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Mass Timber Cost Optimization: How the Details Influence the Big Picture

Bruce Lindsey, Regional Director, WoodWorks – Wood Products Council

Photo: Texas Timber Frames

WHAT’S UNIQUE ABOUT MASS TIMBER?


IT'S (RELATIVELY) NEW
Photo: John Klein

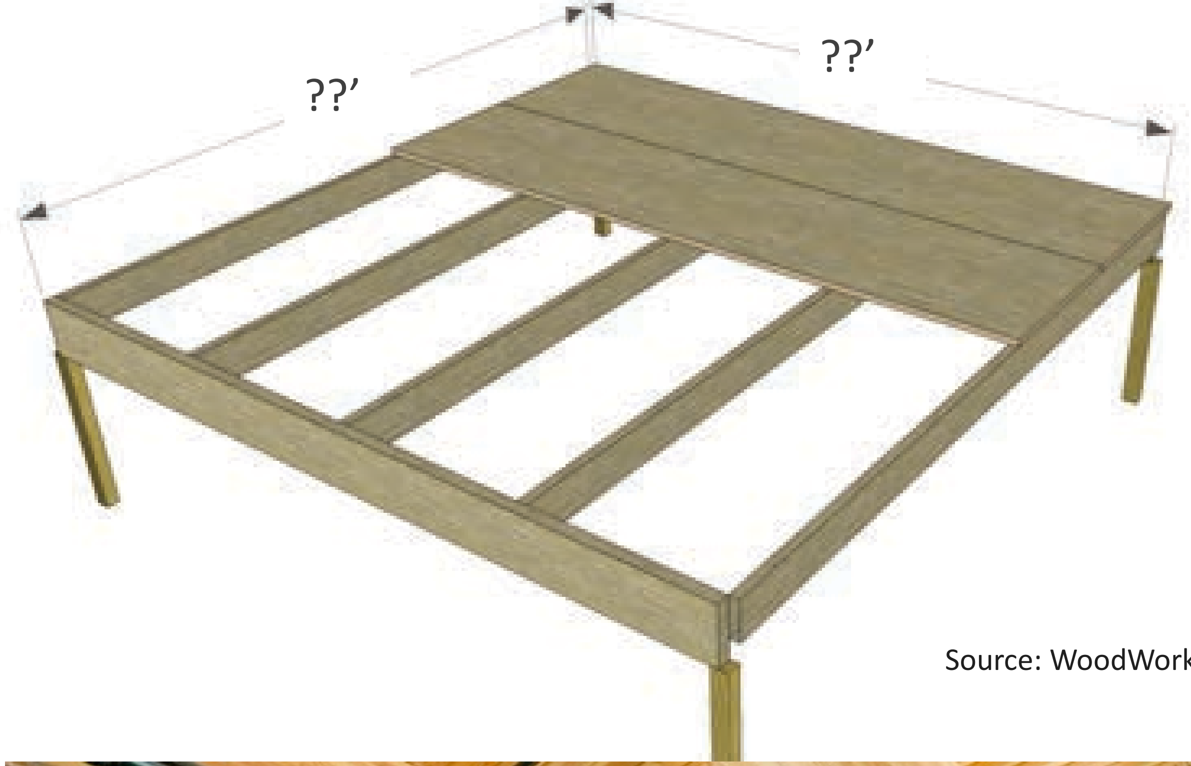


Photo: John Stamets


Photo: Alex Schreyer


