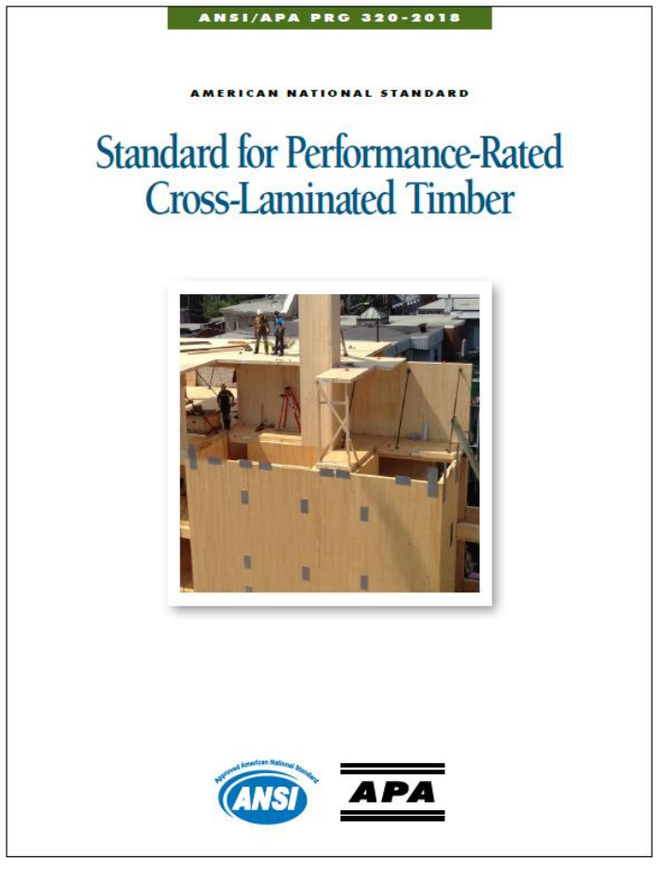
Tall Wood Buildings and Related Code Changes

