th>SCL Beam Only</th>
<th>GWB Only</th>
<th>SCL Beam Only</th>
<th>GWB Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>3½” Wide LVL</td>
<td>56%</td>
<td>5/8” Type X</td>
<td>2</td>
<td>138</td>
<td>50</td>
<td>90</td>
<td>130</td>
<td>50 60</td>
</tr>
<tr>
<td>7” Wide LVL</td>
<td>113%</td>
<td>5/8” Type X</td>
<td>2</td>
<td>139</td>
<td>39</td>
<td>70</td>
<td>30 40</td>
<td>80</td>
</tr>
<tr>
<td>3½” Wide LVL</td>
<td>84%</td>
<td>5/8” Type X</td>
<td>2</td>
<td>114</td>
<td>35</td>
<td>79</td>
<td>106</td>
<td>26 80</td>
</tr>
</tbody>
</table>

1. Gypsum wallboard corners were not finished, resulting in early penetration of fire.

When tested in accordance with ASTM E119, all ten SCL beams lasted longer in the fire tests than the calculated fire resistance corresponding to the actual applied load level. Accordingly, test results support the use of the calculation procedure in NDS Chapter 16 and TR10 for SCL.

### 2015
**AWC; Southwest Research Institute (SwRI)**

**Nail Laminated Timber (NLT) and CLT compartments; 2 hour FRR fire stops**

**Non – Standard; E 814**
<table>
<thead>
<tr>
<th>Year</th>
<th>Organization</th>
<th>Description</th>
<th>Notes</th>
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<tr>
<td>2015</td>
<td>AWC; Southwest Research Institute (SwRI)</td>
<td>Nail Laminated Timber (NLT) and CLT compartments; 2 hour FRR fire stops</td>
<td>Non-Standard; E 814</td>
</tr>
<tr>
<td>Year</td>
<td>Source</td>
<td>Description</td>
<td>Fire Resistance Rating</td>
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<td>------</td>
<td>--------</td>
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<tr>
<td>2015</td>
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</table>

FIRE RESISTANCE PERFORMANCE EVALUATION OF A PENETRATION FIRESTOP SYSTEM TESTED IN ACCORDANCE WITH ASTM E814-13A, STANDARD TEST METHOD FOR FIRE TESTS OF PENETRATION FIRESTOP SYSTEMS

FINAL REPORT
Consisting of 18 Pages

SwRI Project No. 01.21428.01.001a
Test Date: September 30, 2015
Report Date: October 22, 2015

Prepared for:
American Wood Council
222 Catoctin Circle SE
Leesburg, VA 20175
<table>
<thead>
<tr>
<th>Year</th>
<th>Institution</th>
<th>Description</th>
<th>Requirement</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
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<td>AWC; Southwest Research Institute (SwRI)</td>
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<td></td>
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</table>

Figure B-3. Sample after 2-h Exposure.

<table>
<thead>
<tr>
<th>Year</th>
<th>Institution</th>
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<th>Standard</th>
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<td></td>
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</tbody>
</table>

Figure B-4. Sample before the Hose Stream Test.
2016 LEVER Architecture, ARUP; SwRI 2 Hour exposed beam and column test with CLT deck E 119

Slide Courtesy of LEVER Arch

2016 LEVER Architecture, ARUP; SwRI 2 Hour exposed beam and column test with CLT deck E 119

Slide Courtesy of Arup
<table>
<thead>
<tr>
<th>2017</th>
<th>FPRF, NRC; NIST National Fire Research Lab</th>
<th>CLT Compartment Fire Tests (w/ first generation PUR adhesive CLT)</th>
<th>Non-Standard</th>
</tr>
</thead>
</table>

NFPA Fire Protection Research Foundation (FPRF)
- Tests done for NFPA's Property Insurance Research Group (PIRG)
- Purpose: Evaluate the contribution of CLT elements to compartment fires to collect data for insurance modeling
- Tests performed by NRC Canada
- Tests performed at NIST facilities
- 6 Compartment tests:
  - 2 with all CLT protected
  - 4 with various surfaces exposed

No significant contribution of CLT when all surfaces were protected with Type X gypsum wallboard

