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

Presented on 09/17/20 by Mike Romanowski, SE

Photo: Kaiser+Path

Course Description

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.

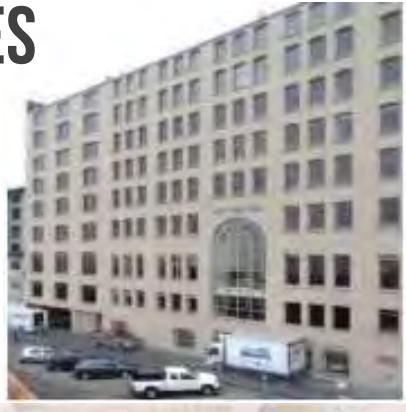
Questions we'll answer:

- 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?

Photo: Michael Green Architecture

TALL WOOD IN NORTH AMERICA CIRCA 1906

9 STORIES



BUTLER SQUARE, MINNEAPOLIS

THE LANDING, VANCOUVER

GLOBAL TALL WOOD CIRCA 2015

7-14 STORIES









GLOBAL TALL WOOD CIRCA 2019

18-24 STORIES


Photo: Moelven Limtre


Photo: naturally:wood


Photo: Rudiger Lainer + Partner

TALL WOOD IN THE US CIRCA 2019

8 STORIES

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman | Architect: PATH Architecture

HEAVY TIMBER

Federal Center South, Seattle, WA
Photo: Benjamin Benschneider

MASS TIMBER

Bullitt Center, Seattle, WA
Photo: John Stamets

GLULAM

Photo: StructureCraft

CROSS-LAMINATED TIMBER (CLT)

Photo: LendLease

NAIL-LAMINATED TIMBER (NLT)

Photo: Think Wood

Photo: Ema Peter

DOWEL-LAMINATED TIMBER (DLT)

Photo: StructureCraft

Photo: StructureCraft

MASS PLYWOOD PANELS (MPP)

Photo: LEVER Architecture

DECKING

Photo: Bernard André Photography

OFFICES | MULTI-FAMILY | COMMERCIAL | EDUCATIONAL


Photo: JC Buck


Photo: William Horne


Photo: LEVER Architecture


Photo: David Sundberg and Gray Organschi Architecture


Photo: ©Albert Vecerka/Esto

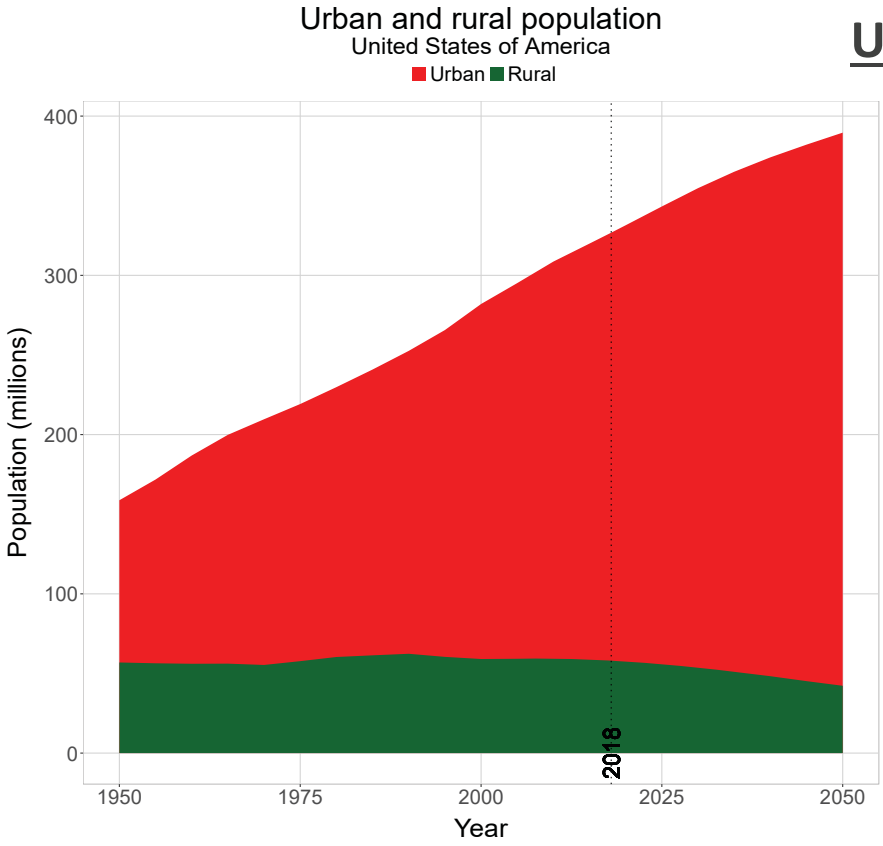

Photo: Christian Columbres

WHY TALL WOOD?

GLOBAL POPULATION BOOM

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

	URBAN	RURAL
2019	271 M	57.7 M
2030	301 M	53.7 M
2050	347 M	42.2 M

Construction Traffic & Noise
Material Stockpiles
Labor Costs
Labor Availability
Weather Risks

Resiliency
Sustainability
Fire & Life Safety

ESTIMATED ENVIRONMENTAL IMPACT OF WOOD USE

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

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

Carbon stored in the wood:
1,753 metric tons of CO_2

Avoided greenhouse gas emissions:
679 metric tons of CO_2

Total potential carbon benefit:
2,432 metric tons of CO_2

THE ABOVE GHG EMISSIONS ARE EQUIVALENT

511 cars off the road for a year

Energy to operate a home for 222 years

*Estimated by the Wood Carbon Calculator for Buildings, based on research by Sathre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations (this relates to carbon stored and avoided GHG).

*CO2 in this case study refers to CO2 equivalent

Source: Naturally:Wood9

Reduced Embodied Carbon

Brock Commons, Vancouver, BC

Photo Credit: UBC

MARKET DRIVERS FOR MASS TIMBER

PRIMARY DRIVERS

- Construction efficiency & speed
- Construction site constraints – urban infill
- Innovation/Aesthetics