Matthew Hunter, BCO – American Wood Council

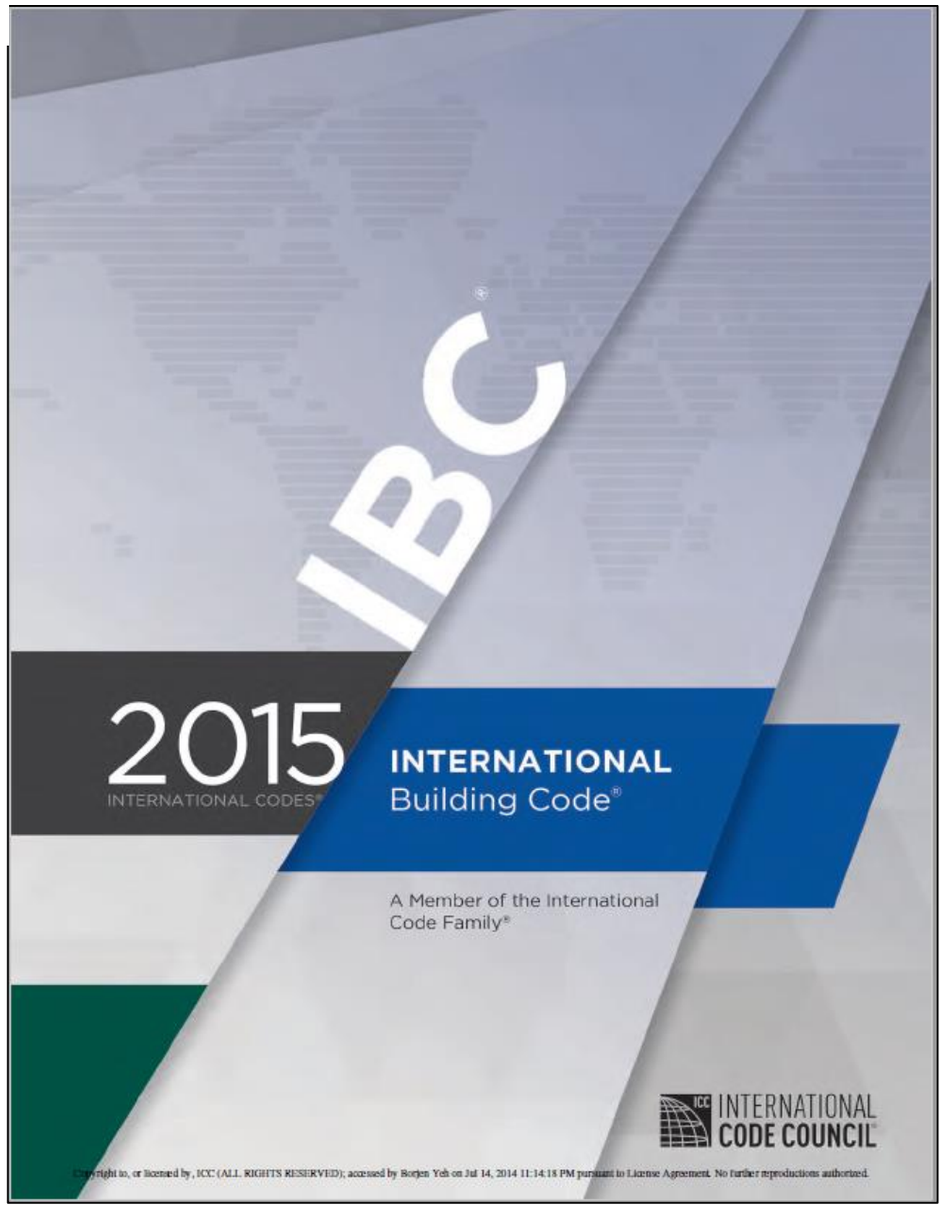
Benjamin Herzog – University of Maine

CLT in 2015 IBC

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

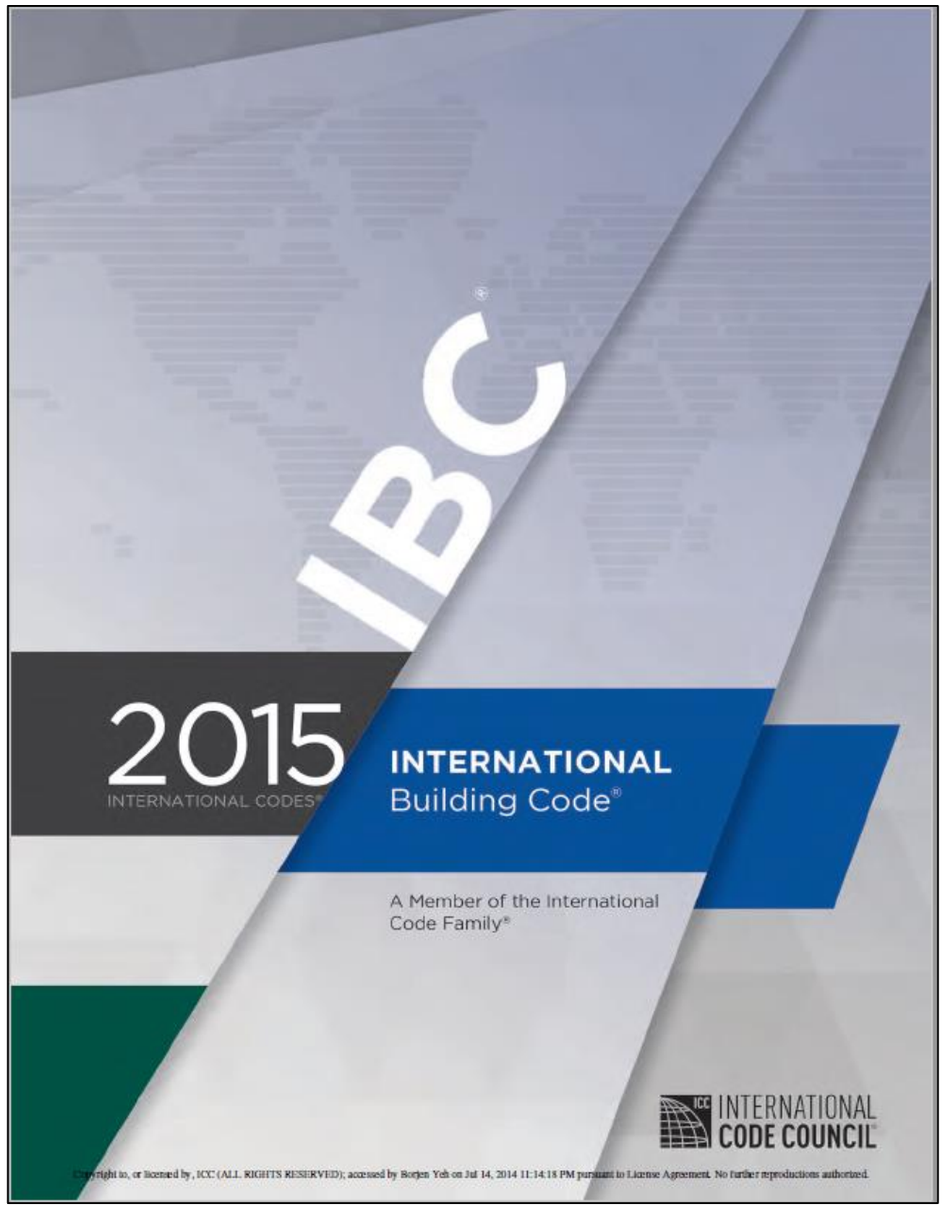


[BS] CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or *structural composite lumber* where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.



CLT in 2015 IBC – Type IV Construction

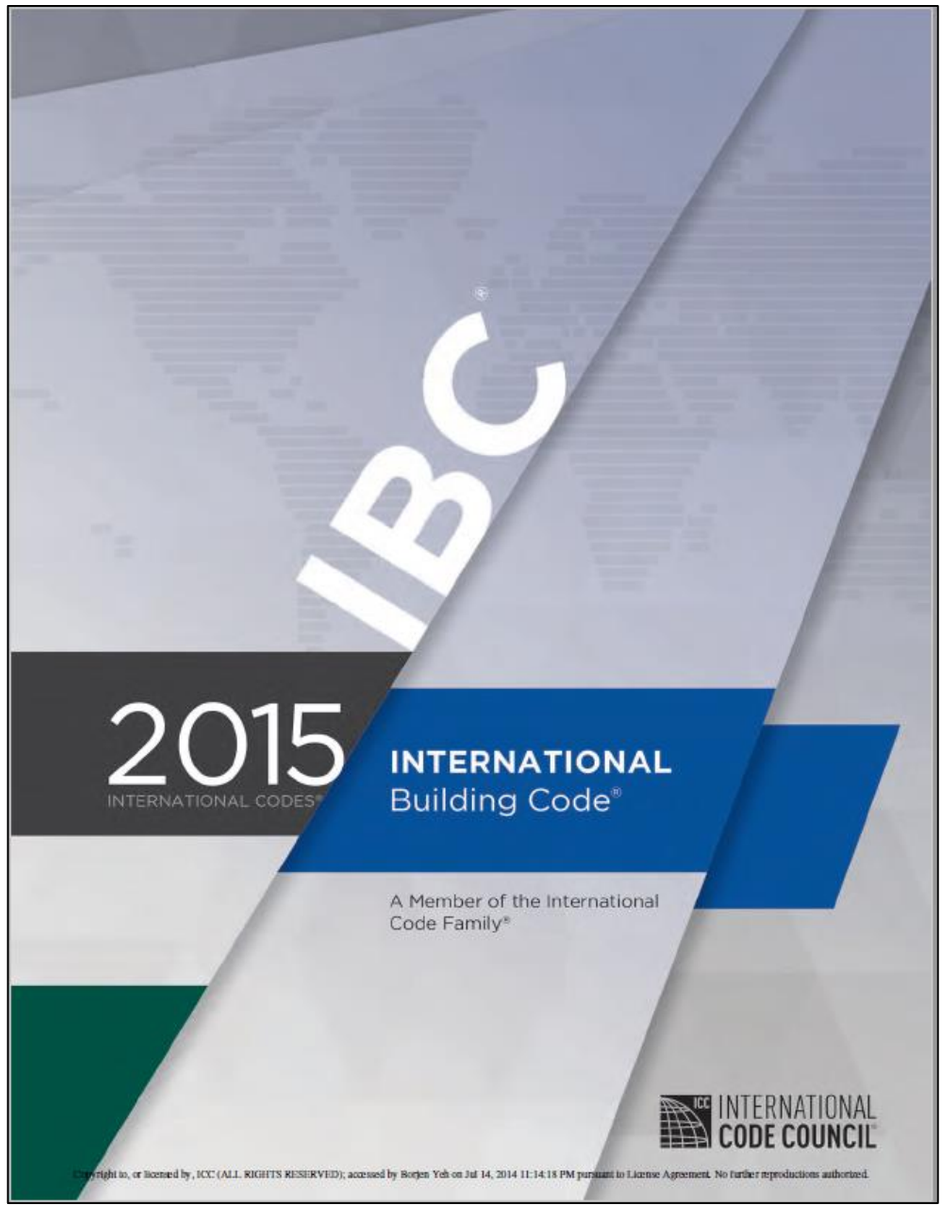
602.4 Type IV. Type IV construction (Heavy Timber, HT) is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood without concealed spaces. The details of Type IV construction shall comply with the provisions of this section and Section 2304.11. Exterior walls complying with Section 602.4.1 or 602.4.2 shall be permitted. Minimum solid sawn nominal dimensions are required for structures built using Type IV construction (HT). For glued-laminated members and structural composite lumber (SCL) members, the equivalent net finished width and depths corresponding to the minimum nominal width and depths of solid sawn lumber are required as specified in Table 602.4. *Cross-laminated timber* (CLT) dimensions used in this section are actual dimensions.



CLT in 2015 IBC – Type IV Construction

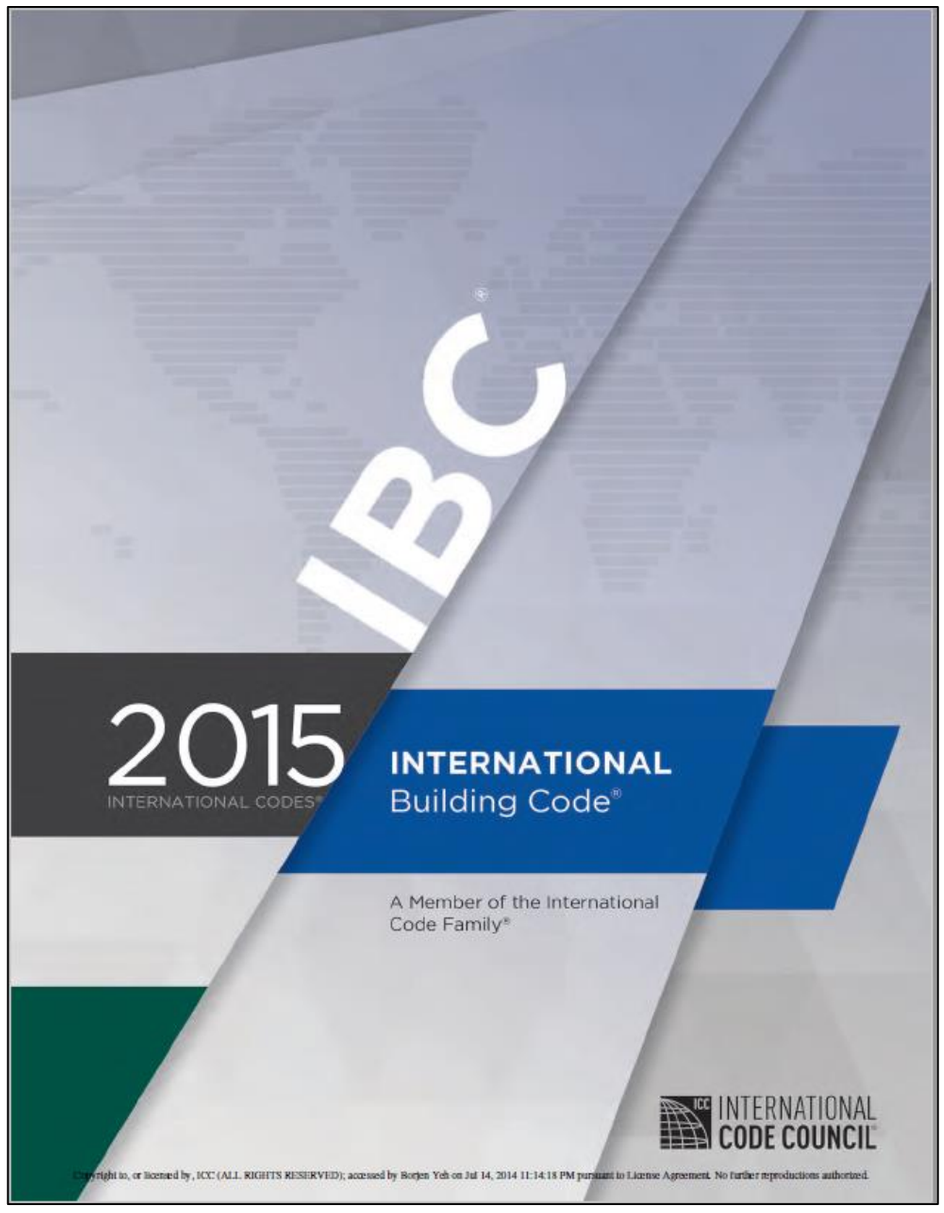
602.4.2 Cross-laminated timber in exterior walls. *Cross-laminated timber* complying with Section 2303.1.4 shall be permitted within exterior wall assemblies with a 2-hour rating or less, provided the exterior surface of the cross-laminated timber is protected by one the following:

1. *Fire-retardant-treated wood* sheathing complying with Section 2303.2 and not less than $^{15}/_{32}$ inch (12 mm) thick;
2. *Gypsum board* not less than $^{1}/_{2}$ inch (12.7 mm) thick; or
3. A noncombustible material.



CLT in 2015 IBC – Type IV Construction

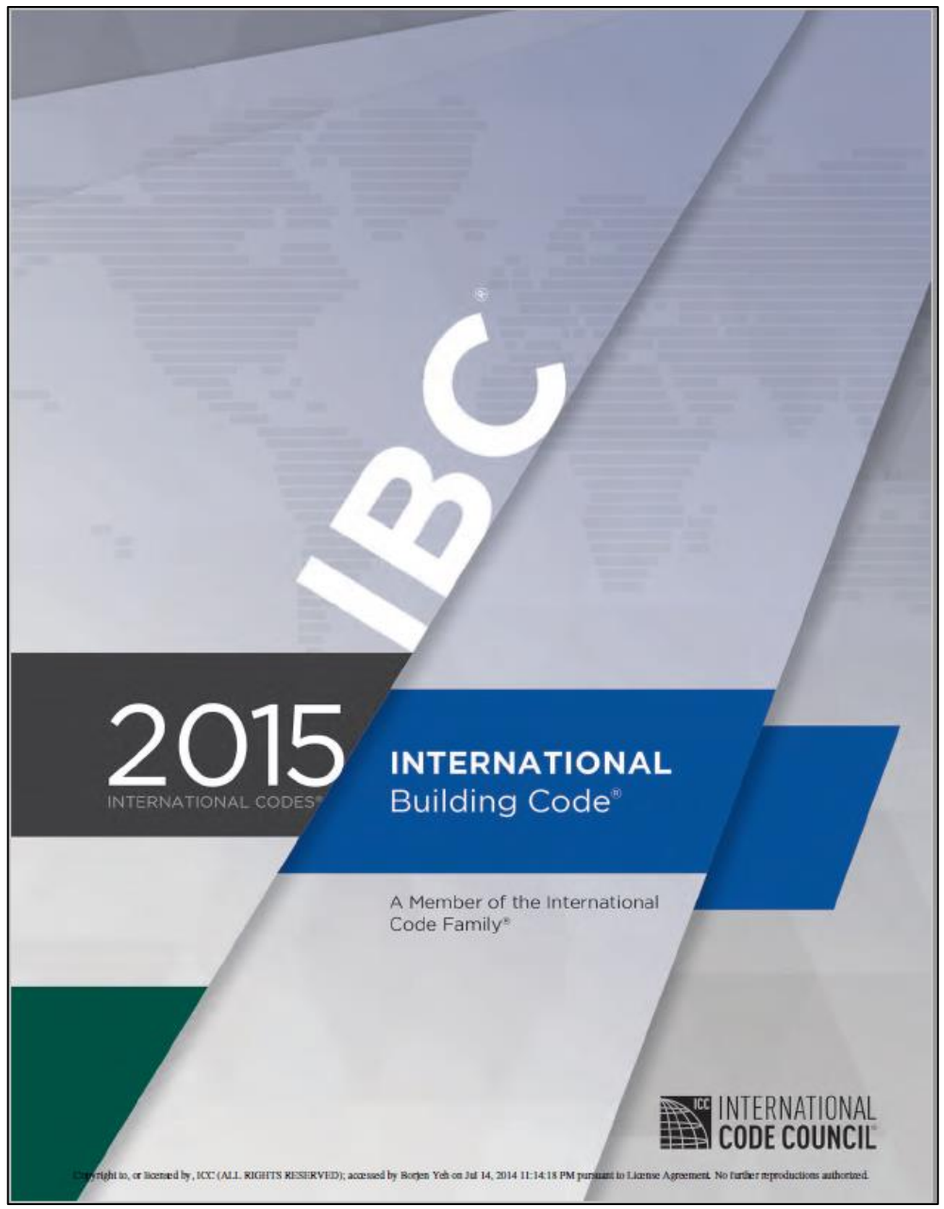
602.4.6.2 Cross-laminated timber floors. *Cross-laminated timber* shall be not less than 4 inches (102 mm) in thickness. *Cross-laminated timber* shall be continuous from support to support and mechanically fastened to one another. *Cross-laminated timber* shall be permitted to be connected to walls without a shrinkage gap providing swelling or shrinking is considered in the design. Corbelling of masonry walls under the floor shall be permitted to be used.



CLT in 2015 IBC – Type IV Construction

602.4.7 Roofs. Roofs shall be without concealed spaces and wood roof decks shall be sawn or glued laminated, splined or tongue-and-groove plank, not less than 2 inches (51 mm) nominal in thickness; $1^1/_8$-inch-thick (32 mm) wood structural panel (exterior glue); planks not less than 3 inches (76 mm) nominal in width, set on edge close together and laid as required for floors; or of cross-laminated timber. Other types of decking shall be permitted to be used if providing equivalent fire resistance and structural properties.

Cross-laminated timber roofs shall be not less than 3 inches (76 mm) nominal in thickness and shall be continuous from support to support and mechanically fastened to one another.



CLT in 2015 IBC

- Type IV: All structural elements can be CLT
  - Exterior walls, floors, roofs, interior walls

- Type V: All structural elements can be combustible construction
  - Exterior walls, floors, roofs, interior walls

- Type III: CLT can be used…
  - Exterior walls need to be non-combustible or FRT wood (2 hours of less)
  - Interior: any material permitted by code
  - roof

