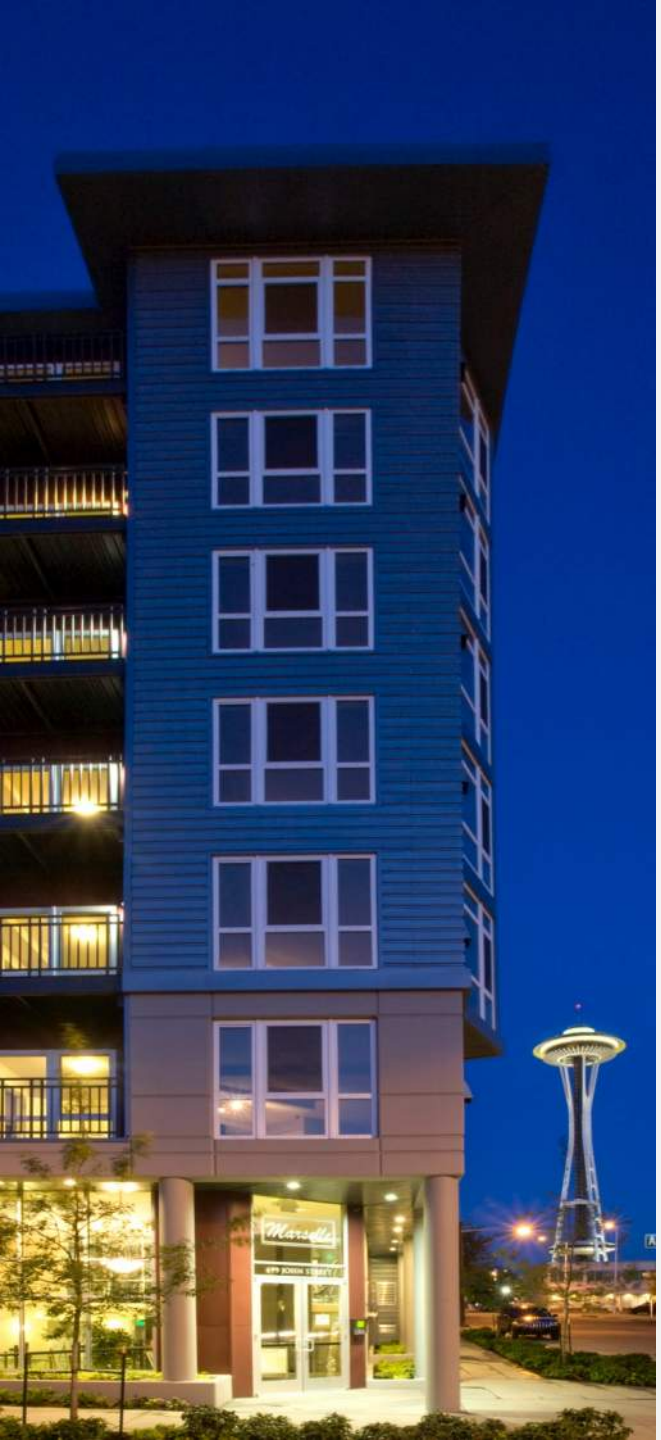

Demystifying Timber Construction Types

March 7, April 11, May 9

3 Part Series 3:30pm-5:30 pm in person at
AIA San Francisco Center for Architecture + Design

March 7

Mid-Rise Design: Optimizing Size, Maximizing Value

April 11

Mid-Rise Mass Timber: Navigating Construction Type Selection

May 9

New Code Provisions for Tall Timber Structures in California

The Canyons, Kaiser+Path, Cantena Consulting Engineers, Photo Jeremy Bittermann

Mid-Rise Mass Timber

Navigating Construction Type Selection

Chelsea Drenick, SE

April 11, 2024

MULTI-FAMILY/MIXED-USE | EDUCATION | OFFICE | RETAIL | INDUSTRIAL | CIVIC | INSTITUTIONAL

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- Construction Types
- Structural Detailing
- Wood-Framed & Hybrid Systems
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- Alternate Means of Compliance
- Energy-Efficient Detailing
- Building Systems & Technologies

River Edge, Kitchen & Associates
photo courtesy of McAlvain Construction

woodworks.org/project-assistance | help@woodworks.org

Questions? Ask me anything.

Chelsea Drenick, SE

Regional Director | CA-North, NV, UT

303.588.1300

chelsea.drenick@woodworks.org

901 East Sixth, Thoughtbarn-Delineate Studio, Leap!Structures, photo Casey Dunn

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Resources

WOOD SOLUTION PAPERS

Acoustics and Mass Timber: Room-to-Room Noise Control

Covers key aspects of mass timber acoustical design. Companion to WoodWorks' Inventory of Acoustically-Tested Mass Timber Assemblies

Mass Timber Cost and Design Optimization Checklists

Guides coordination between designers and builders (GCs, construction managers, estimators, fabricators, installers, etc.) as they estimate and make cost-related decisions on mass timber projects

Visit woodworks.org/tools-guides/ for many more resources.

Upcoming Events

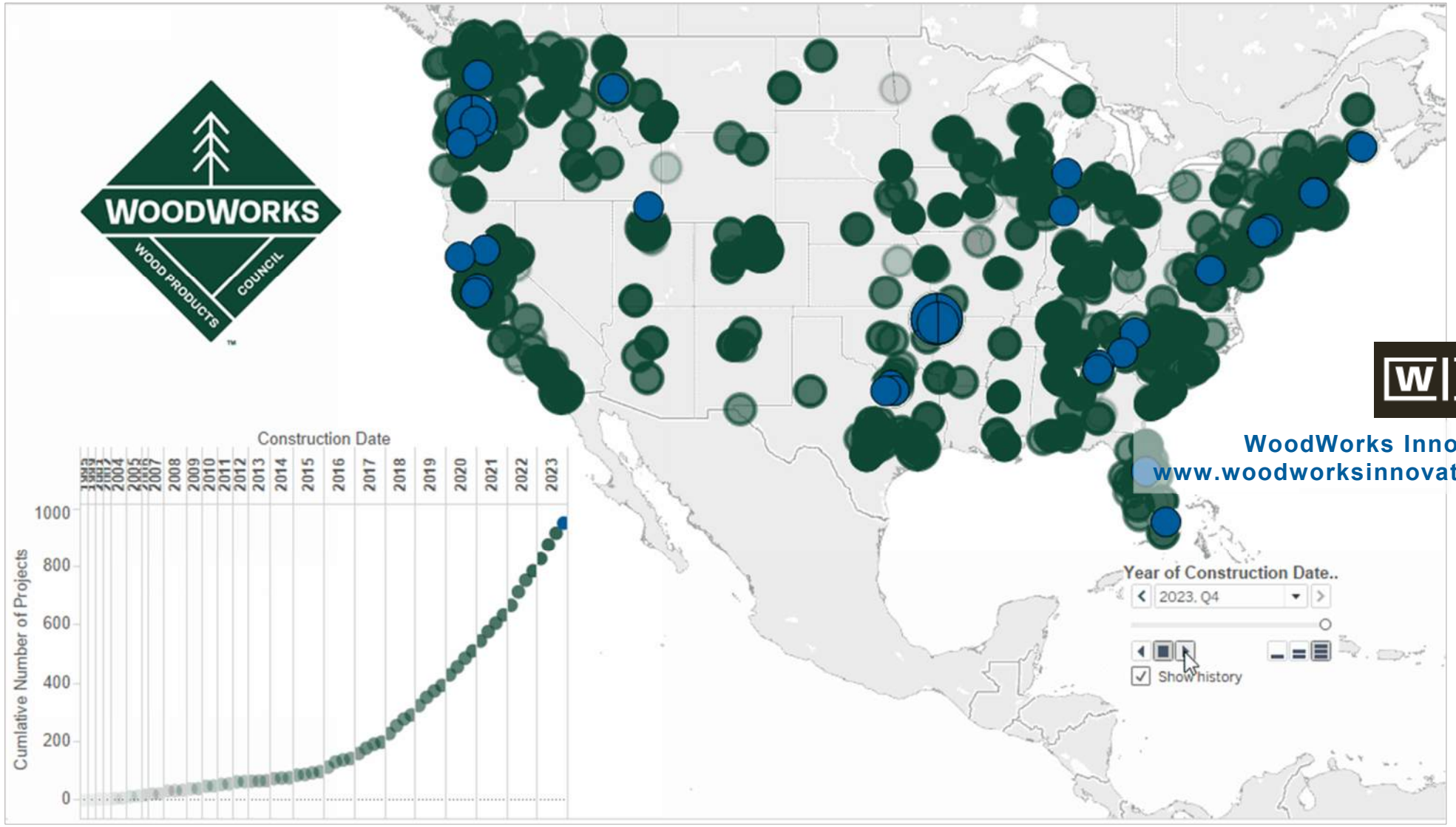
Demystifying Timber Construction Types
AIA San Francisco Series
March 7, April 11, May 9
3 Part Series 3:30pm-5:30 pm in person at AIA SF

The Financial Dynamics of Designing with Mass Timber (virtual)
April 17
1.0 AIA/CES HSW LUs, 1.0 PDH credits, 0.10 ICC credits

Visit woodworks.org/events/

Current State of Mass Timber Projects

As of **year-end 2023**, in the US, **2,035** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



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Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Approved Continuing Education

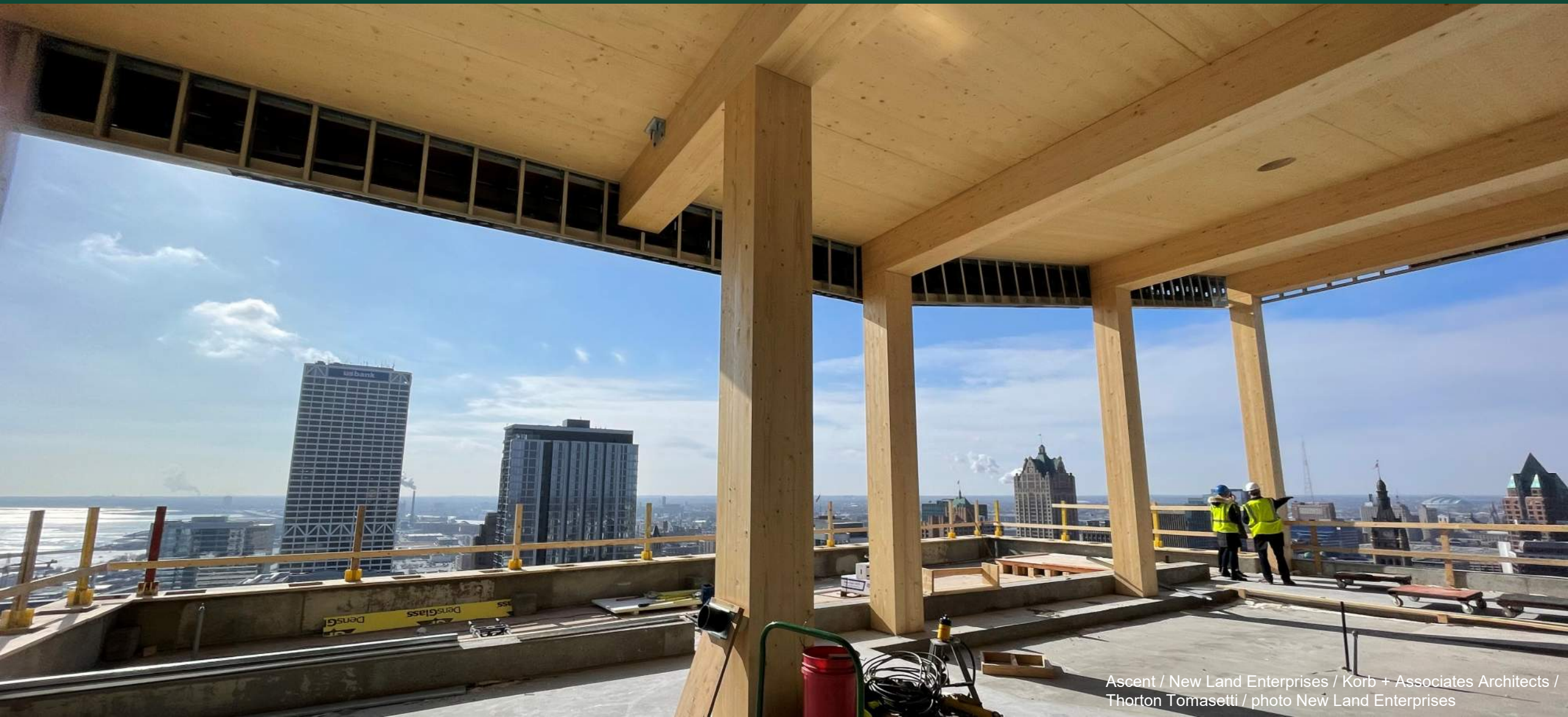
Course Description

Opportunities for using mass timber construction for new building projects have never been greater now that the International Building Code (IBC) allows up to 18 stories with these materials. However, with expanded code options, selecting the right construction type is crucial to making a project pencil. This course focuses on mid-rise mass timber construction, highlighting examples in the five- to eight-story range—including office, mixed-use, and multi-family projects. Discussion will help to inform decisions on how to incorporate mass timber based on a project's intended height, area, and occupancies. The presentation will also cover decisions that need to be made early in the design process, including grid layout, approach to achieving fire ratings, and lateral system selection.

Learning Objectives

1. Review mass timber products, framing options, and the potential benefits of utilizing mass timber in mid-rise construction.
2. Discuss the various building construction types identified in the International Building Code (IBC) and where opportunities exist for mass timber use.
3. Highlight key considerations during the design of mass timber buildings, including grid layout, fire ratings, acoustics, and lateral design.
4. Evaluate the impact of design decisions on providing cost-effective, code-compliant buildings and highlight methods of meeting project goals.

MASS TIMBER OVERVIEW

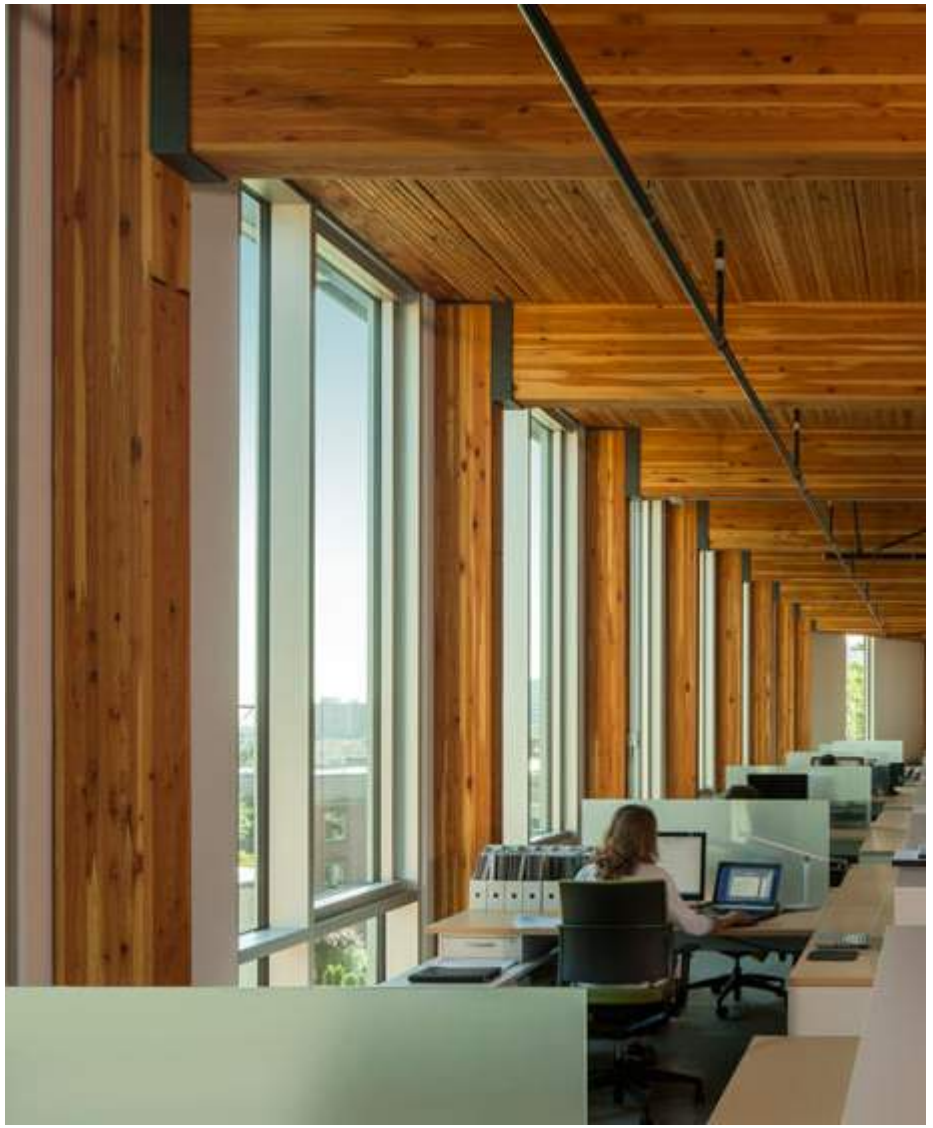


Ascent / New Land Enterprises / Korb + Associates Architects / Thorton Tomasetti / photo New Land Enterprises

Wood Construction Terminology

Light-Frame Wood
Photo: WoodWorks

Heavy Timber
Photo: Benjamin Benschneider



Mass Timber
Photo: John Stamets

Wood Construction Terminology

Glue Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo:
Freres Lumber

Photo: StructureCraft

Photo: LendLease

Photo: LEVER Architecture

Wood Construction Terminology

Dowel-Laminated Timber (DLT)

