Mass Timber: The Case for Developers & Early Design Decisions

August 22, 2024

Presented by

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WoodWorks

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The Ecology School / Simons Architects / Thornton Tomasetti / Photo Trent Bell

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

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Course Description

Would you like to pitch sustainable mass timber to a client? Are you wondering how mass timber might pencil in a project pro forma? If so, attend this session to learn how to complete value proposition for developers and owners. The aesthetic differentiation and biophilic benefits of mass timber have broad appeal to a wide range of stakeholders, from end users to ESG-investors. Professionals hoping to influence decisions to use mass timber will learn how this appeal can translate to return on investment in an overview of initial findings from WoodWorks’ Mass Timber Business Case Study series, written for the developer/owner/investor audience. This session will provide an overview of the case study series highlighting key takeaways. Developers/owners, architects, engineers and builders will all learn how mass timber can create value.

Learning Objectives

1. Discuss the environmental benefits of mass timber and how they resonate with a wide range of stakeholders from occupants to project teams, investors and communities.

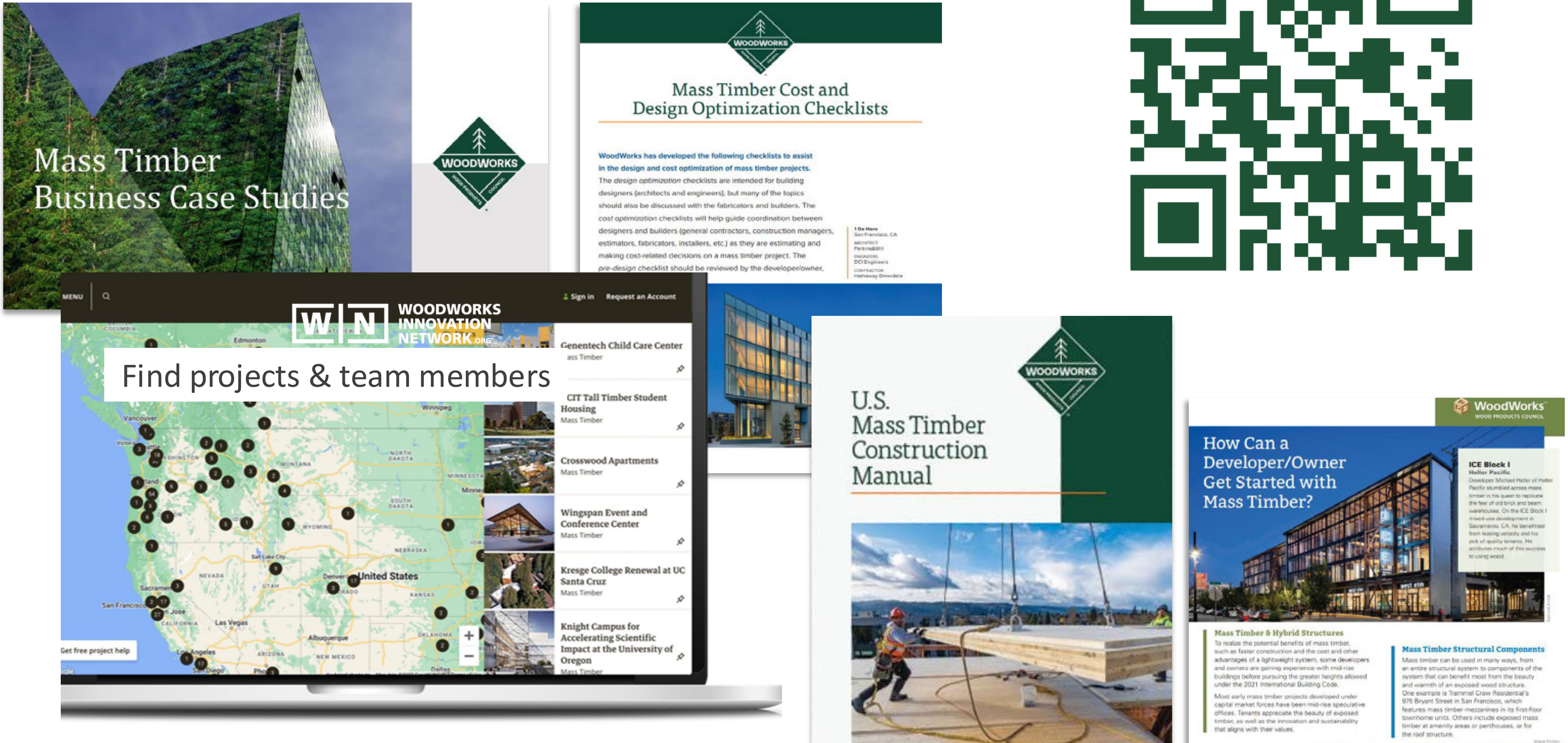
2. Understand how the biophilic benefits of wood can contribute to occupant health, tenant appeal and the financial value of a real estate development.

3. Through case study examples, explore code-compliant design of mass timber structures.

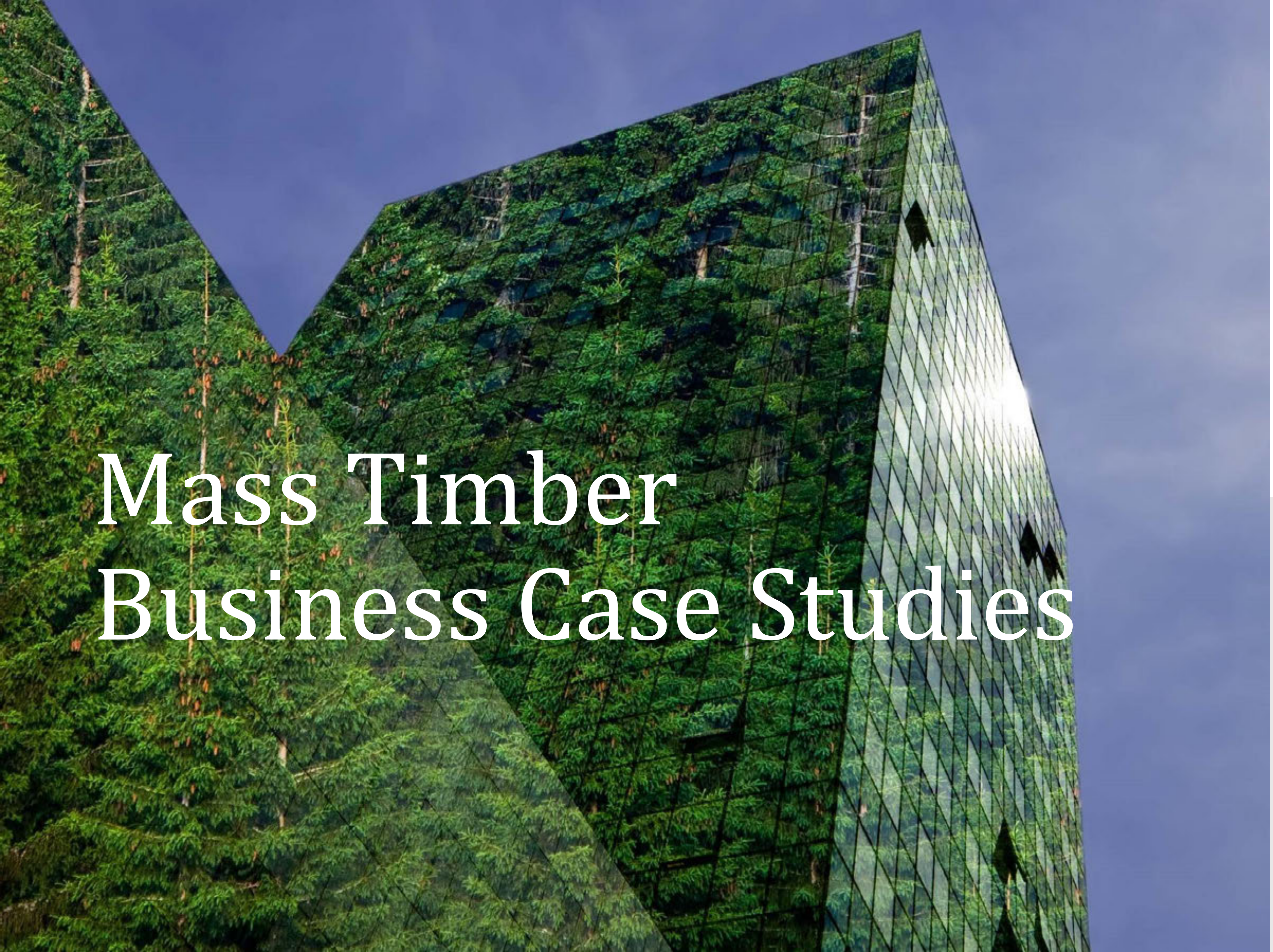
4. Learn talking points to translate the biophilic and ESG-related benefits of mass timber into potential value creation for developers, owners, and investors; helping to convince these decision makers to invest in a more sustainable and healthier built environment

Resources for Developers/Owners

Scan to download



Mass Timber Business Case Studies



Contributors

Contributing Developers/Owners & Investors

HARBOR BAY VENTURES

NEW LAND ENTERPRISES

UNIVERSITY OF ARKANSAS

Heller Pacific

KAISER GROUP

PIEPER PROPERTIES

UD+P

POPULANCE

SKS

Lead Analysis Team

CONRAD INVESTMENT MANAGEMENT

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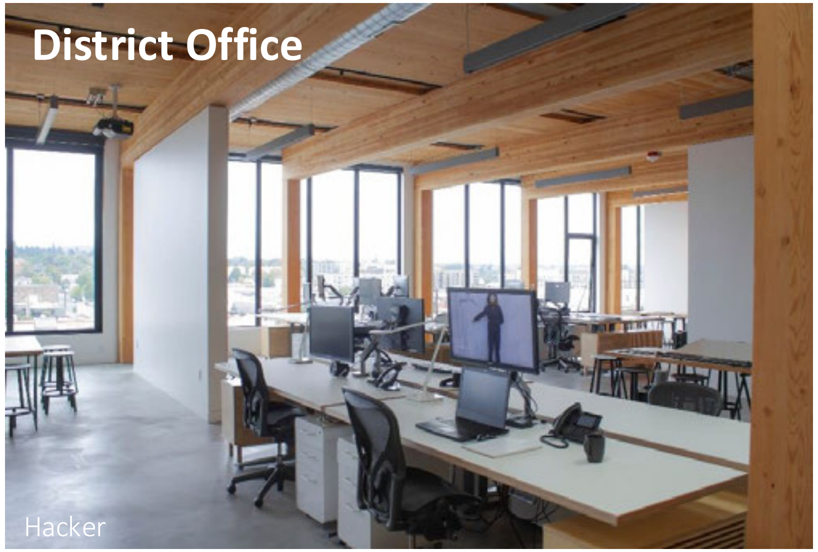
We are grateful to the developers, owners and investors who have publicly shared their stories and financial data in these case studies.

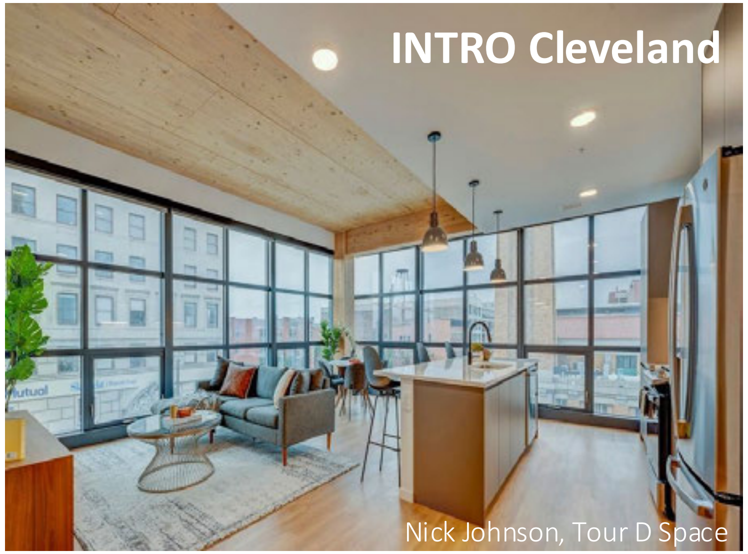
Mass Timber Business Case Studies: Value Creation Analysis

Development Overview
- Property Information
- Product Strategy
- Investment Highlights

Qualitative Discussion
- Challenges
- Lessons Learned
- Successes

Quantitative Overview
- Development Timeline
- Costs
- Rents
- Lease up





Comparative Return Analysis

	Market	Pro Forma	Realized
Yield on cost	6.25%	7.00%	7.35%
Cap rate	4.75%	4.50%	TBD
Value/rentable SF	$550/ RSF	$717/ RSF	TBD ($800+/ RSF)
Leverage	65%	65%	N/A

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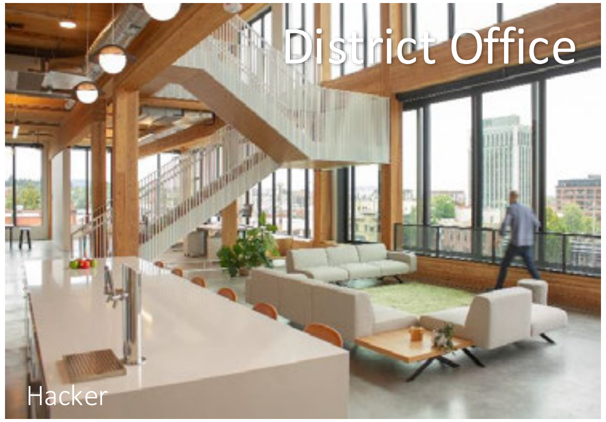
Multifamily | Office | Industrial | Student Housing

Mass Timber Business Case Studies: Value Creation Analysis



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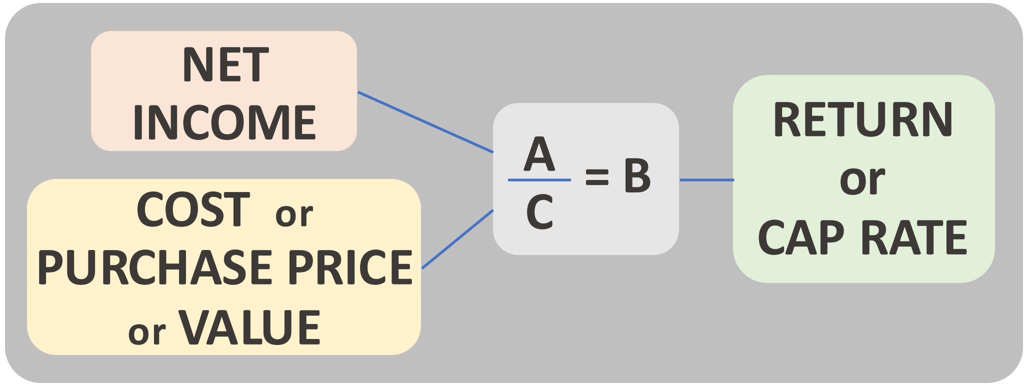
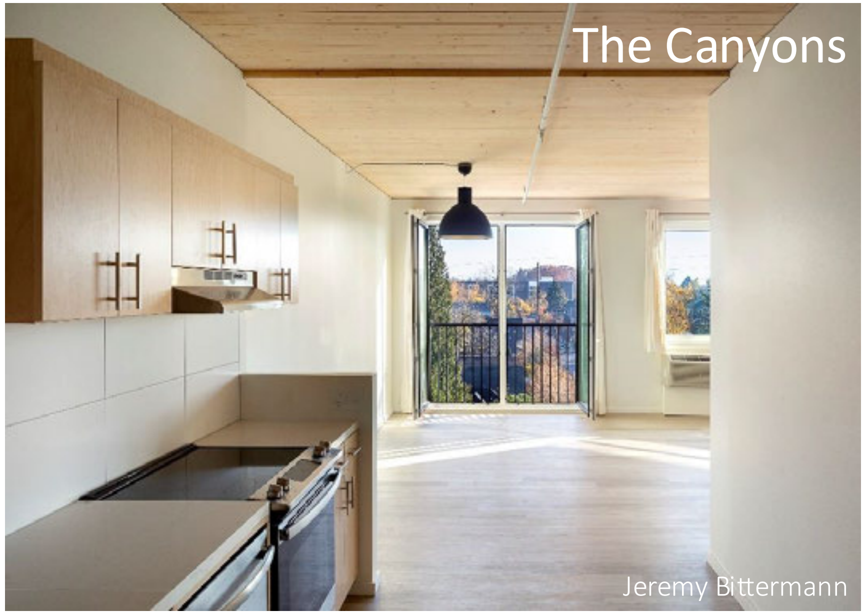
The study uses simple, industry standard means of understanding economic viability

- Net Income (cashflows)
- Cost to develop (purchase price)
- Cap rate (initial return, excluding loans)

Levers for Value Creation





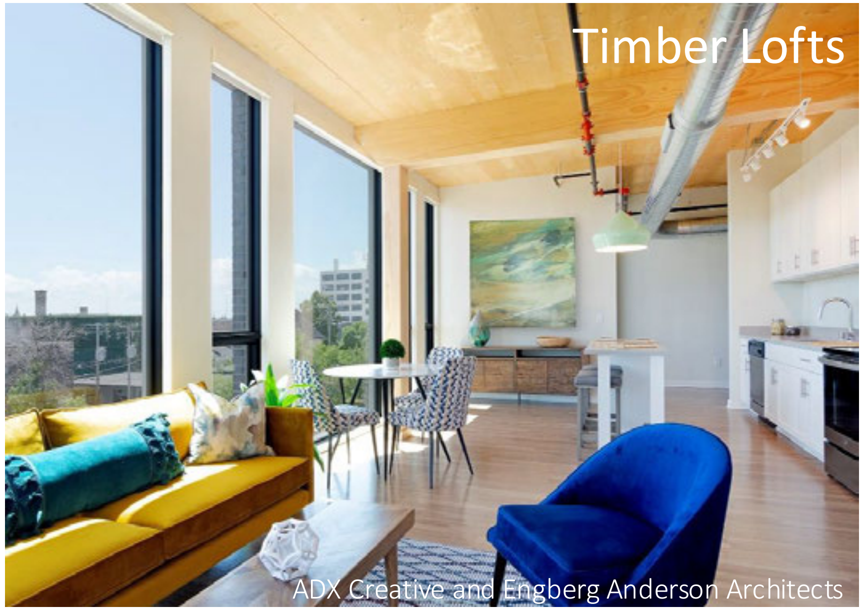
Office & Multifamily Tend to:

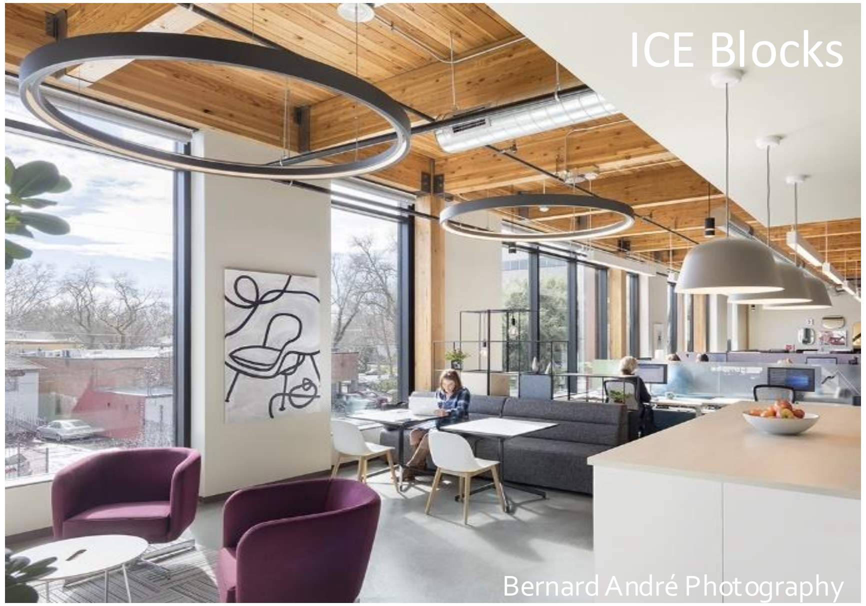
Lease up faster than submarket norms; which translates to:

- Higher net income
- Lower income volatility
- Better IRR
- Lower risk via quicker to refinance/ sell

Attract quality tenants; which translates to:

- Better rent collection
- Better (lower) cap rates
- Better (stable) occupancy



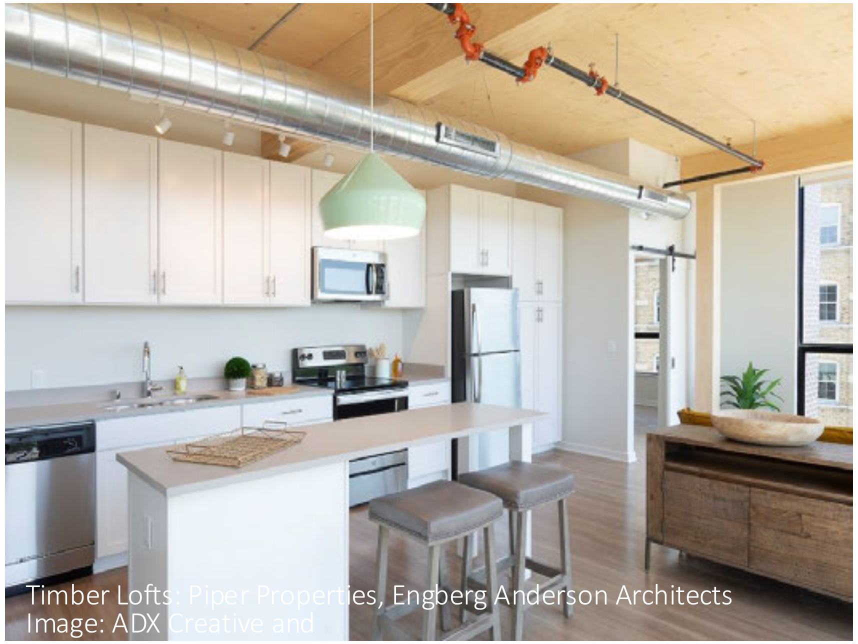


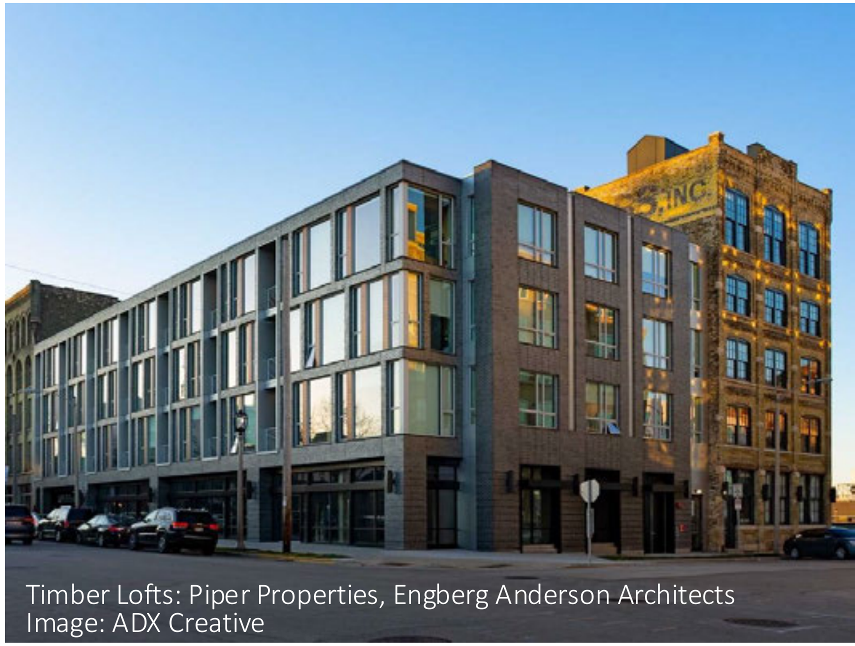

Ascent: New Land Enterprises, Weichmann Enterprises
Image: C.D. Smith Construction


INTRO Cleveland: Harbor Bay Ventures
Image: Nick Johnson, Tour D Space


The Canyons: Kaiser Group
Image: Jeremy Bittermann


Adohi Hall, University of Arkansas
Image: Timothy Hursley


Timber Lofts: Piper Properties, Engberg Anderson Architects
Image: ADX Creative and