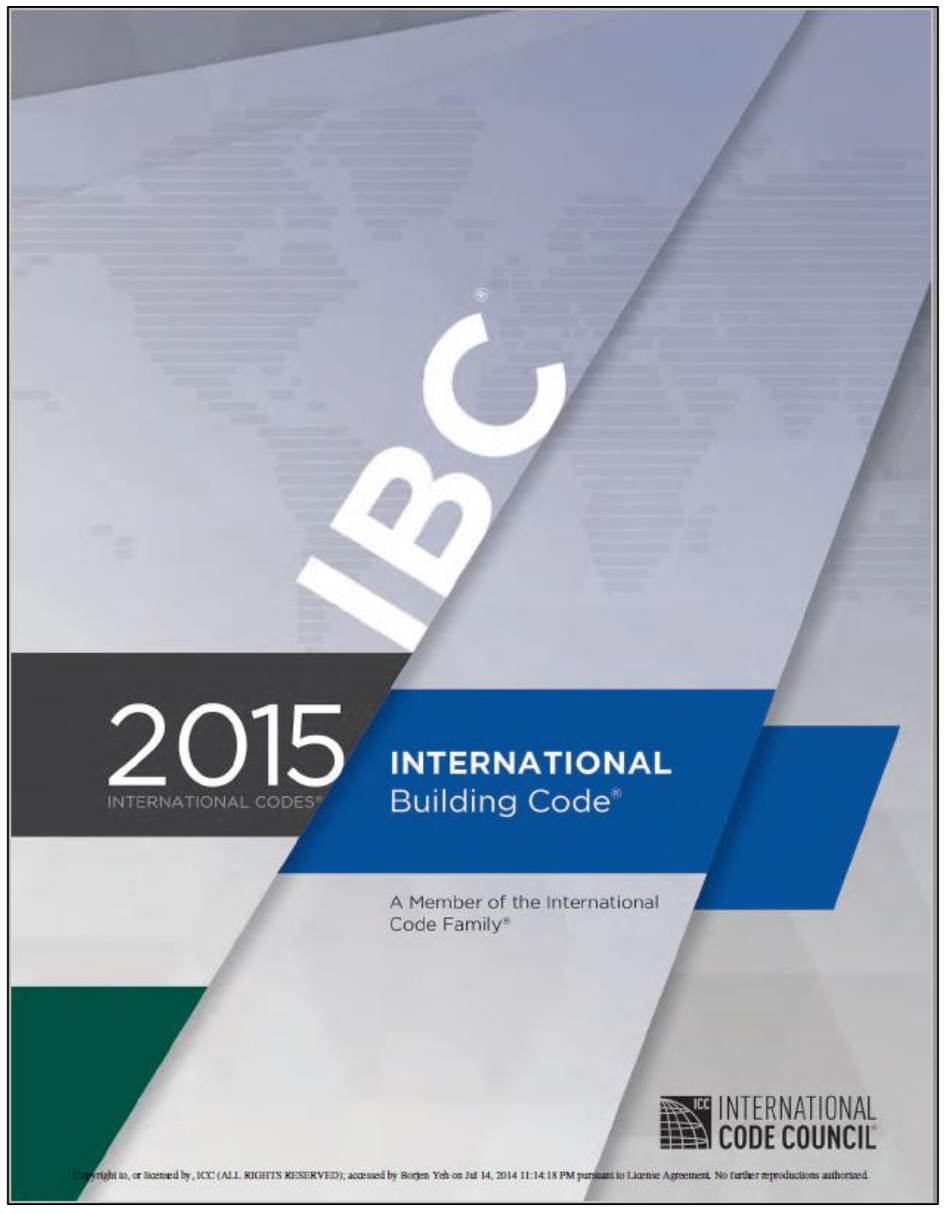


TABLE 504.3[a]
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, f, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R	NS[d, h]	UL	160	65	55	65	55	65	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60

TABLE 504.4[a, b]
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	2	1
	S	UL	6	4	3	4	3	4	3	2
A-2	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-3	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-4	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-5	NS	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	NS	UL	11	5	3	5	3	5	3	2
	S	UL	12	6	4	6	4	6	4	3
E	NS	UL	5	3	2	3	2	3	1	1
	S	UL	6	4	3	4	3	4	2	2
F-1	NS	UL	11	4	2	3	2	4	2	1
	S	UL	12	5	3	4	3	5	3	2
F-2	NS	UL	11	5	3	4	3	5	3	2
	S	UL	12	6	4	5	4	6	4	3
	NS[c, d]									

ICC TALL WOOD AD HOC COMMITTEE

Project Scope

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

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

ICC TALL WOOD AD HOC COMMITTEE

Membership

In making the committee appointments, the Board recognized the need to have a consensus committee comprised of the necessary balance of stakeholders including:

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

ICC TALL WOOD AD HOC COMMITTEE

7 Face-to-Face Meetings of the Full Committee

1. **July 6-8, 2016 - Chicago**
2. **November 14 -16, 2016 - Seattle**
3. **May 1-3, 2017 - Chicago**
4. **August 21 -23, 2017 - Chicago**
5. **November 29 - December 1, 2017 - Phoenix**
6. **March 27-28, 2018 - Chicago**
7. **October 9-10, 2018 - Chicago**

Working Group Conference Calls

1. **Definitions and Standards**
2. **Fire**
3. **Structural**
4. **Codes: Height & Area**
5. **General Information**

82 major issues identified

Presentations, reports, studies on the topic were reviewed: ICC Website

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Fire Resistance

- When mass timber is exposed to fire, the outer layer burns, creating a protective char layer.
- Char acts as insulation.
- Char forms at a predictable rate (~0.025 inch/min).

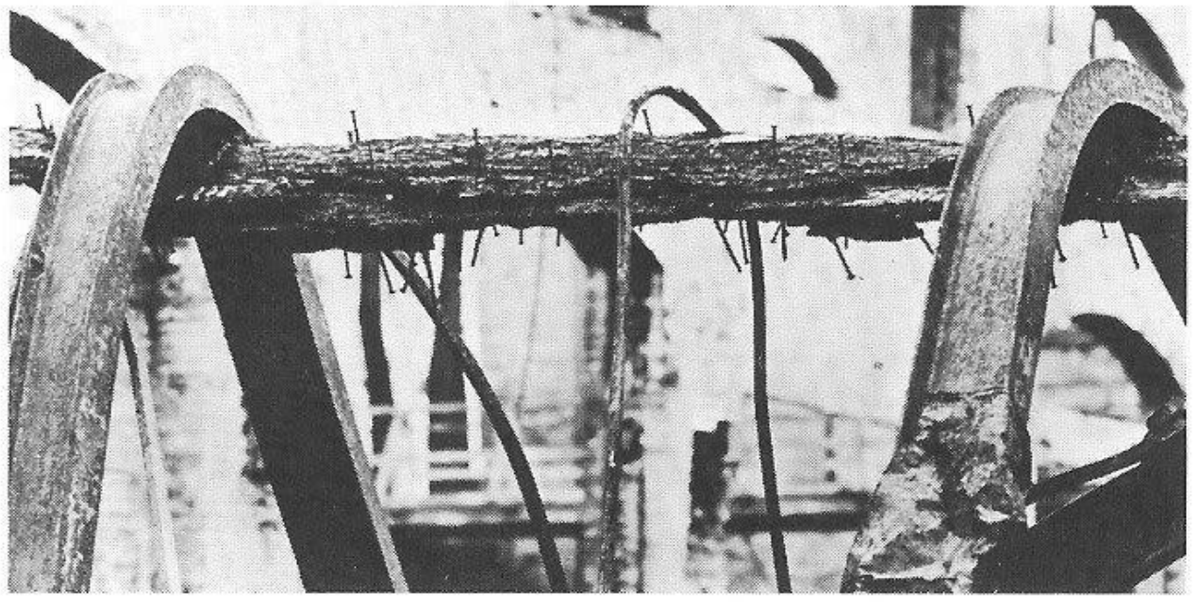
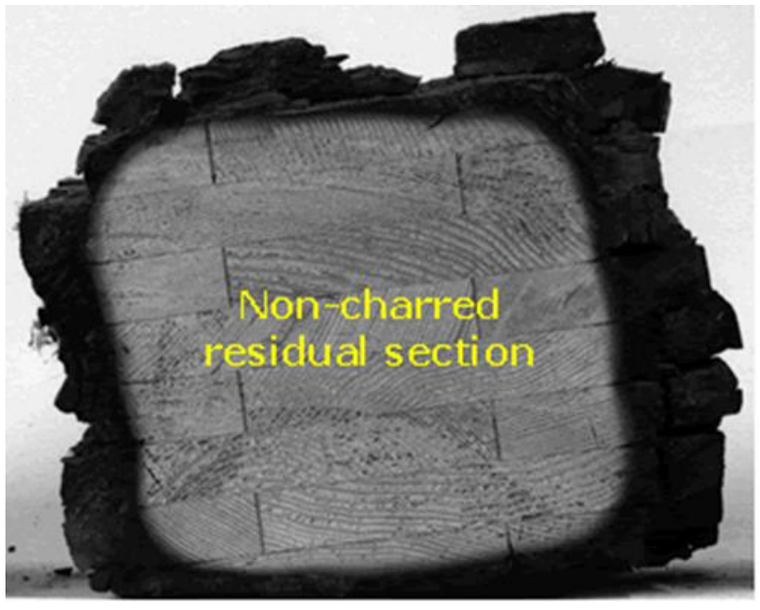


