MASS TIMBER
WHAT FPE'S SHOULD KNOW

14 November 2023

Presented by:
Robert Gerard, PE

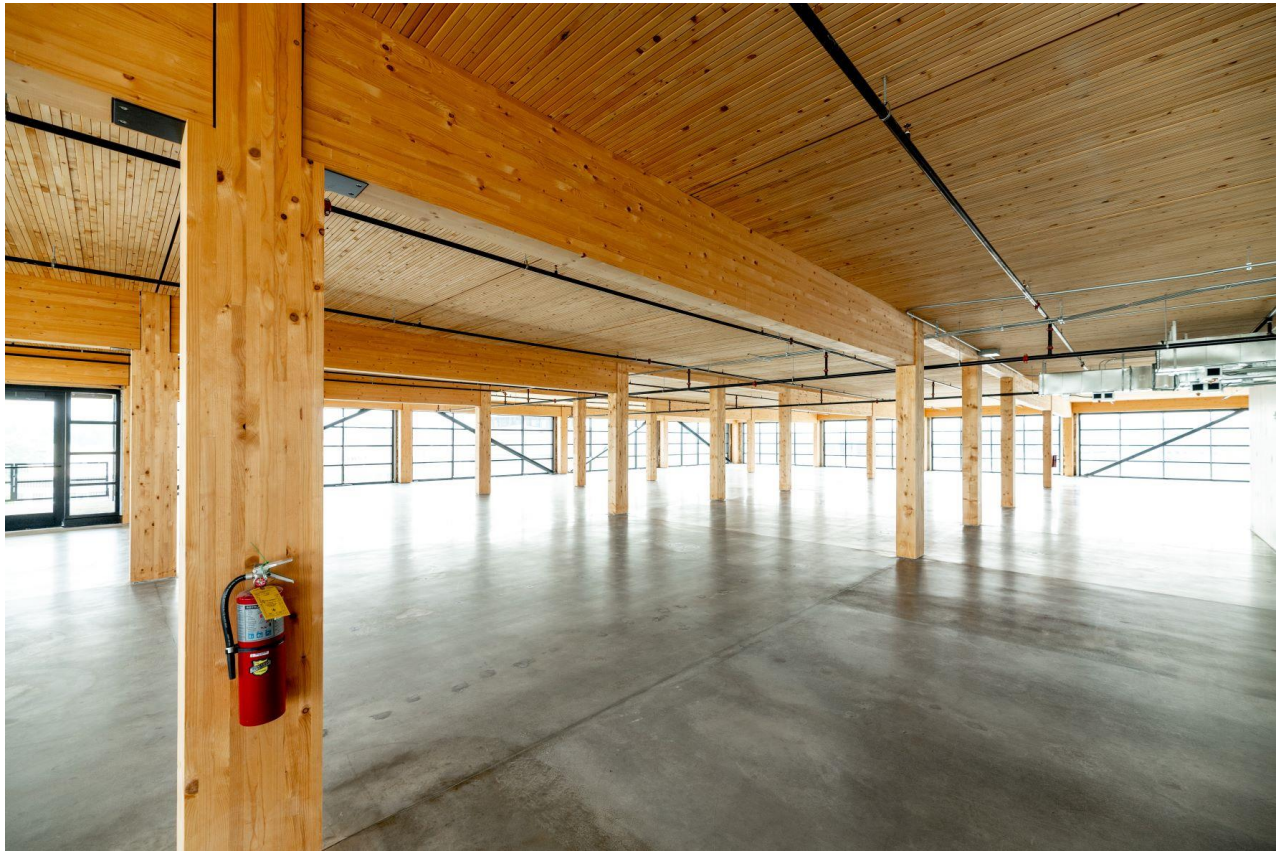
COFFMAN ENGINEERS

COFFMAN ENGINEERS

- Robert Gerard, PE
  - Senior Discipline Engineer, Coffman San Diego
  - Academics
    - BS, Architectural Engineering, Cal Poly SLO, CA
    - MSc, Fire Engineering, University of Canterbury, NZ
  - Specialties
    - Fire Life Safety Code Consulting
    - Performance-Based Fire Engineering
    - Structural Fire Engineering (SFE)
    - Mass Timber Design
    - Smoke Control
    - Evacuation

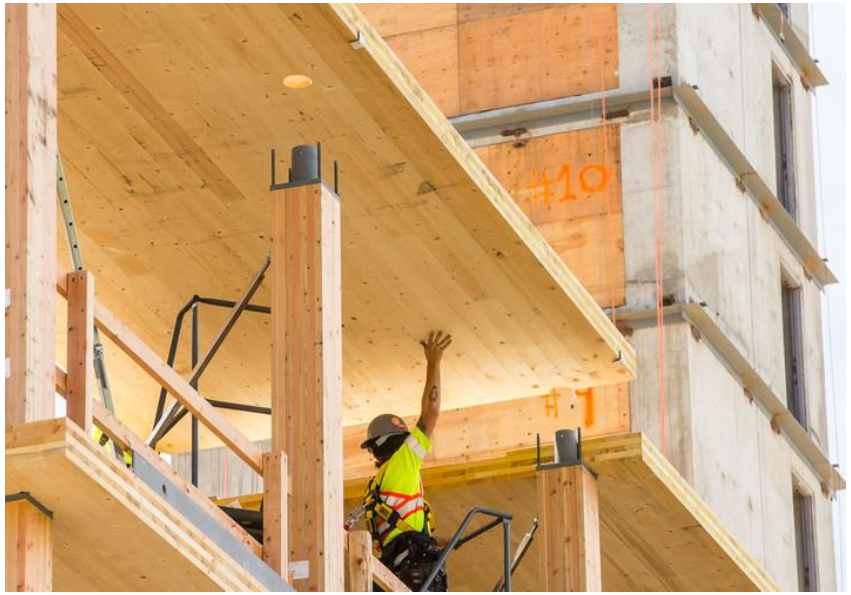
AGENDA

- Mass Timber – What FPE's Should Know
  - Mass Timber Basics
    - Technical Background
    - Code Compliance
    - Research and Development



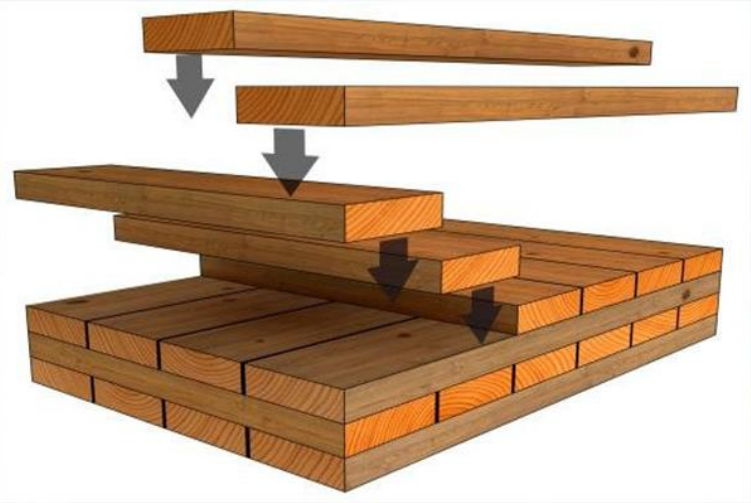
MASS TIMBER BASICS

- Drivers
  - Aesthetics
  - Sustainability
  - Cost
    - Reduced lateral and foundation design
    - Exposed structure and reduced finishes
    - Speak to market
  - Speed of Construction
    - Prefabricated “kit of parts”
    - Modular systems
    - ‘Dry materials’
    - Limited onsite storage



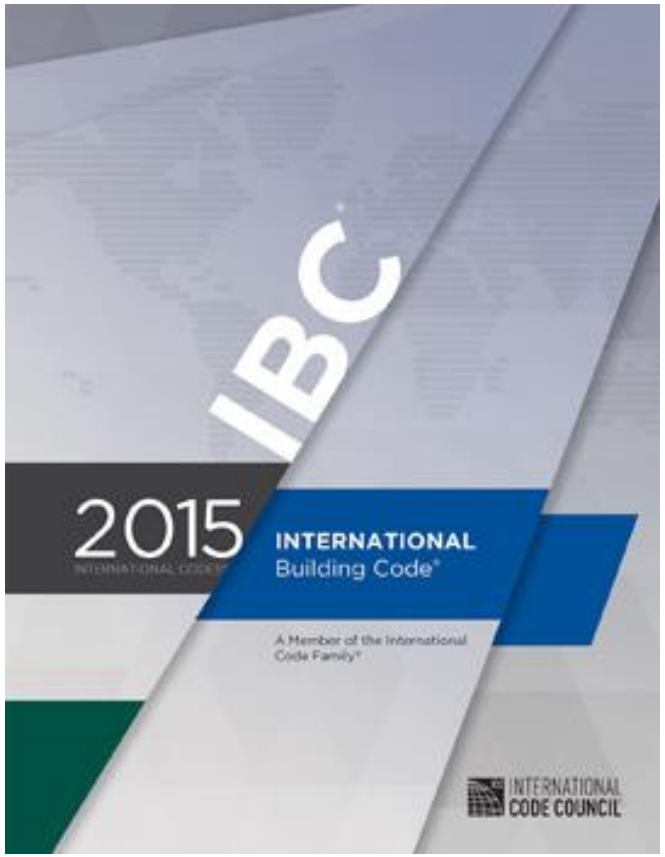
MASS TIMBER BASICS

- Engineered wood products
  - Glulam (Glued Laminated) wood
  - LVL (Laminated Veneer Lumber)
  - NLT (Nail Laminated Timber)
  - DLT (Dowel Laminated Timber)
  - MPP (Mass Plywood Panel)
  - CLT (Cross-Laminated Timber)



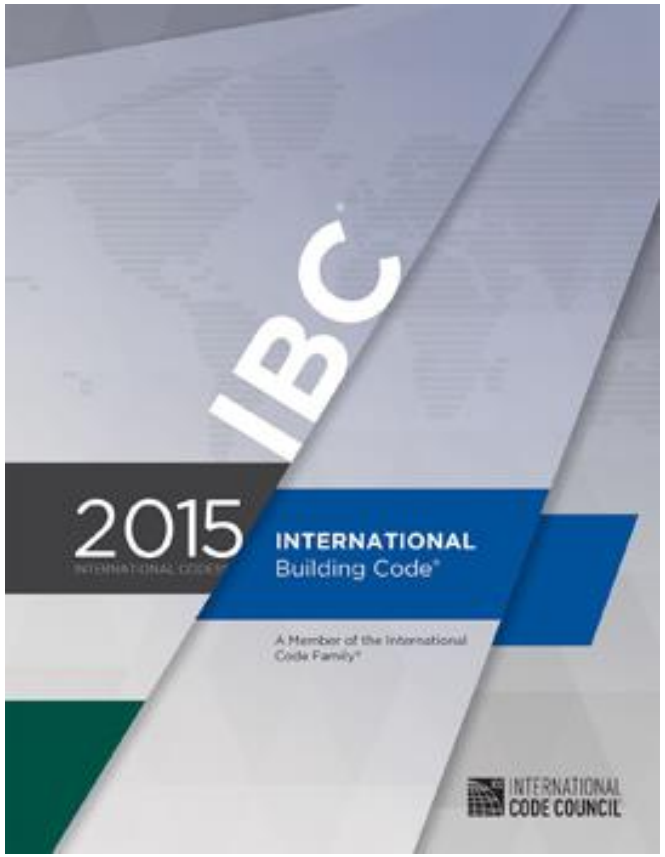
PRE-TWB CODES

- Pre-2015 IBC
  - Growing International Precedence
    - Stadthaus, London, 2009
      - 9 stories CLT
    - Forte, Melbourne, 2012
      - 10 stories mass timber
    - Life Cycle Tower, Austria, 2012
      - 8 stories, mass timber
  - Increasing Domestic Attention
    - Prescriptive Building Code Limitations
      - Max 6 stories, 85’ above grade plane
    - Alternate Means and Methods
      - Type I / II equivalent
      - Type III / IV increased height / # stories



PRE-TWB CODES

- 2015 IBC
  - Prescriptively permitted as a building material
    - **2015 IBC Section 202 Definitions / 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
    - Included in the charging language for 2015 IBC Section 602.4 Type IV construction



PRE-TWB CODES

- 2018 IBC (Base IBC)
  - Increased prescriptive provisions for the use of CLT in modern buildings
  - Prescriptive allowances limited to mid-/low-rise buildings
    - Limited to 6 stories / 85 ft
  - Gaps in prescriptive design
    - Exposed area, fire protection methods, connections, construction, etc.