SECONDARY DRIVERS

- Carbon reductions
- Structural performance – lightweight

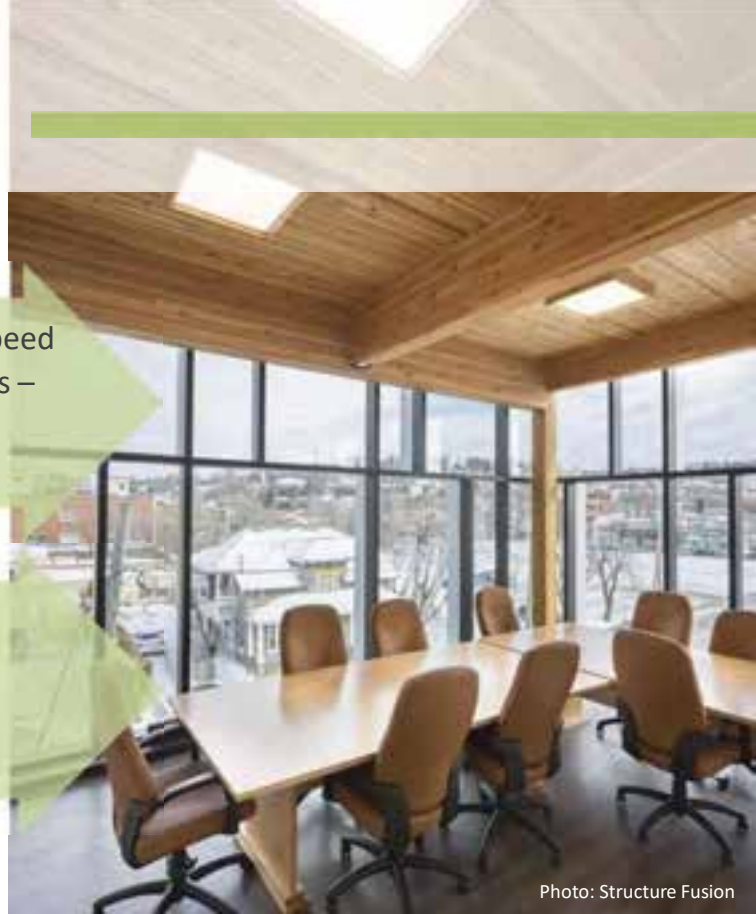
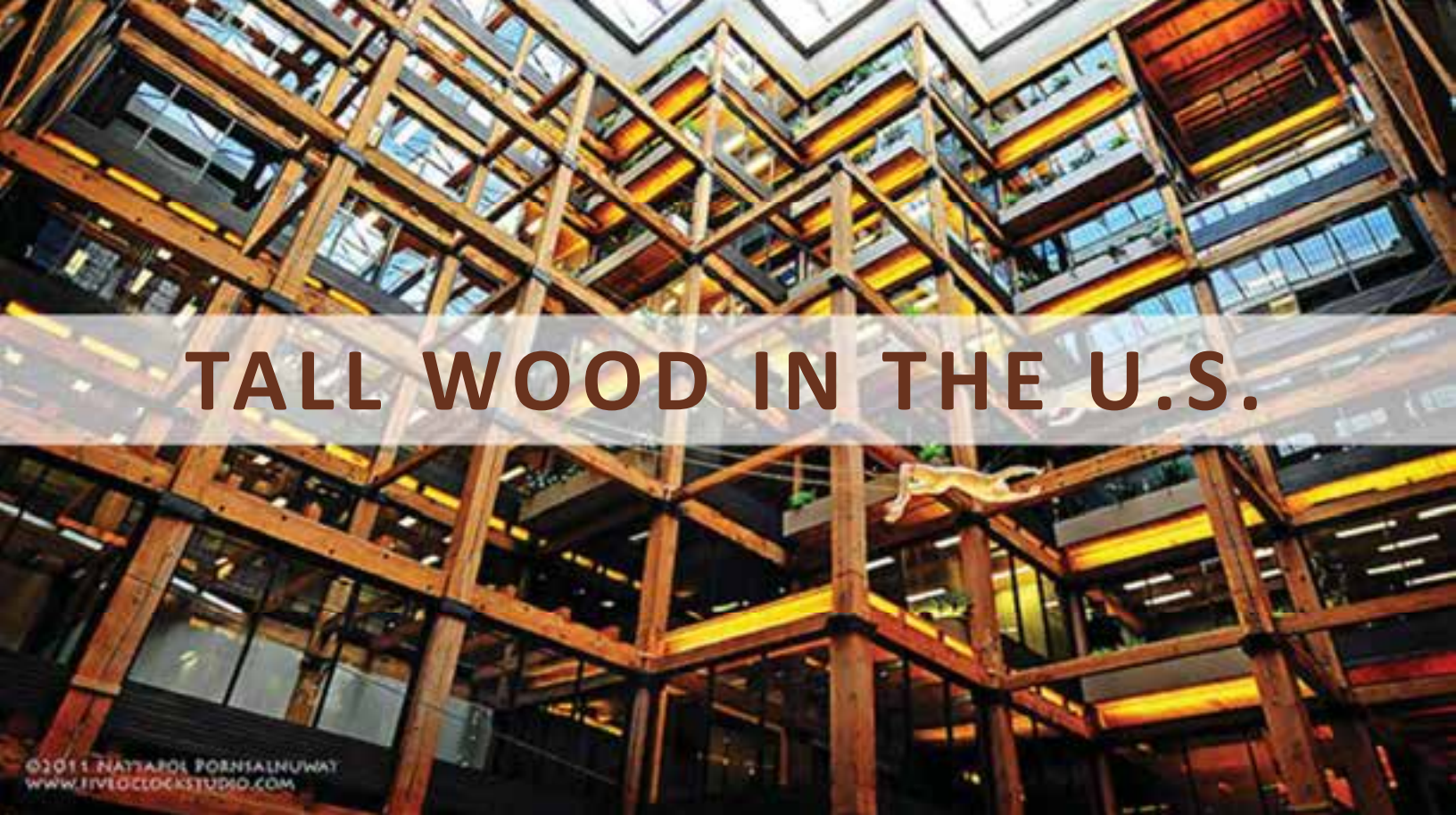
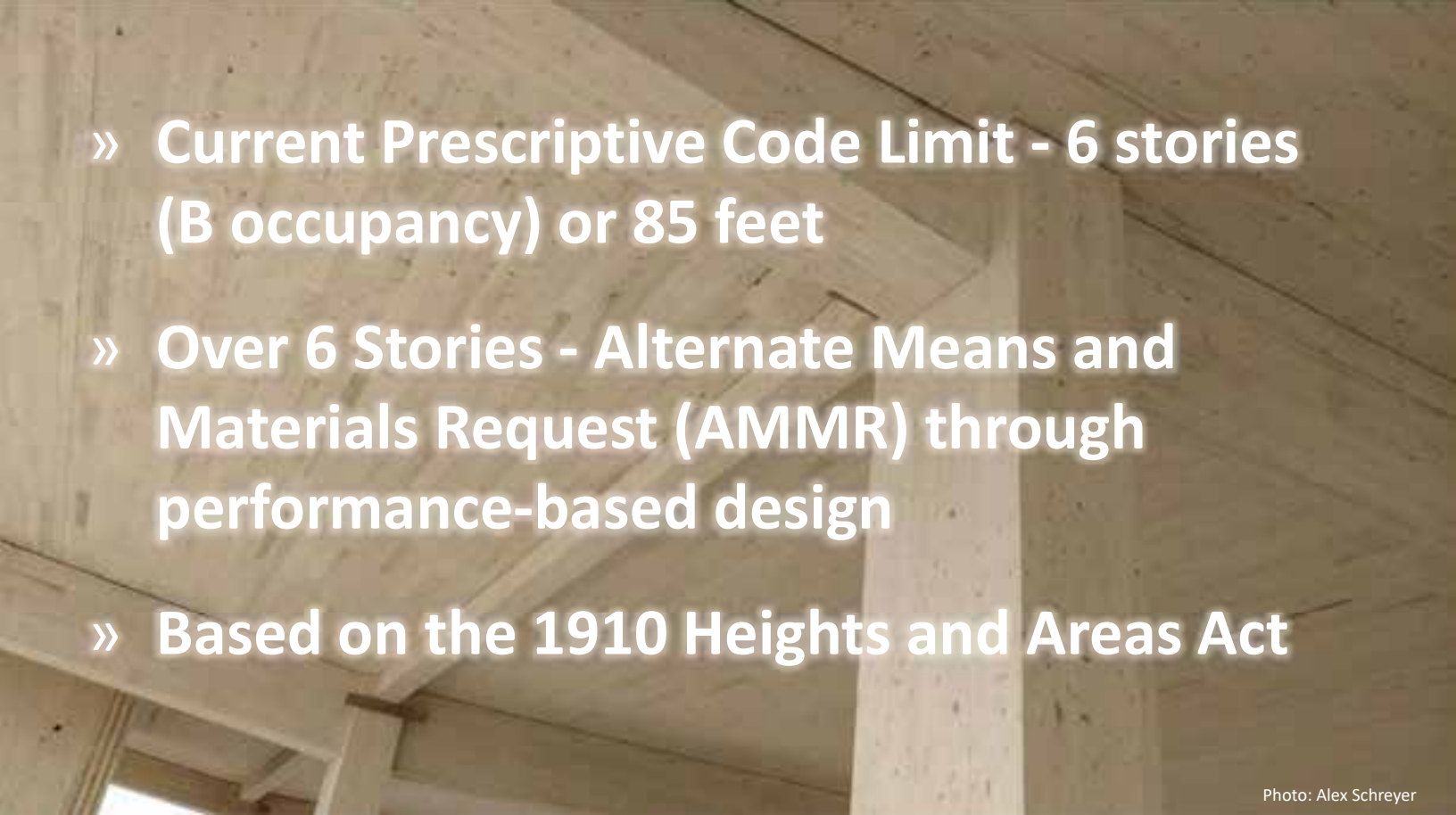


Photo: Structure Fusion



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

Photo: Alex Schreyer

Photo: Blaine Brownell

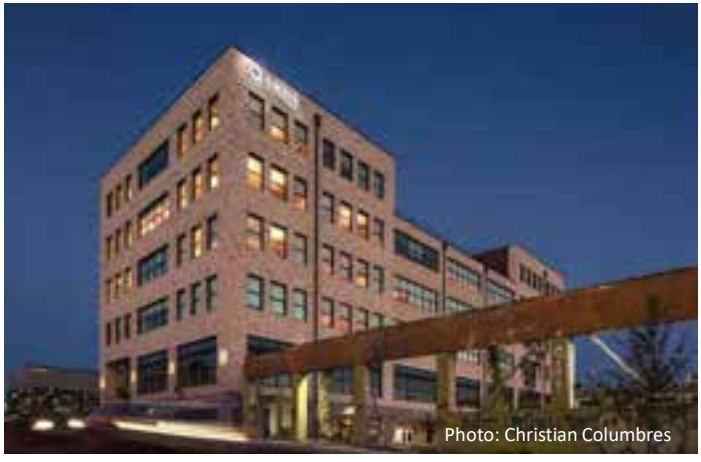


Photo: Christian Columbres

ICE Block I, RMW Architecture & Interiors, Buehler Engineering, Bernard André Photography

Photo: Swinerton

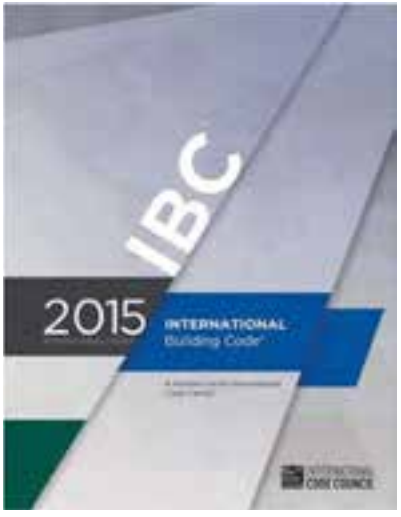
U.S. BUILDING CODE STATUS

Photo: Ema Peter

Seen as the catalyst for the mass timber revolution, CLT IS first recognized in US codes in the 2015 IBC

[BS] CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or *structural composite lumber* where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.



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

Taller wood buildings create new set of challenges to address:

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.


Photo: LEVER Architecture

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.**

Performance Objectives

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.

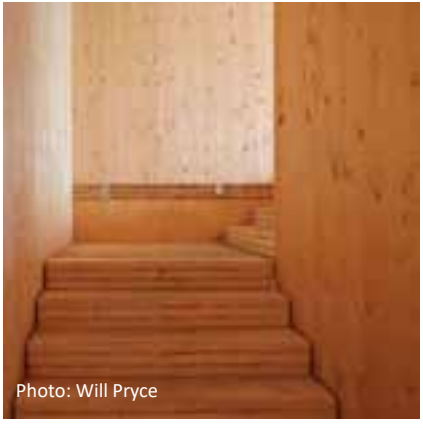


Photo: Will Pryce

U.S. BUILDING CODES
Tall Wood Ad Hoc Committee

Commissioned series of 5 full-scale tests on 2-story mass timber structure at ATF lab in MD, May-June 2017

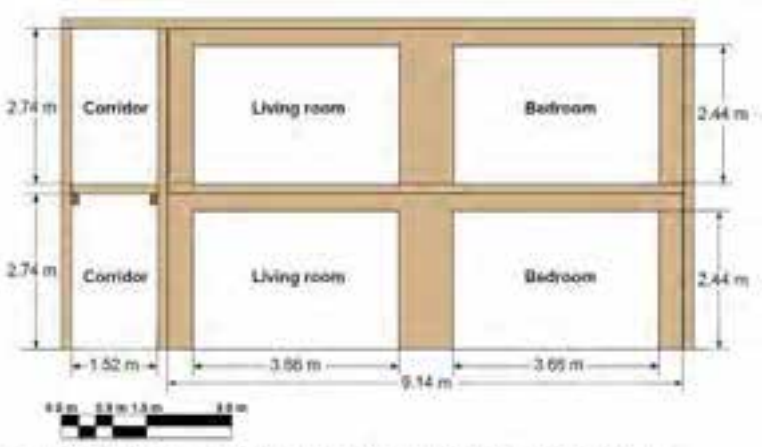


Figure 2. Elevation view of the front of the cross-laminated timber test structure.

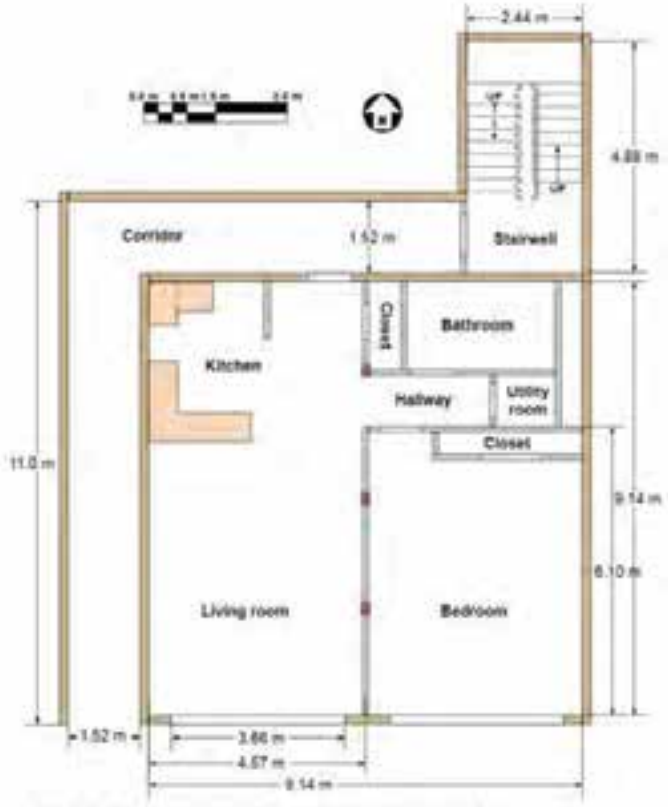


Figure 1. General plan view of cross-laminated timber test structure.