Fig. 20-4. After fire scene. Shows a wood beam supporting twisted steel I-beams. (Forest Products Laboratory)



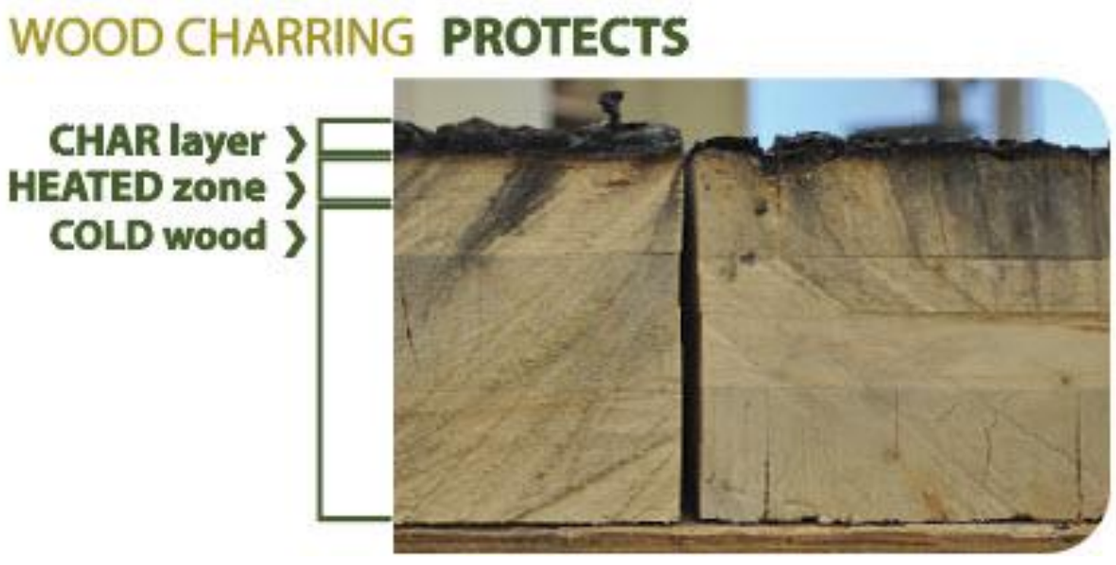


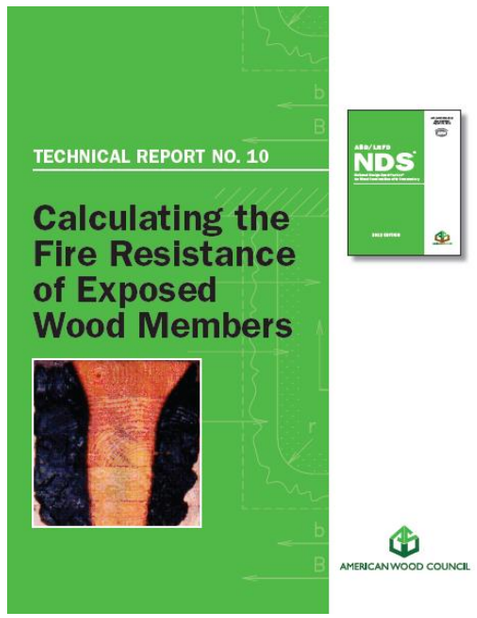
Photo credit: Think Wood

Calculated Fire Resistance

SECTION 722
CALCULATED FIRE RESISTANCE

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).*

Technical Report 10 includes more details, background and commentary on the methods found in NDS chapter 16. **Chapter 16 of NDS** provides for design up to 2 hours



Adhesive Requirements – Elevated Temperatures

- In addition to being a qualified adhesive,
- Fire testing of unprotected floor-ceiling slab under load.
  - Exposed for 240 minutes
  - Requirement: no char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire.

FIGURE X2-6

PICTURE ILLUSTRATING CERAMIC FIBER COVER AROUND PANEL PERIMETER

ANSI/APA PRG 320-2018

AMERICAN NATIONAL STANDARD

Standard for Performance-Rated Cross-Laminated Timber

FIRE TESTS and MASS TIMBER

- Fire Tests related to Mass Timber and Tall Wood Building Ad Hoc Committee code change proposals for 2021 IBC
- Standardized Tests
- ASTM E84, E119, E814; NFPA 285
- Compartment Tests (U.S.)
  - Single Compartment SwRI 2015
  - Single Compartment FPRF 2017
  - Full-scale building ATF 2017
  - Multi-Compartment, Multi-Floor
- Noncombustible Protection WFC 2017

TWB AD HOC OBJECTIVES

TWB identified performance objectives to be met

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

TWB AD HOC OBJECTIVES

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

The TWB has determined that its comprehensive package of proposals meet these performance objectives

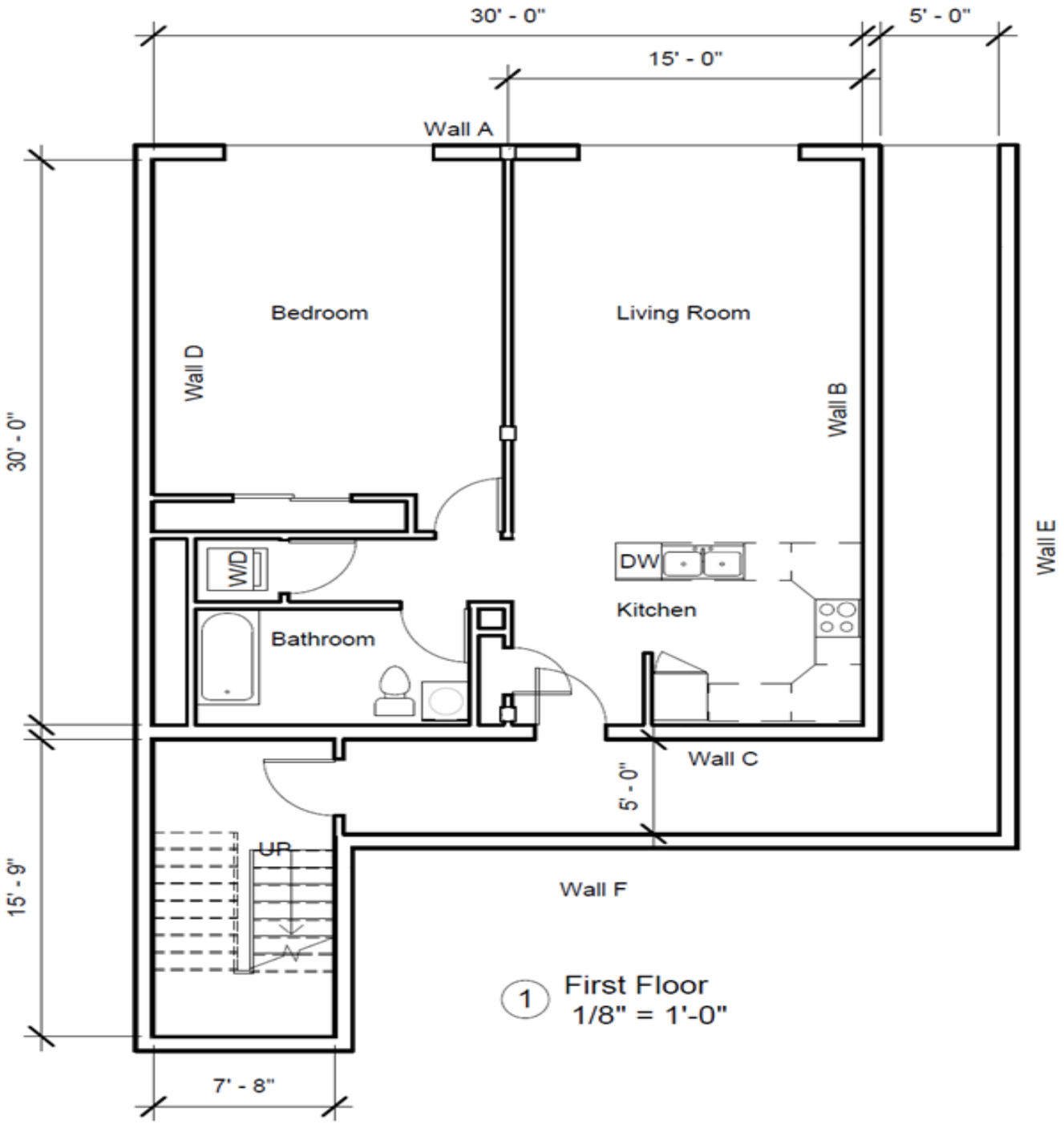
Fire Research

- Purpose: Perform tests of realistic fire scenarios applicable to tall wood construction in order to evaluate occupant and firefighter tenability for egress and suppression efforts, and to provide data necessary to guide further development of relevant code and standard provisions.
- Conducted at U.S. government facilities
- Supervised by U.S. Forest Product Laboratory staff