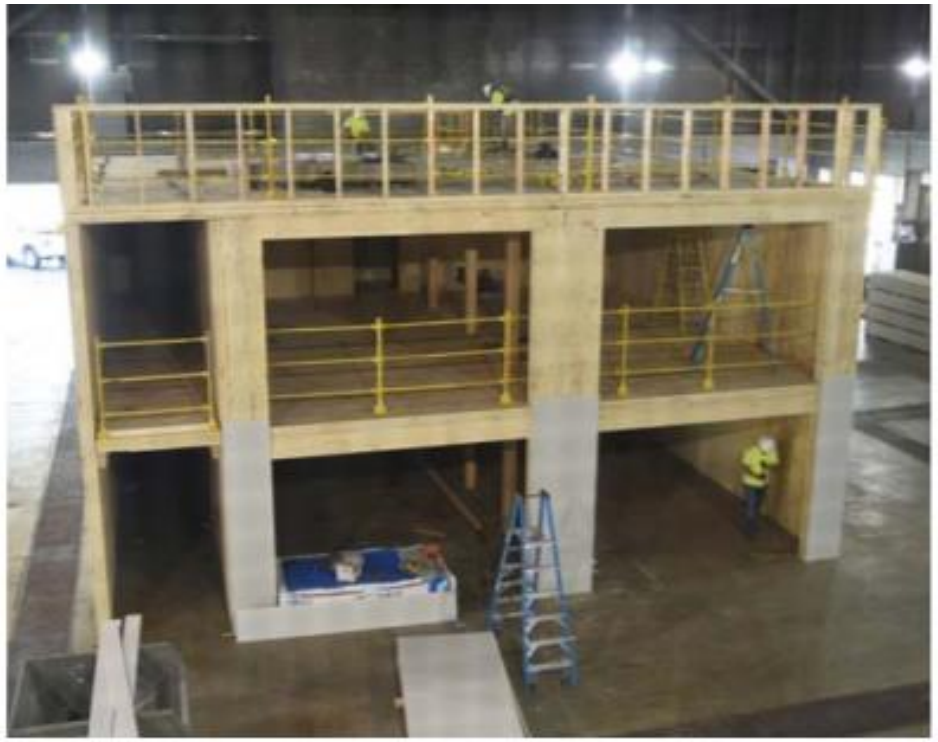
Design Parameter	Construction Type						
	I-A	II-A	III-A	III-B	IV	V-A	V-B
Allowable Height (ft)	UL	85	85	75	85	70	40
Allowable # of Stories	UL	6	6	4	6	4	3
Allowable Area (sf)	UL	112,500	85,500	57,000	108,000	54,000	27,000

PRE-TWB CODES

- ICC AD Hoc Committee TWB's
  - 'One-off' approach to building approval
    - Subjective interpretation of the code intent
  - ICC Ad Hoc Committee (2015+)
    - Demonstrate the intended level of safety can be achieved
    - Diverse group of industry professionals
    - 2021 ICC Code Adoption

AWC / ATF FIRE TESTING

- Performance validation
  - AWC / ATF fire testing (2016+)
    - Tall Wood Building (TWB) Codes
    - AWC Fire Tests



USDA United States Department of Agriculture

Compartment Fire Testing of a Two-Story Mass Timber Building

Samuel L. Zelinka
Laura E. Hasburgh
Keith J. Bourne
David R. Tucholski
Jason P. Ouellette

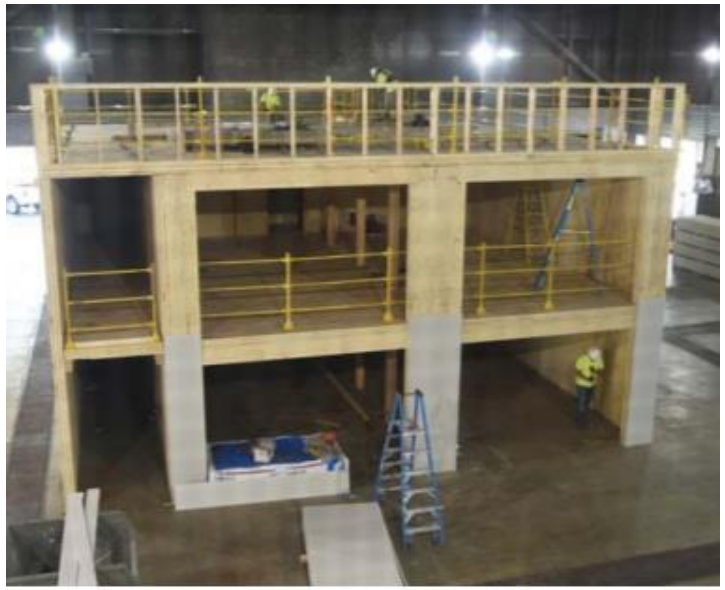
Forest Service | Forest Products Laboratory | General Technical Report FPL–GTR–247 | May 2018

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - Intent of the Code
    - Occupant safety
    - First responder safety
    - Property protection
  - TWB Performance Criteria
    - **No collapse** under reasonable scenarios of complete burn-out without sprinkler activation
    - **No unusually high radiation** exposure to adjacent buildings
    - **No unusual response from radiation** exposure from adjacent buildings
    - **No unusual fire department access issues**
    - Egress systems designed to **protect occupant evacuation**, with a FOS
    - **Highly reliable suppression systems** to reduce risk of failure during reasonable fire scenario

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Test 1: Fully protected, no sprinklers
    - Test 2: 30% unprotected ceiling, no sprinklers
    - Test 3: Exposed walls, no sprinklers
    - Test 4: Fully exposed, sprinkler protection
    - Test 5: Fully exposed, 20-min sprinkler delay



No.	Test Floor / Construction Type	Wall A	Wall B	Wall C	Wall D	Floor/Ceiling	Interior Partition	Active Protection
1	1st / IV-A	60% openings with 2 layers Type X GWB elsewhere	2 Layers Type X GWB	2 Layers Type X GWB	2 Layers Type X GWB	Floor: 2 layers cement board Ceiling: 2 layers GWB	Non-fire rated ½" GWB on each side	None
2	2nd / IV-B		2 Layers Type X GWB	2 Layers Type X GWB	2 Layers Type X GWB	Floor: 2 layers cement board Ceiling: 2 layers GWB with 30% in LR & BR		
3	2nd / IV-B		Livingroom: Exposed CLT Kitchen: 2 Layers GWB	2 Layers Type X GWB	Bedroom: Exposed CLT Bathroom: 2 Layers Type X GWB	Floor: 2 layers cement board Ceiling: 2 layers GWB		
4	1st / IV-C	60% openings with glazing with exposed CLT elsewhere	Exposed CLT			Floor: 2 layers cement board Ceiling: Exposed CLT		NFPA 13, Ordinary Hazard
5	1st / IV-C					Floor: 2 layers cement board Ceiling: Exposed CLT		NFPA 13, Ordinary Hazard with 23-minute activation delay

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Test 1: Fully protected, no sprinklers

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
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    - Test 1: Fully protected, no sprinklers

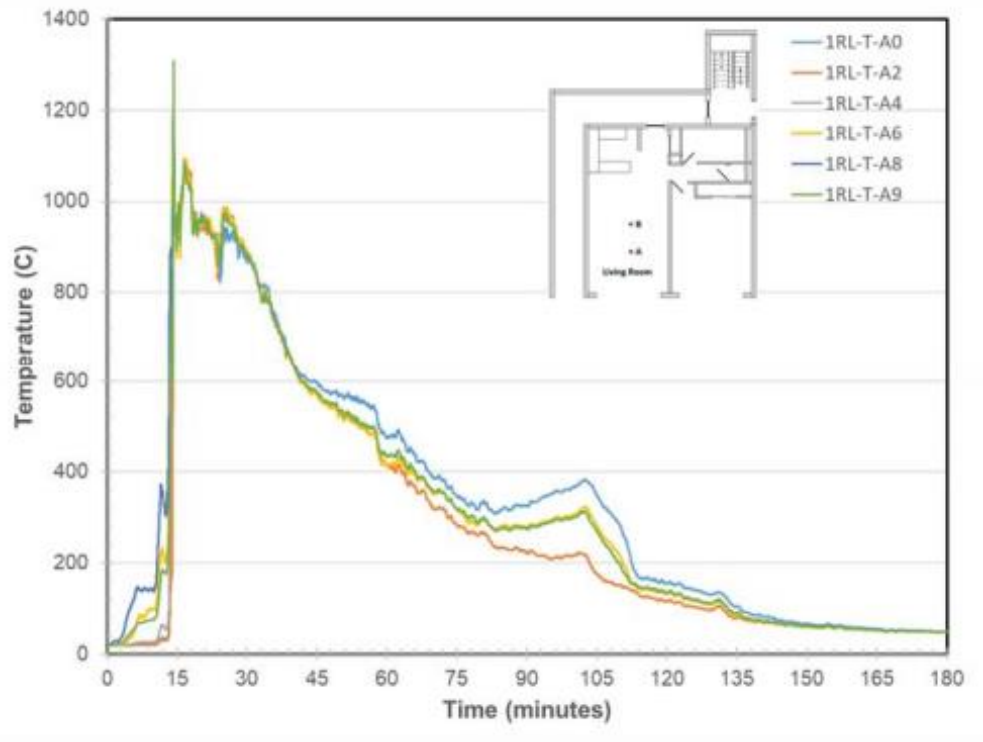


Figure 928. Living Room Temperature at Location A

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Test 3: Two walls exposed, no sprinklers

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Test 3: Two walls exposed, no sprinklers