NOT A COMMODITY PRODUCT
Photo: Marcus Kauffman

Photo: DR Johnson



Source: WoodWorks


Photo: Sauter Timber

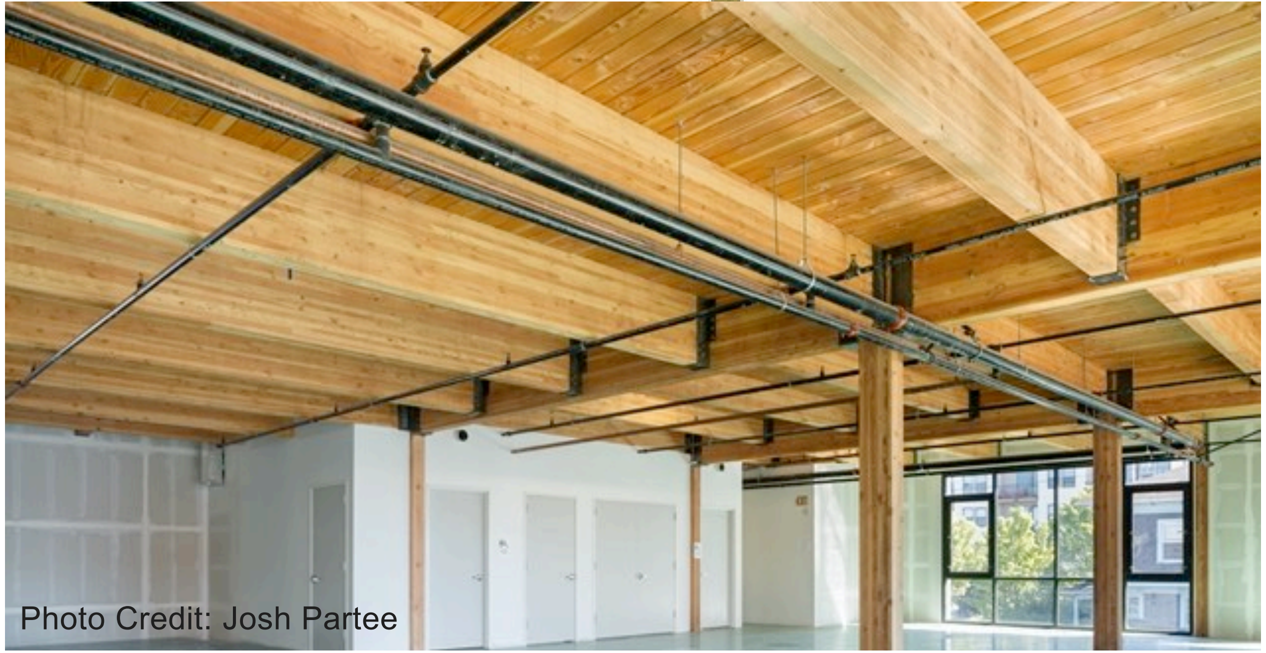


Photo Credit: Josh Partee

STRUCTURE = FINISH = FIRE PROTECTION

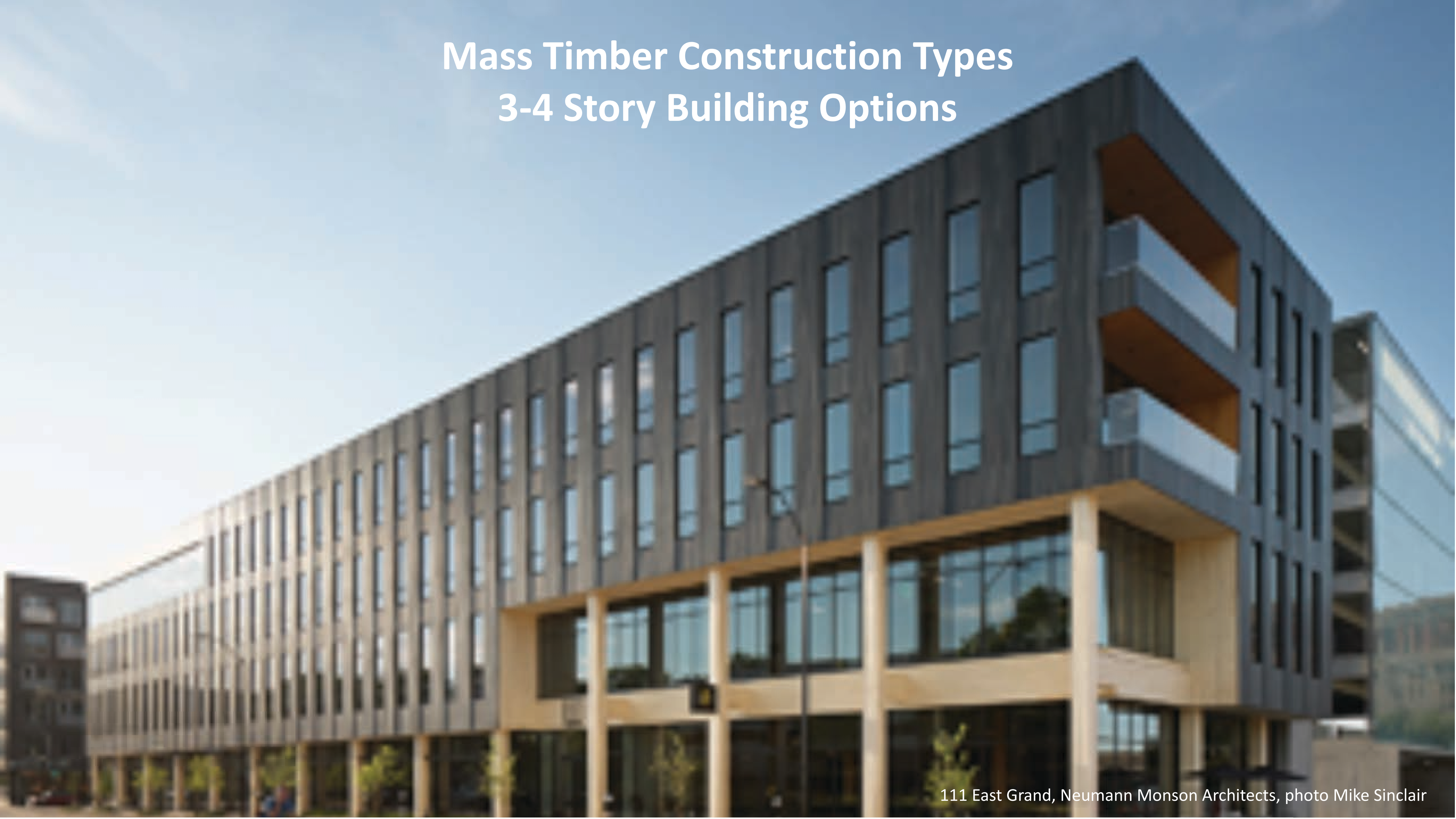
Photo: Structurlam

Photo: Ema Peter Photography

COST OPTIMIZATION MUST ACCOUNT FOR MORE THAN COST (OF TIMBER)

