New Options for Tall Timber Buildings in California: Understanding Codes and Design

Presented on 09/22/20 by Janelle Leafblad, PE
New tall mass timber code provisions approved for the 2021 International Building Code (IBC) will allow up to 18 stories of wood construction. The California Building Code (CBC) is also poised to permit tall timber buildings but following a slightly different path. In August of 2020, the California Building Standards Commission unanimously approved a series of code changes based on the new IBC provisions, but with California-specific modifications. Attendees will learn how tall wood buildings will be covered in both the 2021 IBC and the 2019 CBC. Starting with a review of the technical research and testing that supported the provisions, we’ll then take a detailed look at the new code language and methods of addressing the requirements. Topics will include fire-resistance ratings and allowances for exposed timber, penetrations, sprinklers, connections, exterior walls, and more. Designers can expect to take away the knowledge they need to pursue tall wood projects.
Learning Objectives

1. Review the global history of tall wood construction and highlight the mass timber products used in these structures.

2. Explore the work and conclusions of the ICC Ad Hoc Committee on Tall Wood Buildings in establishing 14 new Group A and 3 new Group B code provisions for the 2021 IBC that address tall wood construction.

3. Discuss code-compliant options for exposing mass timber, where up to 2-hour fire-resistance ratings are required and demonstrate design methodologies for achieving these ratings.

4. Review code requirements unique to tall wood buildings, focusing on items such as sprinklers, shaft construction and concealed spaces.
Questions we’ll answer:
• What is tall wood?
• How tall is tall?
• What has been done?
• What wood products are used in tall wood?
• What does the Code allow now?
• How did we arrive at the proposed tall wood code changes?
• What are the new tall wood code provisions?
TALL WOOD IN NORTH AMERICA CIRCA 1906
9 STORIES

THE LANDING, VANCOUVER

BUTLER SQUARE, MINNEAPOLIS
GLOBAL TALL WOOD CIRCA 2015

7-14 STORIES
GLOBAL TALL WOOD CIRCA 2019
18-24 STORIES
TALL WOOD IN THE US CIRCA 2019

8 STORIES

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman | Architect: PATH Architecture
DOWEL-LAMINATED TIMBER (DLT)  MASS PLYWOOD PANELS (MPP)  DECKING

Photo: StructureCraft

Photo: LEVER Architecture

Photo: Bernard André Photography
WHY TALL WOOD?
Global Population
7.6 billion now
9.8 billion by 2050
30% increase

Source: United Nations Department of Economic and Social Affairs
US URBAN POPULATION BOOM

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>271 M</td>
<td>57.7 M</td>
</tr>
<tr>
<td>2030</td>
<td>301 M</td>
<td>53.7 M</td>
</tr>
<tr>
<td>2050</td>
<td>347 M</td>
<td>42.2 M</td>
</tr>
</tbody>
</table>

© 2018 United Nations, DESA, Population Division. Licensed under Creative Commons license CC BY 3.0 IGO.
MARKET DRIVERS FOR MASS TIMBER

PRIMARY DRIVERS
» Construction efficiency & speed
» Construction site constraints – urban infill
» Innovation/Aesthetics

SECONDARY DRIVERS
» Carbon reductions
» Structural performance – lightweight
Reduction in Embodied Carbon

Brock Commons, Vancouver, BC


*CO2 in this case study refers to CO2 equivalent.
TALL WOOD IN THE U.S.
Current Prescriptive Code Limit - 6 stories (B occupancy) or 85 feet

Over 6 Stories - Alternate Means and Materials Request (AMMR) through performance-based design

Based on the 1910 Heights and Areas Act
Seen as the catalyst for the mass timber revolution, CLT IS first recognized in US codes in the 2015 IBC

[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.

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.
U.S. TALL WOOD DEVELOPMENT AND CHANGES

Interest in tall wood projects in the US was rapidly increasing. Some building officials were reluctant to approved proposed plans, primarily due to lack of code direction and precedent.

Photo: Seagate Structures
In December 2015, the ICC Board established the ICC Ad Hoc Committee (AHC) on Tall Wood Buildings. Objectives:
1. Explore the building science of tall wood buildings
2. Investigate the feasibility of tall wood buildings
3. Take action on developing code changes for tall wood buildings
AHC established 6 performance objectives:

1. No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered.

2. Highly reliable fire suppression systems to reduce the risk of failure during reasonably expected fire scenarios. The degree of reliability should be proportional to evacuation time (height) and the risk of collapse.
Performance Objectives

3. No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios.

4. 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.
5. No unusual fire department access issues.
6. Egress systems designed to protect building occupants during the design escape time, plus a factor of safety.
Commissioned series of 5 full-scale tests on 2-story mass timber structure at ATF lab in MD, May-June 2017
<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Construction Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>All mass timber surfaces protected with 2 layers of 5/8” Type X Gypsum. No sprinklers.</td>
<td>IV-A</td>
</tr>
<tr>
<td>Test 2</td>
<td>30% of CLT ceiling area in living room and bedroom exposed. No sprinklers.</td>
<td>IV-B</td>
</tr>
<tr>
<td>Test 3</td>
<td>Two opposing CLT walls exposed – one in bedroom and one in living room. No sprinklers.</td>
<td>IV-B</td>
</tr>
<tr>
<td>Test 4</td>
<td>All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – normal activation.</td>
<td>IV-C</td>
</tr>
<tr>
<td>Test 5</td>
<td>All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – 20 minute delayed activation.</td>
<td>IV-C</td>
</tr>
</tbody>
</table>
Although not directly affiliated with the TWB AHC, other mass timber and tall wood testing & research was occurring, the results of which the AHC included in their final decisions.
ICC TWB Ad Hoc Committee Group A proposals consisted of the following 14 parts:

