Mass Timber in Multi-Family Housing: Is It a Good Fit for Your Project?

Presented by Jason Bahr, PE and
David Hanley, WoodWorks
April 5, 2022

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WOOD PRODUCTS COUNCIL

Photo Credit: The Canyons, Kaiser+Path / photo Jeremy Bittermann

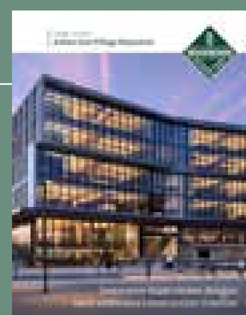
RESOURCES & UPCOMING EVENTS

New WOOD SOLUTION PAPER

CLT Diaphragm Design for Wind and Seismic Resistance

Using SDPWS 2021 and ASCE 7-22

New CASE STUDIES



Adidas East Village Expansion

Innovative mass timber designs meet ambitious construction timeline

Thomas Logan

Wood-frame urban podium project fills need for affordable downtown housing

Visit woodworks.org/publications-media

INTERNATIONAL MASS TIMBER CONFERENCE

April 12 – April 14

Common Challenges in Wood Lateral System Layouts | May 3

1.5 AIA/CES HSW LUs, 1.5 PDH credits, 0.15 ICC credits

Lateral Design for Mass Timber Structures: How to Do It, How It's Been Done | May 5

1.5 AIA/CES HSW LUs, 1.5 PDH credits, 0.15 ICC credits

Virtual International Mass Timber Conference | May 12

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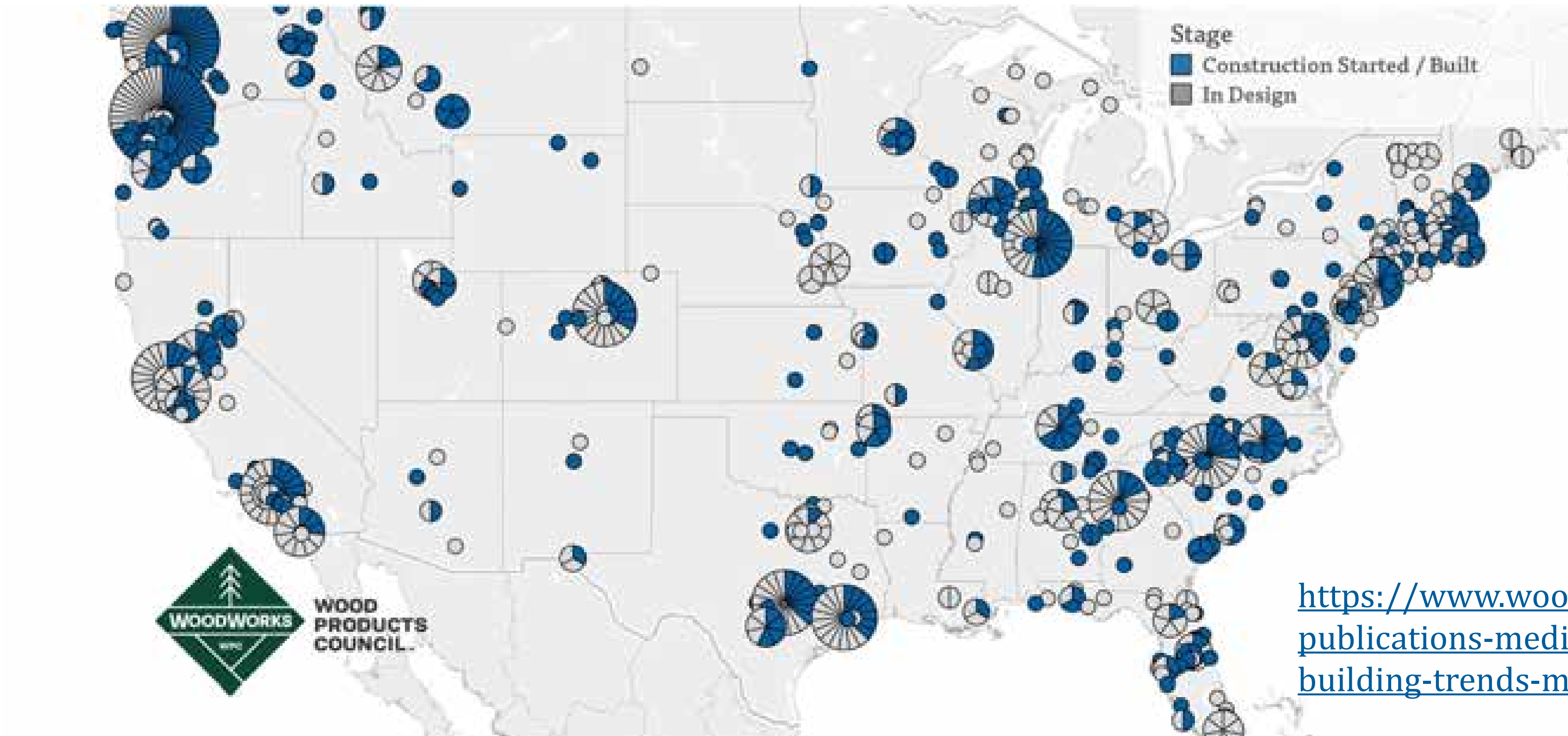
Current State of Mass Timber Projects

As of December 2021, in the US, **1,303** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



https://www.woodworks.org/publications-media/building-trends-mass-timber/

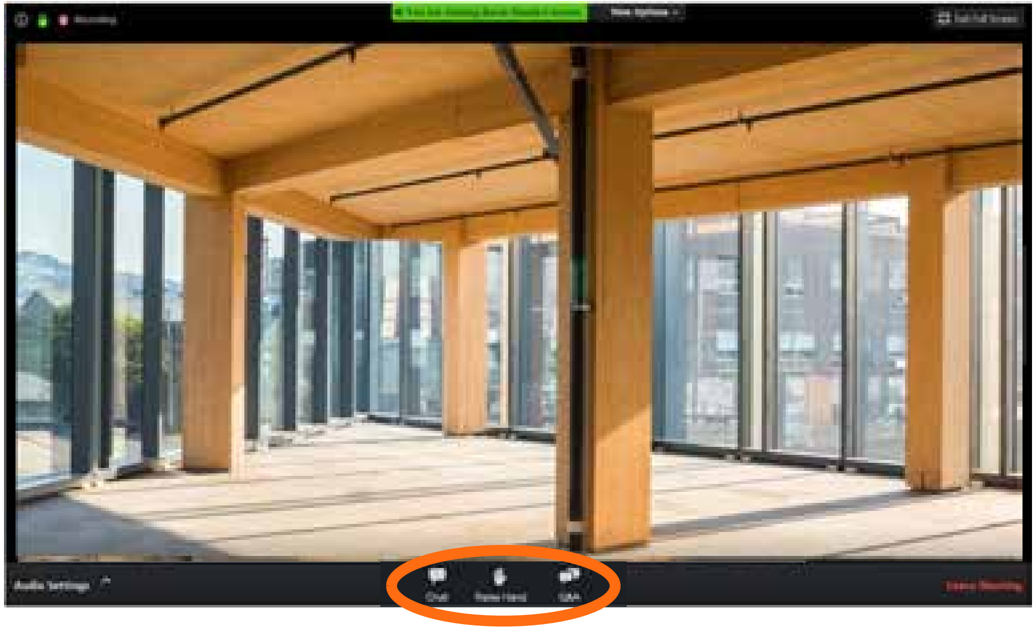
Source: WoodWorks, December 31, 2021

** This total includes modern mass timber and post-and-beam structures built since 2013*

Watch the Chat Window,
Ask Questions through the Q&A Box

» During today's event will be sending links, files and other pertinent information through the Chat window, located at the bottom of your screen.

» Submit questions in the Q&A box at the bottom of your screen as they come up in the presentations. We will get to as many questions as possible.



Questions? Ask us anything.

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

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

Course Description

Mass timber is often attached to the stigma of being more expensive than other building materials. Because of this, some people assume it only makes sense for one-off projects where innovation is celebrated but repeatability is not. Is this true, or do its other benefits result in overall cost efficiency? If it is true, how can we expect to build the number of new housing units needed across our country in a sustainable and affordable manner? Typical multi-family housing developments are in the range of 4-6 stories, often utilizing podium or pedestal construction with 1-2 stories of steel and concrete topped with 3-5 stories of light wood framing. Beyond these heights, building codes have historically required steel or concrete framing and, to justify the added costs of these materials, projects often go much taller. This has created a critical gap in housing developments in the range of 6-12 stories. Can mass timber multi-family projects make financial sense in the 4-6 story range, used in conjunction with light wood-frame systems? What new opportunities will the 2021 International Building Code create for mass timber housing in the 6-18 story range? This presentation will answer these questions and much more.

Learning Objectives

1. Evaluate the code opportunities for mass timber structures in residential mid-rise projects.
2. Discuss code-compliant options for exposing mass timber, where up to 2-hour fire-resistance ratings are required, and demonstrate design methodologies for achieving these ratings.
3. Review code requirements unique to hybrid mass timber and light-frame housing projects, and emphasize solutions for criteria such as construction type, fire-resistance ratings and acoustics design.
4. Highlight the unique benefits of using exposed mass timber in taller multi-family buildings.

Is Mass Timber a Good Fit for Your Multi-Family Project?

Ascent, Milwaukee, WI
Source: Korb & Associates Architects

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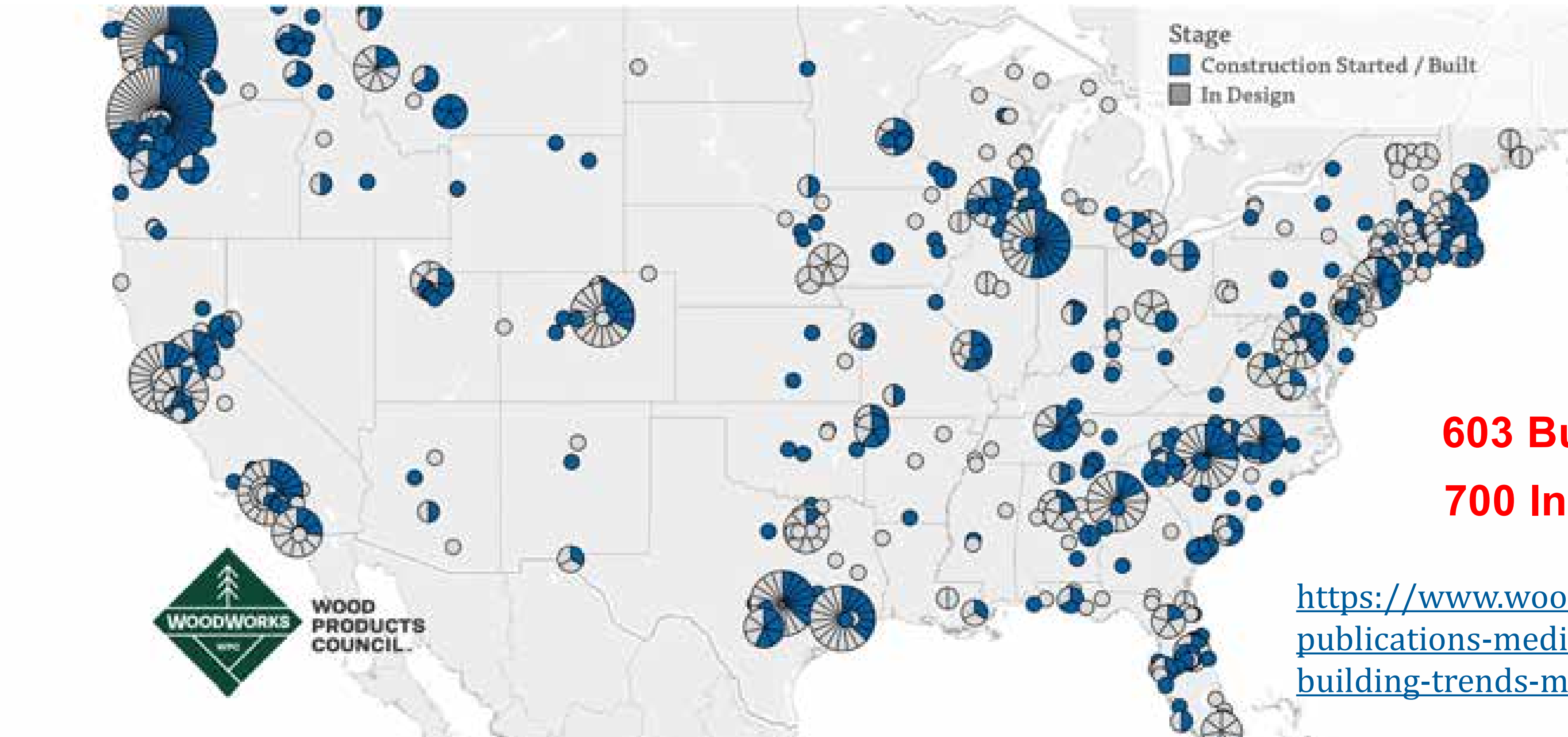

603 Built

700 In Design

https://www.woodworks.org/publications-media/building-trends-mass-timber/

Source: WoodWorks, December 31, 2021

** This total includes modern mass timber and post-and-beam structures built since 2013*

Current State of Mass Timber Projects

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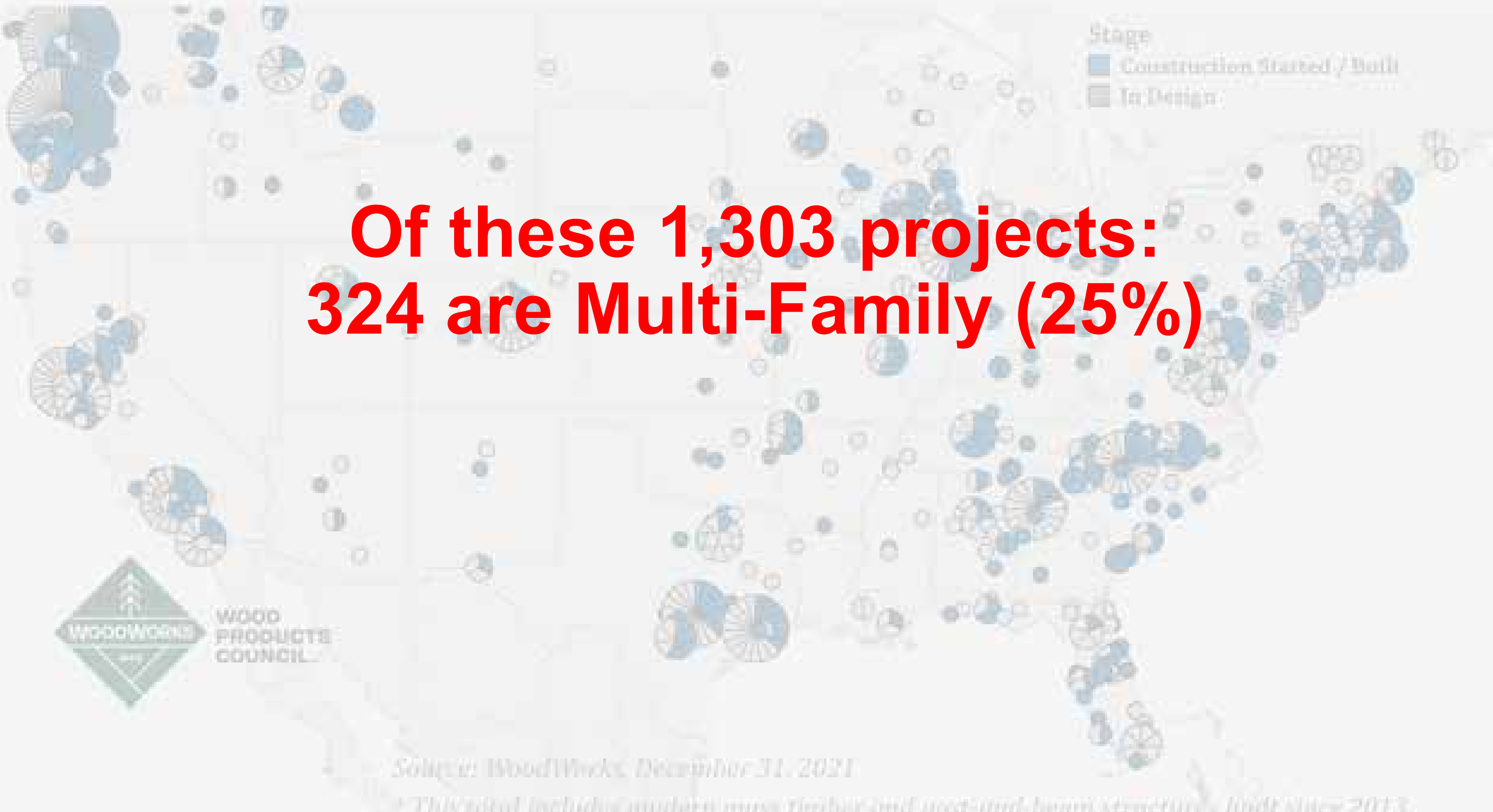

Of these 1,303 projects:
324 are Multi-Family (25%)

Source: WoodWorks, December 31, 2021

** This total includes modern mass timber and post-and-beam structures built since 2013*

Current State of Mass Timber Projects

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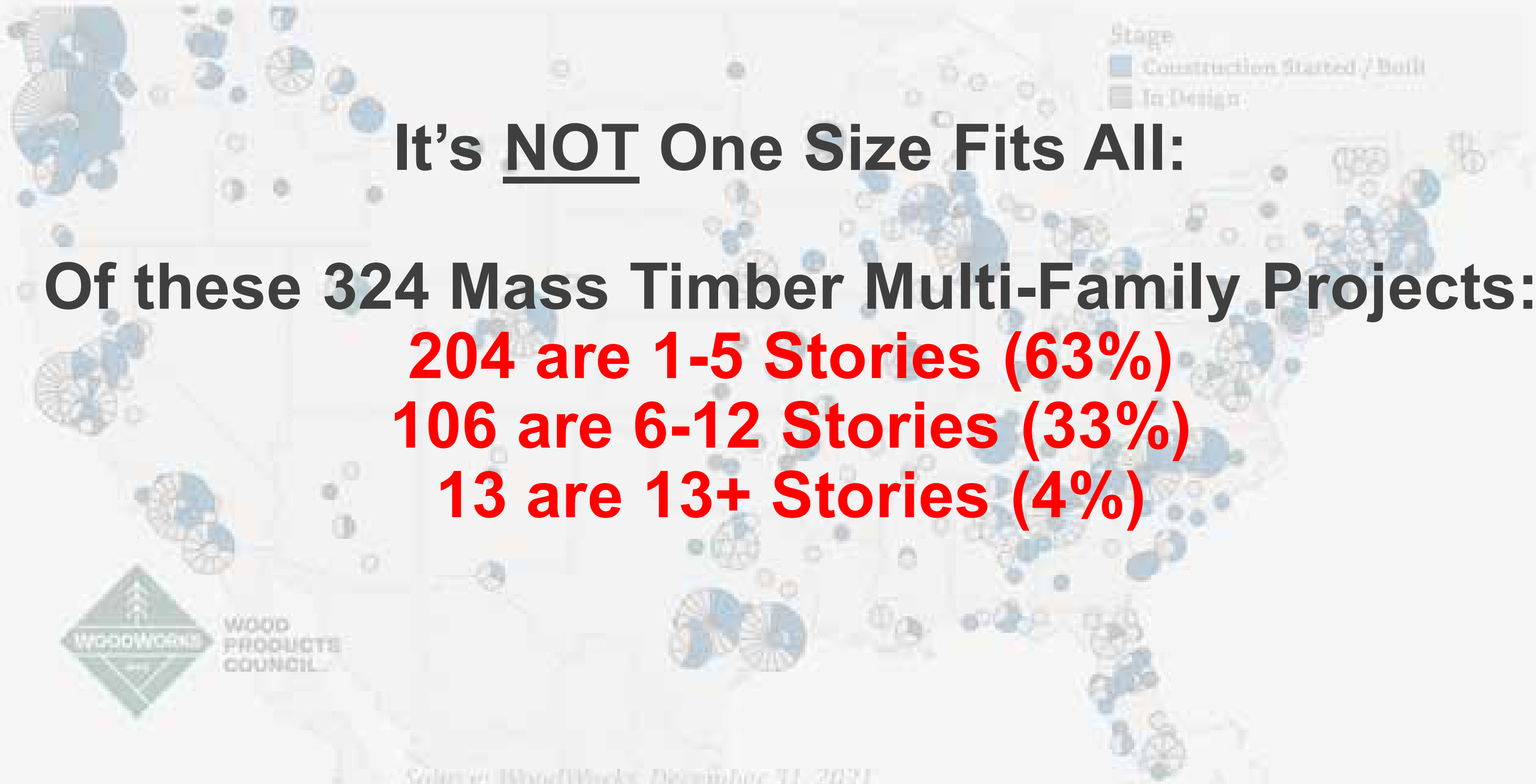


It’s <u>NOT</u> One Size Fits All:

Of these 324 Mass Timber Multi-Family Projects:

204 are 1-5 Stories (63%)
106 are 6-12 Stories (33%)
13 are 13+ Stories (4%)

Source: WoodWorks, December 31, 2021

** This total includes modern mass timber and post-and-beam structures built since 2013*

MASS TIMBER IN MULTI-FAMILY

EVOLUTION
OR
REVOLUTION?