Where surfaces were exposed, CLT contribution increased with increasing exposed CLT surface area

Modeling performed by Research Institute of Sweden (RISE) was close to measured results

Images courtesy of Joseph Su, NRC Canada
Fire re-growth observed in multiple FPRF tests
Fire re-growth caused by failure of bond lines before being reached by char front (i.e., heat-delamination)

Test 1-4: Exposed CLT ceiling

- 1st heat-delamination occurred around 50 minutes, extending fully-developed phase
- 2nd heat-delamination occurred around 150 minutes, resulting in fire re-growth
• **Purpose:** Perform tests of realistic fire scenarios applicable to tall wood construction in order to evaluate occupant and firefighter tenability for egress and suppression efforts, and to provide data necessary to guide further development of relevant code and standard provisions

• Conducted at U.S. government facilities (ATF)

• Supervised by U.S. Forest Product Laboratory staff

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Date</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>All mass timber surfaces protected with 2 layers of 5/8&quot; Type X GWB</td>
<td>5/23/17</td>
<td>3 hours</td>
</tr>
<tr>
<td>Test 2</td>
<td>30% of CLT ceiling area in living room and bedroom exposed</td>
<td>5/31/17</td>
<td>4 hours</td>
</tr>
<tr>
<td>Test 3</td>
<td>Two opposing CLT walls exposed – one in bedroom and one in living room (there is a partition wall)</td>
<td>6/20/17</td>
<td>4 hours</td>
</tr>
<tr>
<td>Test 4</td>
<td>All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – normal activation</td>
<td>6/27/17</td>
<td>6 minutes</td>
</tr>
<tr>
<td>Test 5</td>
<td>All mass timber surfaces fully exposed in bedroom and living room (except bathroom). Sprinklered – 23 min delayed activation</td>
<td>6/29/17</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>
• Partitions used unrated ½” gypsum wallboard
• Kitchen & Living Room: 15 ft x 30 ft
• Bedroom & Bath: 15 ft x 30 ft
• 20-min rated door between compartment and corridor
• 90-min rated door between corridor and stairwell
• Fuel load ~570 MJ/m²
ATF fire Test #2 – 30% CLT Ceilings Exposed

30% of CLT ceiling area in living room and bedroom exposed

Live load applied using water barrels

Photos provided by U.S. Forest Products Laboratory, USDA
Atf fire Test #2 – 30% CLT Ceilings Exposed

Post-Fire Condition of Glulam After Gypsum Removal

• Fire intensity decreased subsequent to consumption of furnishings and contents (known as decay phase)

• Exposed mass timber surfaces self-extinguished in the decay phase

• Mass timber surfaces protected with 2 layers of 5/8” Type X GWB remained mostly uncharred

Section of exposed ceiling (90º angle)
ATF fire Test #3 – Exposed Walls

Two opposing CLT walls exposed one in bedroom and one in living room

Atf Fire Test #3  Walls Exposed

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## ATF Fire Test Results – Event Log

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Time After Ignition (mm:ss)</th>
<th>Flashover (600°C) Living Room</th>
<th>Flashover (600°C) Bedroom</th>
<th>Flames in Hallway</th>
<th>Compartment door fails</th>
<th>Sprinkler Activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>13:27</td>
<td>17:20</td>
<td>26:51</td>
<td>57:46</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>11:42</td>
<td>17:20</td>
<td>30:38</td>
<td>63:59</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>12:37</td>
<td>17:00</td>
<td>13:06 (door frame installation error)</td>
<td>29:42 (door frame installation error)</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2:37</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>23:00</td>
</tr>
</tbody>
</table>

Tests 2 and 3 terminated at 4 hours with no re-growth

## ATF Fire tests

Full Report on FPL Website:

Fire Test Videos on AWC Website:
www.awc.org/tallmasstimber

Link to youtube videos available on this page
Repair in Place?

7:30 AM

Repair of CLT?