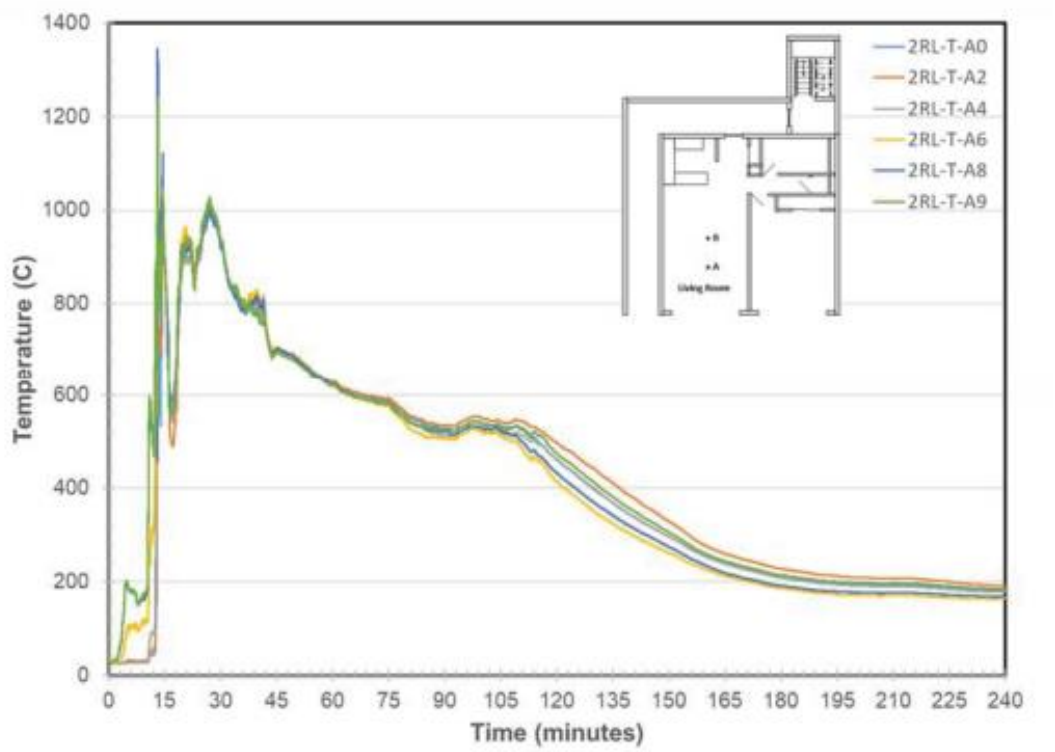


Figure 212. Living Room Temperature at Location A

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Test 4: Fully exposed, sprinkler activation

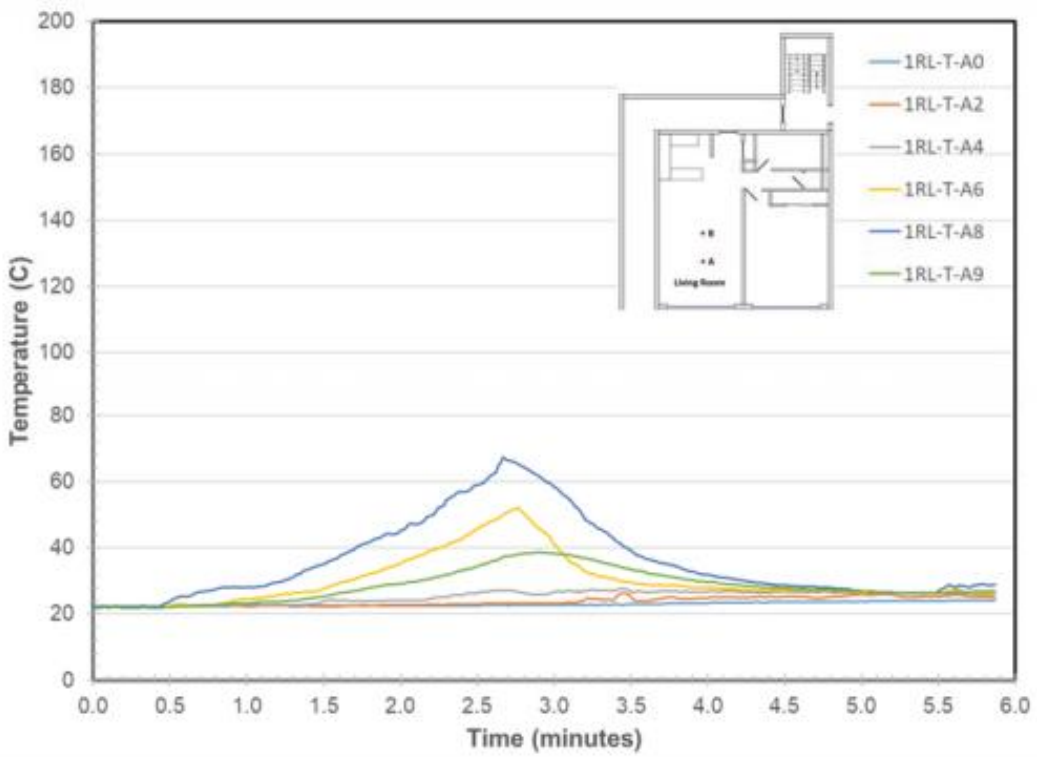
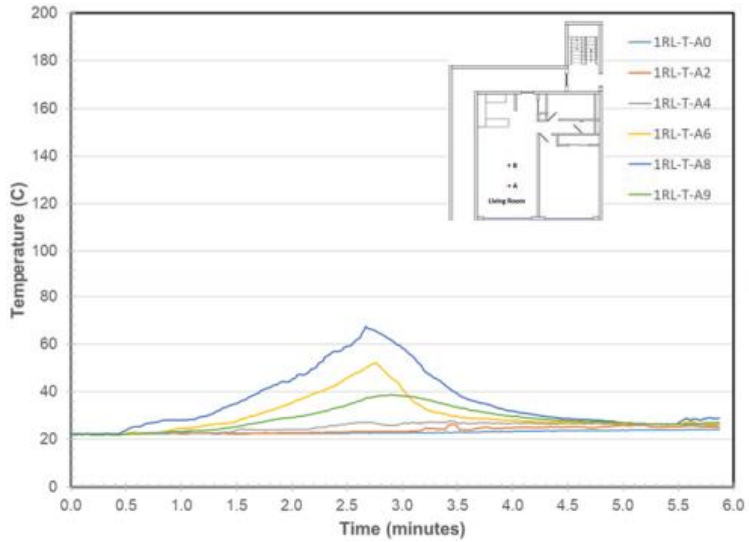
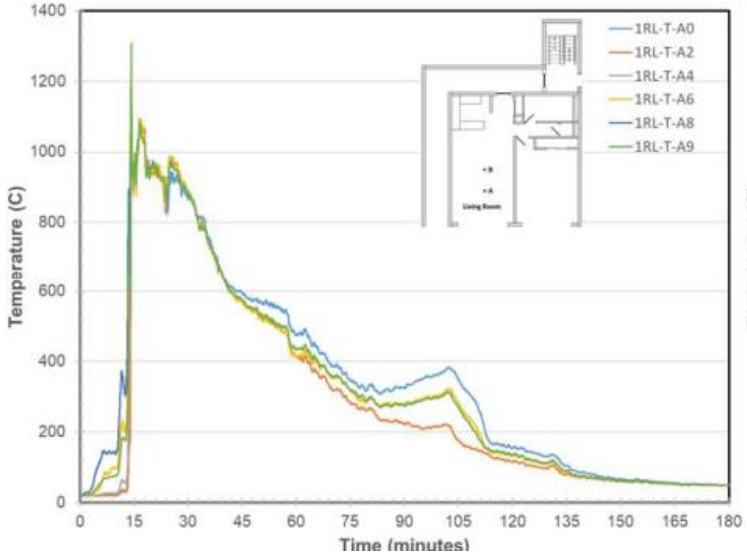


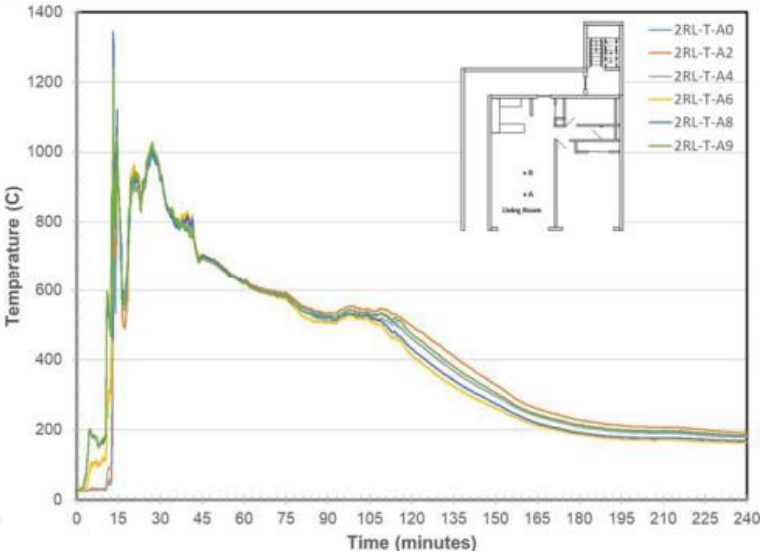
Figure 236. Living Room Temperature at Location A

AWC / ATF FIRE TESTING

- Tall Wood Building (TWB) Codes
  - AWC / ATF fire testing
    - Results
      - Test 1: Self-extinguishment
      - Test 2: Self-extinguishment
      - Test 3: Self-extinguishment
      - Test 4: Sprinkler control
      - Test 5: Sprinkler control

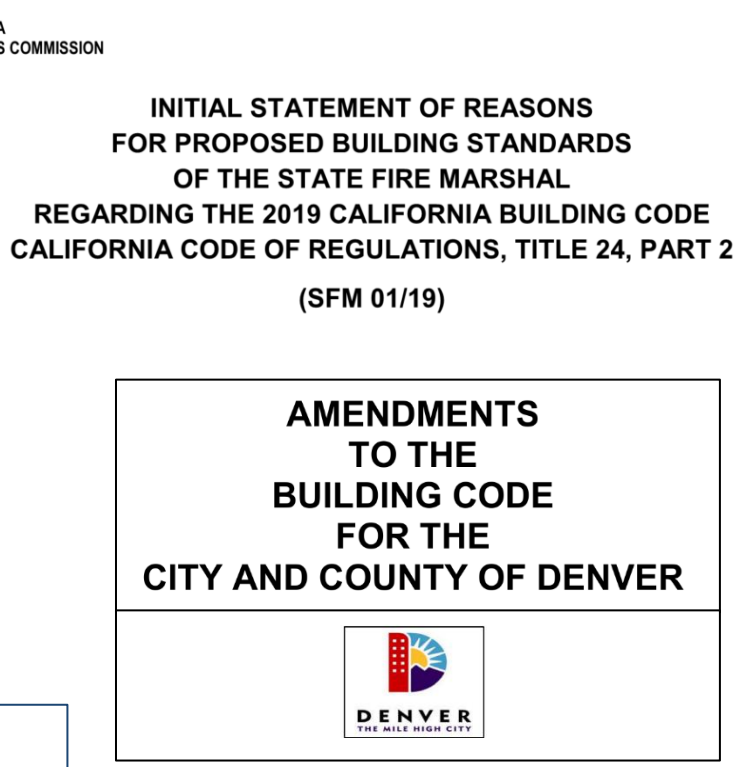






TWB CODES

- Tall Wood Building (TWB) Codes
  - Prescriptive compliance
    - 2021 IBC provisions
      - Design, inspection, construction, etc.
      - Type IV-A, -B, -C, -HT
      - Up to 18 stories mass timber construction
  - Early-adopters
    - Amendments to the 2015/2018 IBC
      - Oregon
      - WA
      - CA
      - Denver