Photo: StructureCraft

Nail-Laminated Timber (NLT)

Photo: Think Wood

Glue-Laminated Timber (GLT)

Plank orientation

Photo: StructureCraft

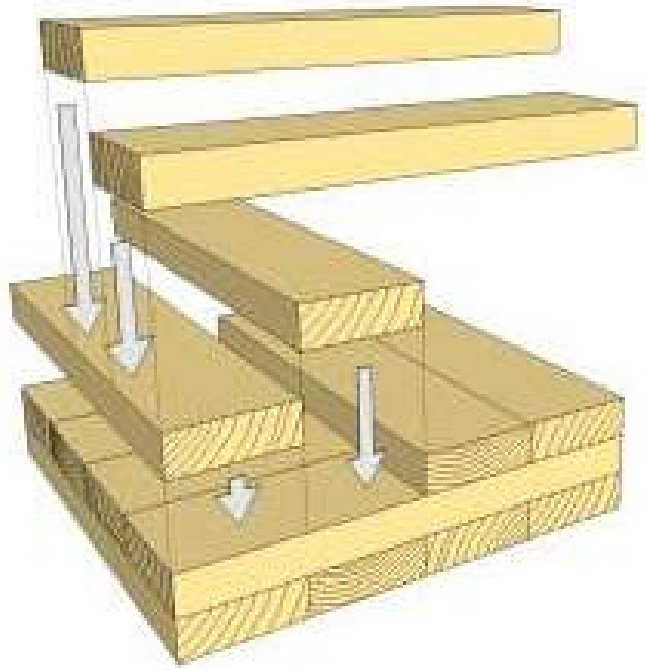
Photo: StructureCraft

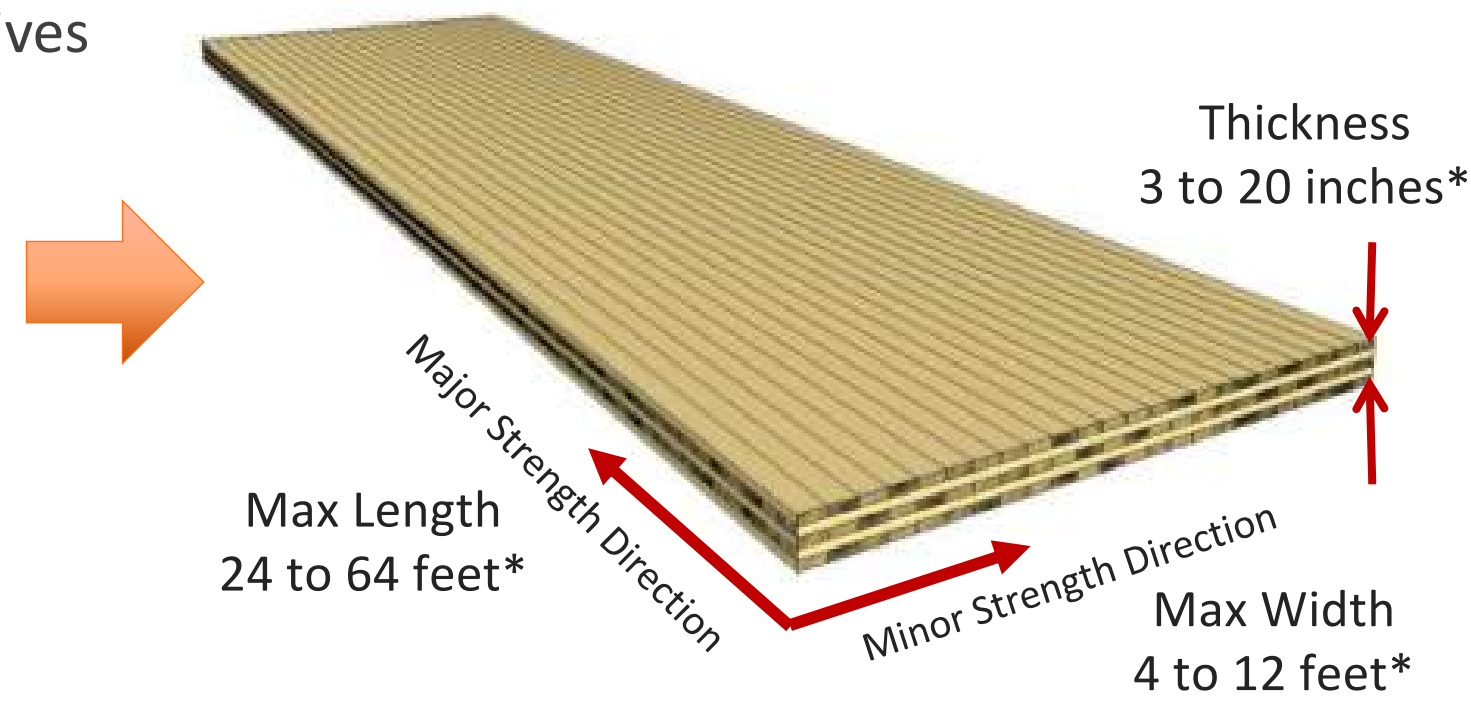
Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

What is CLT?

- 3+ layers of laminations
- Solid Sawn or Structural Composite Lumber Laminations
- Cross-Laminated Layup
- Glued with Structural Adhesives





*All dimensions are approximate.
Consult with manufacturers.

Common CLT Layups

Most Designs
Least $/sf

3-ply 3-layer

5-ply 5-layer

7-ply 7-layer

9-ply 9-layer

Mass Timber Building Options


Photo: Blaine Brownell

Post and Beam


Photo: acton ostry architects

Flat Plate


Photo: : LendLease

Honeycomb

Mass Timber Building Options

Hybrid: Light-frame

Hybrid: Steel framing

Potential Benefits	Project Goal ✓	Value Add ✓
Fast construction/shorter schedules; pre-fabricated and precise		
Exposed wood (structure is finish!) • Aesthetic value; potential for faster leasing and lease premiums; portfolio distinction • Biophilia; healthy indoor environment		
Lightweight structure, especially beneficial on sites with poor soils		
Labor shortage solutions • Small crews for timber frame erection • Utilize more entry-level laborers when MEP and fire protection systems are fully designed, coordinated and pre-planned		
Just-in-time delivery and small staging/lay-down areas; ideal for dense urban areas		
Natural, renewable material; environmentally friendly with a lighter carbon footprint		
Support healthy forests and rural economies • Mass timber can be made from relatively small-diameter trees and those affected by insects or disease; creates a market incentive for forest thinning and other landscape restoration efforts that reduce the risk of high-severity wildfires		

MASS TIMBER IN THE CODE

Central Lofts / Jones Architecture / Froelich Engineers / Photo Jones Architecture

Mass Timber in the IBC: Cross-Laminated Timber (CLT)

- CLT was first recognized in the 2015 IBC
- CLT in the 2021 IBC:
  - Chapter 2: Definitions

    [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.

  - Chapter 23: Wood

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

Which Construction Type?

- Many buildings use higher construction type than necessary
  - Traditional practice
  - Fire ratings
  - Materials
  - Cost!

Which Construction Type?

- Start with lowest common denominator and work up
- Don’t assume construction type, occupancy separation, etc. required simply because of materials or occupancies

Image: Neo Studio

Construction Types – Allowable Materials

IBC/CBC defines 5 construction types: I, II, III, IV, V
A building must be classified as one of these

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types I-B, II-A, II-B

Where does the code allow wood to be used?

- Mass Timber Roof Construction

- IBC/CBC Table 601, Footnote c:
  - In all occupancies, heavy timber complying with Section 2304.11 shall be allowed for roof construction, including primary structural frame members, where a 1-hour or less fire-resistance rating is required.

Wellesley College, Wellesley, MA

Mid-Rise Construction Types

Type III

- Exterior walls non-combustible (may be light frame FRTW)
- Interior elements any allowed by code

Type V

- All building elements any allowed by code

Types III and V can be subdivided:

- A (protected)
- B (unprotected)

Type IV (C & HT)

- All building elements mass timber or non-combustible
  - For IV-HT, interior elements may also be 1-hour FRR light-frame
  - For IV-HT, exterior walls may also be fire retardant treated (FRT) light-frame

Construction Types – Allowable Materials

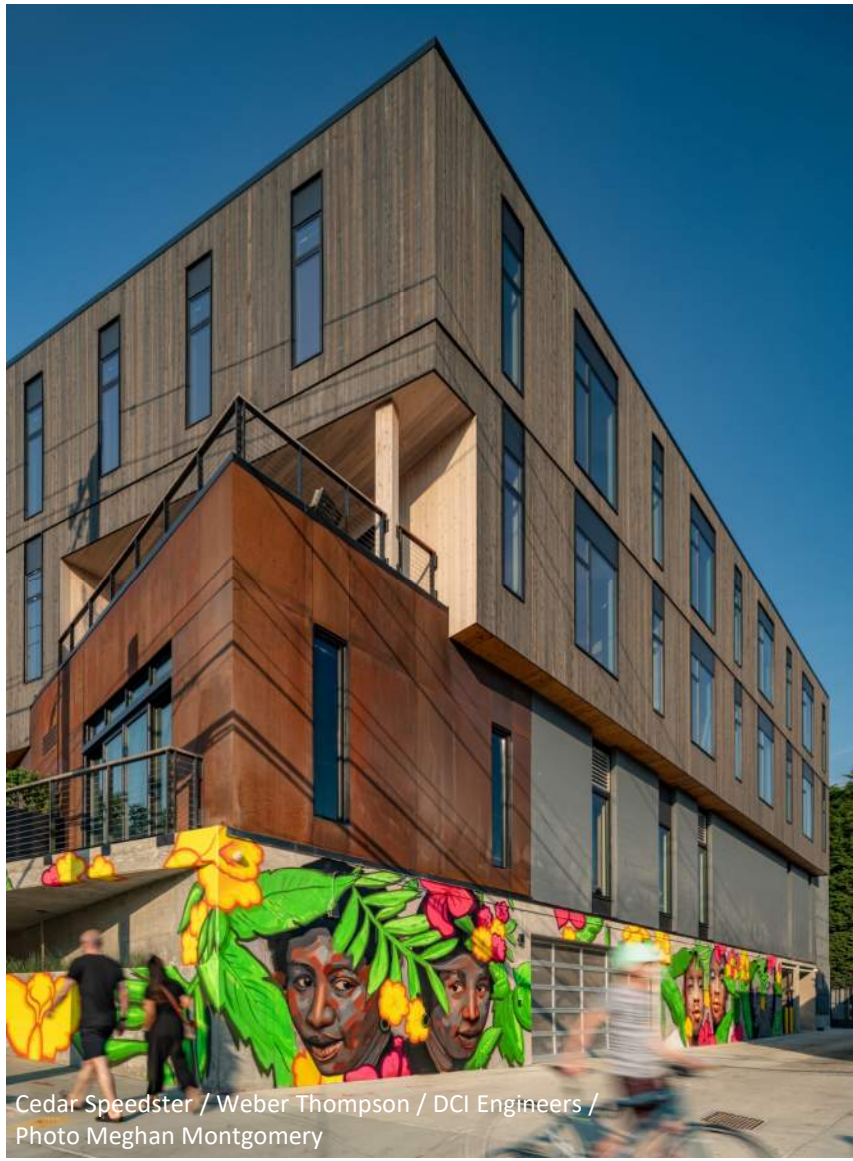
	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types V-A, V-B

IBC/CBC Section 602.5:

- Structural Elements, Exterior Walls, and Interior Walls
  - Any material permitted by code

Cedar Speedster, Seattle, WA



Cedar Speedster / Weber Thompson / DCI Engineers / Photo Meghan Montgomery

Construction Types V-A, V-B

Type V Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - Light-frame walls
  - Mass Timber

Star Lofts, Des Moines, IA

Image: Cutler Development

Construction Types V-A, V-B

Type V Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - Light-frame walls
  - Mass Timber

340+ Dixwell Ave, New Haven, CT

Image: GOA Architecture

Construction Types – Allowable Materials

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types III-A, III-B

IBC/CBC Section 602.3:

- Interior elements
  - Any material permitted by code
- Exterior walls
  - Noncombustible materials or
  - Fire-retardant-treated wood (FRTW) framing and sheathing shall be permitted within exterior wall assemblies
  - Note: CLT not allowed

Adidas Headquarters, Portland, OR

Adidas East Village Expansion / LEVER Architecture / KPFF Consulting Engineers / Photo Jeremy Bittermann

Construction Types III-A, III-B

Type III Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - FRTW light-frame walls

MSU STEM Facility, East Lansing, MI

MSU STEM Teaching and Learning Facility / Integrated Design Solutions / SDI Structures / Photo Kevin Marshall/Integrated Design Solutions

Construction Types III-A, III-B

Type III Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - FRTW light-frame walls

The Canyons, Portland, OR

The Canyons, Kaiser+Path, Cantena Consulting Engineers, Photo Jeremy Bittermann

Construction Types – Allowable Materials

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types IV-HT and IV-A, B, and C

Type IV-HT Construction:

- Interior Elements
  - Mass timber, non-combustible, or 1-hour rated light-frame walls
- Exterior Walls
  - Non-combustible
  - CLT covered at exterior face with FRTW or noncombustible sheathing
  - FRTW walls (light-frame)

The Soto, San Antonio, TX

The Soto, Hixon Properties, Lake|Flato, BOKA Powell, StructureCraft, Photo Erika Brown Edwards

Construction Type IV-A, B, and C

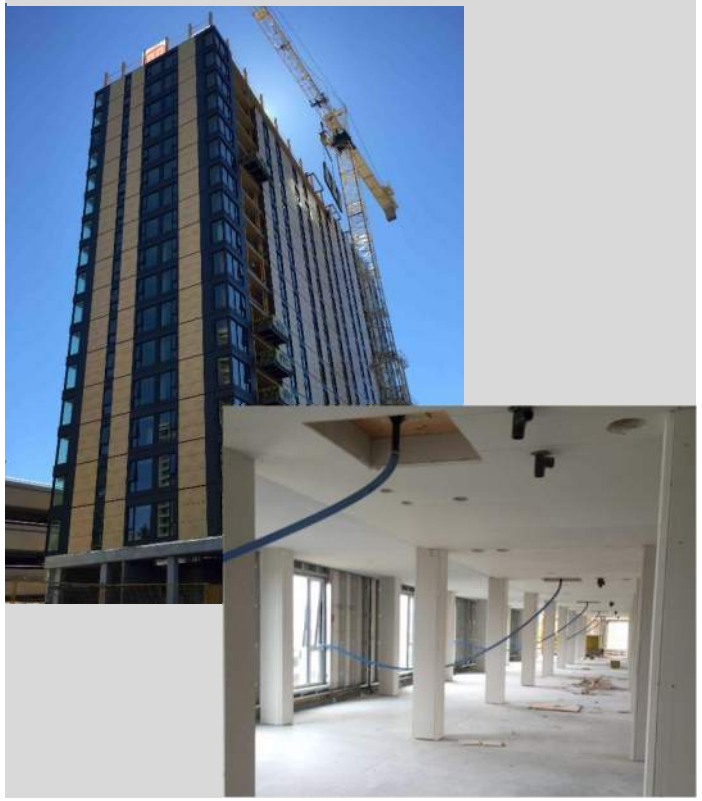
U.S. Building Codes, Tall Wood Ad Hoc Committee (2016-2018)

» Development of code change proposal for prescriptive code allowance of tall wood buildings.

