Designing and Building with Mass Timber: Design, Planning and Performance

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June 13, 2022

The Canyons, photo Marcus Kauffman, Oregon Department of Forestry

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

AIA Approved Continuing Education

Course Description

How can architects, engineers and contractors collaborate to meet the growing demand for mass timber buildings? While developers across the country are pursuing mass timber projects, knowledge among AEC professionals is not yet widespread. Firms have varying degrees of familiarity with both the products and practicalities of designing, sourcing, and building a modern mass timber structure, and early adopters continue to play a significant role in educating the rest of the community. This presentation seeks to build on this openness and environment of shared learning, providing an overview of mass timber products, planning, design and implementation to maximize the benefits these buildings can deliver. We'll also discuss why some mass timber projects face resistance, and how to overcome misconceptions to achieve success. Topics will also include preconstruction coordination and interactions between the manufacturer and design/construction teams, case-based approaches to costing and scheduling, project delivery methods, how to achieve the highest level of efficiency for costs, schedule, and performance, and additional education and training opportunities.

Learning Objectives

1. Identify project planning, coordination and design topics that translate into successful buildings for both the design and construction team.
2. Explore best practices for interaction between manufacturer, design team and preconstruction manager that can lead to cost efficiency and safety on site.
3. Discuss potential construction schedule savings and construction fire safety practices realized through the use of prefabricated mass timber elements.
4. Discuss benefits of using mass timber products, including structural versatility, prefabrication, lighter carbon footprint, and reduced labor costs.

PRESENTATION OUTLINE

MASS TIMBER DESIGN

Products
Structural Solution & Connections
Projects and Code Considerations

MASS TIMBER CONSTRUCTION

Planning for Construction
Performing Construction
Workforce Development

MASS TIMBER OVERVIEW

Photo: PCL Construction

OVERVIEW | TIMBER METHODOLOGIES

Light Wood-Frame
Photo: WoodWorks

Heavy Timber
Photo: Benjamin Benschneider

Mass Timber
Photo: John Stamets

MASS TIMBER PRODUCTS

Glue Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo: Freres Lumber

Photo: StructureCraft

Photo: LendLease

Photo: LEVER Architecture

Dowel-Laminated Timber (DLT)

Photo: StructureCraft

Nail-Laminated Timber (NLT)

Photo: Think Wood

Glue-Laminated Timber (GLT)

Photo: StructureCraft

Photo: StructureCraft

Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

Nail-Laminated Timber (NLT)

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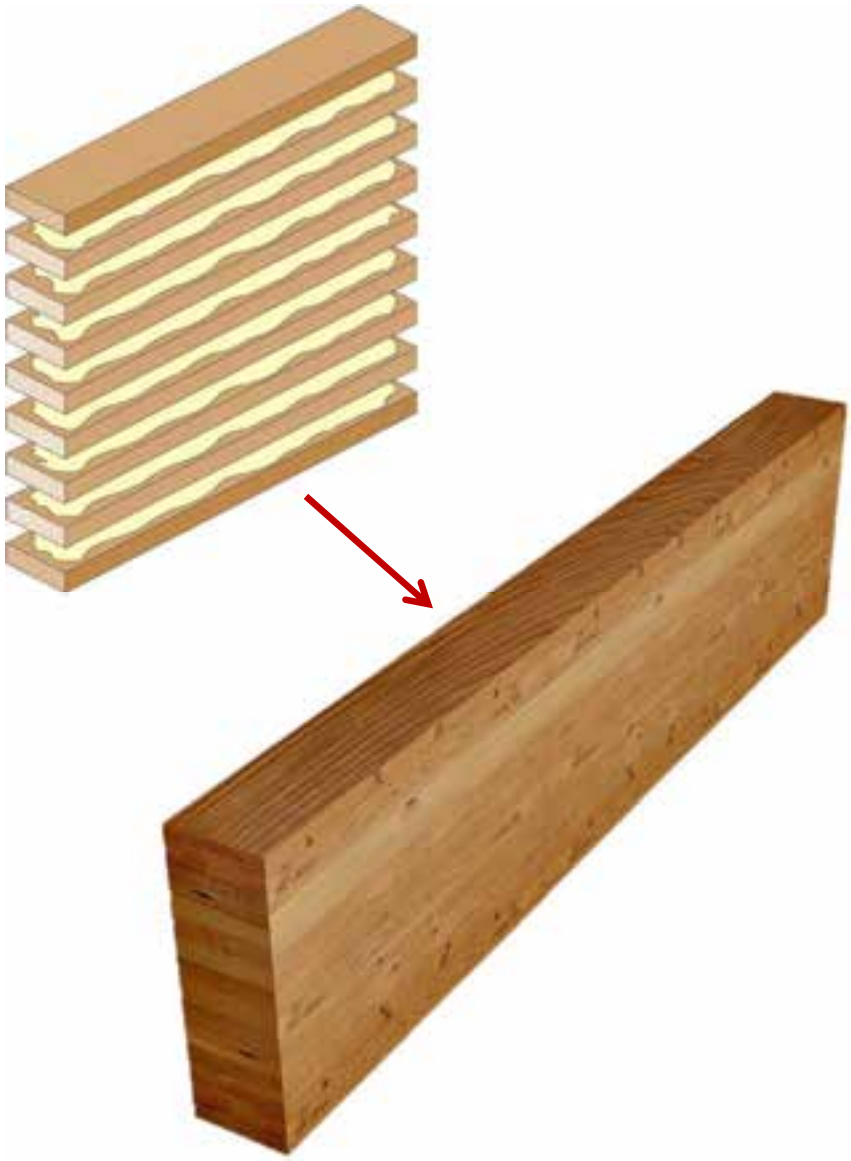
Photo: StructureCraft

Glue Laminated Timber (GLT)