Multi-Housing Typologies

Credit: WGI

Multi-Housing Typologies

MT Floors & Roofs on LWF Bearing Walls

Credit: KL&A Engineers & Builders

MT Floors & Roofs on Post & Beam Framing

Credit: ADX Creative and Engberg Anderson

MT Floors & Roofs on MT Bearing Walls

Credit: Grey Organschi Architecture and Spiritos Properties

EVOLUTION

INCREMENTAL CHANGE

REVOLUTION

TRANSFORMATIONAL CHANGE

Low- and Mid-Rise Multi-Family

Credit: ADX Creative and Engberg Anderson

HYBRID LIGHT-FRAME + MASS TIMBER

THE KIND PROJECT, SACRAMENTO, CA

CONDOS AT LOST RABBIT, MS

Lost Rabbit, MS
Credit: Everett Consulting Group

THE POSTMARK APARTMENTS, SHORELINE, WA

Credit: Katerra, Hans-Erik Blomgren

CIRRUS, DENVER, CO

Credit: KL&A Engineers & Builders

CANYONS, PORTLAND, OR

Credit: Jeremy Bittermann & Kaiser + Path

THE DUKE, AUSTIN, TX

Credit: WGI

PROJECT ONE, OAKLAND, CA

Credit: Gurnet Point

WESSEX WOODS, PORTLAND, ME

Credit: Avesta Housing

POST, BEAM + PLATE

360 WYTHE AVENUE, BROOKLYN, NY

Credit: Flank

BARRACUDA CONDOS, MADISON, WI

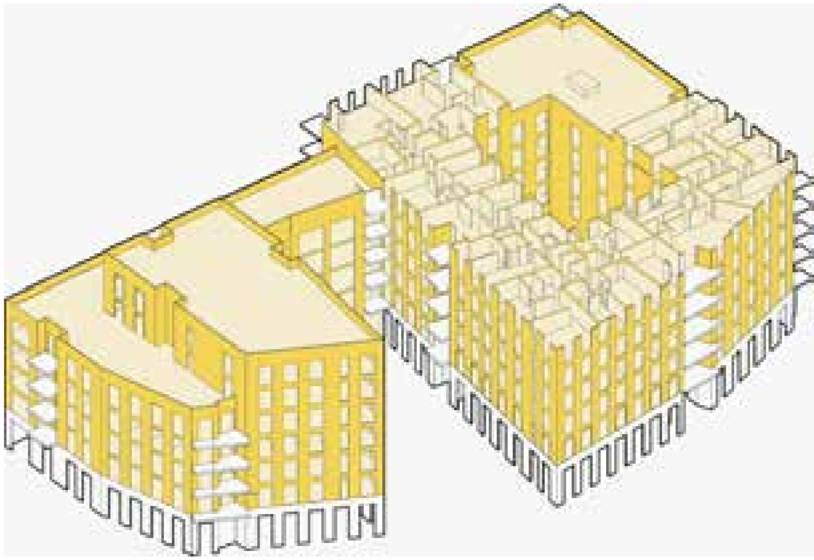
Credit: Populance Architecture and Development


Photo: Lendlease

MASS TIMBER BEARING WALLS

DALSTON WORKS, LONDON


Photos: Daniel Shearin | Waugh Thistleton Architects



Model C, Roxbury, MA

Credit: John Klein, Generate Architecture

Left: 69 A Street, Boston, MA Credit: Greg Folkins
Above: Timber Lofts, Milwaukee, WI
Credit: ADX Creative and Engberg Anderson Architects

VERTICAL ADDITIONS AND ADAPTIVE REUSE

BREWERY LOFTS, TACOMA, WA

Brewery Lofts, Flynn Architecture, Eclipse Engineering, photos: Brewery Blocks Tacoma, SmartLam

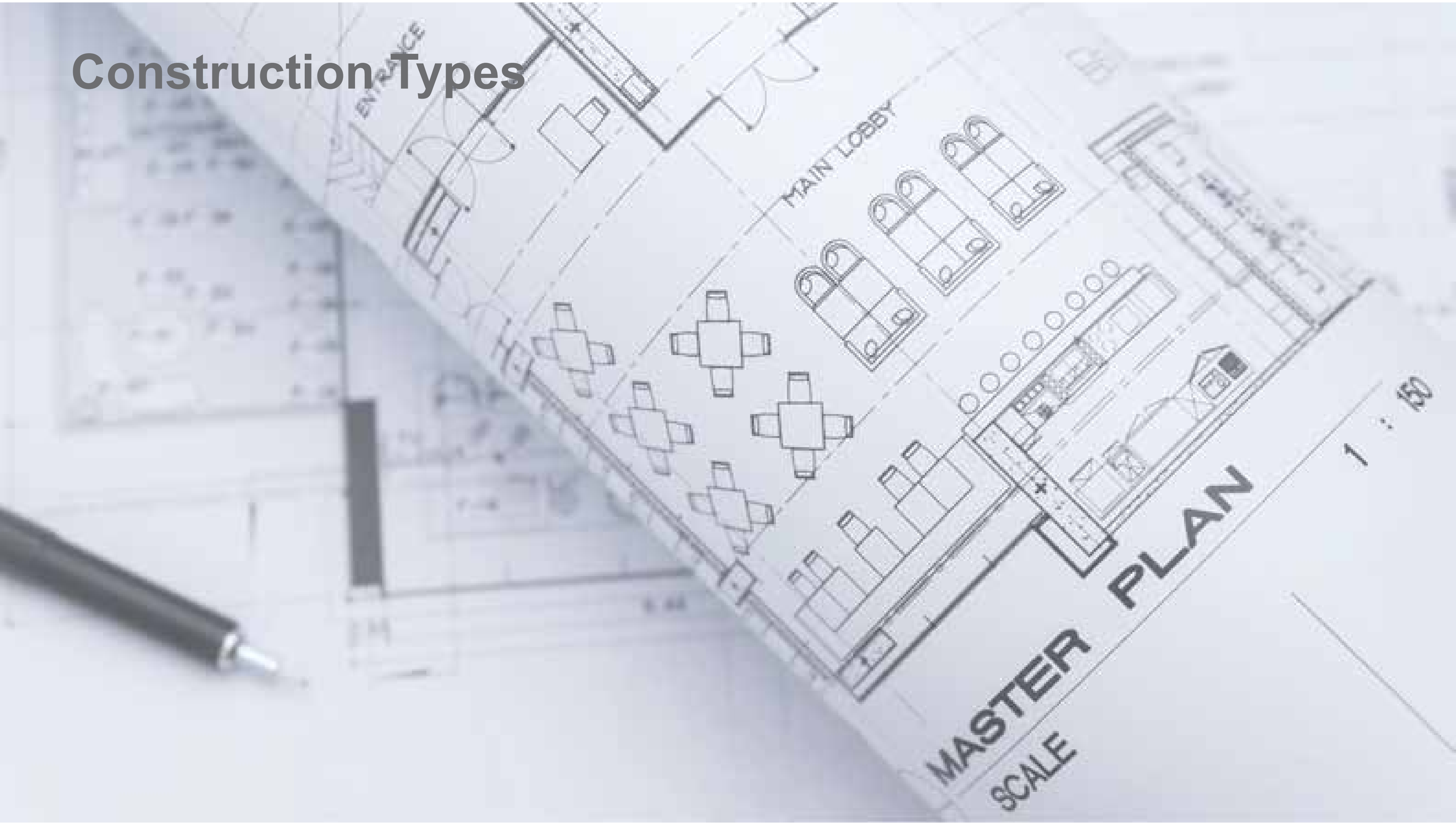
TIMBER LOFTS
MILWAUKEE, WI

Source: ADX Creative and Engberg Anderson Architects

> "Mass timber shaved 20% off our construction schedule. It's a renewable resource and also creates that warm look."

Source: Think Wood

Construction Types



Construction Types

When does the code allow mass timber to be used in low- and mid-rise multi-family projects?

IBC defines mass timber systems in IBC Chapter 2 and notes their acceptance and manufacturing standards in IBC Chapter 23

Permitted anywhere that combustible materials and heavy timber are allowed, plus more

Construction Types

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

Construction Types I & II:
All elements required to be non-combustible materials

However, there are exceptions including several for mass timber

Construction Types

All wood framed building options:

Type III
Exterior walls non-combustible (may be FRTW)
Interior elements any allowed by code, including mass timber

Type V
All building elements are any allowed by code, including mass timber

Types III and V are subdivided to A (protected) and B (unprotected)

Type IV (Heavy Timber)
Exterior walls non-combustible (may be FRTW OR CLT)
Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)

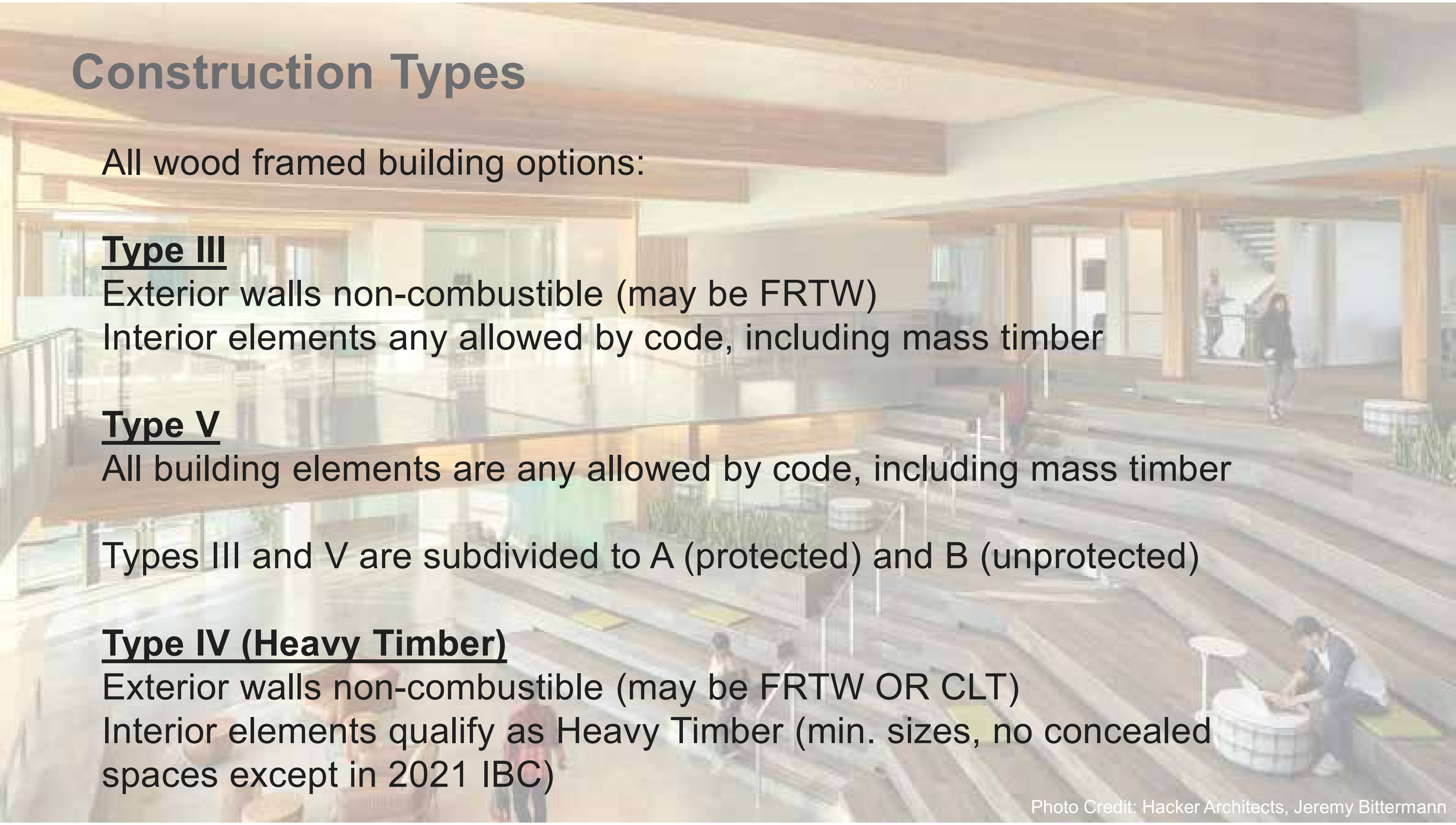


Photo Credit: Hacker Architects, Jeremy Bittermann

Construction Types

Where does the code allow MT to be used?

- Type III: Interior elements (floors, roofs, partitions/shafts) and exterior walls if FRT

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

Construction Types

Where does the code allow MT to be used?

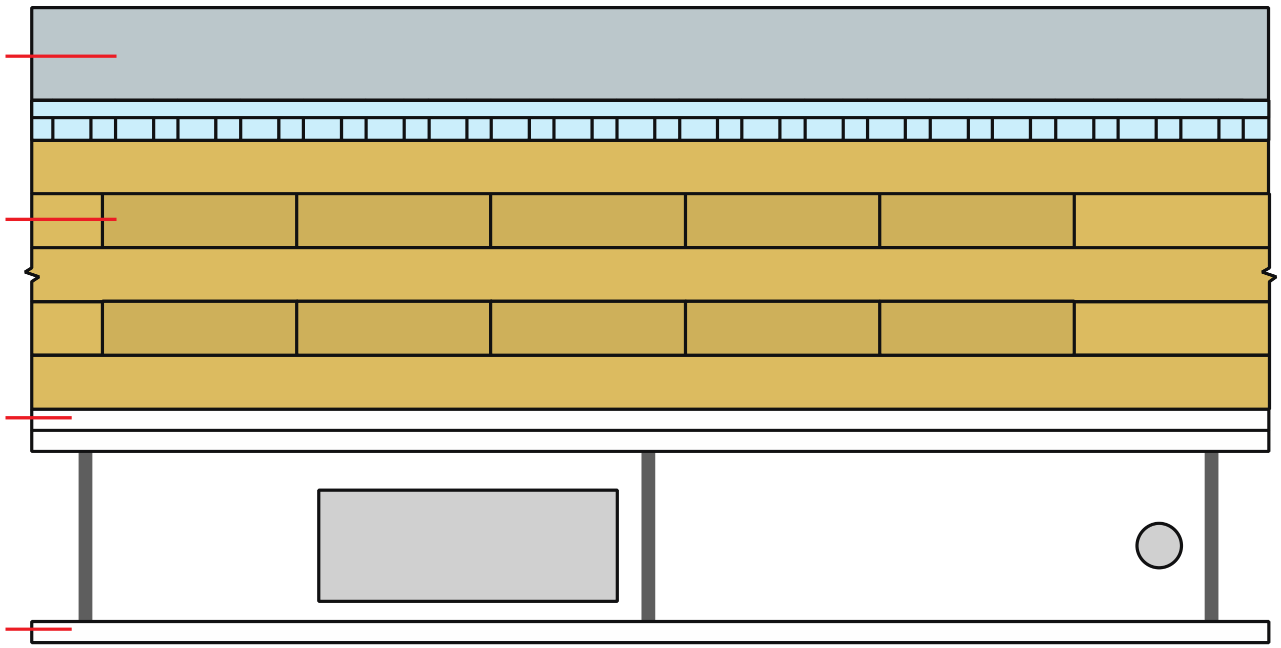
- Type IV: Any exposed interior elements & roofs, must meet min. sizes; exterior walls if CLT or FRT. Concealed space limitations (varies by code version)

Image: Perkins + Will

Construction Types

Type IV concealed spaces

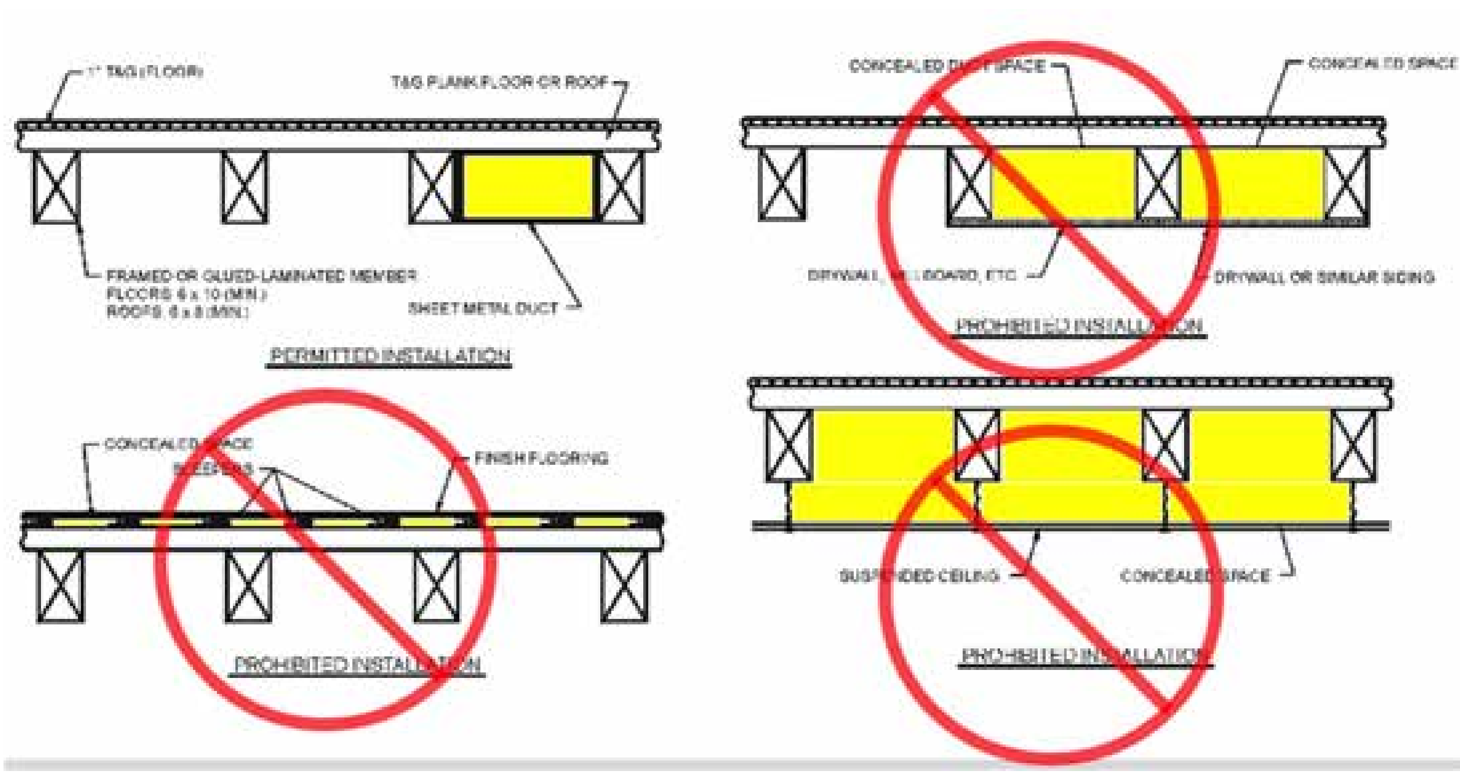
Can I have a dropped ceiling? Raised access floor?