Adhered ONLY
Adhered & Mechanical Fasteners
Adhesive qualification tests

Direction provided by ICC-TWB Ad-Hoc Committee

- Need test protocol capable of identifying heat-delaminating adhesives
- Code-referenced standards governing CLT should require adhesive qualification using this protocol

Test protocol developed by Southwest Research Institute (SwRI)

- Large-scale compartment test (9’ x 19’ compartment)
- Exposed CLT ceiling (as was tested in FPRF Test 1-4)
  - Same CLT span as in FPRF tests (~15’)
  - Same loading as in FPRF tests (20 psf)
  - Same ventilation ratio as in FPRF tests (~0.03 m^0.5)
1. Validate test setup for FPRF T/T curve
2. Recreate char drop off or “delamination” of original PUR
3. Melamine adhesive testing
4. 2\textsuperscript{nd} generation PUR adhesive testing

- Calibration of adhesive qualification test protocol:
  - Exposure replicates conditions of FPRF baseline test (Test 1-1)
  - Exposure based on heat flux to the ceiling to replicate fire curve of FPRF Test 1-1 (no exposed CLT)
Validation of adhesive qualification test protocol

Validation test performed on same CLT used in FPRF tests to verify similar performance

2017 AWC; SwRI
Development of a Fire Performance Assessment Methodology for CLT Adhesives
New PRG 320, Annex B standard

FPRF Test 1-4
Adhesive qualification validation test

FPRF Test 1
Adhesive qualification calibration test

Just prior to fire re-growth (2:59) 2nd Flashover caused by fire re-growth (3:10)
2017  AWC; SwRI  Development of a Fire Performance Assessment Methodology for CLT Adhesives  New PRG 320, Annex B standard

Qualification tests performed on other adhesives
- Fire re-growth observed with PUR
- No fire re-growth observed with
  - Melamine formaldehyde resin
  - Improved PUR
- Test identifies acceptable performance

![Melamine formaldehyde resin](Melamine.png)

![Heat-delaminating PUR](Heat-delaminating.png)

2018 ANSI/APA - PRG 320

**FLOOR MODIFICATION**

**G108-18-DIGIOVANNI-1**

Cross-laminated timber shall be labeled as conforming to PRG 320 - 18 as referenced in Section 2303.14, the heat performance requirements of Section 6.13.4 of DOC PS1 and have no delamination in any specimen, except where occurring at a localized characteristic when permitted in the product standard.

![Calibration Time-Temperature Curve](Calibration.png)

*Photo by AWC*
<table>
<thead>
<tr>
<th>2017</th>
<th>AWC; WFC</th>
<th>CLT Floor/Ceiling Assembly to establish the contribution of GWB to FRR</th>
<th>E 119</th>
</tr>
</thead>
</table>

Figure 1. Representative CLT panels showing (a) cross-section and identification, (b) joint, (c) joined assembly, and (d) complete assembly.

Figure 7. Test floor assembly during test showing (a) before test, (b) field crack – 34 min, (c) flames – 33 min, (d) pathing – 49 min, (e) falling material – 63 min, and (f) glowing at upline joint – 100 min.
<table>
<thead>
<tr>
<th>Year</th>
<th>Organization</th>
<th>Description</th>
<th>E 119</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>AWC; WFC</td>
<td>CLT Floor/Ceiling Assembly to establish the contribution of GWB to FRR</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 12:** Test 2 floor assembly during test showing (a) before test, (b) dekerminent – 1 min, (c) flames – 5 min, (d) embers – 5 min, (e) deflection – 130 min, and (f) sustained flames – 140 min.

**Figure 17:** Test 3 floor assembly during test showing (a) before test, (b) fallen face layer – 90, (c) fallen middle layer – 120 min, (d) increasing flames – 134 min, (e) bowed floor – 273 min, and (f) flames – 277 min.
Other testing of NC protection:
Other testing of NC protection:

Objective: Quantify contribution of other non-combustible protection in addition to gypsum on Mass Timber