**Requirements for the new Types of Construction:**
- IBC Section 602.4 – Type of Construction (G108-18)
- IBC Section 703.8 – Performance Method for Fire Resistance from Noncombustible Protection (FS5-18)
- IBC Section 722.7 – Prescriptive Fire Resistance from Noncombustible Protection (FS81-18)
- IBC Section 703.9 – Sealants at Edges (FS6-18)
- IBC Section 718.2.1 – Fire and Smoke Protection (FS73-18)
- IBC Section 403.3.2 – High-Rise Sprinkler Water Supply (G28-18)
- IBC Section 701.6 – Owners’ Responsibility (F88-18)
- IFC Section 3308.4 – Fire Safety During Construction (F266-18)

**Allowable building size limits:**
- IBC Table 504.3 – Building Height (G75-18)
- IBC Table 504.4 – Number of Stories (G80-18)
- IBC Table 506.2 – Allowable Area (G84-18)

**Housekeeping changes:**
- IBC Section 3102 – Special Construction (G146-18)
- IBC Appendix D – Fire Districts (G152-18)
- IBC Section 508.4 and 509.4 – Fire Barriers (G89-18)
TALL WOOD APPROVED!
Unofficial results posted Dec. 19, 2018
Final votes ratified Jan. 31, 2019

AWC: Tall Mass Timber code changes get final approval
Dec 19, 2018

LEESBURG, VA. – The International Code Council (ICC) has released the unofficial voting results on code change proposals considered in 2018, including passage of the entire package of 14 tall mass timber code change proposals. The proposals create three new types of construction (Types IV-A, IV-B and IV-C), which set fire safety requirements, and allowable heights, areas and number of stories for tall mass timber buildings. Official results are expected to be announced during the first quarter of 2019. The new provisions will be included in the 2021 International Building Code (IBC).

“Mass timber has been capturing the imagination of architects and developers, and the ICC result means they can now turn sketches into reality. ICC’s rigorous study, testing and voting process now recognizes a strong, low-carbon alternative to traditional tall building materials used by the building
Since its debut, IBC has contained 9 construction type options:
5 Main Types (I, II, III, IV, V) with all but IV having sub-types A and B.
Three Main Categories:

1. Noncombustible (Types I and II)
2. Light-Frame (Types III and V)
3. Heavy/Mass Timber (Type IV)

Use of heavy/mass timber products in low- to mid-rise buildings of Types III and V construction is very common.
2021 IBC Introduces 3 new tall wood construction types:
IV-A, IV-B, IV-C
Previous type IV renamed type IV-HT
New Building Types

18 STORIES
BUILDING HEIGHT 270’
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000 SF

12 STORIES
BUILDING HEIGHT 180 FT
ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000 SF

9 STORIES
BUILDING HEIGHT 85’
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

6 STORIES MAXIMUM
85’-0” MAXIMUM BUILDING HEIGHT
324,000 SF MAXIMUM AREA

TYPE IV-A
IBC 2021

TYPE IV-B

TYPE IV-C
IBC 2015

TYPE IV- HT

BUSINESS OCCUPANCY [GROUP B]

*BUILDING FLOOR-TO-FLOOR HEIGHTS ARE SHOWN AT 12'-0" FOR ALL EXAMPLES FOR CLARITY IN COMPARISON BETWEEN 2015 TO 2021 IBC CODES.

Credit: Susan Jones, atelierjones
**Type IV-A**

- **18 STORIES**
- **BUILDING HEIGHT**: 270’
- **ALLOWABLE BUILDING AREA**: 972,000 SF
- **AVERAGE AREA PER STORY**: 54,000 SF

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**TYPE IV-A**

Credit: Susan Jones, atelierjones

Photos: Structurlam, naturally:wood, Fast + Epp, Urban One
Type IV-A Protection vs. Exposed

100% NC protection on all surfaces of Mass Timber

Credit: Susan Jones, atelierjones
## Type IV-A Height and Area Limits

<table>
<thead>
<tr>
<th>Occupancy</th>
<th># of Stories</th>
<th>Height</th>
<th>Area per Story</th>
<th>Building Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>18</td>
<td>270 ft</td>
<td>135,000 SF</td>
<td>405,000 SF</td>
</tr>
<tr>
<td>B</td>
<td>18</td>
<td>270 ft</td>
<td>324,000 SF</td>
<td>972,000 SF</td>
</tr>
<tr>
<td>M</td>
<td>12</td>
<td>270 ft</td>
<td>184,500 SF</td>
<td>553,500 SF</td>
</tr>
<tr>
<td>R-2</td>
<td>18</td>
<td>270 ft</td>
<td>184,500 SF</td>
<td>553,500 SF</td>
</tr>
</tbody>
</table>