Test Structure Floor Plan

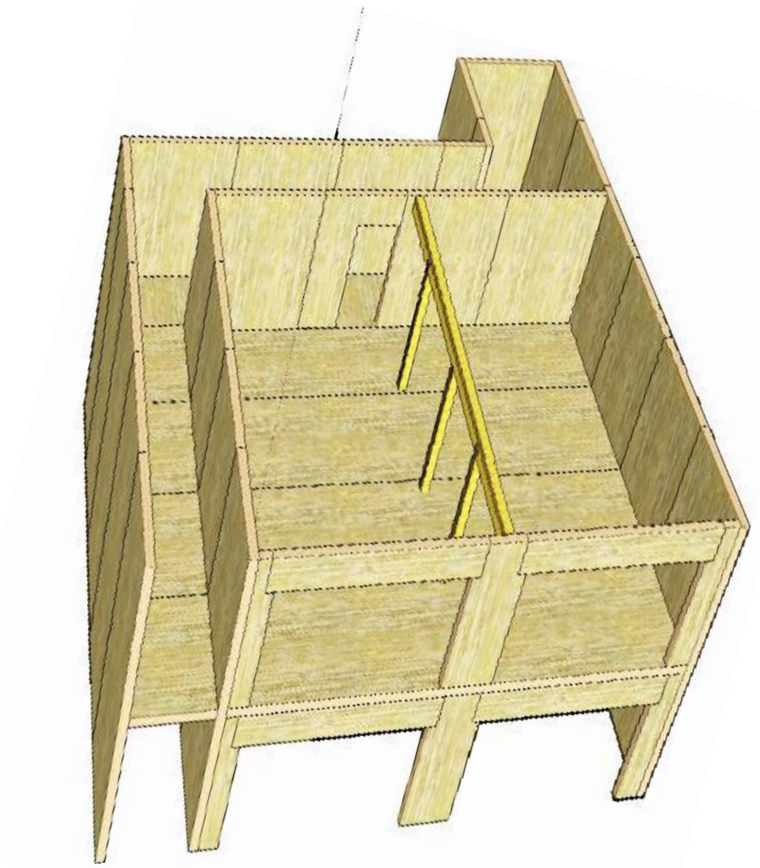
Fire Work Group Plan

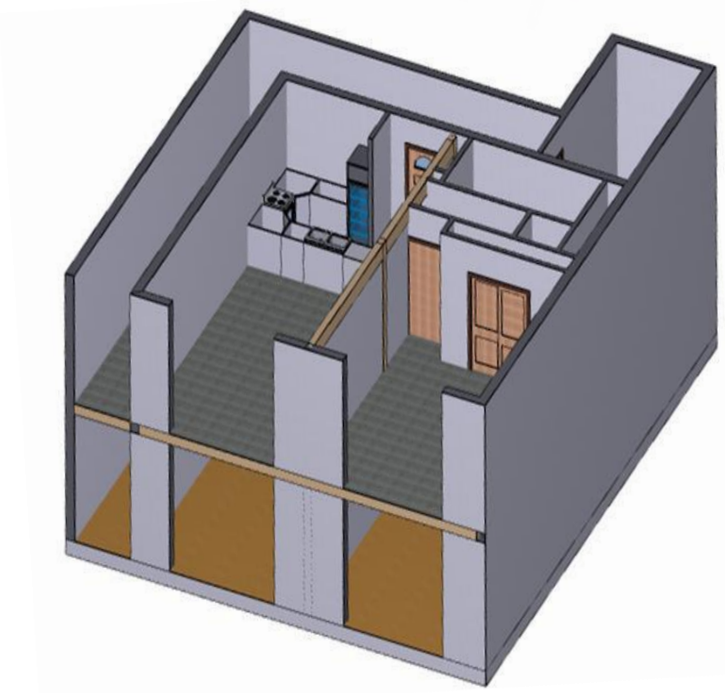
- One bedroom apartment
- 30 feet X 30 feet interior dimensions.
- UL “modern furnishings” fuel load imposed 570 mj/m^2
- Fuel load was approximately 95 percentile of Group R
- 20-minute rated door between compartment and corridor
- 90-minute rated door between corridor and stairwell



Two-Story Structure

- Ceiling height: 9 ft (2.7 m)
- 5-ply CLT
  - Douglas-fir – Larch species group
  - Lamination Thickness: 1.375 inches(35 mm)
  - CLT Thickness: 6.875 inches (175 mm)
  - Polyurethane Adhesive
- Corridor around each apartment and a stairwell
- Ceiling loaded to 20 PSF





Fire Test Scenarios

Test	Description	Date
Test 1	All mass timber surfaces protected with 2 layers of 5/8” Type X GWB	5/23/17
Test 2	30% of CLT ceiling area in living room and bedroom exposed	5/31/17
Test 3	Two opposing CLT walls exposed – one in bedroom and one in living room (there is a partition wall)	6/20/17
Test 4	All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – normal activation	6/27/17
Test 5	All mass timber surfaces fully exposed in bedroom and living room (except bathroom). Sprinklered – 20 min delayed activation	6/29/17

Apartment Furnishings – Kitchen & Living Room

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

Apartment Furnishings – Bedroom & Bath

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

Test #1 - All Mass Timber Protected

All mass timber surfaces protected with 2 layers of 5/8” Type X GWB

ATF Fire Test #1 - 2 Layers GWB

Test #1 - All Mass Timber Protected

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

Test #2 – 30% CLT Ceilings Exposed

- **30% of CLT ceiling area in living room and bedroom exposed**
- **Live load applied using water barrels**