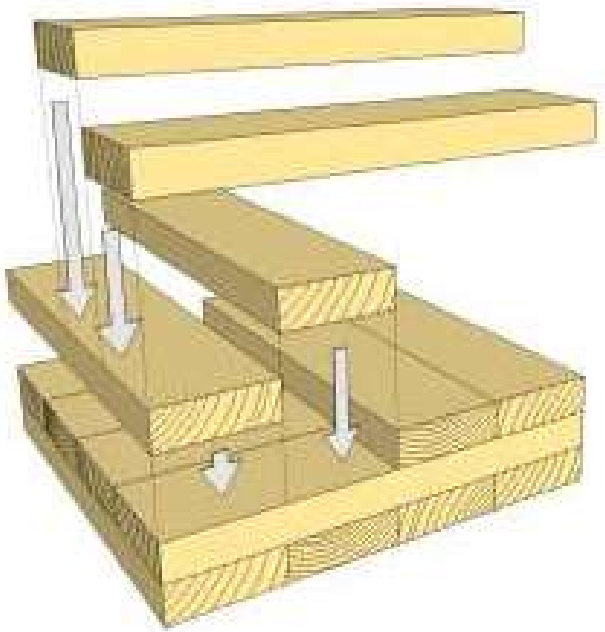
Photo: Manasc Isaac Architects/Fast + Epp

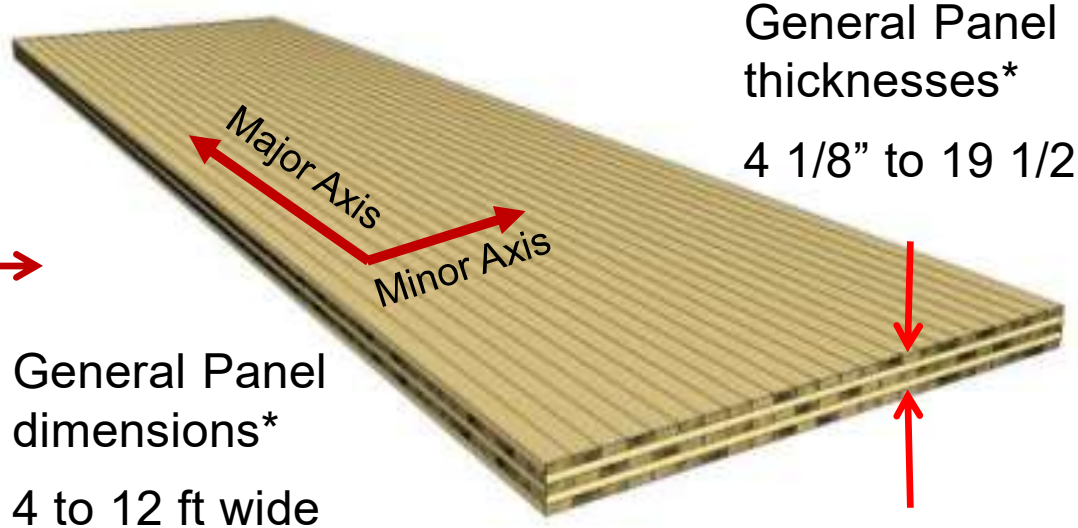


Cross-Laminated Timber (CLT)

Cross-Laminated Timber (CLT)

With solid sawn laminations





General Panel thicknesses*

4 1/8” to 19 1/2”

General Panel dimensions*

4 to 12 ft wide

24 to 64 ft long

*Consult with manufacturers for available panel sizes

Cross-Laminated Timber (CLT)