Areas exclude potential frontage increase

In most cases, Type IV-A height & story allowances = 1.5 × Type I-B height & story allowances

Type IV-A area = 3 × Type IV-HT area

Different in the CBC
Type IV-B

12 STORIES
BUILDING HEIGHT 180 FT
ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000 SF

Credit: Susan Jones, atelierjones
Credit: LEVER Architecture
Type IV-B Protection vs. Exposed

NC protection on all surfaces of Mass Timber except limited exposed areas

≈20% of ceiling or ≈40% of wall can be exposed, see code for requirements

Credit: Susan Jones, atelierjones
## Type IV-B Height and Area Limits

<table>
<thead>
<tr>
<th>Occupancy</th>
<th># of Stories</th>
<th>Height</th>
<th>Area per Story</th>
<th>Building Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>12</td>
<td>180 ft</td>
<td>90,000 SF</td>
<td>270,000 SF</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>180 ft</td>
<td>216,000 SF</td>
<td>648,000 SF</td>
</tr>
<tr>
<td>M</td>
<td>8</td>
<td>180 ft</td>
<td>123,000 SF</td>
<td>369,000 SF</td>
</tr>
<tr>
<td>R-2</td>
<td>12</td>
<td>180 ft</td>
<td>123,000 SF</td>
<td>369,000 SF</td>
</tr>
</tbody>
</table>

Areas exclude potential frontage increase

**In most cases, Type IV-B height & story allowances = Type I-B height & story allowances**

**Type IV-B area = 2 × Type IV-HT area**

Credit: Susan Jones, atelierjones
Type IV-C

9 STORIES
BUILDING HEIGHT 85'
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

Credit: Susan Jones, atelierjones

Photos: Baumberger Studio/PATH
Architecture/Marcus Kauffman
Type IV-C Protection vs. Exposed

All Mass Timber surfaces may be exposed

Exceptions: Shafts, concealed spaces, outside face of exterior walls

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path, Ema Peter
### Type IV-C Height and Area Limits

<table>
<thead>
<tr>
<th>Occupancy</th>
<th># of Stories</th>
<th>Height</th>
<th>Area per Story</th>
<th>Building Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>6</td>
<td>85 ft</td>
<td>56,250 SF</td>
<td>168,750 SF</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>85 ft</td>
<td>135,000 SF</td>
<td>405,000 SF</td>
</tr>
<tr>
<td>M</td>
<td>6</td>
<td>85 ft</td>
<td>76,875 SF</td>
<td>230,625 SF</td>
</tr>
<tr>
<td>R-2</td>
<td>8</td>
<td>85 ft</td>
<td>76,875 SF</td>
<td>230,625 SF</td>
</tr>
</tbody>
</table>

Areas exclude potential frontage increase

In most cases, Type IV-C height allowances = Type IV-HT height allowances, but add ‘l stories permitted due to enhanced FRR

Type IV-C area = 1.25 \times \text{Type IV-HT area}
## Tall Wood Fire Resistance Ratings (FRR)

<table>
<thead>
<tr>
<th>Primary Frame or Brg Wall FRR</th>
<th>Floor Construction FRR</th>
<th>Roof Construction FRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Floor Surface Protection</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 HR (2 HR at Roof)</td>
<td>2 HR (1 HR at Roof)</td>
<td>2 HR (1 HR at Roof)</td>
</tr>
<tr>
<td>2 HR</td>
<td>2 HR</td>
<td>2 HR</td>
</tr>
<tr>
<td>1.5 HR</td>
<td>1 HR</td>
<td>1 HR</td>
</tr>
<tr>
<td>1 inch of NC protection on top</td>
<td>1 inch of NC protection on top</td>
<td>No protection req.'d</td>
</tr>
<tr>
<td>2 layers 5/8” Type X gyp. on underside</td>
<td>2 layers 5/8” Type X gyp. on underside</td>
<td>No protection req.’d unless concealed space</td>
</tr>
</tbody>
</table>
Tall Wood Materials & Protection

If Mass Timber, exterior surface protected with 1 layer 5/8” Type X gyp.

Mass Timber or NC

Permitted, requires NC protection on MT surfaces

<table>
<thead>
<tr>
<th>Exterior Walls</th>
<th>Structural Materials</th>
<th>Concealed Spaces</th>
<th>Gypsum Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV-A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If Mass Timber, exterior surface protected with 1 layer 5/8” Type X gyp.</td>
<td>Mass Timber or NC</td>
<td>Permitted, requires NC protection on MT surfaces</td>
<td>All MT is protected 3 HR: 3 layers 5/8” Type X gyp. 2 HR or less: 2 layers 5/8” Type X gyp. Same as IV-A for protected MT. Limited exposed MT permitted, FRR still applies</td>
</tr>
</tbody>
</table>
Tall Wood Buildings in the 2021 IBC
Up to 18 Stories of Mass Timber

In January 2019, the International Code Council (ICC) approved a set of proposals to allow tall wood buildings as part of the 2021 International Building Code (IBC). Based on these proposals, the 2021 IBC will include three new construction types—Type IV-A, IV-B and IV-C—allowing the use of mass timber or noncombustible materials. These new types are based on previous Heavy Timber construction type (renamed Type IV-HT) but with additional fire-resistance ratings and levels of required noncombustible protection. The code will include provisions for up to 18 stories of Type IV-A construction for Business and Residential Occupancies.