Images: AWC

Photo: LendLease

U.S. BUILDING CODES

Tall Wood Ad Hoc Committee

Test	Description	Construction Type
Test 1	All mass timber surfaces protected with 2 layers of 5/8” Type X Gypsum. No sprinklers.	IV-A
Test 2	30% of CLT ceiling area in living room and bedroom exposed. No sprinklers.	IV-B
Test 3	Two opposing CLT walls exposed – one in bedroom and one in living room. No sprinklers.	IV-B
Test 4	All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – normal activation.	IV-C
Test 5	All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – 20 minute delayed activation.	IV-C

TEST 1 (100% GWB protection, no sprinklers)

Photos provided by U.S. Forest Products Laboratory, USDA

Source: AWC

TEST 2 (partial GWB protection, no sprinklers)


Ignition


Living Room / Kitchen Flashover


Bedroom Flashover


Decay Phase


Living Room Ceiling


Bedroom Ceiling

Photos provided by U.S. Forest Products Laboratory, USDA

Source: AWC

TEST 3 (partial GWB protection, no sprinklers)

Photos provided by U.S. Forest Products Laboratory, USDA

Source: AWC

TEST 4

All mass timber surfaces fully exposed in bedroom and living room.

Sprinkler – normal activation

Source: AWC

Photos provided by U.S. Forest Products Laboratory, USDA

TEST 5

All mass timber surfaces fully exposed in bedroom and living room.

Sprinkler – activation delayed for 20 minutes after smoke detector activation…approximately 23-1/2 minutes from ignition

Source: AWC

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

NFPA RESEARCH FOUNDATION

RESEARCH FOR THE NFPA MISSION

Fire Safety Challenges of Tall Wood Buildings – Phase 2: Task 5 – Experimental Study of Delamination of Cross Laminated (CLT) Timber in Fire

SOUTHWEST RESEARCH INSTITUTE

DEVELOPMENT OF A FIRE PERFORMANCE ASSESSMENT METHODOLOGY FOR QUALIFYING CROSS-LAMINATED TIMBER ADHESIVES

WFCI

WESTERN FIRE CENTER, INC.

2204 Parrott Way, Kelso, Washington 98626

Phone: 360-423-1400 | Fax: 360-423-5083

Fire Resistance Testing of CLT Floor/Ceiling Assemblies to Establish Contribution of Gypsum Protection

U.S. BUILDING CODES
DEVELOPMENT AND CHANGES

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

SO WHAT'S CHANGED??

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

TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
A	B	A	B	A	B	HT	A	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

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B

New Building Types

ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000SF

TYPE IV-A

ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000SF

TYPE IV-B

ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

TYPE IV-C

IBC 2021

324,00 SF MAXIMUM AREA

TYPE IV- HT

IBC 2015

BUSINESS OCCUPANCY [GROUP B]

Credit: Susan Jones, atelierjones

Type IV-A

16 STORIES
BUILDING HEIGHT 270'
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000SF

TYPE IV-A

Credit: Susan Jones, atelierjones

Photos: Structurlam, naturally:wood, Fast + Epp, Urban One

Type IV-A Protection vs. Exposed

Credit: Susan Jones, atelierjones

100% NC protection on all surfaces of Mass Timber

Credit: Acton Ostry Architects, Fast + Epp

Type IV-A Height and Area Limits

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	18	270 ft	135,000 SF	405,000 SF
B	18	270 ft	324,000 SF	972,000 SF
M	12	270 ft	184,500 SF	553,500 SF
R-2	18	270 ft	184,500 SF	553,500 SF

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

Type IV-B

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

TYPE IV-B

Credit: Susan Jones, atelierjones

Credit: LEVER Architecture

Type IV-B Protection vs. Exposed

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path

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 Height and Area Limits

Credit: Susan Jones, atelierjones

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	12	180 ft	90,000 SF	270,000 SF
B	12	180 ft	216,000 SF	648,000 SF
M	8	180 ft	123,000 SF	369,000 SF
R-2	12	180 ft	123,000 SF	369,000 SF

Areas exclude potential frontage increase

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

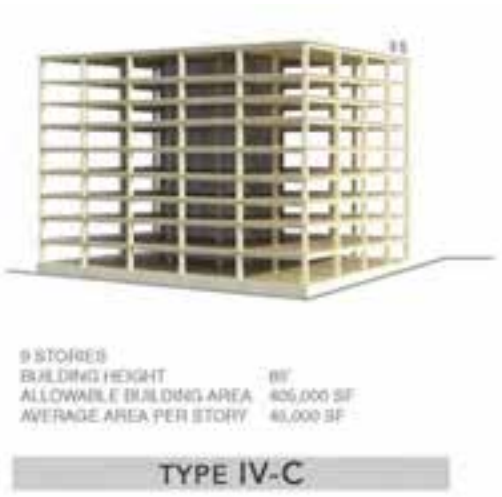
Type IV-B area = 2 × Type IV-HT area

Type IV-C

Credit: Susan Jones, atelierjones

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman

Type IV-C Protection vs. Exposed



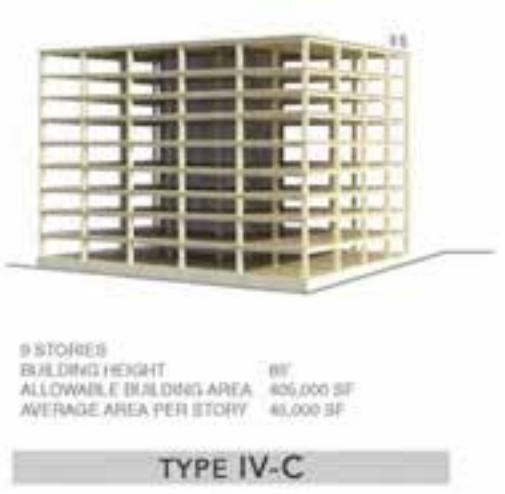
Credit: Susan Jones, atelierjones

Credit: Kaiser+Path, Ema Peter

All Mass Timber surfaces may be exposed

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

Type IV-C Height and Area Limits



Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	6	85 ft	56,250 SF	168,750 SF
B	9	85 ft	135,000 SF	405,000 SF
M	6	85 ft	76,875 SF	230,625 SF
R-2	8	85 ft	76,875 SF	230,625 SF

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 × Type IV-HT area

Credit: Susan Jones, atelierjones

Tall Wood Fire Resistance Ratings (FRR)

	IV-A	IV-B	IV-C
Primary Frame or Brg Wall FRR	3 HR (2 HR at Roof)	2 HR (1 HR at Roof)	2 HR (1 HR at Roof)
Floor Construction FRR	2 HR	2 HR	2 HR
Roof Construction FRR	1.5 HR	1 HR	1 HR
Floor Surface Protection	1 inch of NC protection on top	1 inch of NC protection on top	No protection req.'d
Roof Construction Protection	2 layers 5/8" Type X gyp. on underside	2 layers 5/8" Type X gyp. on underside	No protection req.'d unless concealed space

Tall Wood Materials & Protection

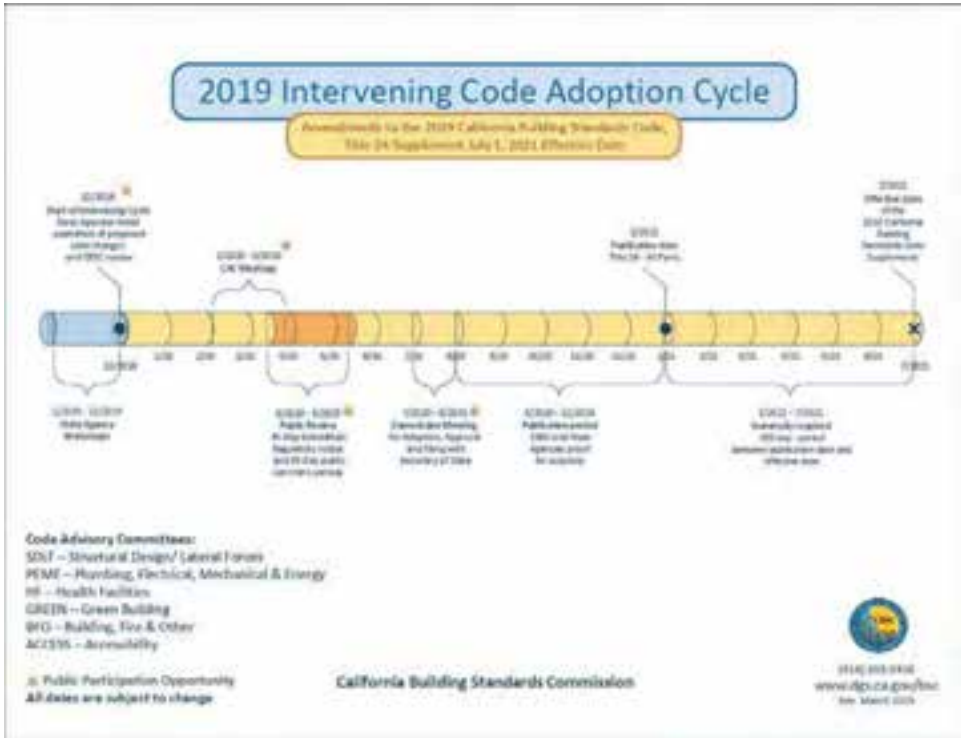
	IV-A	IV-B	IV-C
Exterior Walls	If Mass Timber, exterior surface protected with 1 layer 5/8” Type X gyp.		
Structural Materials	Mass Timber or NC		
Concealed Spaces	Permitted, requires NC protection on MT surfaces		
Gypsum Protection	All MT is protected 3 HR: 3 layers 5/8” Type X gyp. 2 HR or less: 2 layers 5/8” Type X gyp.	Same as IV-A for protected MT. Limited exposed MT permitted, FRR still applies	All MT permitted may be exposed except as noted

WoodWorks Tall Wood Design Resource

http://www.woodworks.org/wp-content/uploads/wood_solution_paper-TALL-WOOD.pdf

EARLY TALL WOOD CODE ADOPTION IN CALIFORNIA

CALIFORNIA AGREES TO EARLY ADOPTION OF TALL WOOD PROVISIONS



Source: Softwood Lumber Board

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.

California Building Standards Commission Passes Tall Wood Code Change Proposals

Source: Softwood Lumber Board

"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."*

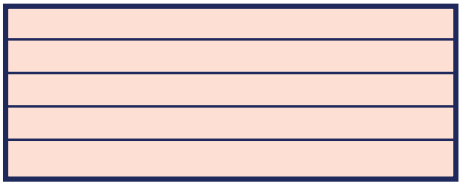
– Chief Mike Richwine, State Fire Marshal

CBC Tall Wood Building Size Limits

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.