Construction Types

Type IV concealed spaces

Until 2021 IBC, Type IV-HT provisions prohibited concealed spaces



Credit: IBC

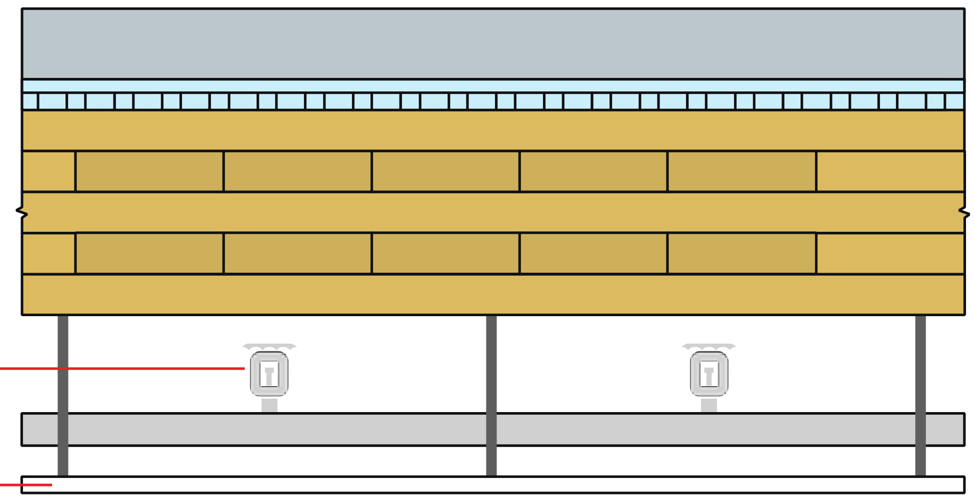
Construction Types

Type IV concealed space options within 2021 IBC

Option 1:

Sprinklers in concealed spaces

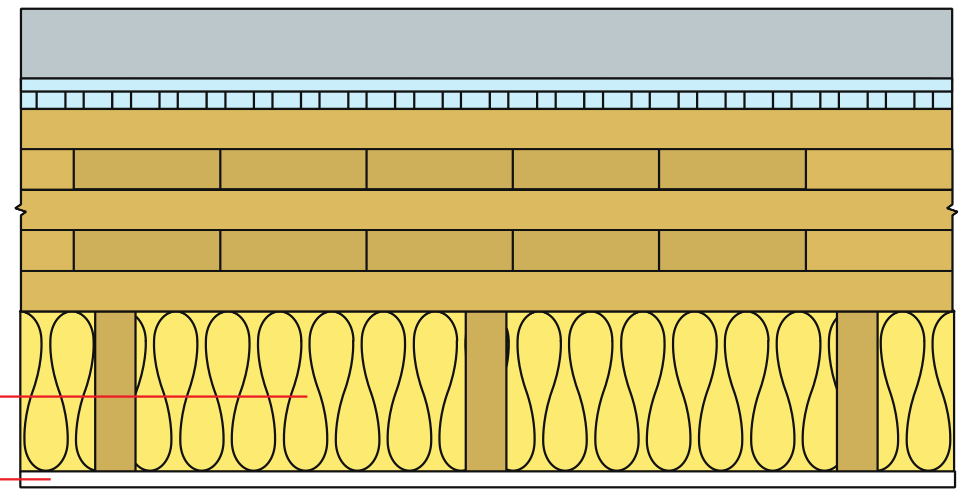
Dropped ceiling



Construction Types

Type IV concealed space options within 2021 IBC

Option 2:



Noncombustible insulation

Dropped ceiling

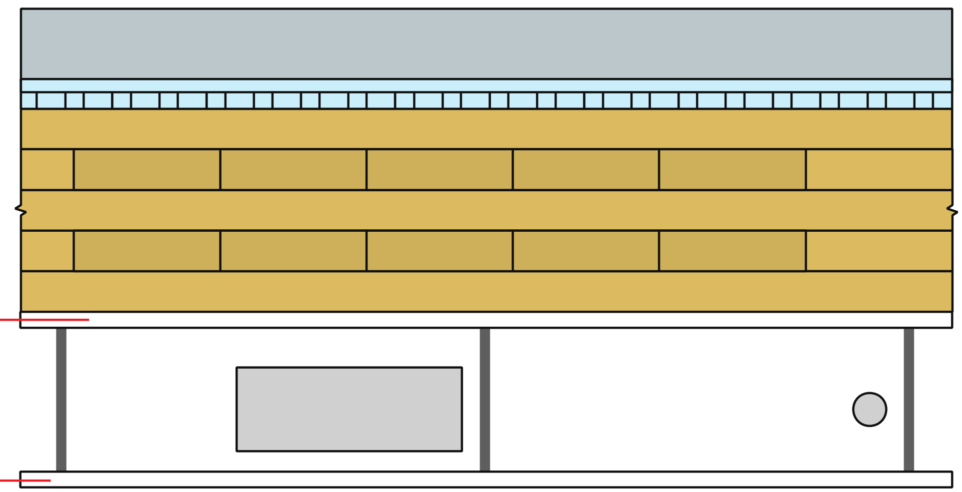
Construction Types

Type IV concealed space options within 2021 IBC

Option 3:

5/8" Type X gypsum on all mass timber surfaces within concealed space

Dropped ceiling



Construction Types

Concealed spaces solutions paper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Concealed Spaces in Mass Timber and Heavy Timber Structures


The John W. Olver Design Building at UMass Amherst includes exposed wood structure in some areas and dropped ceilings in others. Architect: Leers Weinzapfel Associates

https://www.woodworks.org/wp-content/uploads/wood_solution_paper-Concealed_Spaces_Timber_Structures.pdf

Construction Types

Where does the code allow MT to be used?

- Type V: All interior elements, roofs & exterior walls

Image: Christian Columbres Photography

EVOLUTION

INCREMENTAL CHANGE

REVOLUTION

TRANSFORMATIONAL CHANGE

Tall Mass Timber Multi-Family

Credit: Harbor Bay Real Estate Advisors, Purple Film, INTRO, Cleveland, OH

CARBON 12, PORTLAND, OR

Credit: Baumberger Studio/PATH Architecture


INTRO, CLEVELAND
9 Stories | 115 ft
8 Timber Over 1 Podium
512,000 SF
297 Apartments, Mixed-Use
Photo: Harbor Bay Real Estate Advisors, Purple Film | Architect: Hartshorne Plunkard Architecture

INTRO, CLEVELAND

9 Stories | 115 ft
8 Timber Over 1 Podium

Type IV-B
Variance to expose ~50% ceilings

Photo: Harbor Bay Real Estate Advisors, Image Fiction | Architect: Hartshorne Plunkard Architecture

ASCENT, MILWAUKEE

Photo: Korb & Associates Architects | Architect: Korb & Associates Architects

ASCENT, MILWAUKEE

Tallest Mass Timber Building in the World

Photo: CD Smith Construction |
Architect: Korb & Associates Architects


ASCENT, MILWAUKEE
25 STORIES
19 TIMBER OVER 6 PODIUM, 284 FT
Photo: Korb & Associates Architects | Architect: Korb & Associates Architects

11 E LENOX, BOSTON, MA

7 STORIES

70 FT

Passive House

Multi-Family

Credit: H + O Structural Engineering

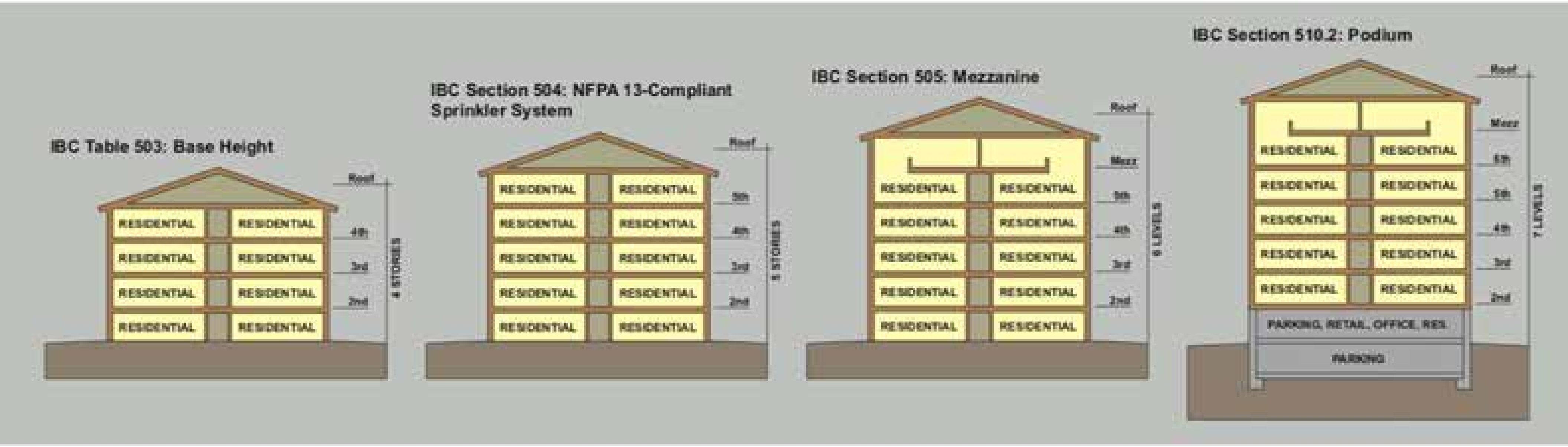
11 E LENOX, BOSTON, MA

Credit: H + O Structural Engineering

11 E LENOX, BOSTON, MA

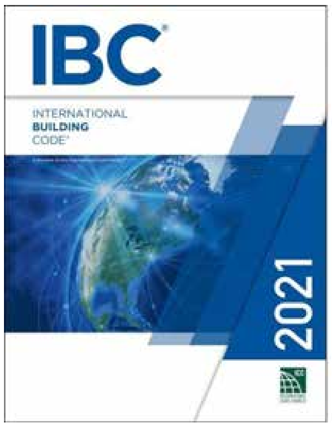
Credit: H+O Structural Engineering

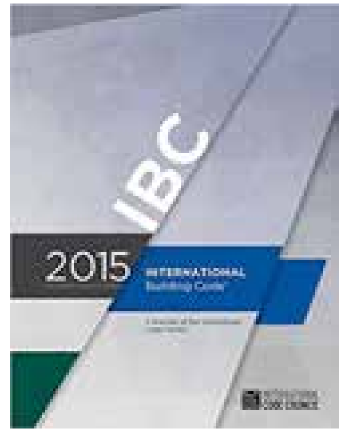
PRESCRIPTIVE BUILDING CODES

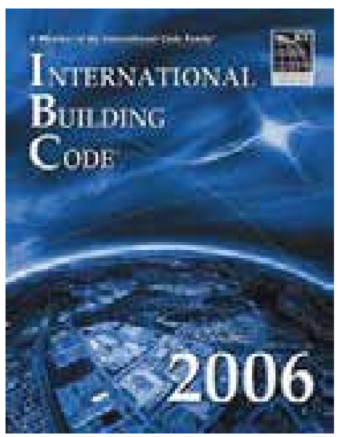


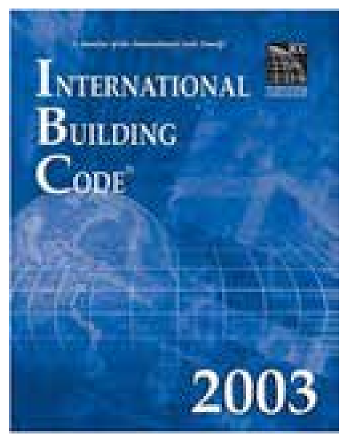
ICC INTERNATIONAL CODE COUNCIL®

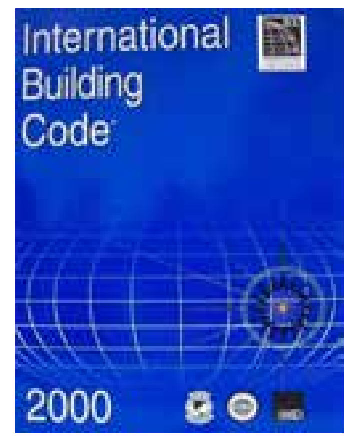
3 YEAR CODE CYCLE











Source: ICC

ATF Lab Tests, 2017
Photo: LendLease


ATF Lab Tests, 2017
Photo: LendLease


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Photo: LendLease

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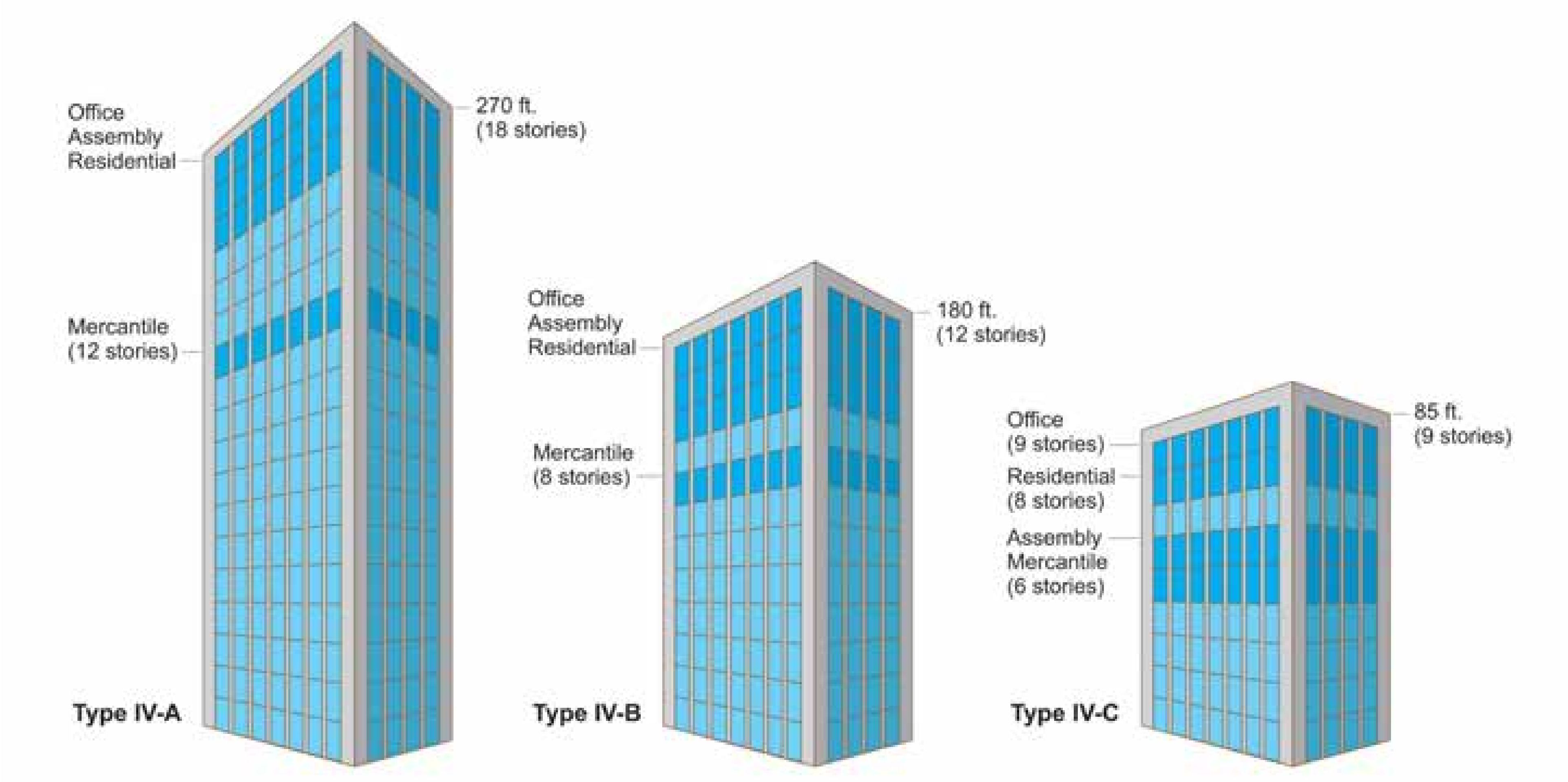
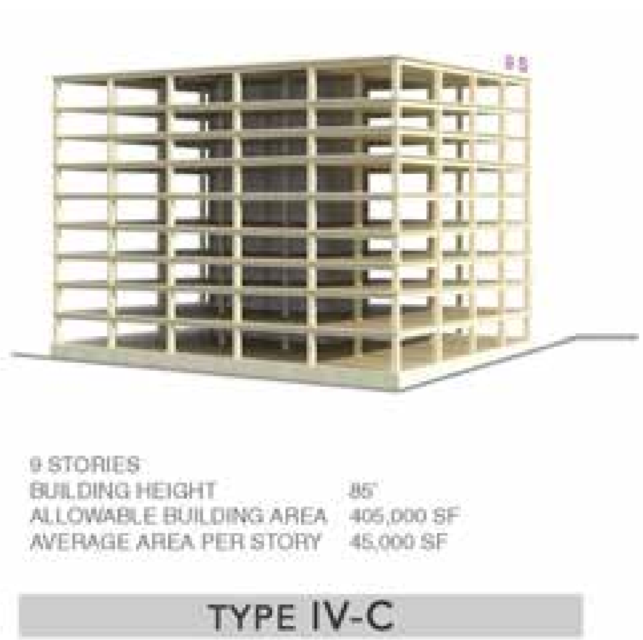
Photo: LendLease