Based on information first published in the Structural Engineers Association of California (SEAOC) 2018 Conference Proceedings, this paper summarizes the background to these proposals, technical research that supported their adoption, and resulting changes to the IBC and product-specific standards.

Background: ICC Tall Wood Building
Ad Hoc Committee

Over the past 10 years, there has been a growing interest in tall buildings constructed from mass timber materials (Breneman 2013, Timmers 2018). Around the world there

WoodWorks Tall Wood Design Resource
CALIFORNIA AGREES TO EARLY ADOPTION OF TALL WOOD PROVISIONS
On August 13, 2020 the California Building Standards Commission grouped the tall wood code change proposals into one agenda item and passed them unanimously.

The changes will be published as an amendment to the 2019 CBC on January 1, 2021 and will become effective on July 1, 2021.
The early adoption of mass timber codes can be a benefit to California in many ways, but I would like to highlight three of those advantages in this proposal.

1. It has the potential to increase the market demand for mass timber production in California to meet the needs of the construction industry.

2. It will increase the pace and scale of our wildland fire prevention and forest management goals of treating 500 thousand acres per year by thinning the forest of smaller diameter trees that can be used in the production of cross laminated timber and other mass timber assemblies.

3. While wood products provide the benefit of storing carbon, another benefit or advantage is that mass timber construction can also help reduce the carbon footprint of concrete and steel production.

– Chief Mike Richwine, State Fire Marshal
The CBC has historically not allowed “double-dipping” for sprinkler increases of building height and area for A, E, H, I, L or R occupancies. The IBC has no such restriction.

Also specific to the CBC, for multi-story buildings that are A, E, H, I, L or R occupancies, the total allowable building area is equal to the allowable floor area multiplied by the number of stories, not to exceed 2. In the IBC, this value is 3 for all occupancies.

This is also the case for Tall Wood.
For example, if using the sprinkler area increases, the allowable height in the CBC is 20 ft and 1 story less than the IBC limits for Type IV-A, IV-B and IV-C construction for A, E, H-4, I-4, R-1 and R-2 occupancies.

<table>
<thead>
<tr>
<th>OCCUPANCY CLASSIFICATION</th>
<th>TYPE OF CONSTRUCTION</th>
<th>TYPE IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SEE FOOTNOTES</td>
<td>A</td>
</tr>
<tr>
<td>B, F, M, S, U</td>
<td>NS</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>65</td>
</tr>
<tr>
<td>A, E</td>
<td>S (without area increase)</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>S (with area increase)</td>
<td>250</td>
</tr>
<tr>
<td>Occupancies</td>
<td>I-A</td>
<td>I-B</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td><strong>Allowable Building Height above Grade Plane, Feet (CBC Table 504.3)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B, F, M, S, U, R-3, R-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, E, R-1, R-2 (w/ area increase)</td>
<td>Unlimited</td>
<td>180 (160)</td>
</tr>
<tr>
<td><strong>Allowable Number of Stories above Grade Plane (CBC Table 504.4)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-2, A-3, A-4 (w/ area increase)</td>
<td>Unlimited</td>
<td>12 (11)</td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>12</td>
</tr>
<tr>
<td>R-1, R-2 (w/ area increase)</td>
<td>Unlimited</td>
<td>12 (11)</td>
</tr>
<tr>
<td><strong>Allowable Area Factor (At) for SM, Feet² (CBC Table 506.2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-1, A-2, A-3, A-4 (w/ height increase)</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>R-1, R-2 (w/ height increase)</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
Example: R-2, Type IV-B Building

CBC Tall Wood – Sprinkler Increase Options

11 Stories
160 ft
123,000 SF per floor
246,000 SF total bldg

w/ area increase

12 Stories
180 ft
41,000 SF per floor
82,000 SF total bldg

w/ height increase
Example: R-2, Type IV-B Building

- 11 Stories
- 160 ft
- 123,000 SF per floor
- 246,000 SF total bldg

Type IA Podium (1 or more stories)

w/ area increase

w/ area increase + podium

11 Stories
123,000 SF per floor
246,000 SF total bldg

160 ft max
Example A-2, Type IV-C Building

- **5 Stories**: 65 ft
- **56,250 SF per floor**
- **112,500 SF bldg**

- **6 Stories**: 85 ft
- **18,750 SF per floor**
- **37,500 SF bldg**

**w/sprinkler area increase**

**w/sprinkler height increase**
## CBC Tall Wood Opportunities – Large Area

### Construction Type (Sprinklered Values)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>I-A</th>
<th>I-B</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
<th>III-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>B, F, M, S, U, R-3, R-4</td>
<td>Unlimited</td>
<td>270</td>
<td>180</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>A, E, R-1, R-2 w/ area increase</td>
<td>Unlimited</td>
<td>160</td>
<td>250</td>
<td>160</td>
<td>65</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>A-2, A-3, A-4 w/ area increase</td>
<td>Unlimited</td>
<td>11</td>
<td>17</td>
<td>11</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>12</td>
<td>18</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>R-1, R-2 w/ area increase</td>
<td>Unlimited</td>
<td>11</td>
<td>17</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>A-1, A-2, A-3, A-4 w/o height increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>135,000</td>
<td>90,000</td>
<td>56,250</td>
<td>45,000</td>
<td>42,000</td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>324,000</td>
<td>216,000</td>
<td>135,000</td>
<td>108,000</td>
<td>85,500</td>
</tr>
<tr>
<td>R-1, R-2 w/o height increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>184,500</td>
<td>123,000</td>
<td>76,875</td>
<td>61,500</td>
<td>72,000</td>
</tr>
</tbody>
</table>