With SCL laminations

Photos: Freres Lumber

Other Mass Timber Product Options

Laminated Veneer Lumber
LVL

Parallel Strand Lumber
PSL

Laminated Strand Lumber
LSL

Timber-Concrete Composite
TCC

Decking

Photos: StructureCraft

Photo: Ema Peter

STRUCTURAL SOLUTIONS | POST, BEAM + PLATE

Photo: Seagate Structures

Photo: Lendlease

STRUCTURAL SOLUTIONS | HYBRID LIGHT-FRAME + MASS TIMBER

STRUCTURAL SOLUTIONS | HYBRID STEEL + MASS TIMBER

Photo: LEVER Architecture

STRUCTURAL SOLUTIONS | HYBRID CONCRETE + MASS TIMBER

OVERVIEW | CONNECTIONS

Concealed Connectors

Photo Marcus Kauffman

Self Tapping Screws

Photo Simpson Strong Tie

Beam to Column

Photo: StructureCraft

Photo: Structurlam

Column to Foundation

Photo: Alex Schreyer

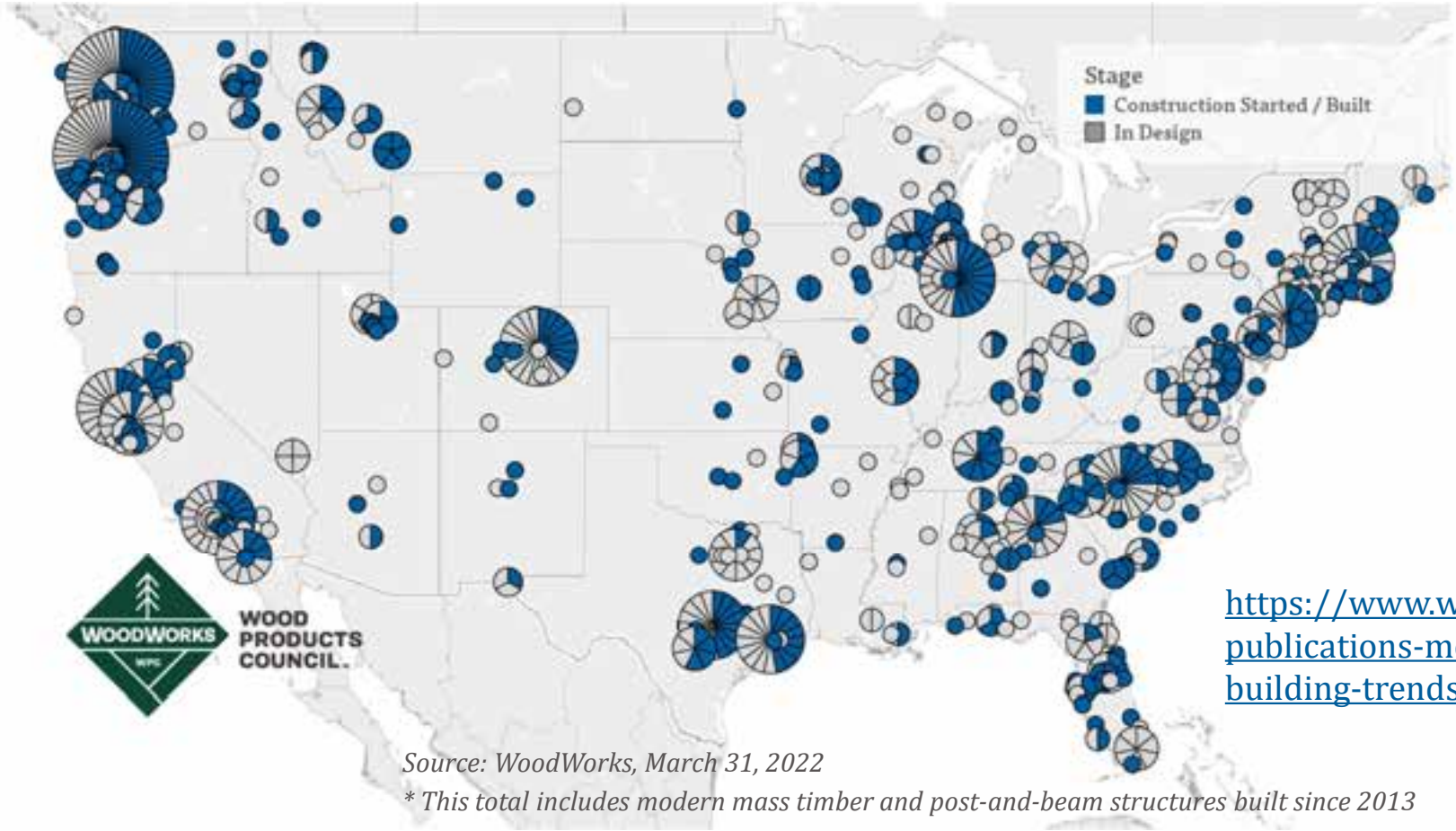
Panel to Panel & Supports

Photo: Charles Judd

Photo: Marcus Kauffman

Current State of Mass Timber Projects

As of March 2022, in the US, **1,384** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



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

Source: WoodWorks, March 31, 2022

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

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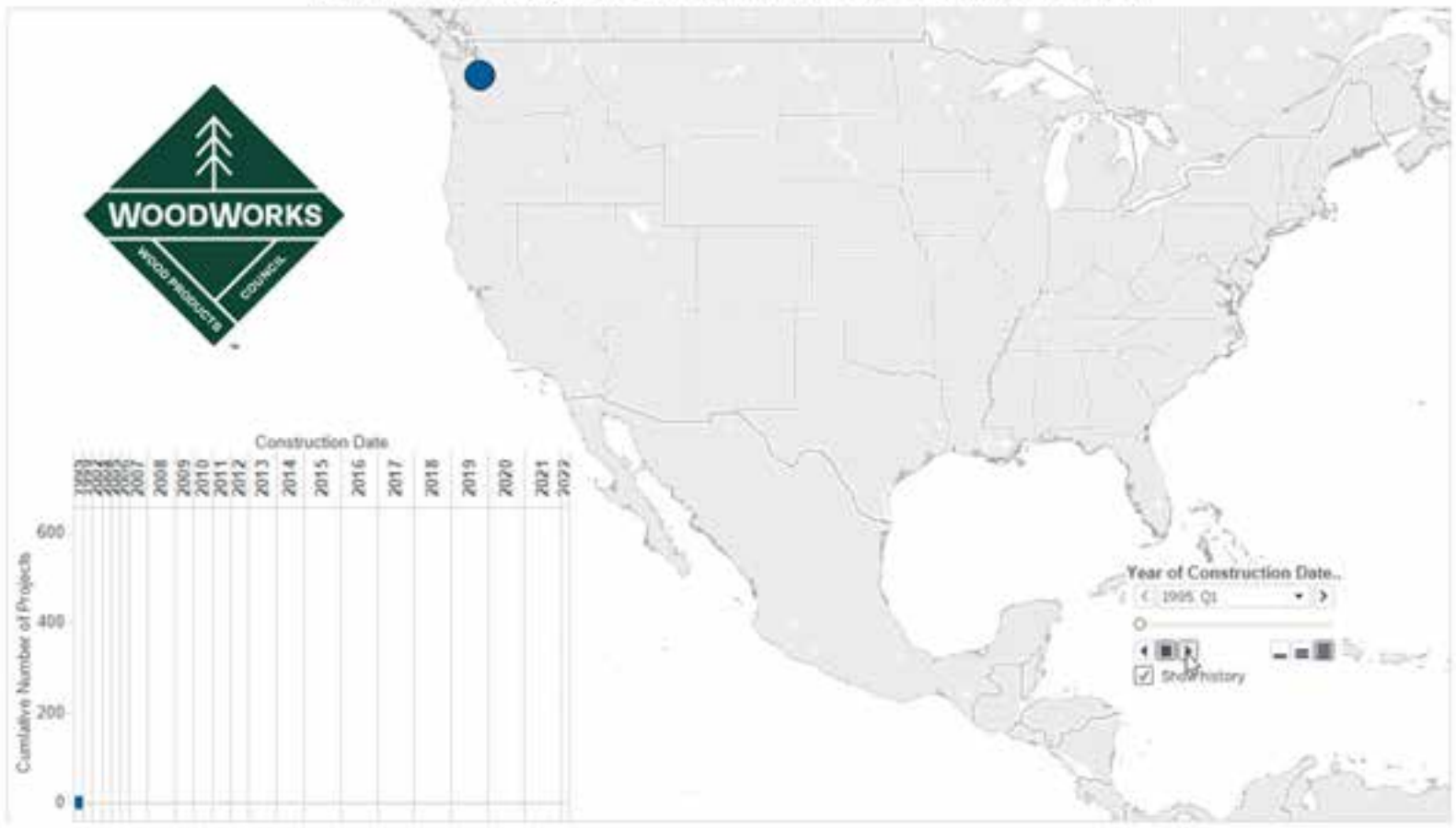