ATF Fire Test #2 – 30% Exposed Ceiling

Test #2 – 30% CLT Ceilings Exposed


Ignition


Living Room / Kitchen Flashover


Bedroom Flashover


Decay Phase

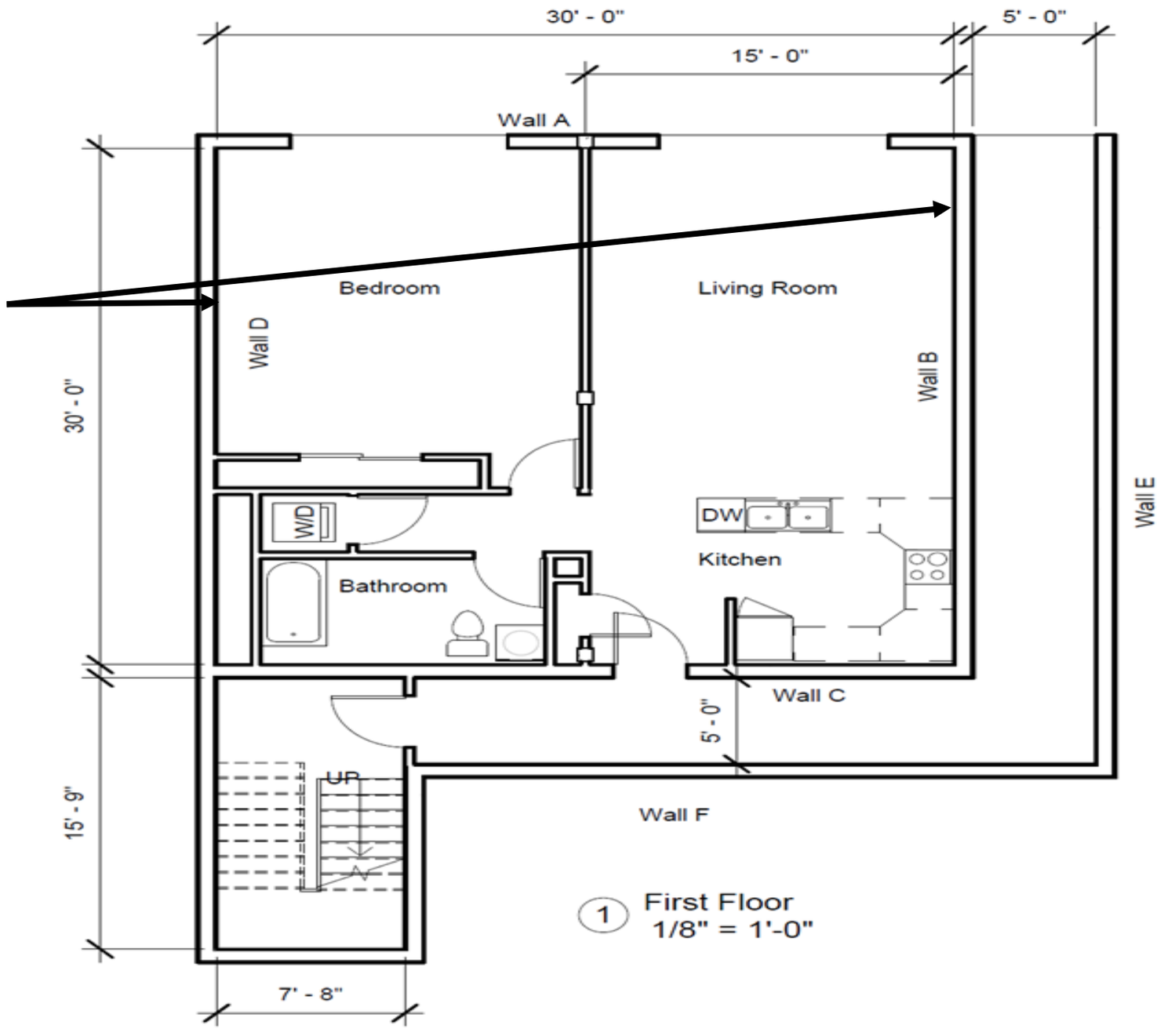

Living Room Ceiling


Bedroom Ceiling

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

Test #3 – Exposed Walls

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



ATF Test #3 – 2 Exposed CLT Walls

Test #3 – 2 Exposed Walls

Ignition

Living Room/
Kitchen Flashover

Bedroom Flashover

Ignition

Ignition

Ignition

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

Test #4 – Sprinklers Protected, Exposed

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

Sprinkler – normal activation

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

Test #5 – Delayed Sprinklers

All mass timber surfaces <u>fully exposed</u> in bedroom and living room.

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

Results – Event Log

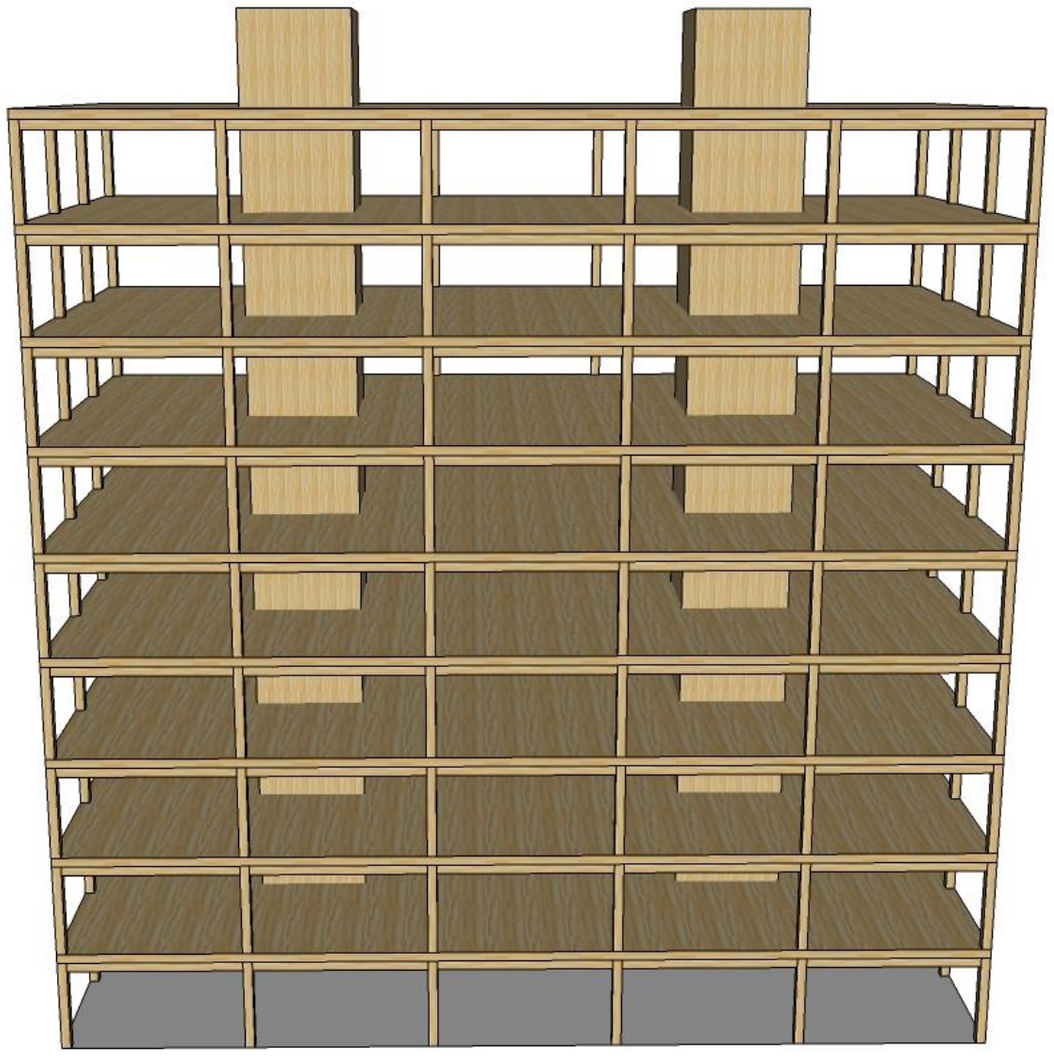
Test No.	Time After Ignition (mm:ss)				
	Flashover (600°C) Living Room	Flashover (600°C) Bedroom	Flames in Hallway	Compartment door Fails	Sprinkler Activation
1 1st floor	13:27	17:20	26:51	57:46	N/A
2 2nd floor	11:42	17:20	30:38	63:59	N/A
3 2nd floor	12:37	17:00	13:06 (door frame installation error)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