Mass Timber Fire Testing at ATF Lab (2017)

Construction Types IV-A, B, and C

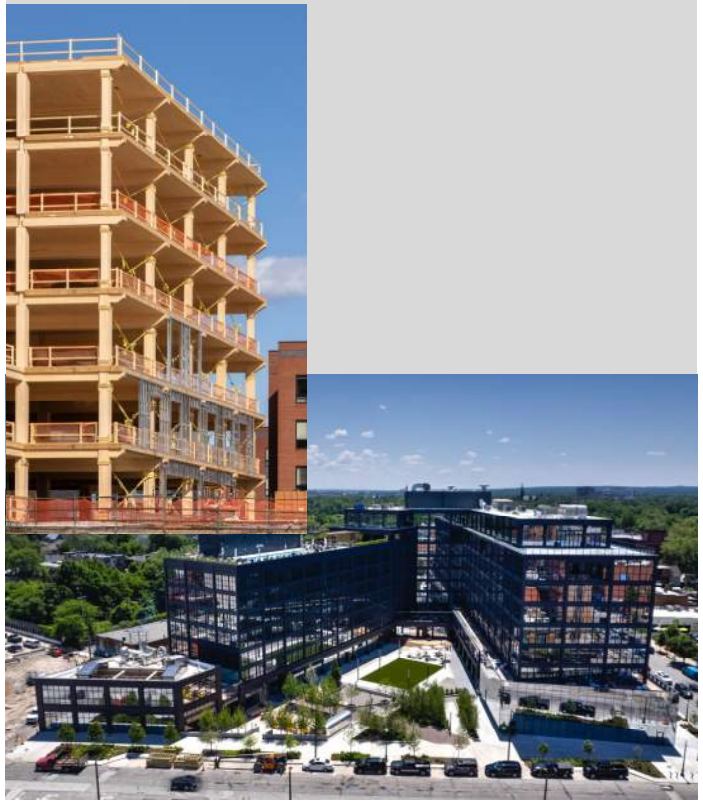
Type IV-A



Photos: Flor Projects

18 STORIES	
BUILDING HEIGHT	270’
PER STORY AREA	324,000 SF
BUILDING AREA	972,000 SF

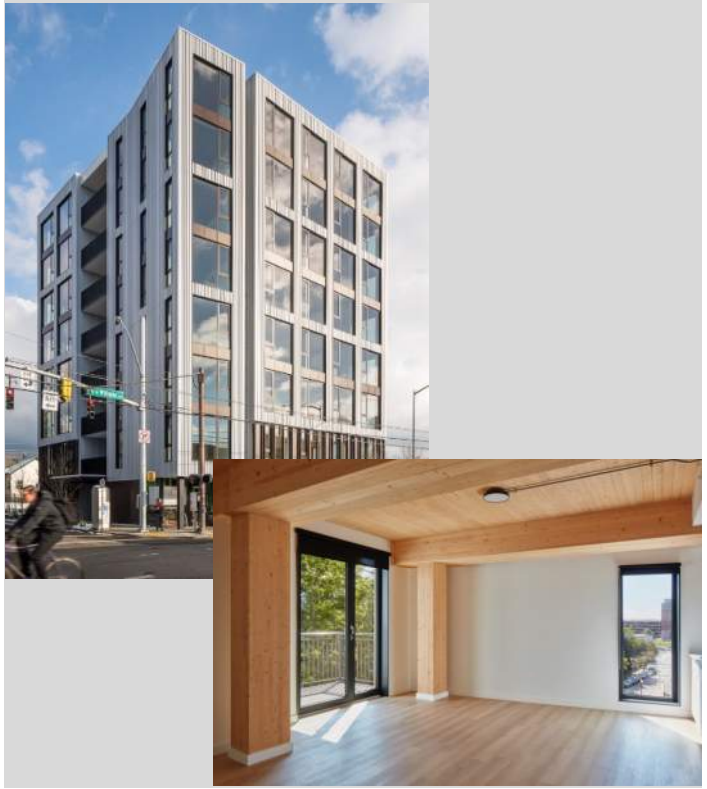
Type IV-B



Photos: ©Prakash Patel

12 STORIES	
BUILDING HEIGHT	180’
PER STORY AREA	216,000 SF
BUILDING AREA	648,000 SF

Type IV-C



Monte French Design Studio, Photos: Jane Messinger

9 STORIES	
BUILDING HEIGHT	85’
PER STORY AREA	135,000 SF
BUILDING AREA	405,000 SF

Construction Types IV-HT and IV-A, B, and C

Type IV-A, B, and C Construction:

- Interior Elements
  - Mass timber or non-combustible
  - No light frame
- Exterior Walls
  - Non-combustible
  - CLT covered at exterior face with noncombustible sheathing
  - No light frame

Heartwood, Seattle, WA

Heartwood, Atelier Jones, DCI Engineers, rendering Atelier Jones

Construction Types IV-HT and IV-A, B, and C

Type IV Minimum Dimensions (IBC/CBC Section 2304.11):

TABLE 2304.11
MINIMUM DIMENSIONS OF HEAVY TIMBER STRUCTURAL MEMBERS

		MINIMUM NOMINAL SOLID SAWN SIZE		MINIMUM GLUED-LAMINATED NET SIZE		MINIMUM STRUCTURAL COMPOSITE LUMBER NET SIZE	
SUPPORTING	HEAVY TIMBER STRUCTURAL ELEMENTS	Width, inch	Depth, inch	Width, inch	Depth, inch	Width, inch	Depth, inch
Floor loads only or combined floor and roof loads	Columns; Framed sawn or glued-laminated timber arches that spring from the floor line; Framed timber trusses	8	8	$6^{3}/_{4}$	$8^{1}/_{4}$	7	$7^{1}/_{2}$
	Wood beams and girders	6	10	5	$10^{1}/_{2}$	$5^{1}/_{4}$	$9^{1}/_{2}$
Roof loads only	Columns (roof and ceiling loads); Lower half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	8	5	$8^{1}/_{4}$	$5^{1}/_{4}$	$7^{1}/_{2}$
	Upper half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	6	5	6	$5^{1}/_{4}$	$5^{1}/_{2}$
	Framed timber trusses and other roof framing;[a] Framed or glued-laminated arches that spring from the top of walls or wall abutments	4[b]	6	3[b]	$6^{7}/_{8}$	$3^{1}/_{2}$[b]	$5^{1}/_{2}$

Which Construction Type? – Building Size & Occupancy

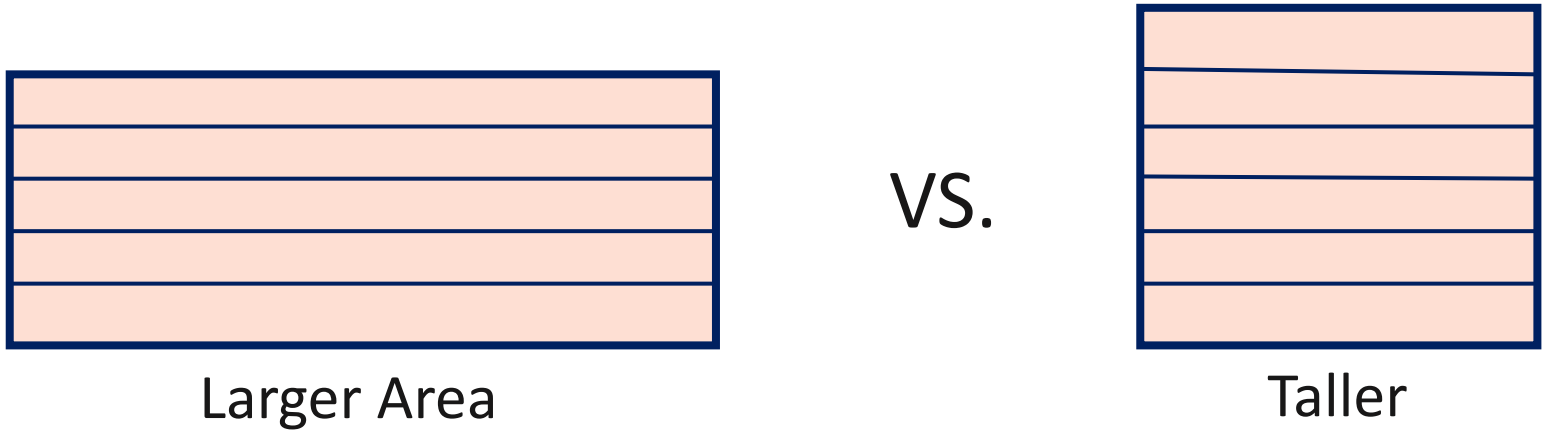
» Building size by construction type (sprinklered construction)

	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	**Allowable Height (IBC Table 504.3)**							
A, B, R	270	180	85	85	85	75	70	60
	Allowable Stories (IBC Table 505.4)							
A-2, A-3, A-4	18	12	6	4	4	3	3	2
B	18	12	9	6	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area per Story (IBC Table 506.2)							
A-2, A-3, A-4	135,000	90,000	56,250	45,000	42,000	28,500	34,500	18,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	184,500	123,000	76,875	61,500	72,000	48,000	36,000	21,000

CALIFORNIA SPECIFIC: CBC Size Limits

CBC has historically not allowed “double-dipping” for sprinkler increases of building area and height for occupancies A, E, H-4, H-5, I, R-1 and R-2

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



CALIFORNIA SPECIFIC: Which Construction Type? – Building Size & Occupancy

» Building size by construction type (sprinklered construction)

	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	**Allowable Height (CBC Table 504.3) – without area increases**							
A, B, R	270	180	85	85	85	75	70	60
	Allowable Stories (CBC Table 505.4) – without area increases							
A-2, A-3, A-4	18	12	6	4	4	3	3	2
B	18	12	9	6	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area per Story (CBC Table 506.2) – including height increases							
A-2, A-3, A-4	45,000	30,000	18,750	15,000	14,000	9,500	11,500	6,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	61,500	41,000	25,675	20,500	24,000	16,000	12,000	7,000

CALIFORNIA SPECIFIC: Which Construction Type? – Building Size & Occupancy

» Building size by construction type (sprinklered construction)

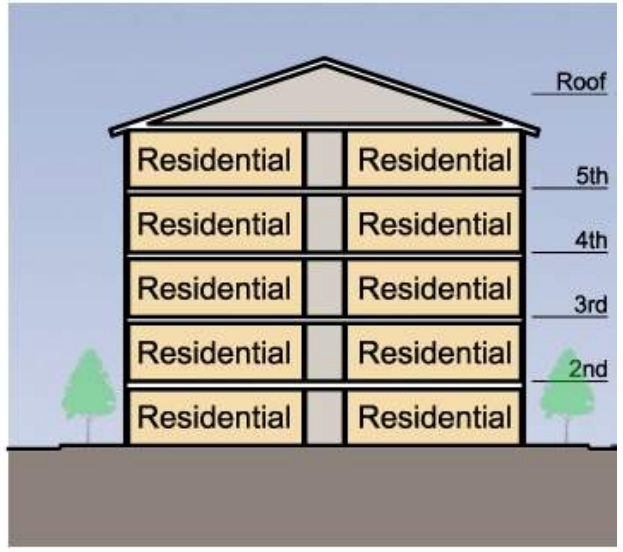
	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	**Allowable Height (CBC Table 504.3) – includes area increases**							
A, R-2	250	160	65	65	65	55	50*	40
B	270	180	85	85	85	75	70	60
	Allowable Stories (CBC Table 505.4) – includes area increases							
A-2, A-3, A-4	17	11	5	3	3	2	2	1
B	18	12	9	6	6	4	4	3
R-2	17	11	7	4	4	4	4	2
	Allowable Area per Story (CBC Table 506.2) – without height increases							
A-2, A-3, A-4	135,000	90,000	56,250	45,000	42,000	28,500	34,500	18,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	184,500	123,000	76,875	61,500	72,000	48,000	36,000	21,000

* See Table 504.3 for R-2 height increase

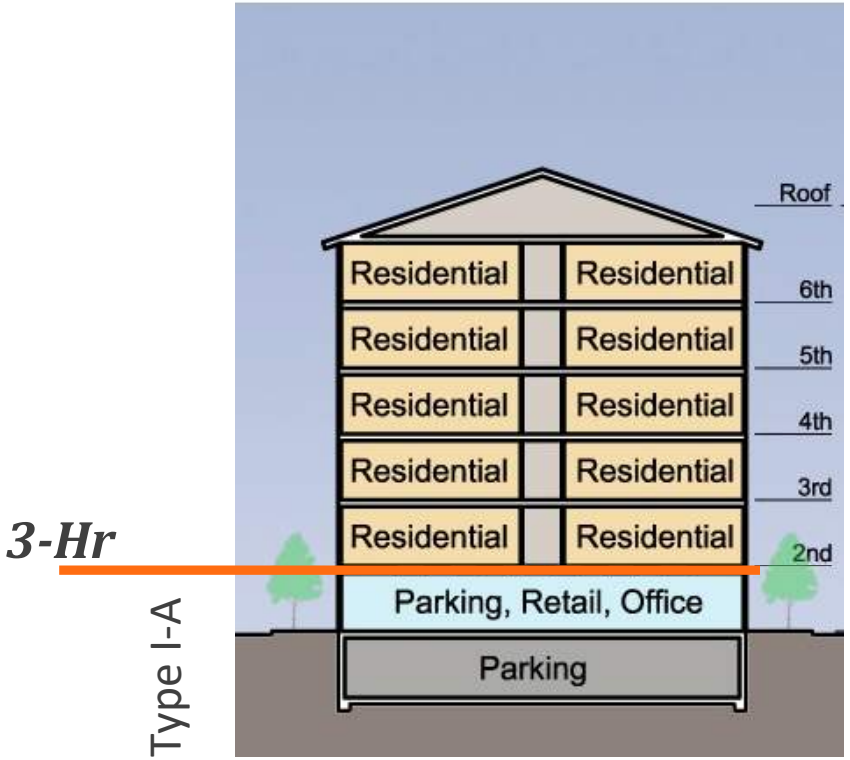
Which Construction Type? - Podium Provisions

Special provisions for podiums (IBC/CBC 510.2)

- Increases allowable stories…. not allowable building height



5 story Type III Building

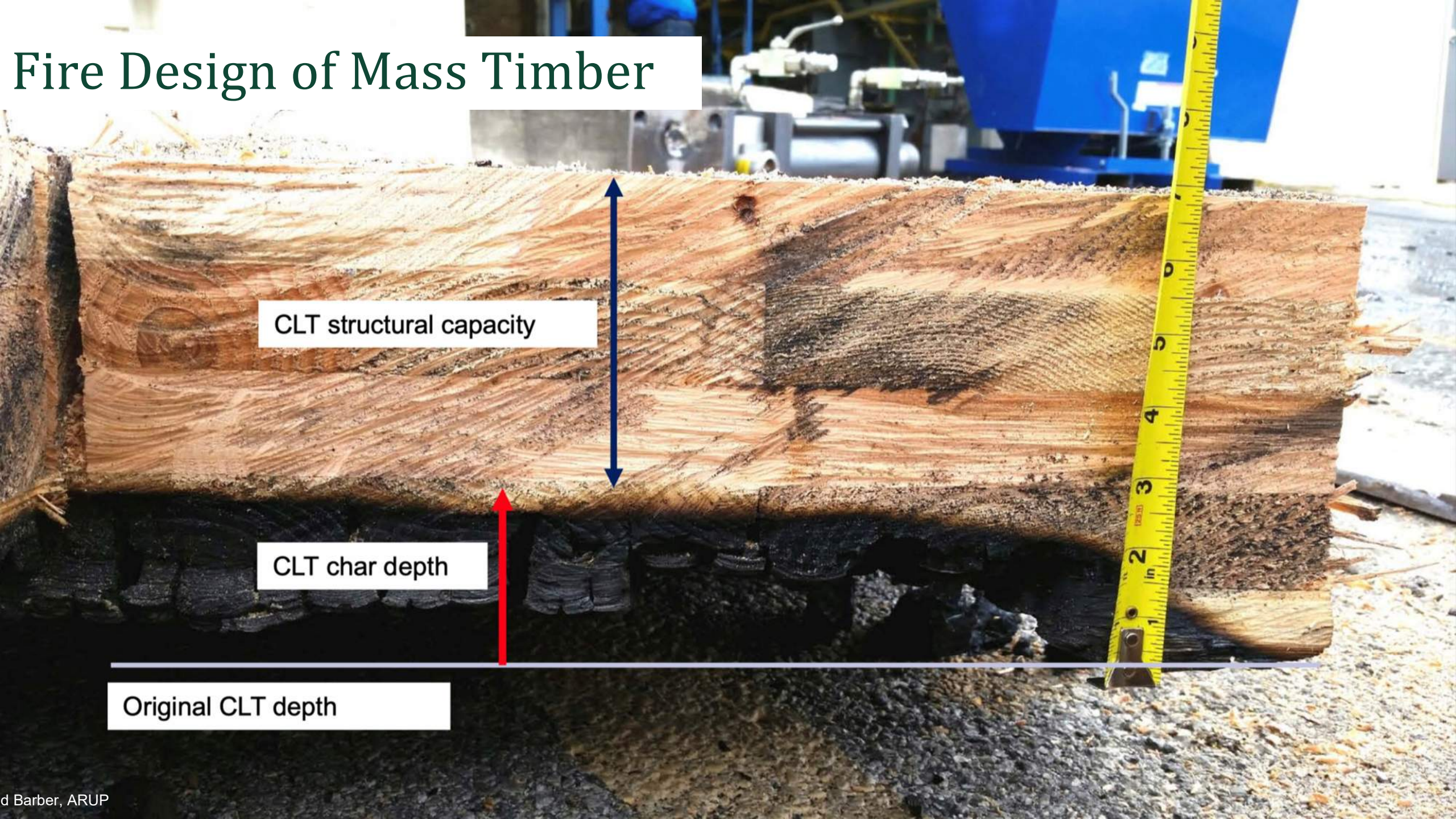


5 story Type III Building
on Top of a Type I-A Podium

Which Construction Type? – Fire Rating

Residential (R-2) Occupancy with NFPA 13 sprinklers		**IV-C**	**III-A**	**IV-HT**	**III-B**
Heights & areas	Area per story (ft^2)	76,875	72,000	61,500	48,000
	Max stories	8	5	5	5
	Max height (ft)	85	85	85	75
Rating Requirements	Primary structural frame	2-hr	1-hr	HT	0-hr
	Exterior bearing walls	2-hr	2-hr	2-hr	2-hr
	Interior bearing walls	2-hr	1-hr	1-hr or HT	0-hr
	Nonbearing exterior walls	Table 705.5			
	Nonbearing interior walls	0-hr	0-hr	2304.11.2 (1-hr or HT)	0-hr
	Floor construction	2-hr	1-hr	HT	0-hr
	Roof construction	1-hr	1-hr	HT	0-hr

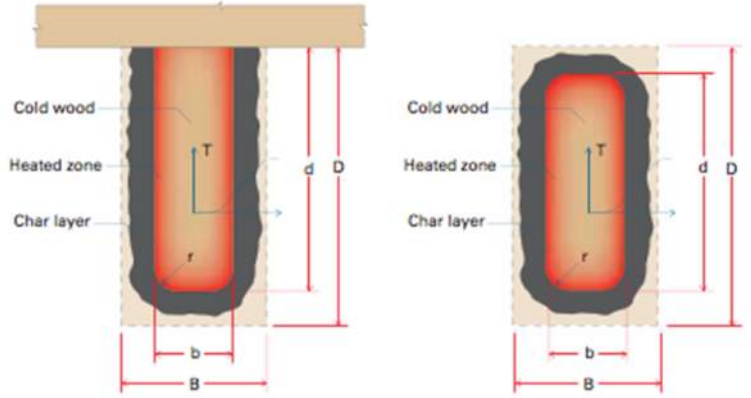
Fire Design of Mass Timber



d Barber, ARUP

Fire Design of Mass Timber

- Mass Timber char depths



Source: AWC's TR 10

- Sawn lumber, glulam, LVL, LSL, PSL

Table 16.2.1A Char Depth and Effective Char Depth (for β_n = 1.5 in./hr.)