### Allowable Building Height above Grade Plane, Feet (CBC Table 504.3)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>I-A</th>
<th>I-B</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
<th>III-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>B, F, M, S, U, R-3, R-4</td>
<td>Unlimited</td>
<td>180*</td>
<td>270</td>
<td>180</td>
<td>85</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>A, E, R-1, R-2 w/ area increase</td>
<td>Unlimited</td>
<td>160</td>
<td>160</td>
<td>65</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-2, A-3, A-4 w/ area increase</td>
<td>Unlimited</td>
<td>17</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-1, R-2 w/ area increase</td>
<td>Unlimited</td>
<td>17</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Allowable Number of Stories above Grade Plane (CBC Table 504.4)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>I-A</th>
<th>I-B</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
<th>III-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2, A-3, A-4 w/ area increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>11</td>
<td>11</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>12</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>R-1, R-2 w/ area increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>11</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

### Allowable Area Factor (At) for SM, Feet² (CBC Table 506.2)

<table>
<thead>
<tr>
<th>Occupancies</th>
<th>I-A</th>
<th>I-B</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
<th>IV-HT</th>
<th>III-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1, A-2, A-3, A-4 w/o height increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>135,000</td>
<td>90,000</td>
<td>56,250</td>
<td>45,000</td>
<td>42,000</td>
</tr>
<tr>
<td>B</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>324,000</td>
<td>216,000</td>
<td>135,000</td>
<td>108,000</td>
<td>85,500</td>
</tr>
<tr>
<td>R-1, R-2 w/o height increase</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>184,500</td>
<td>123,000</td>
<td>76,875</td>
<td>61,500</td>
<td>72,000</td>
</tr>
</tbody>
</table>
OTHER NOTABLE DIFFERENCES:

• Section 403.3.2: The CBC requires all buildings taller than 120 ft to have dual water supply. The IBC requires it for buildings taller than 420 ft, or tall wood buildings more than 120 ft (end result is the same for tall wood).
• Table 504.3: H-1, H-2, H-3 & H-5 occupancies in the CBC allows 85 ft for IV-C; the IBC only allows 65 ft.
• Tables 504.3, 504.4 & 506.2: I occupancies, various differences in allowable heights & areas.
• Table 504.4: R-4 occupancies in the CBC only allows 11/5/5 stories for IV-A/IV-B/IV-C; the IBC allows 18/12/5.

Source: Michael Maltzan Architecture
Section 722.7
The fire resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element (MT) added to the protection time of the noncombustible (NC) protection.

Credit: Urban One
However, FRR doesn’t always need to be from a combination of MT + NC. In some cases, just NC can be used, in other cases, just MT can be used:

Section 602.4
Mass timber elements shall meet the fire resistance rating requirements of this section based on either the fire resistance rating of the noncombustible protection, the mass timber, or a combination of both.
# Noncombustible Protection (NC)

## TABLE 722.7.1(a)
**PROTECTION REQUIRED FROM NONCOMBUSTIBLE COVERING MATERIAL**

<table>
<thead>
<tr>
<th>Required Fire Resistance Rating of Building Element per Tables 601 and 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(b)
**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>
MT Type IV Minimum Sizes

In addition to meeting FRR, all MT elements must also meet minimum sizes.

These minimum sizes have been in place for the old Type IV construction (now called Type IV-HT) and the same minimum sizes also apply to MT used in the new Types IV-A, IV-B and IV-C construction.

Contained in Section 2304.11.
## Type IV Minimum Sizes - Framing

<table>
<thead>
<tr>
<th>Framing</th>
<th>Solid Sawn (nominal)</th>
<th>Glulam (actual)</th>
<th>SCL (actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>Columns 8 x 8</td>
<td>6 3/4 x 8¾</td>
<td>7 x 7½</td>
</tr>
<tr>
<td></td>
<td>Beams 6 x 10</td>
<td>5 x 10½</td>
<td>5 ¼ x 9½</td>
</tr>
<tr>
<td>Roof</td>
<td>Columns 6 x 8</td>
<td>5 x 8¼</td>
<td>5 ¼ x 7½</td>
</tr>
<tr>
<td></td>
<td>Beams* 4 x 6</td>
<td>3 X 6 7/8</td>
<td>3 ½ X 5½</td>
</tr>
</tbody>
</table>

Minimum Width by Depth in Inches
See Section 2304.11 for details

*3” nominal width allowed where sprinklered
Type IV Minimum Sizes – Floor/Roof Panels

Floor Panels/Decking:
• 4” thick CLT (actual thickness)
• 4” NLT/DLT/GLT (nominal thickness)
• 3” decking (nominal thickness) covered with: 1” decking or 15/32” WSP or 1/2” particleboard

Roof Panels/Decking:
• 3” thick CLT (actual thickness)
• 3” NLT/DLT/GLT (nominal thickness)
• 2” decking (nominal thickness)
• 1-1/8” WSP
MT Type IV Minimum Sizes – Walls

Exterior Walls for Type IV-A, B or C
• CLT or Non-combustible

Exterior Walls for Type IV-HT
• CLT or light-frame FRTW or Non-combustible
• 4” thick CLT (if CLT)
• 6” thick wall (if light-frame FRTW)
MT Fire Resistance Ratings (FRR)

How do you determine FRR of MT?