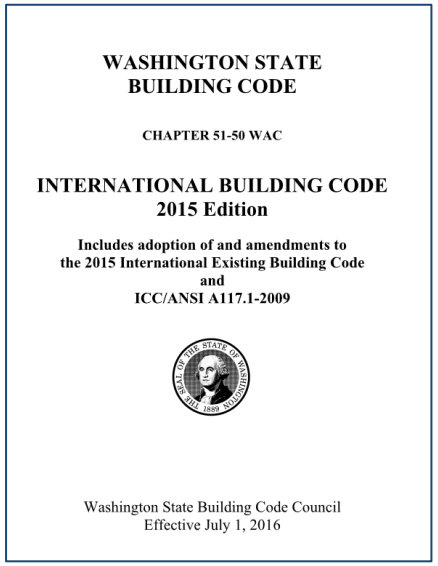

STATE OF CALIFORNIA
BUILDING STANDARDS COMMISSION

INITIAL STATEMENT OF REASONS
FOR PROPOSED BUILDING STANDARDS
OF THE STATE FIRE MARSHAL
REGARDING THE 2019 CALIFORNIA BUILDING CODE
CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 2

(SFM 01/19)

AMENDMENTS
TO THE
BUILDING CODE
FOR THE
CITY AND COUNTY OF DENVER

DENVER
THE MILE HIGH CITY


WASHINGTON STATE
BUILDING CODE

CHAPTER 51-50 WAC

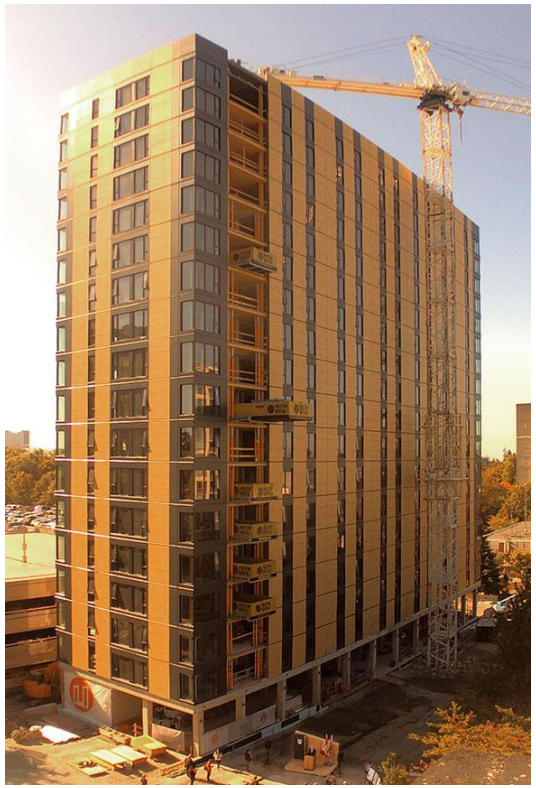
INTERNATIONAL BUILDING CODE
2015 Edition

Includes adoption of and amendments to
the 2015 International Existing Building Code
and
ICC/ANSI A117.1-2009

Washington State Building Code Council
Effective July 1, 2016

TWB CODES

- Building Allowances
  - Construction types (2021 IBC)
    - Type IV-A, IV-B and IV-C



Brock Commons, 2017

*Framework, 2016**

Carbon 12, 2018

TWB CODES

- Building Allowances
  - Construction types (2021 IBC)
    - Type IV-A, IV-B and IV-C

TWB CODES

- Building Allowances
  - Height, area, # of stories
    - Business (B) occupancy
    - Sprinklered, multi-story building
  - Effective in IBC upon adoption
    - Height and area limitations

602.4 Type IV. Type IV construction is that type of construction in which *the building elements are mass timber or noncombustible materials and have fire-resistance ratings in accordance with Table 601. 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 and shall be determined in accordance with Section 703.2 or 703.3. The minimum dimensions and permitted materials for building elements shall comply with the provisions of this section and Section 2304.11. Mass timber elements of Types IV-A, IV-B and IV-C construction shall be protected with noncombustible protection applied directly to the mass timber in accordance with Sections 602.4.1 through 602.4.3. The time assigned to the noncombustible protection shall be determined in accordance with Section 703.8 and comply with Section 722.7.*

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

Exterior load-bearing walls and nonload-bearing walls shall be mass timber construction, or shall be of noncombustible construction.

***Exception:** Exterior load-bearing walls and nonload-bearing walls of Type IV-HT construction in accordance with Section 602.4.4.*

Design Parameter	Construction Type			
	IV-A	IV-B	IV-C	IV-HT
*Allowable Height (ft)	270	180	85	85
*Allowable # of Stories	18	12	9	6
*Allowable Area (sf)	324,000	216,000	135,000	108,000
Exposed Wood Area	0%	< 20% (ceilings) or 40% (walls)	100%	100%

TWB CODES

- Building Allowances
  - Concealed spaces
    - Permitted per Sections 602 and 718 (Concealed spaces)
    - *NFPA 13 requirements for concealed spaces*
    - **2021 IBC IV-HT modification allows concealed spaces in accordance with NFPA 13 (sprinkler protection, NC fill or NC protection)*

Design Parameter	Construction Type			
	IV-A	IV-B	IV-C	IV-HT
Combustible Concealed Spaces	Permitted with NC protection (80 min)		Permitted with NC protection (40 min)	*Not permitted, but combustible stud spaces in light frame walls are permitted and not considered concealed spaces

TWB CODES

- FRR Requirements
  - ‘Explicit’ (A, B and C) vs. ‘implicit’ ratings (HT)
    - Shafts, exit enclosures, etc.
  - Documenting fire-resistance ratings
    - Section 703: Fire-resistance ratings and fire tests
    - Section 722: Calculated fire resistance
    - Section 2304.11: Heavy timber construction

Building Element	Fire-Resistance Rating			
	IV-A	IV-B	IV-C	IV-HT
Primary Frame	3	2	2	HT
Ext Bearing Walls	3	2	2	2
Int Bearing Walls	3	2	2	1/HT
Floors	2	2	2	HT
Roof	1-1/2	1	1	HT

TWB CODES

- FRR Requirements
  - At least 2/3 of FRR provided by noncombustible protection
  - Installation requirements (Section 722)

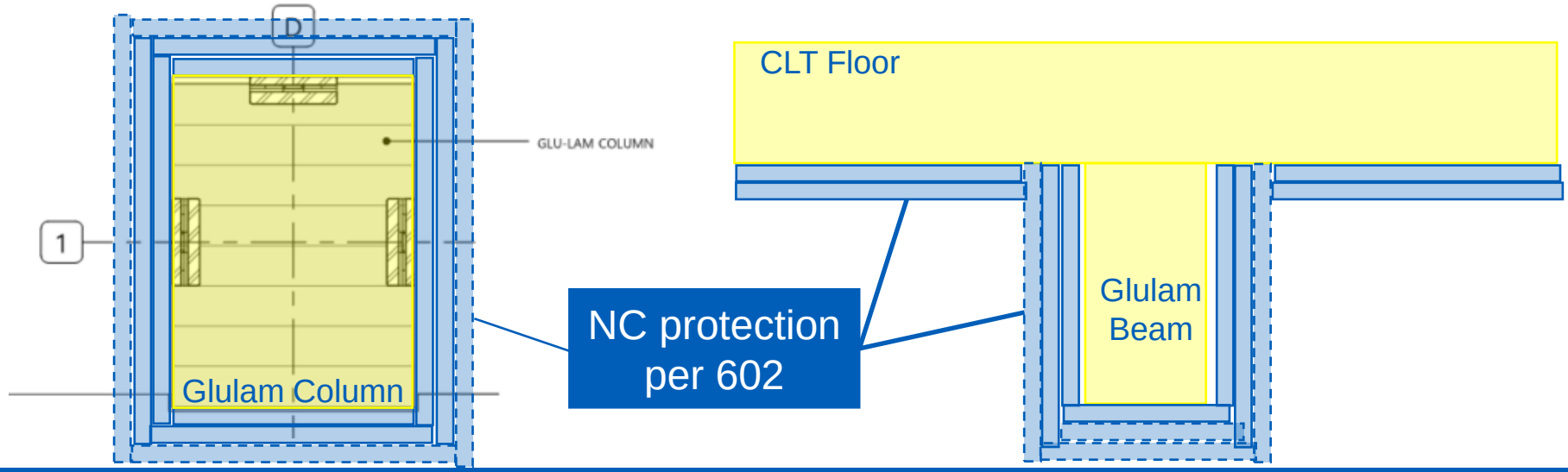
Table 722.7(1) Protection Required from Noncombustible Materials	
Required FRR (hours)	**Minimum Noncombustible Protection (minutes)**
1	40
2	80
3 or more	120

Table 722.7(2) Protection Provided by Noncombustible Material	
Noncombustible Protection	**Protection Contribution (minutes)**
1/2 inch Type X Gyp	25
5/8 inch Type X Gyp	40

TWB CODES

- FRR Assemblies
  - Primary frame
    - Columns
    - Structural members attached to columns (including floor and roof)
    - Bracing elements essential to gravity design

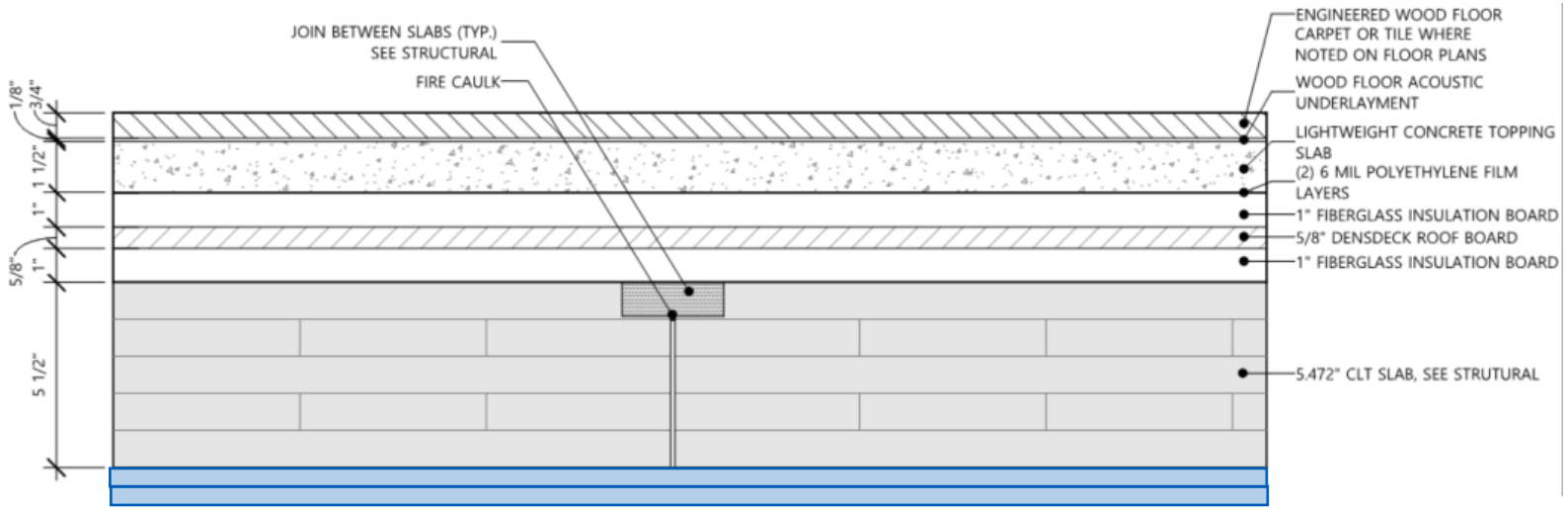
Primary Frame				
Building Element	**Fire-Resistance Rating**			
	IV-A	**IV-B**	**IV-C**	**IV-HT**
Material	MT or NC			MT
FRR	3	2	2	HT
Interior face	NC protection per 602		No protection req'd	