Photos: Michael Elkan | Naturally Wood | UBC


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

INTRO, CLEVELAND

Type IV-B

Variance to expose ~50% ceilings

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

9 Stories | 115 ft

8 Timber Over 1 Podium

ASCENT, MILWAUKEE

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

493,000 SF

259 APARTMENTS, MIXED-USE

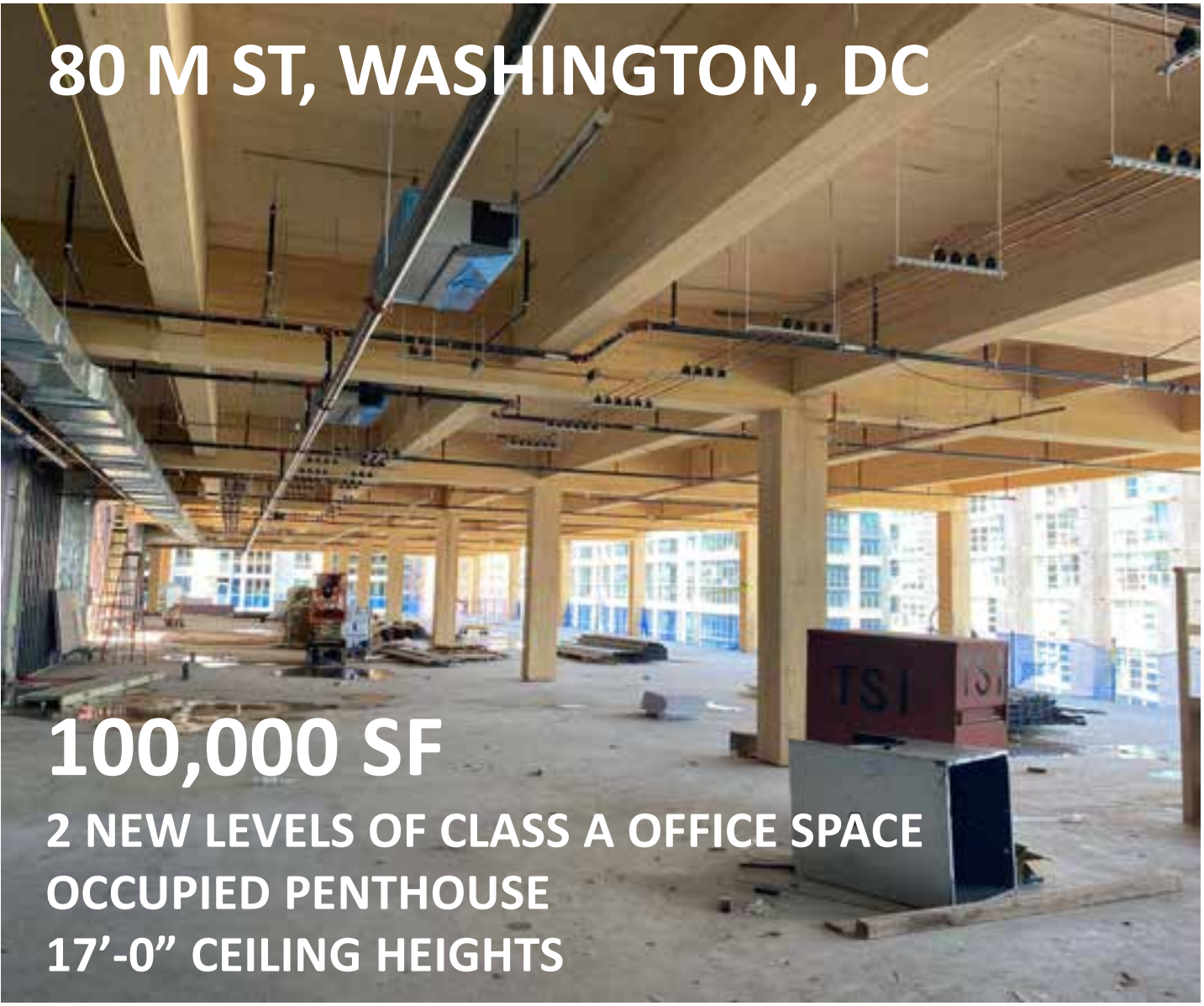
ASCENT, MILWAUKEE

Tallest Mass Timber Building in the World

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


80 M ST, WASHINGTON, DC
3 STORY VERTICAL ADDITION
7 STORY EXISTING BUILDING
Photo: WoodWorks | Architect: Hickok Cole

80 M ST, WASHINGTON, DC



100,000 SF

2 NEW LEVELS OF CLASS A OFFICE SPACE
OCCUPIED PENTHOUSE
17’-0” CEILING HEIGHTS

APEX PLAZA
CHARLOTTESVILLE, VA

187,000 SF

Photo: WoodWorks | Architect: William McDonough + Partners


APEX PLAZA
CHARLOTTESVILLE, VA
8 STORIES
6 TIMBER OVER 2 PODIUM, 100 FT
Monticello Av
Gleason St
PRIMARILY OFFICE SPACE
Photo: William McDonough + Partners | Architect: William McDonough + Partners