Image: WoodWorks

Mass Timber Construction Types
3-4 Story Building Options



111 East Grand, Neumann Monson Architects, photo Mike Sinclair

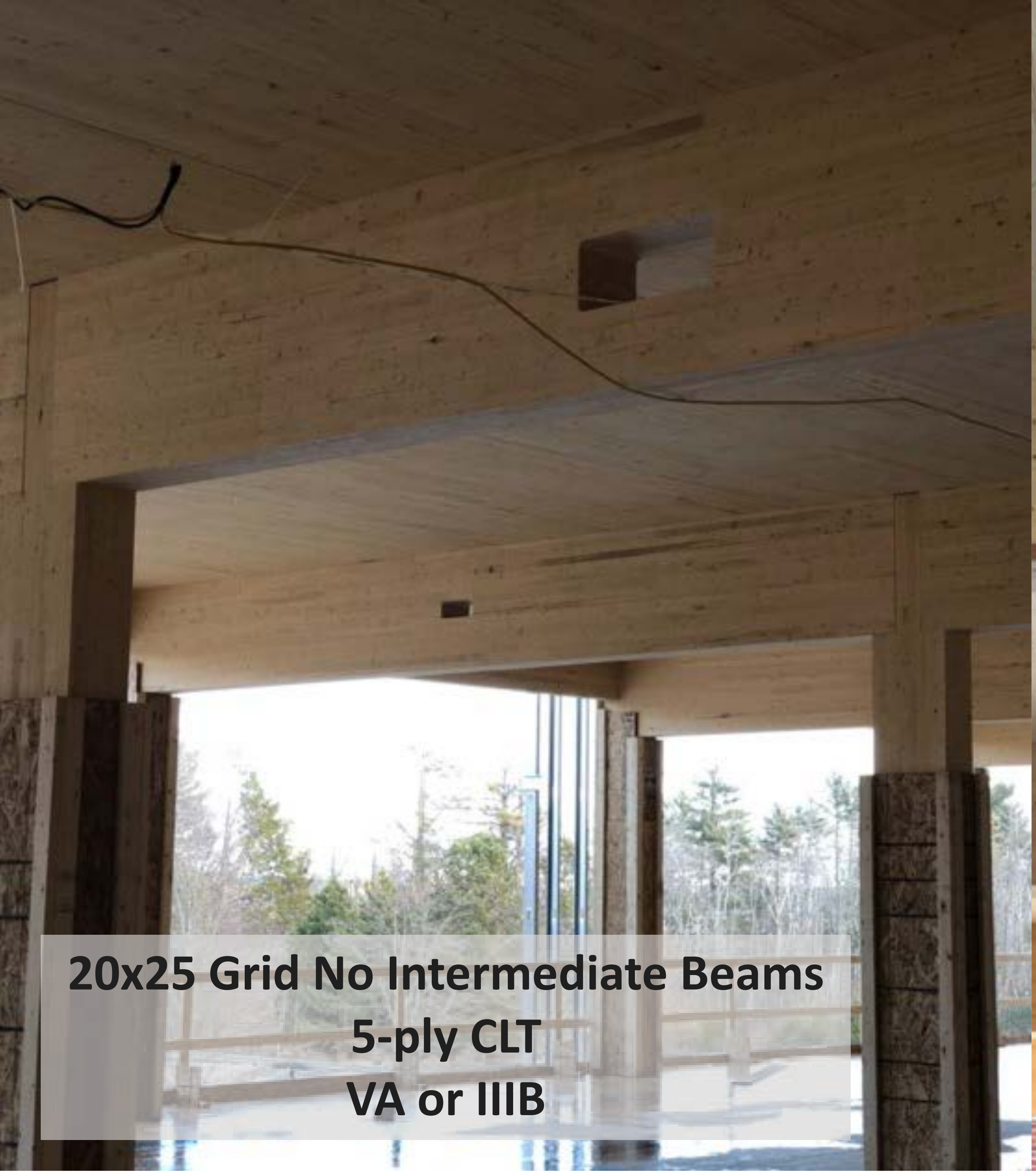
Mass Timber Construction Types

3-4 Story Building Options

	Type IIIB	Type VA
Allowable Building Height	4 stories / 75 ft	4 stories / 70 ft
Allowable Area	57k SF / 171k SF	54k SF / 162k SF
Interior FRR	0 HR	1 HR
Interior materials	Any material	Any material
Interior partitions	0 HR non-brng	0 HR non-brng
Exterior Bearing Walls	FRTW or Non-com, 2 HR	Any material, 1 HR
Concealed Spaces	Permitted	Permitted

3-ply Floors
No CLT ext. walls
Connections/Penetrations not rated

5-ply Floors
CLT ext. walls
Connections/Penetrations rated



20x25 Grid No Intermediate Beams
5-ply CLT
VA or IIIB

20x20 Grid w/1 Intermediate Beam per Bay
3-ply CLT
IIIB

Photos: WoodWorks

Photos: WoodWorks

MT Fire Resistance Ratings (FRR)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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
- Construction type considerations
- Free download at woodworks.org

Credit: WoodWorks

MT Fire Resistance Ratings (FRR)

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 1.5E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	3	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypsum over Maxxon acoustical mat	Reduced 50% 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 gypsum over Maxxon acoustical mat or proprietary sound board	Reduced 50% 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	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Gyp-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" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1950 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 59% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Unreduced 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced 101% Moment Capacity	2.5	1 (Test 7)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	SmartLam	SL-V4	None	Half-Lap	nominal 1/2" plywood with 8d nails	Loaded, See Manufacturer	2	12 (Test 4)	Western Fire Center 10/26/2016
5-ply CLT (175mm 6.875")	SmartLam	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails	Loaded, See Manufacturer	2	12 (Test 5)	Western Fire Center 10/28/2016
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, See Manufacturer	1	14	SwRI [illegible]

Credit: WoodWorks

New Tall Mass Timber Types

Credit: Susan Jones, atelierjones

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Tall Wood Buildings in the 2021 IBC
Up to 18 Stories of Mass Timber

Scott Breneman, PhD, SE, WoodWorks – Wood Products Council • Matt Timmers, SE, John A. Martin & Associates • Dennis Richardson, PE, CBO, CASp, American Wood Council

In January 2019, the International Code Council (ICC) approved a set of proposals to allow tall wood buildings as part of the 2021 International Building Code (IBC). Based on these proposals, the 2021 IBC will include three new construction types—Type IV-A, IV-B and IV-C—allowing the use of mass timber or noncombustible materials. These new types are based on the previous Heavy Timber construction type (renamed Type IV-HT) but with additional fire-resistance ratings and levels of required noncombustible protection. The code will include provisions for up to 18 stories of Type IV-A construction for Business and Residential Occupancies.