TWB CODES

- FRR Assemblies
  - Floors
    - NC protection
    - Panel thickness
    - Connections

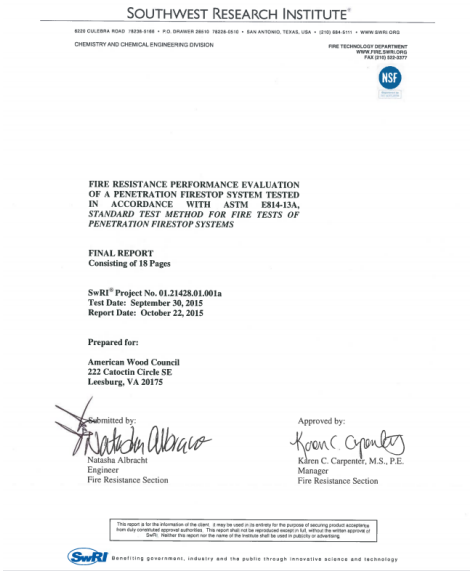
Floors				
Building Element	**Fire-Resistance Rating**			
	IV-A	**IV-B**	**IV-C**	**IV-HT**
Materials	MT or NC			MT
FRR	3	2	2	HT
Above MT	At least 1” NC material		Not Req’d	
Below MT	NC protection per 602		Not Req’d	



TWB CODES

- FRR Assemblies
  - Floors
    - NC protection
    - Panel thickness
    - Connections

Floors				
Building Element	**Fire-Resistance Rating**			
	IV-A	**IV-B**	**IV-C**	**IV-HT**
Materials	MT or NC			MT
FRR	3	2	2	HT
Above MT	At least 1” NC material		Not Req’d	
Below MT	NC protection per 602		Not Req’d	



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:

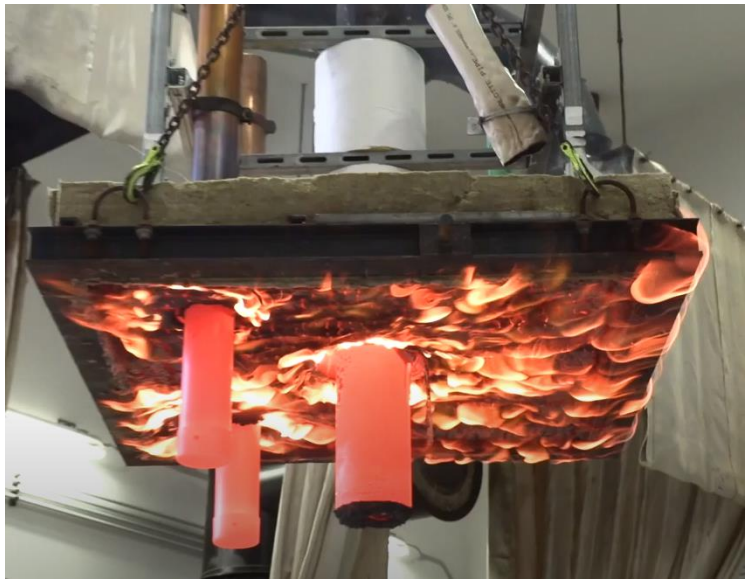
American Wood Council
222 Catoctin Circle SE
Leesburg, VA 20175

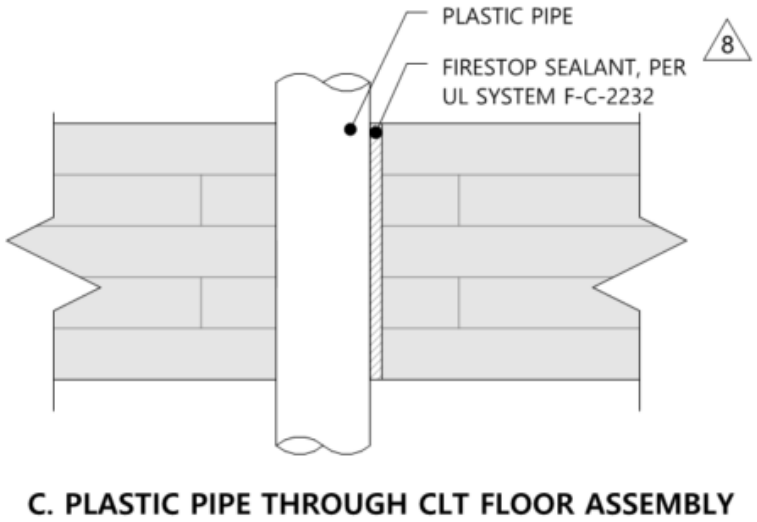
Submitted by:
Natasha Albracht
Engineer
Fire Resistance Section

Approved by:
Karen C. Carpenter, M.S., P.E.
Manager
Fire Resistance Section

TWB CODES

- FRR Assemblies
  - Penetrations
    - Hilti Guidance
    - Firestopping CLT Case Study
  - (Typical details for 1-hr / 2-hr ratings)





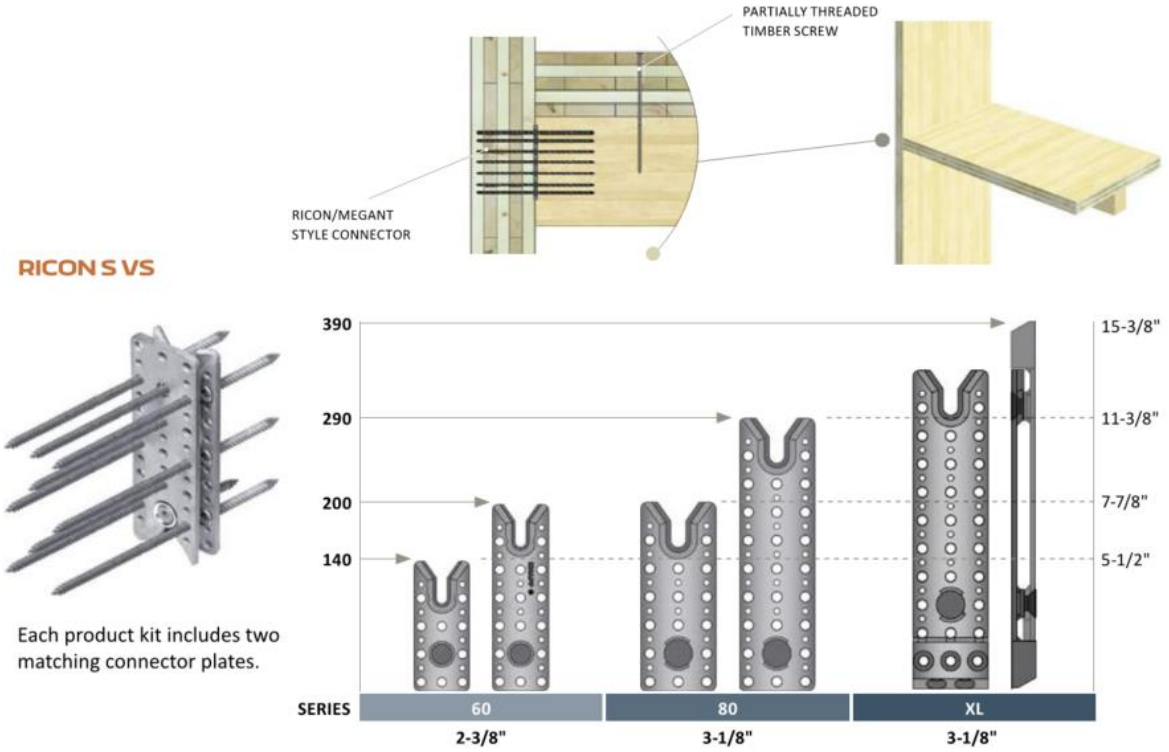
C. PLASTIC PIPE THROUGH CLT FLOOR ASSEMBLY

TWB CODES

- FRR Assemblies
  - Connections
    - Concealed
    - Exposed
  - Tested assemblies
  - Engineering analysis temperature rise less than 250°F and max temp of 325°F
    - Connections
    - Fasteners
    - Associated wood

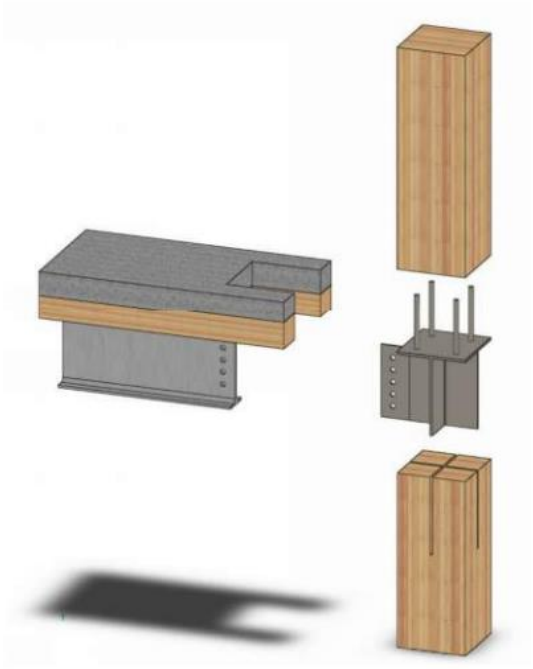
TWB CODES

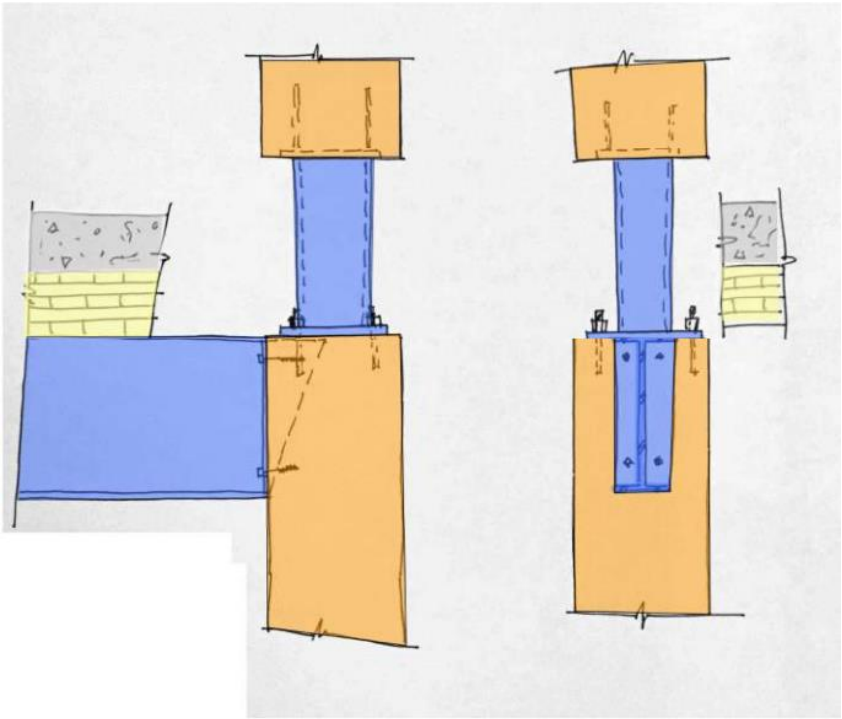
- FRR Assemblies
  - Connections
    - Tested assemblies
    - Proprietary connectors