11 E LENOX, BOSTON, MA

7 STORIES

70 FT

Passive House

Multi-Family

Credit: H + O Structural Engineering

Credit: Monte French Design Studio

11 E LENOX, BOSTON, MA

Credit: H + O Structural Engineering

Photos: StructureCraft

Photo: Hartshorne Plunkard Architectur

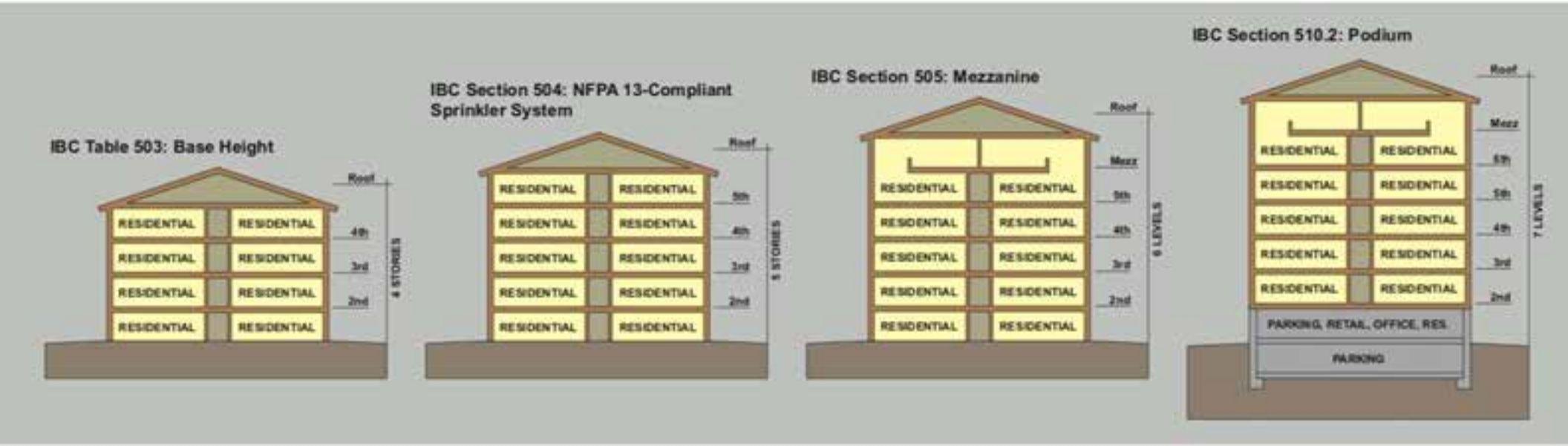
MASS TIMBER PROJECT CONSIDERATIONS

Photo: Hacker Architects

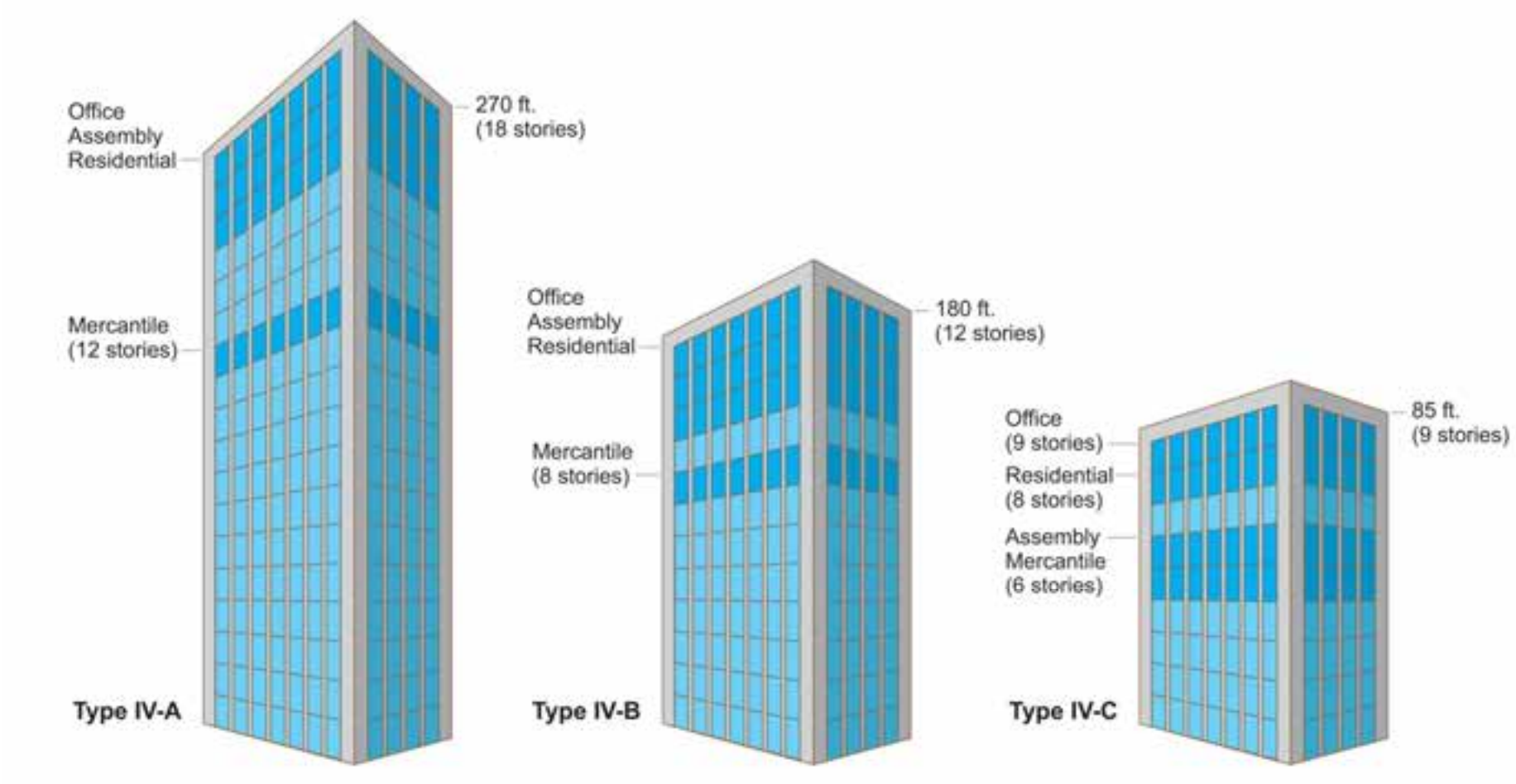
MASS TIMBER IN THE CODE

Photo: Freres Lumber

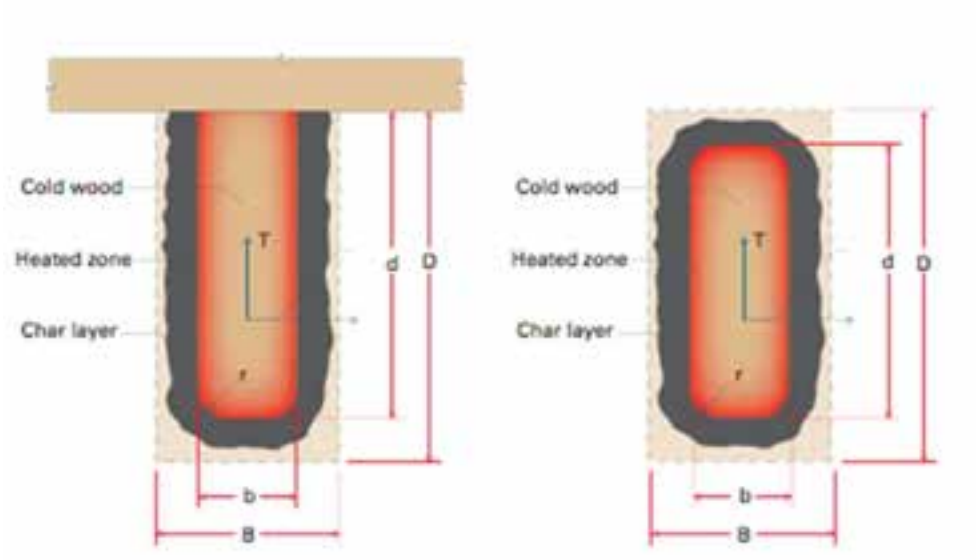
Mass Timber in Low- to Mid-Rise: 1-6 Stories in Construction Types III, IV or V



Tall Mass Timber: Up to 18 Stories in Construction Types IV-A, IV-B or IV-C



Mass Timber's Fire-Resistive Performance is Well-Tested, Documented and Recognized via Code Acceptance



Source: AWC's TR 10

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

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

Source: AWC's NDS


Credit: David Barber, ARUP

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

Mass Timber Fire Design Resource

- Code compliance options for demonstrating FRR
- Updated as new tests are completed
- Free download at woodworks.org

Value: Program

Level 1

Level 2

Concept Plan

Hillsboro Community Center at 53rd Ave.

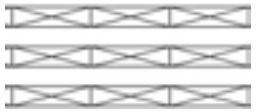
Cost: Construction Type

TABLE 601
Fire Resistance Rating Requirements for Building Elements (Hours)

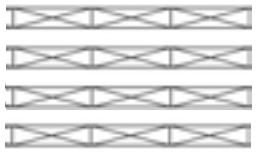
Building Element	I-A	I-B	III-A	III-B	IV-A	IV-B	IV-C	IV-HT	V-A	V-B
Primary Structural Frame	3*	2*	1	0	3*	2	2	HT	1	0
Ext. Bearing Walls	3*	2*	2	2	3*	2	2	2	1	0
Int. Bearing Walls	3*	2*	1	0	3*	2	2	1/HT	1	0
Floor Construction	2	2*	1	0	2	2	2	HT	1	0
Roof Construction	1.5*	1*	1	0	1.5	1	1	HT	1	0
Exposed Mass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