Based on information first published in the Structural Engineers Association of California (SEAOC) 2018 Conference Proceedings, this paper summarizes the background to these proposals, technical research that supported their adoption, and resulting changes to the IBC and product-specific standards.

Background: ICC Tall Wood Building Ad Hoc Committee

Over the past 10 years, there has been a growing interest in tall buildings constructed from mass timber materials (Breneman 2013, Timmers 2015). Around the world there

Via Cenni	Milan, Italy	9	2013

WoodWorks Tall Wood Design Resource

http://www.woodworks.org/wp-content/uploads/wood_solution_paper-TALL-WOOD.pdf

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TECHNICAL BRIEF

Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures

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

Changes to the 2021 International Building Code (IBC) have created opportunities for wood buildings that are much larger and taller than prescriptively allowed in past versions of the code. Occupant safety, and the need to ensure fire performance in particular, was a fundamental consideration as the changes were developed and approved. The result is three new construction types—Type IV-A, IV-B and IV-C—which are based on the previous Heavy Timber construction type (renamed Type IV-HT), but with additional fire protection requirements.

One of the main ways to demonstrate that a building will meet the required level of passive fire protection, regardless of structural materials, is through hourly fire-resistance ratings (FRRs) of its elements and assemblies. The IBC defines an FRR as *the period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests, or the methods based on tests, prescribed in Section 703.*

FRRs for the new construction types are similar to those required for Type I construction, which is primarily steel and concrete.[1] (See Table 1.) They are found in IBC Table 601, which includes FRR requirements for all construction types and building elements; however, other code sections should be checked for overriding provisions (e.g., occupancy separation, shaft enclosures, etc.) that may alter the requirement.

Ascent | Milwaukee, WI
Architect: Korb + Associates Architects
Structural Engineer: Thornton Tomasetti

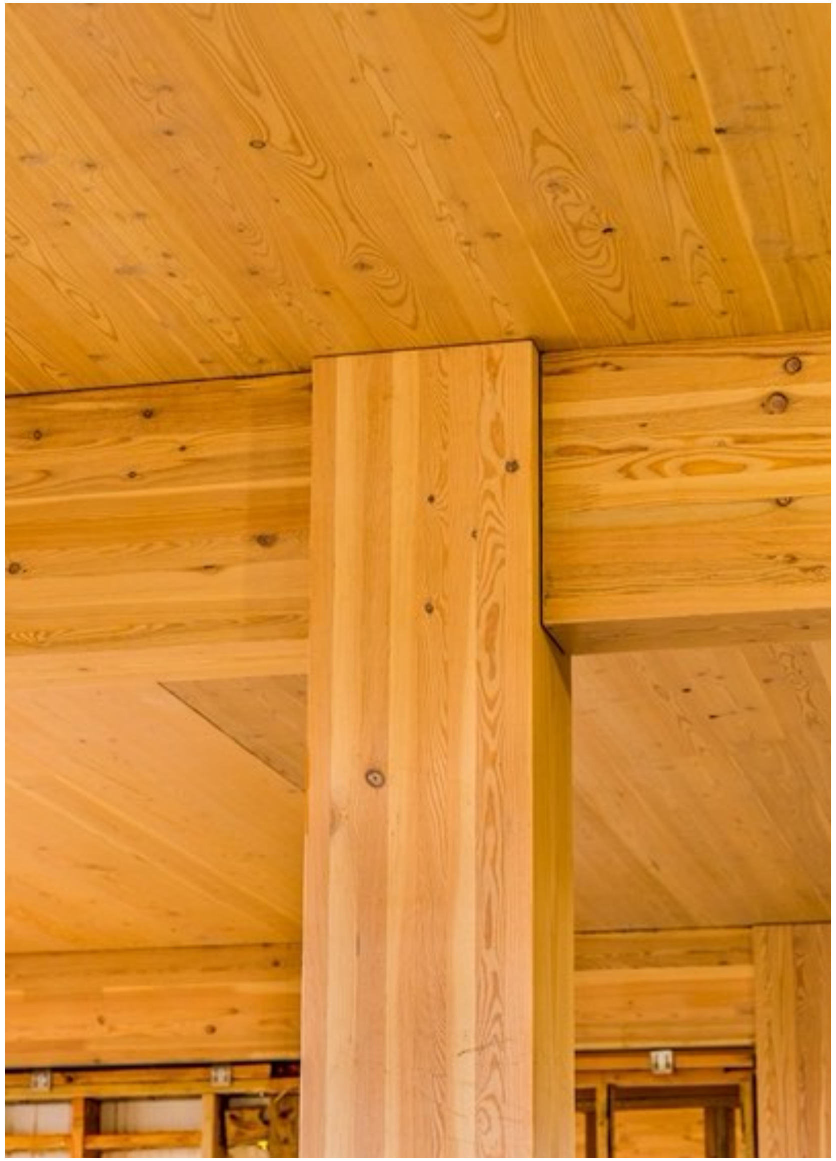
Image: Korb + Associates Architects

TABLE 1:
FRR Requirements (Hours) for Tall Mass Timber Construction Types and Existing Type I

Building Element	I-A *Unlimited stories,*	IV-A *Max. 18 stories,*	I-B *Max. 12 stories,*	IV-B *Max. 12 stories,*	IV-C *Max. 9 stories,*
Interior Bearing Walls	3	3	2	2	2
Roof Construction	1.5	1.5	1	1	1