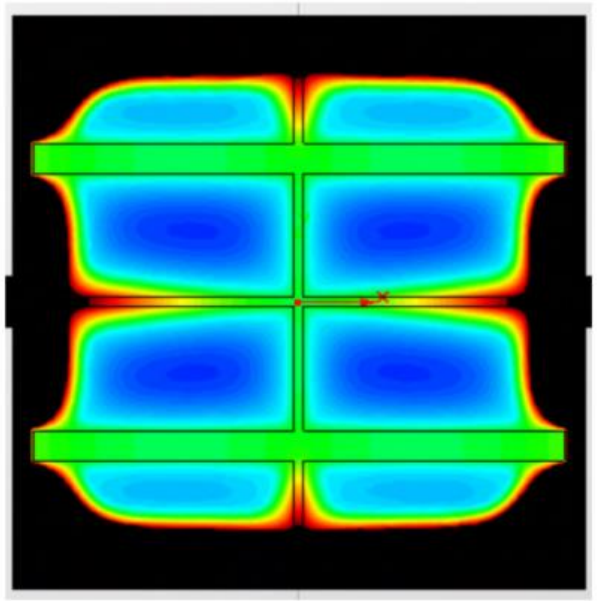


TWB CODES

- FRR Assemblies
  - Connections
    - Engineering analysis
    - Hybrid designs

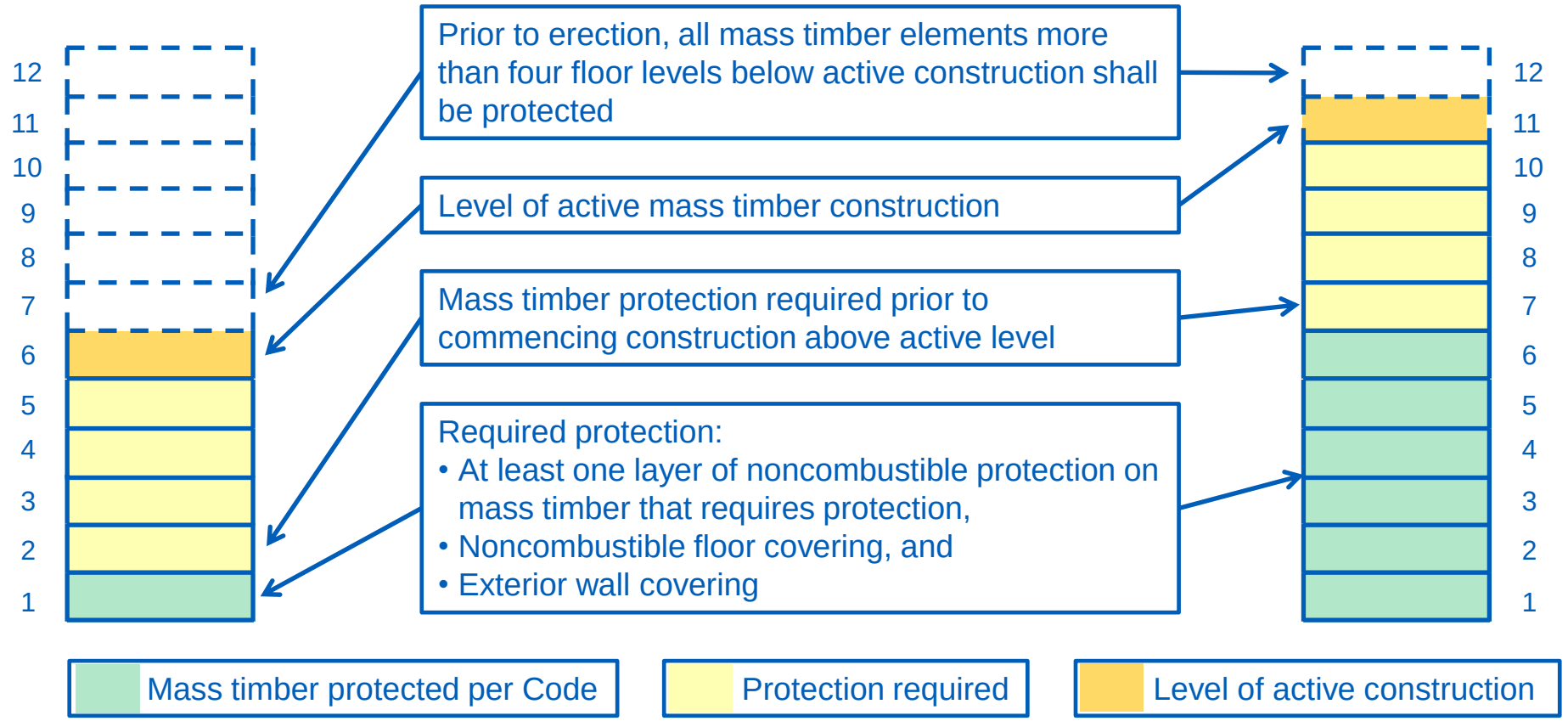






TWB CODES

- Fire Safety During Construction
  - Buildings greater than six stories above grade



TWB CODES

- Exposed Wood Allowances (2021 IBC)
  - Key driver for aesthetic preservation
  - Building features and appearance
  - Fire protection

Design Parameter	Construction Type			
	IV-A	IV-B	IV-C	IV-HT
Allowable Height (ft)	270	180	85	85
Allowable # of Stories	18	12	9	6
Allowable Area (sf)	324,000	216,000	135,000	108,000
Exposed Wood Area	0%	< 20% (ceilings) or 40% (walls)	100%	100%
Effective in CA in July 2021				

TWB CODES

- Exposed Wood Allowances (2021 IBC)
  - Type IV-A: Fully protected

TWB CODES

- Exposed Wood Allowances (2021 IBC)
  - Type IV-B: Partially protected
    - Up to 20% of ceilings ***or*** 40% of walls exposed
    - Ratio of ceilings ***and*** walls exposed (Equation 6-1)
    - Min separation of at least 15 feet for unprotected walls and ceilings

TWB CODES

- Exposed Wood Allowances (2021 IBC)
  - Type IV-B: Partially protected
    - Up to 20% of ceilings ***or*** 40% of walls exposed
    - Ratio of ceilings ***and*** walls exposed (Equation 6-1)
    - Min separation of at least 15 feet for unprotected walls and ceilings

$(U_{tc}/Uac) + (U_{tw}/U_{aw}) \leq 1$ (Equation 6-1) where:

U_{tc} = Total unprotected mass timber ceiling areas

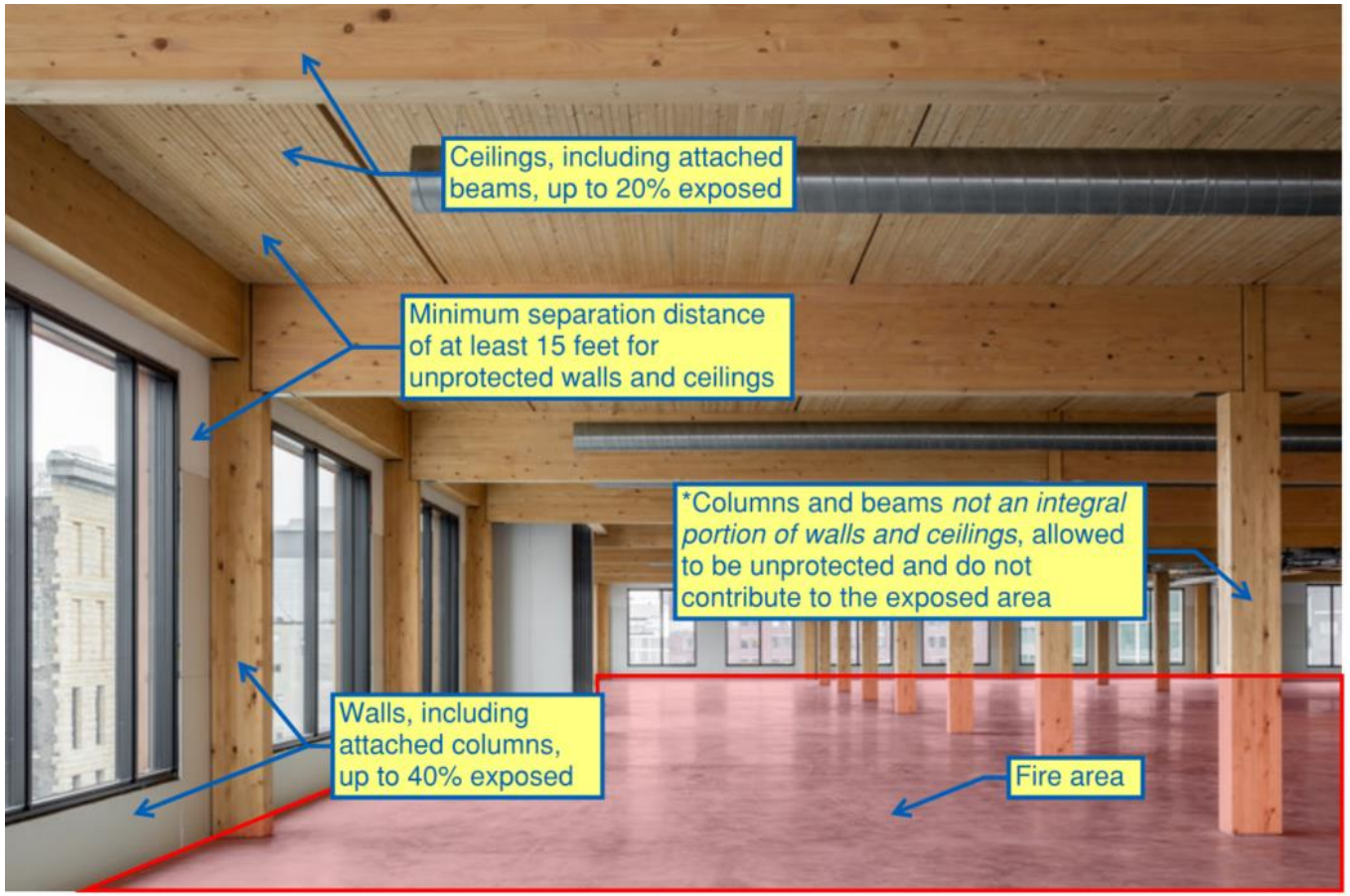
U_{ac} = Allowable unprotected mass timber ceiling area conforming to Section 602.4.2.2.2, Exception 1.

U_{tw} = Total unprotected mass timber wall areas

U_{aw} = Allowable unprotected mass timber wall area conforming to Section 602.4.2.2.2, Exception 2.