Timber Lofts: Piper Properties, Engberg Anderson Architects
Image: ADX Creative

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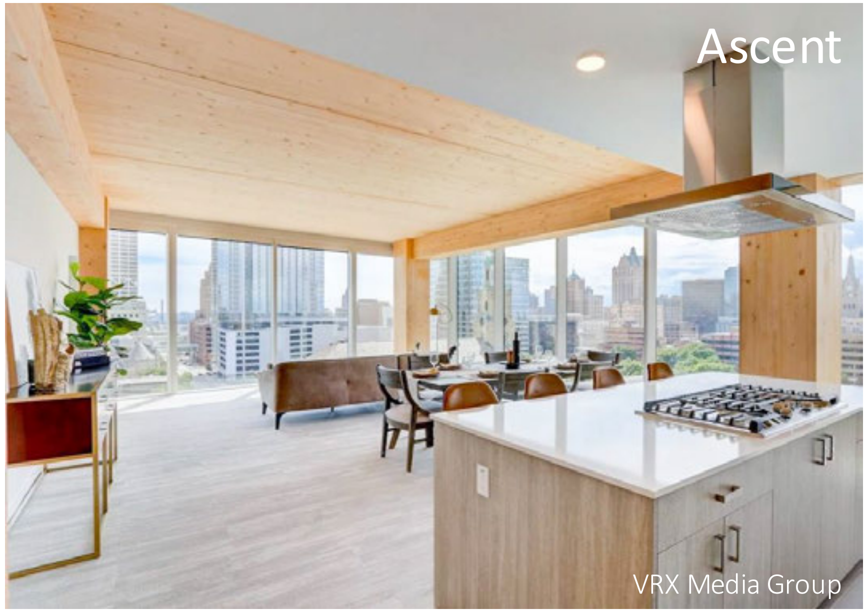
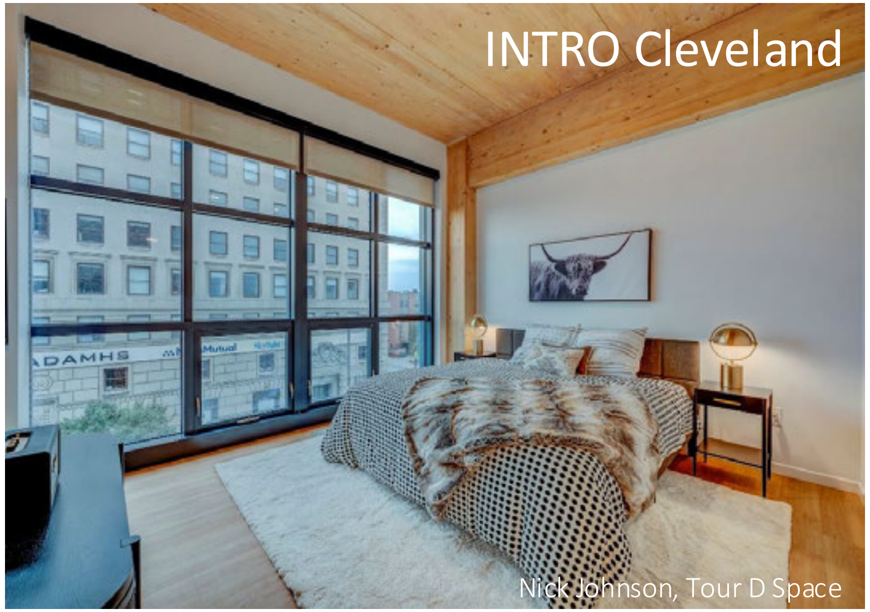
Mass Timber Business Case Studies

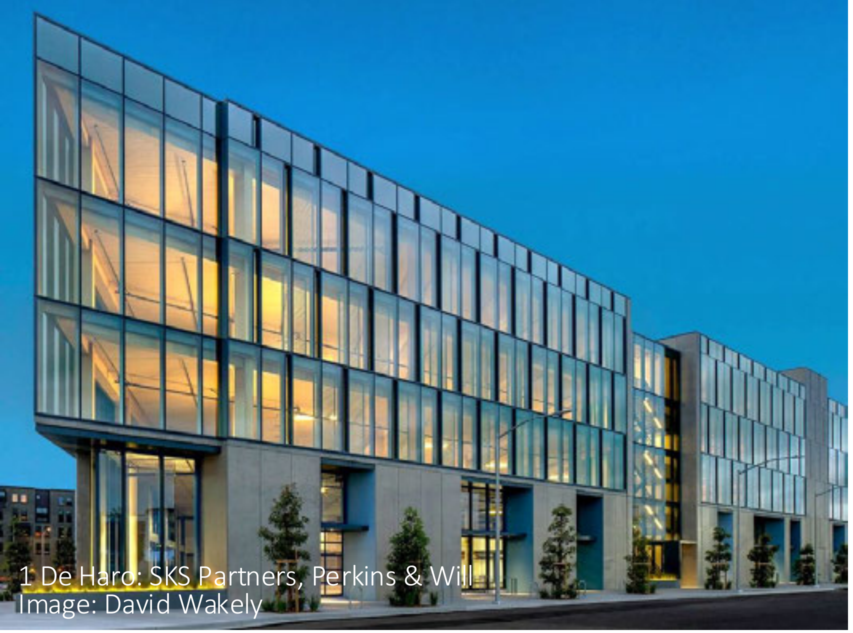
December 2022

Residents respond to "look & feel"

- Aesthetics seem to be broadly appealing; wider target markets = better market demand
- Robust pre-leasing = lower costs & risks
    - More income sooner = lowers operating & interest budgets
    - Faster to stabilization = faster to refinance
- Tangible distinction = mitigates future supply risk
- Tangible realization of desired brand identities






1 De Haro: SKS Partners, Perkins & Will
Image: David Wakely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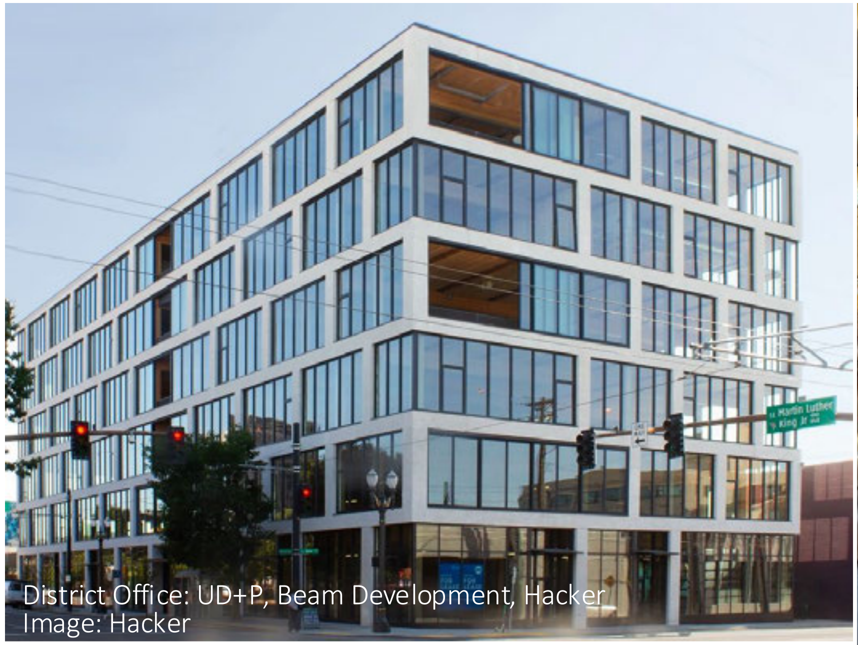
Platte Fifteen: Crescent Real Estate, Oz Architecture
Image: Arch Angle Media


ICE Blocks: Heller Pacific, RMW Architecture & Interiors
Image: Bernard André Photography


District Office: UD+P, Beam Development, Hacker
Image: Hacker


Boulder Industrial Warehouse: Mojo Partners
Image: WoodWorks

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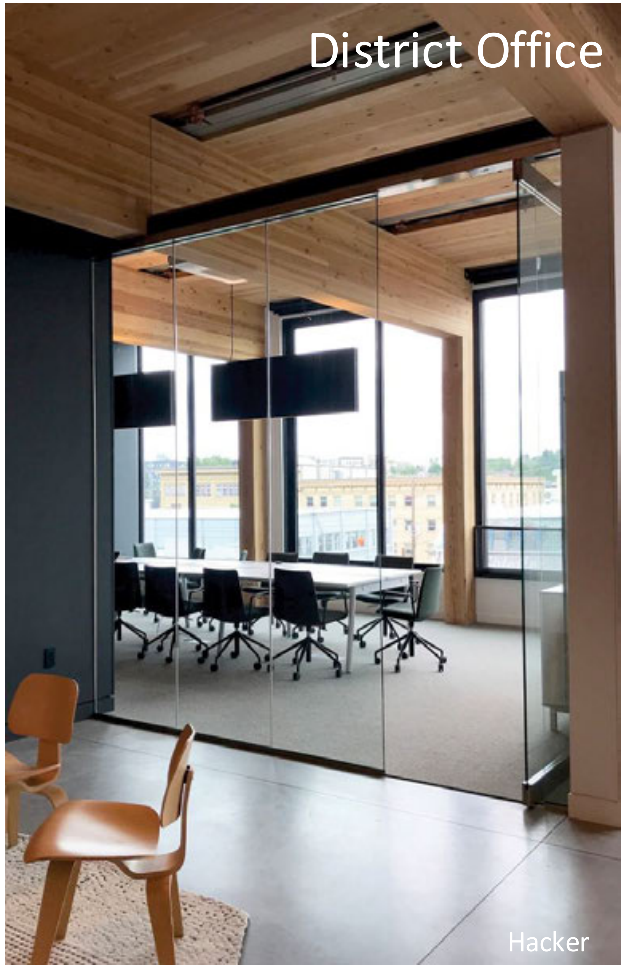
Mass Timber Business Case Studies

December 2022

Firms Attracted for Myriad Reasons

- Most tenants are "creditworthy"
- Desire intangible stakeholder benefits
  - Workforce Desires
  - Regulatory Perceptions
  - Brand Position
- Tend to see impressive pre-leasing
  - Enables better construction debt
  - Sets perceptions of desirable development
- Seeing sustained occupancy via subleasing
  - Tested by COVID disruptions



Case Studies

Ascent

MILWAUKEE,WI

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Mass Timber Business Case Study

Ascent: Project Team

Development Team:
New Land Enterprises
Wiechmann Enterprises

Lenders
Mezzanine: **Hines Realty Income Fund**
Senior: **Bank OZK**

Investors:
Local high net worth + Crowd funding (Realty Mogul)

Architect
Korb + Associates Architects

Structural Engineer
Thornton Tomasetti

Contractors
C.D. Smith Construction
Catalyst Construction

Development Overview

- 284' tall, 25-story apartment tower; world's tallest timber structure at the time of construction
- 19 stories of mass timber over 6 story parking podium
- Strategy: reset Milwaukee standard for luxury high-rise living while appealing to a broad market segment

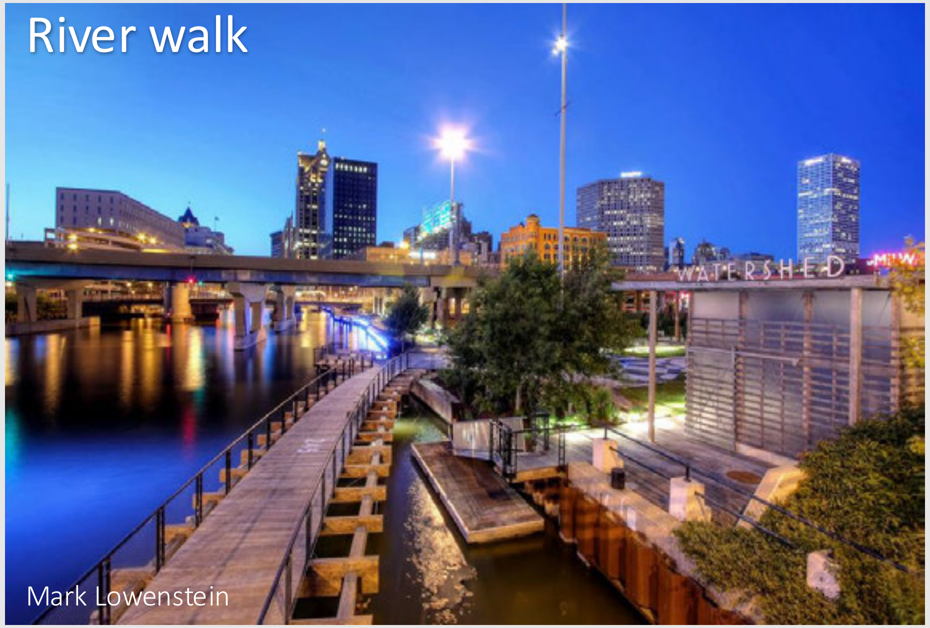
Property Information	
Property timing	Delivered July & August 2022
Submarket	Milwaukee's East Town
Construction Type	4 (w/ fire ratings for high-rise)
Site size	28,504 SF /.65 acres
Gross building area	493,000 SF 273,000 SF mass timber
Net rentable/saleable area	279,475 SF


VRX Media Group

Milwaukee's East Town Market

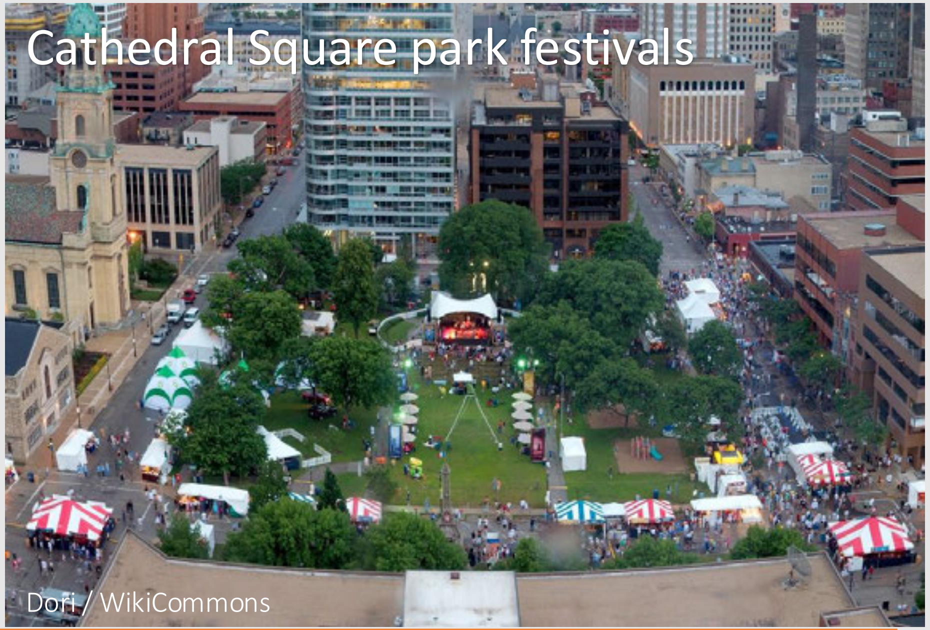
- **East Town:** Revitalizing the northern edge of downtown, where cultural institutions, lakefront parks and water access bridge to desired residential areas
- **Neighborhood:** Large corporations and healthcare drive employment for Milwaukee.

River walk



Mark Lowenstein

Cathedral Square park festivals



Dori / WikiCommons

Quantitative Overview

Costs

Total project cost	$130,000,000		
	$501,930/ unit		
Land	$6,250,000	@ appraised value	
	Market Standard*	**Pro Forma****	**Realized*****
Construction costs (normalized wo/COVID)	$200 / GSF	$190 / GSF	$190 / GSF****

NOI

Apartment	Market	Realized***	
Rental rates			
1-BR	$1,850	$2,046	~11%% higher
2-BR	$3,500	$3,956	~13% higher
3-BR	$5,500	$8,551	~55% higher
Occupancy at stabilization	95%	54%	Property still in lease up
Parking Revenue	**Market**	**Pro Forma****	**Realized*****
In addition to lease	$175	$185	$175

Retail	Market	Pro Forma**	Realized***
Retail rental rates	$25 / RSF/YR	$21 / RSF/YR	$TBD/ COVID
Rent type (e.g., NNN)	Modified Gross	NNN	TBD
Tenant improvement allowance	Varies	$86 / SF	$TBD / SF
Occupancy after 12 months	Varies	100%	TBD%

Market rental rates for apartments sourced from a CoStar report dated September 2022

**Market standard costs refer to normal cost to build for subject's use, irrespective of structural approach*
***Pro forma dated early 2020*
****Realized metrics as of October 2022*
*****Average unit size is larger than the market contributing to lower cost per square foot. Mass timber was a slight premium. A longer iterative design process proved beneficial in maximizing efficiencies, thereby driving down costs to make mass timber competitive.*

Return Performance

	Market	Pro Forma**	Realized***
Yield on cost – untrended	6.00%	5.85%	TBD / on track
Cap rate (mkt vs. appraisal subject conclusion)	5.00%	4.70%	TBD
Value per unit	$500,000	$594,000	TBD / on track
Leverage	65%	70%	50%
Mezzanine leverage	15%	15%	20%

Timeline

	Date	Context/Comment
Date of conception (first dollar spent)	April 2018	Mid cycle
Date underwriting finalized (go/no-go decision)	May 2020	Mid cycle
Date equity capital secured	June 2020	Late cycle
Permitting duration	6 months	Longer (started early & ran concurrent w/design)
GMP in place	July 2020	
Construction start	Aug 2020	
Duration of construction (anticipated without delays)	22 months	Faster (by 4 months)
Duration of construction (realized w/ delays)	24 months	Delays due to COVID + Suez Canal obstruction
Construction completed	Aug 2022	Two phases of completion: July 15 & Aug 31
Date stabilized (80% occupancy, NOI, or at pro forma or refinanced)	TBD	Projected June 2023

Project Context

Economic case made by demand

- Lease up velocity averaging 20 units/month is better than the market's typical average of 14 units/month (per the appraisal) and better than the pro forma expectations
- Superior luxury product with minimal comps in Milwaukee market

Above-market absorption

Good Design is a Good Investment for all Stakeholders

Lessons Learned

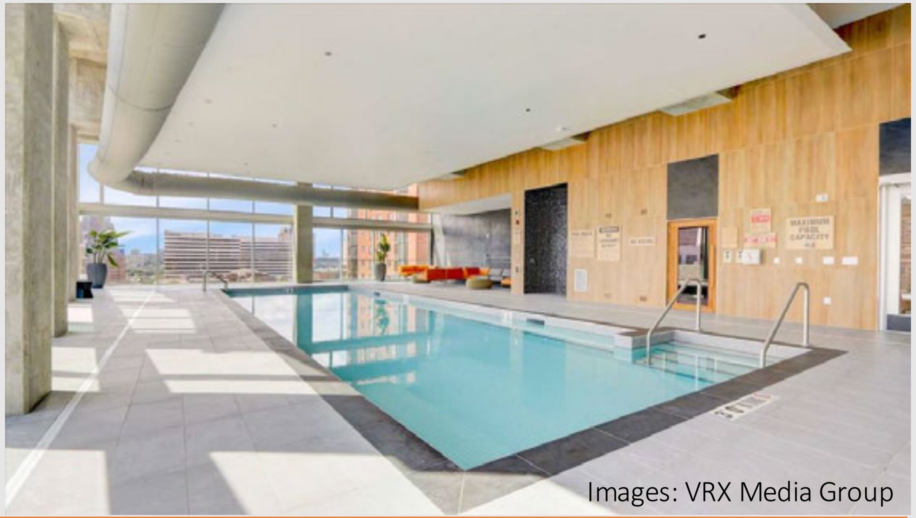
- **Intensive coordination:** Bldg scale and performance-based code approach required extraordinary coordination + precise MEPF design
- **Fire Testing:** AHJ required fire ratings for a high-rise; glulam columns passed 3-hr fire-resistance ratings

Challenges

- **Insurance:** More costly, (3x) standard rate
- **Extra considerations:** For developers on a variety of technical A/E/C topics

Successes

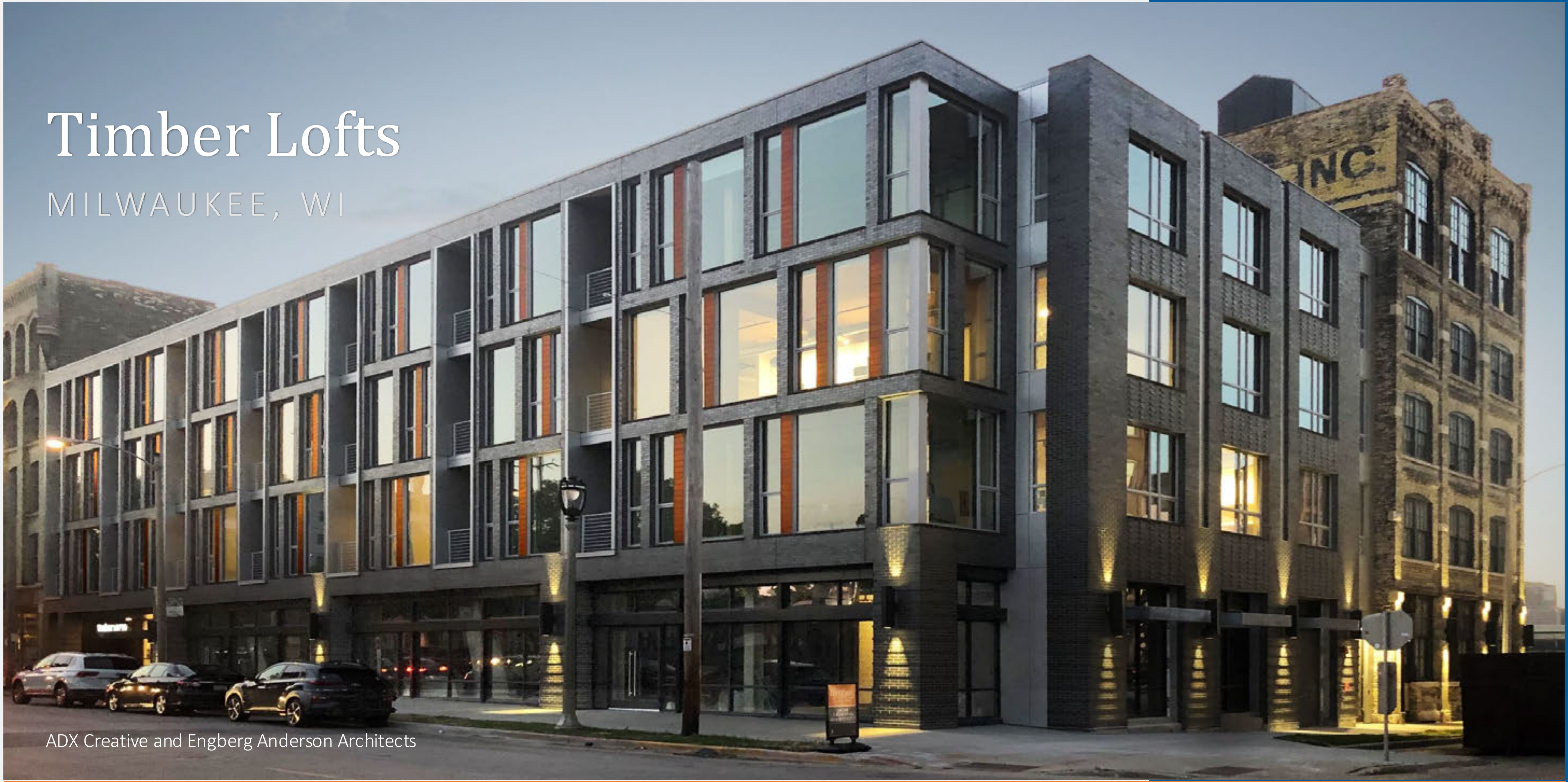
- **Cost:** Slight premium for optimized mass timber system over market rates for similar apartment towers
- **Lease-up**: Amazing pre-leasing w/ ~45% pre-leased at construction completion



Images: VRX Media Group

Timber Lofts

MILWAUKEE, WI



ADX Creative and Engberg Anderson Architects

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Mass Timber Business Case Study

Development Overview

- Redevelop 128-year-old, 5-story warehouse originally built by Pabst Brewing
- Develop new apartment building addition
- Difficult to achieve premium rents in submarket; goal was to ensure top rents were realized

Timing	Completed June 2020		
Submarket	Downtown Milwaukee		
Construction Type	Type 3-B		
Site Size	20,208 sf		
Building:	Total	Added	Original
Gross Bldg Area	68,400 sf	35,400 sf	33,000 sf
Total Units	60	27	33
Net Rentable Area	38,576 sf		
Parking	Zero owned		


ADX Creative and Engberg Anderson Architects

Notable Aesthetic & Economic Impacts

Lessons Learned

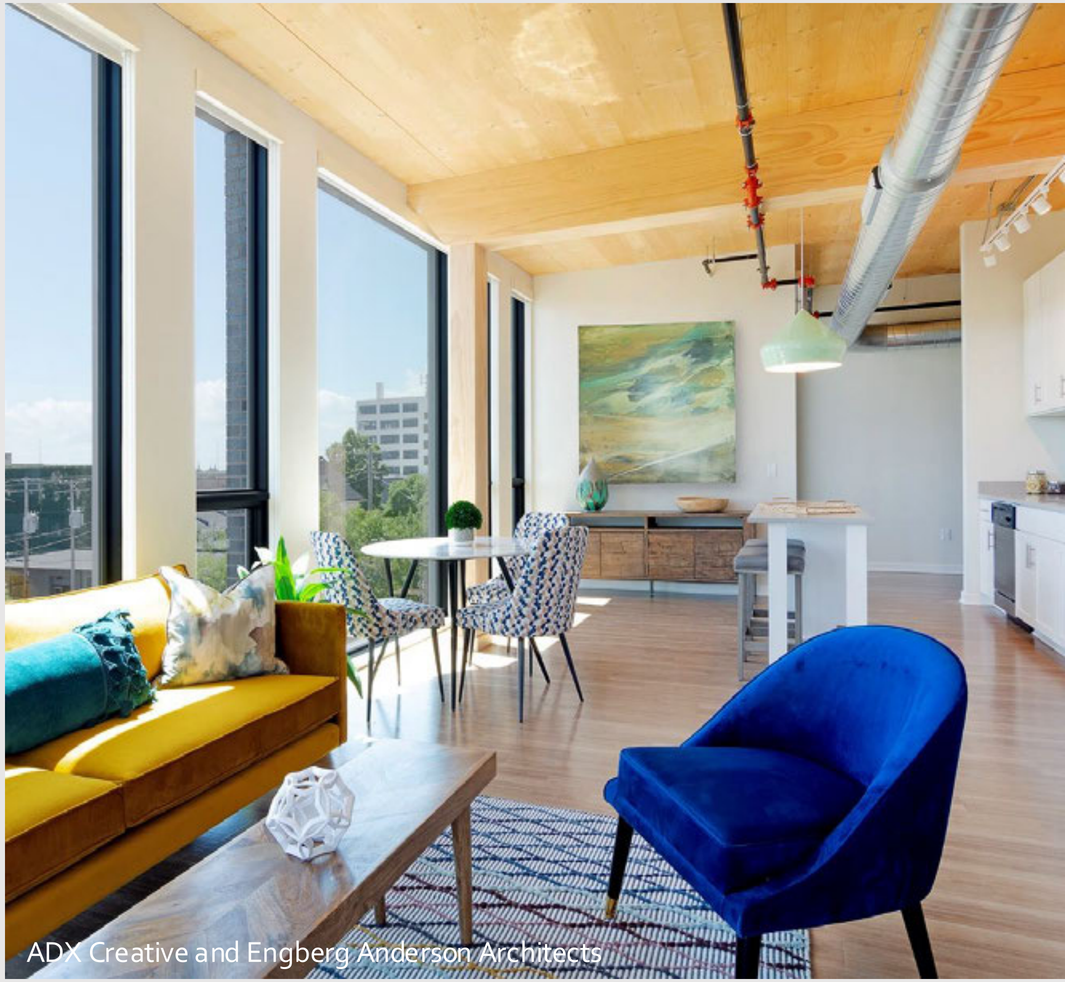
- Mass timber contributed to a differentiated product.