Tall Timber Fire-Resistance Design

Mass Timber: Structure Often is Finish



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

But by Itself, Not Adequate for Acoustics

Mass Timber Acoustics

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[7]	6" with 1/2" plywood	34	33

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

Mass Timber Acoustics

One of the main reasons is “mass”
Recall the three ways to increase acoustical performance:

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

Mass Timber Acoustics

<u>Concrete Slab:</u>
6" Thick
80 PSF
STC 53

<u>CLT Slab:</u>
6-7/8" Thick
18 PSF
STC 41

Mass Timber Acoustics

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

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

Mass Timber Acoustics

Solutions Paper


WoodWorks
WOOD PRODUCTS COUNCIL

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


Example Mass Timber Wall Assembly, STC 58

Mass Timber Assembly Options: Walls

Acoustical Differences between Mass Timber Panel Options

Improving Performance by Minimizing Flanking

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

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

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

WoodWorks

CLT Panel	Concrete/Gypsum Topping	Acoustical Mat Product Between CLT and Topping	Finish Floor	STC	IIC	Source
CLT 5-ply (6.875")	1-1/2" Gyp-Crete®	Maxxon Acousti-Mat® 3/4	None	47 ASTC	47 AIIC	1
			LVT	-	49 AIIC	
			Carpet + Pad	-	75 AIIC	
			LVT on Acousti-Top®	-	52 AIIC	
			Eng Wood on Acousti-Top®	-	51 AIIC	
		Maxxon Acousti-Mat® ¾ Premium	None	49 ASTC	45 AIIC	
			LVT	-	47 AIIC	
			LVT on Acousti-Top®	-	49 AIIC	
	1-1/2" Levelrock® Brand 2500	USG SAM N25 Ultra	None	45	39	15
			LVT	48	47	16
			LVT Plus	48	49	58
			Eng Wood	47	47	59
			Carpet + Pad	45	67	60
			Ceramic Tile	50	46	61
		Soprema® Insonomat	None	45	42	15
			LVT	48	44	16
			LVT Plus	48	47	58
			Eng Wood	47	45	59
			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]
			Eng Wood	47	49	59