Two options:
1. Calculations in accordance with Section 722 → NDS Chapter 16
2. Tests in accordance with ASTM E119
MT FRR Calculation Method:

- Section 703.3 allows several methods of determining FRR; one is calculations per Section 722
- Section 722.1 refers to NDS Chapter 16 for exposed wood FRR

703.3 Methods for determining fire resistance. The application of any of the methods listed in this section shall be based on the fire exposure and acceptance criteria specified in ASTM E119 or UL 263. The required fire resistance of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

3. Calculations in accordance with Section 722.

722.1 General. The provisions of this section contain procedures by which the fire resistance of specific materials or combinations of materials is established by calculations. These procedures apply only to the information contained in this section and shall not be otherwise used. The calculated fire resistance of concrete, concrete masonry and clay masonry assemblies shall be permitted in accordance with ACI 216.1/TMS 0216. The calculated fire resistance of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 29. The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA National Design Specification for Wood Construction (NDS).
Nominal char rate of 1.5”/HR is recognized in NDS Chapter 16. Effective char depth calculated to account for duration of fire and structural reduction in heat-affected zone. AWC’s TR 10 is a great resource for explanations and design examples of NDS Chapter 16 char calculations.
MT Fire Resistance Ratings (FRR)

Tested Assemblies Method:

- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers

Contact WoodWorks for Inventory of Tests
MT Fire Resistance Ratings (FRR)

Mass Timber Fire Design Resource

- Code compliance options for demonstrating FRR
- Free download at woodworks.org
Type IV-A Protection vs. Exposed

100% NC protection on all surfaces of Mass Timber

Credit: Susan Jones, atelierjones
## Type IV-A Fire Resistance Ratings (FRR)

### Primary Frame FRR

<table>
<thead>
<tr>
<th>FRR</th>
<th>Min. NC Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 HR (2 HR at Roof)</td>
<td>120 min (80 min at Roof)</td>
</tr>
<tr>
<td>3 HR</td>
<td>120 min</td>
</tr>
<tr>
<td>2 HR</td>
<td>80 min</td>
</tr>
<tr>
<td>1.5 HR</td>
<td>80 min</td>
</tr>
</tbody>
</table>

### Ext or Int Bearing Wall FRR

### Floor Construction FRR

### Roof Construction FRR
Type IV-A Protection

Floor Surface Protection
Min. 1 inch of NC protection

Roof Construction Protection
Min. 2 layers 5/8” type X gyp on inside face
Min. 1 layer 5/8” type X gyp on outside face
Min. 2 layers 5/8” type X gyp on inside face (non-brg)
Min. 3 layers 5/8” type X gyp on inside face (brg)

Ext Wall Protection

Credit: Maxxon
Type IV-A Fire Resistance Ratings (FRR)

Floor Panel Example (2 HR):

Min. 1” NC

Mass Timber Floor Panel

40 minutes of MT FRR + 2 layers 5/8” type X gypsum

OR

3 layers 5/8” type X gypsum
Type IV-A Fire Resistance Ratings (FRR)

Primary Frame (3 HR) + Floor Panel Example (2 HR):

- Min. 1” NC
- 2 layers 5/8” type X gypsum
- 40 minutes of MT FRR

Glulam Beam (Primary Structural Frame)

- 60 minutes of MT FRR
- 3 layers 5/8” type X gypsum
Type IV-B Protection vs. Exposed

NC protection on all surfaces of Mass Timber except limited exposed areas

≈20% of ceiling or ≈40% of wall can be exposed, see code for requirements
# Type IV-B Fire Resistance Ratings (FRR)

<table>
<thead>
<tr>
<th>Component</th>
<th>FRR</th>
<th>Min. NC Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Frame FRR</strong></td>
<td><strong>2 HR (1 HR at Roof)</strong></td>
<td><em><em>80 min</em> (40 min</em> at Roof)**</td>
</tr>
<tr>
<td><strong>Ext or Int Bearing Wall FRR</strong></td>
<td><strong>2 HR</strong></td>
<td><strong>80 min</strong>*</td>
</tr>
<tr>
<td><strong>Floor Construction FRR</strong></td>
<td><strong>2 HR</strong></td>
<td><strong>80 min</strong>*</td>
</tr>
<tr>
<td><strong>Roof Construction FRR</strong></td>
<td><strong>1 HR</strong></td>
<td><strong>40 min</strong>*</td>
</tr>
</tbody>
</table>

*Applicable to most locations; limited exposed MT permitted*
Type IV-B Protection