Required Fire Resistance (hr.)	Char Depth, a_{char} (in.)	Effective Char Depth, a_{eff} (in.)
1-Hour	1.5	1.8
1½-Hour	2.1	2.5
2-Hour	2.6	3.2

Source: AWC's NDS

- CLT

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

Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (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

Source: AWC's NDS

Fire Design of Mass Timber

- Construction Type dictates fire resistance rating (FRR)

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[a]	1	0
Nonbearing walls and partitions Exterior					See Table 705.5							
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1½	1	1	HT	1[b,c]	0

Source: 2021 IBC

Dwelling Unit Separation Requirements

IBC/CBC 708.3 (711 for horizontal assembly reqs):

Fire-resistance = 1 hour

except = 0.5 hour in IIB, IIIB and VB

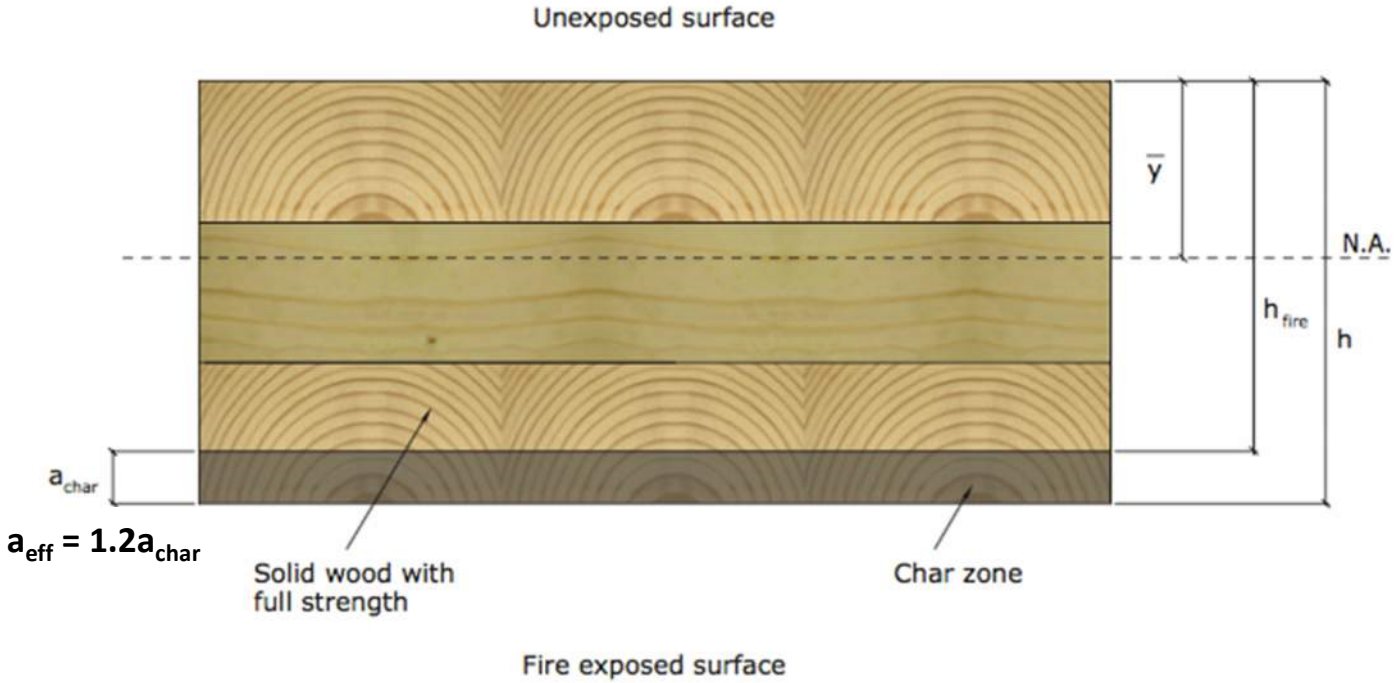
708.3 Fire-resistance rating. *Fire partitions* shall have a *fire-resistance rating* of not less than 1 hour.

Exceptions:

1. Corridor walls permitted to have a $^1/_2$-hour *fire-resistance rating* by Table 1020.1.
2. *Dwelling unit* and *sleeping unit* separations in buildings of Types IIB, IIIB and VB construction shall have *fire-resistance ratings* of not less than $^1/_2$ hour in buildings equipped throughout with an *automatic sprinkler system* in accordance with Section 903.3.1.1.

Fire Design of Mass Timber

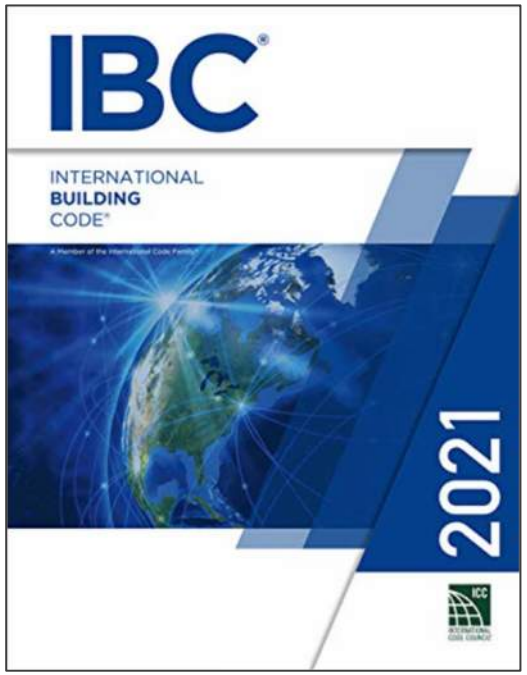
- Demonstrating FRR of mass timber:
  - 1. Calculations in accordance with IBC/CBC 722 (NDS Chapter 16)
  - 2. Tests in accordance with ASTM E119

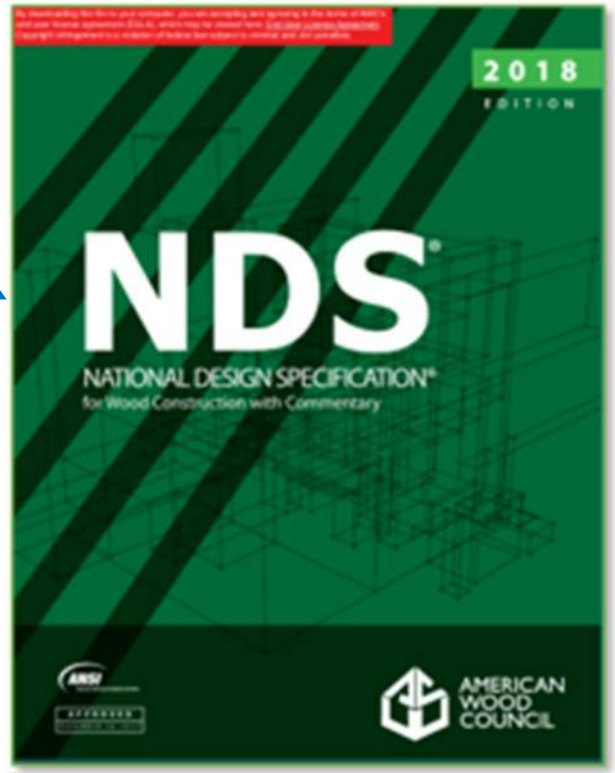


Fire Design of Mass Timber

Calculated FRR of Exposed MT:

» IBC to NDS code compliance path





Code Path for Exposed Wood Fire-Resistance Calculations

IBC 703.2.2
Methods for determining fire resistance

- Prescriptive designs per IBC 721.1
- ***Calculations in accordance with IBC 722***
- Fire-resistance designs documented in sources
- Engineering analysis based on a comparison
- Alternate protection methods as allowed by 104.11

IBC 722
Calculated Fire Resistance

"The calculated *fire resistance* of exposed wood members and wood decking shall be permitted in accordance with **Chapter 16 of ANSI/AWC National Design Specification for Wood Construction (NDS)**

NDS Chapter 16
Fire Design of Wood Members

- Limited to calculating fire resistance up to 2 hours
- Char depth varies based on exposure time (i.e., fire-resistance rating), product type and lamination thickness. Equations and tables are provided.
- TR 10 and NDS commentary are helpful in implementing permitted calculations.

Fire Design of Mass Timber

WoodWorks Inventory of Fire Tested Mass Timber Assemblies

Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies

WoodWorks™ WOOD PRODUCTS COUNCIL

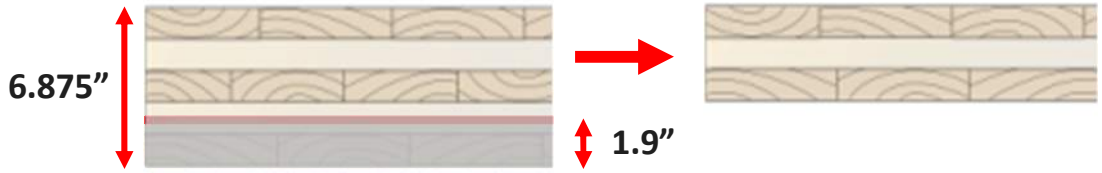
CLT Panel	Manufacturer	CLT Grade or Major x Minor Grade	Ceiling Protection	Panel Connection in Test	Floor Topping	Load Rating	Fire Resistance Achieved (Hours)	Source	Testing Lab
3-ply CLT (114mm 4.488 in)	Nordic	SPF 1650 Fb 1.5E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 50% Moment Capactiy	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X Gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool beween Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1 M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Grete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap & Topside Spline	2" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1950 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 59% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Unreduced 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced 101% Moment Capacity	2.5	1 (Test 7)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	SmartLam	SL-V4	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 4)	Western Fire Center 10/26/2016
5-ply CLT (175mm 6.875")	SmartLam	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 5)	Western Fire Center 10/28/2016

Fire Design of Mass Timber

- Fire Resistance Ratings (FRR)
  - Thinner panels (i.e. 3-ply) can be difficult to achieve 1+ hour FRR
  - 5-ply CLT panels can usually achieve 1- or 2-hour FRR
  - Construction Type -> FRR -> Member size -> Grid (order as needed)

Panel	Example Floor Span Ranges
3-ply CLT (4-1/8" thick)	Up to 12 ft
5-ply CLT (6-7/8" thick)	14 to 17 ft
7-ply CLT (9-5/8")	17 to 21 ft
2x4 NLT	Up to 12 ft
2x6 NLT	10 to 17 ft
2x8 NLT	14 to 21 ft
5" MPP	10 to 15 ft

3 ply (after 1-hour rating)



5 ply (after 1-hour rating)

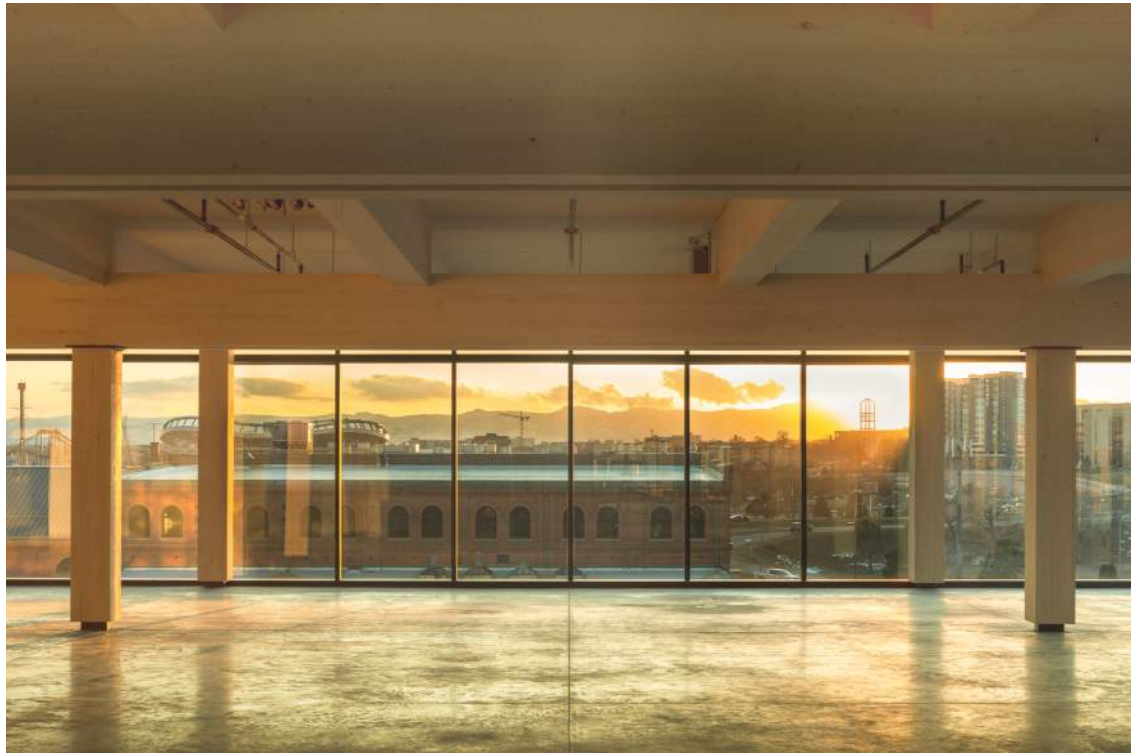
Structural Grid

- 0-Hour FRR: Consider 3-ply panel
  - Efficient spans: 10-12 feet
  - Efficient grids:
    - **20’ x 20’ (1 purlin)**
    - to 30’ x 30’ (2 purlins)

Albina Yard, Portland, OR
Type III-B Construction
20x20 Grid, 1 purlin per bay
3-ply CLT
Image: Lever Architecture

Structural Grid

- 0-Hour FRR: Consider 3-ply panel
  - Efficient spans: 10-12 feet
  - Efficient grids:
    - 20’ x 20’ (1 purlin)
    - to **30’ x 30’ (2 purlins)**



Platte Fifteen, Denver, CO
Type III-B Construction
30x30 Grid, 2 purlins per bay
3-ply CLT
Image: JC Buck

Structural Grid

- 1- or 2-Hour FRR: Likely 5-ply panel
  - Efficient spans: 14-17 feet
  - Efficient grids:
    - **15’ x 30’ (no purlins)**
    - to 30’ x 30’ (1 purlin)

First Tech Credit Union, Hillsboro, OR
Type III-A Construction
12x32 Grid, One-Way Beams
5-ply (5.5”) CLT
Image: Swinerton

Structural Grid

- 1- or 2-Hour FRR: Likely 5-ply panel
  - Efficient spans: 14-17 feet
  - Efficient grids:
    - 15’ x 30’ (no purlins)
    - to **30’ x 30’ (1 purlin)**

Clay Creative, Portland, OR
Type III-A Construction
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie

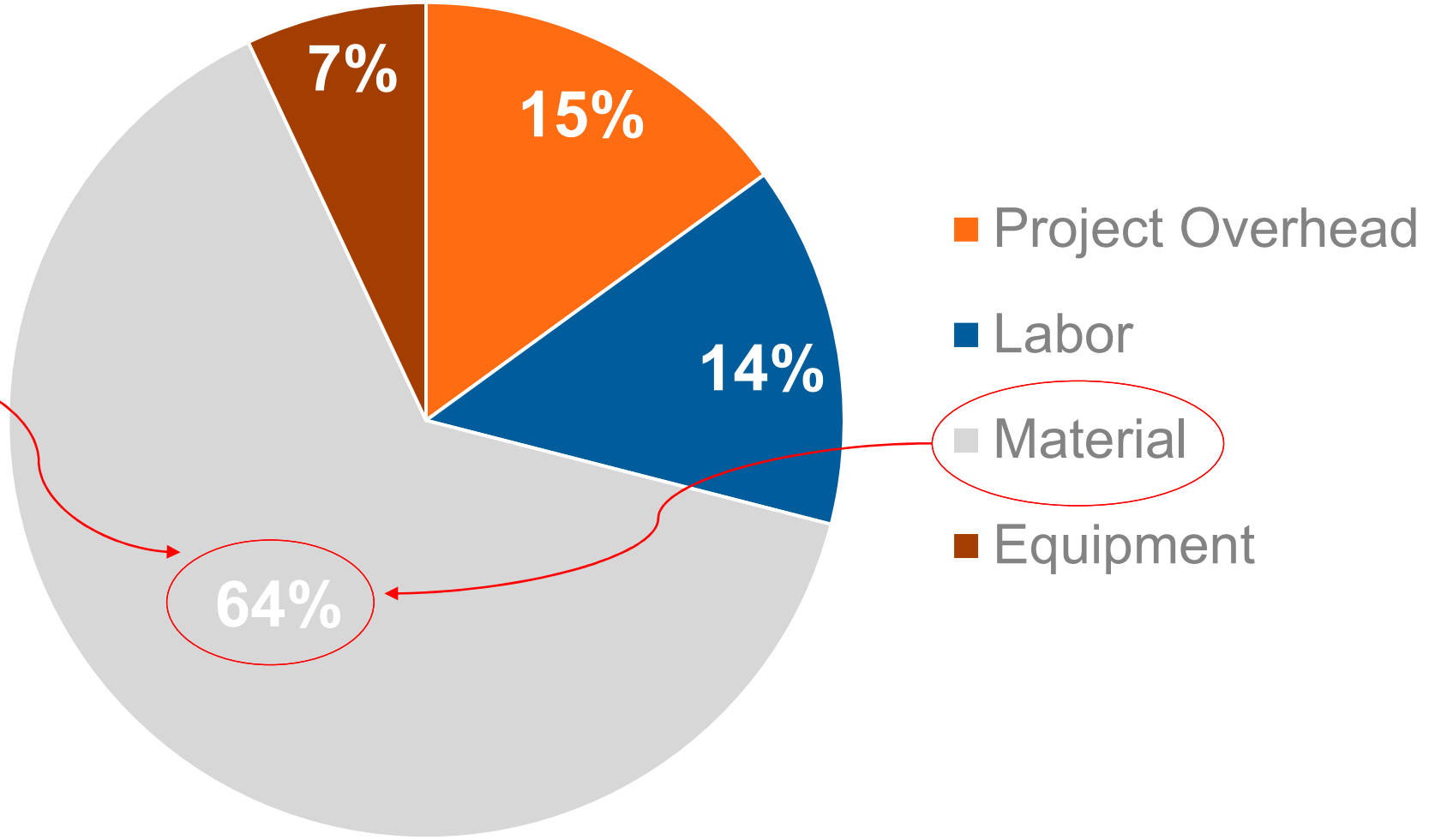
Structural Grid - Panels

- Why so much focus on panel thickness?