A Few Notes About the Inventory

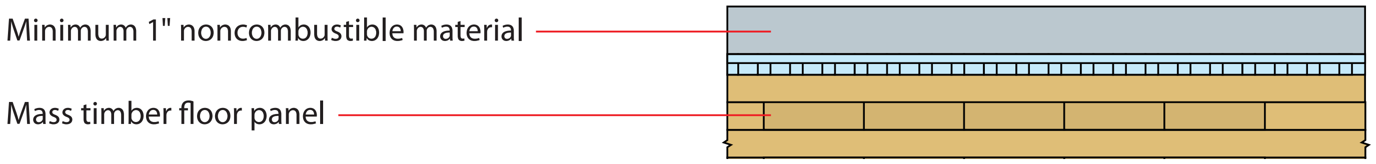
http://bit.ly/mass-timber-assemblies

Mass Timber Assemblies

Effect of Timber Thickness

LVT on 2” Concrete

Without Dropped Ceiling

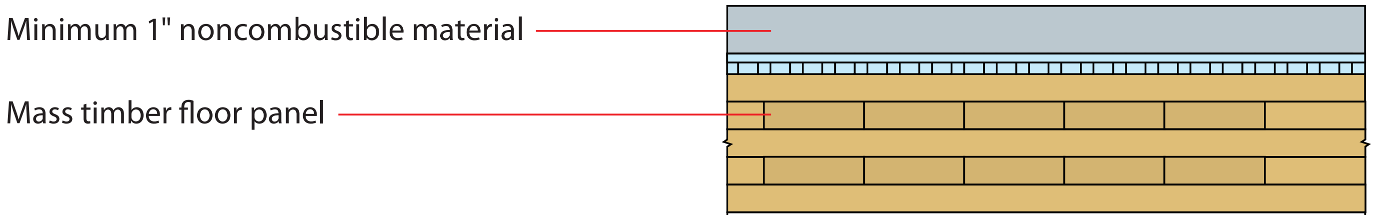


3-ply CLT

STC 53

IIC 48

Without Dropped Ceiling



5-ply CLT

STC 53

IIC 52

Mass Timber Assemblies

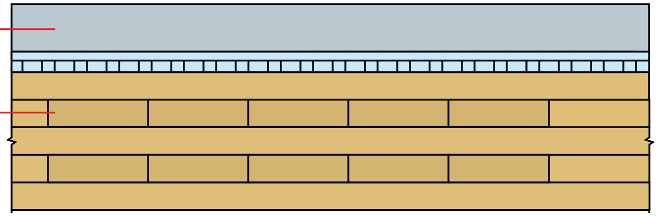
LVT on 1” Gypsum

Effect of Gypsum Ceiling

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel



STC 51

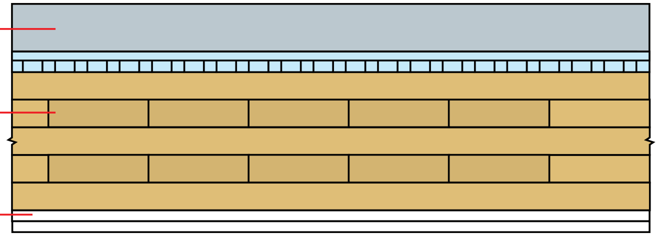
IIC 43

Without Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel

Two layers 5/8" Type X gypsum*



**Applicable to most locations; limited exposed mass timber permitted in IV-B*

STC 52

IIC 48

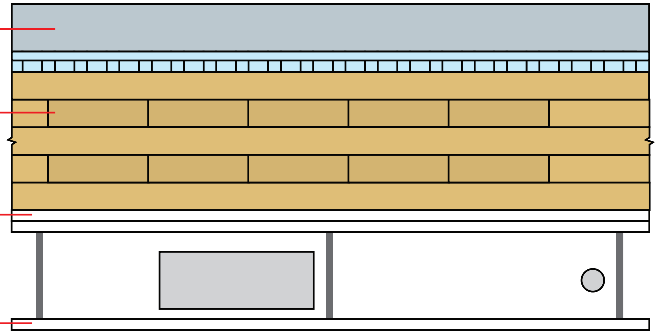
With Dropped Ceiling

Minimum 1" noncombustible material

Mass timber floor panel

Two layers 5/8" Type X gypsum

Dropped ceiling



STC 63

IIC 63

MASS TIMBER WHY'S

- Innovation and Aesthetic Appeal
- Speed of Construction
- Construction Site Constraints – Urban Infill
- Labor Shortages
- Structural Performance - Lightweight
- Business Case for Healthy Buildings

Tremblay Laliberté Building, Structure Fusion, Photo Stephane Groleau

KNOW YOUR WHY

Potential Benefits	Project Goal ✓	Value Add ✓
Fast construction		
Aesthetic Value (Leasing velocity/ premiums) Healthy Building / Biophilia		
Lightweight structure		
Labor shortage solution • small crews • entry level workers		
Just-in-time delivery (ideal for dense urban sites)		
Environmentally friendly (low carbon footprint)		
Healthy forests/ wildfire resiliency & support rural economies		

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

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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.

First Tech Federal Credit Union – Hillsboro, OR
ARCHITECT: Hacker
ENGINEERS: Kramer Gehlen & Associates, Equilibrium Consulting
CONTRACTOR: Swinerton

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

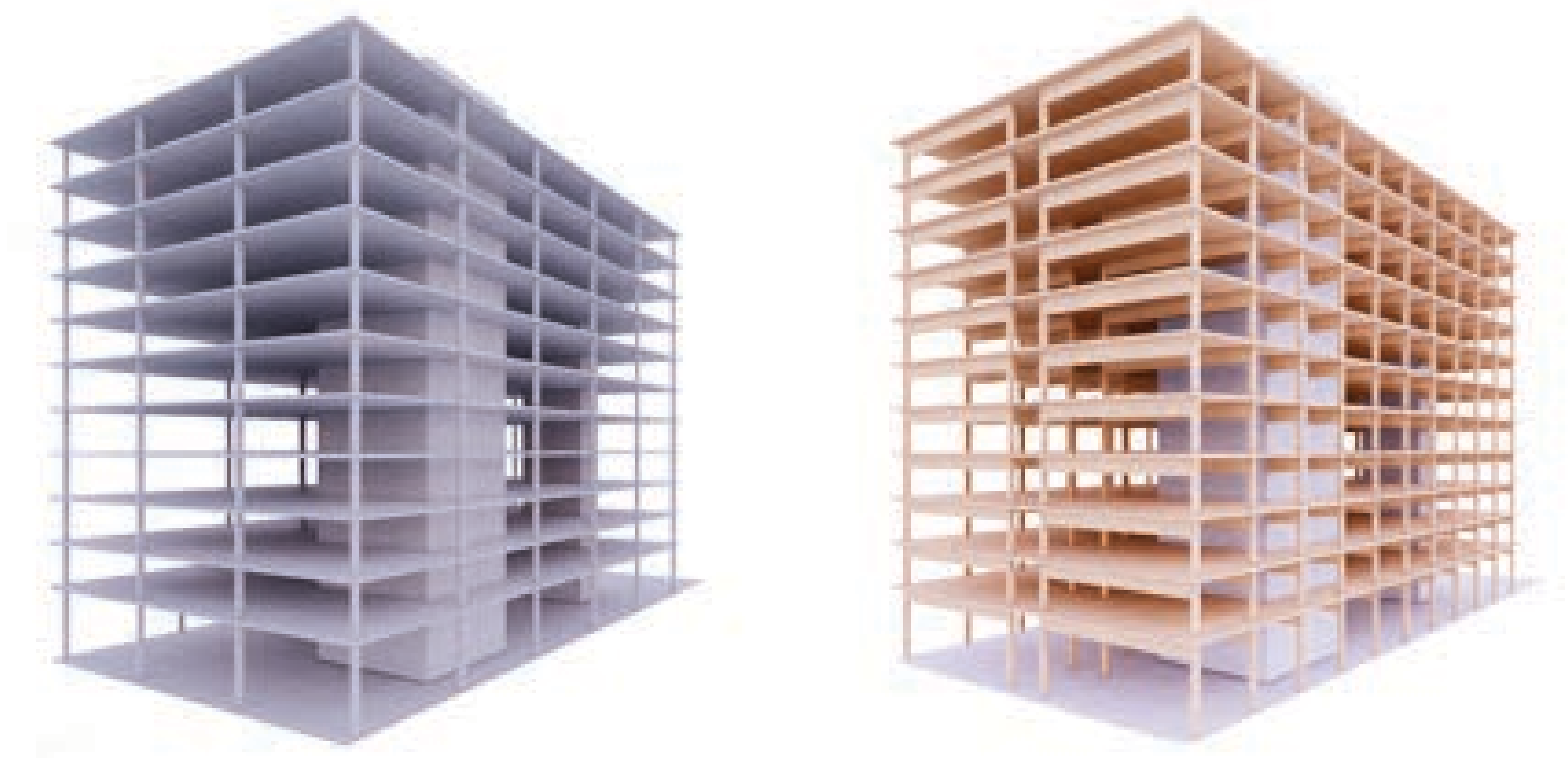

Photo Credit: Swinerton Builders


Photo Credit: Alexander Schreyer

Is Mass Timber Cost Competitive?