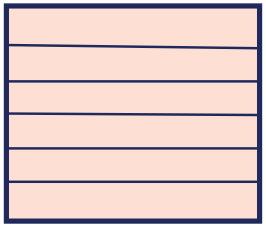
Also specific to the CBC, for multi-story buildings that are A, E, H, I, L or R occupancies, the total allowable building area is equal to the allowable floor area multiplied by the number of stories, not to exceed 2. In the IBC, this value is 3 for all occupancies.

This is also the case for Tall Wood.



Larger Area

VS.



Taller

CBC Tall Wood Building Size Limits

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.

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION				
	SEE FOOTNOTES	TYPE IV			
		A	B	C	HT
B, F, M, S, U	NS[b]	65	65	65	65
	S	270	180	85	85
A, E	NS[b]	65	65	65	65
	S (without area increase)	270	180	85	85
	S (with area increase)	250	160	65	65

CBC Tall Wood Building Size Limits

	Construction Type (Sprinklered Values)						
	I-A	I-B	IV-A	IV-B	IV-C	IV-HT	III-A
Occupancies	**Allowable Building Height above Grade Plane, Feet (CBC Table 504.3)**						
B, F, M, S, U, R-3, R-4	Unlimited	180*	**270**	**180**	**85**	85	85
A, E, R-1, R-2 (w/ area increase)	Unlimited	180 (160)	**270 (250)**	**180 (160)**	**85 (65)**	85 (65)	85 (65)
	Allowable Number of Stories above Grade Plane (CBC Table 504.4)						
A-2, A-3, A-4 (w/ area increase)	Unlimited	12 (11)	**18 (17)**	**12 (11)**	**6 (5)**	4 (3)	4 (3)
B	Unlimited	12	**18**	**12**	**9**	6	6
R-1, R-2 (w/ area increase)	Unlimited	12 (11)	**18 (17)**	**12 (11)**	**8 (7)**	5 (4)	5 (4)
	Allowable Area Factor (At) for SM, Feet^2 (CBC Table 506.2)						
A-1, A-2, A-3, A-4 (w/ height increase)	Unlimited	Unlimited	**135,000 (45,000)**	**90,000 (30,000)**	**56,250 (18,750)**	45,000 (15,000)	42,000 (14,000)
B	Unlimited	Unlimited	**324,000**	**216,000**	**135,000**	108,000	85,500
R-1, R-2 (w/ height increase)	Unlimited	Unlimited	**184,500 (61,500)**	**123,000 (41,000)**	**76,875 (25,625)**	61,500 (20,500)	72,000 (24,000)

CBC Tall Wood Opportunities – Large Area

	Construction Type (Sprinklered Values)						
	I-A	I-B	IV-A	IV-B	IV-C	IV-HT	III-A
Occupancies	**Allowable Building Height above Grade Plane, Feet (CBC Table 504.3)**						
B, F, M, S, U, R-3, R-4	Unlimited	180*	**270**	**180**	**85**	85	85
A, E, R-1, R-2 w/ area increase	Unlimited	160	**250**	**160**	**65**	65	65
	Allowable Number of Stories above Grade Plane (CBC Table 504.4)						
A-2, A-3, A-4 w/ area increase	Unlimited	11	**17**	**11**	**5**	3	3
B	Unlimited	12	**18**	**12**	**9**	6	6
R-1, R-2 w/ area increase	Unlimited	11	**17**	**11**	**7**	4	4
	Allowable Area Factor (At) for SM, Feet^2 (CBC Table 506.2)						
A-1, A-2, A-3, A-4 w/o height increase	Unlimited	Unlimited	**135,000**	**90,000**	**56,250**	45,000	42,000
B	Unlimited	Unlimited	**324,000**	**216,000**	**135,000**	108,000	85,500
R-1, R-2 w/o height increase	Unlimited	Unlimited	**184,500**	**123,000**	**76,875**	61,500	72,000

CBC Tall Wood – Sprinkler Increase Options

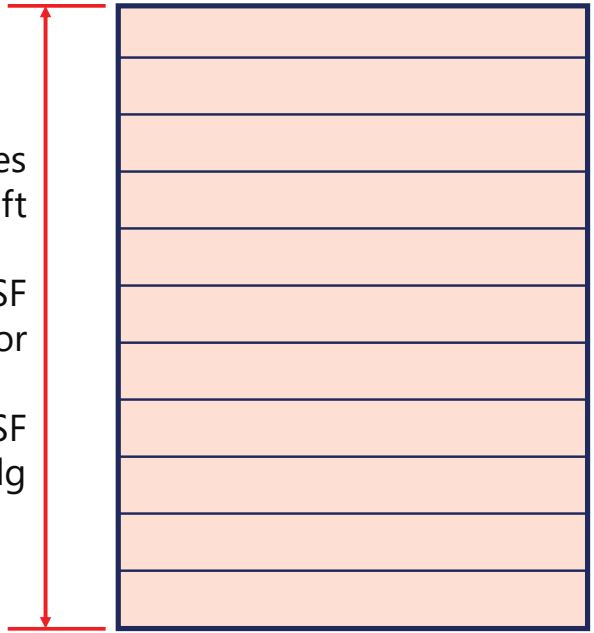
Example: R-2, Type IV-B Building

w/ area increase

11 Stories
160 ft

123,000 SF
per floor

246,000 SF
total bldg

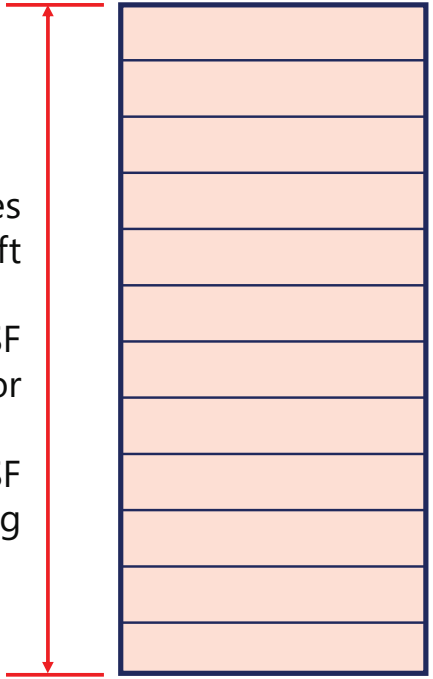


w/ height increase

12 Stories
180 ft

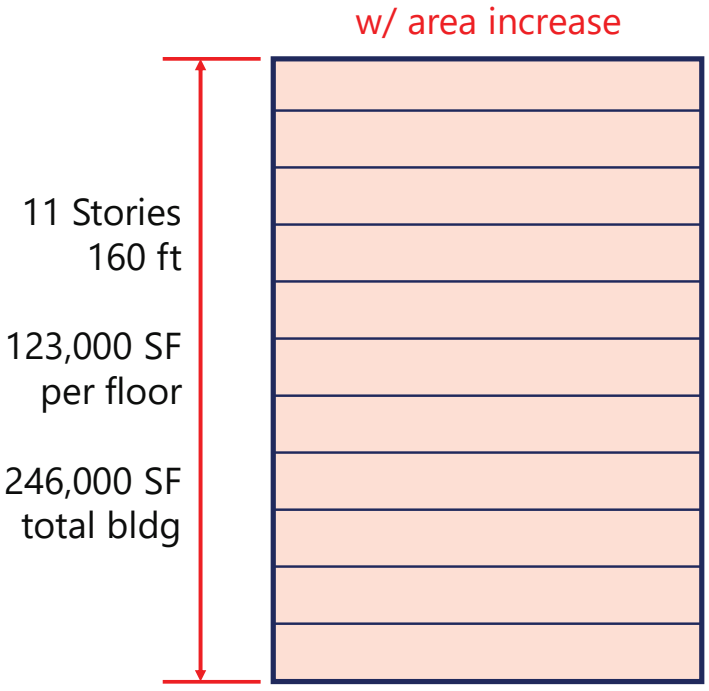
41,000 SF
per floor

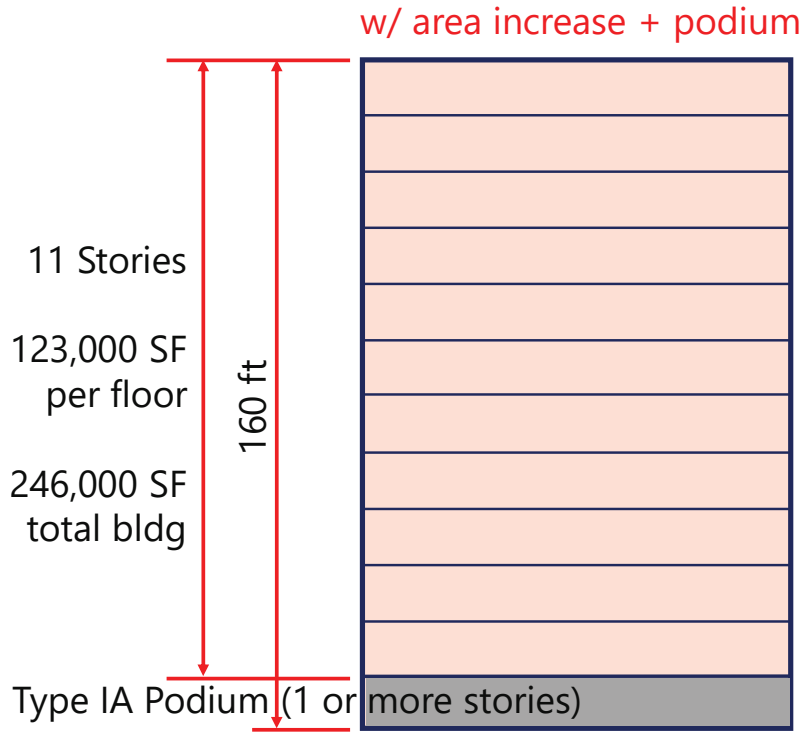
82,000 SF
total bldg



CBC Tall Wood – Podium Option (w/ Sprinkler Increase)

Example: R-2, Type IV-B Building





CBC Tall Wood – Other Differences from IBC

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

MT Fire Resistance Ratings (FRR)

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.