Structural Grid - Panels

» Typical Mass Timber Package Costs

Panels are the biggest part of the biggest piece of the cost pie



Source: Swinerton

Structural Grid - Panels

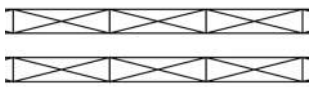
» Cost and Construction Type – Panel selection

TABLE 601

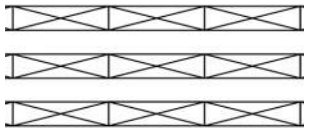
Fire Resistance Rating Requirements for Building Elements (Hours)

Building Element	I-A	I-B	III-A	III-B	IV-A	IV-B	IV-C	IV-HT	V-A	V-B
Primary Structural Frame	3*	2*	1	0	3*	2	2	HT	1	0
Ext. Bearing Walls	3*	2*	2	2	3*	2	2	2	1	0
Int. Bearing Walls	3*	2*	1	0	3*	2	2	1/HT	1	0
Floor Construction	2	2*	1	0	2	2	2	HT	1	0
Roof Construction	1.5*	1*	1	0	1.5	1	1	HT	1	0
Exposed Mass Timber Elements					None	20-40%	Most	All		

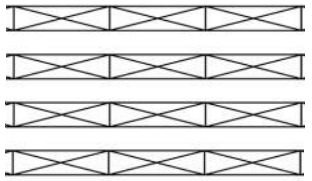
Baseline
0hr & HT



+$10/SF
1hr & maybe 2hr



+$12-15/SF
2hr FRR



Cost Source: Swinerton

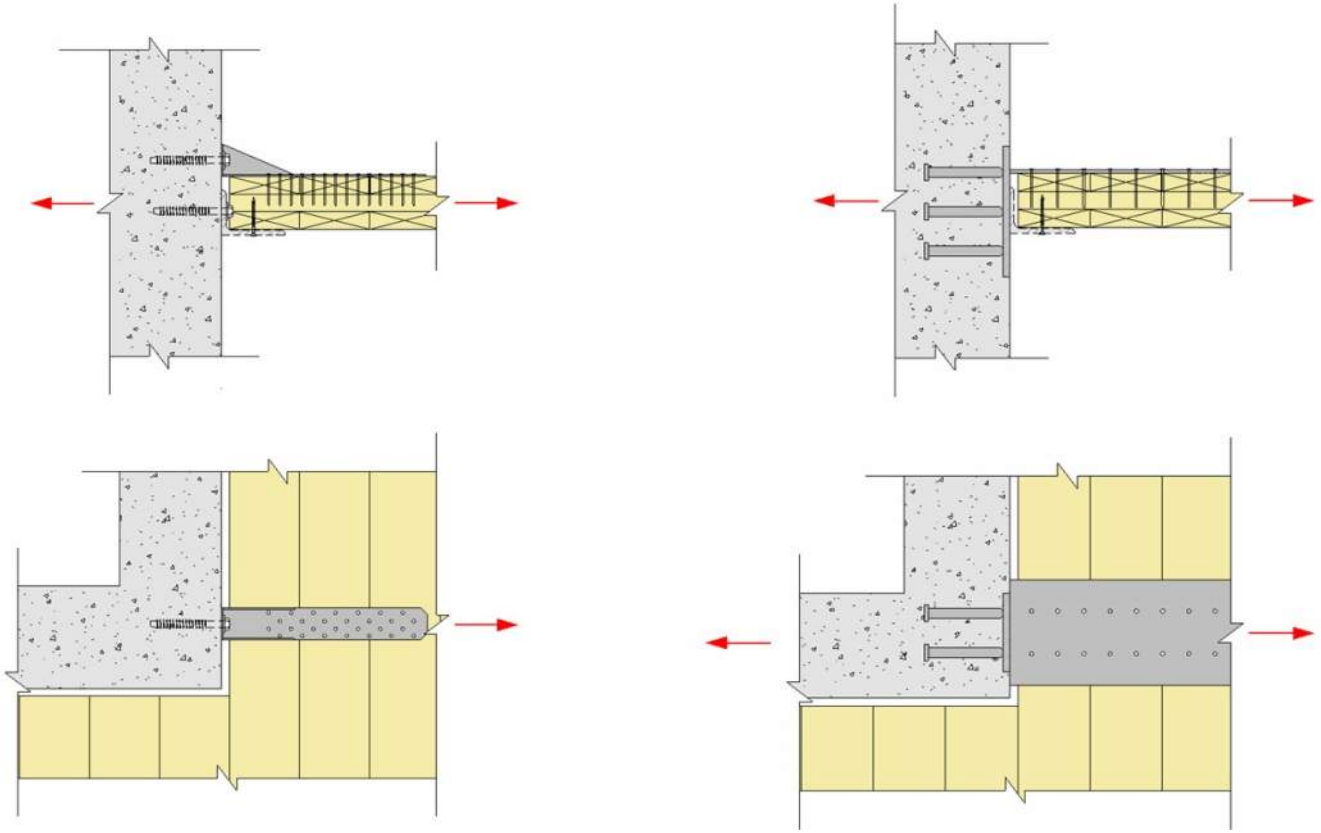
*These values can be reduced based on certain conditions in IBC 403.2.1, which do not apply to Type IV buildings.

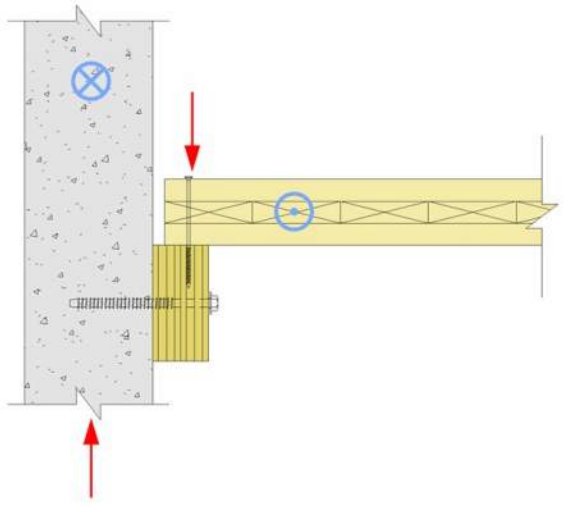
LATERAL DESIGN OPTIONS

Lateral System Options – Concrete Shear Wall

Lateral System Options – Concrete Shear Wall

- Connections to concrete core
  - Tolerances & adjustability
  - Drag / collector forces

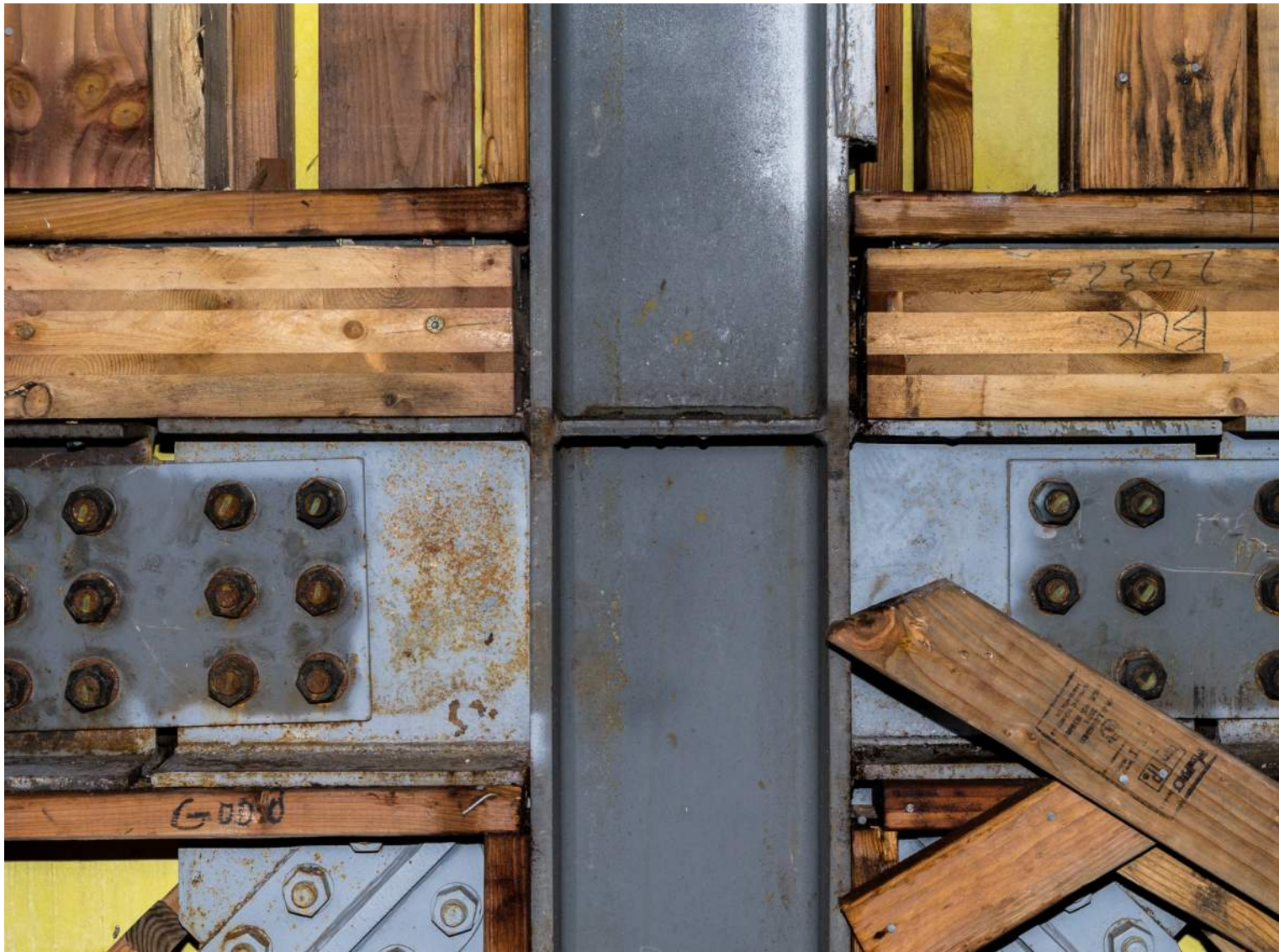




Lateral System Options – Steel Braced Frame

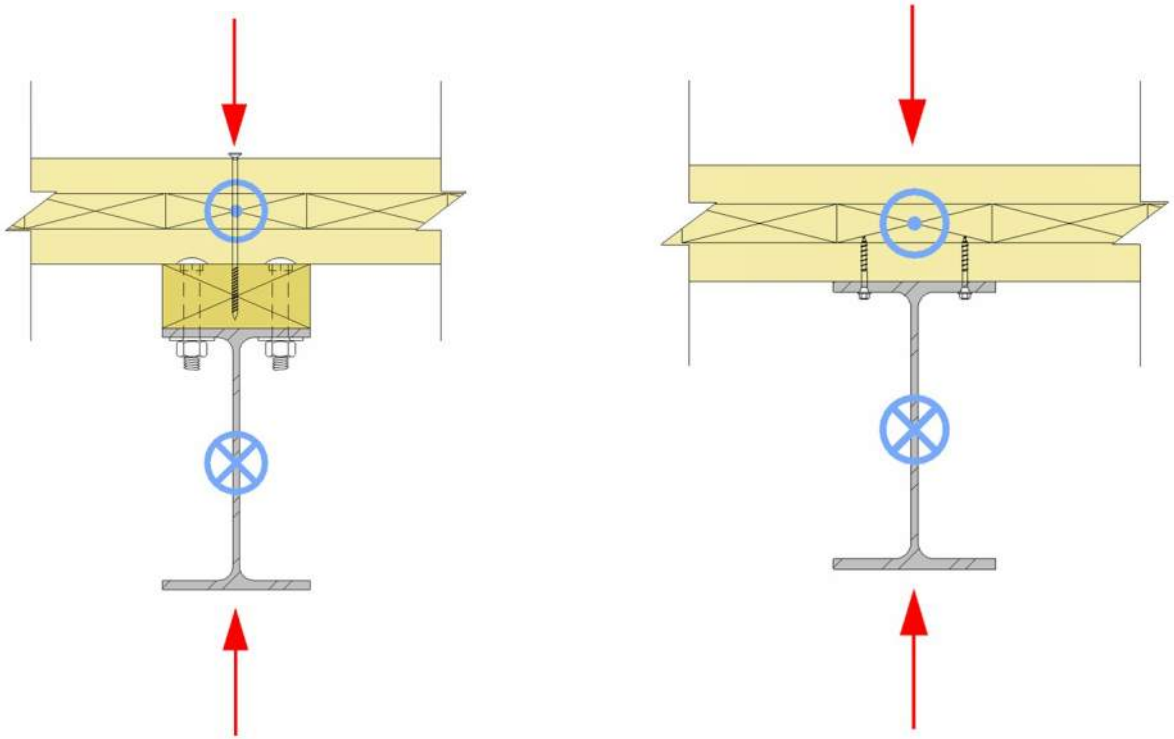
- Steel Braced Frame

Photos: Marcus Kauffmann, ODF



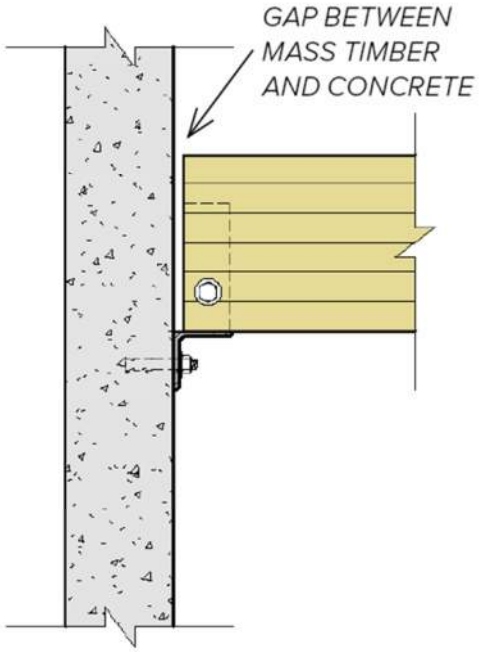
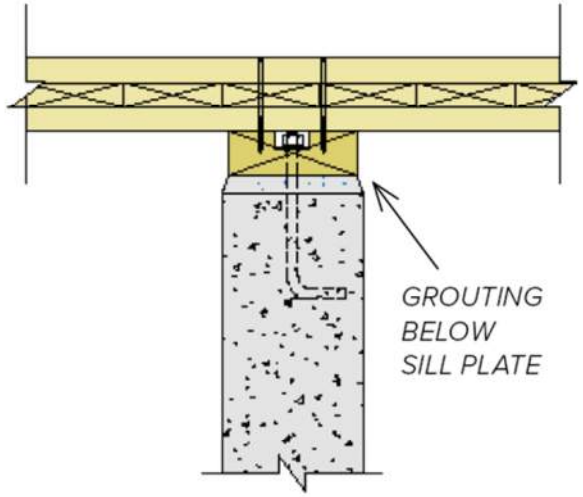
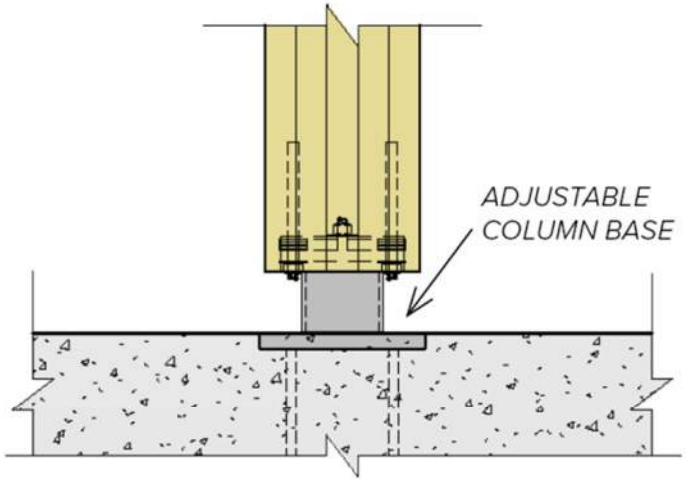
Lateral System Options – Steel Braced Frame

- Connections to steel frame
  - Tolerances & adjustability
  - Consider temperature fluctuations
  - Rust staining (paint the steel!)