Challenges

- Retail demands at all time lows during Covid pandemic
- Overcoming the myth that mass timber is more expensive.

Successes

- Integrated innovative mass timber structure at market rate rents.
- Project created positive “spill-over” effects via its noteworthy nature that helps fuel positive momentum and perceptions of submarket/ street.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The ICE Blocks

SACRAMENTO, CA

RMW Architecture & Interiors, Bernard André Photography

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Mass Timber Business Case Study

Distinctive Interiors Attract Quality Tenants at Competitive Rents


RMW Architecture & Interiors, Chad Davies Photography

Successes:

- **Community/municipal support:** Sacramento embraced the innovation and environmental benefits of mass timber and came to table as a partner to resolve challenges
- **Renewals:** Leasing agent believes it will lease at a premium on second go-around: “I wish I had 4 more of them to lease up”

Lessons Learned:

- **Expenses:** Only slightly more expensive to deliver differentiated space that is instantly warm and inviting

Barracuda Condos

MADISON, WI

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Mass Timber Business Case Study

Madison Market

- Desirable Basset Street neighborhood one block from Lake Monona and State Capitol
- Highly diversified economy with a large presence in tech
- Home ownership demand continues to increase in Madison with price per SF increasing by 12% from $161/SF in 2021 to $180/SF in 2022

District Office

PORTLAND, OR

Hacker

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Mass Timber Business Case Study

Portland's Central Eastside Market

Submarket

- Central Eastside submarket- an area transformed from an industrial hub to the epicenter of Portland's creative scene
- Abundance of smaller industrial & maker-oriented businesses
- Approximately 22,000 now employed across digital, food, manufacturing, educational, retail, entertainment

INTRO, Cleveland

CLEVELAND, OH

Nick Johnson, Tour D Space

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Mass Timber Business Case Study

Quantitative Overview

Costs			
Total project cost	$147,000,000		
	$494,950/ unit		
Land Cost	$10,450,000	@ appraised value	
	Market Standard*	**Pro Forma**	**Realized****
Construction costs	$212 / GSF	$200 / GSF	$215 / GSF

NOI				
Apartment		**Market**	**Realized**	
Rental rates				
	Studio	$1,279	$1,500 -$1,750 (P.H. $2,000)	~26% higher
	1-BR	$1,631	$1,675 -$2,500 (P.H. $5,700)	~28% higher
	2-BR	$2,301	$2,500 -$5,200 (P.H. $7,800)	~67% higher
	3-BR	$3,334	$8,800 -$19,500 P.H.	~324% higher
Occupancy at stabilization		91%	98%	~7% higher
Parking Revenue		**Market**	**Pro Forma**	**Realized****
Included or in addition to lease?		Additional	Additional	Additional
Rate		$175 / lot / month	$185 -$200 / lot / month	$225 -$375 / lot / month
Retail		**Market**	**Pro Forma**	**Realized****
Retail rental rates		$30 -$40 / RSF/YR	$45 / RSF/YR	$45 / RSF/YR
Rent type (e.g., NNN)		NNN & Gross	NNN	NNN
Expenses		$7 -$10 / RSF/YR	$8 / RSF/YR	$8 / RSF/YR
Tenant improvement allowance		$40 -$50 / RSF	$150 / RSF	$150 / RSF
Occupancy after 12 months		60% -70%	90%	75%

Market standard costs refer to normal cost to build for subject's use, irrespective of structural approach.
***Realized metrics at stabilization*
****Conversations with local building officials were held concurrent to land use entitlement approvals processes such that the overall building code review process was only slightly longer. This concurrent approach was essential given that Ohio was not adopting the 2021 IBC, so the Type 4 code path was performance-based, albeit a mirror of what other states have adopted.*

Return Performance	Market	Pro Forma	Realized**	
Yield on cost – untrended	6.25%	7.00%	7.35%	Higher
Cap rate	4.75%	4.50%	TBD	
Value/rentable SF	$550 / RSF	$717 / RSF	TBD ($800+ / RSF)	Higher
Leverage	65%	65%	N/A	

Timeline	Date	Context/Comment
Date of conception (first dollar spent)	Mid 2018	Mid-cycle
Date underwriting finalized (go/no-go decision)	Mid 2019	Mid-cycle
Date equity capital secured	N/A	Developer is equity
Permitting duration***	3 + 6 mo.	Demolition permit first, then building permit
GMP in place	Feb/March 2020	COVID
Construction start	April 2020	
Duration of construction	24 months	Faster by about 2 months
Construction completed	April 2022	Early-cycle
Date stabilized (80% occupancy, NOI, or at pro forma or refinanced)	June 2022	Faster

Project Context

Unparalleled leasing velocities at significant premiums

- The project was 90% leased 4 months after completion
- The premium product drives both velocity and rates with rents significantly higher than market counterparts
- Leasing velocity allowed refinancing activities to start 3 months after completion

Unparalleled leasing velocities at significant premiums

Clay Creative

PORTLAND, OR

Mackenzie, Christian Colombres Photography

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Mass Timber Business Case Study

Quantitative Overview

Costs	Market Standard*	Actual	Realized
Total project cost	$325 / GSF	$356 / GSF $27,250,000	~ 9% higher
Construction costs	$190 / GSF	$213 / GSF $16,250,000	~ 12% higher
	(raised floor plenum HVAC + mass-timber drove premium)		
Tenant improvement allowance	$60 / RSF	$46 / RSF	23% savings
Broker commissions	$15 / RSF	$16 / RSF	

NOI

Office	Market	Pro Forma	Realized
Office rental rates	$22.00 / RSF/YR	$24.00 / RSF/YR	$27.00 / RSF/YR
Lease structure	NNN	NNN	NNN
Expenses	$10.00 / RSF/YR	$8.00 / RSF/YR	$8.00 / RSF/YR
Load factor	15% to 18%	18%	18%
Lease term (years)	5 – 7 Years	8.5 Years	10 Years
Occupancy after 18 months (stabilized)	90% – 95%	94%	93%

Parking Revenue	Market	Pro Forma	Realized
Included or in addition to lease	Additional	Additional	
Rate	$125 / Month	$150 / Month	$25 / Month

Retail	Market	Pro Forma	Realized
Retail rental rates	NA	NA	NA
Rent type (e.g., NNN)	NA	NA	NA
Tenant improvement allowance	NA	NA	NA
Occupancy after 18 months	NA	NA	NA

Return Performance (at Stabilization)

Metric	Market	Pro Forma	Realized
Yield on cost – untrended	7.50%	7.50%	7.70%
Cap rate (mark-to-market if not sold)	5.75%	6.00%	5.75%
Value/rentable SF	$375 to $450 / RSF	$460 / RSF	$479 / RSF
Leverage	60%	65%	67%
Gross leveraged IRR (mark-to-market if not sold)	N/A	Not measured	Higher
Gross leveraged equity multiple (deal level)	1.75x	1.90x	2.00x

Timeline

Event	Date	Context/Comment
Date of conception (first dollar spent)	End of 2012	Very early-cycle
Date underwriting finalized (go/no-go decision)	Early 2015	Early-cycle
Date equity capital secured	Early 2015	
Permitting duration	7 months	Longer than standard methodology
GMP in place	Early 2015	
Construction start	Spring 2015	Mid-cycle
Duration of construction	Approx. 12 months	Shorter than standard methodology
Construction completed	Spring 2016	Mid-cycle
First TI completed	Spring 2016	
Date stabilized (80% occupancy, NOI, or at pro forma or refinanced)	Summer 2016	Mid-cycle

Fast lease-up at top-of-market rental rates

**Market standard costs refer to normal cost to build for subject's use, irrespective of structural approach*

Adohi Hall
University of Arkansas
FAYETTEVILLE, AR

Timothy Hursley

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Mass Timber Business Case Study

Quantitative Overview

Costs

Total project cost	$64,100,000 / $90,537 / bed		Student Housing 100% auxiliary budget
Apportioned residential project cost	$48,900,000 / $69,068/ bed		Excludes land, classrooms, and exterior park
	Market Standard*	**Realized**	
Construction costs (total)	$304 / GSF	$317 / GSF	
Apportioned residential project cost	$304 / SF	$316 / SF	~4% higher**
Architecture & engineering fees	NA	$5,086,000	higher

**Viewed as investment in the state, not a cost premium

NOI (Spring 2022)

Dormitory Rooms	Market (off campus) 2022-23 year	Market (dorm) 2021-22 year	Realized*** 2021-22 year	
Rental rates per bed (per semester, all rates annualized)				
Single room	$13,756	$8,658	$11,131	~29% > than dorms
Double room	$9,342	$3,544	$4,452	~26% > than dorms
Occupancy	100%	100%	92%	

***Blended rate of pods & semi-suites

Parking Revenue	Market (off-campus)	Resident Reserved (closest to Adohi)	Student Parking (Not close to Adohi)
Campus Parking	$270	$693	$107

Parking figures are annualized

**Market standard costs refer to normal cost to build for subject's use, irrespective of structural approach*

Value Creation

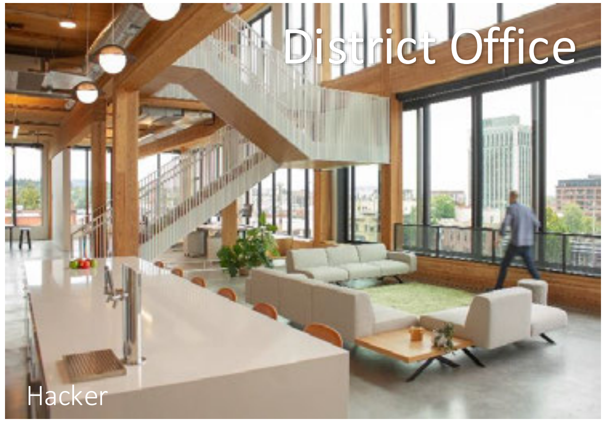
Person(s)/ Department(s)	Comments
Students	Ethics-aligned identity housing option; pride in where you go to school
Faculty	Leader in university planning; design & academic integration with student life
Housing department	Highly desirable rental option at top of market rents; hit pro forma & paying its debt
Chancellor's office	Example project contributing to state economic development of timber industry
Statewide real estate sector	Lower perceived risk for private developer/owners and other institutions Set proof of concept example for new mass timber Walmart Headquarters
Local AEC community	Increased professional & skilled trade knowledge/generated educational opportunities
Neighborhood	CLT connected to exterior public park landscaping to create iconic "sense of place"

Timeline

Event	Date	Context/Comment
Date of conception (first dollar spent)	November 2016	Board of Trustees approval
Construction document preparation	7 months	4 months longer due to design for prefabrication
Permitting duration (state building authority)	3 months	Longer (typically 1 month; subsequent mass timber projects more in line with normal review times)
GMP in place	December 2017	
Construction start	June 2017	Notice to proceed
Duration of construction	27 months	27% faster than normal (10-week reduction)
Construction completed	August 2019	
Date occupied (students move-in)	August 2019	

Living & Learning building delivered on a dorm budget. Impressive value creation for a wide range of stakeholders.

Mass Timber Business Case Studies: Value Creation Analysis



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WOODWORKS™ WOOD PRODUCTS COUNCIL

CONRAD INVESTMENT MANAGEMENT

Early Design Decisions:
Priming Mass Timber Projects for Success

Presented by
Patrick Duffy, PE
WoodWorks

Apex Plaza / Courtesy William McDonough + Partner

Course Description

Mass timber is a unique, non-commodity building material and, to lay the groundwork for success, certain critical decisions must be made as early as possible. These decisions can have a big impact on cost and can either increase or limit opportunities later in design. There are many cases of project teams that want to realize the full benefits of mass timber, but, because they base their designs on traditional building practices instead of optimizing them for mass timber, end up with avoidable price premiums. This presentation will walk through early project decisions and design steps, focusing on how to optimize projects for mass timber and how one early decision can influence others. Topics will include construction types, fire ratings, column grids and beam/panel spans, acoustics and MEP integration. Completed mass timber projects will be used to illustrate the variety of viable options when navigating these key decisions.

Learning Objectives

1. Identify construction types within the International Building Code where a mass timber structure is permitted.

2. Discuss the impacts of construction type on required fire-resistance ratings of structural elements, noting the impacts that these ratings have on effective member spans and resulting grids.

3. Review code-compliance requirements for acoustics and primary frame connections, and provide solutions for meetings these requirements with tested mass timber assemblies.

4. Highlight effective methods of integrating MEP services in a mass timber building and discuss the relative impacts of each on cost, aesthetics, occupant comfort and future tenant renovations.

Key Early Design Decisions

What is the Single Most Important Early Design Decision on a Mass Timber Project? Is it:

Construction Type
Fire-Resistance Ratings
Member Sizes
Grids & Spans
Exposed Timber (where & how much)

MEP Layout
Acoustics
Concealed Spaces
Connections
Penetrations

The Answer is…They All Need to Be Weighed (Plus Others)

Key Early Design Decisions

Significant Emphasis Placed on the Word Early

Early Because:

Avoids placing limitations due to construction norms or traditions that may not be efficient with mass timber

Allows greater integration of all building elements in 3D models, ultimately used throughout design, manufacturing and install

Key Early Design Decisions

One *potential* design route:

1. **Building size & occupancy informs construction type & grid**

2. **Construction type informs fire resistance ratings**

3. **Grid & fire resistance ratings inform timber member sizes & MEP layout**

But that's not all…

Architects: The Miller Hull Partnership with Lord Aeck Sargent
Engineer: Uzun + Case
Contractor: Skansa USA
Photo: Jonathan Hillyer

Key Early Design Decisions

Other impactful decisions:

- **Acoustics informs member sizes (and vice versa)**
- **Fire-resistance ratings inform connections & penetrations**
- **MEP layout informs use of concealed spaces**

Miller Hull Partnership, photo: John Sta

Key Early Design Decisions

Other impactful decisions:

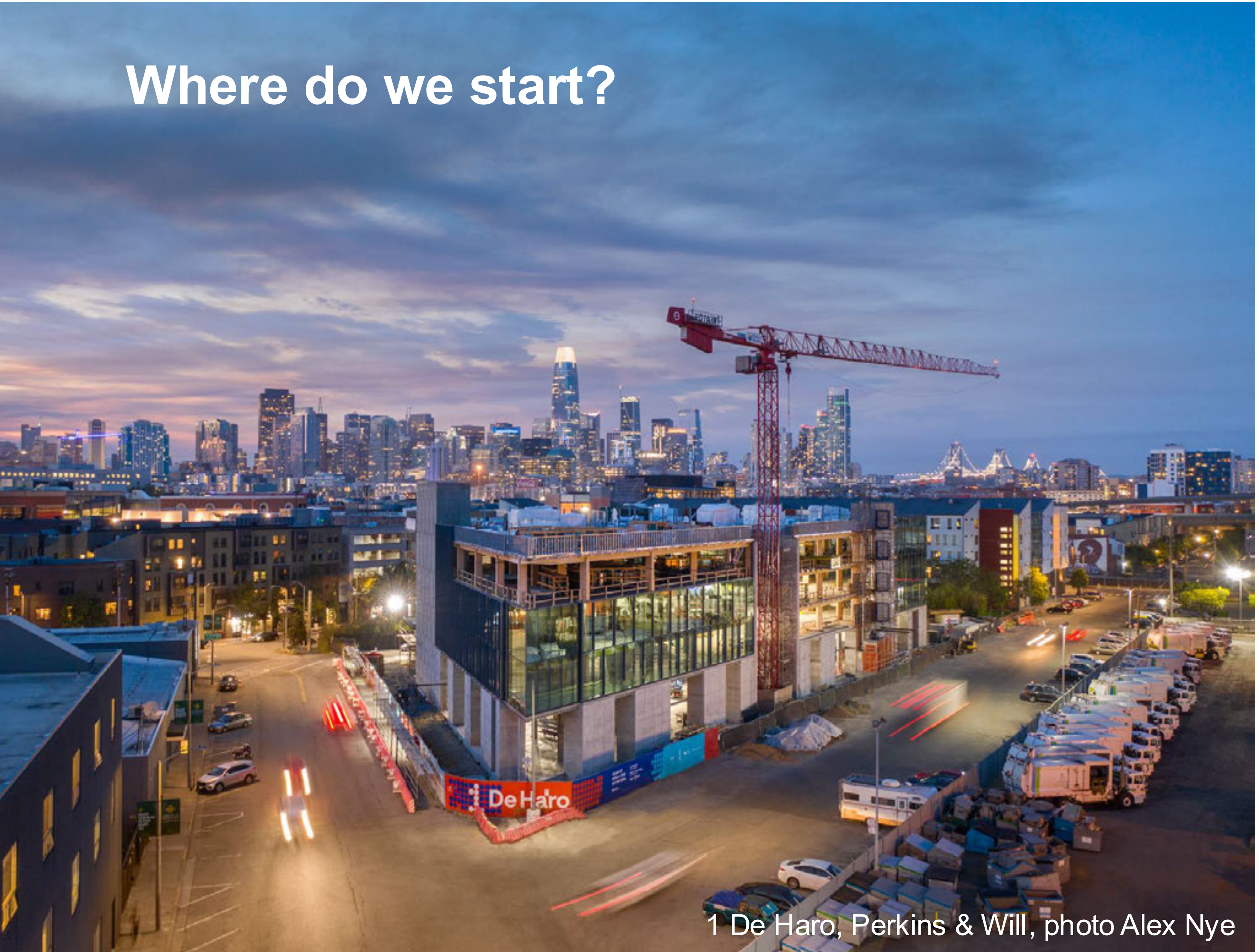
- **Grid** informs efficient spans, MEP layout
- **Manufacturer capabilities** inform member sizes, grids & connections
- **Lateral system** informs connections, construction sequencing

And more…

Platte Fifteen, Oz Architecture, KL&A Engineers & Builders, Arch Angle Media

Key Early Design Decisions

Where do we start?



1 De Haro, Perkins & Will, photo Alex Nye

Key Early Design Decisions

Construction Type – Primarily based on building size & occupancy

	Construction Type (All Sprinklered Values)							
	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)							
A, B, R	270	180	85	85	85	85	70	60
	Allowable Number of Stories above Grade Plane (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 Factor (At) for SM, $Feet^2$ (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

Key Early Design Decisions

Fire-Resistance Ratings

- **Driven primarily by construction type**
- **Rating achieved through timber alone or is non-combustible 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)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1 1/2	1	1	HT	1[b,c]	0

Key Early Design Decisions

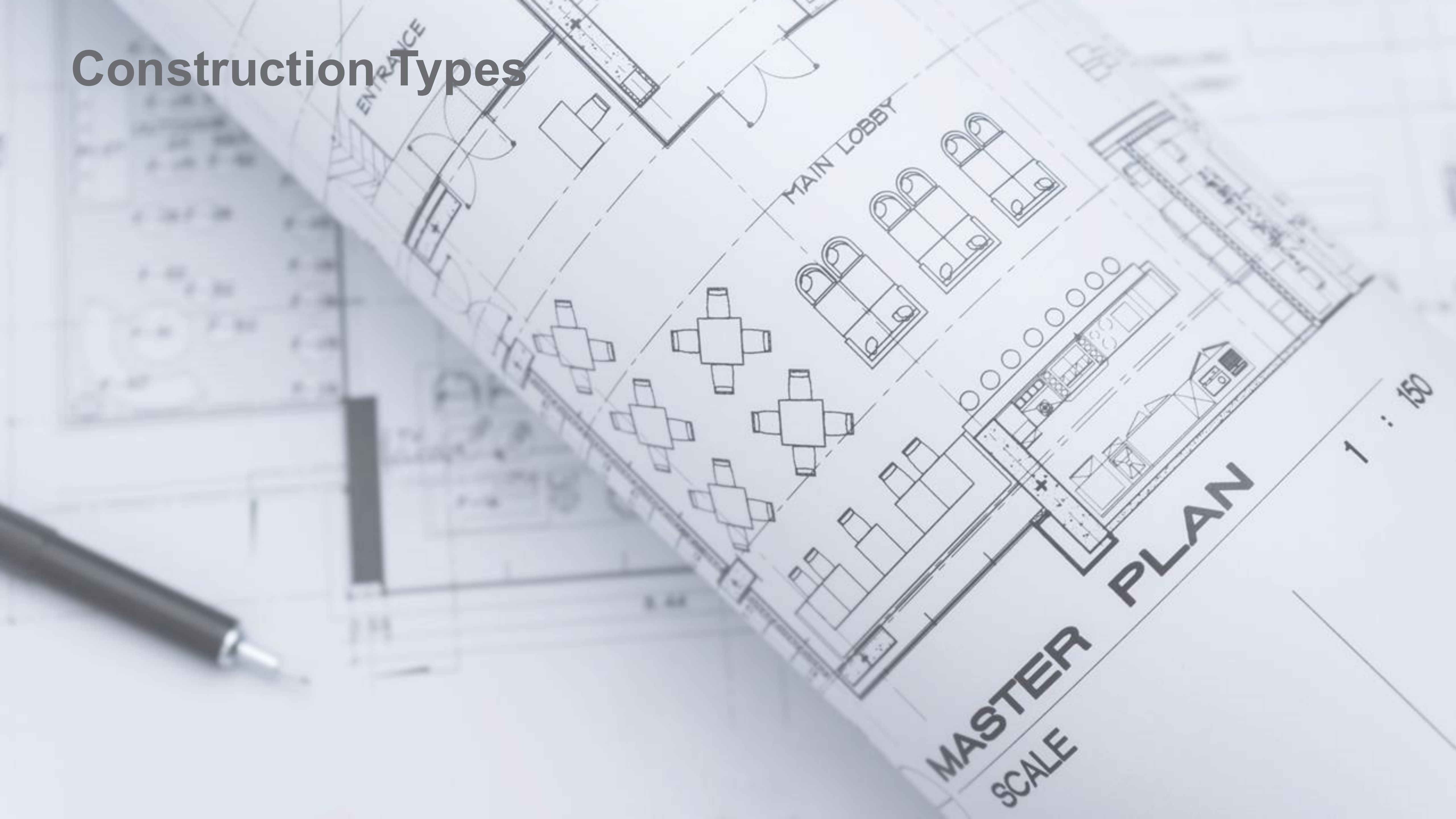
Fire-Resistance Ratings (FRR)

- 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

Construction Types



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

Where does the code allow MT to be used?

- Type IB & II: Roof Construction

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)

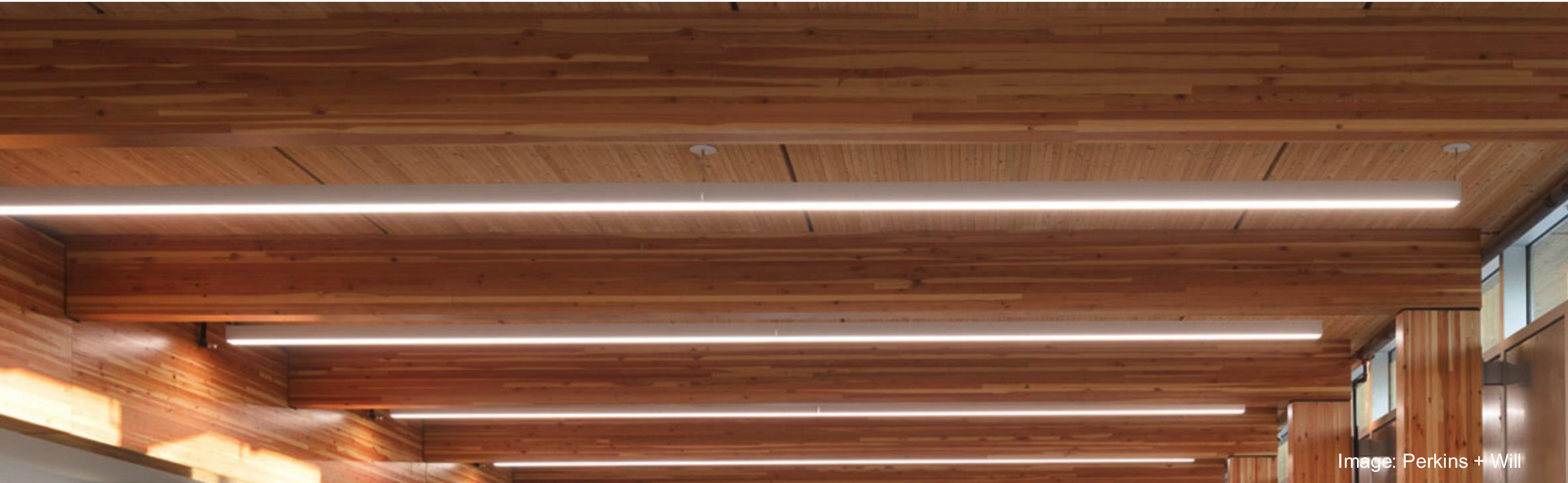


Image: Perkins + Will

Construction Types

Type IV construction permits exposed heavy/mass timber elements of min. sizes.