PRESCRIPTIVE BUILDING CODES



Type IV-C

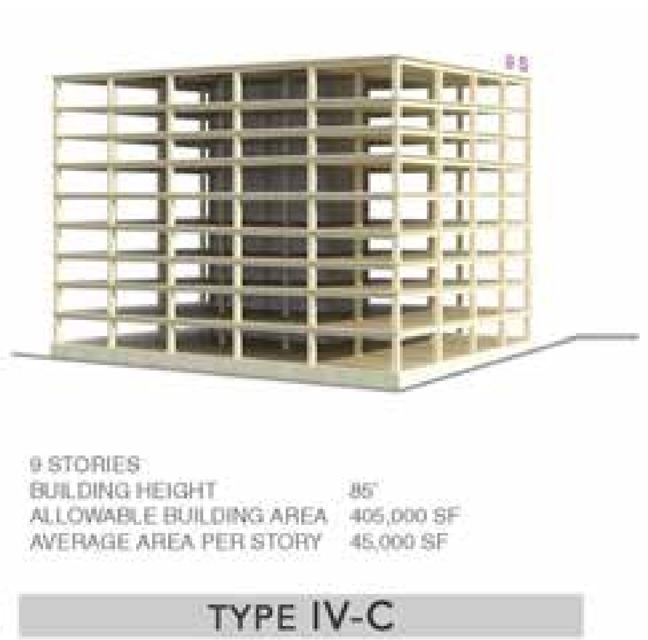


Credit: Susan Jones, atelierjones

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman

Type IV-C Height and Area Limits

IV-C



Credit: Susan Jones, atelierjones

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

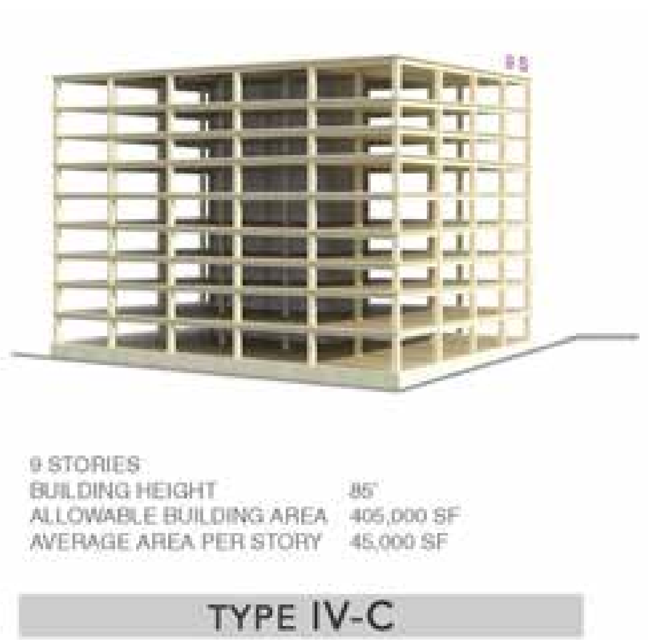
Areas exclude potential frontage increase

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

Type IV-C area = 1.25 * Type IV-HT area

Type IV-C Protection vs. Exposed

IV-C



Credit: Susan Jones, atelierjones

Credit: Kaiser+Path, Ema Peter

All Mass Timber surfaces may be exposed

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

IV-C

IV-C

Type IV-B

Credit: Susan Jones, atelierjones

Credit: LEVER Architecture

IV-B

Type IV-B Height and Area Limits

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

Areas exclude potential frontage increase

Credit: Susan Jones, atelierjones

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

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

Type IV-B Protection vs. Exposed

IV-B

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path

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

~20% of Ceiling or ~40% of Wall can be exposed

Type IV-B Protection vs. Exposed

IV-B

Limited Exposed MT allowed in Type IV-B for:

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

Credit: Kaiser+Path

Type IV-B Protection vs. Exposed

IV-B

Mixed unprotected areas, exposing both ceilings and walls:

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

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

- **U_{tc} = Total unprotected MT ceiling areas**
- **U_{ac} = Allowable unprotected MT ceiling areas**
- **U_{tw} = Total unprotected MT wall areas**
- **U_{aw} = Allowable unprotected MT wall areas**

Credit: Kaiser+Path

Type IV-B Protection vs. Exposed

IV-B

Design Example: Mixing unprotected MT walls & ceilings

Credit: AWC

800 SF dwelling unit

- U_{ac} = (800 SF)*(0.20) = 160 SF
- U_{aw} = (800 SF)*(0.40) = 320 SF
- Could expose 160 SF of MT ceiling, OR 320 SF of MT Wall, OR
- If desire to expose 100 SF of MT ceiling in Living Room, determine max. area of MT walls that can be exposed

Type IV-B Protection vs. Exposed

IV-B

Design Example: Mixing unprotected MT walls & ceilings

Credit: AWC

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

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

$U_{tw} = 120$ SF

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

IV-B

IV-B

Type IV-A

Credit: Susan Jones, atelierjones

Photos: Structurlam, naturally:wood, Fast + Epp

IV-A

Type IV-A Height and Area Limits

Credit: Susan Jones, atelierjones

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

Areas exclude potential frontage increase

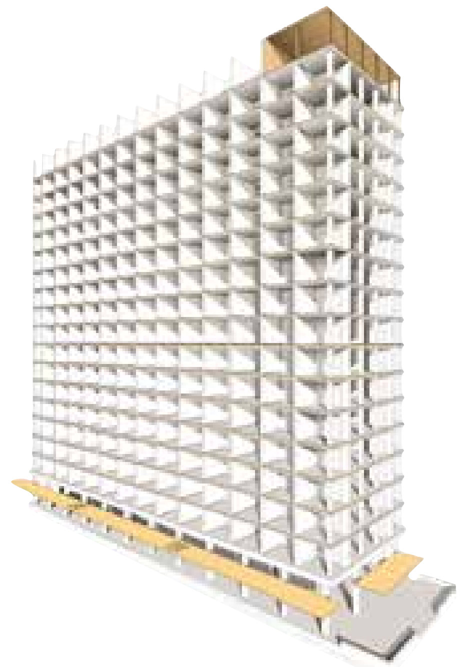
In most cases, Type IV-A height & story allowances = 1.5 * Type I-B height & story allowances

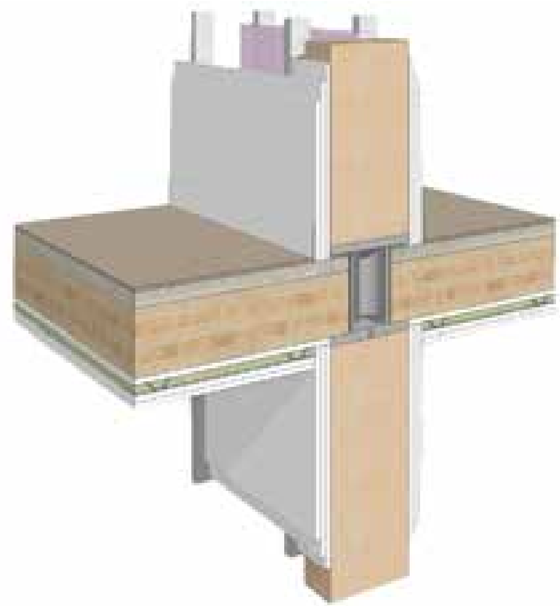
Type IV-A area = 3 * Type IV-HT area

IV-A

Type IV-A Protection vs. Exposed

Credit: Susan Jones, atelierjones





Credit: Acton Ostry Architects, Fast + Epp

100% NC protection on all surfaces of Mass Timber

IV-A

2024 IBC Changes

RISE Tests, 2020
Photo: RISE

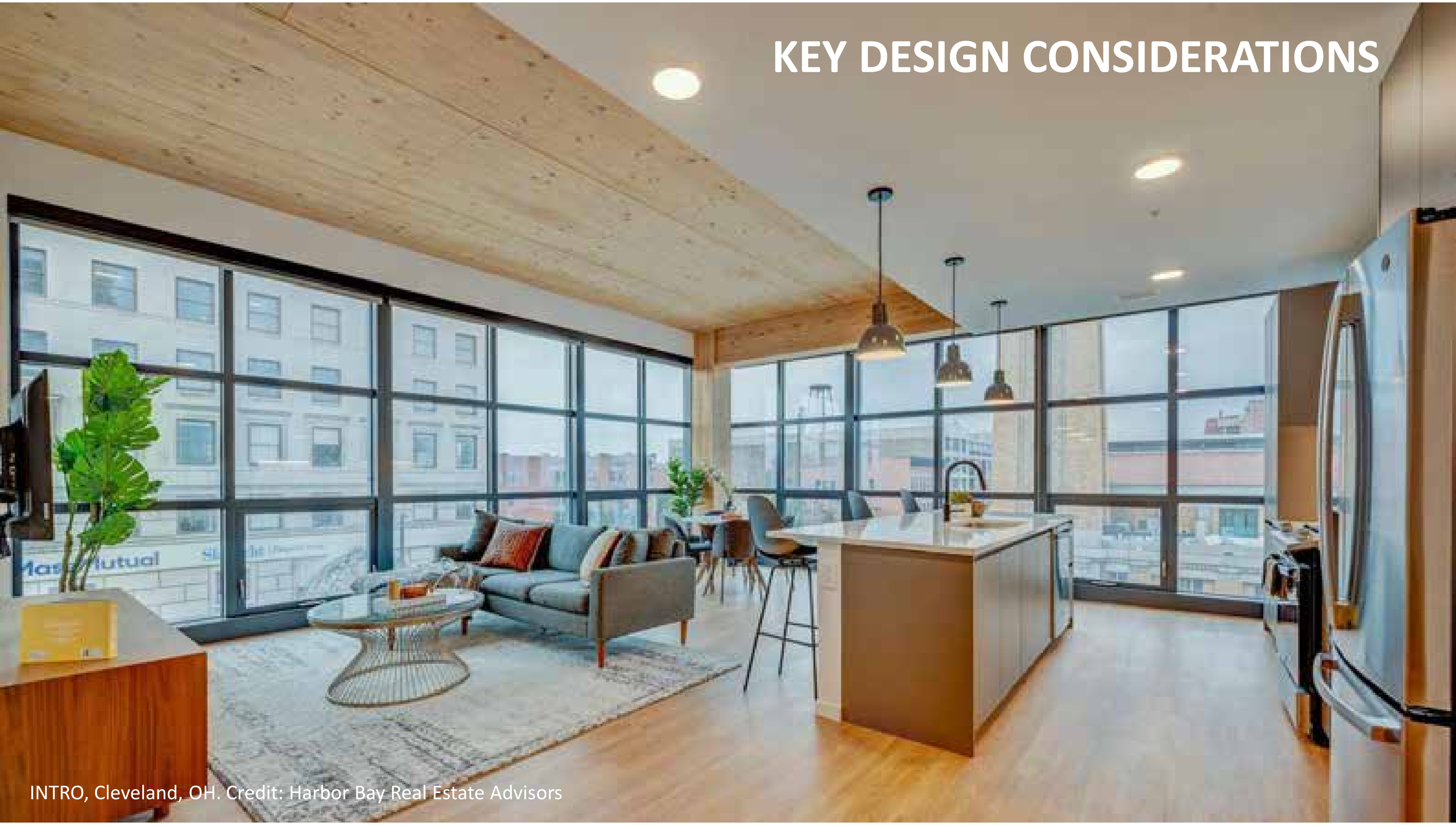
WoodWorks Online Event

Kendeda Building for Innovataive Sustainable Design, The Miller Hull Partnership with Lord Aeck Sargent, photo Jonathan Hillyer

1430 Q, The HR Group Architects, Buehler Engineering, Greg Folkins Photography

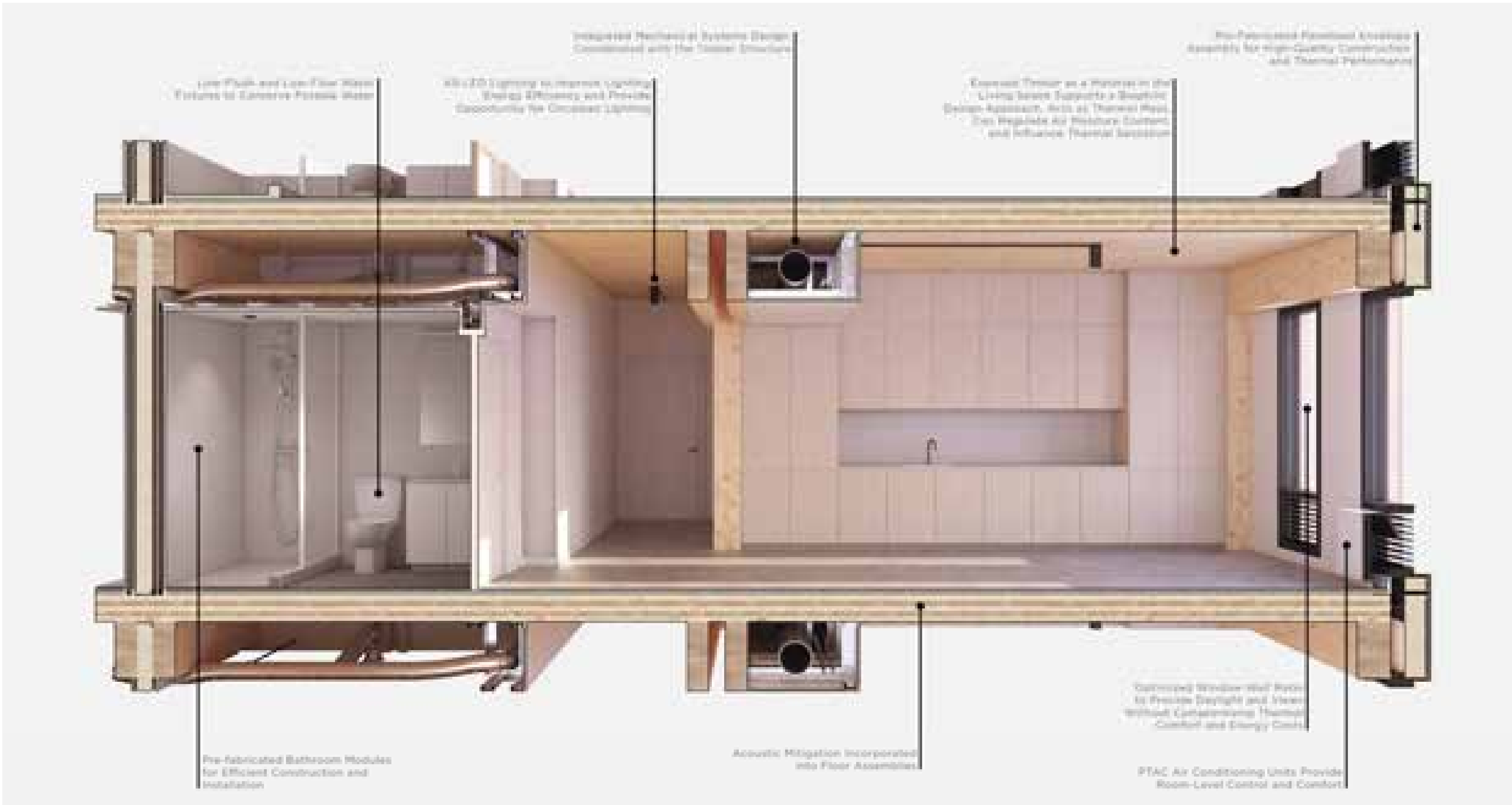
T3 Minneapolis, MGA, DLR Group, Magnusson Klemencic Associates, StructureCraft, photo Ema Peter

KEY DESIGN CONSIDERATIONS



INTRO, Cleveland, OH. Credit: Harbor Bay Real Estate Advisors

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

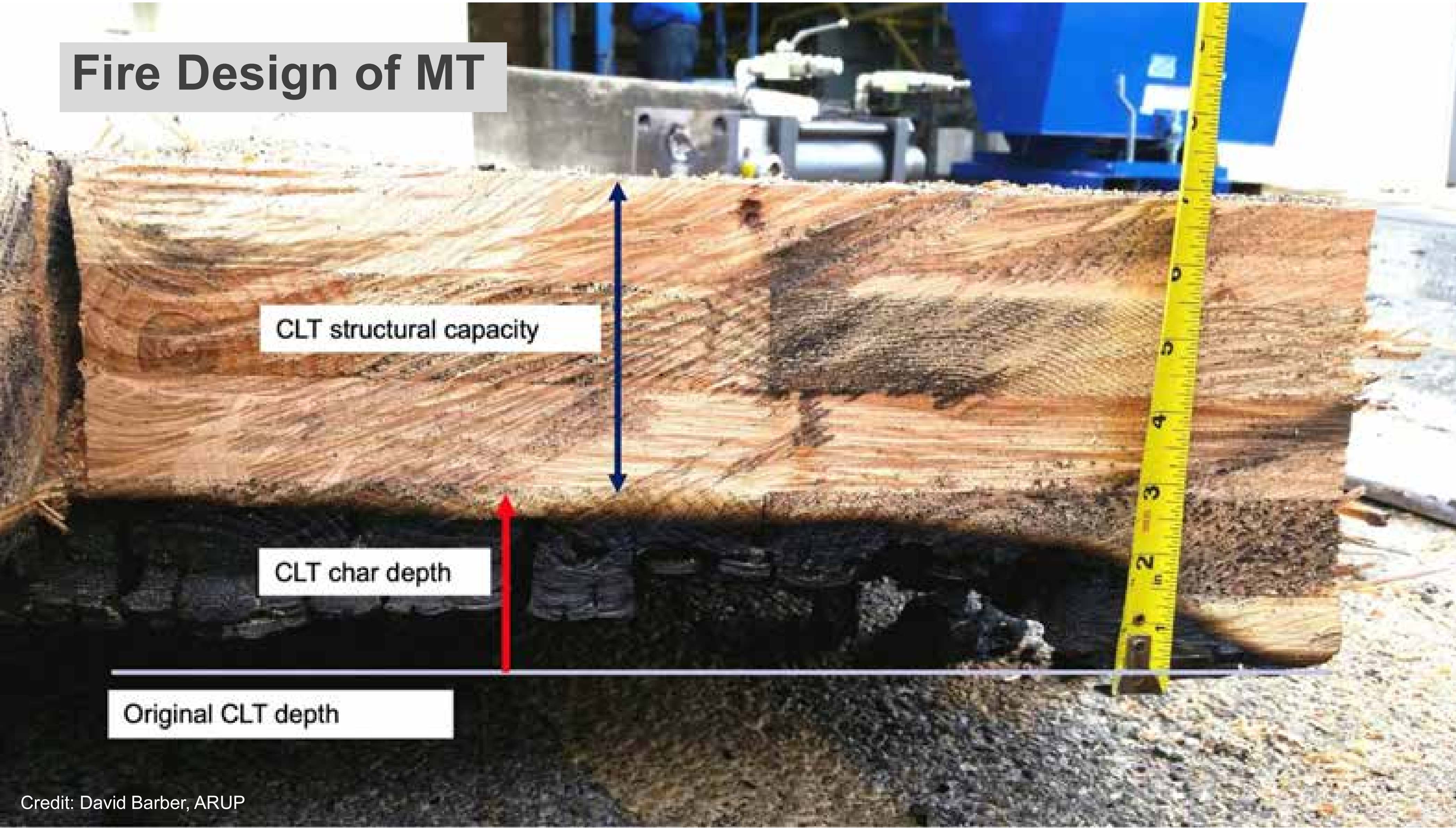
MEP Layout & Integration

Key considerations:

- Level of exposure desired
- Floor to floor, structure depth & desired head height
- Building occupancy and configuration (i.e. central core vs. double loaded corridor)
- Grid layout and beam orientations
- Need for future tenant reconfiguration
- Impact on fire & structural design: concealed spaces, penetrations

Credit: WoodWorks

Fire Design of MT



Credit: David Barber, ARUP

Key Early Design Decisions

Fire-Resistance Ratings

- **Driven primarily by construction type**
- **Rating achieved through timber alone or non-com protection required?**

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[g]	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

Key Early Design Decisions

Fire-Resistance Ratings (FRR)

- Thinner panels (i.e. 3-ply) generally difficult to achieve a 1+ hour FRR
- 5-ply CLT / 2x6 NLT & DLT panels can usually achieve a 1- or 2-hour FRR
- Construction Type | FRR | Member Size | Grid (or re-arrange that process but follow how one impacts the others)

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


Credit: David Barber, ARUP

Key Early Design Decisions

Construction type influences 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	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Source: 2018 IBC