TWB CODES

- Exposed Wood Allowances (2021 IBC)
  - Type IV-B: Partially protected



TWB CODES

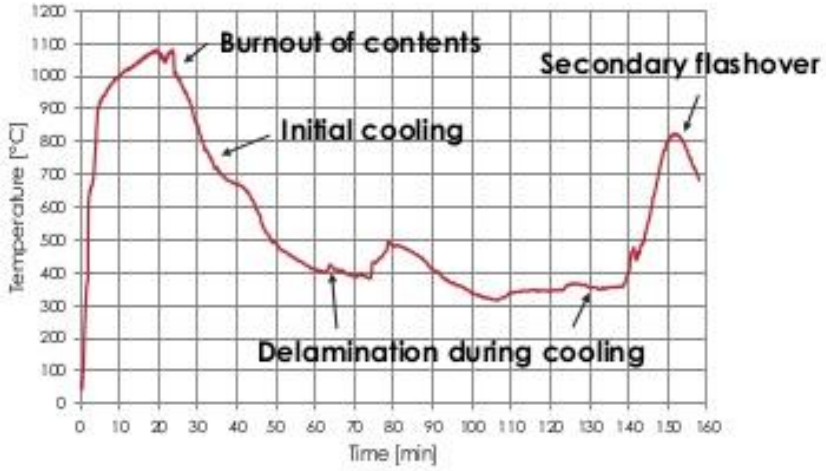
- Exposed Wood Allowances (2021 IBC)
  - Type IV-C: Fully exposed wood

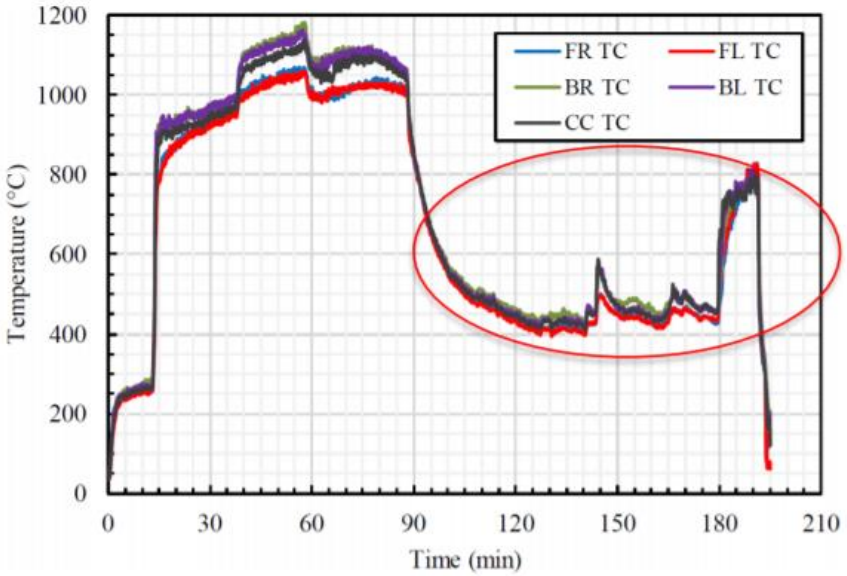
TWB CODES

- Exposed Wood Allowances
  - Delamination / char fall off
    - Pre- PRG 320 – 2018

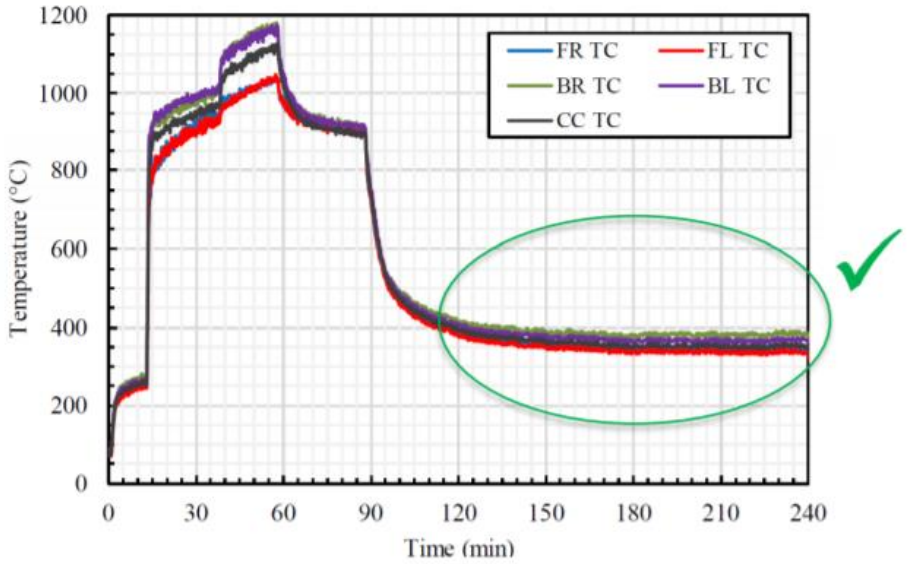
TWB CODES

- Exposed Wood Allowances
  - Delamination / char fall off
    - Pre- PRG 320 – 2018
    - PRG 320 – 2018





Heat-delaminating PUR



Temperature-resistant PUR

TWB CODES

- Modern Mass Timber Buildings
  - Economic ‘sweet spot’
    - 6-12 stories
  - Prescriptive framework
    - 2021 IBC
  - *Exposed area*
    - *Up to 20% - 40%*

Design Parameter	Construction Type			
	IV-A	IV-B	IV-C	IV-HT
*Allowable Height (ft)	270	180	85	85
*Allowable # of Stories	18	12	9	6
*Allowable Area (sf)	324,000	216,000	135,000	108,000
Exposed Wood Area	0%	< 20% (ceilings) or 40% (walls)	100%	100%

R&D

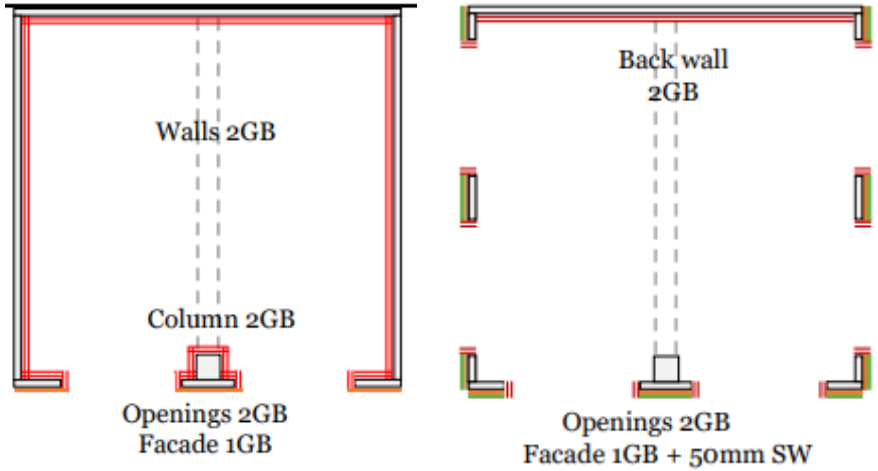
- RISE Fire Testing (2019+)
  - US Forest Service, US Dept of Agriculture
  - Research Institute of Sweden
  - Five full-scale CLT compartment tests
    - Evaluate increased exposed wood area
      - Self-extinguishment with sufficient separation
      - Adjacent surface avoided
      - PRG 320-2018 compliant material
    - Summary Report
    - YouTube Channel

Fire Safe Implementation of Mass Timber In Tall Buildings

Research of the fire performance of CLT and Glued Laminated Timber buildings, with visible wood surfaces.

R&D

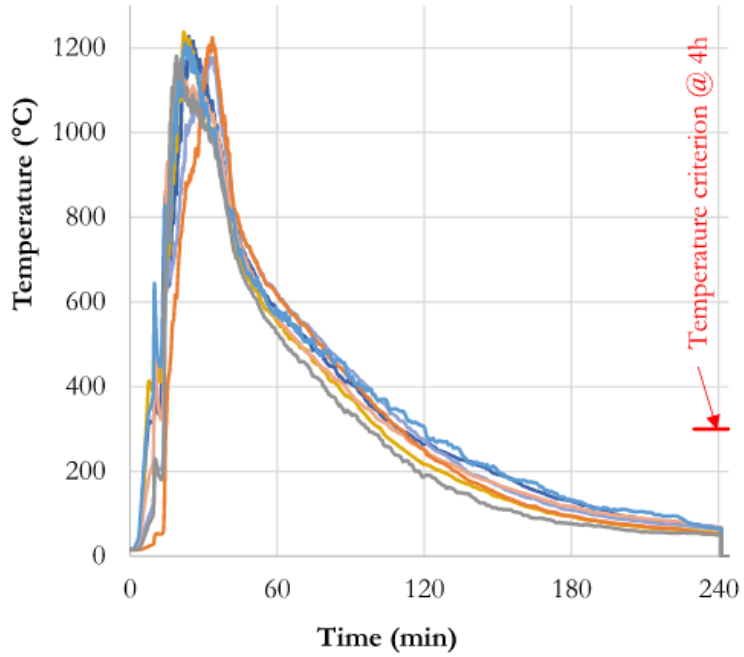
- RISE Fire Testing
  - Test setup
    - Exposure area



Test	Protected Surfaces	Exposed Surfaces	Notes
1	100% walls and column (2 layers gyp)	100% ceilings and beams	2 window openings (86 sf)
2	100% back wall and front wall (3 layers gyp)	100% ceilings, beam, left and right walls	2 window openings (86 sf)
3	100% back wall, back 5’ of right wall (3 layers gyp)	100% ceilings and beams, left side wall, 78% right wall, 100% front and column	2 window openings (86 sf)
4	100% back wall (2 layers gyp)	100% ceilings and beams, walls and column	6 window openings (336 sf)
5	100% back wall and 2.3’ front walls	100% ceilings and beams, left and right walls and column, 60% front wall	2 window openings (86 sf)

R&D

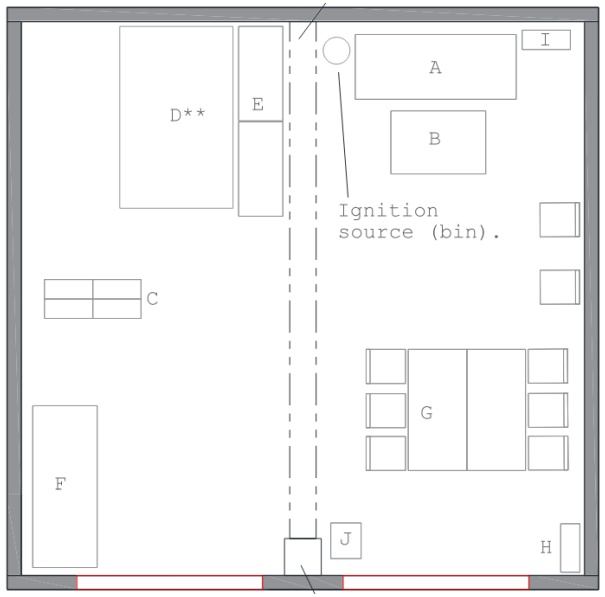
- RISE Fire Testing
  - Acceptance criteria
    - At 4 hours after ignition, plate compartment temps less than 300°C
      - Self-extinguishment criteria to confirm re-ignition does not occur
    - No secondary flashover between 3 and 4 hours after ignition
      - Heat release rate exceeds 0.12 MW/m^2
      - Average upper layer temperature exceeds 600°C
      - External flaming