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

Minimum Width by Depth in Inches
See IBC 2018 2304.11 or IBC 2015 602.4 for Details

*3" nominal width allowed where sprinklered

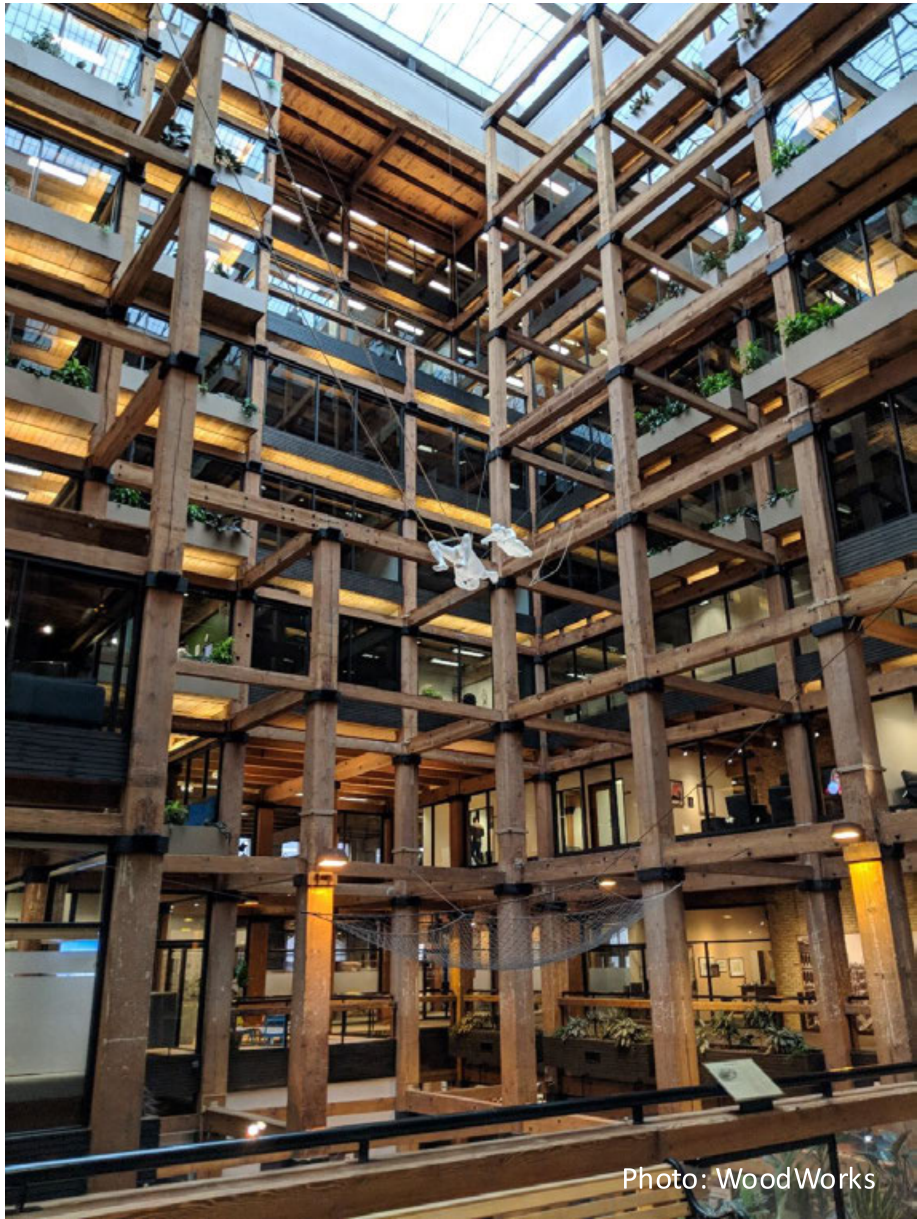


Photo: WoodWorks

Construction Types

Type IV min. sizes:

<u>Floor Panels/Decking:</u>

- 4” thick CLT (actual thickness)
- 4” NLT/DLT/GLT (nominal thickness)
- 3” thick (nominal) decking covered with: 1” decking <u>or</u> 15/32” WSP <u>or</u> ½” particleboard

Photo: StructureCraft

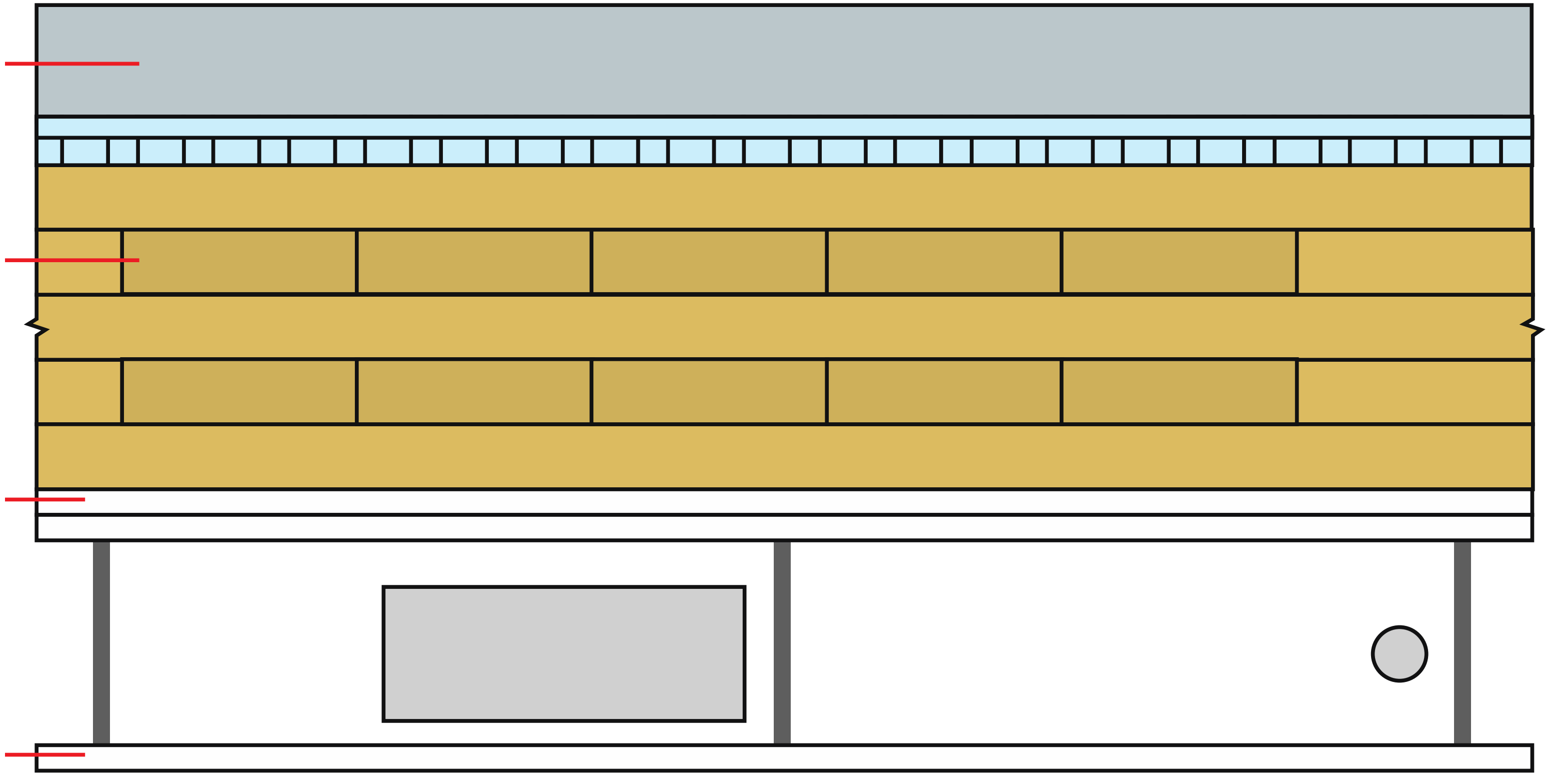
Photo: Aitor Sanchez/ Ewing Cole

Photo: WoodWorks

Construction Types

Type IV concealed spaces

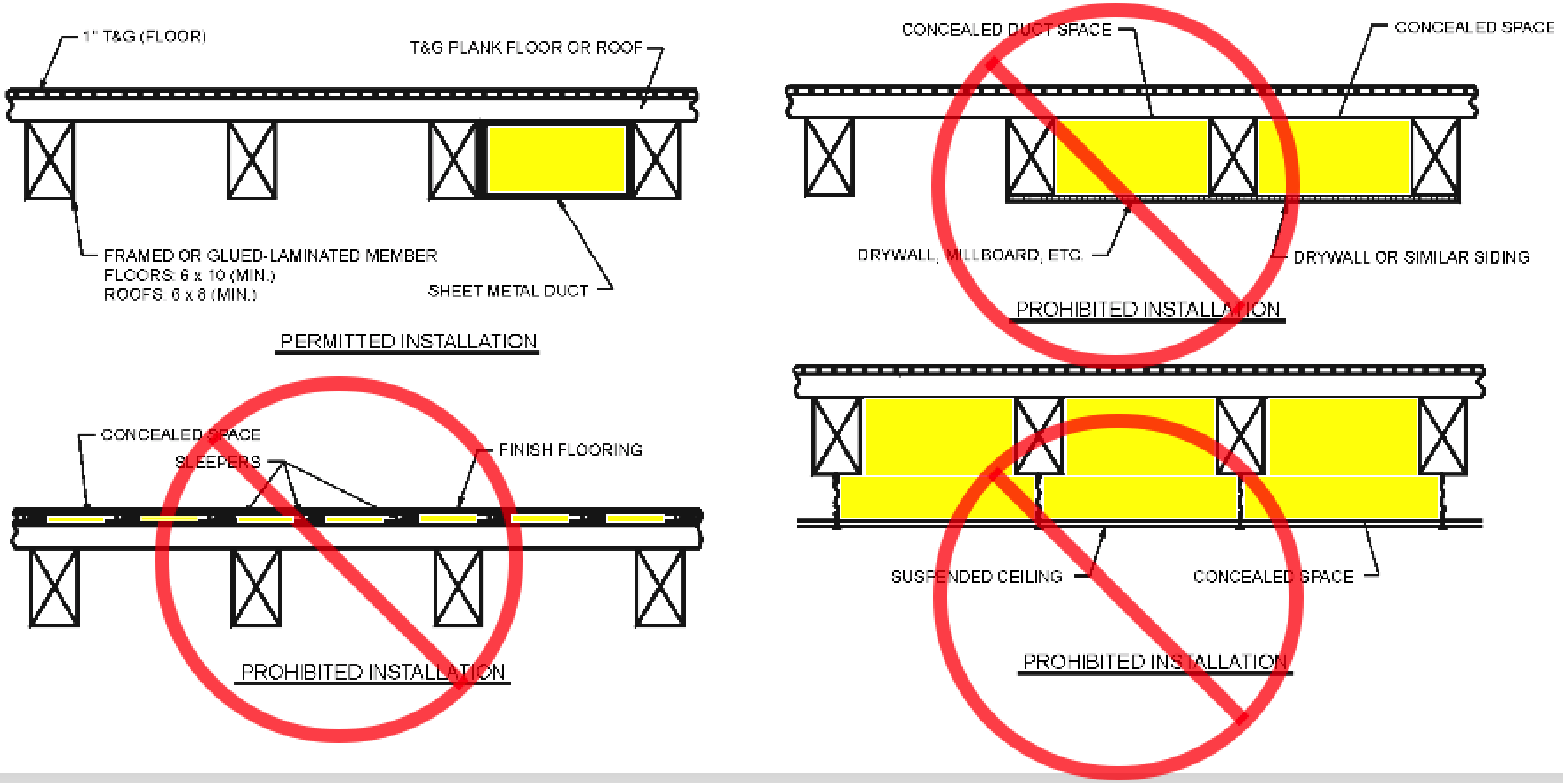
Can I have a dropped ceiling? Raised access floor?



Construction Types

Type IV concealed spaces

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

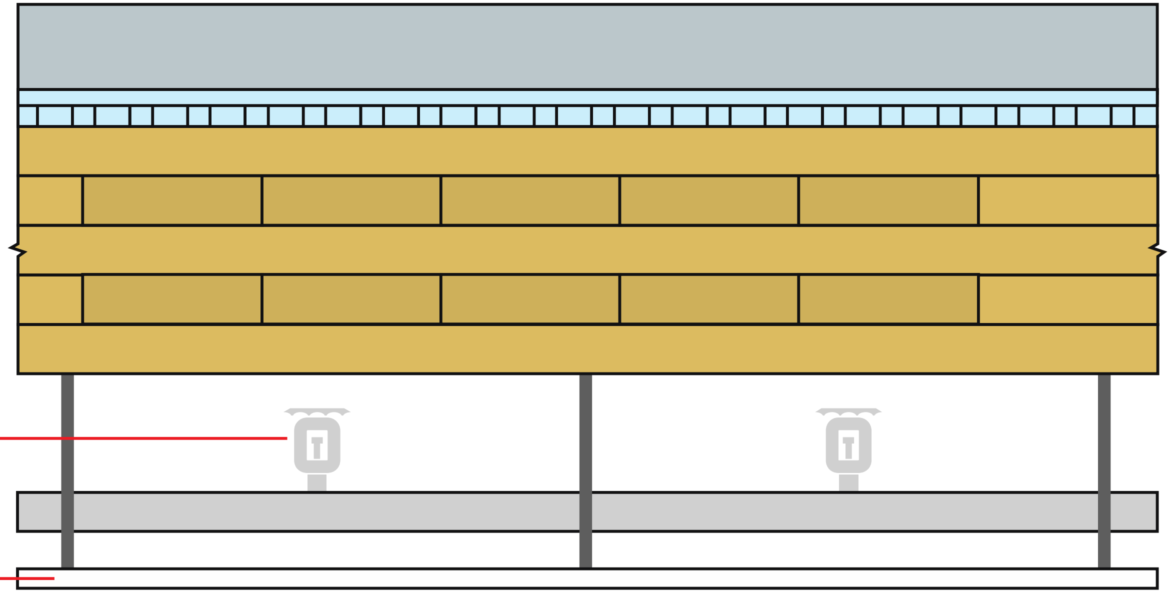


Credit: IBC

Construction Types

Type IV-HT concealed space options within 2021 IBC

Option 1:



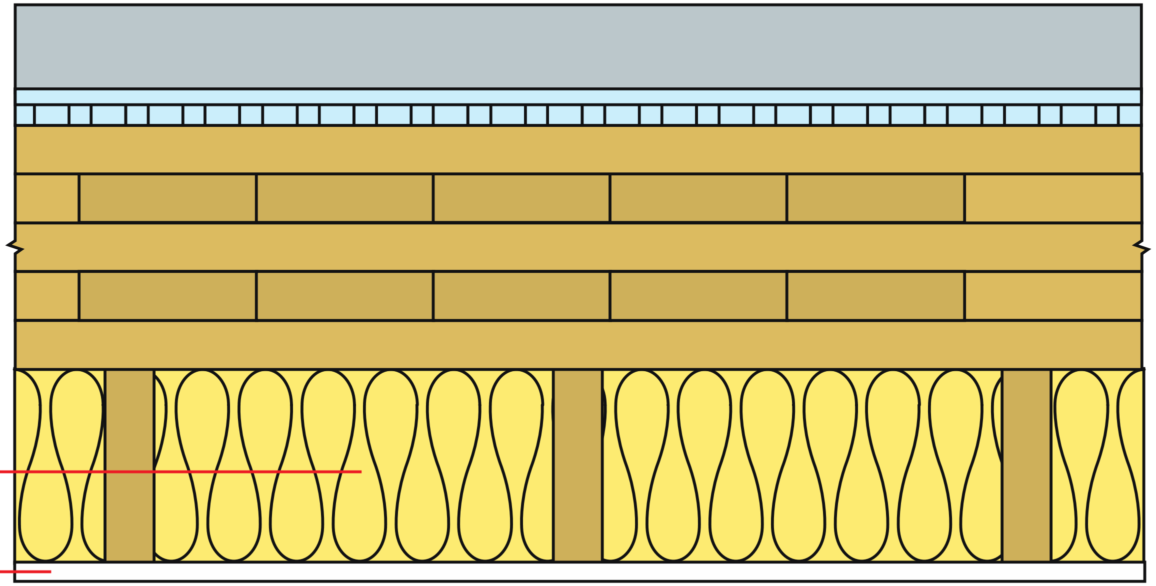
Sprinklers in concealed spaces

Dropped ceiling

Construction Types

Type IV-HT concealed space options within 2021 IBC

Option 2:



Noncombustible insulation

Dropped ceiling

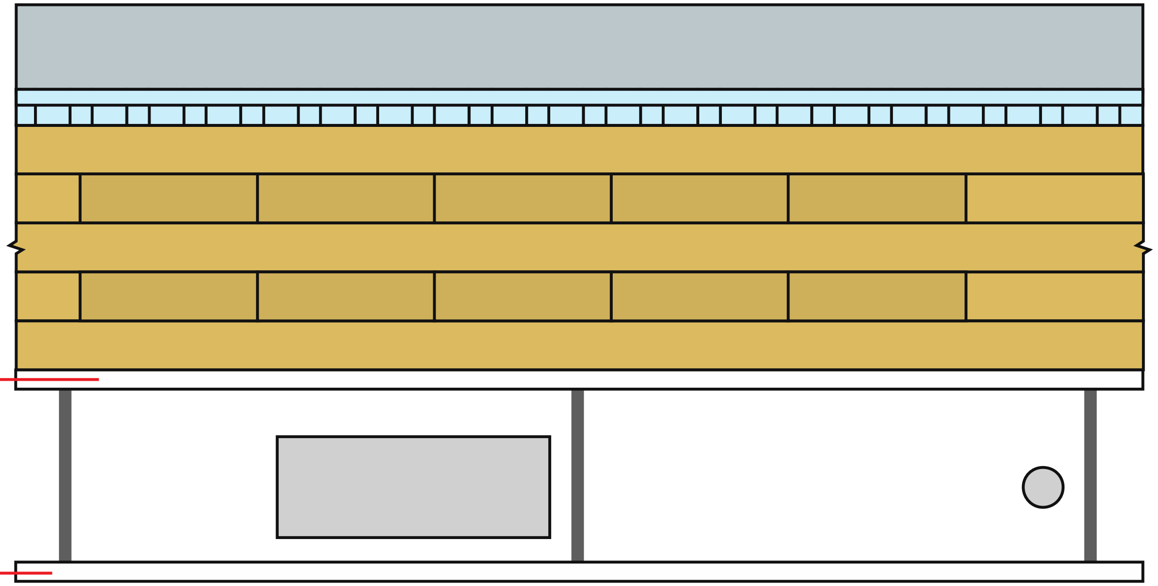
Construction Types

Type IV-HT 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

Richard McLain, PE, SE
Senior Technical Director – Tall Wood
WoodWorks – Wood Products Council

WOODWORKS WOOD PRODUCTS COUNCIL

Concealed Spaces in Mass Timber and Heavy Timber Structures

Concealed spaces, such as those created by a dropped ceiling in a floor/ceiling assembly or by a stud wall assembly, have unique requirements in the International Building Code (IBC) to address the potential of fire spread in non-visible areas of a building. Section 718 of the 2018 IBC includes prescriptive requirements for protection and/or compartmentalization of concealed spaces through the use of draft stopping, fire blocking, sprinklers and other means. For information on these requirements, see the WoodWorks Q&A, *Are sprinklers required in concealed spaces such as floor and roof cavities in multi-family wood-frame buildings?*[1]

For mass timber building elements, the choice of construction type can have a significant impact on concealed space requirements. Because mass timber products such as cross-laminated timber (CLT) are prescriptively recognized for Type IV construction, there is a common misperception that exposed mass timber building elements cannot be used or exposed in other construction types. This is not the case.

In addition to Type IV buildings, structural mass timber elements—including CLT, glue-laminated timber (glulam), nail-laminated timber (NLT), structural composite lumber (SCL), and tongue-and-groove (T&G) decking—can be utilized and exposed in the following construction types, whether or not a fire-resistance rating is required:

- **Type III** – Floors, roofs and interior walls may be any material permitted by code, including mass timber; exterior walls are required to be noncombustible or fire retardant-treated wood.
- **Type V** – Floors, roofs, interior walls and exterior walls (i.e., the entire structure) may be constructed of mass timber.
- **Types I and II** – Mass timber may be used in select circumstances such as roof construction—including the primary frame in the 2021 IBC—in Types I-B, II-A or II-B; exterior columns and arches when 20 feet or more of horizontal separation is provided; and balconies, canopies and similar projections.

INTRO, Cleveland | Cleveland, Ohio
Harbor Bay Real Estate Advisors
HPA Architecture

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

2021 IBC Introduces

3 New Tall Wood Construction Types:

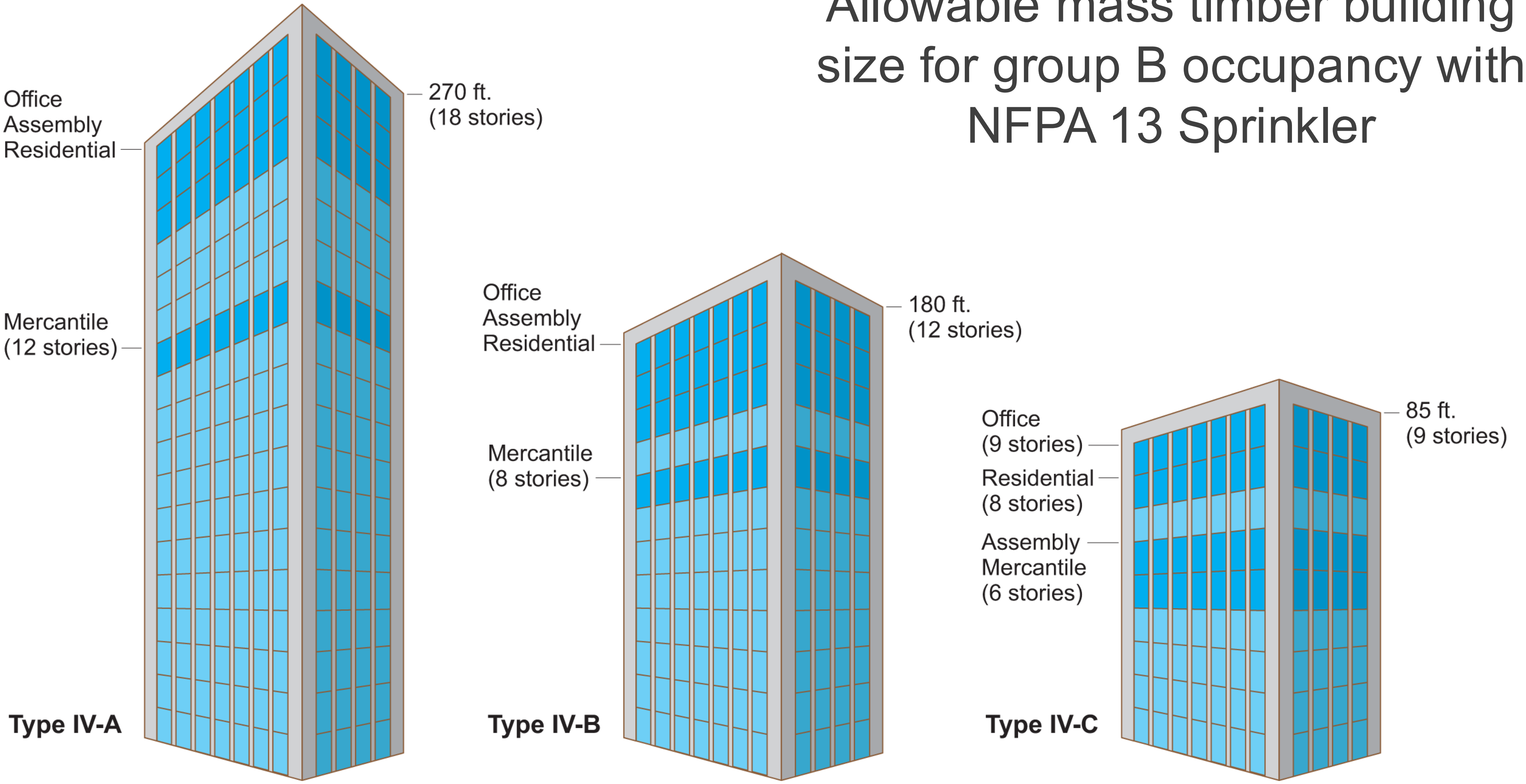
IV-A, IV-B, IV-C,

Previous Type IV is renamed Type IV-HT

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

Construction Types

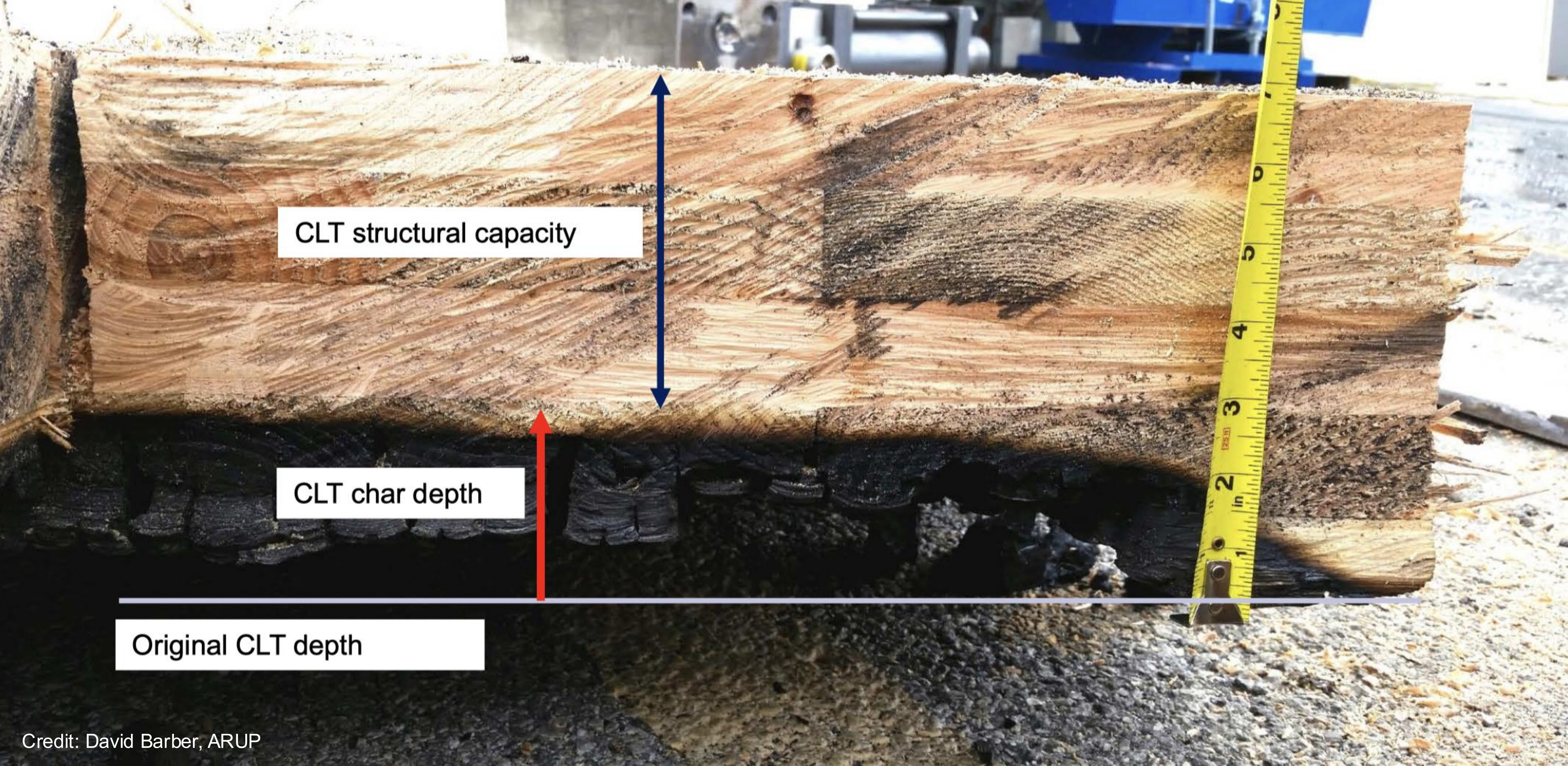
New Options in 2021 IBC
Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler



Tall Wood Building Size Limits

	Construction Type (All Sprinklered Values)						
	I-A	I-B	**IV-A**	**IV-B**	**IV-C**	IV-HT	III-A
Occupancies	**Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)**						
A, B, R	Unlimited	180	**270**	**180**	**85**	85	85
	Allowable Number of Stories above Grade Plane (IBC Table 505.4)						
A-2, A-3, A-4	Unlimited	12	**18**	**12**	**6**	4	4
B	Unlimited	12	**18**	**12**	**9**	6	6
R-2	Unlimited	12	**18**	**12**	**8**	5	5
	Allowable Area Factor (At) for SM, Feet^2 (IBC Table 506.2)						
A-2, A-3, A-4	Unlimited	Unlimited	**135,000**	**90,000**	**56,250**	45,000	42,000
B	Unlimited	Unlimited	**324,000**	**216,000**	**135,000**	108,000	85,500
R-2	Unlimited	Unlimited	**184,500**	**123,000**	**76,875**	61,500	72,000

Fire Design of MT



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 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1 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)
- **Other than type IV-HT**: Demonstrated fire resistance

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

NGC Testing Services — Fire Testing Laboratory — IAS ACCREDITED Testing Laboratory TL-216

TEST REPORT
for
American Wood Council

222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

Standard Methods of Fire Tests of Building Construction and Materials
ASTM E 119 – 11a

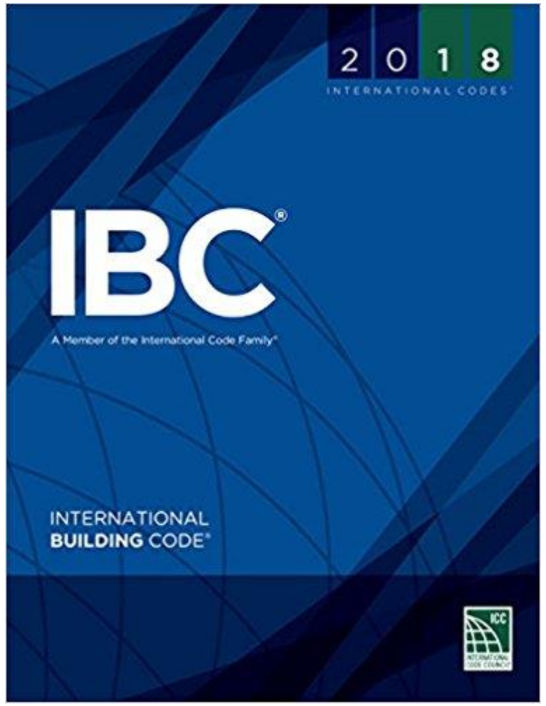
Page 1 of 53

Test Report No: WP-1950
Assignment No: K-1089
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)
Test Date: October 4, 2012
Report Date: October 15, 2012

Prepared by: Michael J. Rizzo, Test Engineer

Reviewed by: Robert J. Menchetti, Director, Laboratory Facilities and Testing Services

The results reported in this document apply to specific samples submitted for measurement. No responsibility is assumed for performance of any other specimen. This report may not be reproduced, except in full, without the written approval of the laboratory. The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by this laboratory.

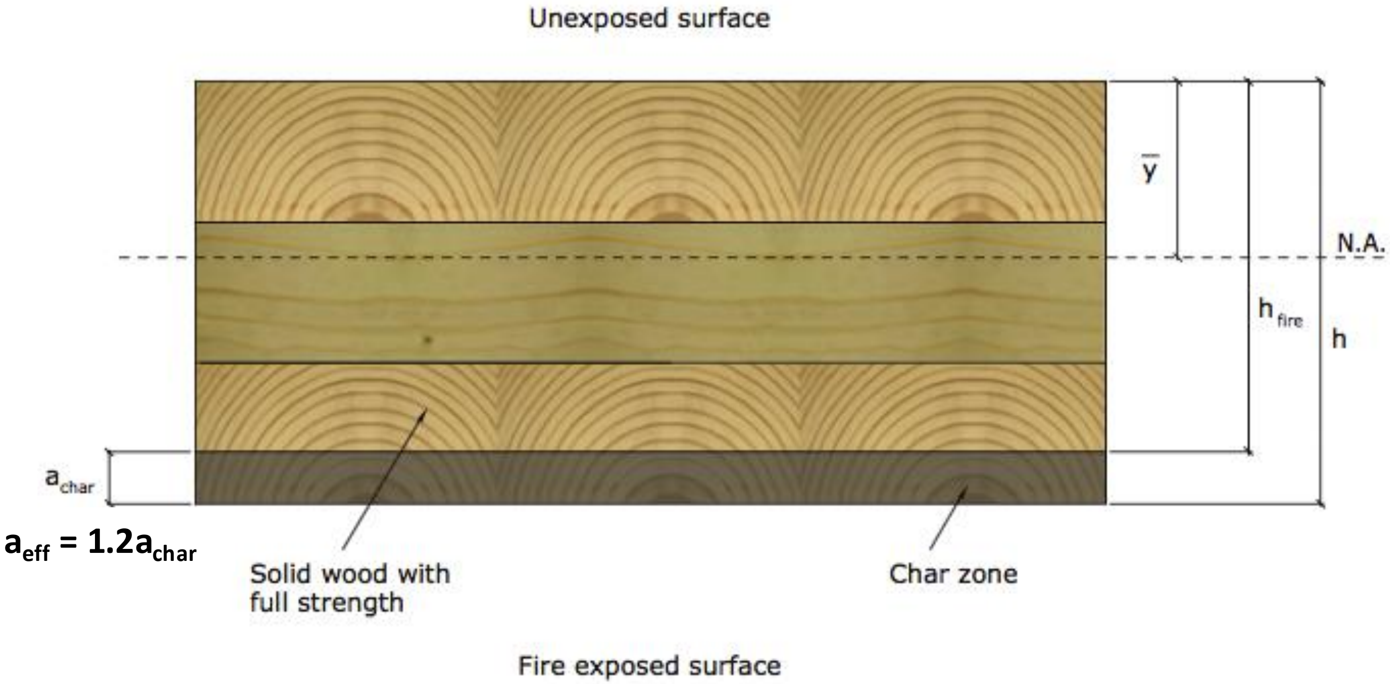


Key Early Design Decisions

Which Method of Demonstrating FRR of MT is Being Used?

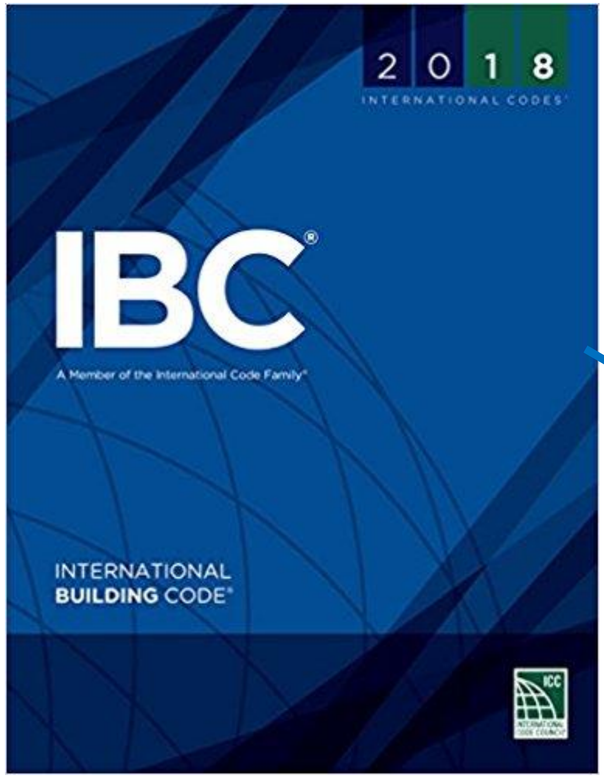
1. Calculations in Accordance with IBC 722 → NDS Chapter 16
2. Tests in Accordance with ASTM E119

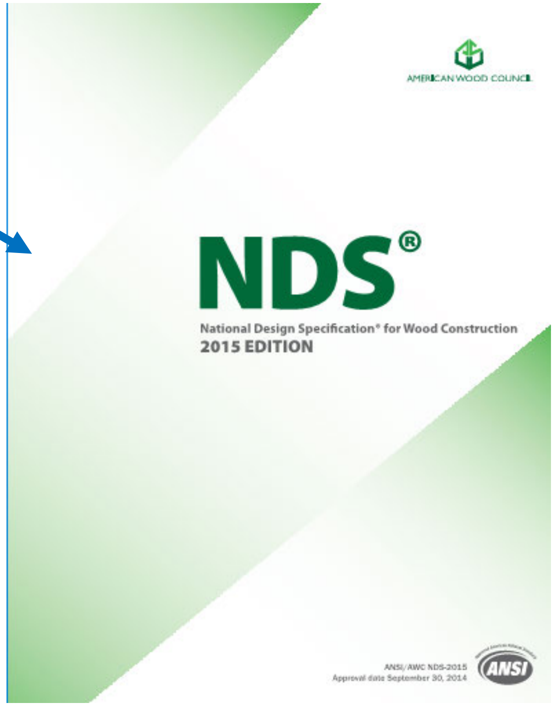
Credit: Urban One



FRR Design of MT

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





Code Path for Exposed Wood Fire-Resistance Calculations

IBC 703.3
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

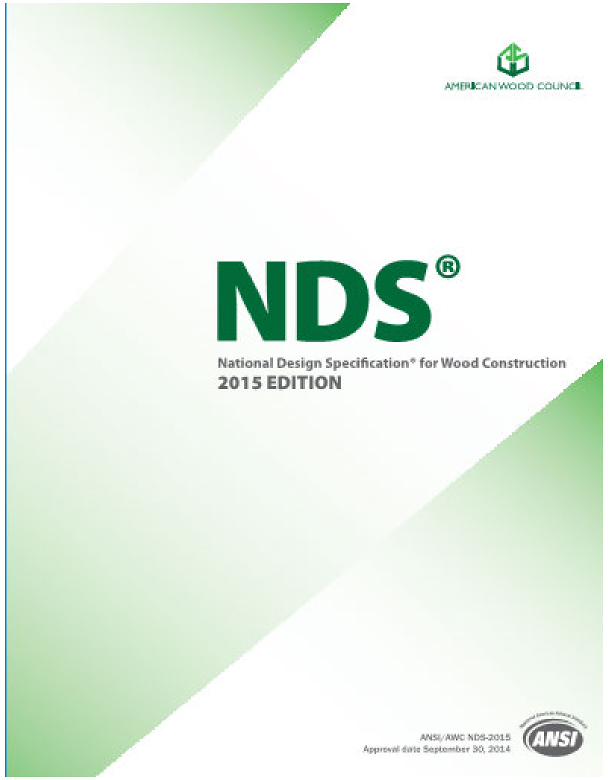
IBC 722
Calculated Fire Resistance

"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.

FRR Design of MT



FIRE DESIGN OF WOOD MEMBERS

16.1 General 150
16.2 Design Procedures for Exposed Wood Members 150
16.3 Wood Connections 151
Table 16.2.1 Effective Char Rates and Char Layer Thicknesses (for β_n = 1.5 in./hr.) 150
Table 16.2.2 Adjustment Factors for Fire Design 151

16


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

Tested FRR of Exposed MT:

- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers

NGC Testing Services
Fire Testing Laboratory
IAS ACCREDITED Testing Laboratory TL-216

TEST REPORT
for
American Wood Council

Page 1 of 53

222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

Standard Methods of
Fire Tests of Building Construction and Materials
ASTM E 119 – 11a

Test Report No: WP-1950
Assignment No: K-1089
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)
Test Date: October 4, 2012
Report Date: October 15, 2012

Prepared by:
Michael J. Rizzo
Test Engineer

Reviewed by:
Robert J. Menchetti
Director, Laboratory Facilities and Testing Services

The results reported in this document apply to specific samples submitted for measurement. No responsibility is assumed for performance of any other specimen. This report may not be reproduced, except in full, without the written approval of the laboratory. The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by this laboratory.

TEST REPORT

Intertek

REPORT NUMBER: 102891256SAT-001
ORIGINAL ISSUE DATE: February 27, 2017
REVISED DATE: N/A

EVALUATION CENTER
16015 Shady Falls Road
Elmendorf, TX 78112
Phone: (210) 635-8100
Fax: (210) 635-8101
www.intertek.com

RENDERED TO

Structurlam Products LP
2176 Government Street
Penticton, BC V2A 8B5
Canada

PRODUCT EVALUATED: CrossLam® CLT Un-restrained Load-Bearing Floor/Ceiling Assembly
EVALUATION PROPERTY: Fire Resistance

Report of Testing a CrossLam® CLT Un-restrained Load-Bearing Floor/Ceiling Assembly for compliance with the applicable requirements of the following criteria: *ASTM E119–16a, Standard Test Methods for Fire Tests of Building Construction and*

FPInnovations
NRC-CNRC

Project No. 301006155
Final Report 2012/13

Preliminary CLT Fire Resistance Testing Report

by

Lindsay Osborne, M.A.Sc.
Christian Dagenais, Eng., M.Sc.
Scientists
Advanced Building Systems – Serviceability and Fire Group

and

Noureddine Bénichou, Ph.D.
Senior Research Officer
National Research Council of Canada – Fire Research Resource Centre

July 2012

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 1.5EMSR 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	El	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	El	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	El	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	El	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	El	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	El 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	VI	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	VI	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	VI	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 (160mm 6.3")	KLH	CV3M1	None	Half-Lap & Topside spline	None	Loaded, See Manufacturer	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

Richard McLain, PE, SE • Senior Technical Director • WoodWorks
Scott Breneman, PhD, PE, SE • Senior Technical Director • WoodWorks

For many years, exposed heavy timber framing elements have been permitted in U.S. buildings due to their inherent fire-resistance properties. The predictability of wood's char rate has been well-established for decades and has long been recognized in building codes and standards.

Today, one of the exciting trends in building design is the growing use of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction. Like heavy timber, mass timber products have inherent fire resistance that allows them to be left exposed and still achieve a fire-resistance rating. Because of their strength and dimensional stability, these products also offer a low-carbon alternative to steel, concrete, and masonry for many applications. It is this combination of exposed structure and strength that developers and designers across the country are leveraging to create innovative designs with a warm yet modern aesthetic, often for projects that go beyond traditional norms of wood design.

This paper has been written to support architects and engineers exploring the use of mass timber for commercial and multi-family construction. It focuses on how to meet fire-resistance requirements in the International Building Code (IBC), including calculation and testing-based methods. Unless otherwise noted, references refer to the 2018 IBC.

Mass Timber & Construction Type

Before demonstrating fire-resistance ratings of exposed mass timber elements, it's important to understand under what circumstances the code currently allows the use of mass timber in commercial and multi-family construction.

A building's assigned construction type is the main indicator of where and when all wood systems can be used. IBC Section 602 defines five main options (Type I through V) with all but Type IV having subcategories A and B. Types III and V permit the use of wood framing throughout much of the structure and both are used extensively for modern mass timber buildings.

Type III (IBC 602.3) – Timber elements can be used in floors, roofs and interior walls. Fire-retardant-treated wood (FRTW) framing is permitted in exterior walls with a fire-resistance rating of 2 hours or less.

Type V (IBC 602.5) – Timber elements can be used throughout the structure, including floors, roofs and both interior and exterior walls.

Type IV (IBC 602.4) – Commonly referred to as 'Heavy Timber' construction, this option

Carbon12 | Portland, Oregon
Kaiser Group | Path Architecture
Munzing Structural Engineering

Mass Timber Fire Design Resource

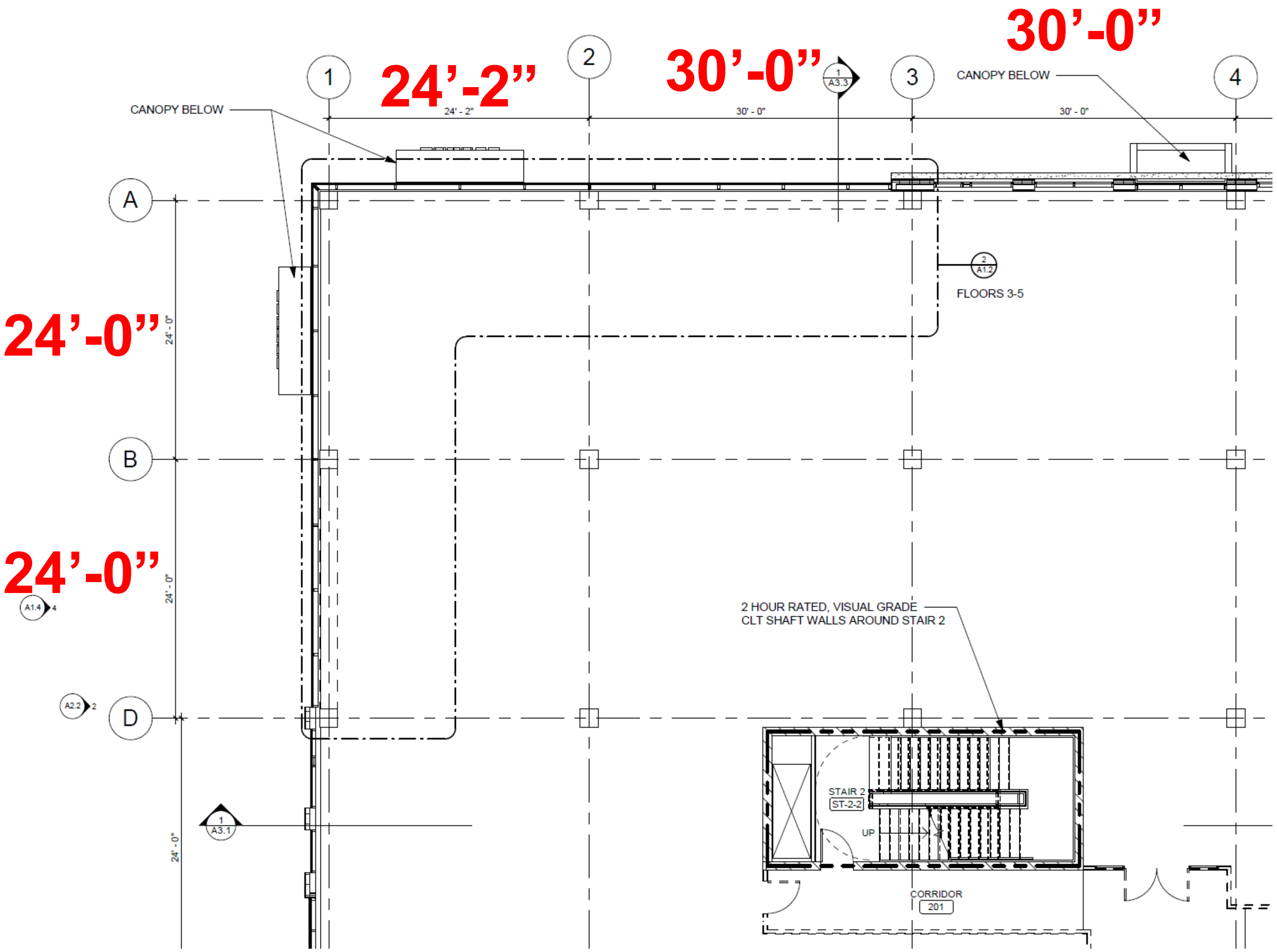
- Code compliance options for demonstrating FRR
- Free download at woodworks.org

Structural Grid

Structural Grid

Grids & Spans

- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation



Structural Grid

Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

0 HR FRR: Consider 3-ply Panel

- Efficient Spans of 10-12 ft
- Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

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

Structural Grid

Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
- Consider connections – can drive member sizing

1 or 2 HR FRR: Likely 5-ply Panel

- Efficient spans of 14-17 ft
- Grids of 15x30 (no purlins) to 30x30 (1 purlin) may be efficient

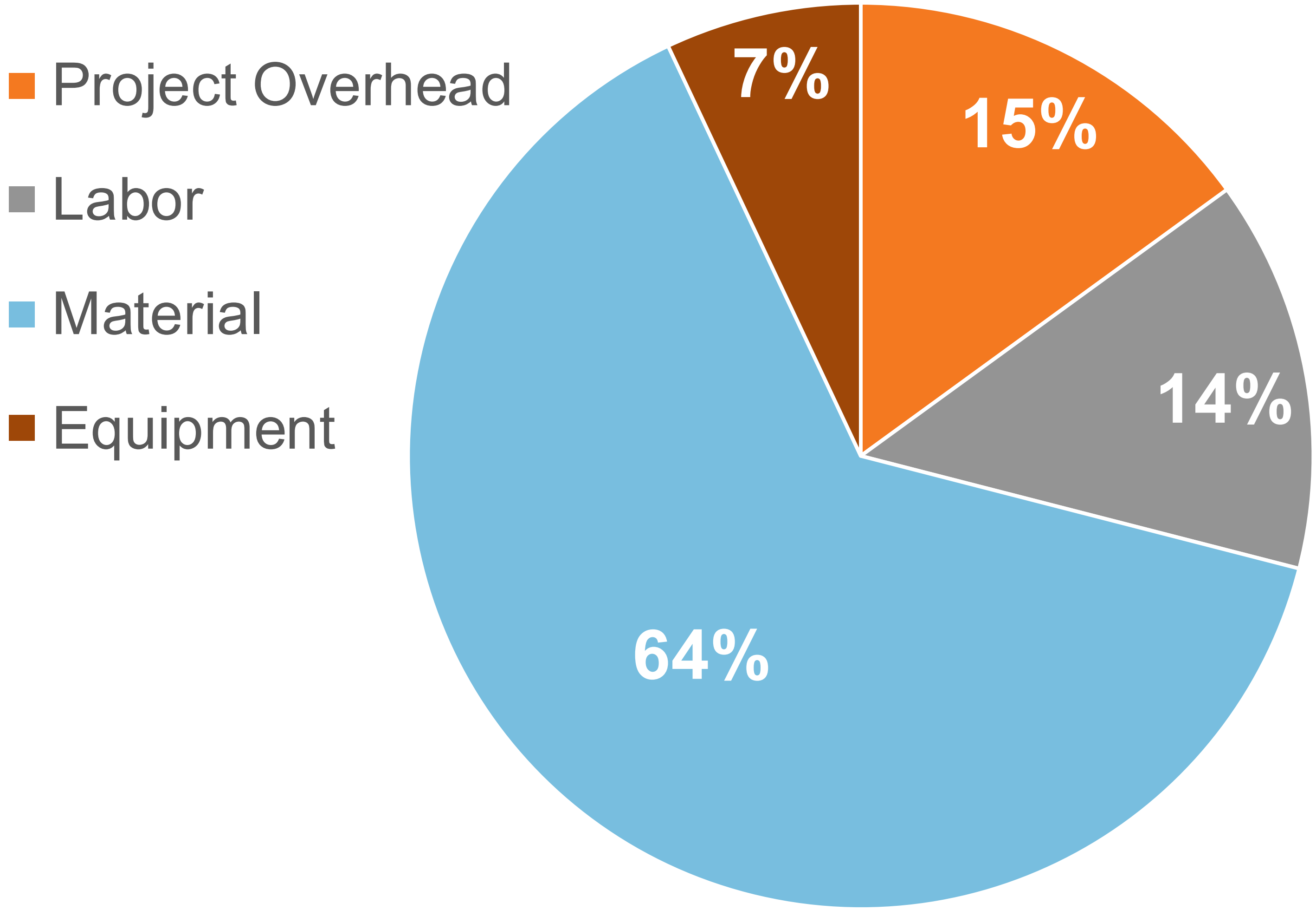
First Tech Credit Union, Hillsboro, OR
12x32 Grid, One-Way Beams
5-ply (5.5”) CLT
Image: Swinerton

Key Early Design Decisions

Why so much focus on panel thickness?