<table>
<thead>
<tr>
<th></th>
<th>Unprotected CLT (control test)</th>
<th>Single-Layer Protection</th>
<th>Triple-Layer Protection</th>
<th>Mineral Wool Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT type/grade</td>
<td>5-Layer V4 (Smartlam)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLT panel size</td>
<td>Two 7'x18' panels per test, joined together for an overall size of 14'x18'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loading</td>
<td>24 sand-filled barrels, uniformly-distributed for an applied load of 60 psf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span</td>
<td>17'-10&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load Ratio</td>
<td>75% of ASD moment (including self-weight)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncombustible protection</td>
<td>None</td>
<td>1 layer of 5/8&quot; Type X gypsum wallboard</td>
<td>3 layers of 5/8&quot; Type X gypsum wallboard</td>
<td>2&quot; thick; 8 psf mineral wool</td>
</tr>
<tr>
<td>GWB attachment</td>
<td>None</td>
<td>Type S screws @ 12&quot; o.c. both directions, 1&quot; penetration into CLT. 1.5&quot; edge distance.</td>
<td>Type S screws @ 12&quot; o.c. both directions, staggered 4&quot; each layer, 1&quot; penetration into CLT. 1.5&quot; edge distance.</td>
<td>Type S screws and 1.5&quot; fender washers at</td>
</tr>
<tr>
<td>Deflection at End of Test</td>
<td>12.5&quot;</td>
<td>12.5&quot;</td>
<td>12.0&quot;</td>
<td>12.0&quot;</td>
</tr>
<tr>
<td>Test duration</td>
<td>149.4 minutes</td>
<td>189.7 minutes</td>
<td>276.8 minutes</td>
<td>261.3 minutes</td>
</tr>
<tr>
<td>Noncombustible protection contribution</td>
<td>--</td>
<td>40.3 minutes</td>
<td>127.4 minutes</td>
<td>113 minutes</td>
</tr>
<tr>
<td>Time attributed to each layer</td>
<td>--</td>
<td>40.3 min/layer</td>
<td>42.5 min/layer</td>
<td>113 minutes</td>
</tr>
</tbody>
</table>

2018 NRC, CNRC Fire Testing of Rooms with Exposed Second Generation PUR adhesive CLT

FIRE TESTING OF ROOMS WITH EXPOSED WOOD SURFACES IN ENCAPSULATED MASS TIMBER CONSTRUCTION

Joseph Su, Patrice Leroux, Pier-Simon Lafrance, Rob Berzins, Karl Gratton, Eric Gibbs, Mark Weinlferter
8 August 2018

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<table>
<thead>
<tr>
<th>Year</th>
<th>Organization</th>
<th>Description</th>
<th>Non-Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>NRC, CNRC</td>
<td>Fire Testing of Rooms with Exposed Second Generation PUR adhesive CLT</td>
<td>Non-Standard</td>
</tr>
</tbody>
</table>

![Figure 4. Room schematic for Test 4 – fully exposed ceiling, column (4 sides) and beam (3 sides).](image)

![Figure 4. Photograph of test-burned elements after Test 4.](image)
Summary of code changes:

2018 ANSI/APA - PRG 320

FLOOR MODIFICATION

G108-18-DIGIOVANNI-1

Cross-laminated timber shall be labeled as conforming to PRG 320 - 18 as referenced in Section 2303.14. The heat performance requirements of Section 6.3.3.4 of DOC PS1 and have no delamination in any specimen, except where occurring at a localized characteristic when permitted in the product standard.
Groups of code changes:

14 approved changes fall into 6 basic subjects:

- Non-combustible protection
- New construction types (materials and amount of protection)
- Height and area
- Other building requirements
- Construction and maintenance
- Correlation with existing code

Type of construction – G 108-18

Key considerations in Chapter 6:

- Allowed Materials (mass timber or noncombustible, no light frame combustible)
- Structural FRR (Table 601)
- Amount and location of non-combustible protection
- Protection of concealed spaces
Other building requirements

Other Building Requirements:

• Sealant at edges (FS6-18)
• High-rise sprinkler redundant water supply for Type IVA and IV B greater than 120 height above grade (G 28-18)
• Separated occupancy and incidental use separations additional requirements (G89-18)

Correlation with existing code

Other Building Requirements:

• Fireblocking (FS73-18)
• Special construction (G 146-18)
• Fire Districts (G152-18)
Construction and maintenance

Fire Code Requirements:
• Construction Fire Safety (F266-18)
• Owners Responsibilities (F 88-18)