+

= **FRR**

MT Fire Resistance Ratings (FRR)

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

Required Fire Resistance Rating of Building Element per Tables 601 and 602 (hours)	Minimum Protection Required from Noncombustible Protection (minutes)	
1	40	1 layer 5/8 Type X
2	80	2 layers 5/8 Type X
3 or more	120	3 layers 5/8 Type X

TABLE 722.7.1(b)
PROTECTION PROVIDED BY NONCOMBUSTIBLE COVERING MATERIAL

Noncombustible Protection	Protection Contribution (minutes)
1/2 inch Type X Gypsum Board	25
5/8 inch Type X Gypsum Board	40

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

Framing		Solid Sawn (nominal)	Glulam (actual)	SCL (actual)
Floor	Columns	8 x 8	$6^{3}/_{4}$ x 8¼	7 x 7½
	Beams	6 x 10	5 x 10½	5¼ x 9½
Roof	Columns	6 x 8	5 x 8¼	5¼ x 7½
	Beams*	4 x 6	3 X $6^{7}/_{8}$	3½ X 5½

Minimum Width by Depth in Inches
See Section 2304.11 for details

*3” nominal width allowed where sprinklered


Photo: WoodWorks

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**


Photo: StructureCraft


Photos: Aitor Sanchez/ Ewing Cole


Photo: LEVER Architecture

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

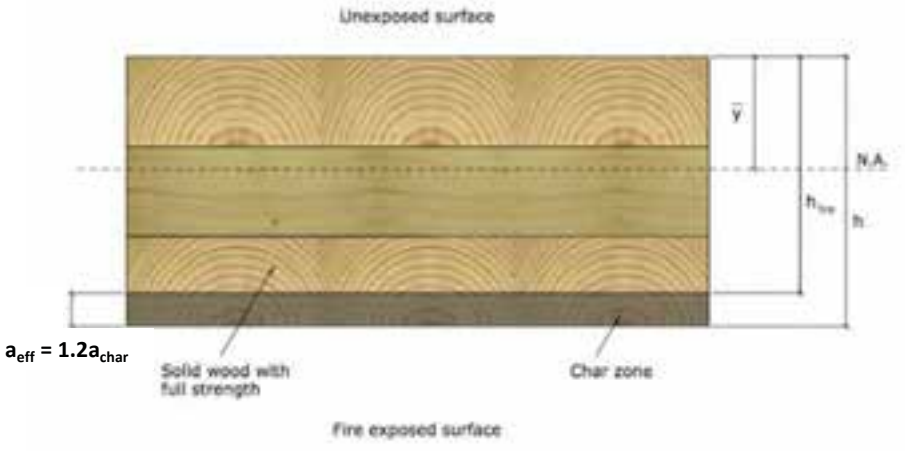
- **CLT or light-frame FRTW or Non-combustible**
- **4” thick CLT (if CLT)**
- **6” thick wall (if light-frame FRTW)**

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 Fire Resistance Ratings (FRR)

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)*.

MT Fire Resistance Ratings (FRR)

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.


Credit: ARUP

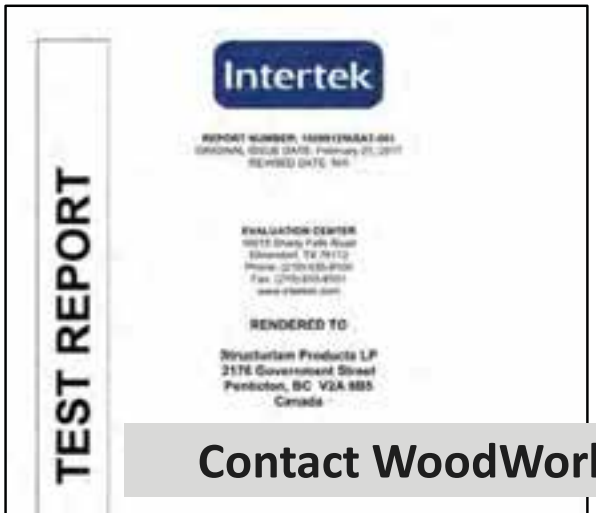
Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	Lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

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)


WoodWorks
WOOD PRODUCTS COUNCIL

Fire-Resistive Design
of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

Mass Timber & Construction Type

Mass Timber Fire Design Resource

- **Code compliance options for demonstrating FRR**
- **Free download at woodworks.org**

IV-A

Type IV-A Protection vs. Exposed

Credit: Susan Jones, atelierjones

100% NC protection on all surfaces of Mass Timber

Credit: Acton Ostry Architects, Fast + Epp

Type IV-A Fire Resistance Ratings (FRR)

IV-A

	FRR	Min. NC Protection
Primary Frame FRR	3 HR (2 HR at Roof)	120 min (80 min at Roof)
Ext or Int Bearing Wall FRR	3 HR	120 min
Floor Construction FRR	2 HR	80 min
Roof Construction FRR	1.5 HR	80 min

Credit: Urban One

Type IV-A Protection

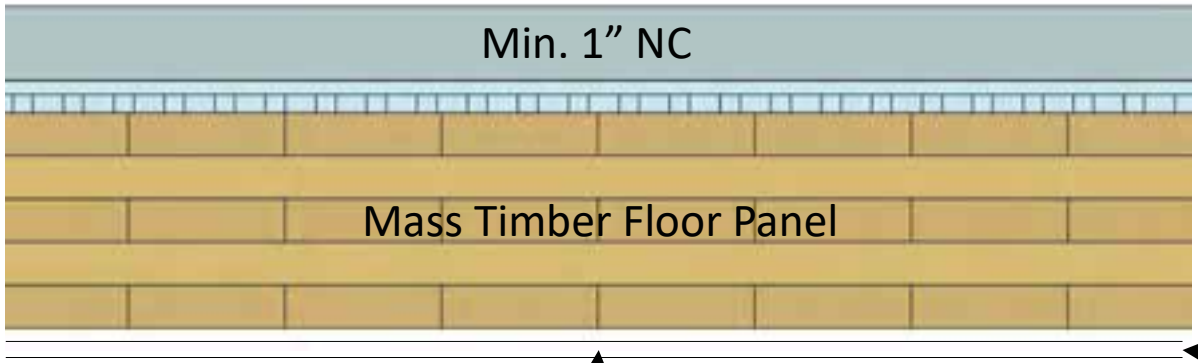
IV-A

Floor Surface Protection	Min. 1 inch of NC protection
Roof Construction Protection	Min. 2 layers 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 (non-brg) Min. 3 layers 5/8” type X gyp on inside face (brg)

Type IV-A Fire Resistance Ratings (FRR)

IV-A

Floor Panel Example (2 HR):

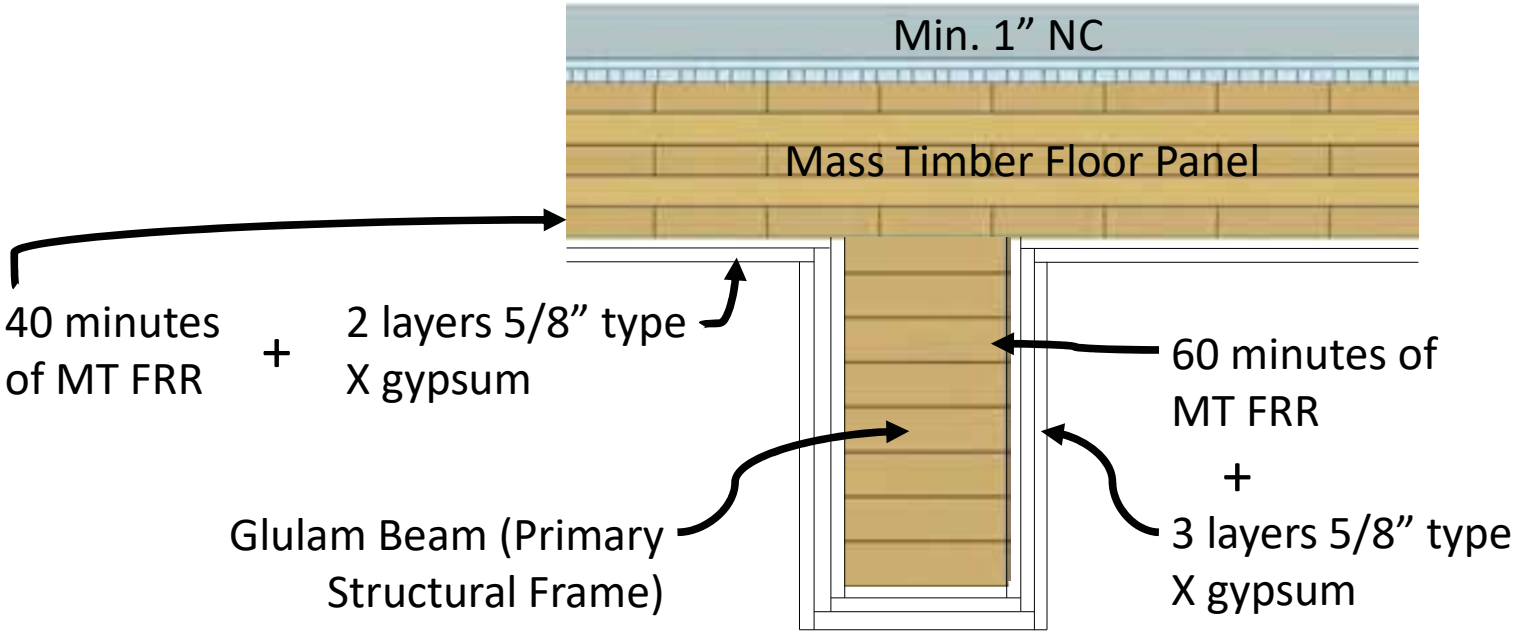


40 minutes of MT FRR + 2 layers 5/8” type X gypsum OR 3 layers 5/8” type X gypsum

Type IV-A Fire Resistance Ratings (FRR)

IV-A

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



Type IV-B Protection vs. Exposed

IV-B

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path

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)

IV-B

	FRR	Min. NC Protection
Primary Frame FRR	2 HR (1 HR at Roof)	80 min* (40 min* at Roof)
Ext or Int Bearing Wall FRR	2 HR	80 min*
Floor Construction FRR	2 HR	80 min*
Roof Construction FRR	1 HR	40 min*

*Applicable to most locations; limited exposed MT permitted

Credit: Urban One

Type IV-B Protection

IV-B

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*

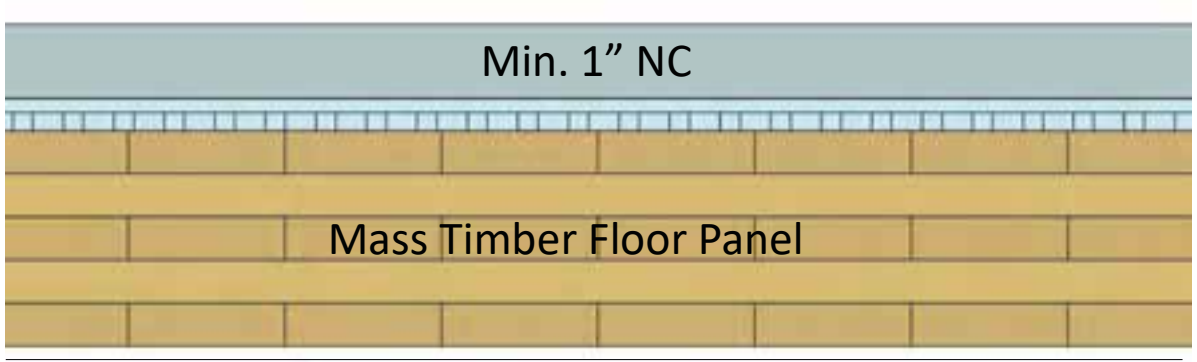
*Applicable to most locations; limited exposed MT permitted


Credit: Maxxon

Type IV-B Fire Resistance Ratings (FRR)

IV-B

Floor Panel Example (2 HR):