Key Early Design Decisions

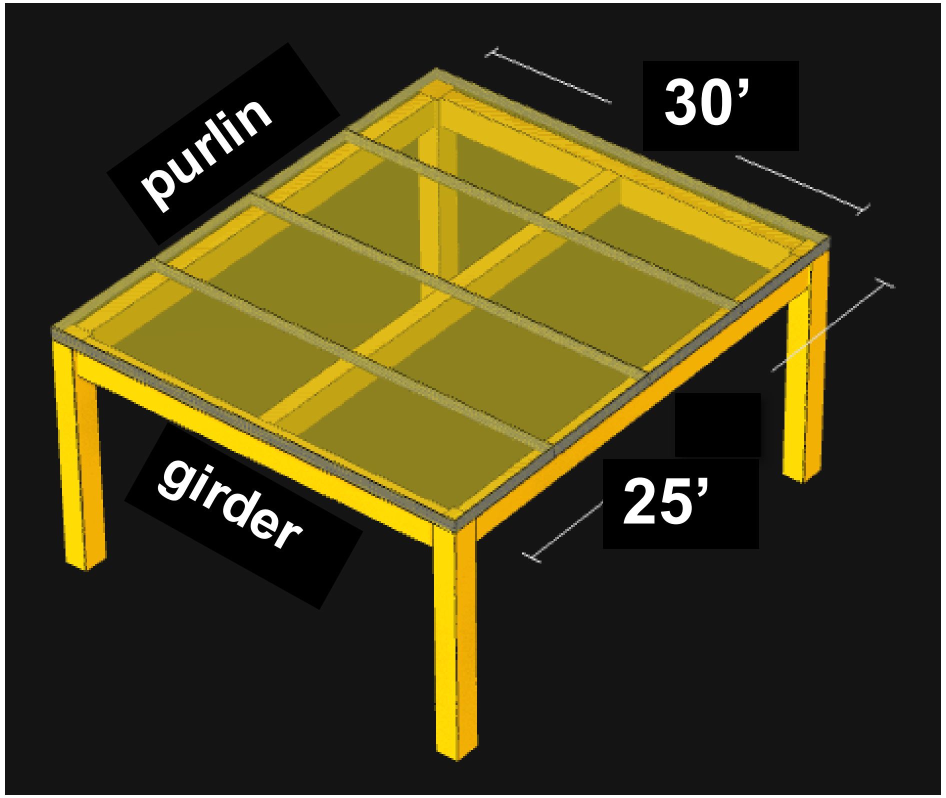
Typical MT Package Costs



Source: Swinerton

Key Early Design Decisions

Which is the most efficient option?



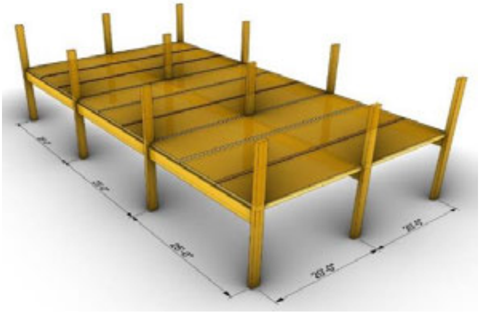
Source: Fast + Epp, Timber Bay Design Tool

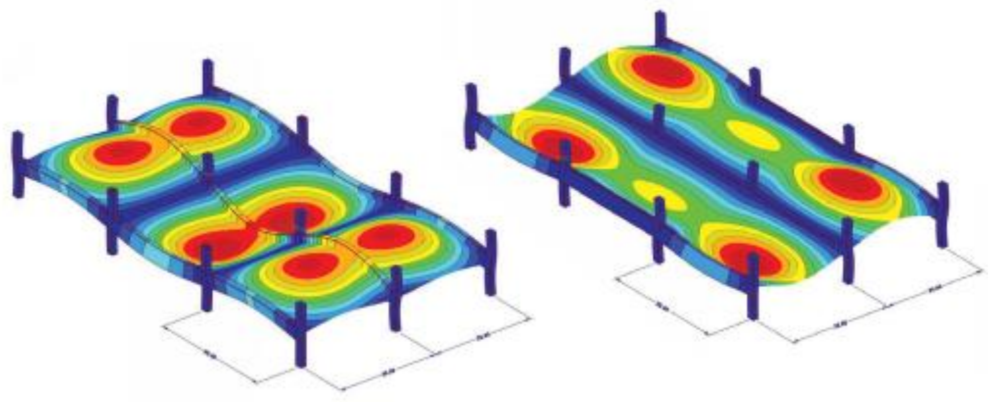
	Timber Volume Ratio	Podium on 1st Floor?
IIIA – Option 1	0.73 CF / SF	Yes
IIIA – Option 2	0.74 CF / SF	Yes
IV-HT	0.51 CF / SF	Yes
IV-C	0.82 CF / SF	No

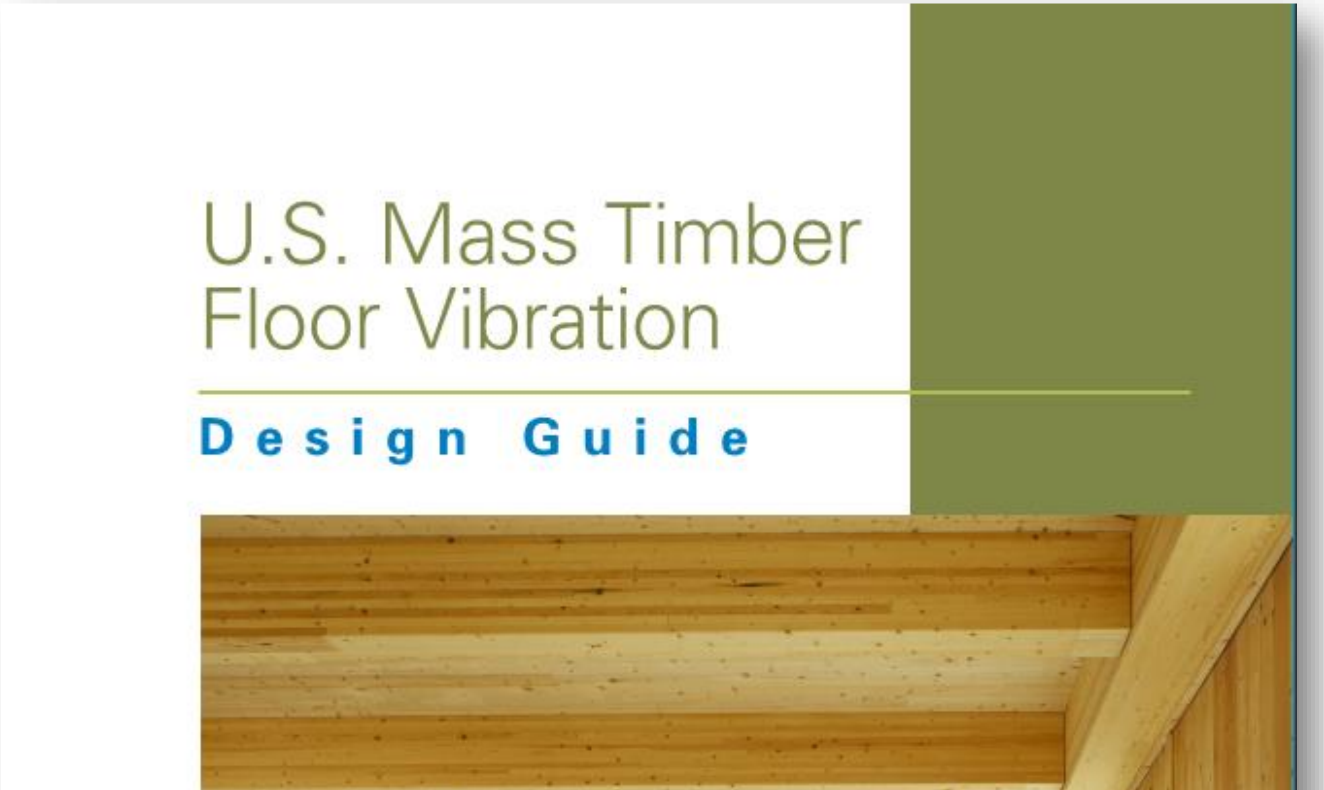
A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

Key Early Design Decisions

NEW MASS TIMBER FLOOR VIBRATION DESIGN GUIDE







Worked office, lab and residential Examples

Covers simple and complex methods for bearing wall and frame supported floor systems

Connections

Credit: Structurlam

Key Early Design Decisions

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


Photo: John Stamets


Photo: Josh Partee

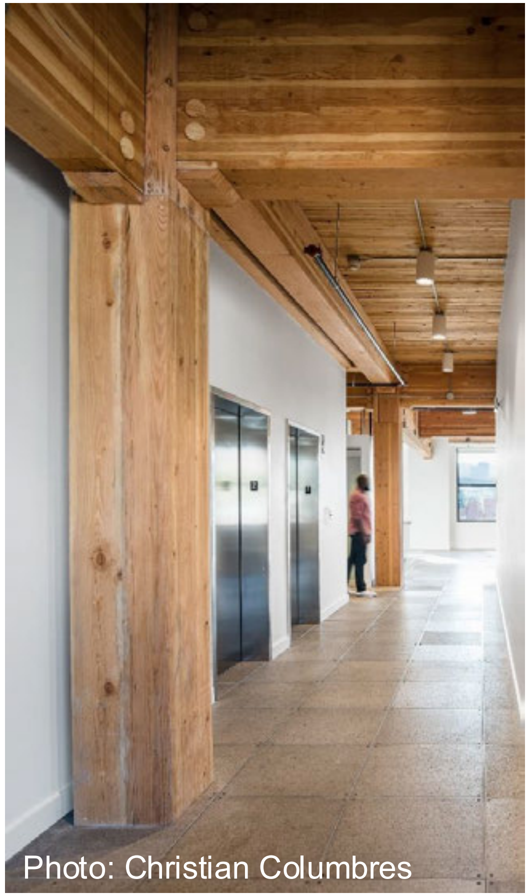


Photo: Christian Columbres

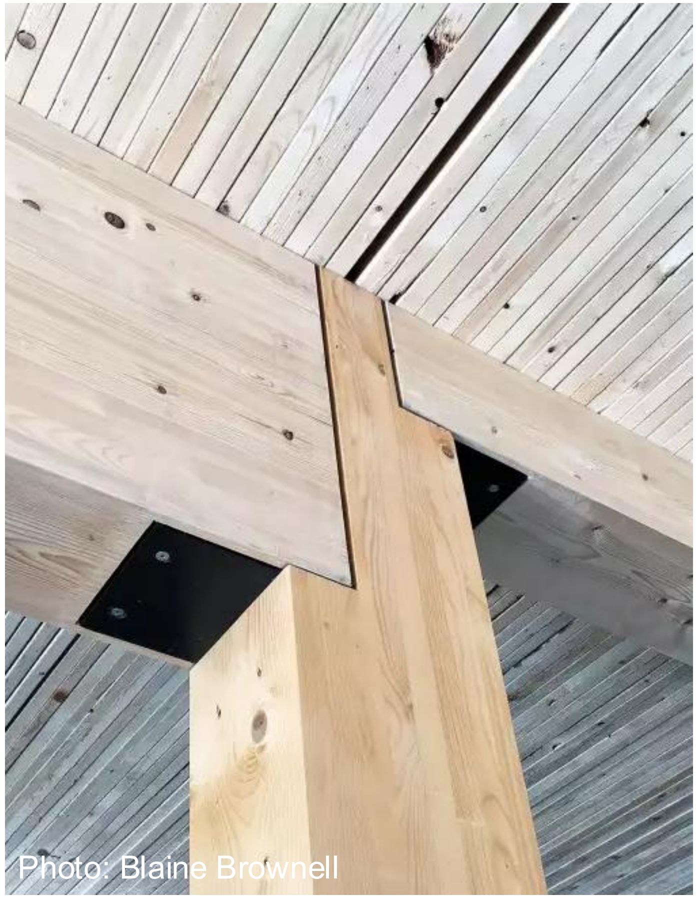
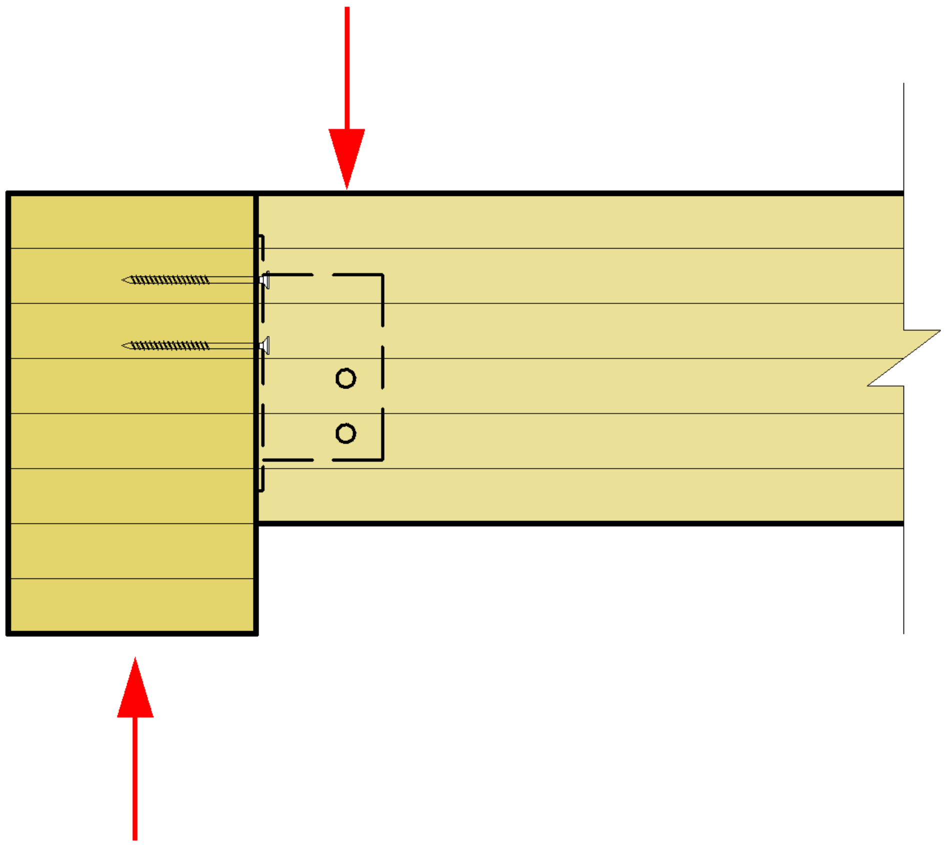


Photo: Blaine Brownell

Key Early Design Decisions

Steel hangers/hardware fully concealed within a timber-to-timber connection is a common method of fire protection



Key Early Design Decisions

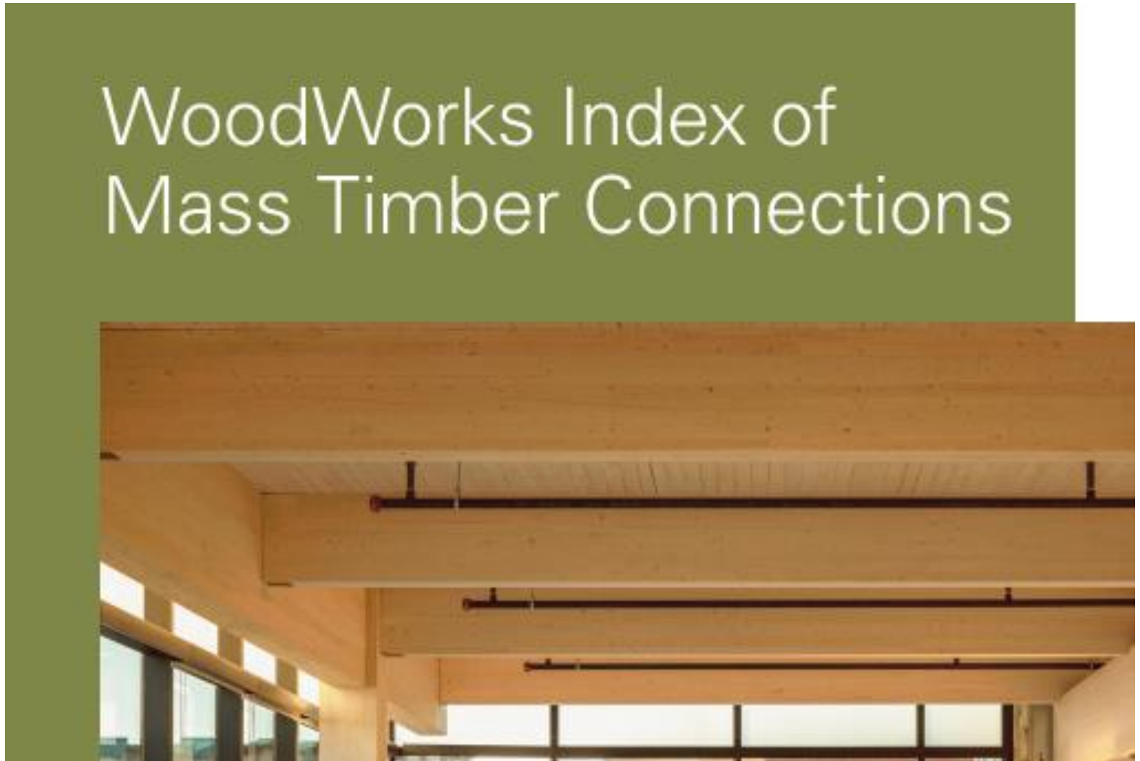
2017 Glulam Beam to Column Connection Fire Tests under standard ASTM E119 time-temperature exposure

Key Early Design Decisions

Member to member bearing also commonly used, can avoid some/all steel hardware at connection

Key Early Design Decisions

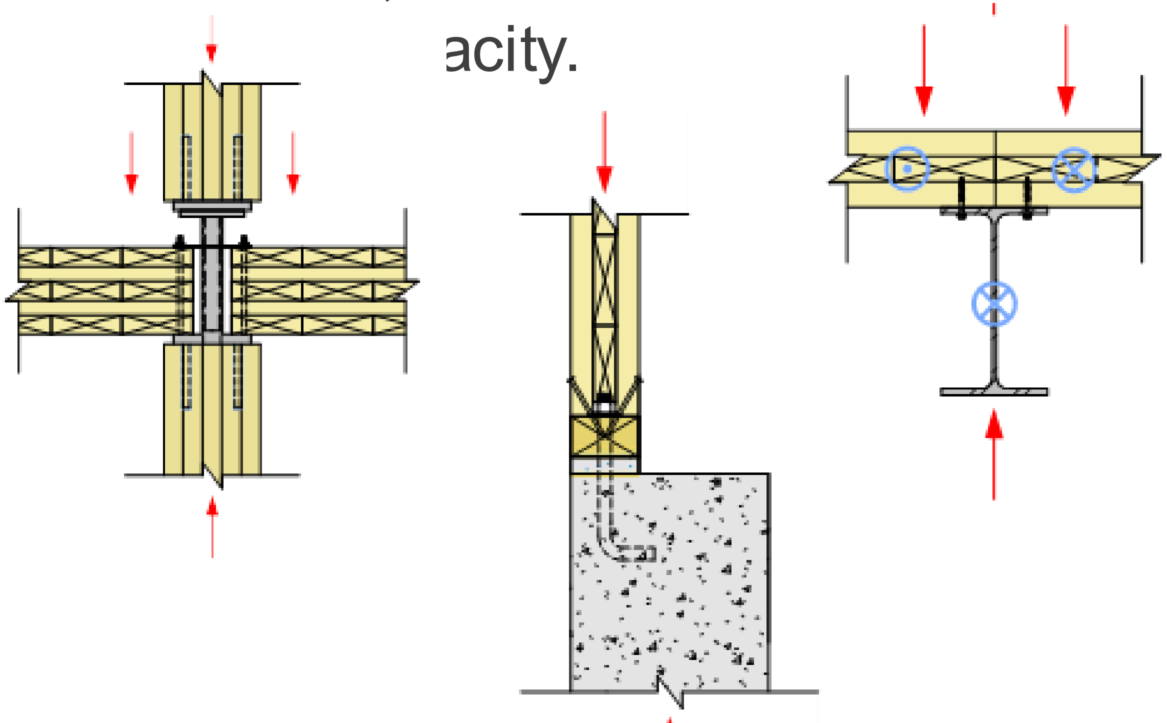
ARCHITECTURE
URBAN DESIGN
INTERIOR DESIGN



MASS TIMBER CONNECTIONS INDEX

A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load-

acity.



Connections

Other connection design considerations:

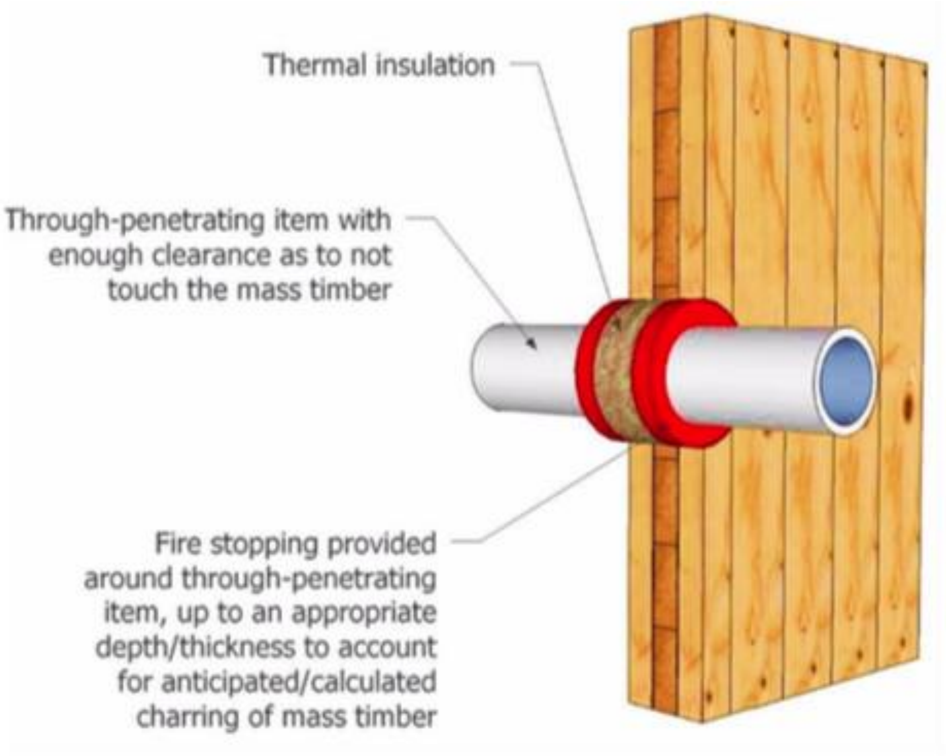
- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost

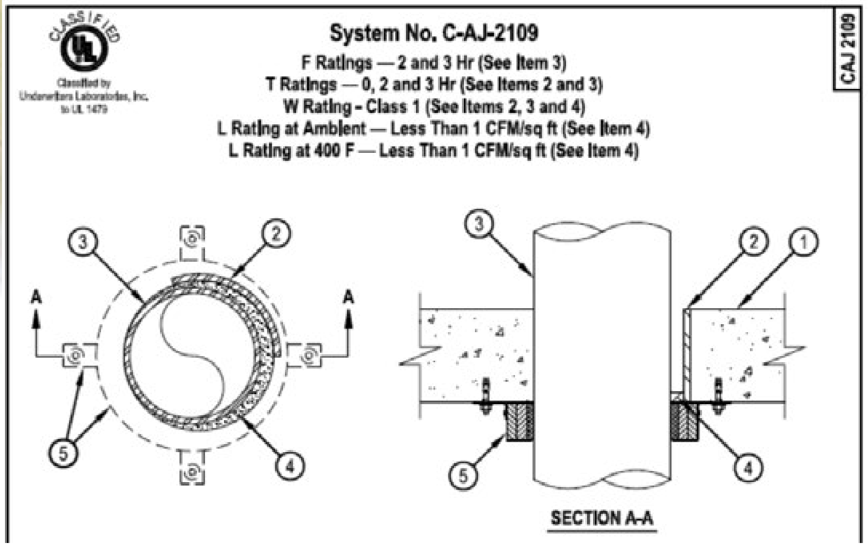
Penetrations & Firestopping

Photo: Alex Schreyer

Penetrations & Firestopping

Most firestopping systems include combination of fire safing (eg. noncombustible materials such as mineral wool insulation) plus fire caulk