Photos: Marcus Kauffmann, ODF

Tolerance Solutions

Solution	**Gap Between Mass Timber Beam and Concrete Wall**	**Grouting Below Sill Plate at Mass Timber Panel to Concrete Wall**	**Adjustable Column Base at Mass Timber Column to Concrete**
Connection example			
	Beam Perpendicular to Wall Connected to Face of Wall	Panel Bears at Top of Wall	Column Bears on Concrete with Adjustable Standoff Base

Lateral System Options – Light-Frame Wood Shear Walls

- Light Frame Wood Shear Walls

Credit: KL&A Engineers & Builders

Lateral System Options – Light-Frame Wood Shear Walls

- Code compliance
- Standard of construction practice well know
- Limited to 65’ shear wall height, 85’ overall building height (Type III-A)

Lateral System Options – Platform Framed CLT Shear Walls

2021 SDPWS Update

Platform Frame CLT Shear Walls

Prescribed nailed metal plate connectors

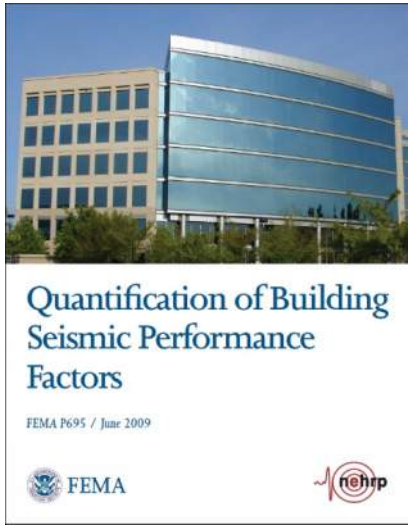
Panel aspect ratio, h:b_p from 2:1 to 4:1

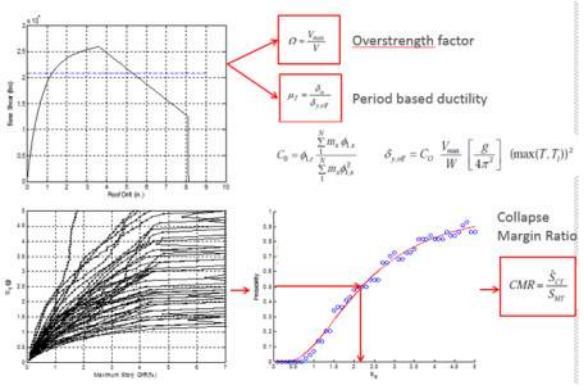
2022 ASCE 7 Update

Include Platform Frame CLT Shear Walls

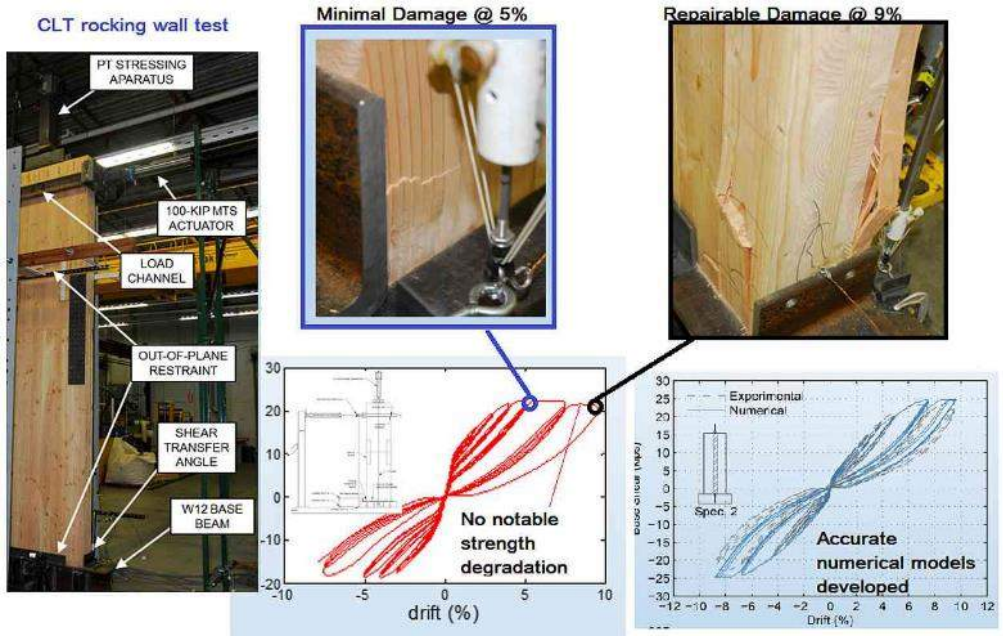
R = 3 to 4

65 ft height limit – all Seismic Design Categories





Lateral System Options – CLT Rocking Shear Walls



Source: S. PEI et al. http://nheritallwood.mines.edu/

Lateral System Options – Code Permitted Options

	Max Height	Lateral Systems Permitted by Construction Type			
		Type IV-C	Type IV-HT	Type III (A & B)	Type V (A & B)
Concrete Shear Wall	> 85’	✓	✓	✓	✓
Steel Braced Frame	> 85’	✓	✓	✓	✓
Light Frame Wood Shear Wall	≤ 65’ (SDC D,E,F) 85’ (SDC B,C)	✗	✓ (FRTW at exterior, ≥1-hr FRR at interior)	✓ (FRTW at exterior)	✓
Platform CLT Shear Wall	≤ 65’ (SDPWS 2021 & ASCE 7-22)	✓ (shafts require noncombustible covering)	✓	✓ (interior walls only)	✓

Acoustics & Sound Control

Code requirements only address residential occupancies:

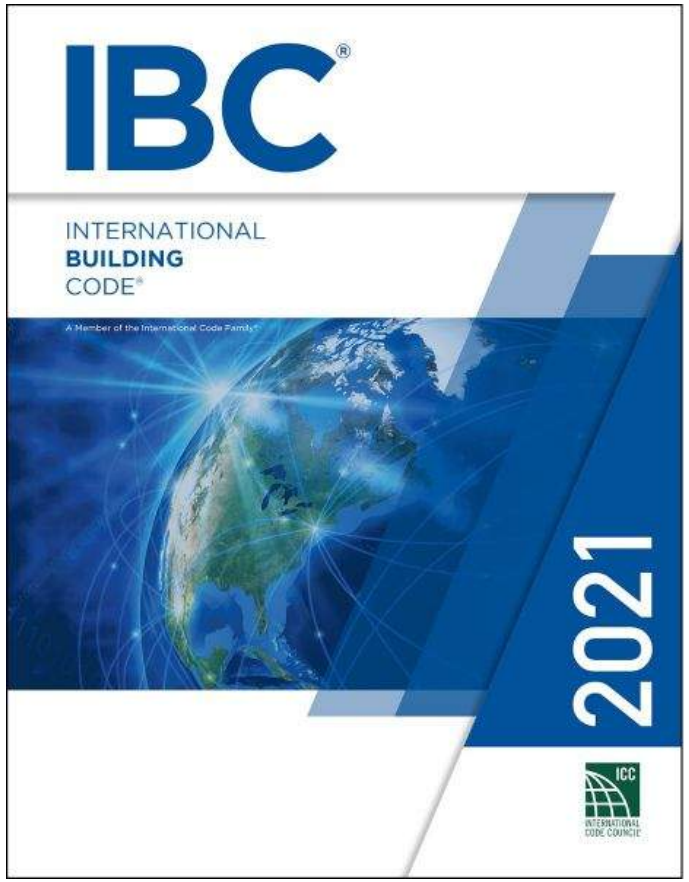
For unit to unit or unit to public or service areas:

Min. STC of 50 (45 if field tested):

- Walls, Partitions, and Floor/Ceiling Assemblies

Min. IIC of 50 (45 if field tested) for:

- Floor/Ceiling Assemblies



Acoustics & Sound Control

TABLE 1:

Examples of Acoustically-Tested Mass Timber Panels

Mass Timber Panel	Thickness	STC Rating	IIC Rating
3-ply CLT wall[4]	3.07"	33	N/A
5-ply CLT wall[4]	6.875"	38	N/A
5-ply CLT floor[5]	5.1875"	39	22
5-ply CLT floor[4]	6.875"	41	25
7-ply CLT floor[4]	9.65"	44	30
2x4 NLT wall[6]	3-1/2" bare NLT 4-1/4" with 3/4" plywood	24 bare NLT 29 with 3/4" plywood	N/A
2x6 NLT wall[6]	5-1/2" bare NLT 6-1/4" with 3/4" plywood	22 bare NLT 31 with 3/4" plywood	N/A
2x6 NLT floor + 1/2" plywood[2]	6" with 1/2" plywood	34	33

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks[7]

Acoustics & Sound Control

Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5” to 4” thick concrete/gypcrete topping
- Acoustical mat
- Mass timber floor panels

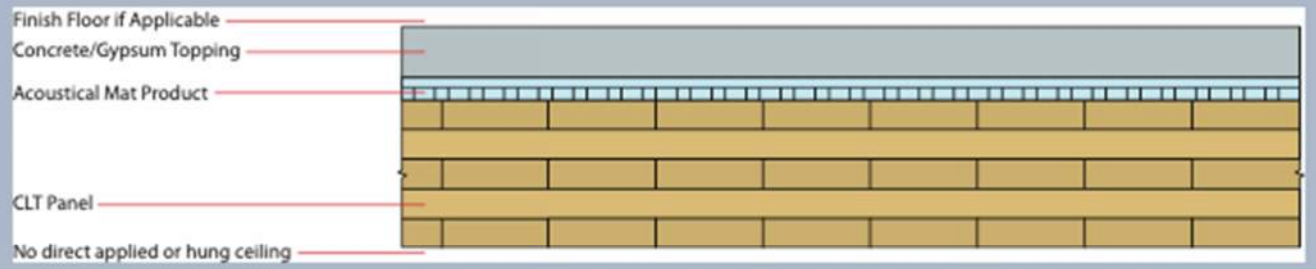
Credit: AcoustiTECH

Acoustics & Sound Control

Inventory of Tested Assemblies

Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed

WoodWorks WOOD PRODUCTS COUNCIL

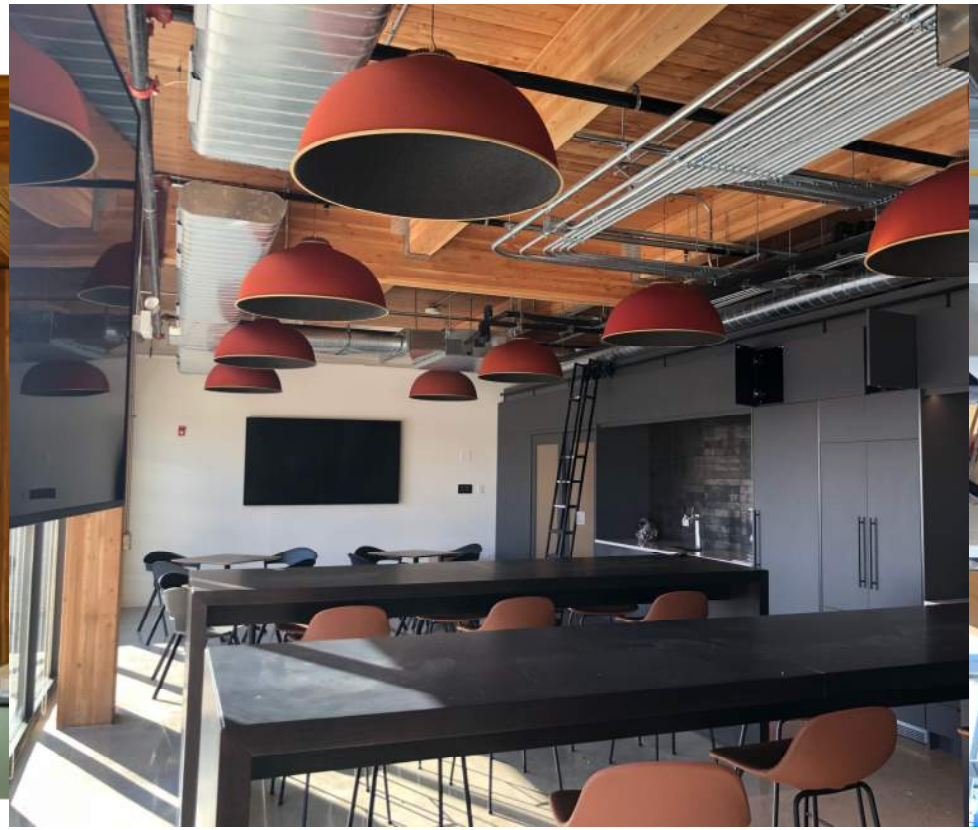


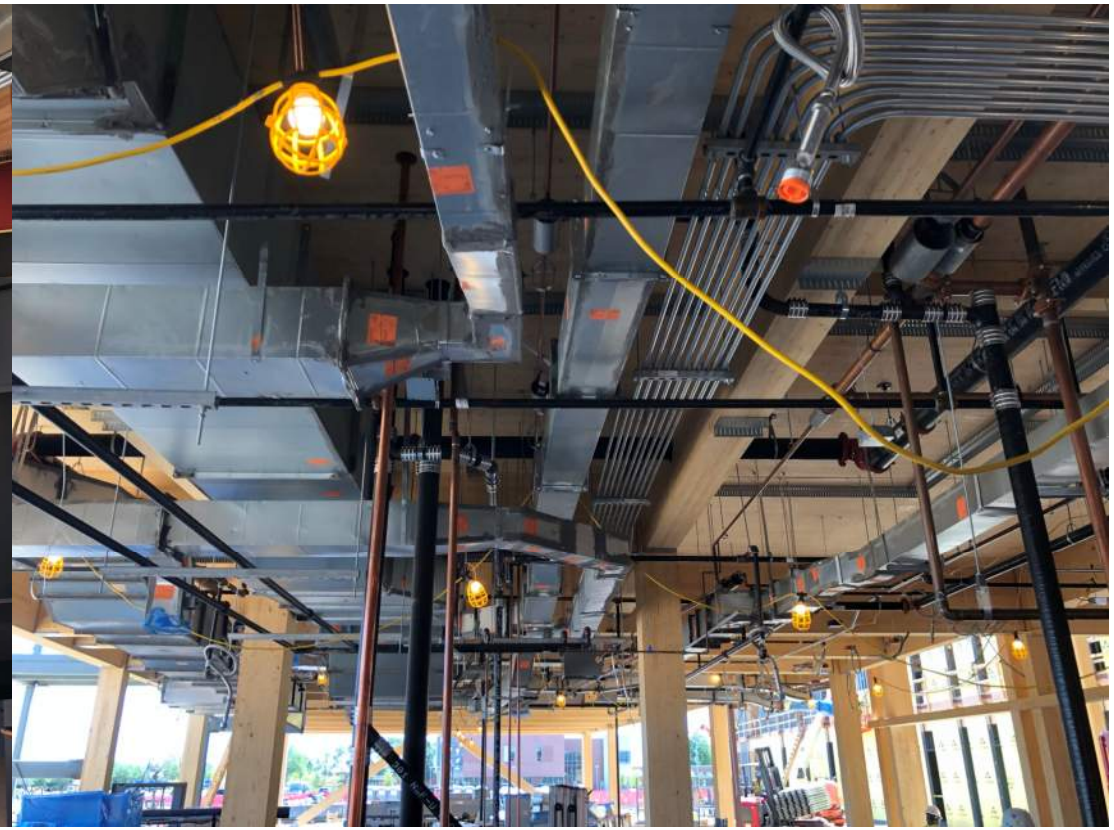
CLT Panel	Concrete/Gypsum Topping	Acoustical Mat Product Between CLT and Topping	Finish Floor	STC[1]	IIC[1]	Source
CLT 5-ply (6.875")	1-1/2" Gyp-Crete®	Maxxon Acousti-Mat® 3/4	None	47[2] ASTC	47[2] AIIC	1
			LVT	-	49[2] AIIC	
			Carpet + Pad	-	75[2] AIIC	
			LVT on Acousti-Top®	-	52[2] AIIC	
			Eng Wood on Acousti-Top®	-	51[2] AIIC	
		Maxxon Acousti-Mat® ¾ Premium	None	49[2] ASTC	45[2] AIIC	
			LVT	-	47[2] AIIC	
			LVT on Acousti-Top®	-	49[2] AIIC	
	1-1/2" Levelrock®	USG SAM N25 Ultra	None	45[6]	39[6]	15
			LVT	48[6]	47[6]	16
			LVT Plus	48[6]	49[6]	58
			Eng Wood	47[6]	47[6]	59
			Carpet + Pad	45[6]	67[6]	60
			Ceramic Tile	50[6]	46[6]	61
			None	45[6]	42[6]	15
			LVT	48[6]	44[6]	16

MEP Layout & Integration

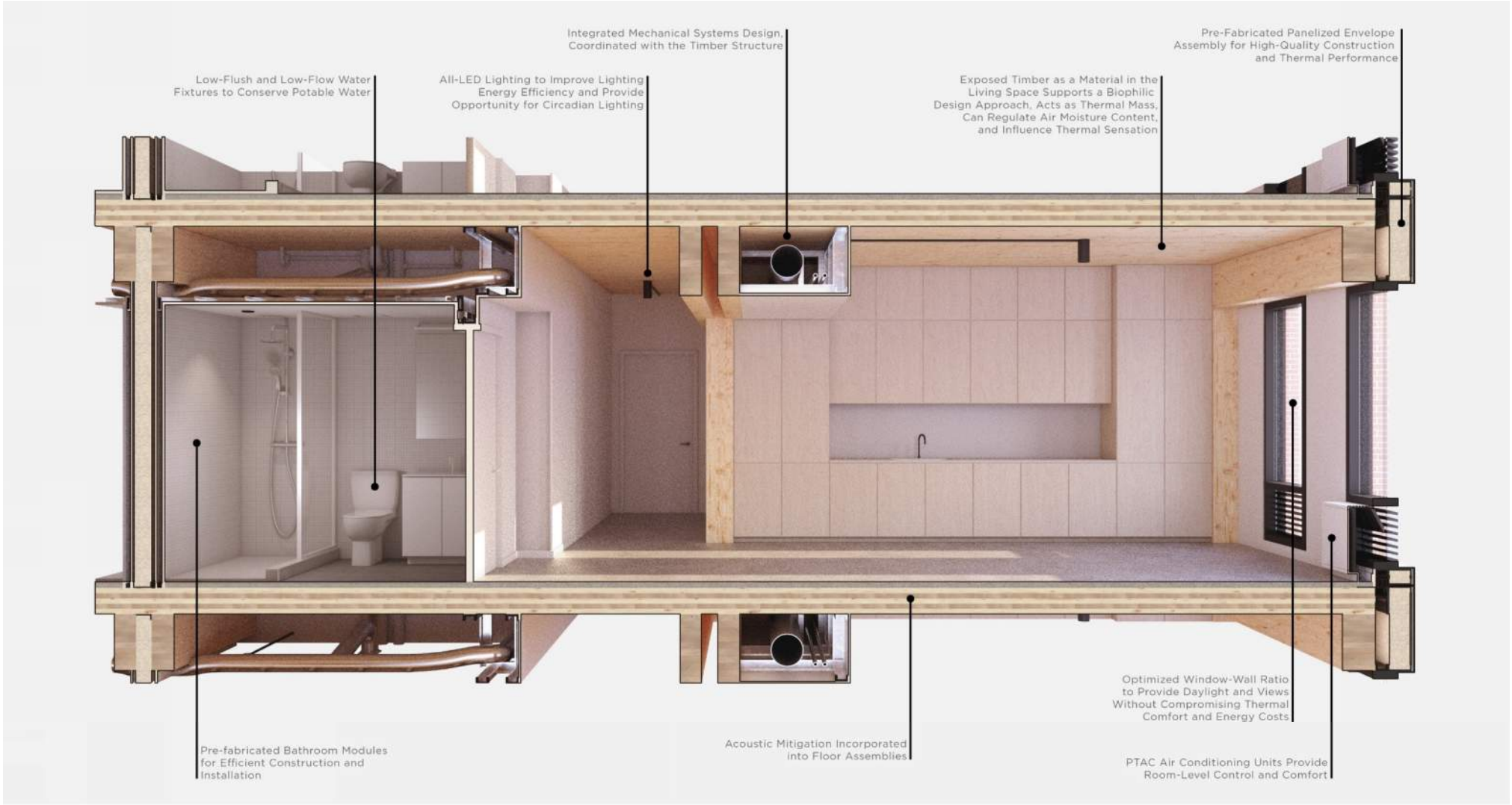
Set Realistic Owner Expectations About Aesthetics

- MEP fully exposed with mass timber structure, or limited exposure?