Key Early Design Decisions

Construction type influences 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[g]	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)	$1\frac{1}{2}$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	$1\frac{1}{2}$	1	1	HT	1[b,c]	0

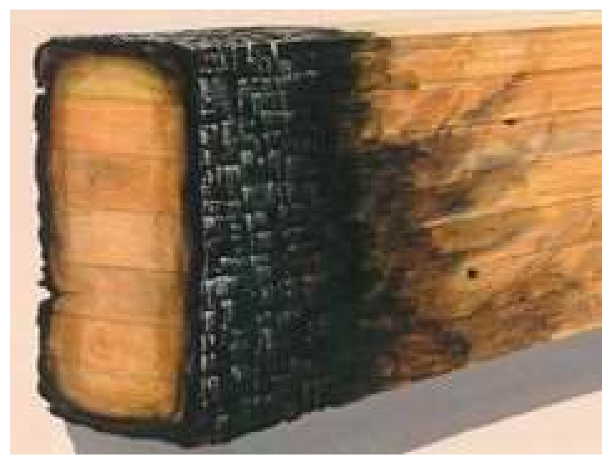
Source: 2021 IBC

Key Early Design Decisions

Construction type influences FRR

- Type IV-HT Construction (minimum sizes)
- **<u>Other than type IV-HT</u>**: Demonstrated fire resistance

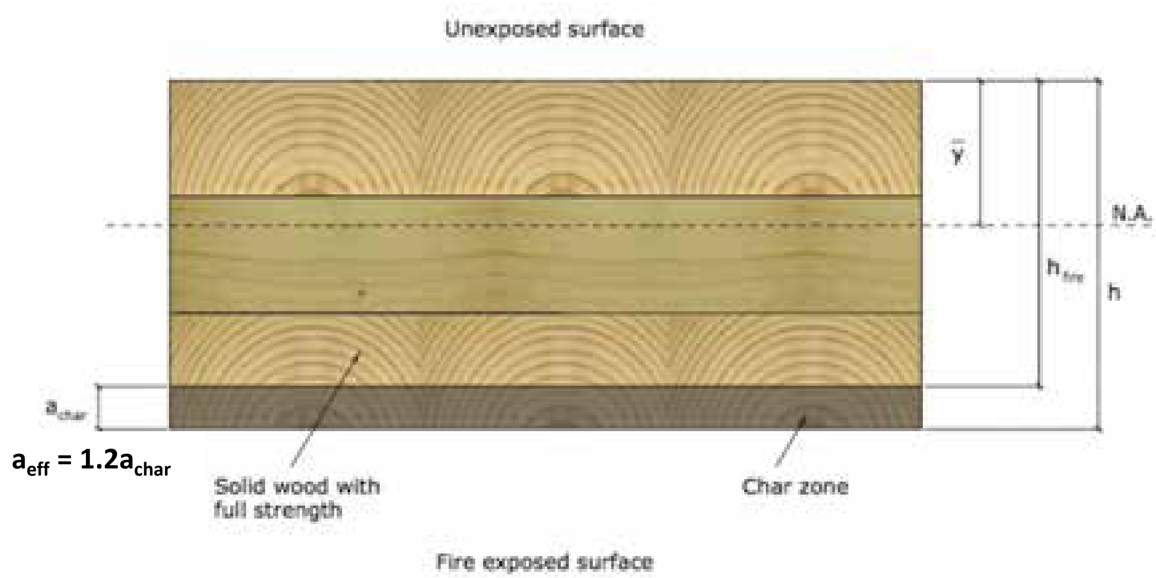
Method of demonstrating FRR (calculations or testing) can impact member sizing



Key Early Design Decisions

Which Method of Demonstrating FRR of MT is Being Used?

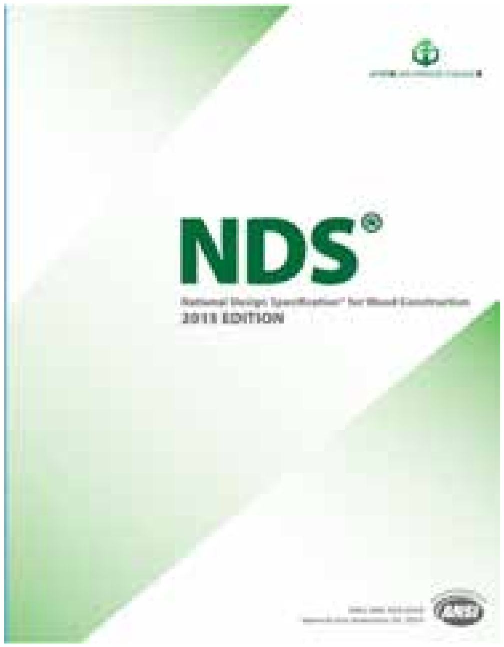
1. Calculations in Accordance with IBC 722 → NDS Chapter 16
2. Tests in Accordance with ASTM E119



FRR Design of MT

Calculated FRR of Exposed MT:
IBC to NDS code compliance path

FRR Design of MT




Credit: FPInnovations

NDS Chapter 16 includes calculation of fire resistance of NLT, CLT, Glulam, Solid Sawn and SCL wood products

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

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

FRR Design of MT

Nominal char rate of 1.5"/HR is recognized in NDS. Effective char depth calculated to account for duration, structural reduction in heat-affected zone

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

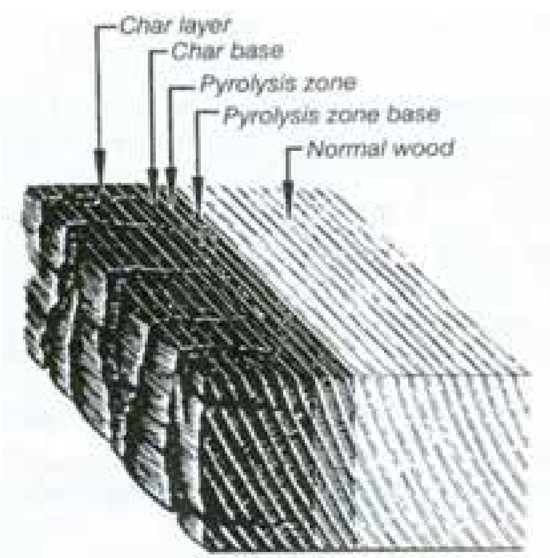
Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

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

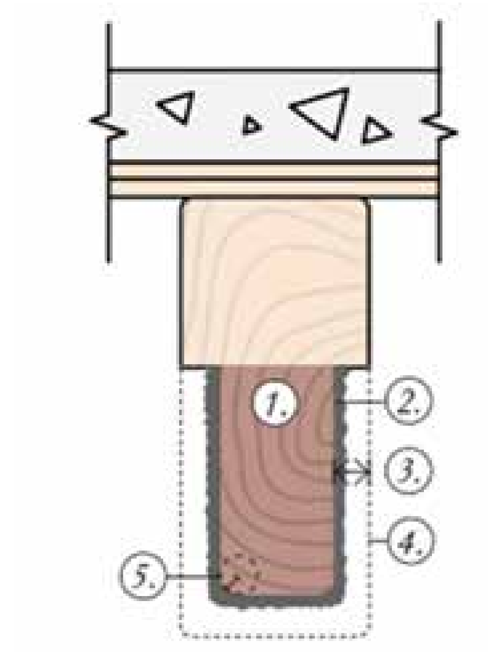
FRR Design of MT

Two structural capacity checks performed:

1. On entire cross section neglecting fire effects
2. On post-fire remaining section, with stress increases



Credit: Forest Products Laboratory



$$a_{char} = \beta_t t^{0.813}$$ Solid Sawn, Glulam, SCL

$$a_{char} = n_{lam} h_{lam} + \beta_t \left(t - \left(n_{lam} t_{gi}\right)\right)^{0.813}$$ CLT

$$a_{eff} = 1.2 a_{char}$$ Effective Char Depth

FRR Design of MT

WoodWorks Inventory of Fire Tested MT 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 1.5 EMSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced [illegible]% 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 [illegible]% 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 [illegible]% Moment Capacity	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 [illegible]% Moment Capacity	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 between Joists	Half-Lap	None	Loaded, See Manufacturer	2	11	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-Crete 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" gypcrete 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 [illegible]% 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
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails	Loaded, See Manufacturer	2	12 (Test 6)	Western Fire Center 11/01/2016
5-ply CLT [illegible]	KLH	CV3M1	None	Half-Lap & [illegible]	None	Loaded, [illegible]	1	18	SwRI [illegible]

FRR Design of MT

WoodWorks
WOOD PRODUCTS COUNCIL

Fire-Resistive Design of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

Mass Timber & Construction Type

Mass Timber Fire Design Resource

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


Acoustics & Sound Control

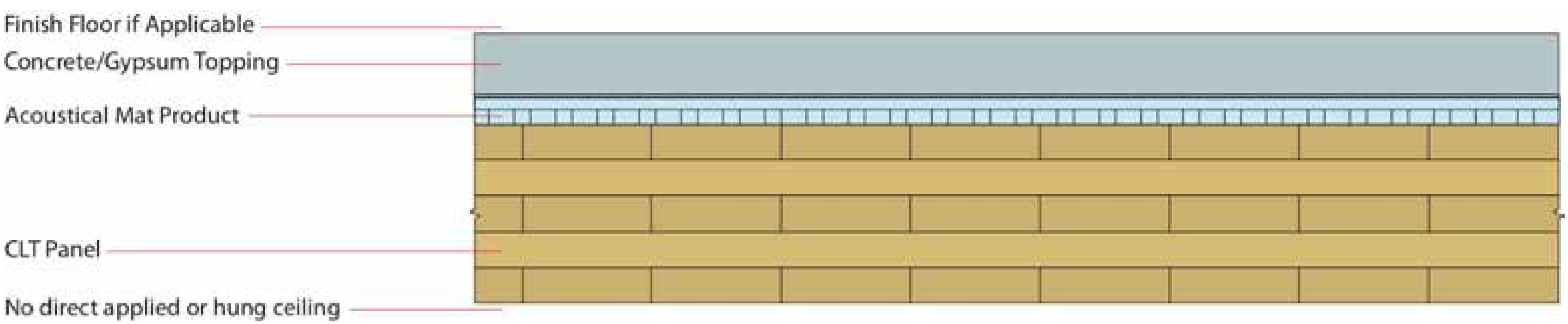
Acoustics & Sound Control

Consider Impacts of:

- Timber & Topping Thickness
- Panel Layout
- Gapped Panels
- Connections & Penetrations
- MEP Layout & Type

Credit: Rothoblaas

Acoustics & Sound Control

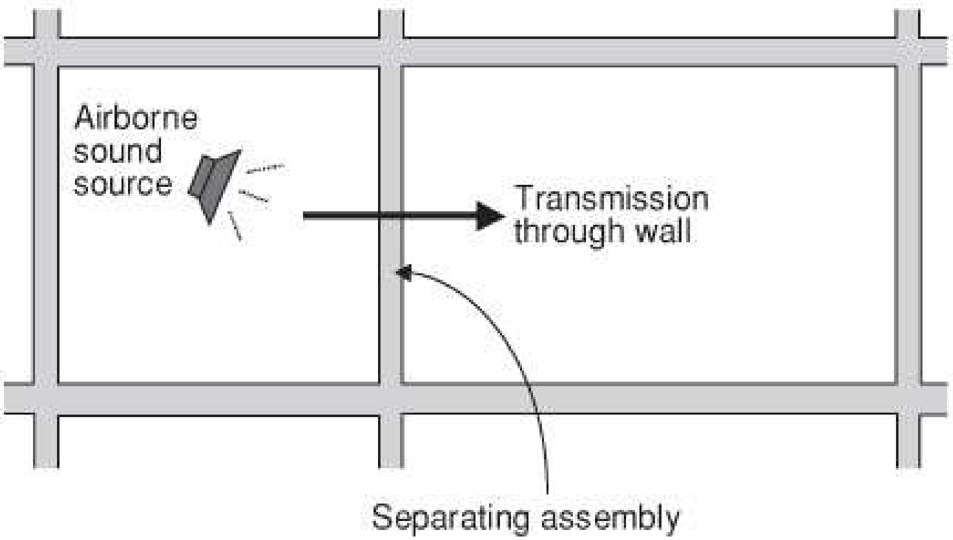


Acoustics & Sound Control

Air-Borne Sound:

Sound Transmission Class (STC)

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies

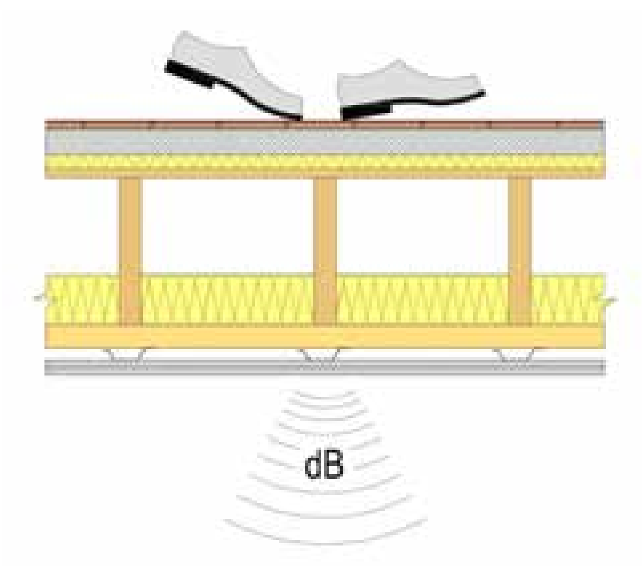


Acoustics & Sound Control

<u>Structure-borne sound:</u>

Impact Insulation Class (IIC)

- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies



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

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

Acoustics & Sound Control

MT: Structure Often is Finish

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

Acoustics & Sound Control

But by Itself, Not Adequate for Acoustics

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

Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:

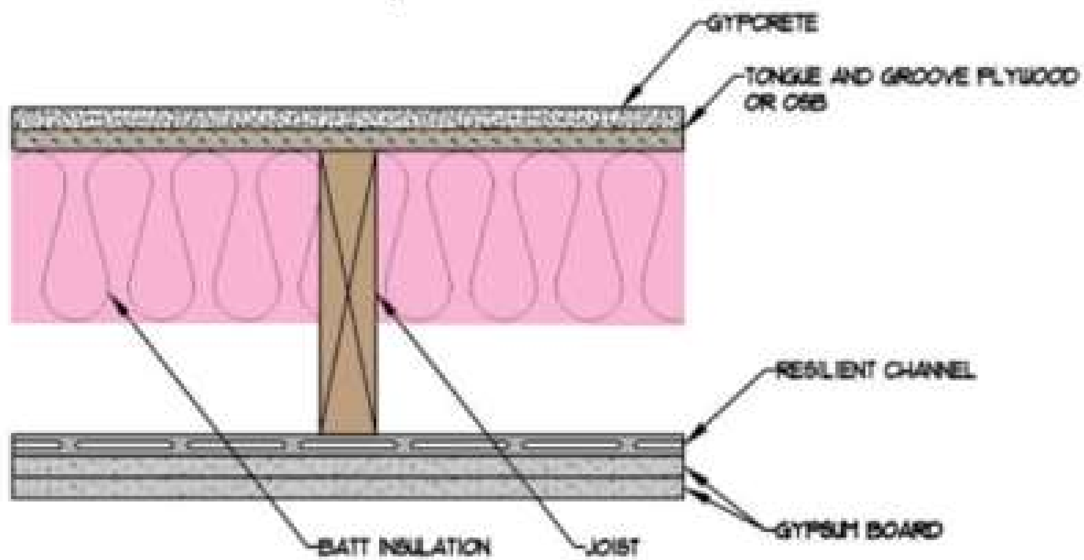
1. Add mass
2. Add noise barriers
3. Add decouplers