Photos: AWC/FPInnovations/Hilti

Penetrations & Firestopping

Inventory of Fire Tested Penetrations in MT Assemblies

WoodWorks™ WOOD PRODUCTS COUNCIL

Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies

CLT Panel	Exposed Side Protection	Penetrating Item	Penetrant Centered or Offset in Hole	Firestopping System Description	F Rating	T Rating	Stated Test Protocal	Source	Testing Lab
3-ply (78mm 3.07")	None	1.5" diameter data cable bunch	Centered	3.5 in diameter hole. Mineral wool was installed in the 1in. annular space around the data cables to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	0.5 hour	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	2" copper pipe	Centered	4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	2.5" sched. 40 pipe	Centered	4.92 in diameter hole. Pipe wrap was installed around the schedule 40 pipe to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	6" cast iron pipe	Centered	8.35 in diameter hole. Mineral wool was installed in the 1in. annular space around the cast iron pipe to a total depth of approximately 2 – 5/64in. The remaining 1in. annular space starting at the top of the pipe wrap to the top of the floor assembly was filled with Hilti FS-One Max caulking.	1 hour	N.A.	CANULC S115	26	Intertek March 30, 2016
3-ply (78mm 3.07")	None	Hilti 6 in drop in device. System No.: F-B-2049	Centered	9.01" diameter hole. Mineral wool was installed in the 1 – 1/4in. annular space around the drop-in device to a total depth of approximately 1 – 7/64in and the remaining 1in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64in. hole in the CLT was filled with Hilti FS-One Max caulking.	1 hour	0.75 hour	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	1.5" diameter data cable bunch	Centered	3.5" diameter hole. Mineral wool was installed in the 1in. annular space around the data cables to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space from the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	1.5 hours	CANULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	None	2" copper pipe	Centered	4.375 in diameter hole. Pipe wrap was installed around the copper pipe to a total depth of approximately 4 – 5/32 in. The remaining 1in. annular space starting at the top of the mineral wool to the top of the floor assembly was filled with Hilti FS-One Max caulking.	2 hours	N.A.	CANULC S115	26	Intertek March 30, 2016
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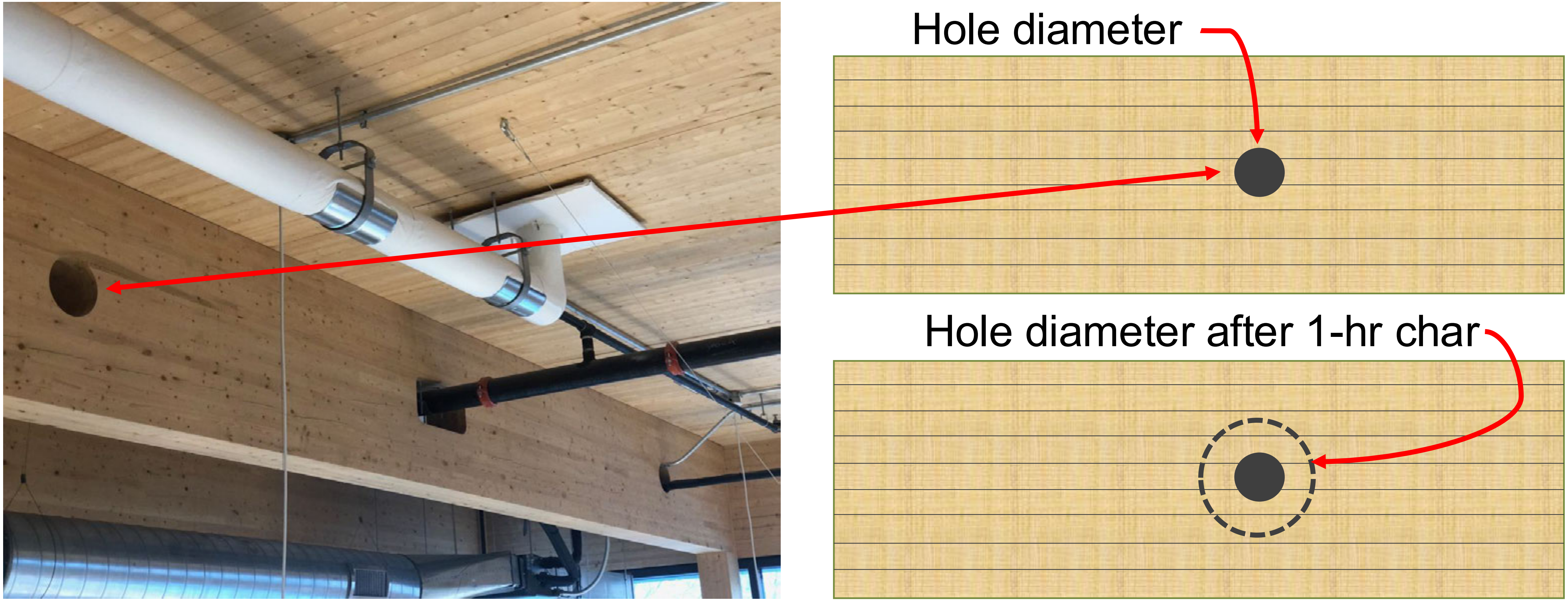
5-ply CLT (131mm 5.16")	None	Hilti 6 in drop in device. System No.: F-B-2049	Centered	9.01" diameter hole. Mineral wool was installed in the 1 – 1/4in. annular space around the drop-in device to a total depth of approximately 1 – 7/64in and the remaining 1in. annular space from the top of the mineral wool to the top edge of the 9 – 1/64in. hole in the CLT was filled with Hilti FS-One Max caulking.	2 hours	1.5 hours	CANULC S115	26	Intertek March 30, 2016
5-ply (175mm 6.875")	None	1" nominal PVC pipe	Centered	4.21 in diameter with a 3/4 in plywood reducer flush with the top of the slab reducing the opening to 2.28 in. Two wraps of Hilti CP 648-E W45/1-3/4" Firestop wrap strip at two locations with a 30 gauge steel sleeve which extended from the top of the slab to 1 in below the slab. The first location was with the bottom of the wrap strip flush with the bottom of the steel sleeve and the second was with the bottom of the wrap strip 3 in. from the bottom of the slab. The void between the steel sleeve and the CLT and between the steel sleeve and pipe at the top was filled with Roxul Safe mineral wool leaving a 3/4 in deep void at the top of the assembly. Hilti FS-One Max Intumescent Firestop Sealant was applied to a depth of 3/4 in on the top of the assembly between the plywood and steel sleeve as well as the steel sleeve and pipe.	2 hours	2 hours	ASTM E814	24	QAI Laboratories March 3, 2017

Penetrations & Firestopping

Beam penetrations:

- If FRR = 0-hr, analyze structural impact of hole diameter only
- If FRR > 0-hr, account for charred hole diameter or firestop penetration



MEP Layout & Integration

MEP Layout & Integration

Key considerations:

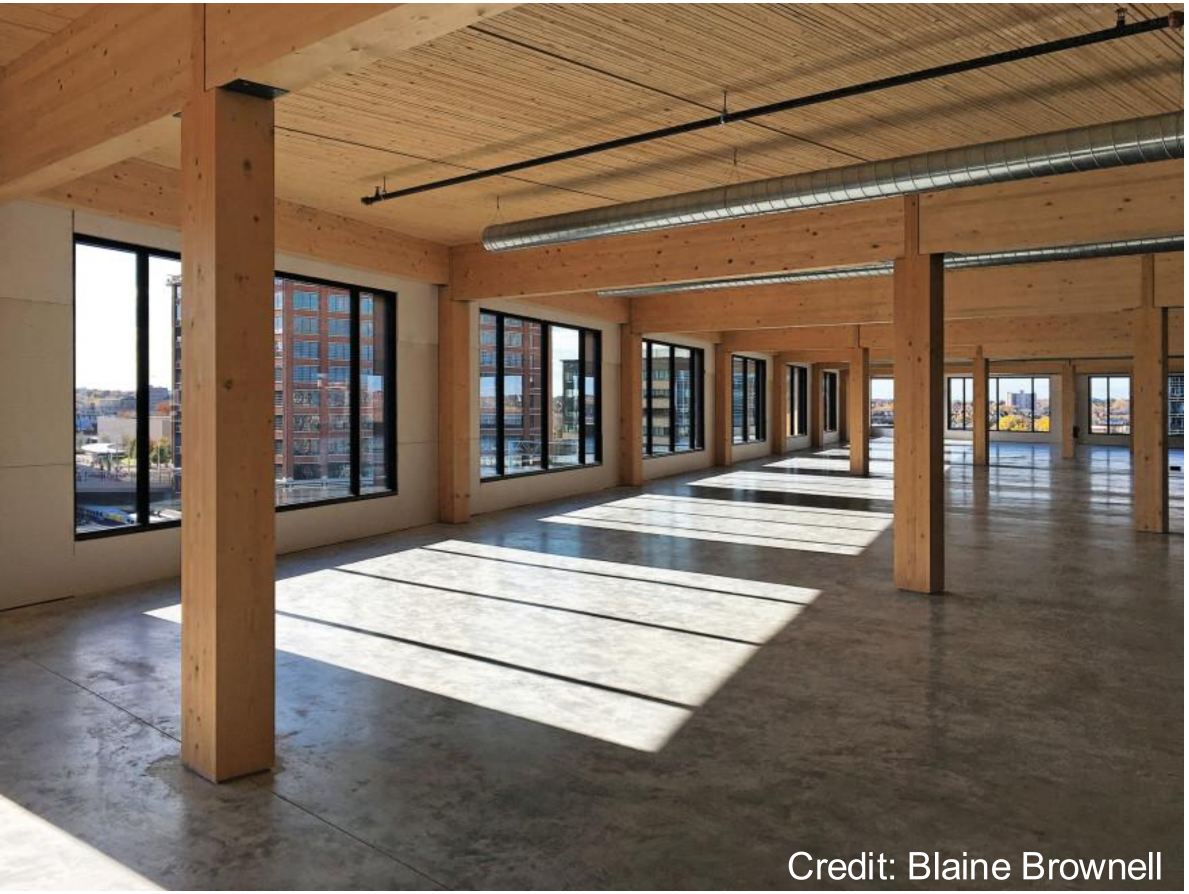
- Level of exposure desired
- Floor to floor, structure depth & desired head height
- Building occupancy and configuration (i.e. central core vs. double loaded corridor)
- Grid layout and beam orientations
- Need for future tenant reconfiguration
- Impact on fire & structural design: concealed spaces,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

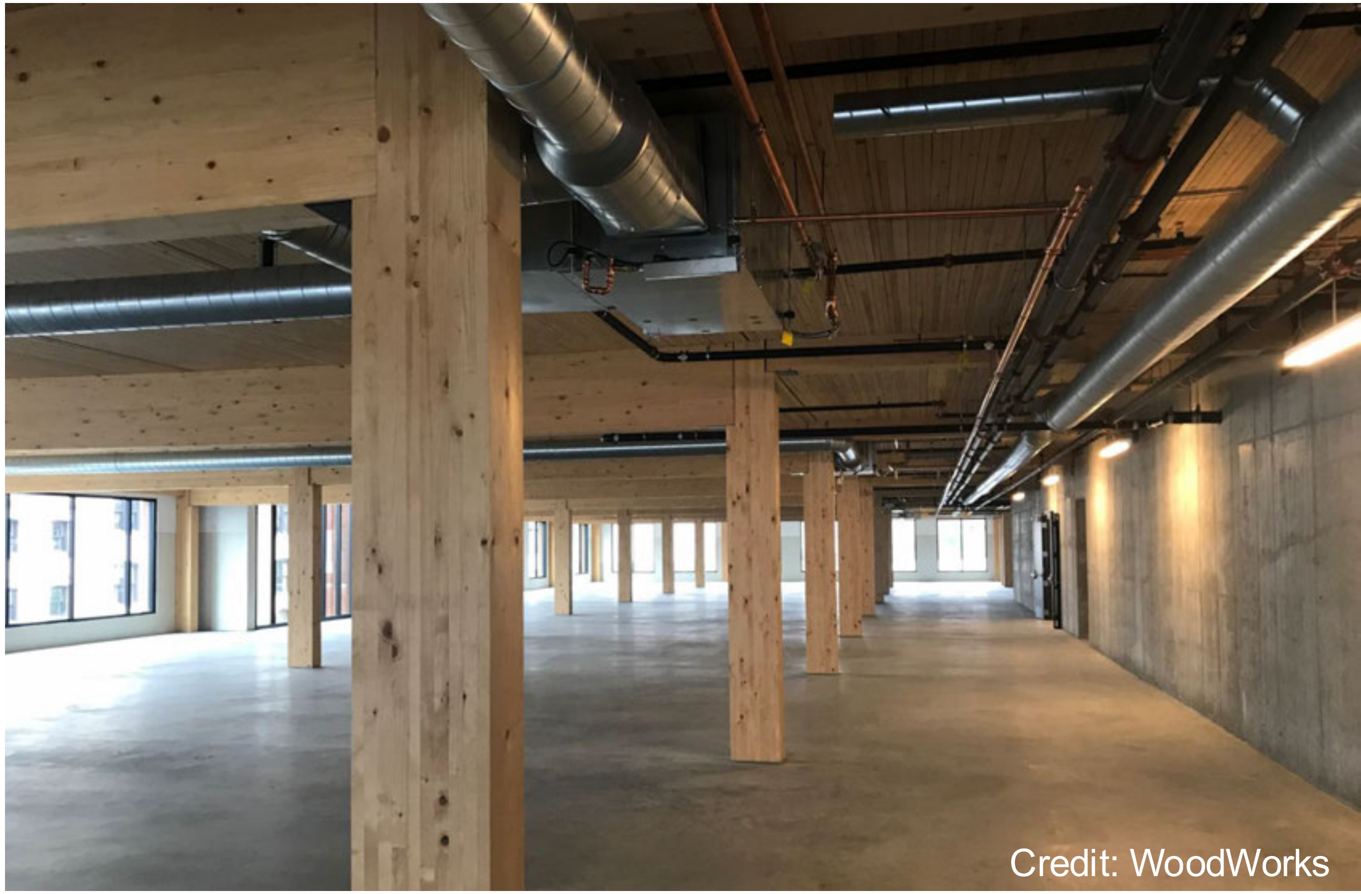
Credit: WoodWorks

MEP Layout & Integration

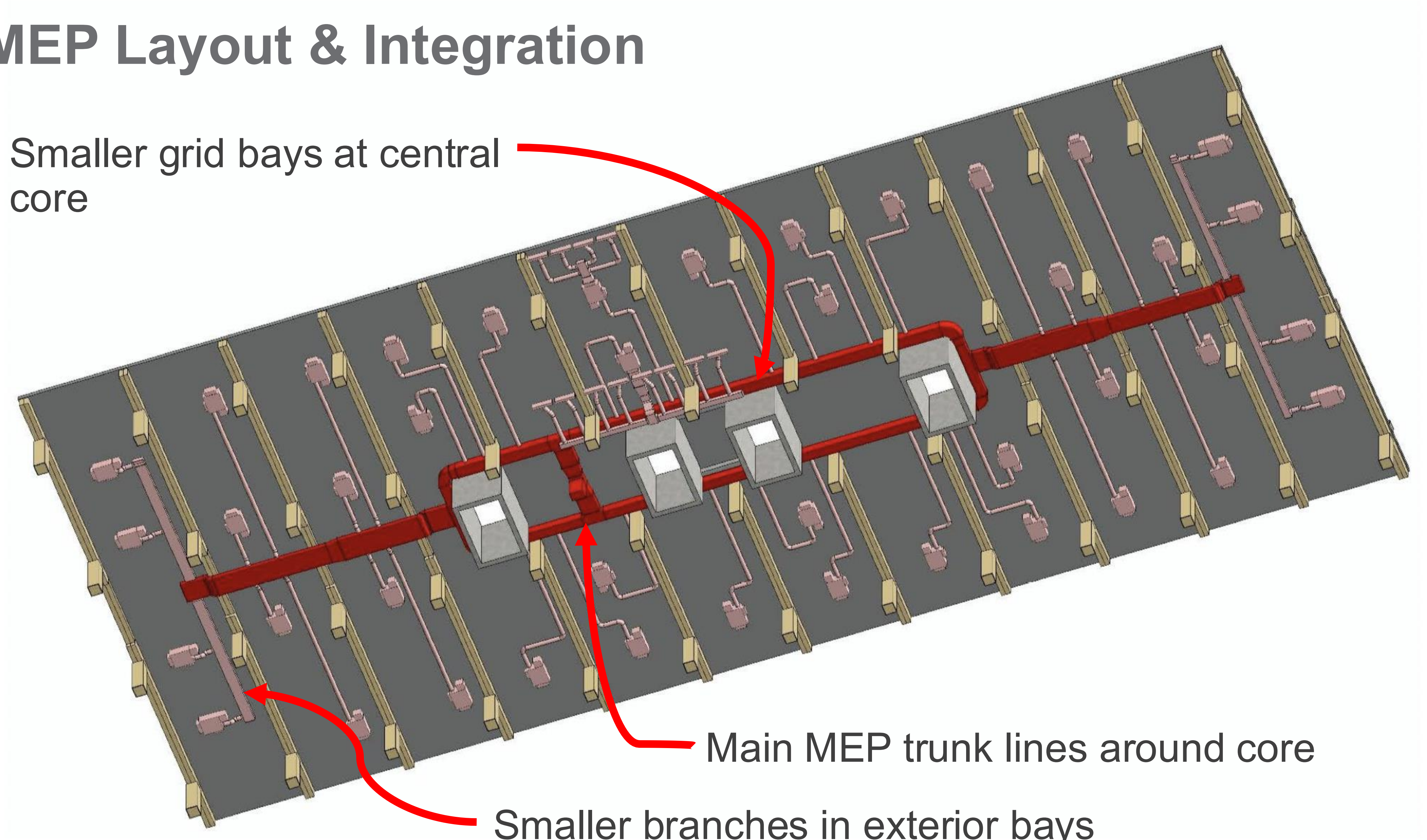
Smaller grid bays at central core (more head height)

- Main MEP trunk lines around core, smaller branches in exterior bays


Credit: Blaine Brownell


Credit: WoodWorks

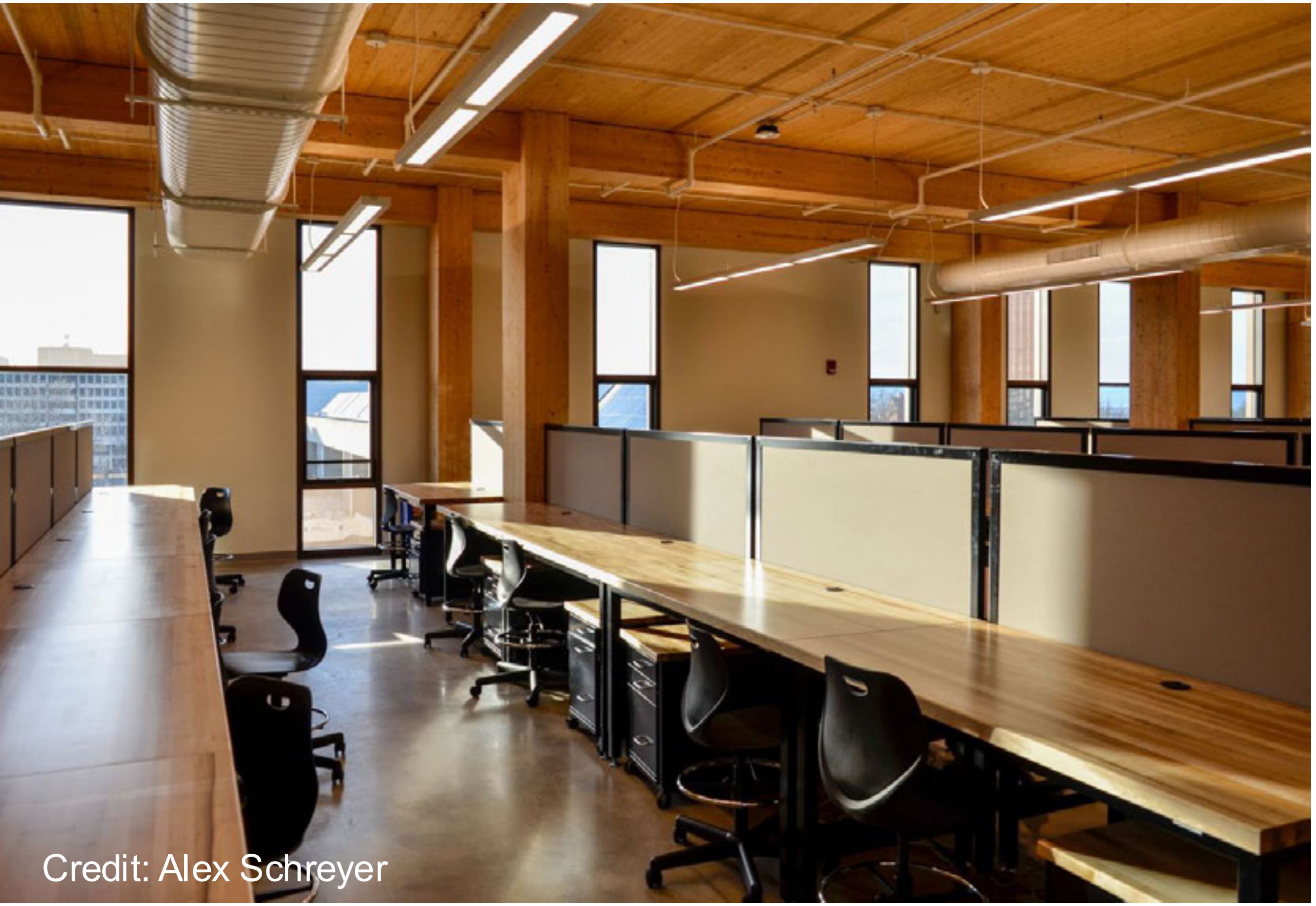
MEP Layout & Integration



Credit: ARUP

MEP Layout & Integration

Dropped below MT framing
- Can simplify coordination (fewer penetrations)
- Bigger impact on head height



Credit: Alex Schreyer

Credit: WoodWorks

MEP Layout & Integration

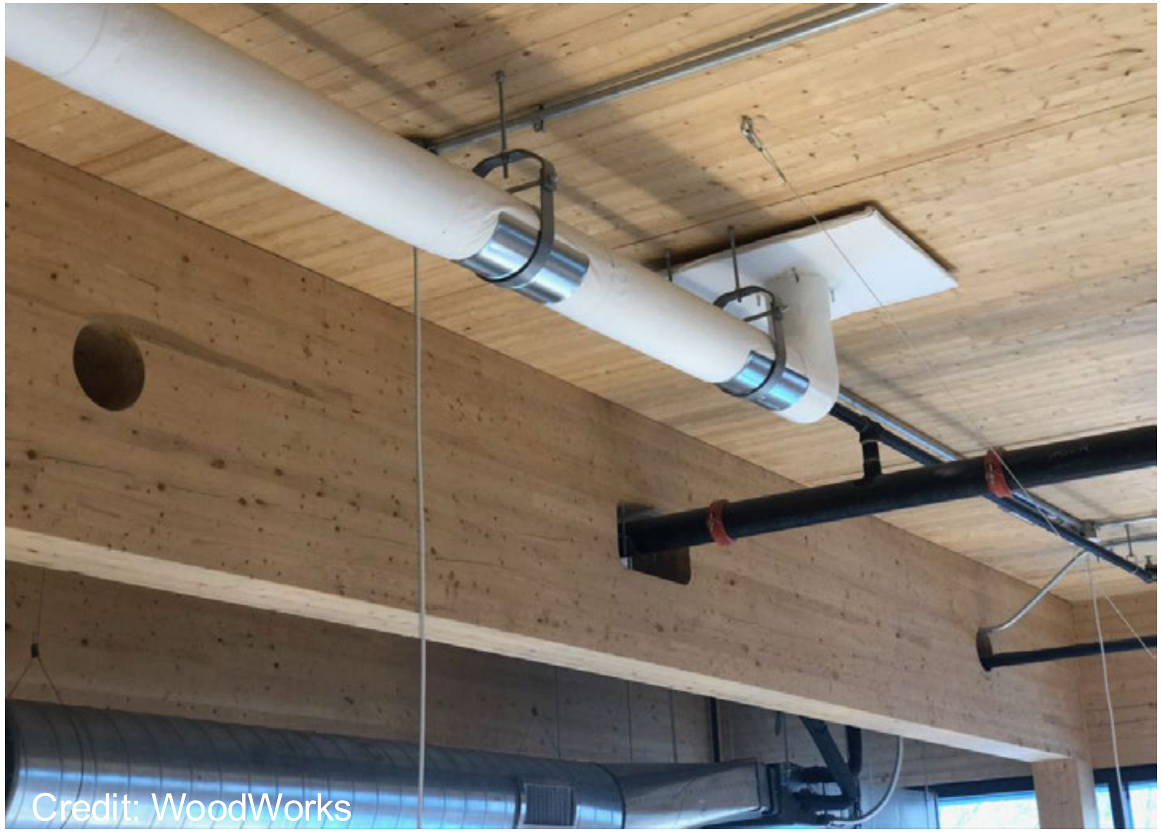
Grid impact: Usually more efficient when using a square-ish grid with beams in two directions

Credit: SOM Timber Tower Report

MEP Layout & Integration

In penetrations through MT framing

- Requires more coordination (penetrations)
- Bigger impact on structural capacity of penetrated members
- Minimal impact on head height

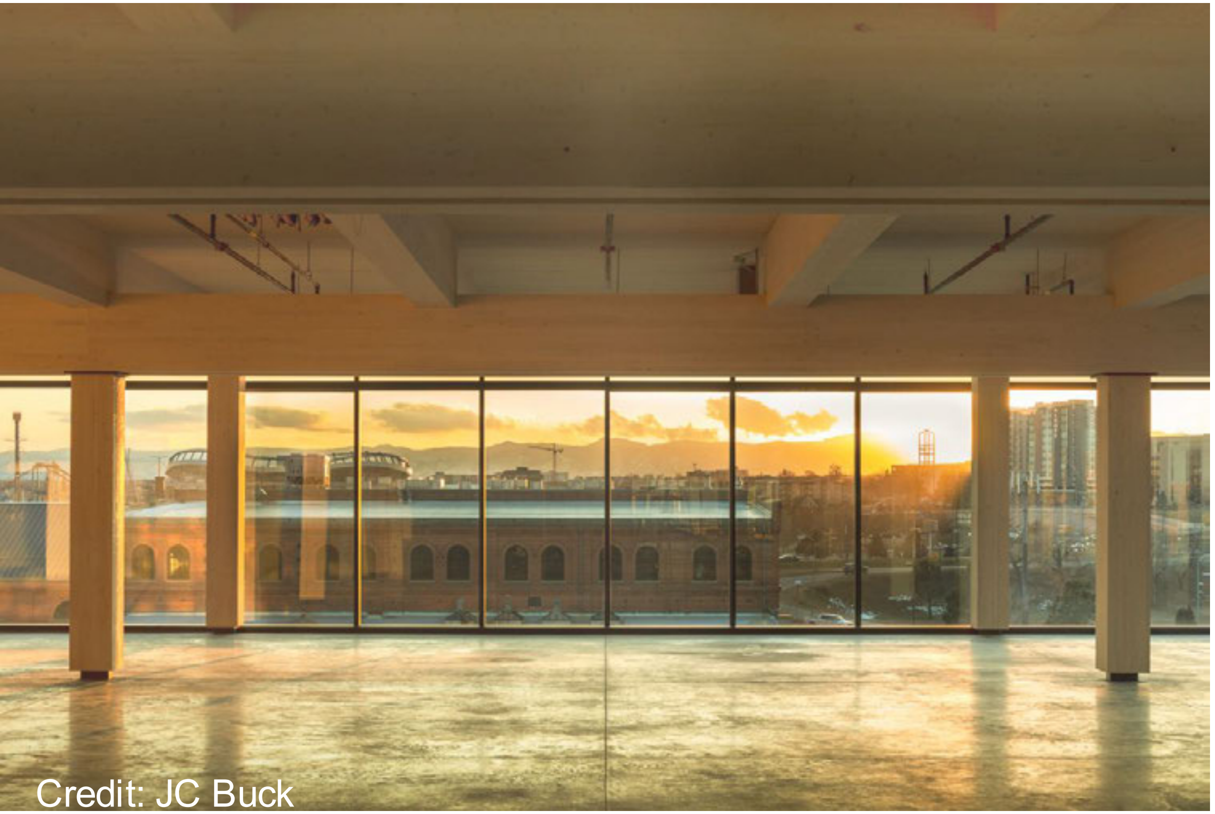

Credit: WoodWorks


Credit: WoodWorks

MEP Layout & Integration

In chases above beams and below panels

- Fewer penetrations
- Bigger impact on head height (overall structure depth is greater)
- FRR impacts: top of beam exposure