TALL WOOD CODE CHANGES

19 code change proposals to date

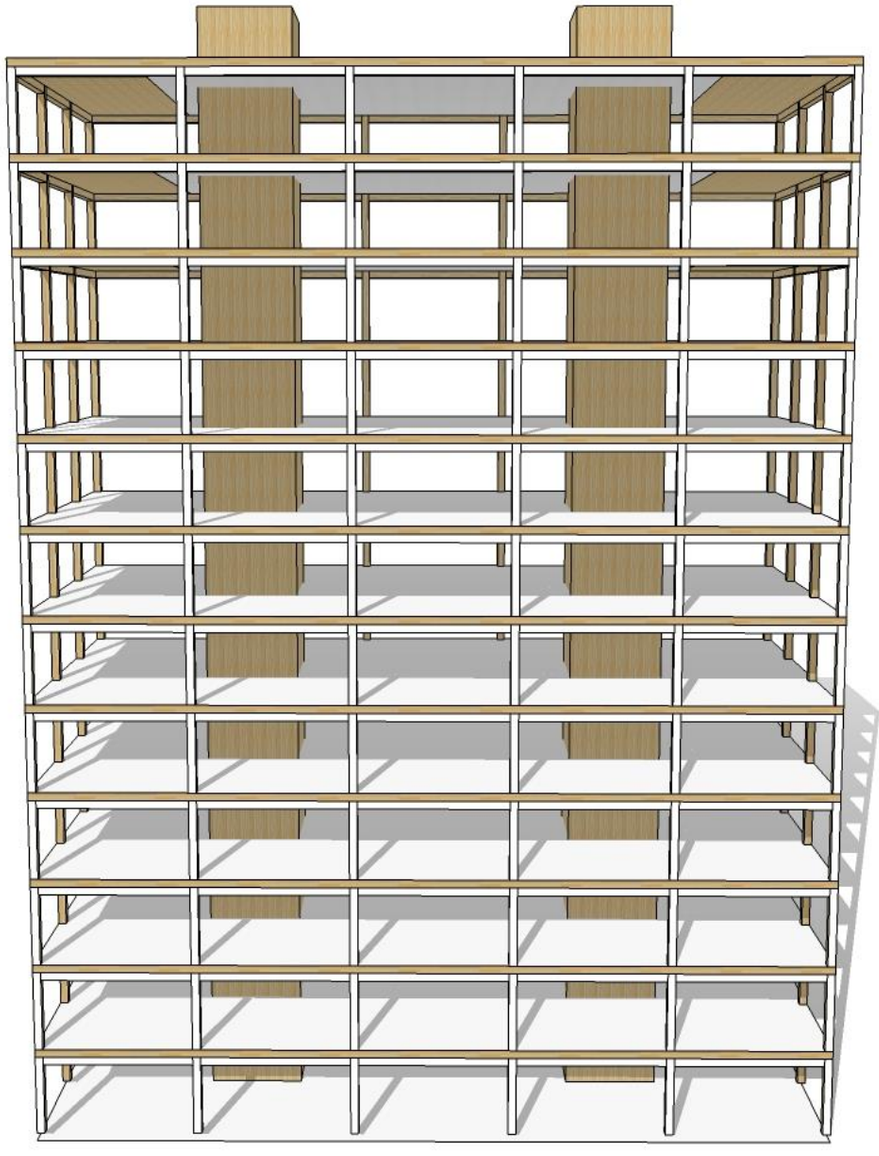
- **New definitions**
- **3 new types of construction proposed**
- **New entries in height (feet), height (stories) and area for the IBC**
- **Determining added contribution to FRR time from non-combustible protection**
- **New requirements for safety while under construction**
- **OLD exterior wall test standard still required (NFPA 285)**
- **Caulking of mass timber elements**
- **Owner Responsibilities**

Type of Construction IV-C



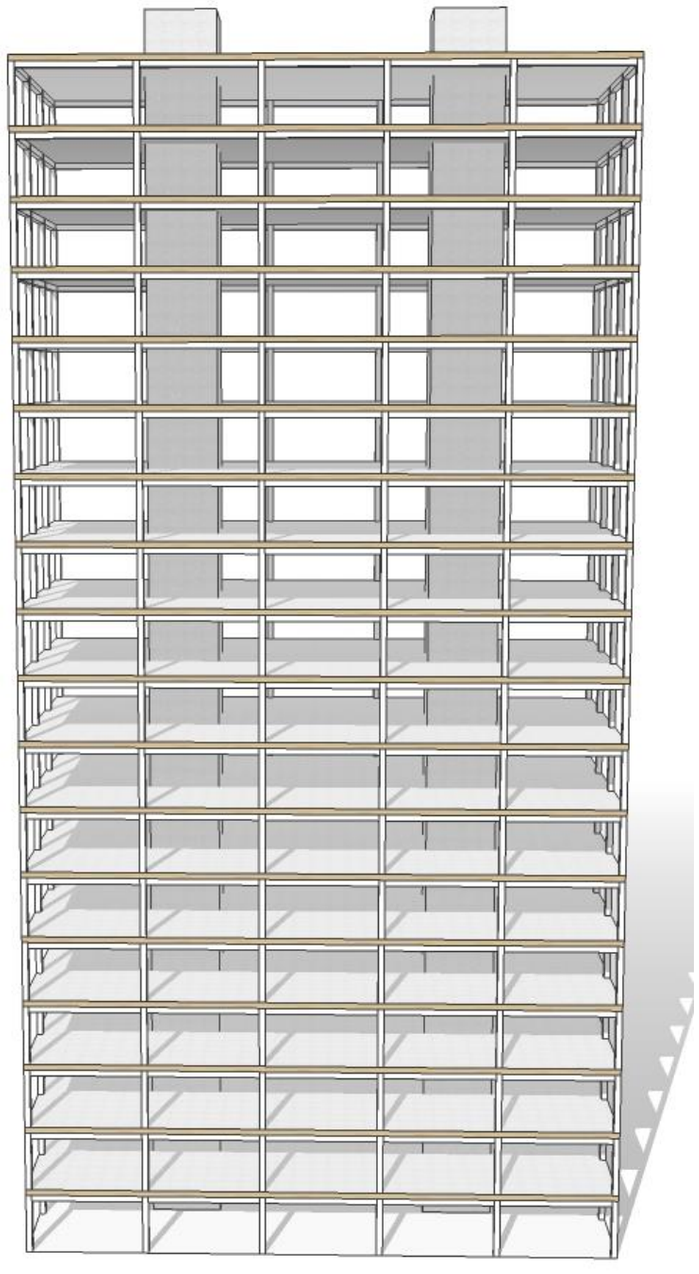
Building Element	
Maximum Height	85”
Number of Stories	4 - 9
Exposed Mass Timber	Fully Exposed
Sprinklers	Yes
Primary Frame FRR	2 hours
Floor FRR	2 hours
Stairs Tower	Mass Timber
FRR from Non-combustibles	0 hours
Concealed Spaces	OK if Protected
Floor topping	No requirement

Type of Construction IV-B



Building Elements	
Maximum Height	180’
Number of Stories (except H’s)	6 - 12
Exposed Mass Timber	Partially
Sprinklers	Yes
Primary Frame FRR	2 hours
Floor FRR	2 hours
Fire Resistance from Non-com	80 minutes
Stairs Tower	Mass Timber
Concealed Spaces	OK if Permitted
Floor topping	Noncombustible

Type of Construction IV-A



Building Elements	
Maximum Height	270’
Number of Stories (except H’s)	9 - 20
Exposed Mass Timber	Fully Protected
Sprinklers	Yes
Primary Frame FRR	3 hours
Floor FRR	3 hours
Fire Resistance from Non-com	120 minutes
Stairs Tower	Non-combustible
Concealed Spaces	Permitted
Floor Topping	Noncombustible

TWB Ad-Hoc Committee – Draft Proposal

Type of Construction	Height	# of Stories	Exposed Mass Timber	Sprinklers	Primary Frame FRR	Floor FRR	Stair Tower	Concealed Spaces
IV – HT Existing	85’	4-6	Fully Exposed	Yes	NR	HT	Mass Timber	Not Permitted
IV – C Proposed	85’	4-9	Fully Exposed	Yes	2 hours	2 hours	Mass Timber	Permitted
IV – B Proposed	180’	6-12	Partially Exposed	Yes	2 hours	2 hours	Mass Timber	Permitted
IV – A Proposed	270’	9-18	Fully Protected	Yes	3 hours	2 hours	Noncombustible	Permitted

ICC Procedure

- Step 1: January 8 – Final Proposed Language submitted to ICC COMPLETED

- Step 2: February 28 – Changes are posted for Public Viewing COMPLETED

- Step 3: April 15-25 – Committee Action Public Hearing – Columbus, OH
  - Floor Discussion – The code change proposals are considered and discussed at the floor COMPLETED
  - Committee Action – The code development committee makes a recommendation on the code change proposal disposition COMPLETED
  - Assembly Action – ICC members in attendance can challenge committee actions
    - Online assembly floor motion voting period is 2 week and beings approximately 2 weeks after the hearings close – NOT CHALLENGED


ICC
INTERNATIONAL CODE COUNCIL
G108-18
Next: G89-18
Track 2: M67-18
IBC-General
ICC
INTERNATIONAL CODE COUNCIL®
Steven Winkel

ICC Procedure

- Step 4: May 30 – Committee Action Hearing results posted COMPLETED

- Step 5: June 1 – July 16 – Public comments sought on Committee Action Hearing Results - COMPLETED

- Step 6: August 31 – Public Comments Posted

- Step 7: October 24-31 – Public Comment Hearing and Vote

- Step 8: Fall 2020 – New Edition is Published

For Detailed Information

- **www.iccsafe.org/codes-tech-support/cs/icc-ad-hoc-committee-on-tall-wood-buildings/**

- **www.buildtallbuildsafe.com/**

- **https://www.awc.org/tallmasstimber**

New market for CLT?

QUESTIONS?