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

OR

3 layers 5/8” type X gypsum*

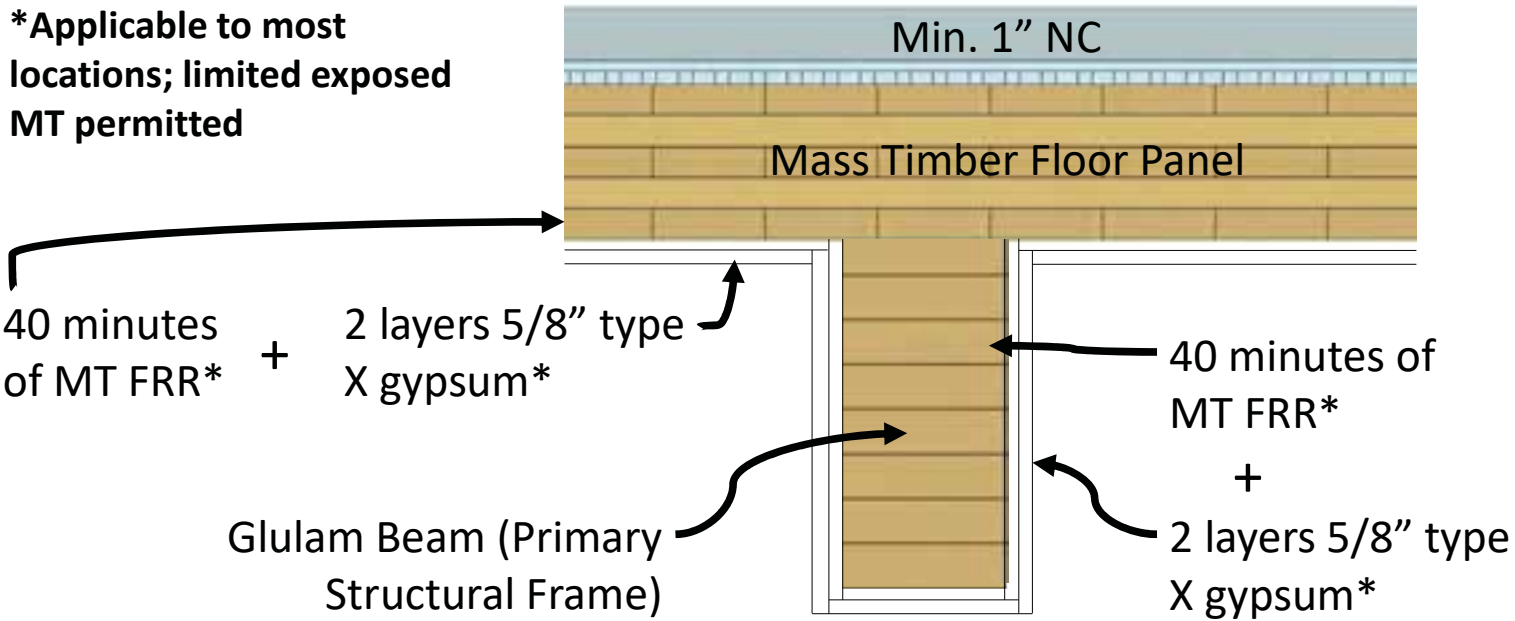
***Applicable to most locations; limited exposed MT permitted**

Type IV-B Fire Resistance Ratings (FRR)

IV-B

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

***Applicable to most locations; limited exposed MT permitted**



Type IV-B Protection vs. Exposed

IV-B

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:**

Credit: Kaiser+Path

Type IV-B Protection vs. Exposed

IV-B

Mixed unprotected areas, exposing both ceilings and walls:

- **In each dwelling unit or fire area, max. unprotected area =**

$$(U_{tc}/U_{ac}) + (U_{tw}/U_{aw}) \leq 1.0$$

- **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**

Credit: Kaiser+Path

Type IV-B Protection vs. Exposed

IV-B

Design Example: Mixing unprotected MT walls & ceilings

Credit: AWC

800 SF dwelling unit

- U_{ac} = (800 SF)*(0.20) = 160 SF
- U_{aw} = (800 SF)*(0.40) = 320 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

IV-B

Design Example: Mixing unprotected MT walls & ceilings

Credit: AWC

$(U_{tc}/U_{ac}) + (U_{tw}/U_{aw}) \leq 1.0$

$(100/160) + (U_{tw}/320) \leq 1.0$

$U_{tw} = 120$ SF

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

Type IV-B Protection vs. Exposed

IV-B

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.

Credit: Kaiser+Path

Type IV-C Protection vs. Exposed

IV-C

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path, Ema Peter

All Mass Timber surfaces may be exposed

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

Type IV-C Fire Resistance Ratings (FRR)

IV-C

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

IV-C

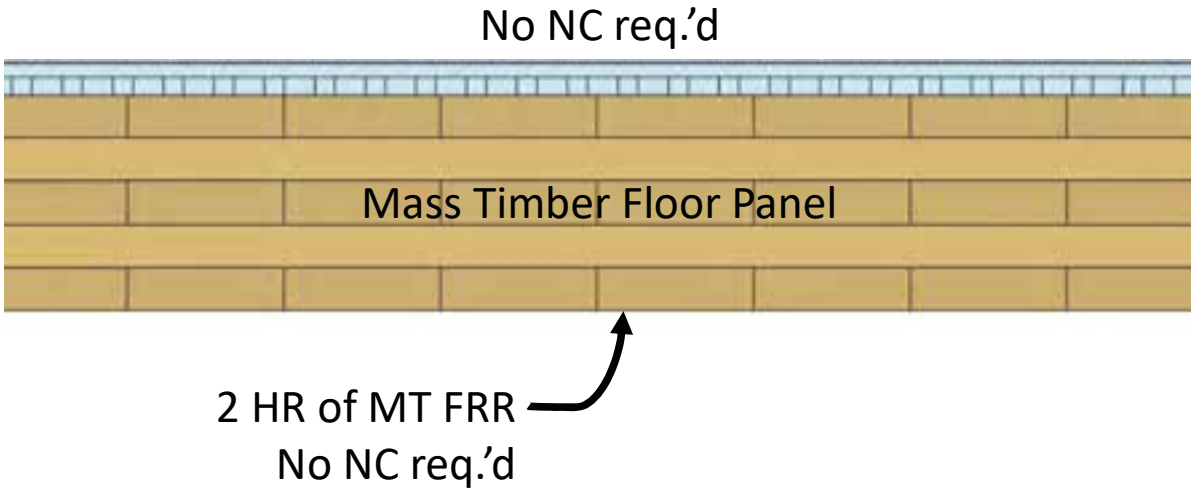
Floor Surface Protection	None req.'d
Roof Construction Protection	None req.'d
Ext Wall Protection	Min. 1 layer 5/8" type X gyp on outside face None req.'d on inside face


Credit: Maxxon

Type IV-C Fire Resistance Ratings (FRR)

IV-C

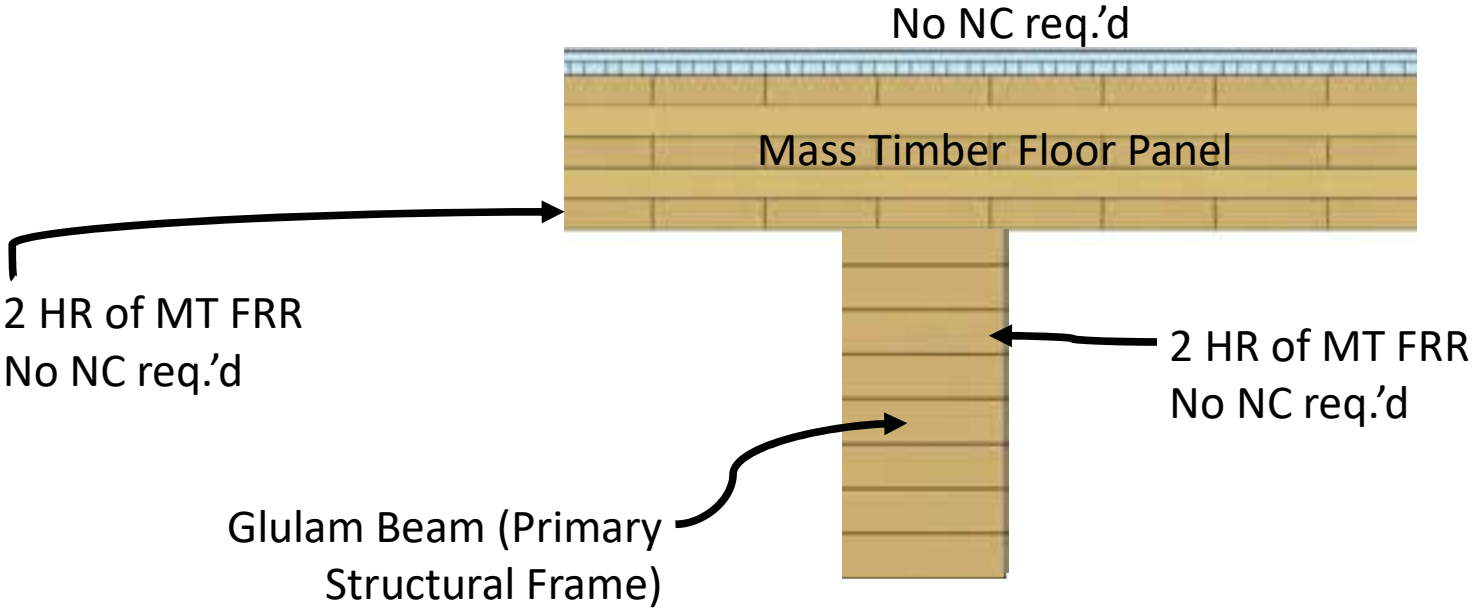
Floor Panel Example (2 HR):



Type IV-C Fire Resistance Ratings (FRR)