Credit: JC Buck

Credit: KL&A Engineers & Builders

MEP Layout & Integration

In gaps between MT panels

- Fewer penetrations, can allow for easier modifications later

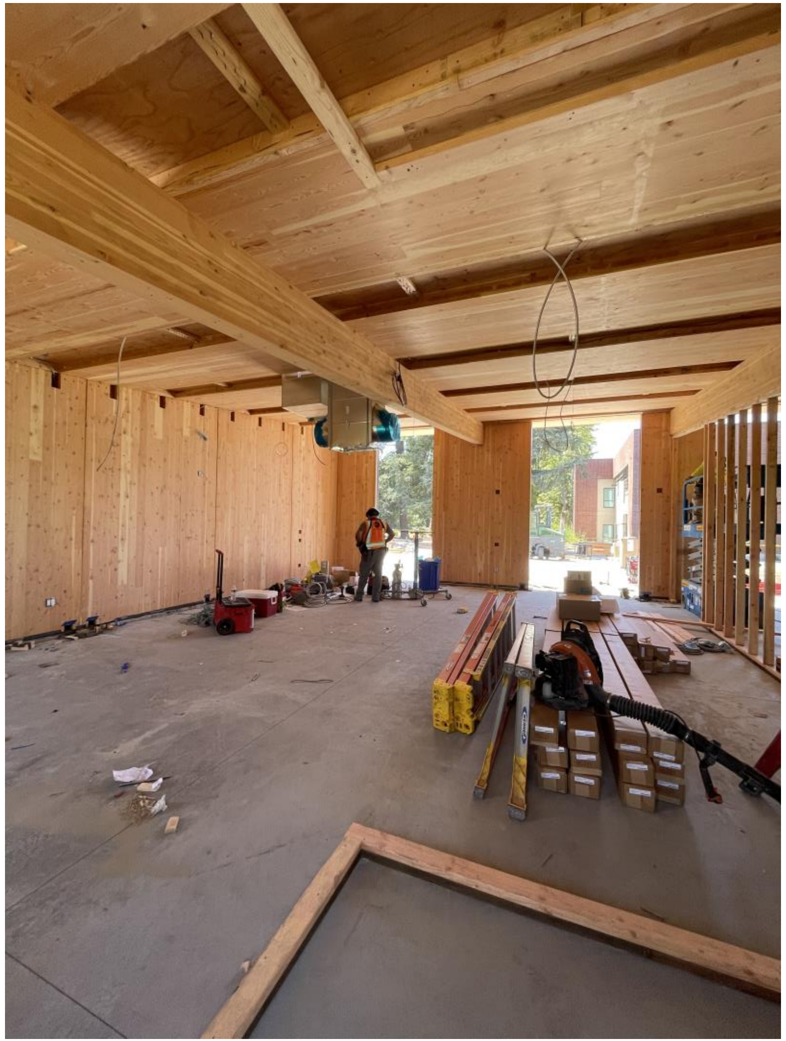
Credit: Ema Peter/MGA

Credit: Hacker Architects

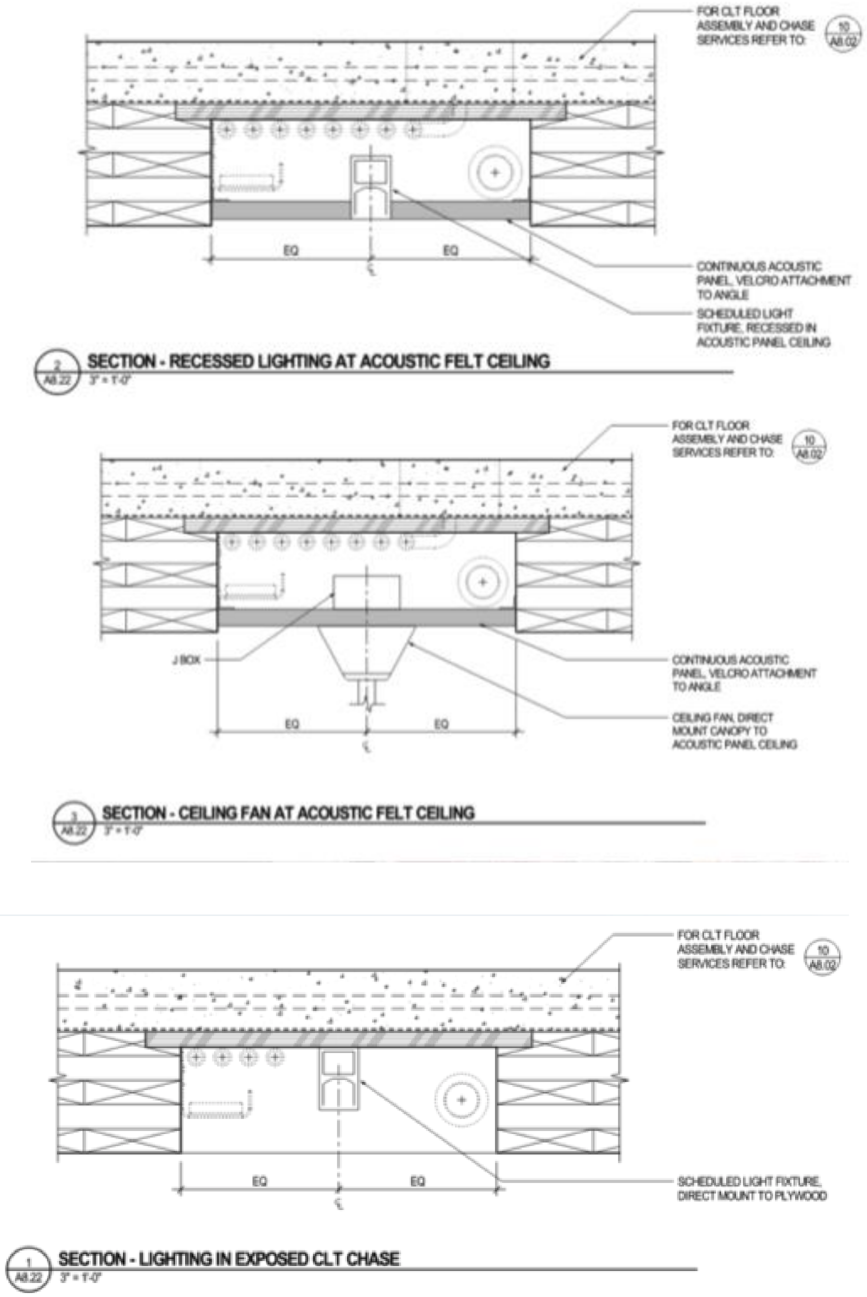
MEP Layout & Integration

In gaps between MT panels

- Greater flexibility in MEP layout



Credit: WoodWorks



Credit: PAE Consulting Engineers

MEP Layout & Integration

In gaps between MT panels

- Aesthetics: often uses ceiling panels to cover gaps

Credit: Ema Peter/MGA

MEP Layout & Integration

In raised access floor (RAF) above MT

- Aesthetics (minimal exposed MEP)

MEP Layout & Integration

In topping slab above MT

- Greater need for coordination prior to slab pour
- Limitations on what can be placed (thickness of topping slab)
- No opportunity for renovations later


Credit: Alex Schreyer

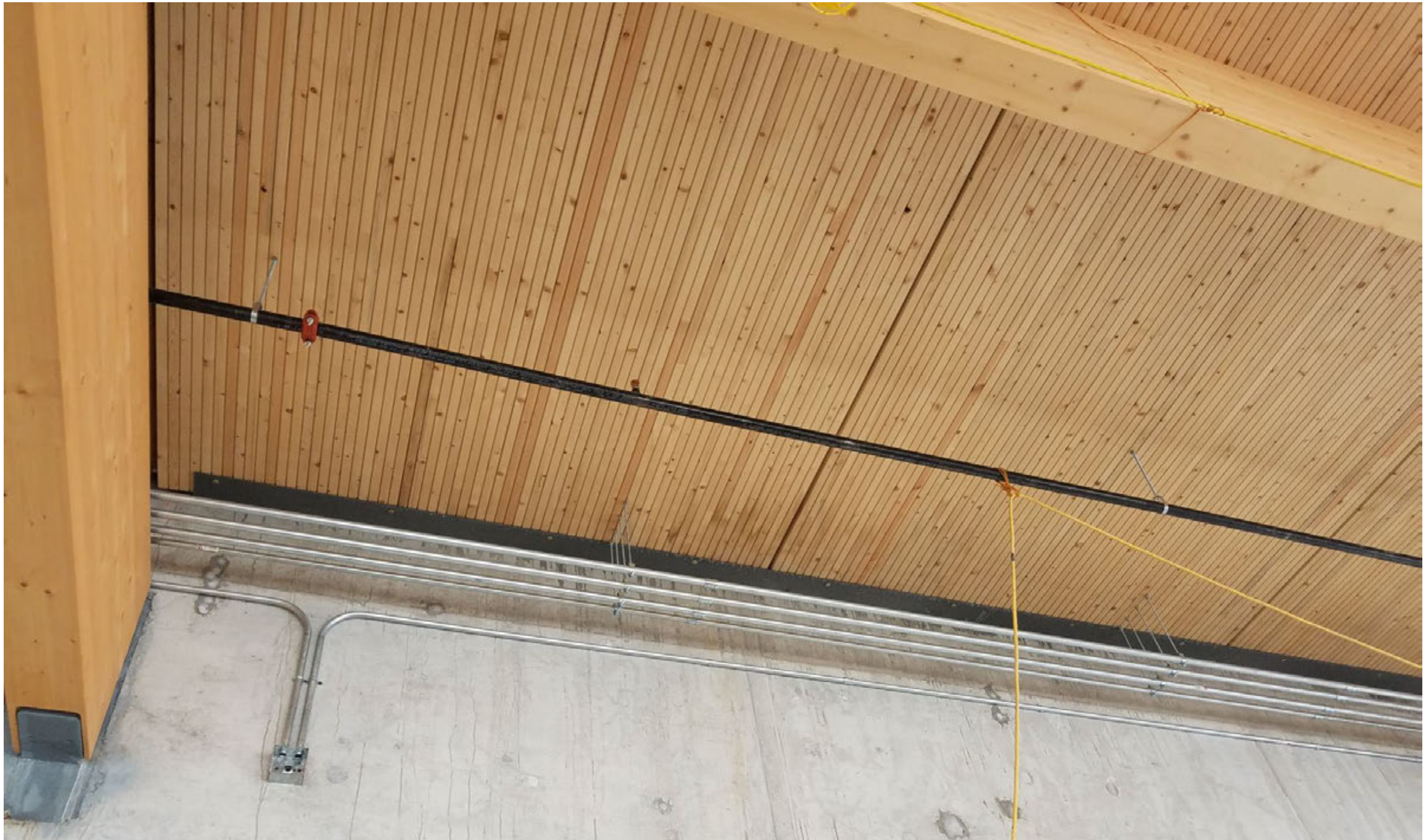
Lateral System Choices & Impacts

Lateral System Choices

Concrete Shearwalls

Lateral System Choices

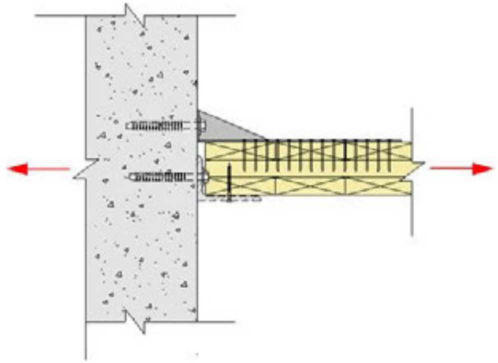
Connection to concrete core

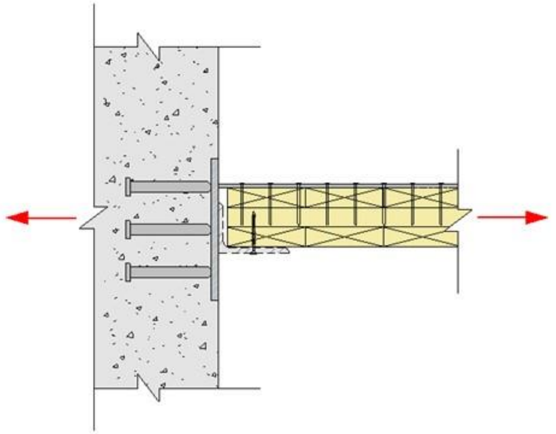


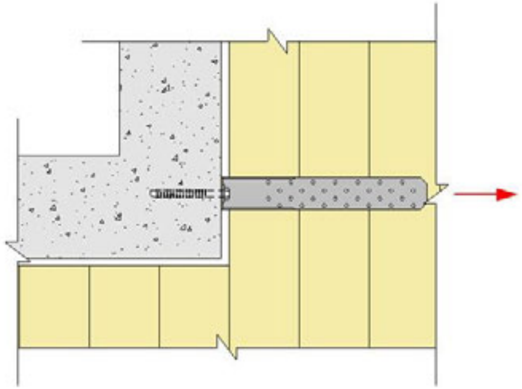
Lateral System Choices

Connections to concrete core

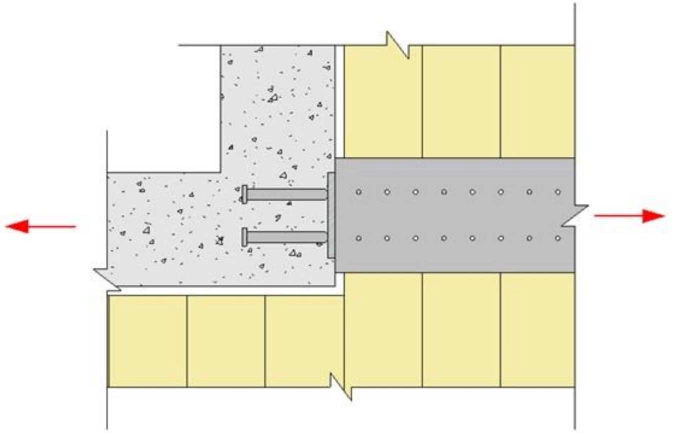
- Tolerances & adjustability
- Drag/collector forces



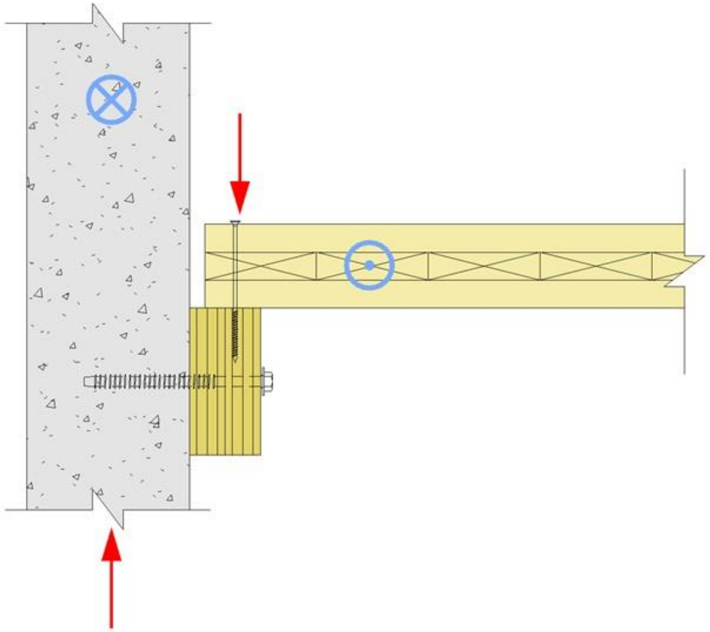




PLAN VIEW



PLAN VIEW



Lateral System Choices

Steel Braced Frame

Photos: Marcus Kauffmann, ODF

Lateral System Choices

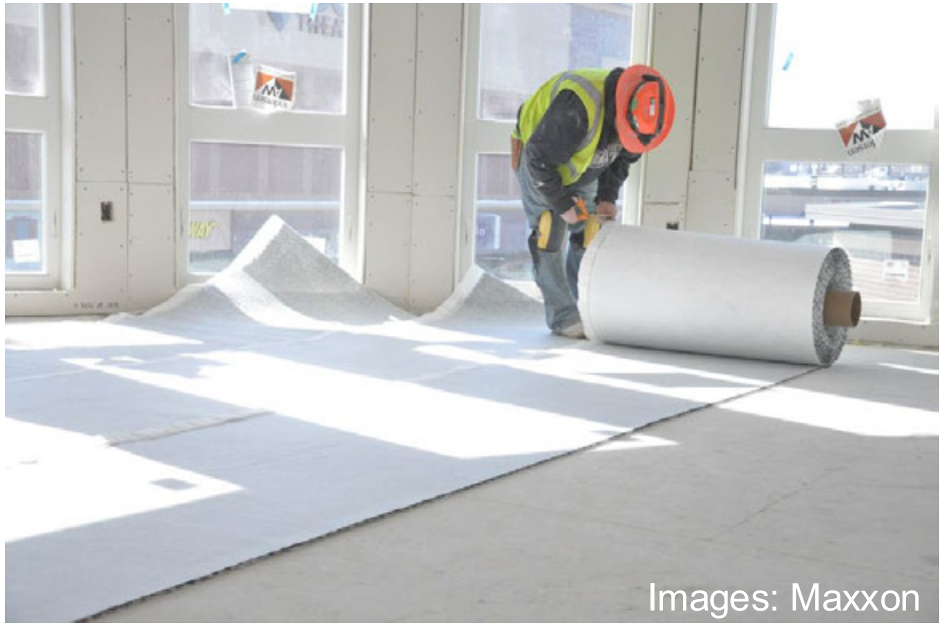
Wood-Frame Shearwalls

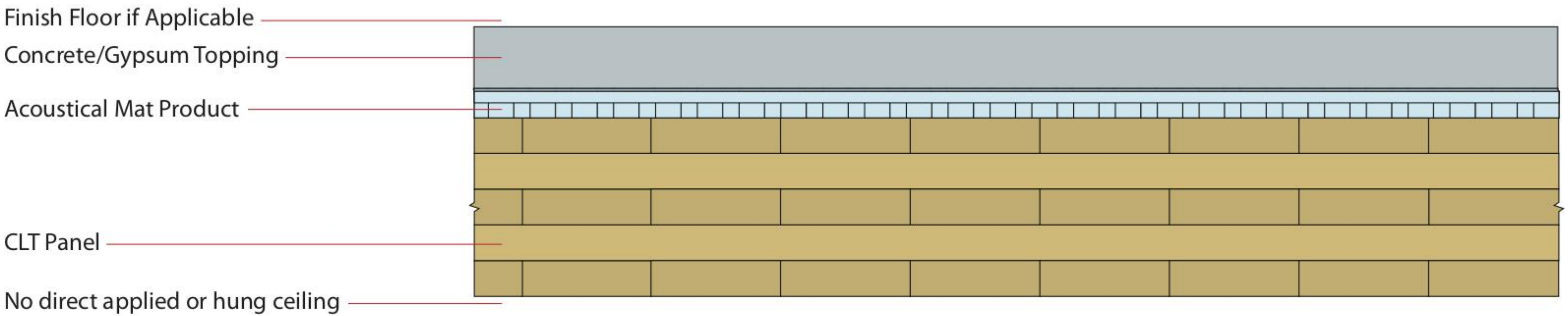
Lateral System Choices

MT Shearwalls

Acoustics & Sound Control

Acoustics & Sound Control





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

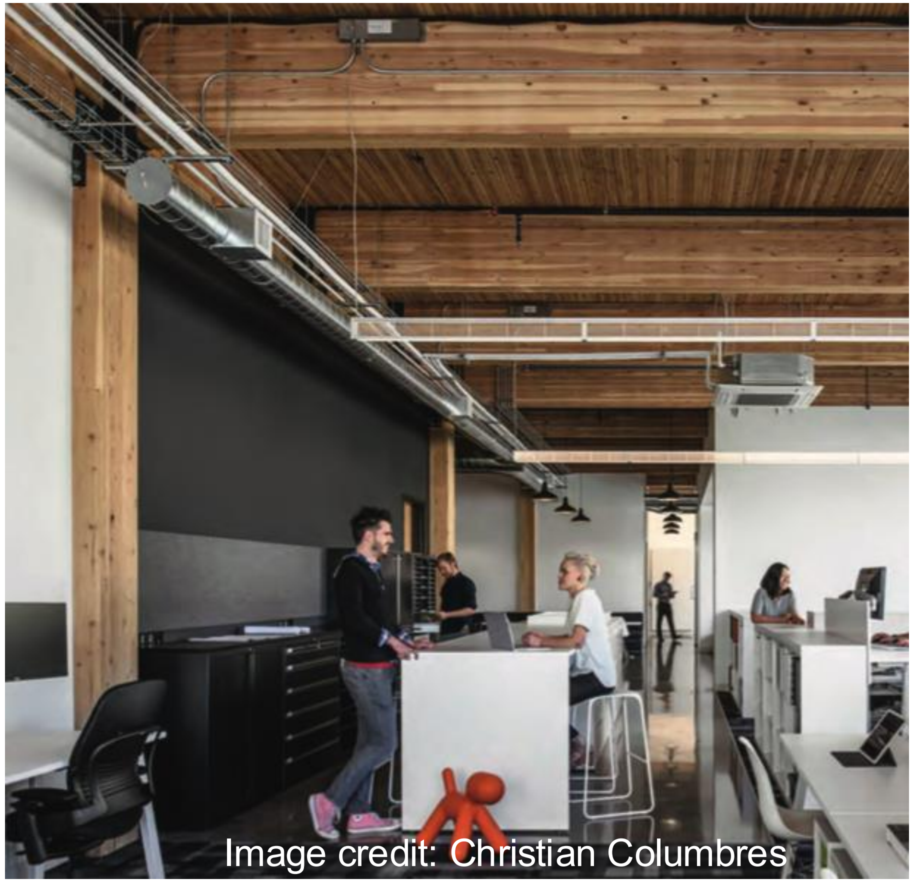
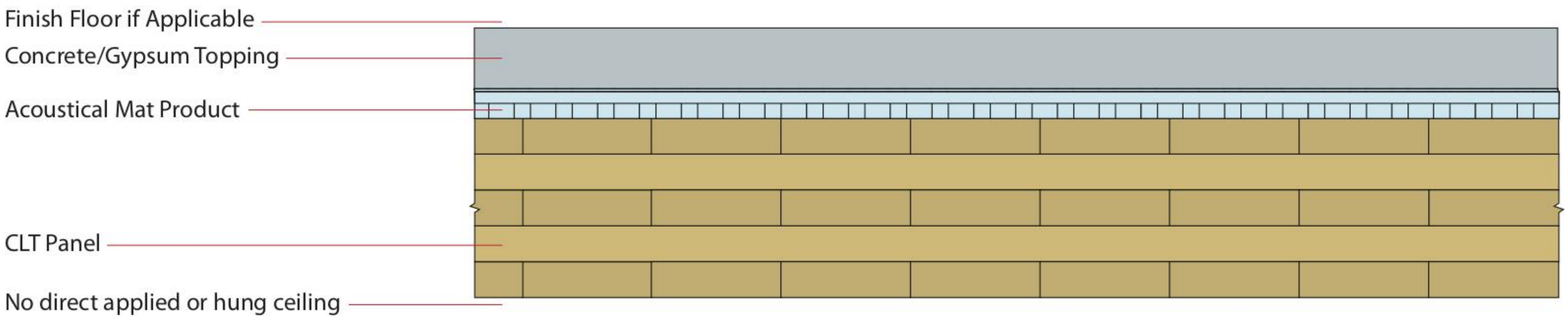


Image credit: Christian Columbres

Acoustics & Sound Control

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

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

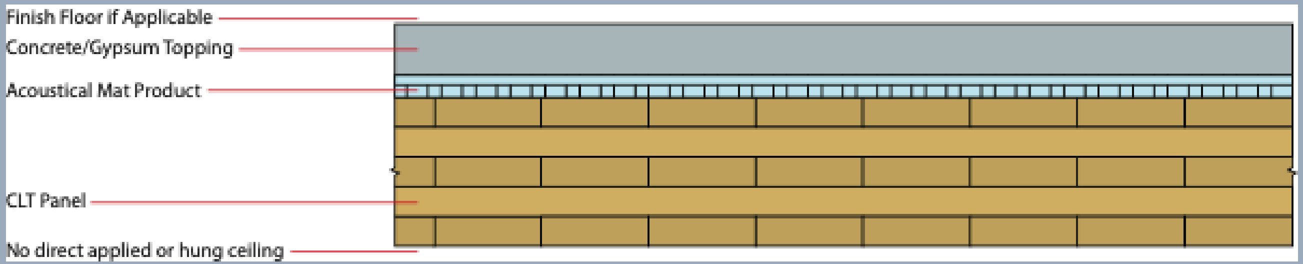


Acoustics & Sound Control

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

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

Questions? Ask us anything.

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

Funding provided in part by the Softwood Lumber Board