Photo Credit: Structurecraft Builders


Photo Credit: Structurlam



Source: GBD Architects

Risk: Cost Analysis of Structure Only

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[1]

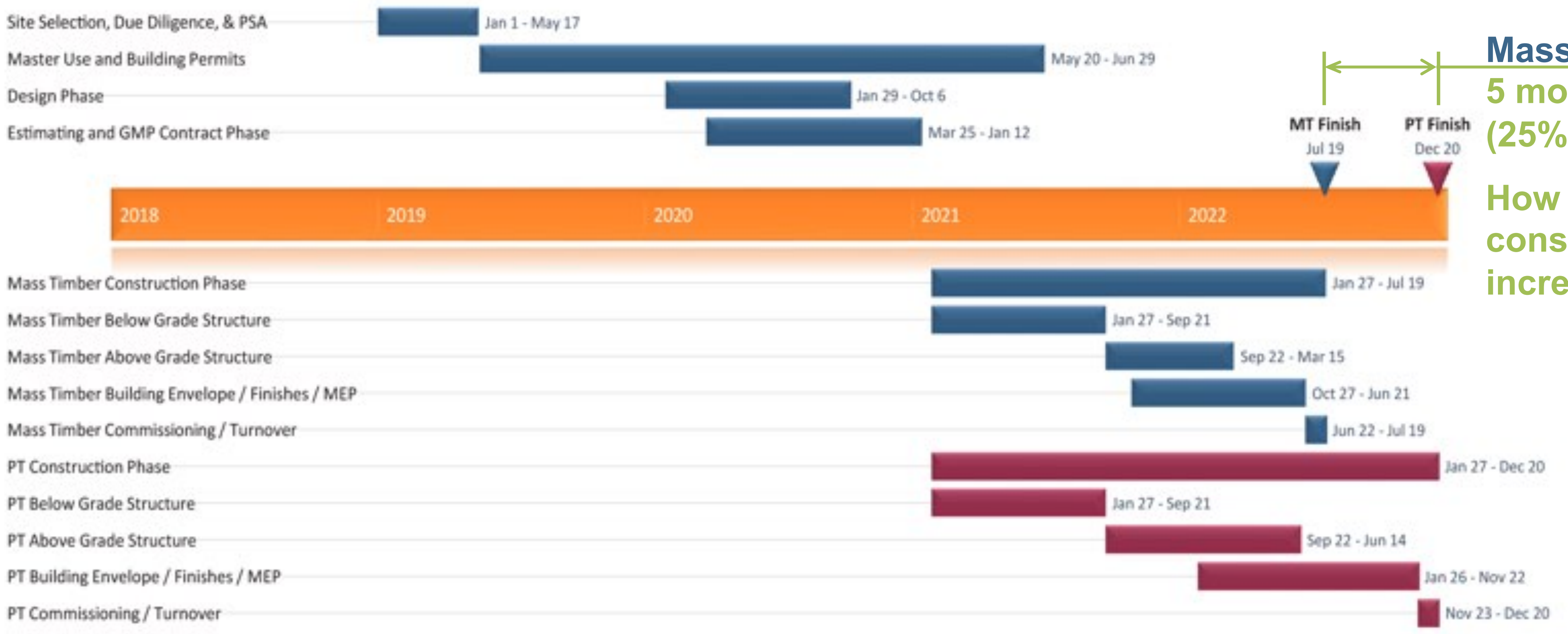
Download Case Study:

http://www.fastepp.com/wp-content/uploads/181109-Seattle-Mass-Timber-Tower-Book.pdf

Seattle Mass Timber Tower

Fast Construction

Construction Schedule:



Mass Timber

5 months (25%) faster

How can faster construction increase your ROI?