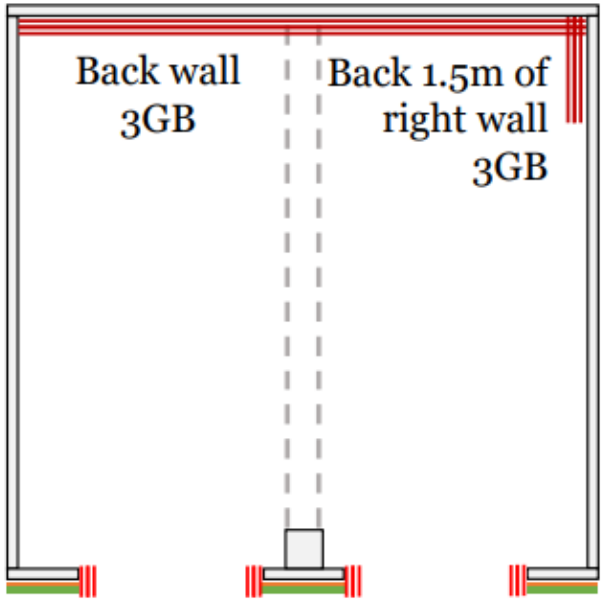


R&D

- RISE Fire Testing
  - Key test results
    - Delamination and re-radiation

Key Event	Test (hrs)				
	1	2	3	4	5
Flashover	0:14	0:08	0:12	0:15	0:04
Start of Decay	0:36	0:36	0:43	0:29	0:34
Duration Ext Flaming	0:22	0:28	0:31	0:14	0:30
Fall-off Exposed Gyp	-	0:32 (1-2m above A)	-	-	0:36 (~1m above A)
Fall-off Other Gyp	-	-	-	-	-
Temp Increase During Decay	-	-	3:05+	-	-
Smoldering @ Joints	*	-	*	-	-
Stop of Test	4:00	4:00	*3:31*	4:00	4:00





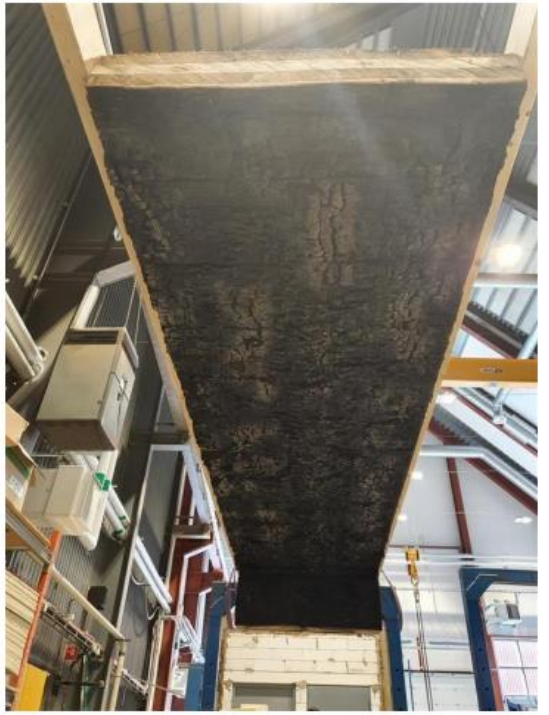
Openings 3GB**
Facade 1GB + 45mm SW

R&D

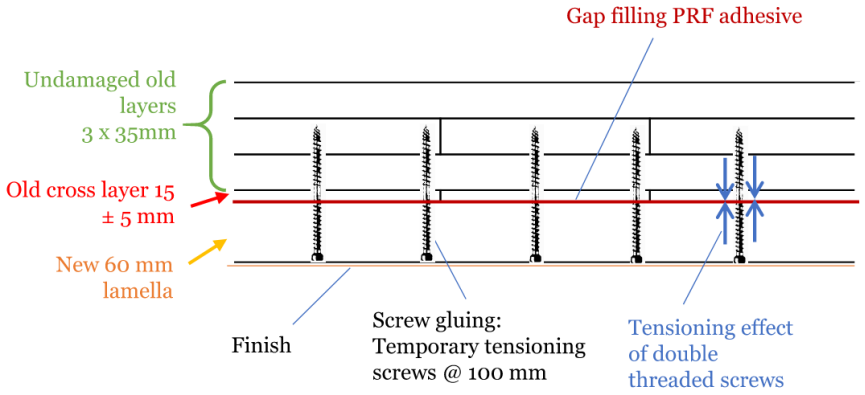
- RISE Fire Testing
  - Conclusions
    - Self-extinguishment within at least 4hrs and temps less than 300°C
      - 100% exposed ceilings and beams
        - Fully protected walls and columns
        - At least (2) layers of 5/8” Type X gyp board
      - 100% exposed ceilings and beams
        - Walls and columns exposed up to 90% of the floor area
        - At least (3) layers of 5/8” Type X gyp board
    - Re-radiation a concern where unprotected CLT intersects at a corner – recommended to not be permitted
    - A post-flashover fire with a larger opening factor results in quick self-extinguishment

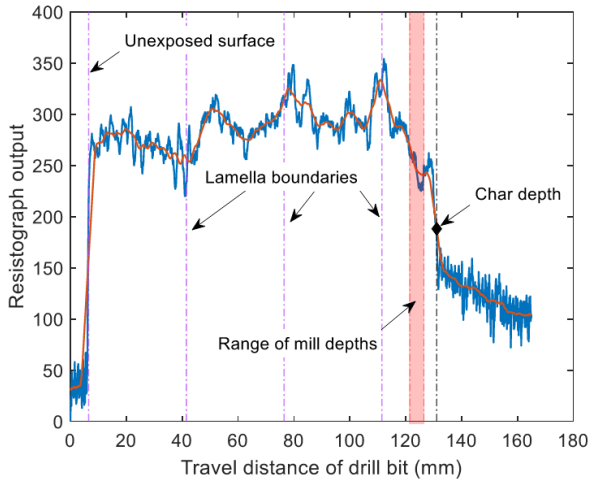
R&D

- RISE Fire Testing
  - Conclusions
    - Post-Fire Rehabilitation of CLT
    - Methodology
      - Map the thickness
      - Evaluate and design
      - Remove the char layer
      - Plane the surface
      - Replace lamella
      - Finish to architectural requirements



Post-Fire Rehabilitation of CLT



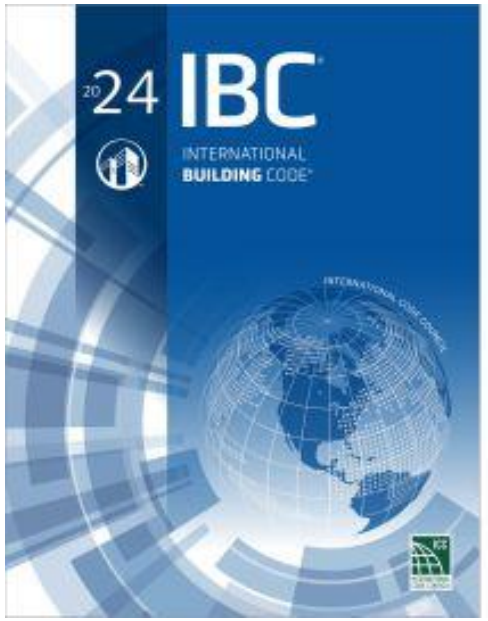


R&D

- 2024 IBC Modifications
  - Type IV-B Protected Area
    - 2024 IBC Section 602.4.2.2.2
      - Unprotected portions of mass timber ceilings… permitted to an area less than or equal to **100% of the floor area**…
      - Unprotected portions of mass timber walls… permitted to an area less than or equal to **40% of the floor area**…
    - 2024 IBC Section 602.4.2.2.4
      - … Unprotected portions of mass timber walls shall be **not less than 15 ft** from unprotected portions of other walls measured horizontally along the floor

R&D

- 2024 International Building Code
  - Type IV-A, -B and –HT:
    - Unchanged
  - 2024 IBC – Type IV-B:
    - Up to 100% mass timber ceiling exposed
    - Up to 40% mass timber walls exposed



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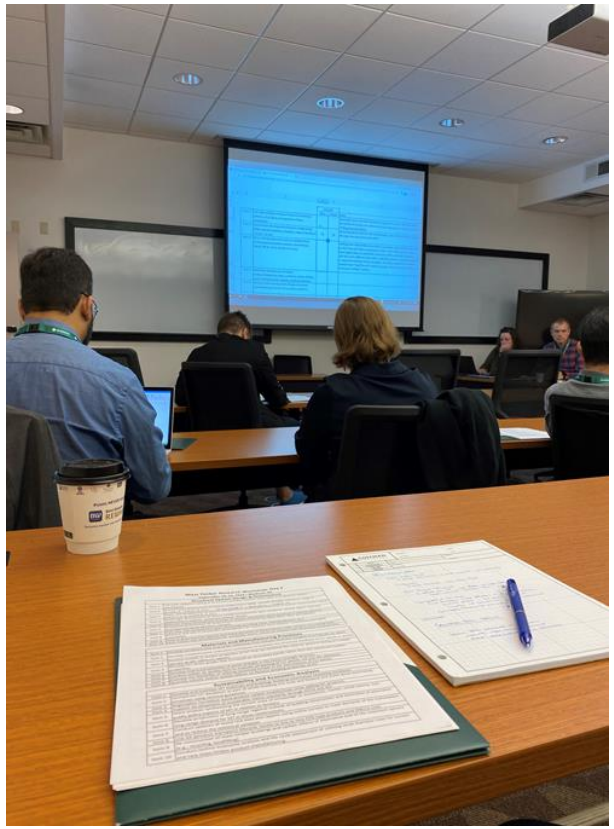
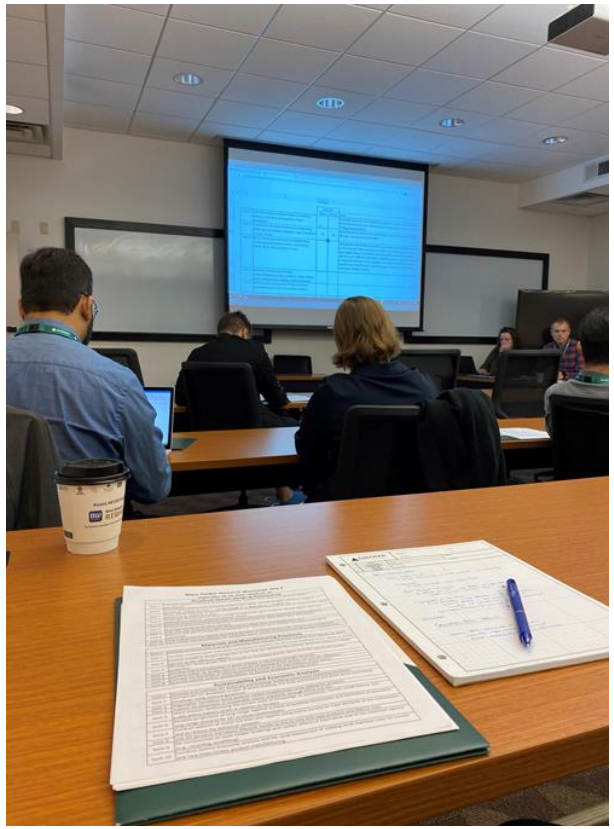
R&D

- Mass Timber Research Needs
  - USDA, March 2023
    - 2022 Research Needs Workshop, September 20-22, 2022, WI
      - Design professionals across the industry
    - Results
      - Fire Performance
      - Durability and Building Physics
      - Architectural and Construction Research
      - Structural System Design and Performance
      - Materials and Manufacturing Processes
      - Sustainability and Economic Analysis
      - Infrastructure and Nonbuilding Applications



R&D

- Mass Timber Research Needs
  - USDA, March 2023
    - Fire Performance
      - Non-gypsum methods of protection
      - Penetrations
      - Hybrid connections
      - Construction fires
      - Post-fire impacts
      - Performance-based guidelines or tools



R&D

- Modern Mass Timber Buildings
  - Ascent, Milwaukee, 2023
    - 25-story mixed use residential
  - T3, Denver, 2023
    - Six-story commercial office
  - Return to Form, Denver, ~2025
    - 12-story multi-family residential

QUESTIONS

MASS TIMBER
WHAT FPE'S SHOULD KNOW

14 November 2023

Presented by:
Robert Gerard, PE

COFFMAN ENGINEERS