Floor Surface Protection
- Min. 1 inch of NC protection

Roof Construction Protection
- Min. 1 layer 5/8” type X gyp on inside face*

Ext Wall Protection
- Min. 1 layer 5/8” type X gyp on outside face
- Min. 2 layers 5/8” type X gyp on inside face*

*Applicable to most locations; limited exposed MT permitted
Type IV-B Fire Resistance Ratings (FRR)

Floor Panel Example (2 HR):

Min. 1” NC

Mass Timber Floor Panel

IV-B

40 minutes of MT FRR* + 2 layers 5/8” type X gypsum* OR 3 layers 5/8” type X gypsum*

*Applicable to most locations; limited exposed MT permitted
Type IV-B Fire Resistance Ratings (FRR)

Primary Frame (2 HR) + Floor Panel Example (2 HR):

*Applicable to most locations; limited exposed MT permitted

40 minutes of MT FRR* + 2 layers 5/8” type X gypsum*

Glulam Beam (Primary Structural Frame)

Mass Timber Floor Panel

Min. 1” NC

40 minutes of MT FRR* + 2 layers 5/8” type X gypsum*
Limited Exposed MT allowed in Type IV-B for:

- MT columns which are not an integral part of walls, no area limitation applies
- MT ceilings/beams up to 20% of floor area in dwelling unit or fire area, or
- MT walls/columns up to 40% of floor area in dwelling unit or fire area, or
- Combination of ceilings/beams and walls/columns, calculated as follows:
Mixed unprotected areas, exposing both ceilings and walls:

• In each dwelling unit or fire area, max. unprotected area = 
  \( \left( \frac{U_{tc}}{U_{ac}} \right) + \left( \frac{U_{tw}}{U_{aw}} \right) \leq 1.0 \)

• \( U_{tc} = \) Total unprotected MT ceiling areas
• \( U_{ac} = \) Allowable unprotected MT ceiling areas
• \( U_{tw} = \) Total unprotected MT wall areas
• \( U_{aw} = \) Allowable unprotected MT wall areas
Design Example: Mixing unprotected MT walls & ceilings

800 SF dwelling unit
- $U_{ac} = (800 \text{ SF})*(0.20) = 160 \text{ SF}$
- $U_{aw} = (800 \text{ SF})*(0.40) = 320 \text{ SF}$
- Could expose 160 SF of MT ceiling, OR 320 SF of MT walls, OR
- If desire to expose 100 SF of MT ceiling in Living room, determine max. area of MT walls that can be exposed
Type IV-B Protection vs. Exposed

Design Example: Mixing unprotected MT walls & ceilings

\[
\left( \frac{U_{tc}}{U_{ac}} \right) + \left( \frac{U_{tw}}{U_{aw}} \right) \leq 1.0
\]

\[
\left( \frac{100}{160} \right) + \left( \frac{U_{tw}}{320} \right) \leq 1.0
\]

\( U_{tw} = 120 \text{ SF} \)

- Can expose 120 SF of MT walls in dwelling unit in combination with exposing 100 SF of MT ceiling

Credit: AWC
Horizontal separation of unprotected areas:

- Unprotected portions of mass timber walls and ceilings shall be not less than 15 feet from unprotected portions of other walls and ceilings, measured horizontally along the ceiling and from other unprotected portions of walls measured horizontally along the floor.
Type IV-C Protection vs. Exposed

All Mass Timber surfaces may be exposed

Exceptions: Shafts, concealed spaces, outside face of exterior walls

Credit: Susan Jones, atelierjones
Type IV-C Fire Resistance Ratings (FRR)

- Primary Frame FRR: 2 HR (1 HR at Roof)
- Ext or Int Bearing Wall FRR: 2 HR
- Floor Construction FRR: 2 HR
- Roof Construction FRR: 1 HR

Credit: Ema Peter
Type IV-C Protection

- Floor Surface Protection: None req’d
- Roof Construction Protection: None req’d
- Ext Wall Protection: Min. 1 layer 5/8” type X gyp on outside face, None req’d on inside face

Credit: Maxxon
Type IV-C Fire Resistance Ratings (FRR)

Floor Panel Example (2 HR):

No NC req.’d

Mass Timber Floor Panel

2 HR of MT FRR
No NC req.’d
Type IV-C Fire Resistance Ratings (FRR)

Primary Frame (2 HR) + Floor Panel Example (2 HR):

Glulam Beam (Primary Structural Frame)

Mass Timber Floor Panel

No NC req.'d

2 HR of MT FRR
No NC req.'d

2 HR of MT FRR
No NC req.'d
Concealed Spaces in previous Type IV

Previous Type IV (now IV-HT) provisions prohibited concealed spaces
Concealed Spaces in Type IV-HT

Type IV-HT will now permit concealed spaces where one of the following conditions exists:

1. The building is sprinklered throughout with an NFPA 13 sprinkler system and sprinklers are provided in the concealed space.
2. The concealed space is completely filled with noncombustible insulation.
3. Surfaces within the concealed space are fully sheathed with not less than 5/8” Type X gypsum.