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

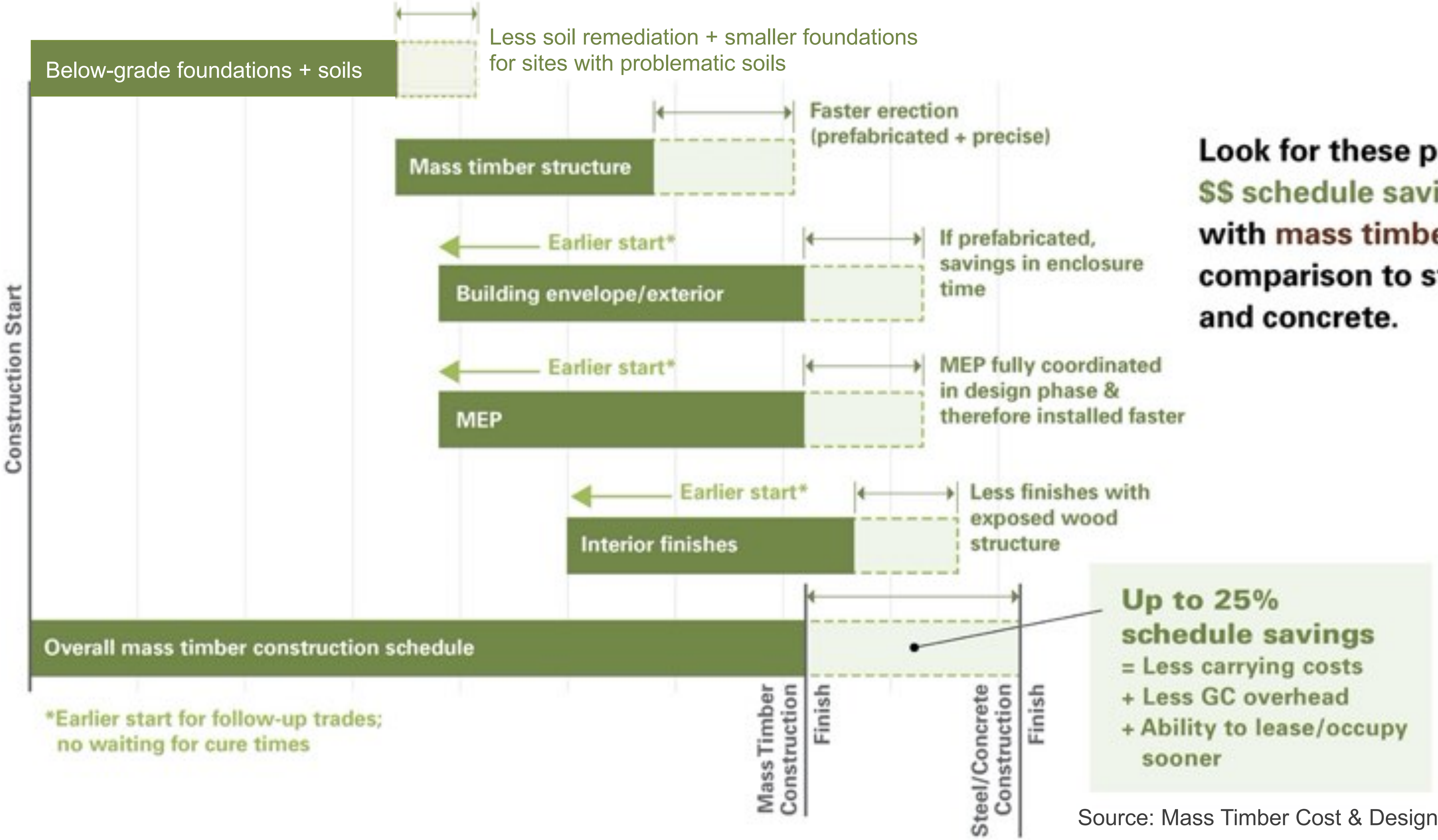
Seattle Mass Timber Tower

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

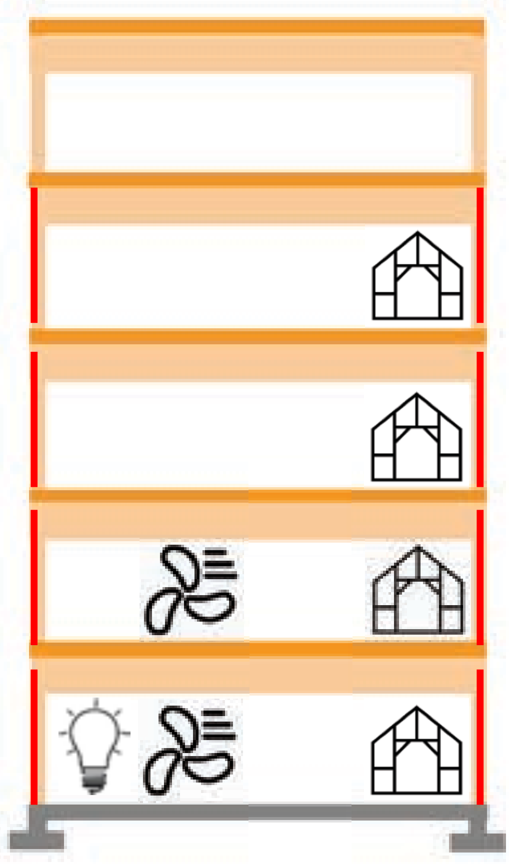


Look for these potential $$ schedule savings with mass timber in comparison to steel and concrete.

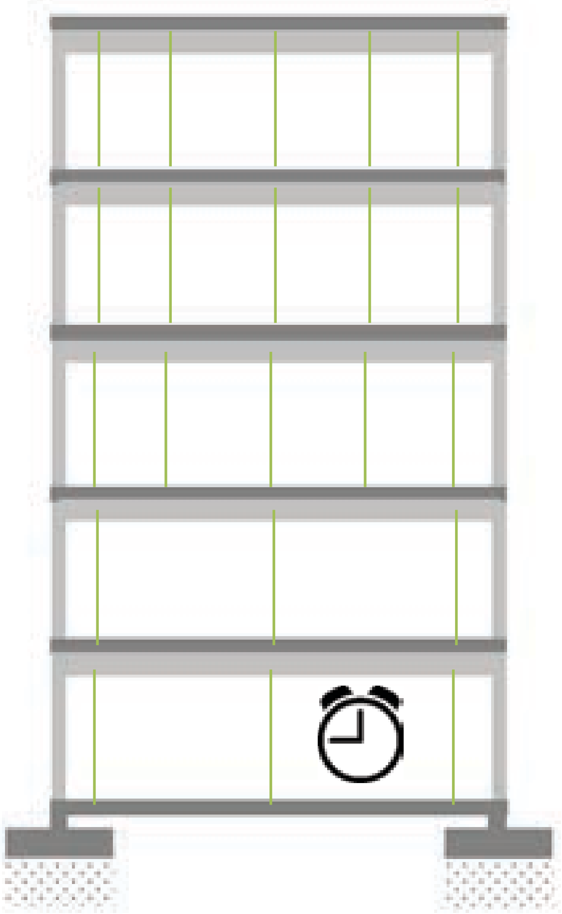
Source: Mass Timber Cost & Design Optimization, WoodWorks[2]

Schedule Savings for Rough-In Trades

Fast Construction



NO curing
(mass timber)



Curing & maze of shores (concrete)

PREFABRICATION & COORDINATION

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

Keys to Mass Timber Success:

Know Your <u>WHY</u>
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?

This concludes The American Institute of Architects Continuing Education Systems Course

Bruce Lindsey

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