Additional Fire Protection During Construction Requirements
• Requirements for fire protection during construction:
  • Standpipes in accordance with IFC 3313
  • Water supply for fire department operations
  • One layer of noncom protection, if required, on all mass timber more than 4 stories below uppermost floor under construction
  • Exterior wall coverings on all floor levels more than 4 levels below floor under construction – includes mezzanines
Fire safety during construction

Fire safety during construction
Fire safety during construction

Structural Connections and Special Inspections
Group B changes:

S100-19
IBC: 1705.5.3 (New), TABLE 1705.5.3 (New)

Proponent: Stephen DiGiovanni, representing ICC Ad Hoc Committee on Tall Wood Buildings (TWB) (TWB@iccsafe.org)

2018 International Building Code
Add new text as follows:

1705.5.3 Mass timber construction. Special inspections of Mass Timber elements in Types IV-A, IV-B and IV-C construction shall be in accordance with Table 1705.5.3.

<table>
<thead>
<tr>
<th>TABLE 1705.5.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>REQUIRED SPECIAL INSPECTIONS OF MASS TIMBER CONSTRUCTION</td>
</tr>
</tbody>
</table>

ADM35-19
IBC®: 1103.5.5 (New)

Proponent: Stephen DiGiovanni, representing ICC Ad Hoc Committee on Tall Wood Buildings (TWB) (TWB@iccsafe.org)

2018 International Building Code
Add new text as follows:

110.3.5 Type IV-A, IV-B, and IV-C connection protection inspection. In buildings of Type IV-A, IV-B, and IV-C Construction, where connection fire resistance ratings are provided by wood cover calculated to meet the requirements of Section 2302.10.1, inspection of the wood cover shall be made after the cover is installed, but before any other coverings or finishes are installed.
Group B: Connection code proposal

GROUP B DRAFT LANGUAGE 2021 IBC  S170-19

2304.10.1 Connection fire resistance rating. Fire resistance ratings for connections in Type IV-A, IV-B, or IV-C construction shall be determined by one of the following:
1. Testing in accordance with Section 703.2 where the connection is part of the fire resistance test.
2. Engineering analysis which demonstrates that the temperature rise at any portion of the connection is limited to an average temperature rise of 250 °F, and a maximum temperature rise of 325 °F; for a time corresponding to the required fire resistance rating of the structural element being connected. For the purposes of this analysis, the connection includes connectors, fasteners, and portions of wood members included in the structural design of the connection.

State adoptions:
Oregon CLT and MT Alt Means

Statewide Alternate Method
January 2015
No. 15-01
Cross-Laminated Timber Provisions
(Rel. OBS 172.400)

Statewide Alternate Methods are approved by the Division administrator in consultation with the appropriate advisory board. The advisory board’s review of a proposal alternate method. In addition:

- Building officials shall approve the use of any alternate method.
- A decision to use a statewide alternate method must be made by the Division administrator.
- Stateswide alternate methods do not limit the use of another proposal alternate methods encompassed.

Abstract
August 2018
Statewide Alternate Method
No. 18-01 Tall Wood Buildings – Background

Statewide Alternate Method (SAM) Number 18-01 provides prescriptive path elements for Tall Wood Buildings of mass timber construction. This alternate path includes scientific conclusions established by the International Code Council’s Ad Hoc Committee on Tall Wood Buildings that were incorporated into fourteen national proposals and utilized concrete, steel, or masonry for the vertical elements of the seismic force-resisting system.

The provisions detailed in the SAM are crafted to coincide with the 2014 Oregon Structural Specialty Code (OSSC) when selected for use. These new types of construction are introduced under this method, all of which are organized under Type IV construction, typically referred to as heavy timber.

The new types of construction are:

- Type IV A
- Type IV B
- Type IV C

Washington State: MT changes

State-Wide Code Change Proposal

CLT Coalition
Language from ICC TWB
Educational Outreach to SBCC members
TAG and Code Council Process
Public Hearings

ESB 5450 was vital
2015 vs. 2018
SBCC process...
WABO: In-step with National Process
Could be enacted as early as July 2019

Slide Courtesy of Joe Mayo
CA Accelerated MT Process:

Governor Brown Executive Order B 52-18:

In effect July 2021:

Questions? ...Thank You!

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- Dennis Richardson
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- drichardson@awc.org