Concealed spaces within interior walls and partitions with a one hour or greater fire resistance rating complying with Section 2304.11.2.2 do not require additional protection.
Concealed Spaces in Type IV-HT

Option 1
Sprinklers in concealed spaces

Option 2
Noncombustible insulation

Option 3
5/8” Type X gypsum on all MT surfaces
Concealed Spaces in Type IV-A, IV-B & IV-C

New Type IV-HT concealed space provisions do not apply to Type IV-A, IV-B & IV-C;
But, can still have concealed spaces in Type IV-A, IV-B & IV-C:

- **Type IV-A & IV-B:** Combustible construction forming concealed spaces protected with NC of 80 minutes (2 layers of 5/8” Type X Gypsum)
- **Type IV-C:** Combustible construction forming concealed spaces protected with NC of 40 minutes (1 layer of 5/8” Type X Gypsum)
Concealed Spaces in Type IV-A & IV-B

- Min. 1" NC

Mass Timber Floor Panel

w/o dropped ceiling

- 2 layers 5/8" type X gypsum*

w/ dropped ceiling

*Applicable to most locations; limited exposed MT permitted in IV-B

2 layers 5/8" type X gypsum
Concealed Spaces in Type IV-C

No NC req.’d

Mass Timber Floor Panel

w/o dropped ceiling

1 layer 5/8” type X gypsum

w/ dropped ceiling
Shaft Enclosures in Type IV-A, IV-B & IV-C

<table>
<thead>
<tr>
<th>Exit &amp; Hoistway Enclosures</th>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 12 Stories or 180 ft: MT protected with 2 layers 5/8” type X gyp (if 2 HR req’d) or 3 layers 5/8” type X gyp (if 3 HR req’d) both sides</td>
<td>NC or MT protected with 2 layers 5/8” type X gyp (Section 602.4.2.6) both sides</td>
<td>NC or MT protected with 1 layer 5/8” type X gyp (Section 602.4.3.6) both sides</td>
<td></td>
</tr>
<tr>
<td>Above 12 Stories or 180 ft: Noncombustible shafts (Section 602.4)</td>
<td>2 HR (not less than FRR of floor assembly penetrated, Section 713.4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mid-Rise vs. High-Rise

If this dimension exceeds 75 feet, building is considered a high rise.

10’ floor to floor

Lowest Level of Fire Dept. Vehicle Access

FIGURE 6-6 Determination of high-rise building
In tall buildings, preventing fire re-growth is key. Fire re-growth is a phenomenon in which the heat-release rate of a fire intensifies following a decay phase. Fire re-growth can be initiated when delamination occurs (char fall-off), as this exposes un-charred wood surfaces, thereby resulting in an influx of fuel available for consumption by the fire.
CLT Fire Performance – Char Fall-Off

Facts about CLT char fall-off:
• Only an item to consider in tall buildings. Important to avoid in high-rise construction where required performance is containment of fire within compartment of origin with no sprinkler or fire service suppression
• Not applicable when discussing mid-rise mass timber (or any building under types II, III, IV-HT or V)
• Largely a function of adhesive performance under high temps
• Has been addressed in PRG 320-18 (required for all CLT, not just tall wood)
Section 602.4 added:
Cross-laminated timber shall be labeled as conforming to PRG 320-18 as referenced in Section 2303.1.4.
In Construction Types IV-A, IV-B & IV-C, building elements are required to be FRR as specified in Tables 601 and 602. Connections between these building elements must be able to maintain FRR no less than that required of the connected members.

16.3 Wood Connections

Wood connections, including connectors, fasteners, and portions of wood members included in the connection design, shall be protected from fire exposure for the required fire resistance time. Protection shall be provided by wood, fire-rated gypsum board, other approved materials, or a combination thereof.

Source: NDS
Many ways to demonstrate connection fire protection: calculations, prescriptive NC, test results, others as approved by AHJ
Connection Fire Protection

2017 Glulam Beam to Column Connection Fire Tests under standard ASTM E119 time-temperature exposure

Photo: ARUP/SLB
Connection Fire Protection

Full Report Available at:
Penetration Fire Protection

Although not a new code requirement or specific to tall wood, more testing & information is becoming available on firestopping of penetrations through MT assemblies.

Photos: AWC/FPInnovations
Penetration Fire Protection

Most firestopping systems include combination of fire safing (e.g. noncombustible materials such as mineral wool insulation) plus fire caulk.
Penetration Fire Protection

Firestop systems tests on Mass Timber: Contact WoodWorks for information
Section 703.9 Sealing of adjacent mass timber elements. In buildings of Type IV-A, IV-B and IV-C construction, sealant or adhesive shall be provided to resist the passage of air in the following locations:

1. At abutting edges and intersections of mass timber building elements required to be fire resistance-rated
2. At abutting intersections of mass timber building elements and building elements of other materials where both are required to be fire resistance-rated.
Sealants at MT Panel Edges

Sealants shall meet the requirements of ASTM C920 (elastomeric joint sealants). Adhesives shall meet the requirements of ASTM D3498 (gap filling construction adhesives, i.e. not fire caulk).

**Exception:** Sealants or adhesives need not be provided where they are not a required component of a fire resistance-rated assembly.
Several MT fire tested assemblies have successfully been completed w/o adhesives/sealants at abutting panel edges

Periodic special inspections of adhesive/sealant installation will be required (when required to be installed)
This concludes The American Institute of Architects Continuing Education Systems Course

QUESTIONS?

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