MEP SYSTEMS, ROUTING, INTEGRATION



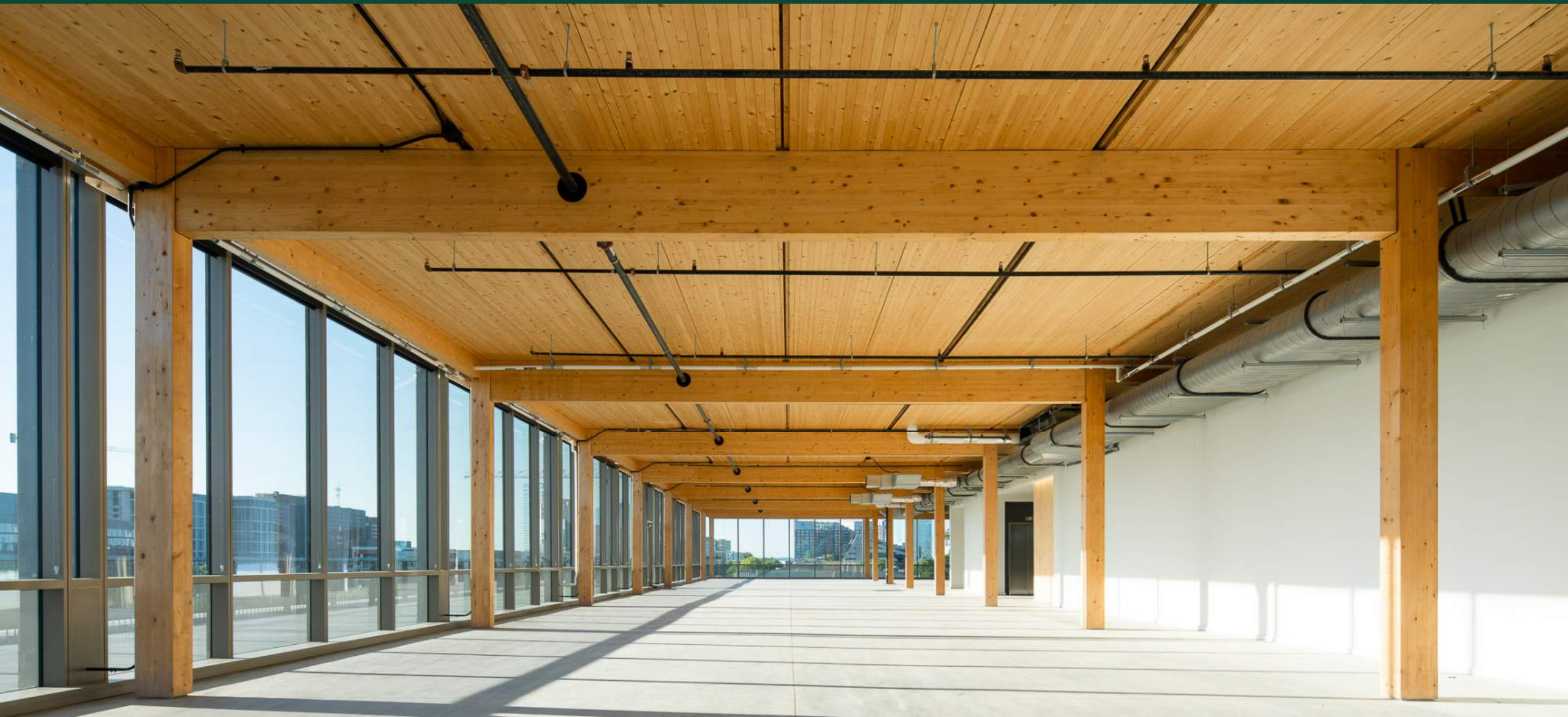
INTEGRATED SYSTEMS

The Tallhouse building system prioritizes the integration of design, engineering, and construction. This results in a high performance building finely tuned to meet energy, comfort, acoustic, and design criteria that has been vetted by constructability experts to ensure fast, efficient production.

Utilizing Pre-Fabricated Facade Panels and Bathroom Modules that are manufactured off-site in factories allows for reducing construction time on-site, higher quality control practices, and safer labor conditions for construction workers. Efficient routing of duct-work conserves material, and associated embodied carbon, allowing more exposed timber all while providing the air quality needed for healthy living. Water conserving fixtures reduce potable water use as a precious resource, while maintaining reliable performance.

Credit: John Klein, Generate Architecture

CASE STUDIES



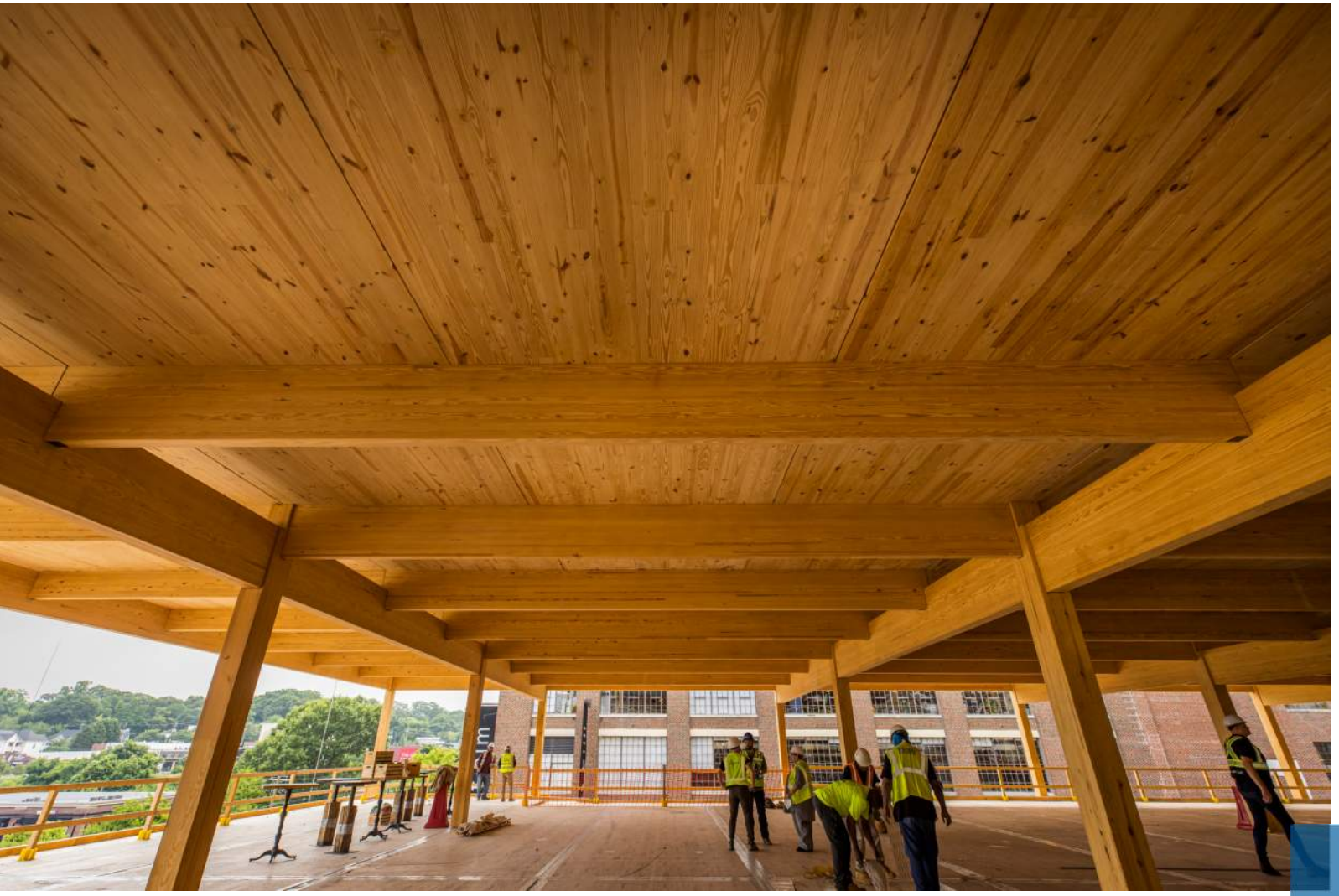
Timber House

Brooklyn, NY

- 24,000 sf, 6 stories
- Type III-A

Photos: Travis Mark

MESH architectures
Silman



619 Ponce St.

Atlanta, GA

120,000 sf, 4 stories

Type III-B

Office / Retail

WN PROFILE

Handel Architects
StructureCraft
Photo: StructureCraft

1 De Haro

San Francisco, CA

Perkins&Will
DCI Engineers
Photo: David Wakely

134,000 sf, 4 stories

Type IV-HT

Office

Completed 2021

MT / CLT

WN PROFILE

BUSINESS CASE STUDY

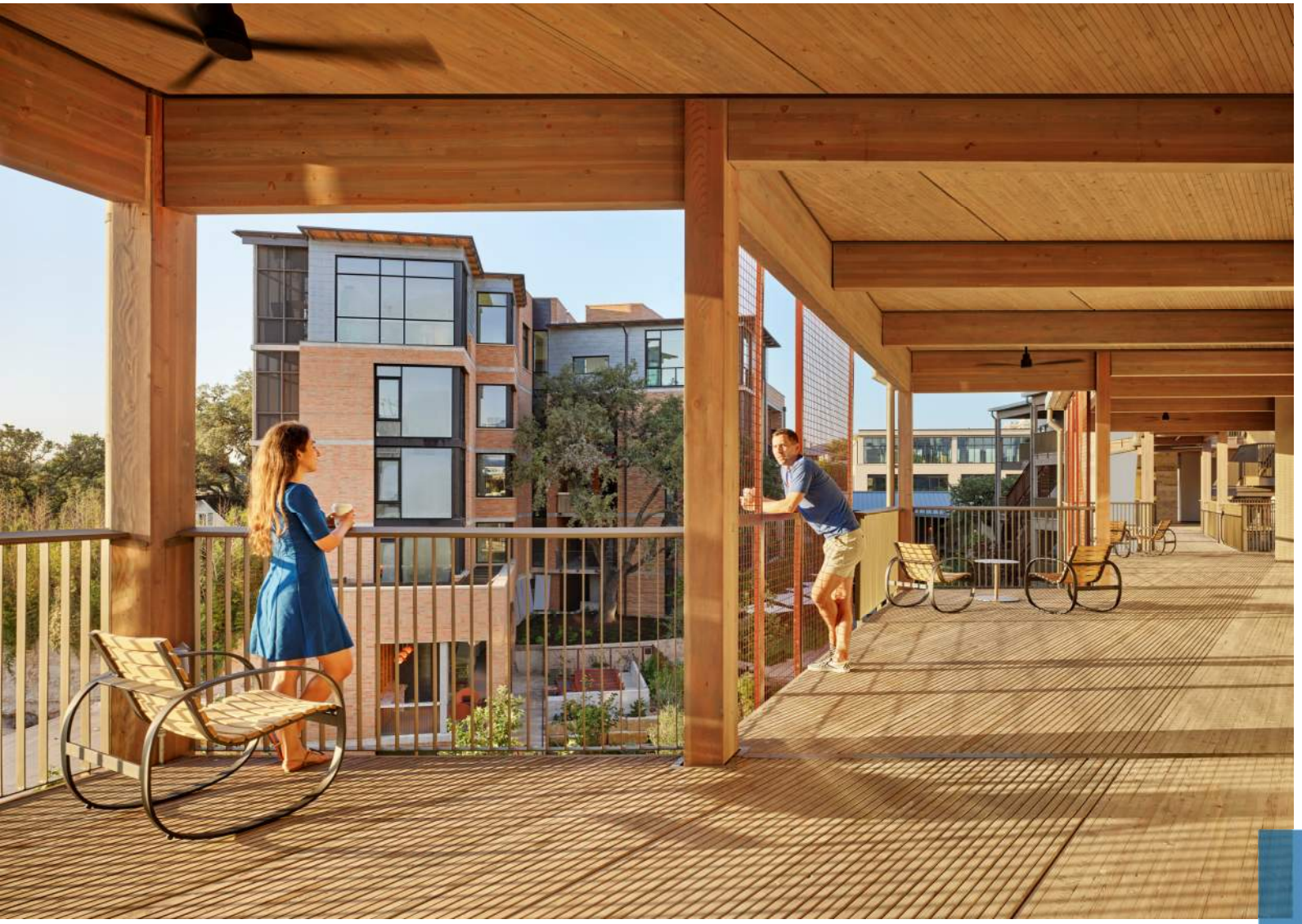
WOOD DESIGN AWARD WINNER

Photo: Casey Dunn

Hotel Magdalena

Austin, TX

Building Facts	100,000 sf
	3 buildings: 5, 4, and 3 stories
	Type V-A for MT structures
	Hotel
	Completed 2020
Developer	Bunkhouse Group
Architect	Lake|Flato
Engineer	StructureCraft
General Contractor	MYCON