Image credit: Christian Columbres

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

1. Add mass
2. Add noise barriers
3. Add decouplers

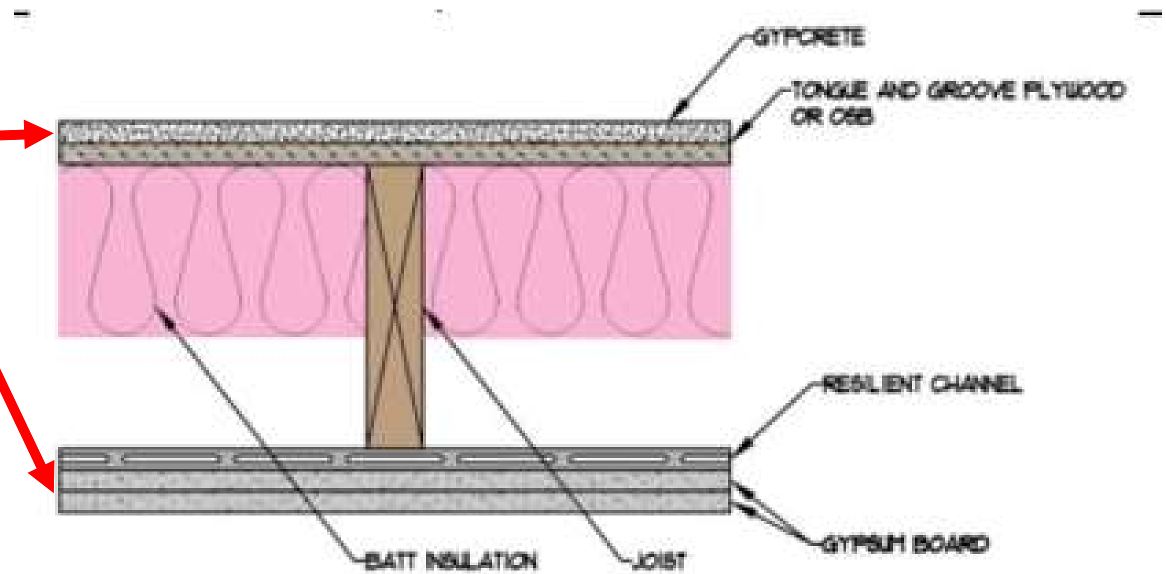


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

1. Add mass
2. Add noise barriers
3. Add decouplers

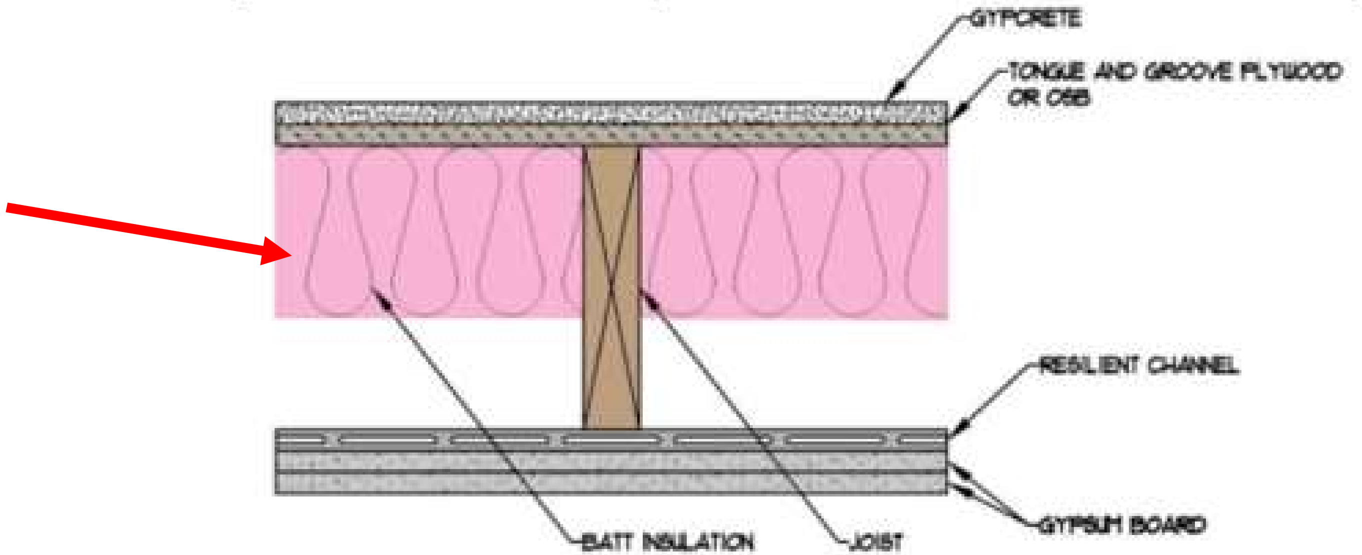


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

1. Add mass
2. Add noise barriers
3. Add decouplers

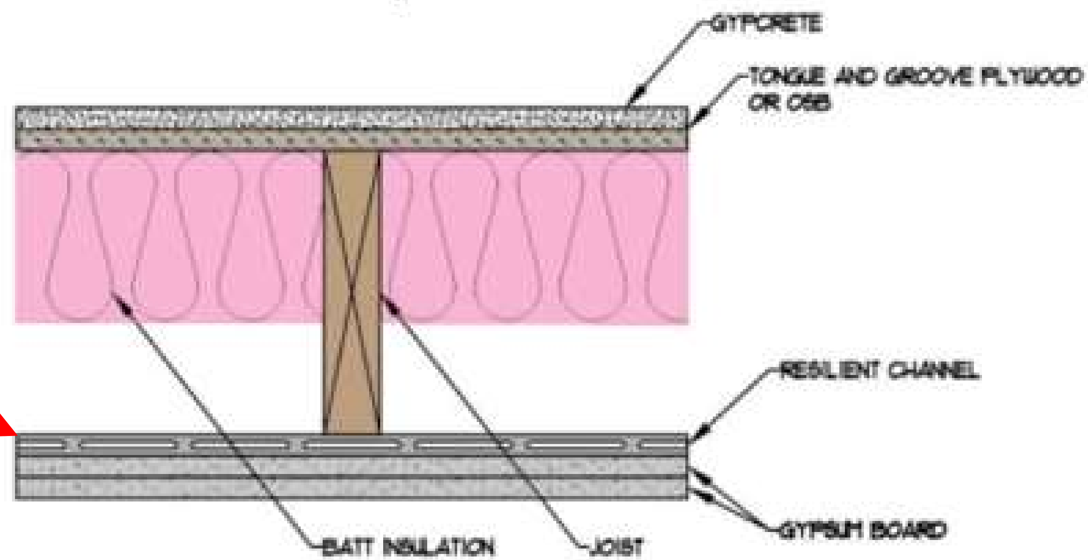


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

1. Add mass
2. Add noise barriers
3. Add decouplers



STC 62

Acoustics & Sound Control

Mass timber has relatively low "mass"
Recall the three ways to increase acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers


Credit: Christian Columbres

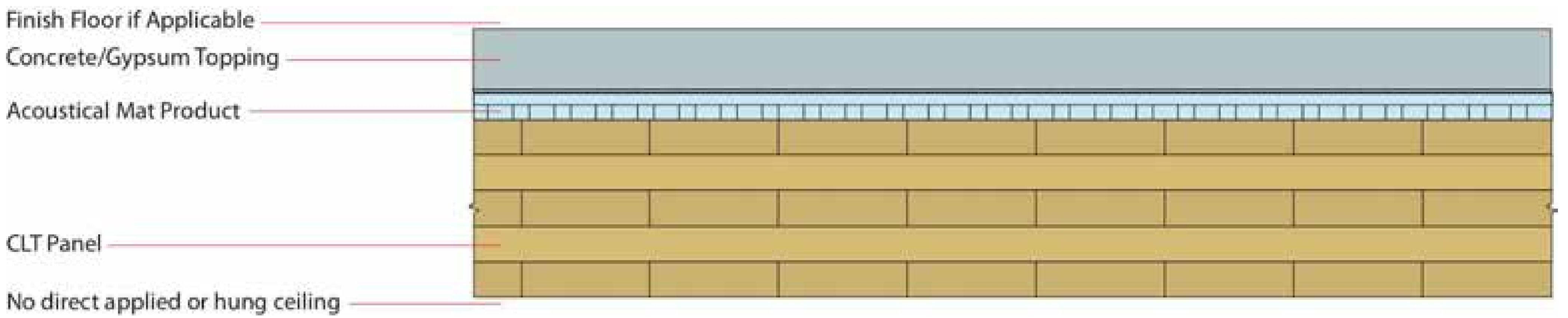
Acoustics & Sound Control

Concrete Slab:	CLT Slab:
6” Thick	6-7/8” Thick
80 PSF ↔	18 PSF
STC 53 ↔	STC 41

Acoustics & Sound Control

There are three main ways to improve an assembly's acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers



Acoustics & Sound Control

There are three main ways to improve an assembly's acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers

Acoustical Mat:

- Typically roll out or board products
- Thicknesses vary: Usually ¼" to 1"+


Credit: Maxxon

Acoustics & Sound Control

Acoustical floor underlayments

Photo: AcoustiTECH

Photo: Kinetics Noise Control, Inc.,

Photo: Maxxon Corporation

Photo: Pliteq Inc.,

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
- WSP (if applicable)
- Mass timber floor panels

Credit: AcoustiTECH

Acoustics & Sound Control

Solutions Paper


WoodWorks
WOOD PRODUCTS COUNCIL

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

http://www.woodworks.org/wp-content/uploads/wood_solution_paper-MASS-TIMBER-ACOUSTICS.pdf


Mass Timber Assembly Options: Walls

Acoustical Differences between Mass Timber Panel Options

Improving Performance by Minimizing Flanking

Acoustics & Sound Control

Inventory of Tested Assemblies

Acoustically-Tested Mass Timber Assemblies

Following is a list of mass timber assemblies that have been acoustically tested as of January 23, 2019. Sources are noted at the end of this document. For free technical assistance on any questions related to the acoustical design of mass timber assemblies, or free technical assistance related to any aspect of the design, engineering or construction of a commercial or multi-family wood building in the U.S., email help@woodworks.org or contact the WoodWorks Regional Director nearest you: http://www.woodworks.org/project-assistance

Contents:

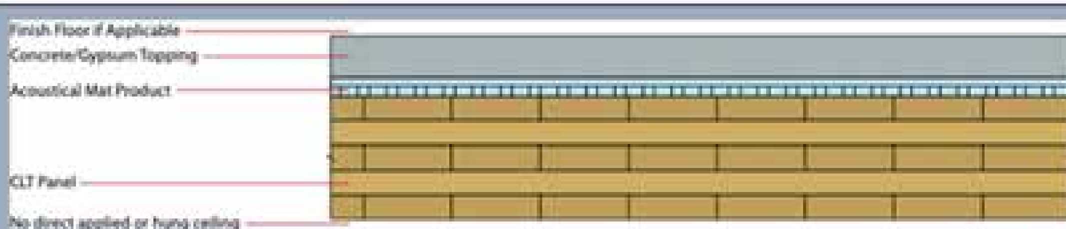
http://bit.ly/mass-timber-assemblies

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

Mass Timber in Multi-Family

Early Design Decision Example

7-story, 84 ft tall multi-family building

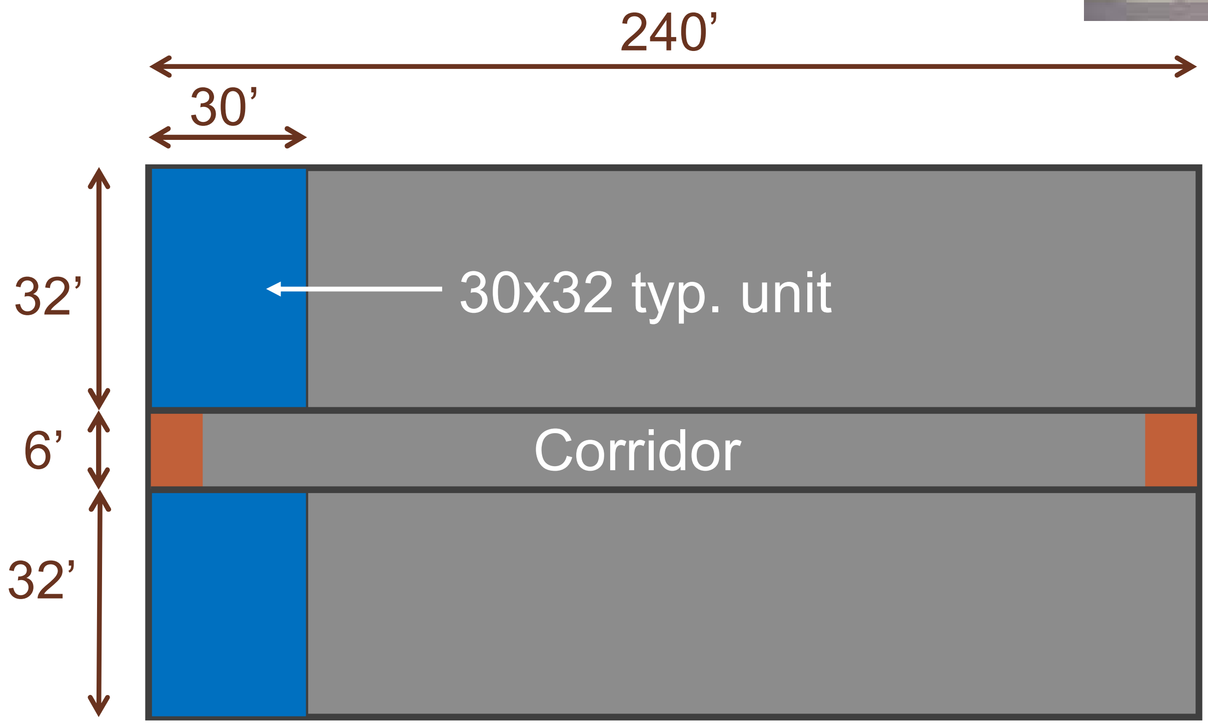
- Parking & Retail on 1st floor, residential units on floors 2-7
- NFPA 13 sprinklers throughout
- Floor plate = 18,000 SF
- Total Building Area = 126,000 SF

Key Early Design Decisions

Early Design Decision Example

7-story, multi-family building, typ. floor plan:


Credit: Monte French Design Studio

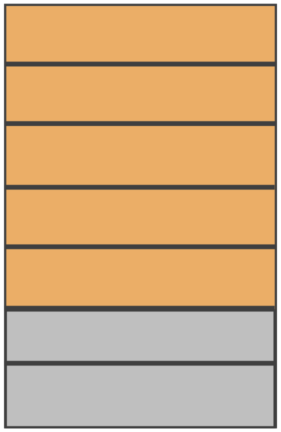


Key Early Design Decisions

Early Design Decision Example

MT 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



Key Early Design Decisions

Early Design Decision Example


Credit: Monte French Design Studio

MT 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:

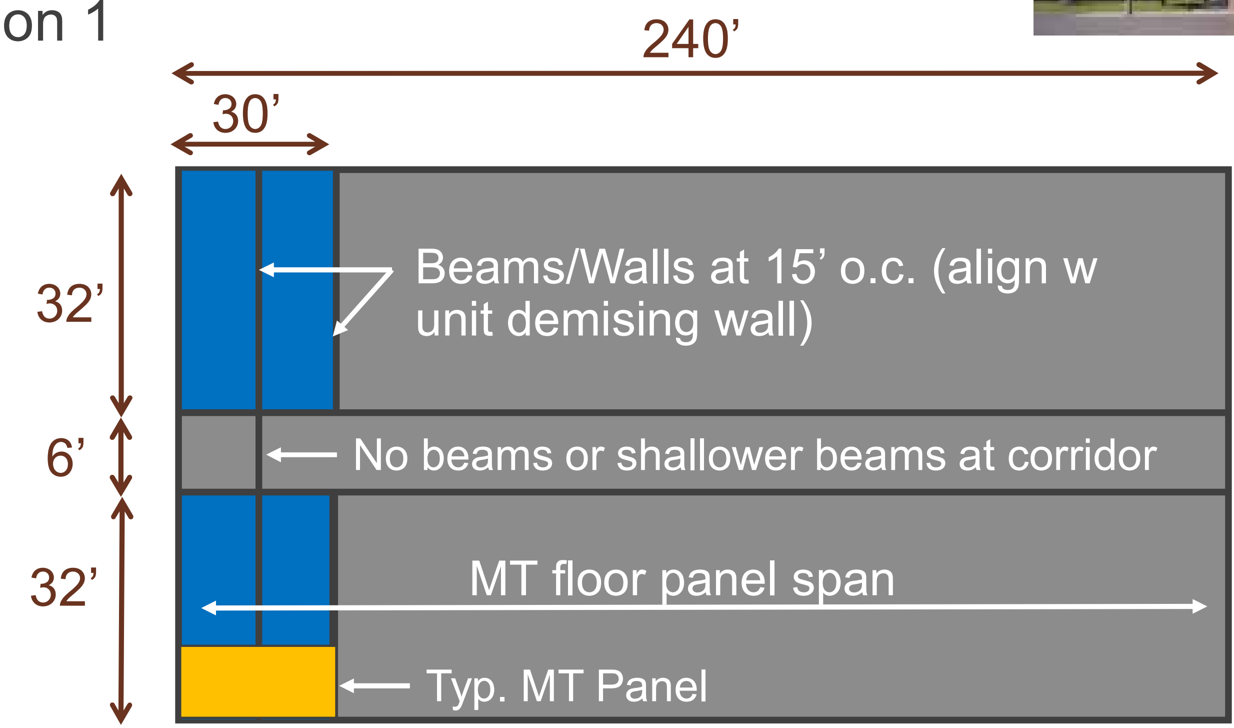
- 2 hr FRR, all exposed floor panels, beams, columns
- Likely will need at least 5-ply CLT / 2x6 NLT/DLT
- Efficient spans in the 14-17 ft range
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
- CLT exterior walls permitted

Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

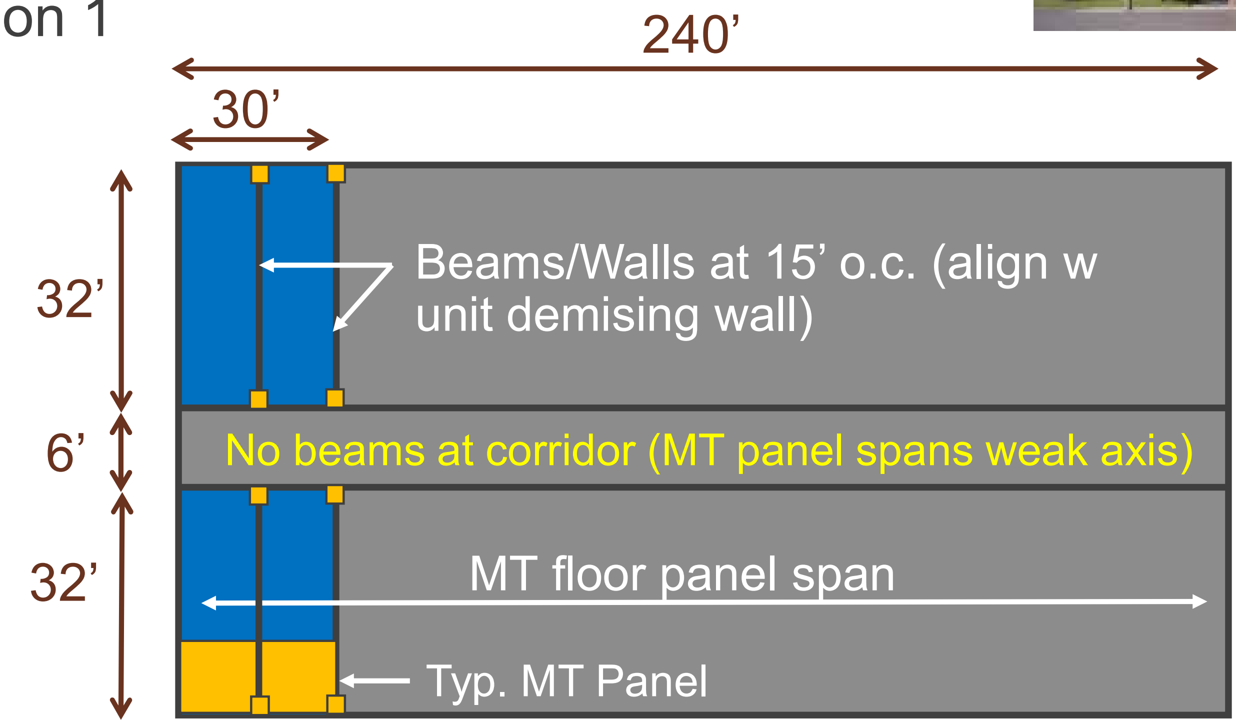


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

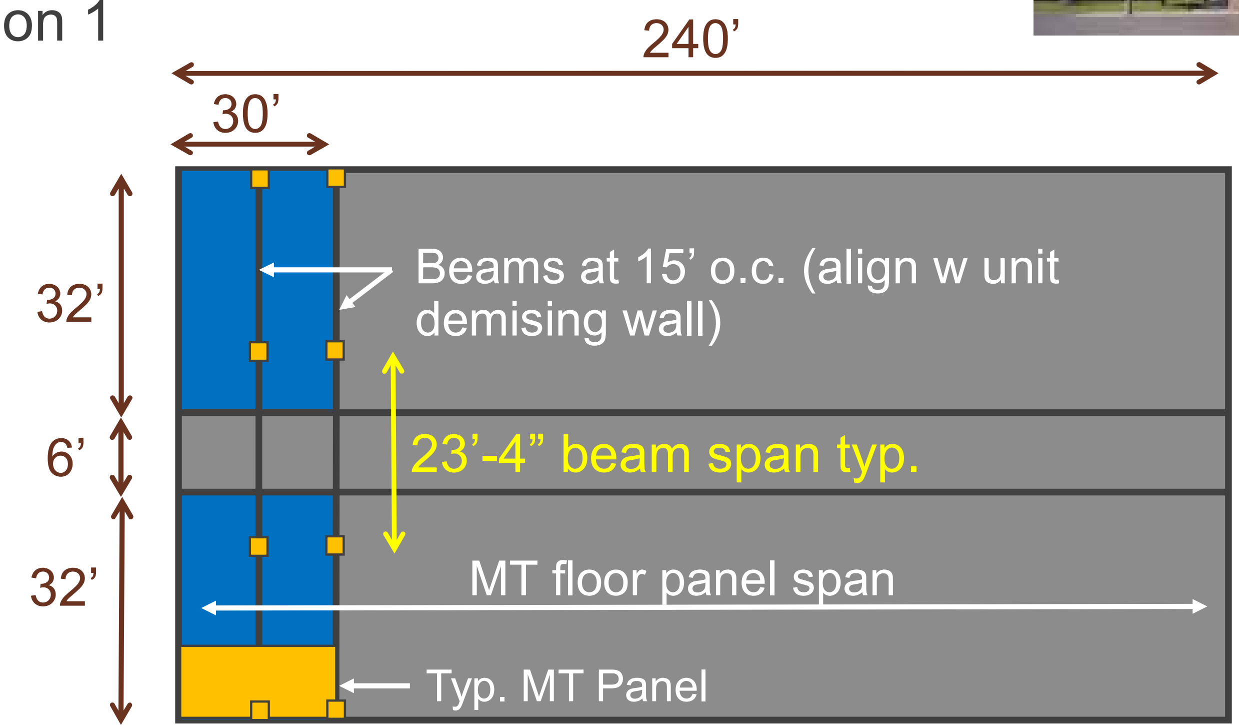


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

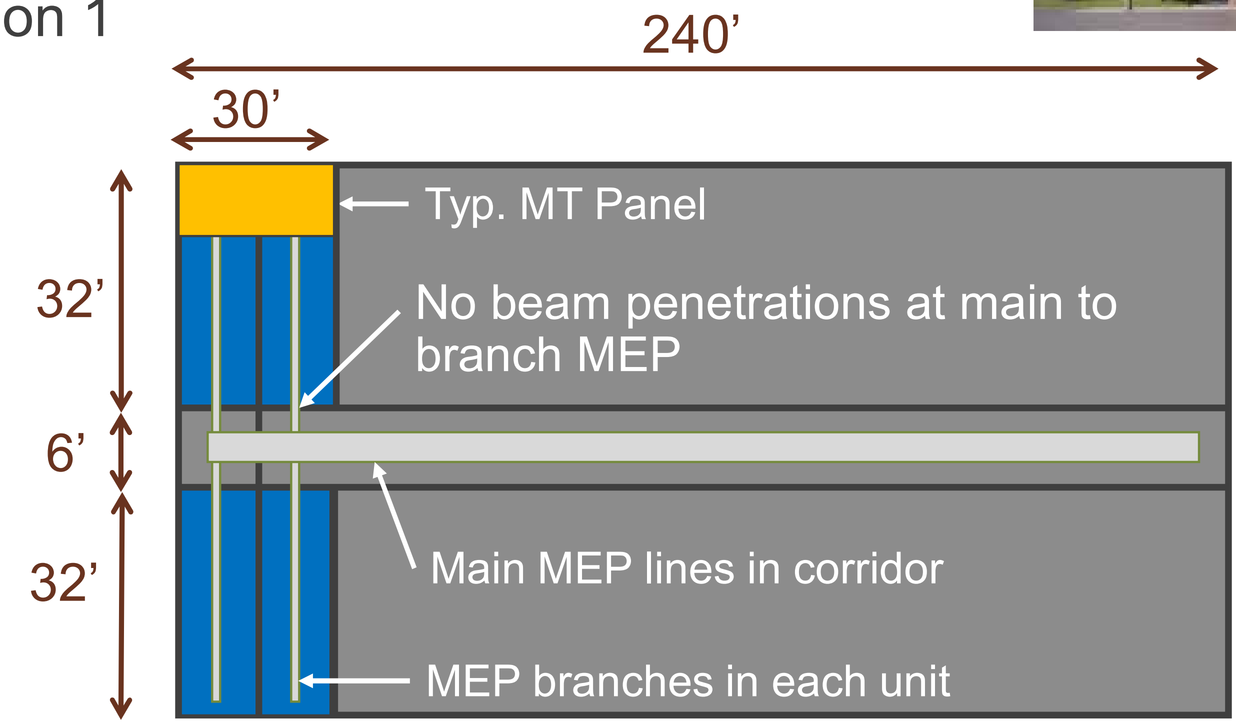


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 1

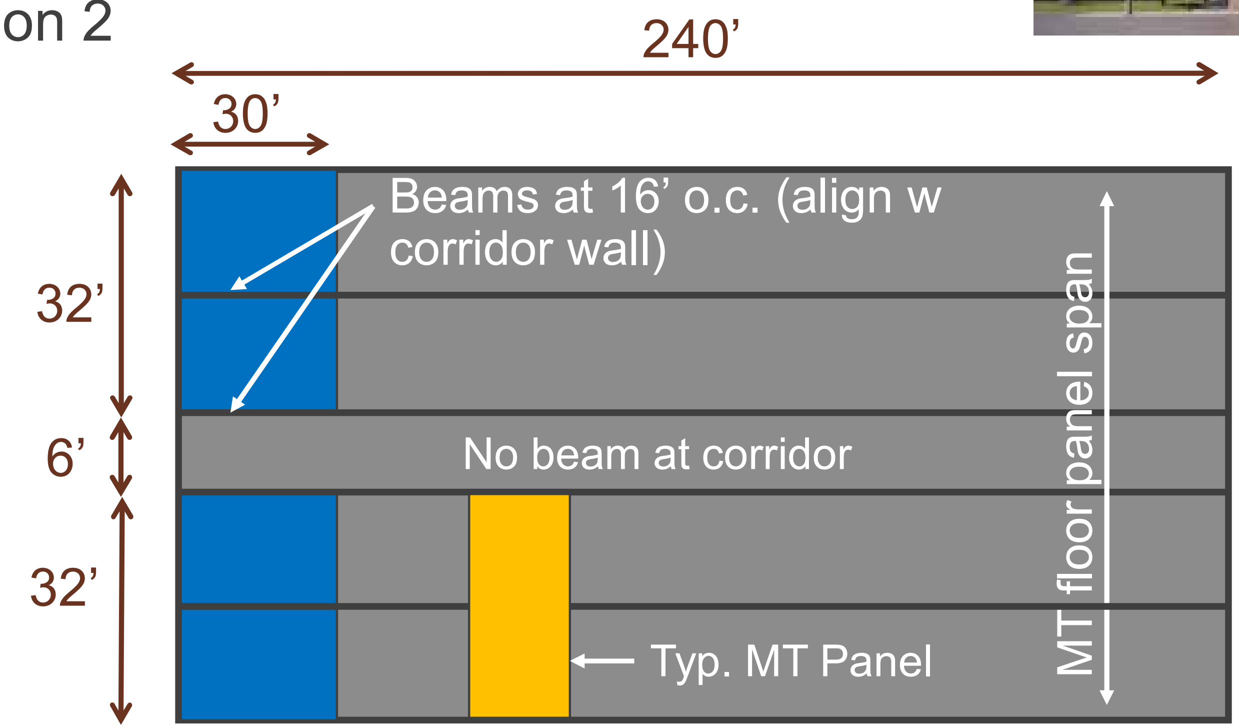


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2

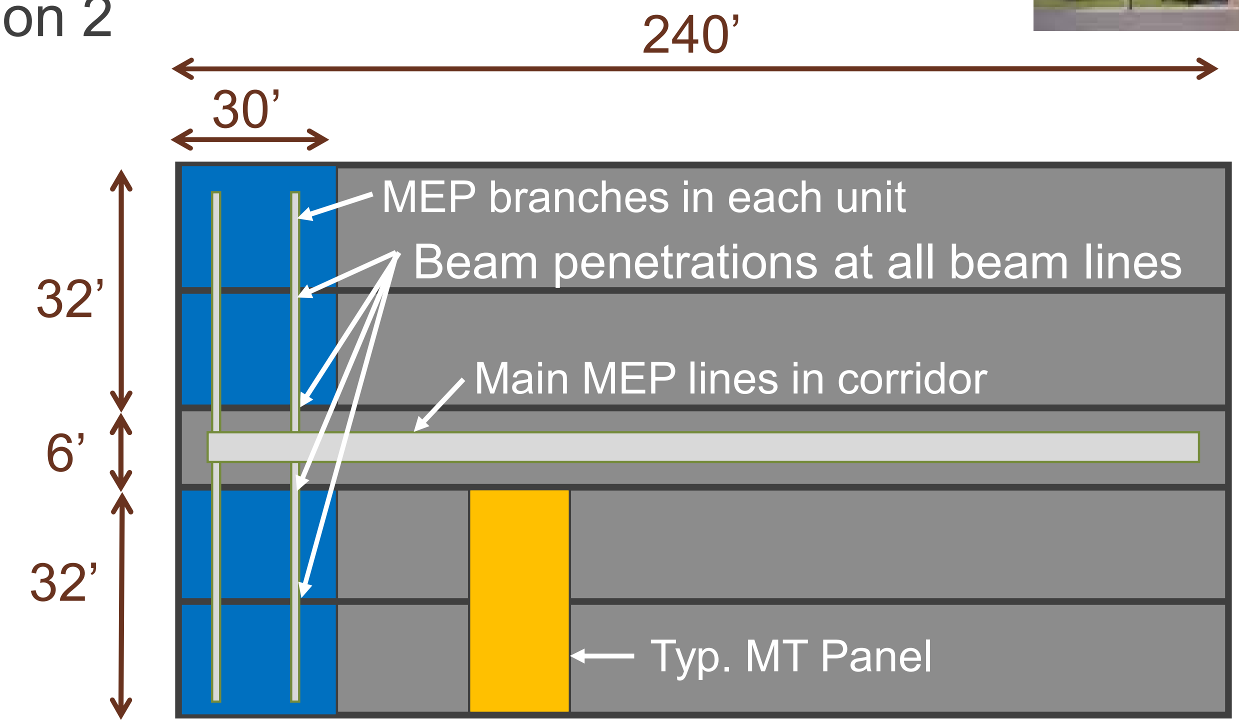


Key Early Design Decisions

Early Design Decision Example

Type IV-C Grid Options

- Option 2

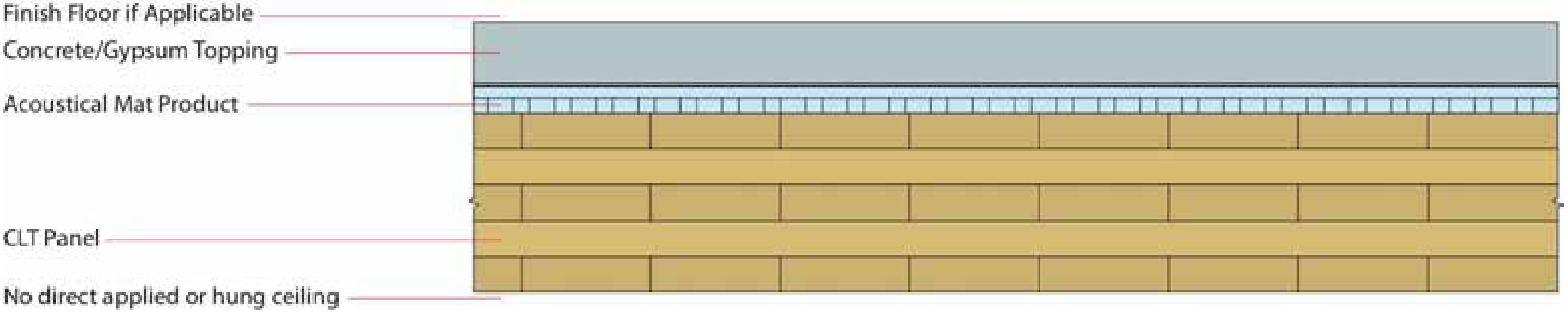


Key Early Design Decisions

Early Design Decision Example

Type IV-C Floor Assembly Options


Credit: Monte French Design Studio



- 2-hr FRR: 5-ply CLT (tested assembly) or 7-ply CLT (char calculations)
- STC & IIC 50 min: 2” topping (5-ply CLT) or 1.5” topping (7-ply CLT)

Note: many other acoustic mat and topping options exist, one example shown here
Note: 5-ply is most efficient for the 15-16 ft panel spans shown

Key Early Design Decisions

Early Design Decision Example

MT 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:

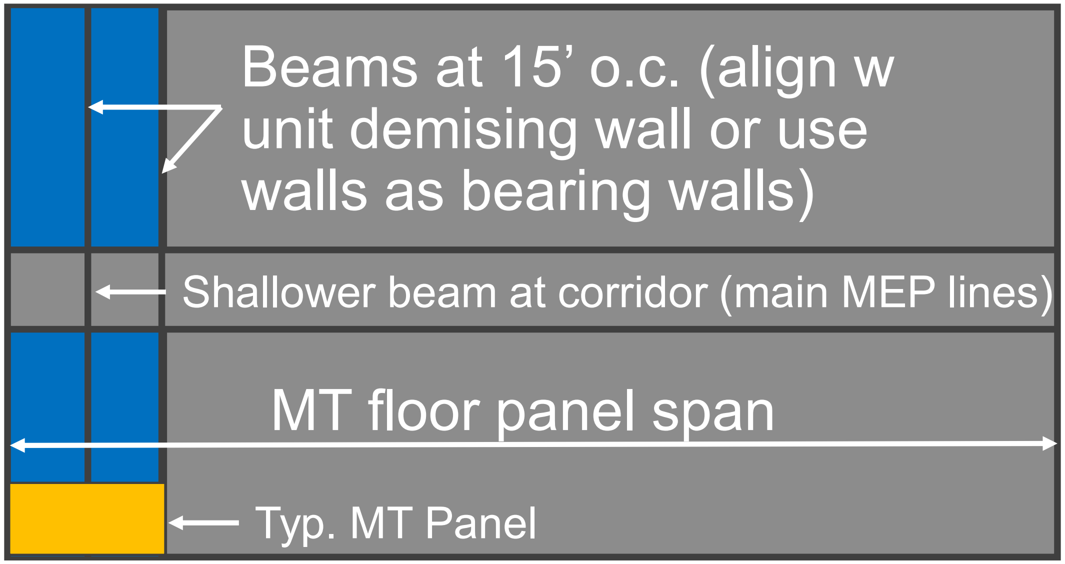
- 1 hr FRR
- Potential to use 3-ply or thin 5-ply CLT
- Efficient spans vary with panel thickness
- Efficient grids of that or multiples of that (i.e. 20x25, etc)
- 1 story Type IA podium required
- CLT exterior walls not permitted

Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

- Option 1

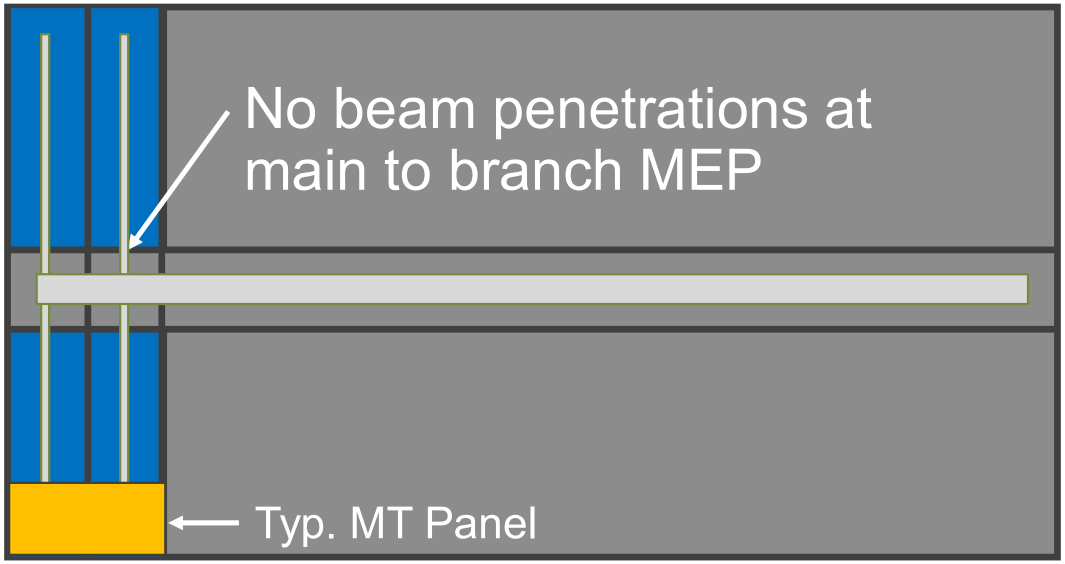


Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

- Option 1

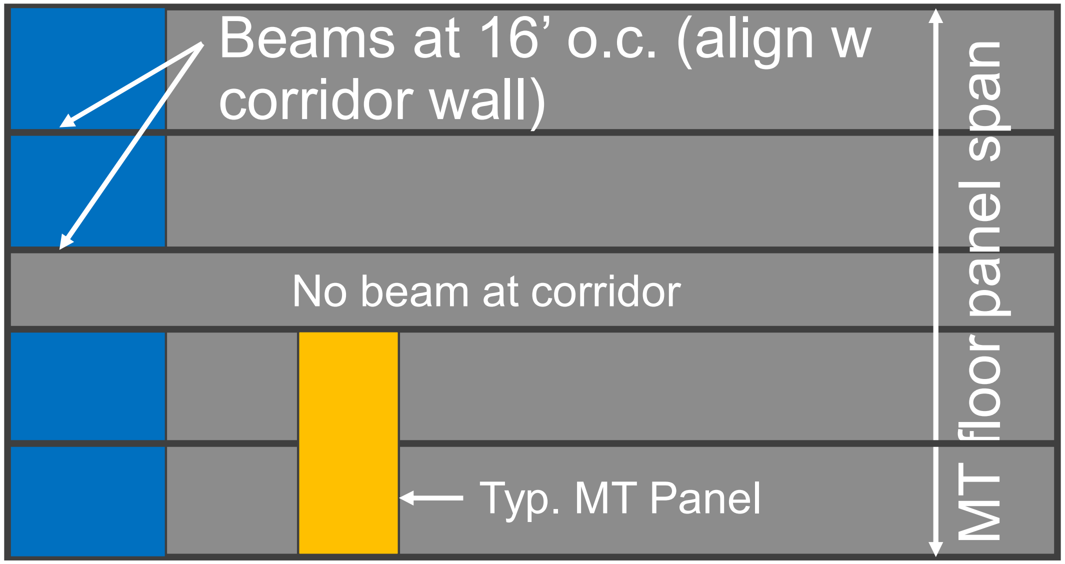


Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options

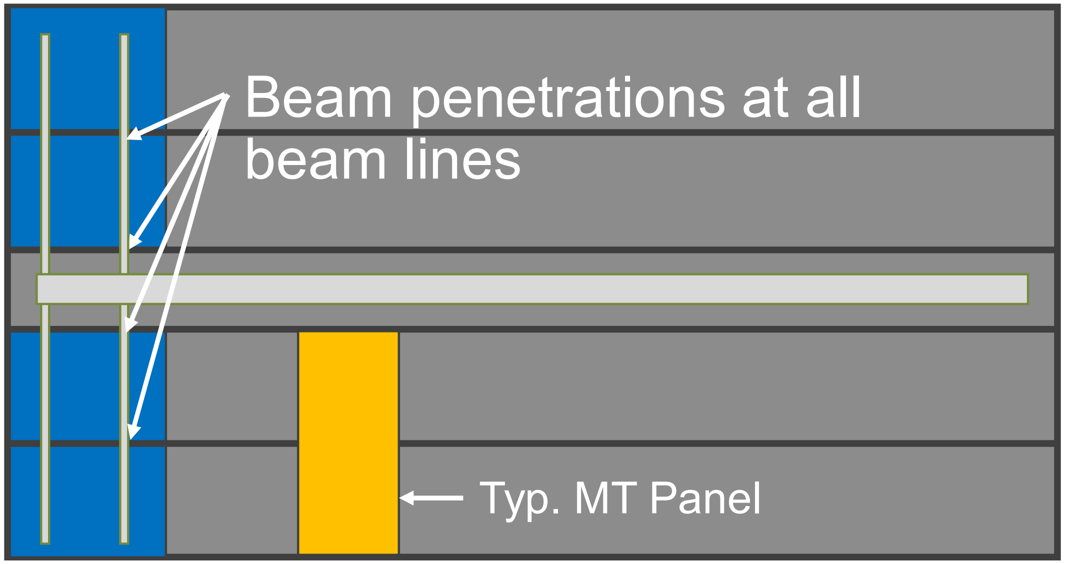
- Option 2



Key Early Design Decisions

Early Design Decision Example

Type IIIA Grid Options
- Option 2



Key Early Design Decisions

Early Design Decision Example

MT Construction Type Options:
- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- <u>5 stories of IV-HT over 2 stories of IA podium</u>