Baseline
0hr & HT

+$10/SF
1hr & maybe 2hr



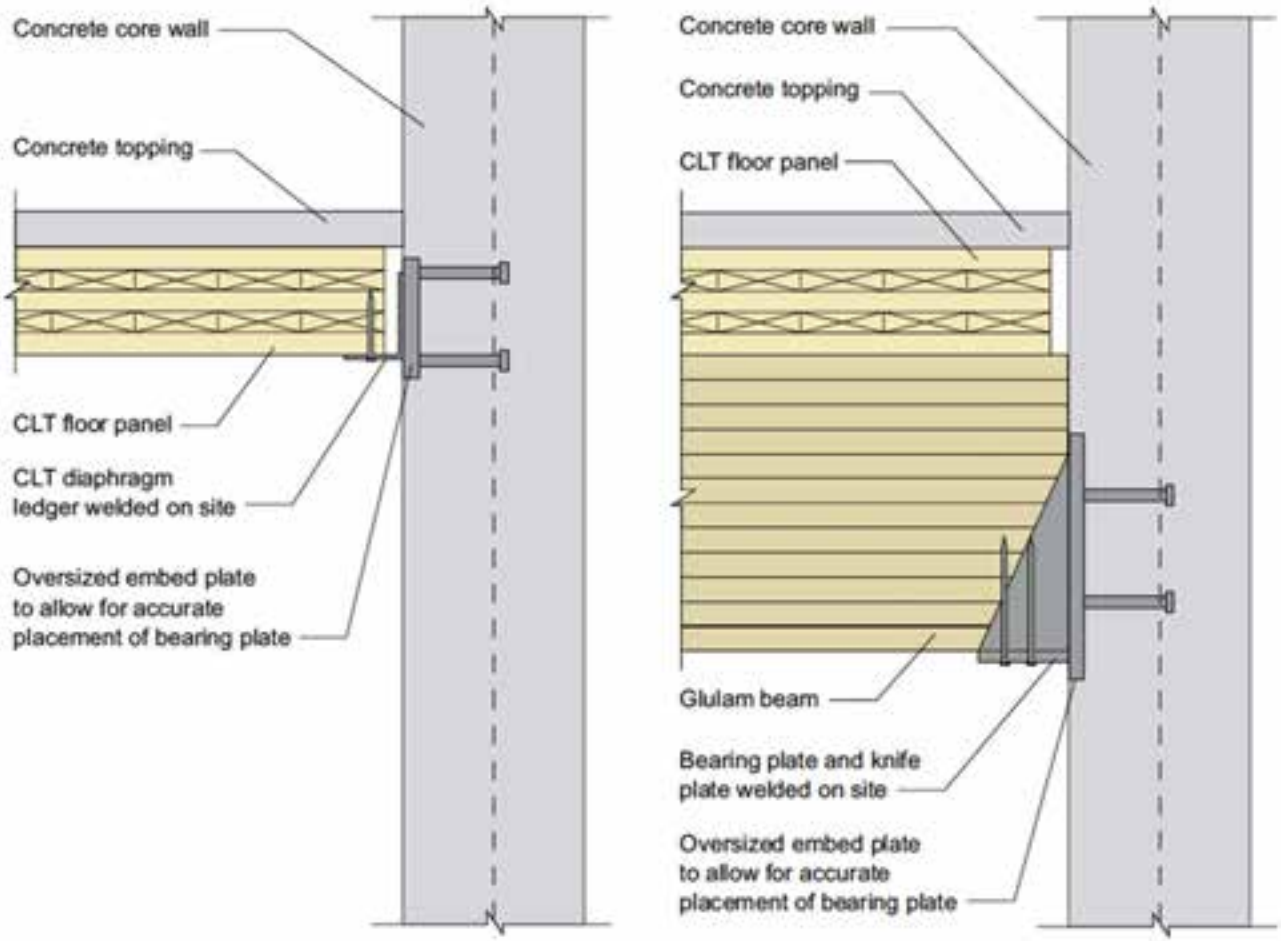
+$12-15/SF
2hr FRR



Cost Source: Swinerton

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

Options for accommodating differential movement



Cost Impacts of Construction Type

Construction Type Early Decision Example

3-story building on college campus

- Mostly Group B occupancy, some assembly (events) space
- NFPA 13 sprinklers throughout
- Floor plate = 7,700 SF
- Total Building Area = 23,100 SF

Impact of Assembly Occupancy Placement:

Owner originally desires events space on top (3rd) floor

- Requires Construction Type IIIA

If owner permits moving events space to 1st or 2nd floor

- Could use Type IIIB

Cost Impacts of Construction Type

Construction Type Early Decision Example

3-story building on college campus

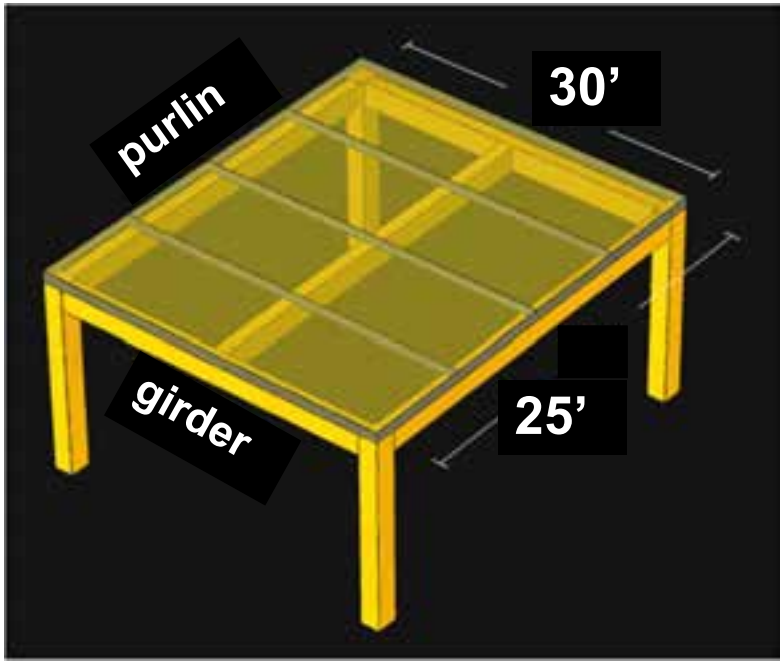
Cost Impact of Assembly Occupancy Placement:

Location of Event Space	3rd Floor	1st Floor
Construction Type	III-A	III-B
Assembly Group	A-3	A-3
Fire Resistive Rating	1-Hr	0-Hr
Connections	Concealed	Exposed
CLT Panel Thickness	5-Ply	3-Ply
Superstructure Cost/SF	**$65/SF**	**$53/SF**