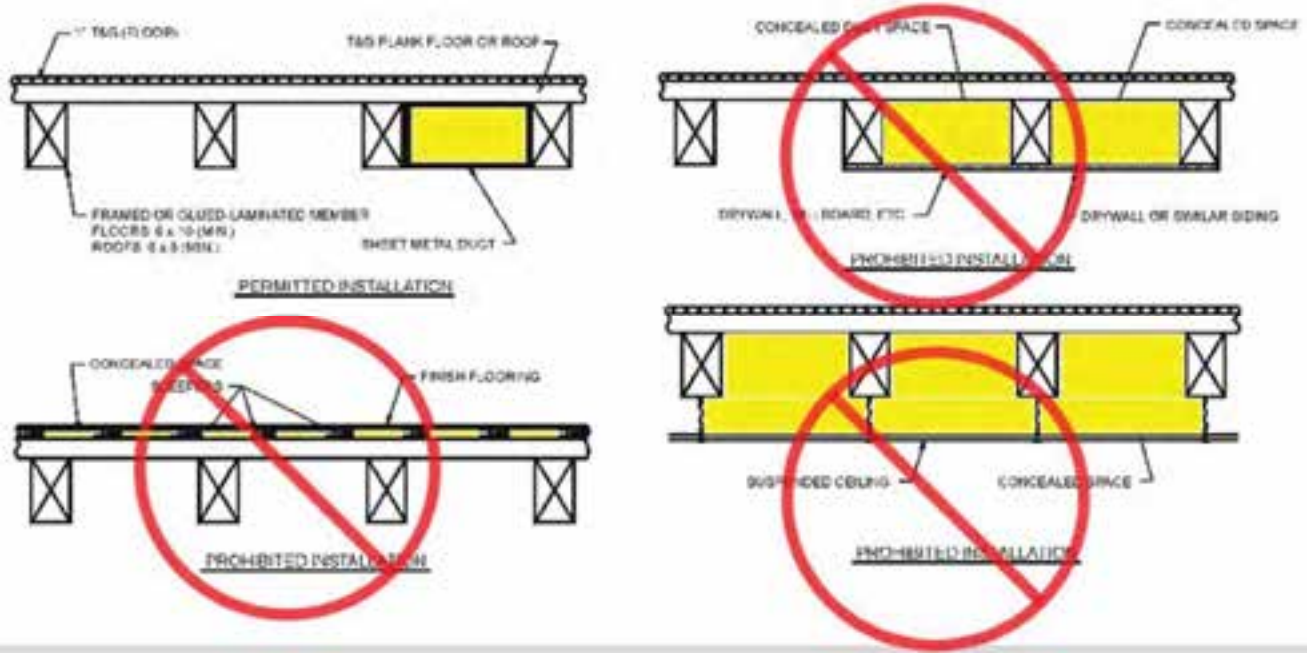
IV-C

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



Concealed Spaces in previous Type IV

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



Credit: IBC

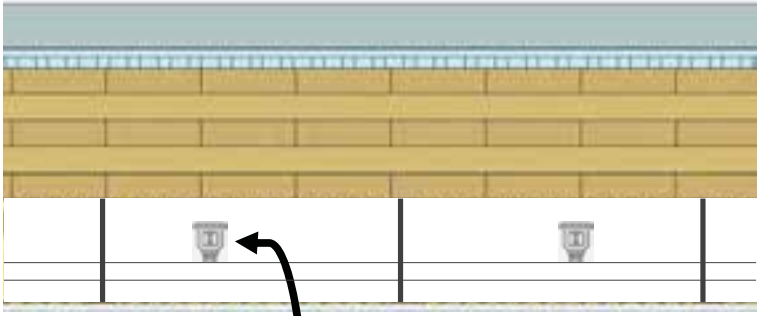
Concealed Spaces in Type IV-HT

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.

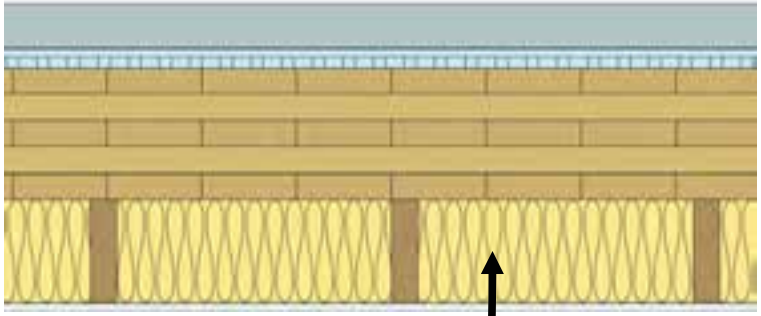
Concealed spaces within interior walls and partitions with a one hour or greater fire resistance rating complying with Section 2304.11.2.2 do not require additional protection.

Concealed Spaces in Type IV-HT



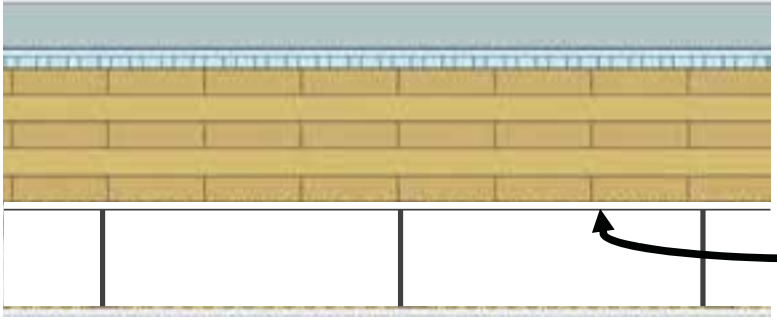
Option 1

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)

Photo: Ema Peter Photography

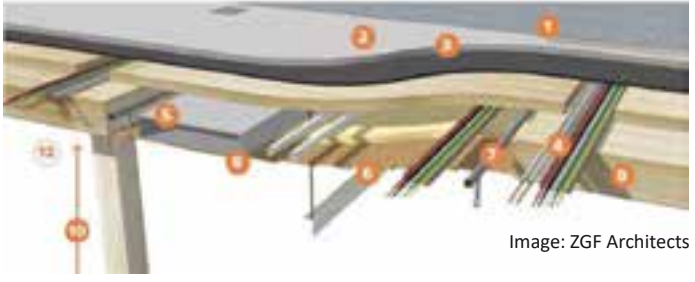
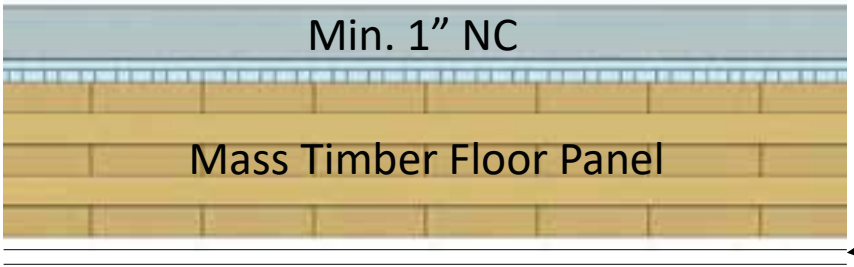


Image: ZGF Architects

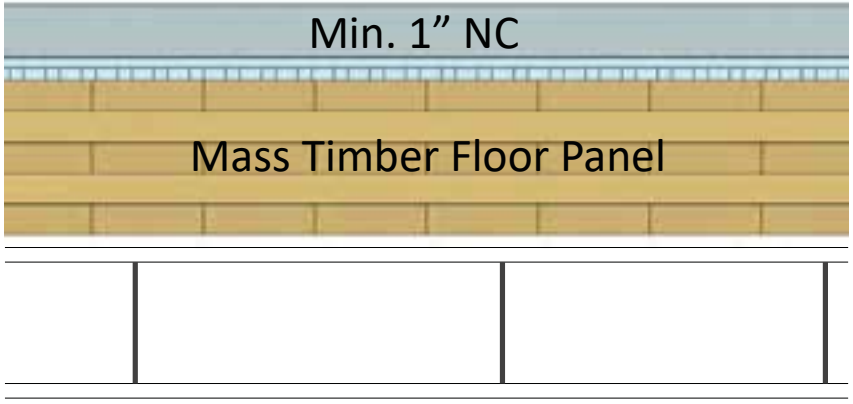
Concealed Spaces in Type IV-A & IV-B



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

2 layers 5/8” type X gypsum*

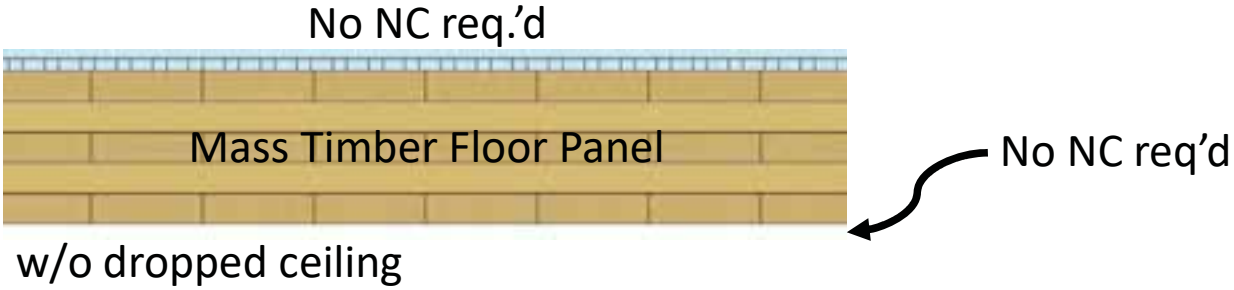
w/o dropped ceiling

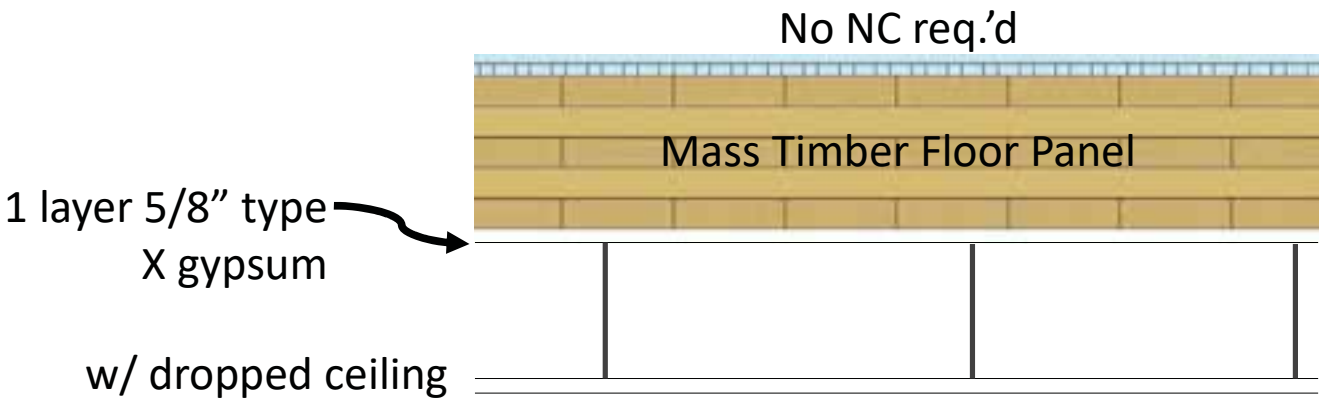


2 layers 5/8” type X gypsum

w/ dropped ceiling

Concealed Spaces in Type IV-C





Shaft Enclosures in Type IV-A, IV-B & IV-C

	IV-A	IV-B	IV-C
Exit & Hoistway Enclosures	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 Above 12 Stories or 180 ft: Noncombustible shafts (Section 602.4)	NC or MT protected with 2 layers 5/8" type X gyp (Section 602.4.2.6) both sides	NC or MT protected with 1 layer 5/8" type X gyp (Section 602.4.3.6) both sides
E&H Enclosures FRR	2 HR (not less than FRR of floor assembly penetrated, Section 713.4)		