Hotel Magdalena

Austin, TX

100,000 sf

3 buildings: 5, 4, and 3 stories

Type V-A for MT structures

Hotel

Completed 2020

WN PROFILE

WOOD DESIGN AWARD WINNER

Lake|Flato Architecta
StructureCraft
Photo: Casey Dunn

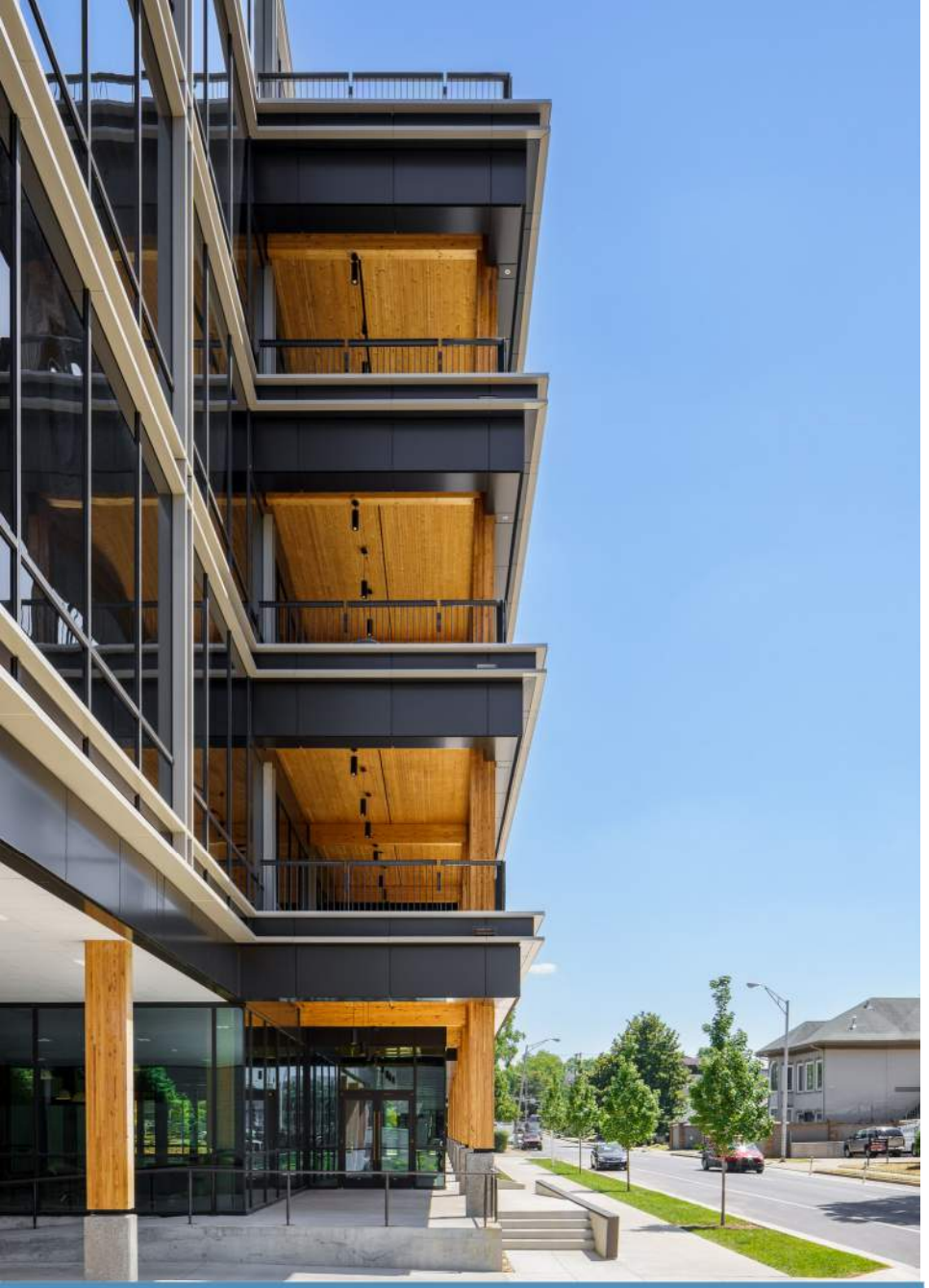


Photo: Andrew Keithly

1030 Music Row

Nashville, TN

Building Facts	110,000, 5 Stories
	Type IV-HT
	Office
	Completed 2022

Developer	Panattoni Development
Architect	Anecdote
Engineer	StructureCraft
General Contractor	Turner Construction
Timber Supplier	StructureCraft and Hasslacher

11 E LENOX, BOSTON, MA

Credit: H + O Structural Engineering

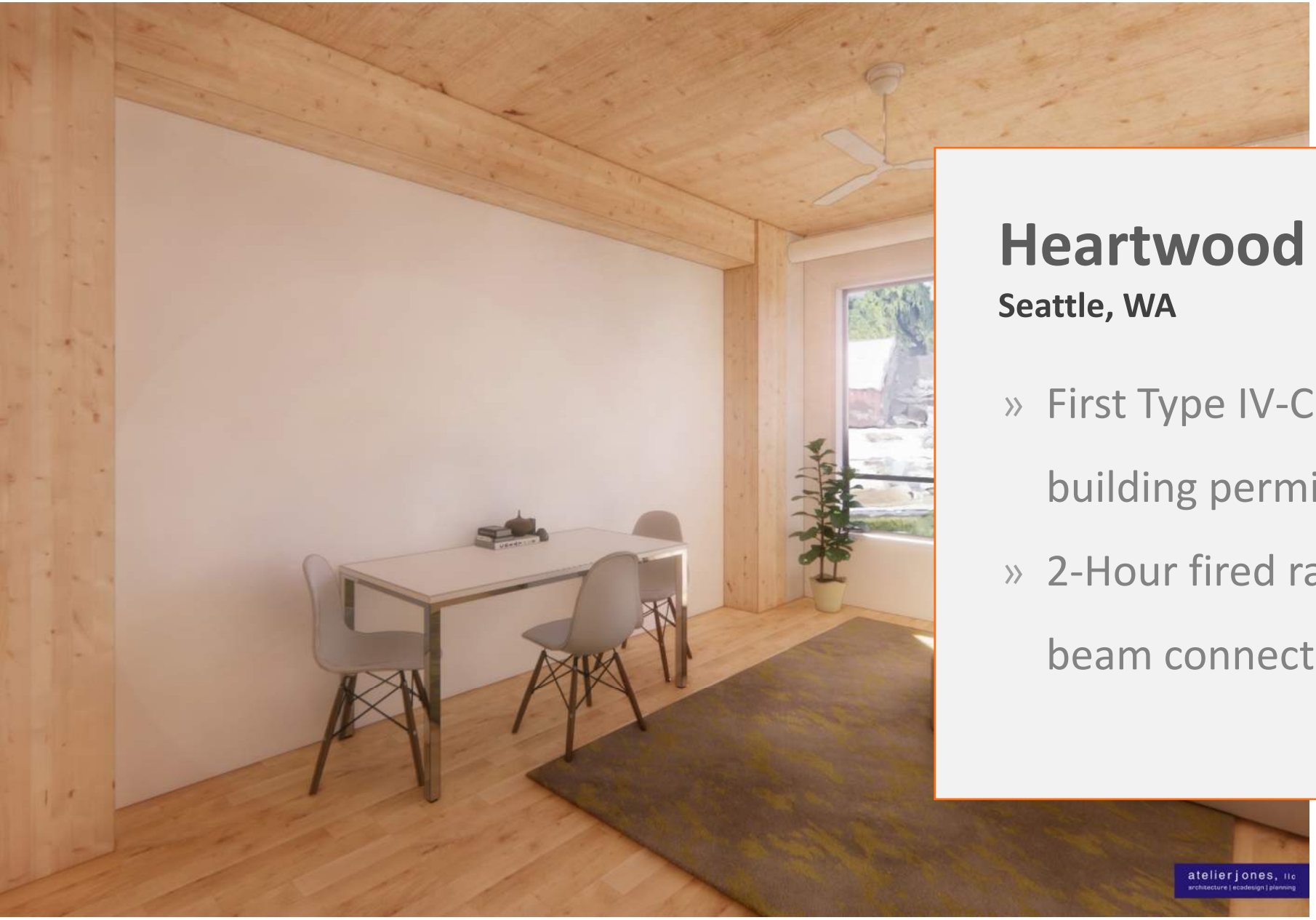
Image: atelierjones LLC

Heartwood

Seattle, WA

Building Facts	66,000 sf, 8 stories
	Type IV-C
	Workforce Housing
	Completed 2023

Developer	Skipstone Development / Community Roots Housing
Architect	atelierjones LLC
Engineer	DCI Engineering
General Contractor	Swinerton Construction



Heartwood

Seattle, WA

- First Type IV-C Building Code building permitted in WA
- 2-Hour fired rated beam-to-beam connections

WN PROFILE

atelierjones LLC
DCI Engineers
Image: atelierjones LLC

CANYONS, PORTLAND, OR

Credit: Jeremy Bittermann & Kaiser + Path

1510 Webster

Oakland, CA

- 18 stories mass timber over one-level concrete
- Designed with Tall Wood code provisions in the 2021 IBC. Mass Timber with concrete cores and staircases.

Photos: Flor Projects

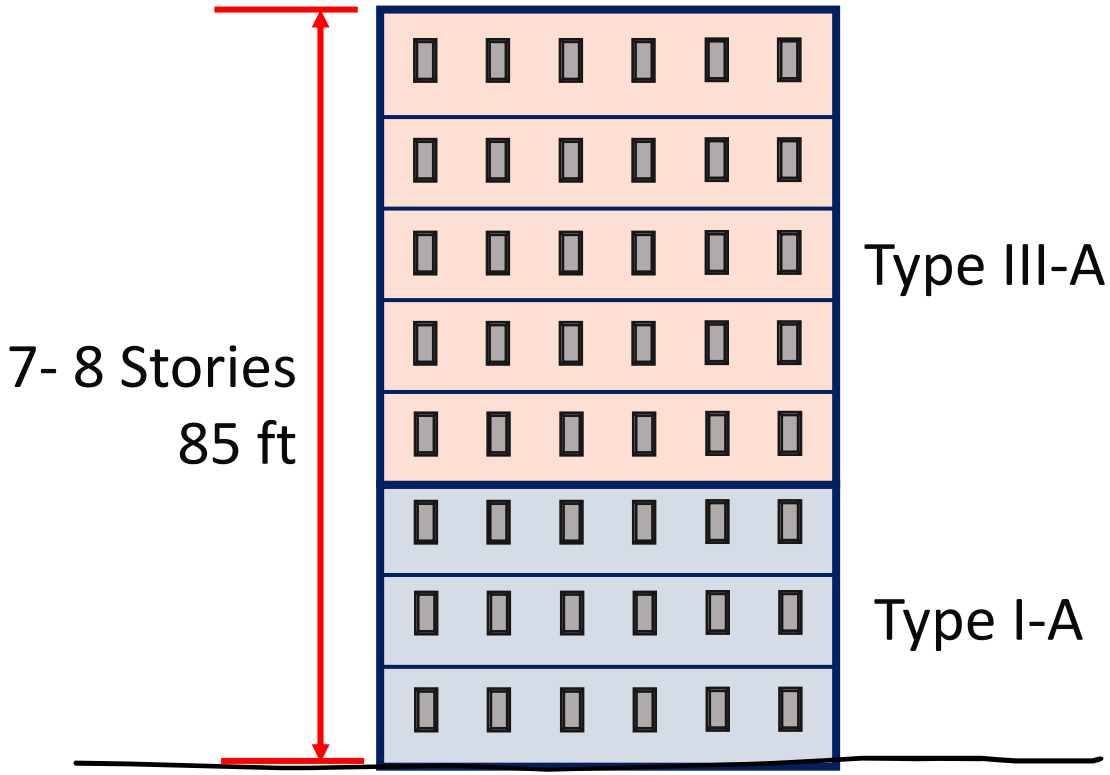
oWow
DCI Engineers

Which Construction Type?

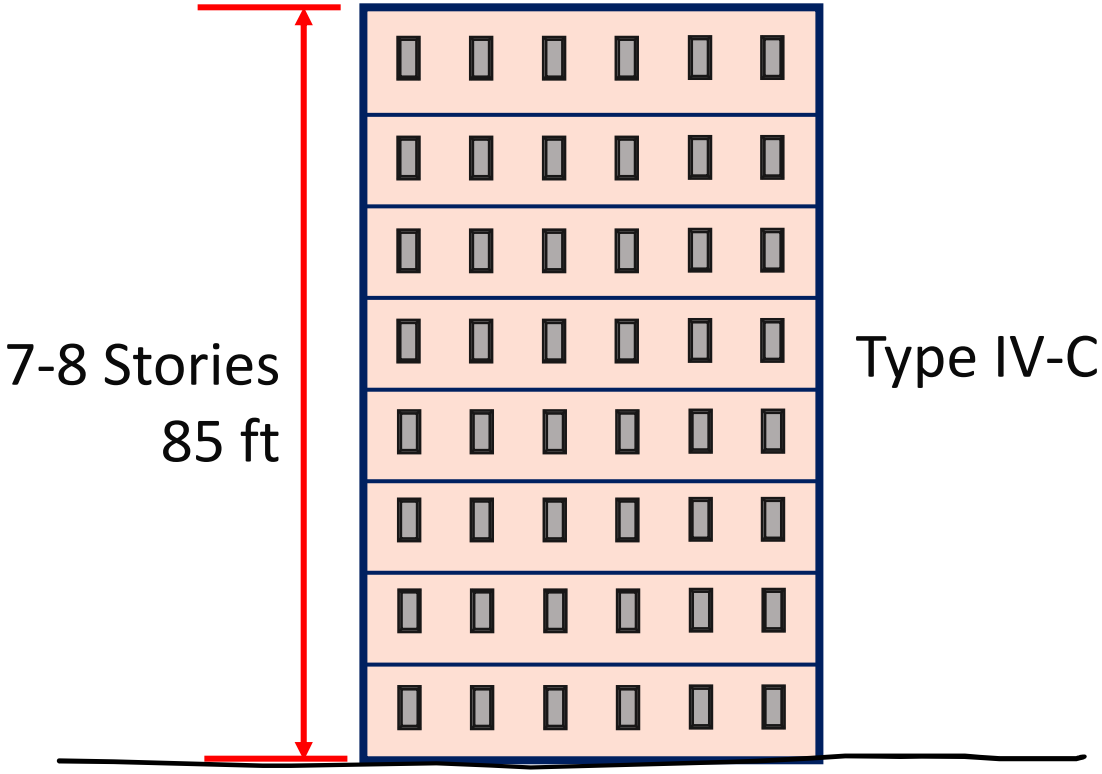
- Start with lowest common denominator and work up
- Don’t assume construction type, occupancy separation, etc. required simply because of materials or occupancies

Image: Neo Studio

R-2 Occupancy, Type III-A vs Type IV-C



Type III-A



Type IV-C

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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chelsea.drenick@woodworks.org

EARLY DESIGN EXAMPLE

Mid-Rise Design Example


Credit: Monte French Design Studio

7-story, 84 ft tall multi-family building

- Parking & Retail on 1st floor, residential units on floors 2-7
- NFPA 13 sprinklers throughout
- Floor plate = 18,000 SF
- Total Building Area = 126,000 SF

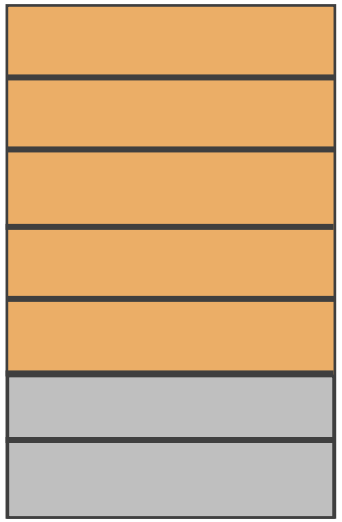

Credit: Monte French Design Studio

Mid-Rise Design Example


Credit: Monte French Design Studio

Construction Type Options:

- 7 stories of IV-C (mass timber)
- 5 stories of IIIA over 2 stories of IA podium (mass timber or light-frame)
- 5 stories of IV-HT over 2 stories of IA podium (mass timber)

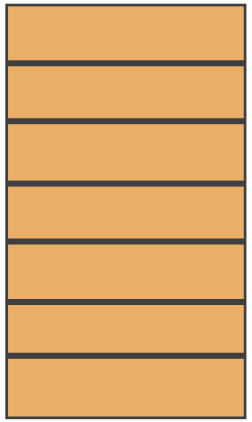


Mid-Rise Design Example


Credit: Monte French Design Studio

Timber Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium



Implications of Type IV-C:

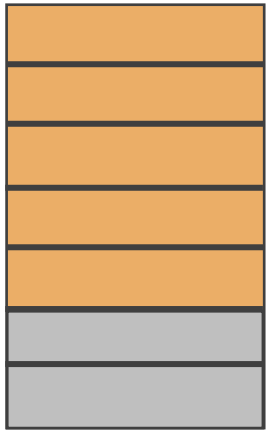
- 2 hr FRR, all exposed floor panels, beams, columns (+min sizes)
- Likely will need at least 5-ply CLT (maybe 7-ply)
- Efficient spans in the 14-17 ft range (5 ply)
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
- CLT exterior walls permitted
- Exposed CLT ceilings – aesthetic value
- Materials are mass timber or non-combustible (no light-frame wood permitted!)
- Lateral System: likely steel or concrete

Mid-Rise Design Example


Credit: Monte French Design Studio

Timber Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium



Implications of Type IIIA:

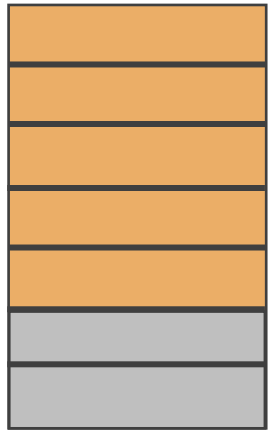
- 1 hr FRR floors, interior bearing walls, 2 hr exterior bearing walls
- Light frame wood (joists, trusses, prefab option) **OR** 5-ply CLT
- 2 story Type IA podium required
- CLT exterior walls not permitted, non-combustible or FRT wood only
- Can use light-frame wood framing for interior walls
- Lateral System: If <65 feet for wood portion, light frame wood shear walls are an option

Mid-Rise Design Example


Credit: Monte French Design Studio

Timber Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium



Implications of Type IV-HT:

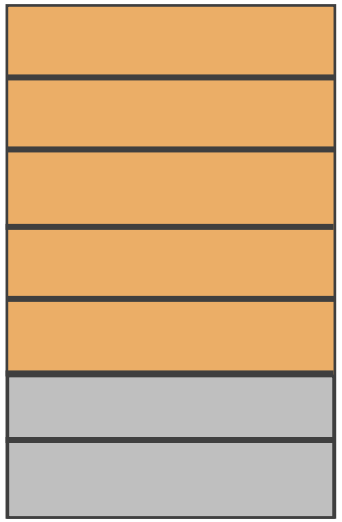
- 1 hr FRR (dwelling separation) and min. sizes
- Likely 5-ply CLT (no light-frame floor, must meet min. sizes)
- 2 story Type IA podium required
- Essentially the same panel and grid options as IIIA
- CLT exterior walls permitted
- Exposed CLT ceilings – aesthetic value
- **All walls require 1-hr rating** (non-bearing included)
  (IBC/CBC Table 601 -> 2304.11.2)
- Lateral System: light frame wood permitted up to 65 ft, 1-hour minimum.

Mid-Rise Design Example


Credit: Monte French Design Studio

Construction Type Options:

- 7 stories of IV-C (mass timber)
- 5 stories of IIIA over 2 stories of IA podium (mass timber or light-frame)
- ~~5 stories of IV-HT over 2 stories of IA podium (mass timber)~~



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