Type IV-HT in Group R Occupancy:

- Separation walls (fire partitions) and horizontal separation (horizontal assemblies) between dwelling units require a 1-hour rating.
- Floor panels require a 1-hour rating in addition to minimum sizes
- **<u>Essentially the same panel and grid options as IIIA</u>**

Ref. IBC 420.2, 420.3, 708.3, 711.2.4.3

Speed of Construction

Market Distinction

KNOW YOUR WHY

Sustainability

Lightweight

Leasing Velocity

Cost

Urban Density

Seattle Mass Timber Tower: Detailed Cost Comparison
Fast Construction

- Textbook example done by industry experts
- Mass timber vs. PT conc
- Detailed cost, material takeoff & schedule comparisons

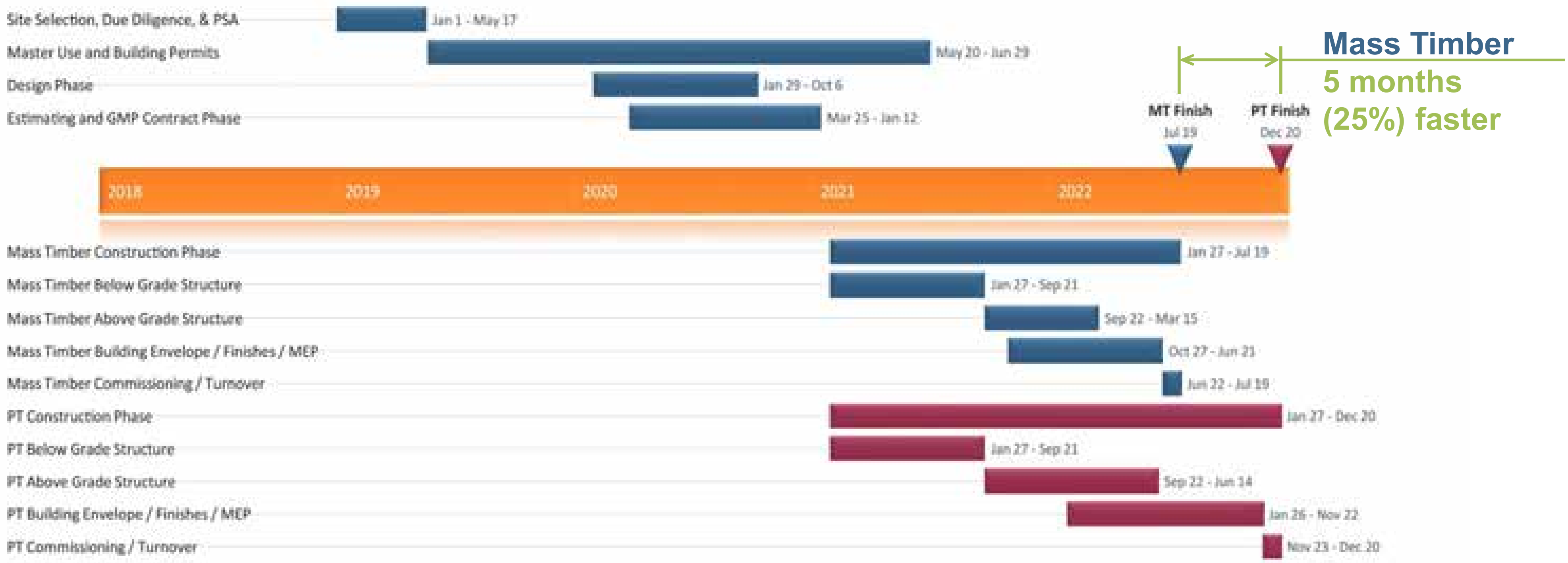
"The initial advantage of Mass Timber office projects in Seattle will come through the
leasing velocity
that developers will experience."

- Connor Mclain, Colliers

Seattle Mass Timber Tower

Fast Construction

Construction Schedule:



Source: Tall With Timber
A Seattle Mass Timber Tower Case Study by DLR Group[1]

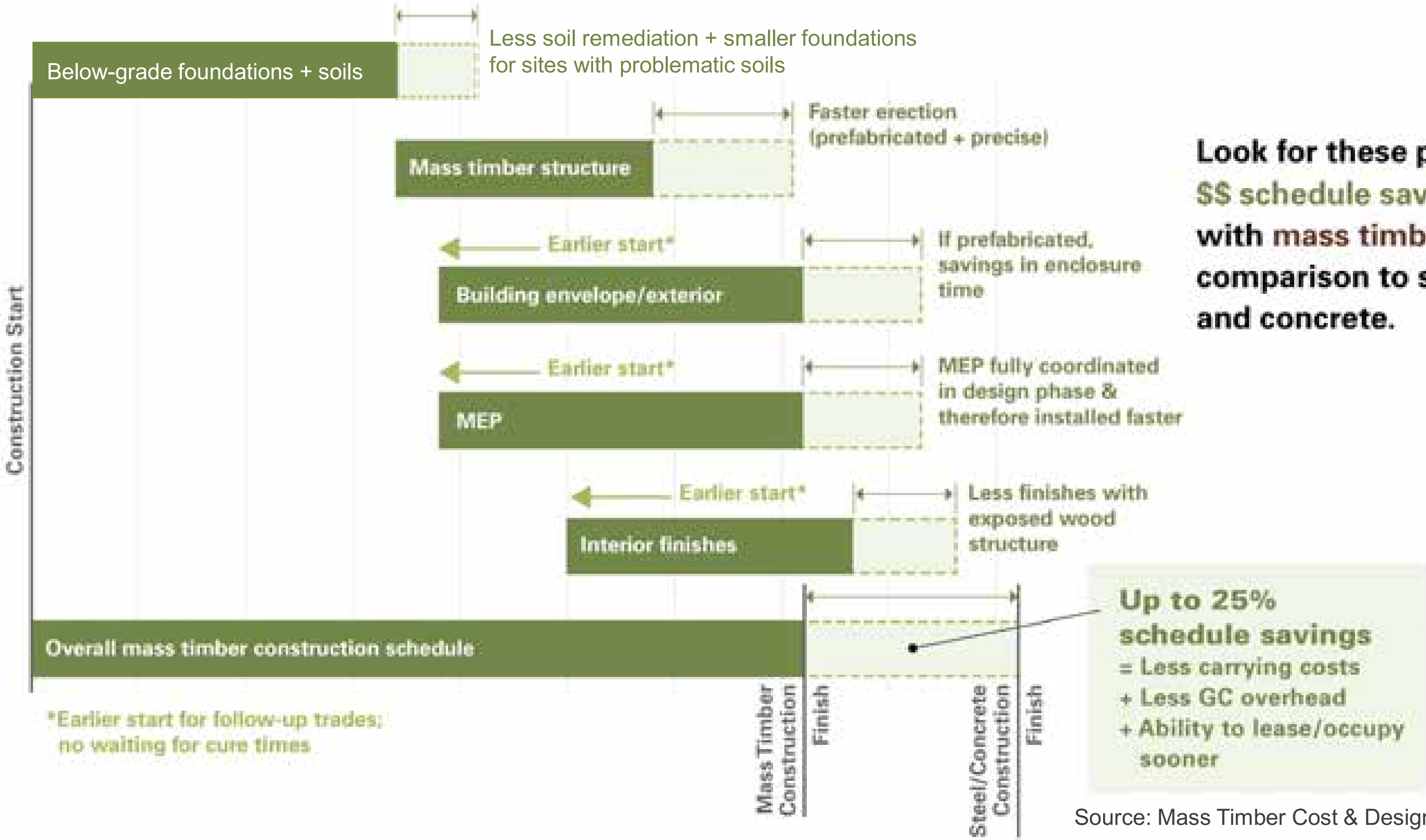
Seattle Mass Timber Tower

Faster Construction + Higher Material Costs = Cost Competitive

System	Mass Timber Design	PT Concrete Design	Mass Timber Savings
Direct Cost of Work	$86,997,136	$85,105,091	2.2%
Project Overhead	$ 9,393,750	$11,768,750	-20.2%
Add-Ons	$ 8,387,345	$ 8,429,368	-0.5%
Total	**$104,778,231**	**$105,303,209**	**-0.5%**

Source: DLR Group | Fast + Epp | Swinerton Builders

Compressing the Typical Schedule

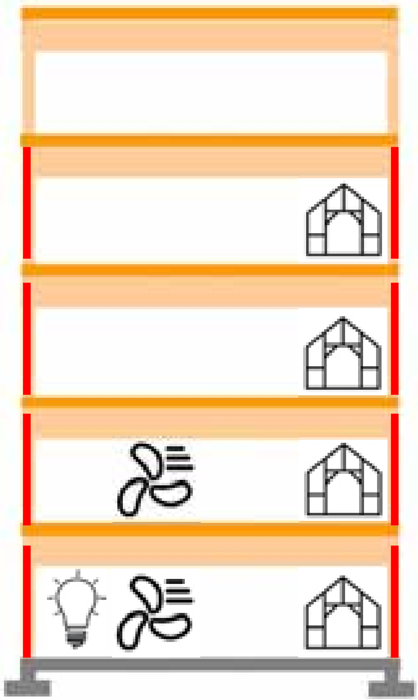


Look for these potential $$ schedule savings with mass timber in comparison to steel and concrete.

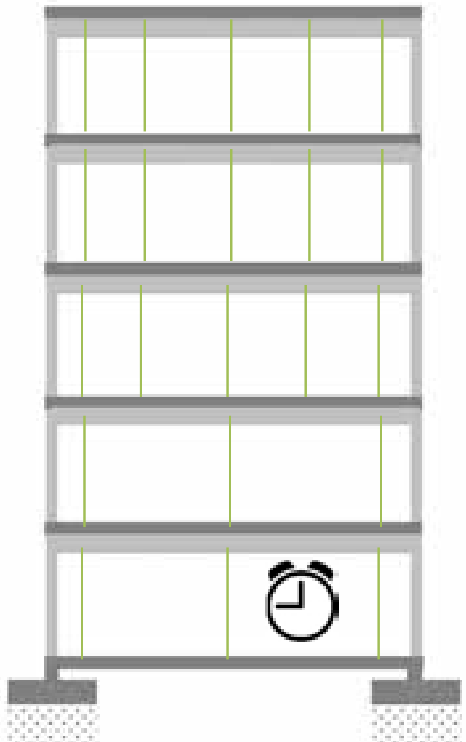
Source: Mass Timber Cost & Design Optimization, WoodWorks[2]

Schedule Savings for Rough-In Trades

Fast Construction



NO curing
(mass timber)

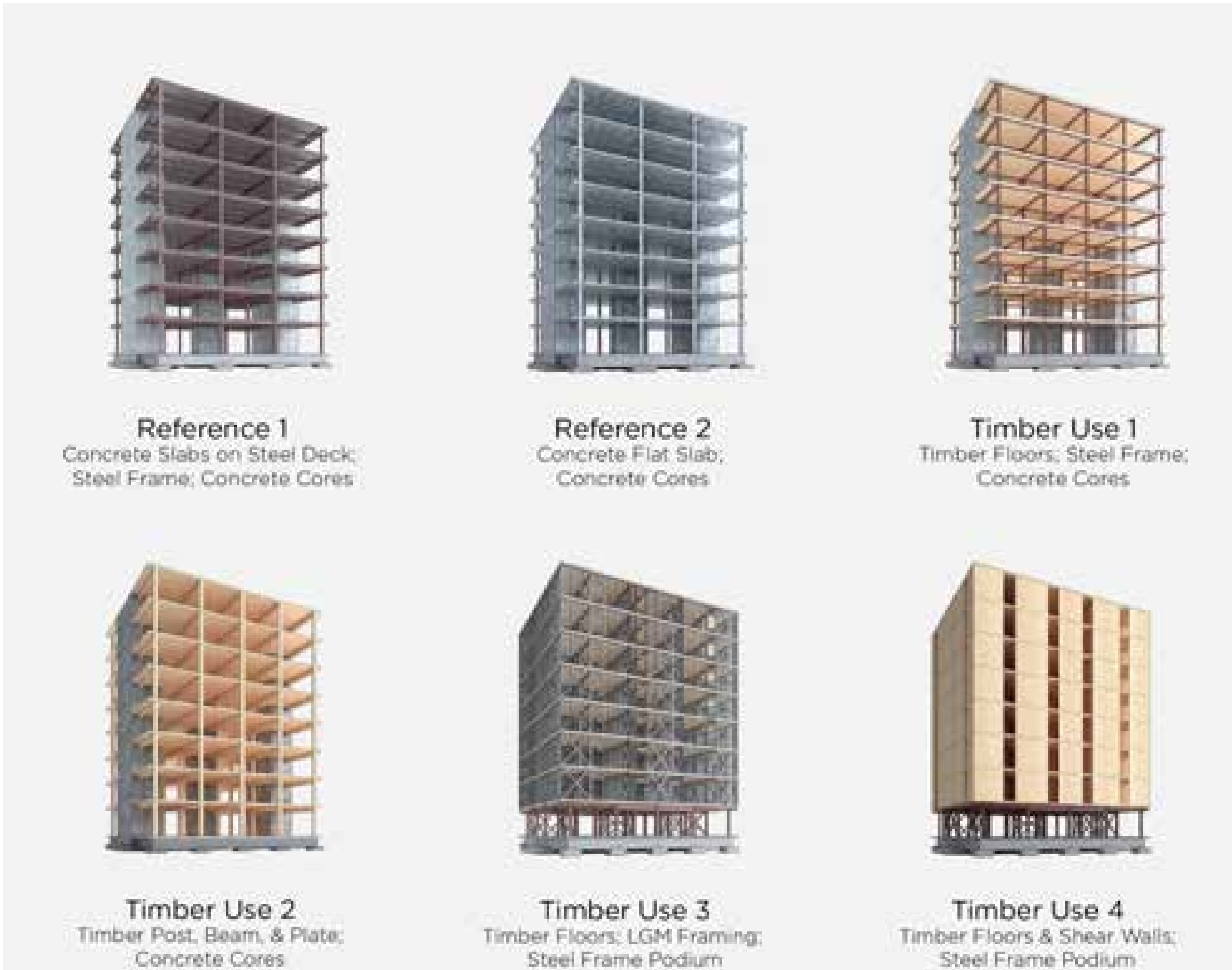


Curing & maze of
shores (concrete)

Photo: WoodWorks


Source: Generate Architecture + Technologies

Holistic Cost Assessment



Source: Generate Architecture + Technologies

Sustainability Impacts

GLOBAL WARMING POTENTIAL & MATERIAL MASS
(PER BUILDING ASSEMBLY)

Source: Generate Architecture + Technologies

Reduce Risk

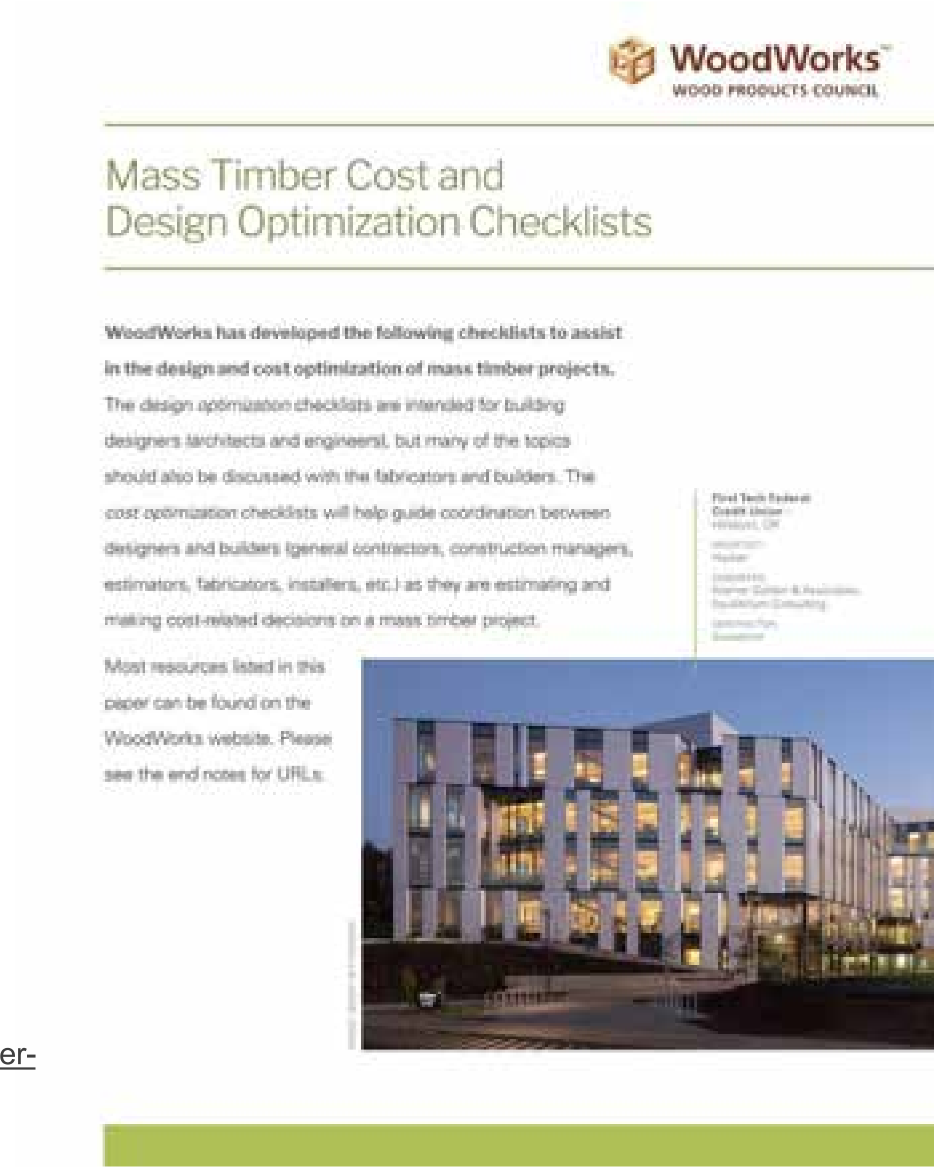
Optimize Costs

- For the entire project team, not just builders
- Lots of reference documents

Download Checklists at

www.woodworks.org

www.woodworks.org/wp-content/uploads/wood_solution_paper-Mass-Timber-Design-Cost-Optimization-Checklists.pdf



WoodWorks

WOOD PRODUCTS COUNCIL

Mass Timber Cost and Design Optimization Checklists

WoodWorks has developed the following checklists to assist in the design and cost optimization of mass timber projects. The design *optimization* checklists are intended for building designers (architects and engineers), but many of the topics should also be discussed with the fabricators and builders. The *cost optimization* checklists will help guide coordination between designers and builders (general contractors, construction managers, estimators, fabricators, installers, etc.) as they are estimating and making cost-related decisions on a mass timber project.

Most resources listed in this paper can be found on the WoodWorks website. Please see the end notes for URLs.

Keys to Mass Timber Success:

Know Your WHY
Design it as Mass Timber From the Start
Leverage Manufacturer Capabilities
Understand Supply Chain
Optimize Grid
Take Advantage of Prefabrication & Coordination
Expose the Timber
Discuss Early with AHJ
Work with Experienced People
Let WoodWorks Help for Free
Create Your Market Distinction

Images: Korb & Associates

The challenge is not in learning how to accept change, but in how to orchestrate the most efficient change

Carbon12, Portland, OR Credit: Kaiser + Path

Mass Timber in Multi-Family Housing: Is it a Good Fit for Your Project?

There's a good chance it is…Let's talk about it!

Credit: D/O Architects

Questions?

Speaker Name

Title

Phone

email

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

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