Mid-Rise vs. High-Rise

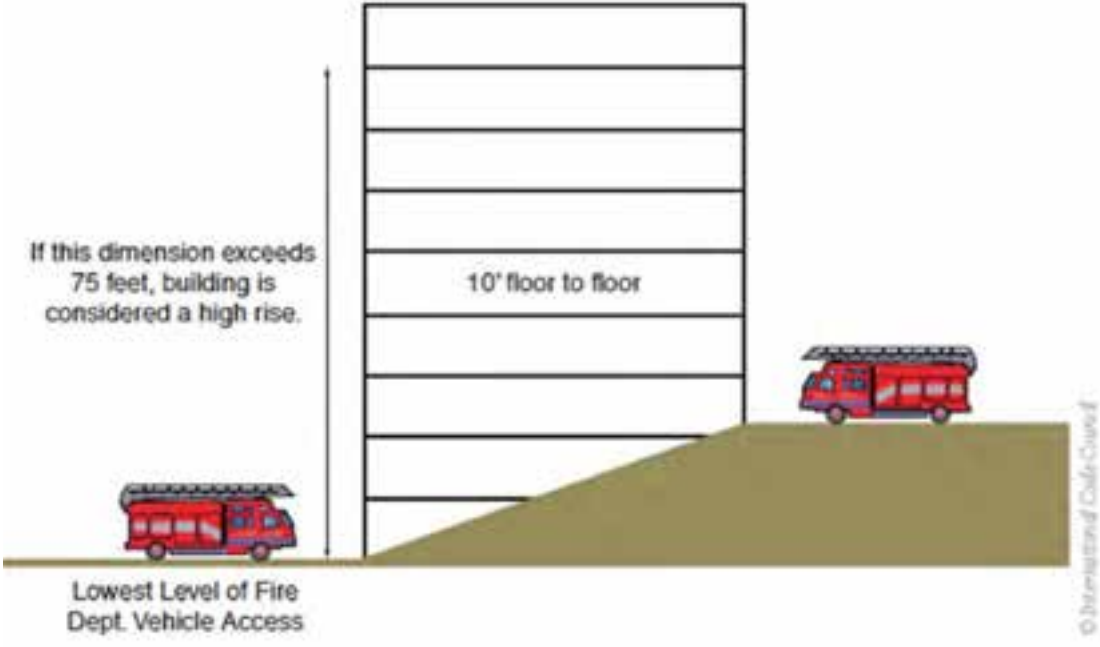


FIGURE 6-6 Determination of high-rise building

Sprinklers in High-Rise

- **Two Water Mains Required if:**
  - Building Height Exceeds 420 ft, or
  - **Type IV-A and IV-B buildings that exceed 120 ft in height**

Photo: Michael Green Architecture

CLT Fire Performance – Fire Re-Growth

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.


Photo: Urban One


Photo: ARUP

CLT Fire Performance – Char Fall-Off

Facts about CLT char fall-off:

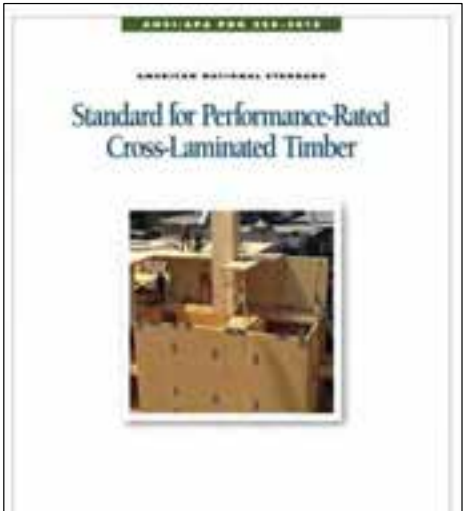
- **Only an item to consider in tall buildings. Important to avoid in high-rise construction where required performance is containment of fire within compartment of origin with no sprinkler or fire service suppression**
- **Not applicable when discussing mid-rise mass timber (or any building under types 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)**

Photo: FPInnovations

CLT Fire Performance – PRG 320

Section 602.4 added:

Cross-laminated timber shall be labeled as conforming to PRG 320-18 as referenced in Section 2303.1.4.



Connection Fire Protection

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.

Photo: MyTiCon

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

Connection Fire Protection

Many ways to demonstrate connection fire protection: calculations, prescriptive NC, test results, others as approved by AHJ


Photo: John Stamets


Photo: Josh Partee

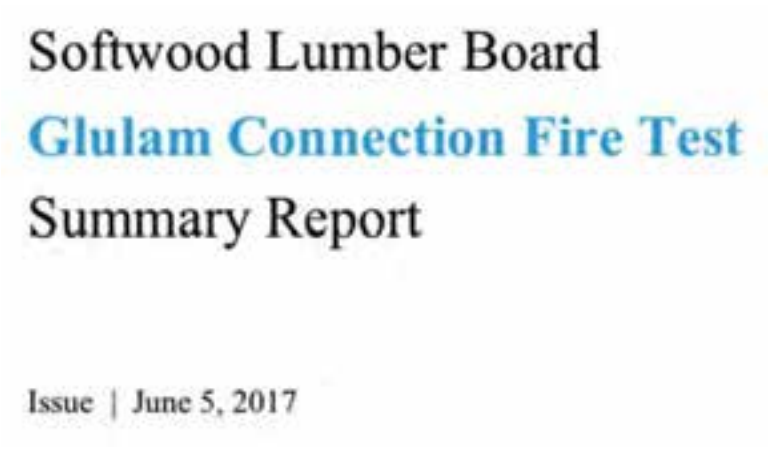

Photo: Christian Columbres


Photo: Blaine Brownell

Connection Fire Protection

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

Connection Fire Protection


Softwood Lumber Board

Glulam Connection Fire Test

Summary Report

Issue | June 5, 2017


SOUTHWEST RESEARCH INSTITUTE

CHEMISTRY AND CHEMICAL ENGINEERING DIVISION

FIRE PERFORMANCE EVALUATION OF A LOAD BEARING GLULAM BEAM TO COLUMN CONNECTION, INCLUDING A CLT PANEL, TESTED IN GENERAL ACCORDANCE WITH ASTM E119-16a, *STANDARD TEST METHODS FOR FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS*

FINAL REPORT
Consisting of 32 Pages

Full Report Available at:

https://www.thinkwood.com/wp-content/uploads/2018/01/reThink-Wood-Arup-SLB-Connection-Fire-Testing-Summary-web.pdf

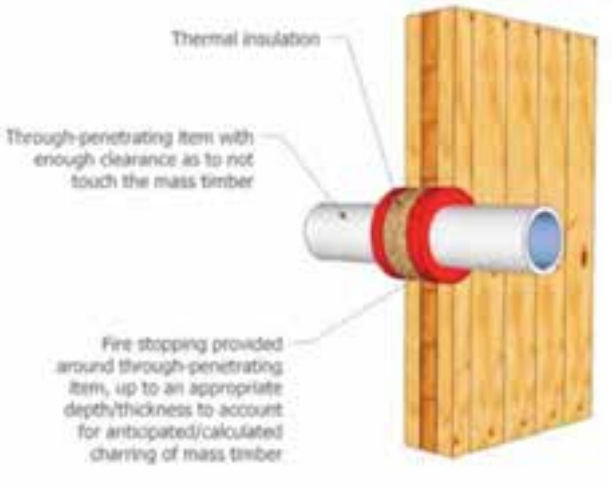
Penetration Fire Protection

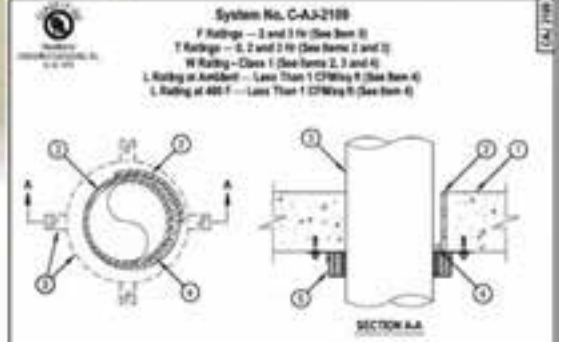
Although not a new code requirement or specific to tall wood, more testing & information is becoming available on firestopping of penetrations through MT assemblies

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





Photos: AWC/FPInnovations/Hilti

Penetration Fire Protection

Firestop systems tests on Mass Timber: Contact WoodWorks for information

SOUTHWEST RESEARCH INSTITUTE

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

WCTE 2018

FIRE PERFORMANCE OF FIRESTOPS, PENETRATIONS, AND FIRE DOORS IN MASS TIMBER ASSEMBLIES

Lindsay Ranger [1], Christian Dagenais [2], Conroy Lum[3], Tony Thomas[3]

ABSTRACT: Integrity and continuity must be maintained for fire separations required to provide fi
prevent passage of hot gases or increased temperature on the unexposed side. Vulnerable locations, whe
are introduced into mass timber systems, are susceptible to fire spread. Service and closure penetra
under fire separation have been investigated. Many of the fire stop systems were able to achieve 1-h
accordance with CAN/ULC-S115, which would be required for 2-hr fire resistance rated assemblies, no
tall wood buildings. Construction details are outlined which ensure adequate fire performance of these p

KEYWORDS: Firestop, through-penetrations, fire rated doors, mass timber, cross-laminated tim
buildings, fire resistance

1 INTRODUCTION

Many tall wood buildings using mass timber are planned or are currently being designed for construction around the world. A few have been built in Canada, including an 18 storey cross-laminated timber (CLT) and glulam building in British Columbia. The prescriptive requirements in the National Building Code of Canada (NBCC) [1] do not (yet) permit the construction of wood buildings taller than six storeys, however an alternative

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FIRESTOPPING TEST WITNESS REPORT

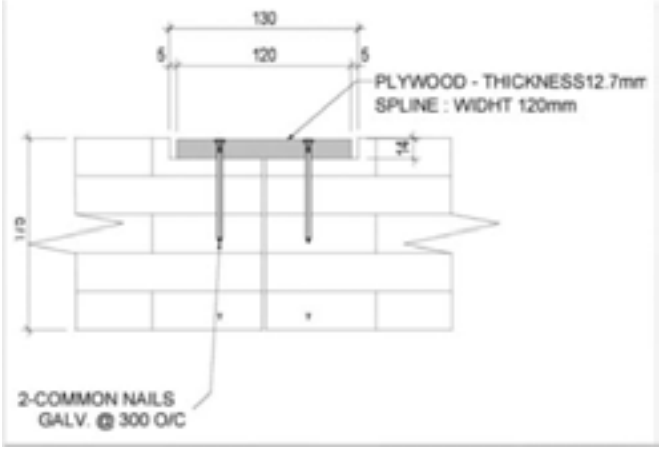
for

NORDIC STRUCTURES

Sealants at MT Panel Edges

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.


Photo: NRCAN


Photo: Charles Judd


Photo: ARUP

Sealants at MT Panel Edges

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)


Photo: NRCAN


Photo: Fast + Epp


Photo: ARUP

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

WoodWorks – Wood Products Council

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