Source: PCL Construction

Cost Implication of Design Choices

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

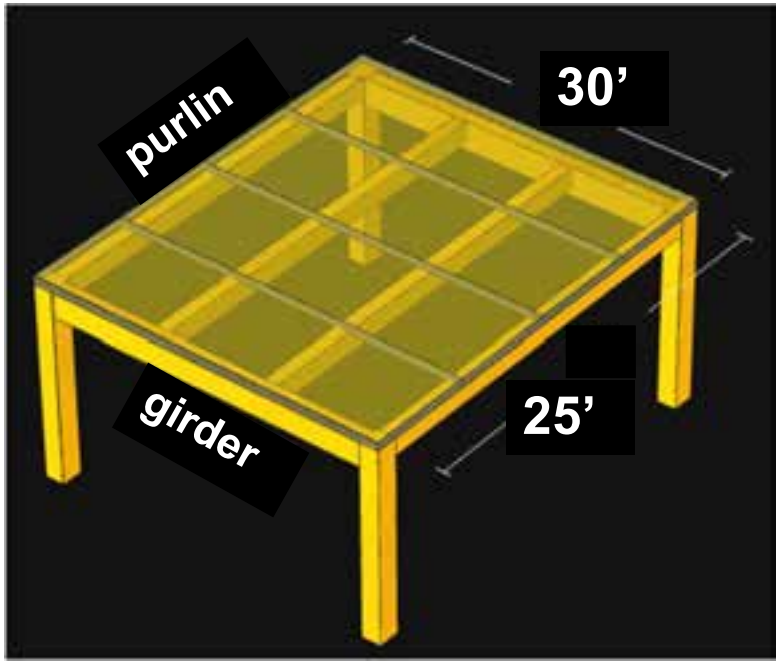
Type IIIA option 1

1-hr FRR
Purlin: 5.5”x28.5”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

Glulam volume = 118 CF (22% of MT)
CLT volume = 430 CF (78% of MT)
Total volume = 0.73 CF / SF

Cost Implication of Design Choices

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

Type IIIA option 2

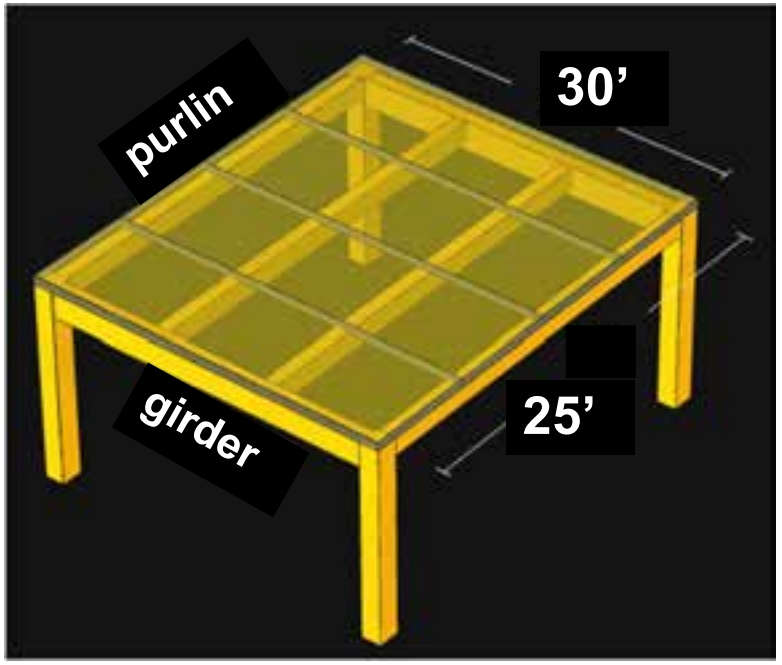
1-hr FRR
Purlin: 5.5”x24”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

Glulam volume = 123 CF (22% of MT)
CLT volume = 430 CF (78% of MT)
Total volume = 0.74 CF / SF

Cost considerations: One additional beam (one additional erection pick), 2 more connections

Cost Implication of Design Choices

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

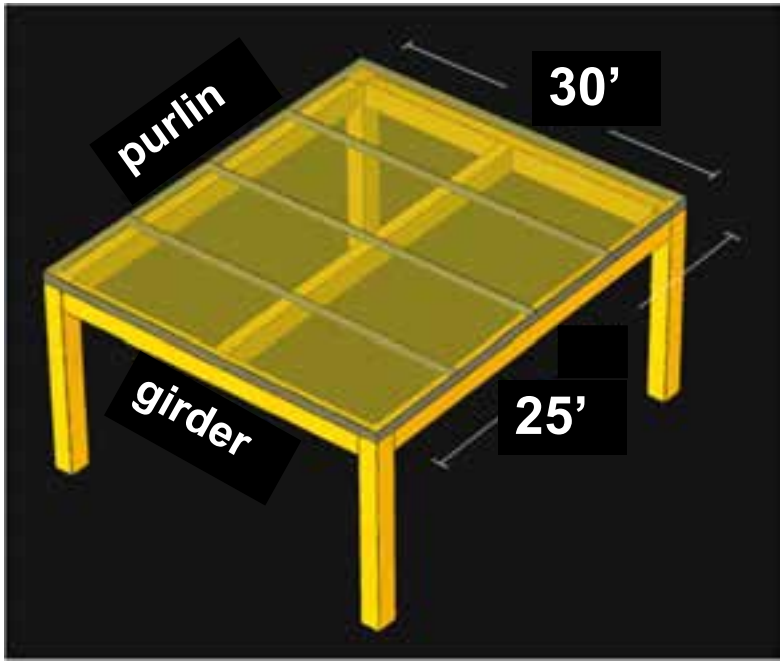
Type IV-HT

0-hr FRR (min sizes per IBC)
Purlin: 5.5”x24” (IBC min = 5”x10.5”)
Girder: 8.75”x33” (IBC min = 5”x10.5”)
Column: 10.5”x10.75” (IBC min = 6.75”x8.25”)
Floor panel: 3-ply (IBC min = 4” CLT)

Glulam volume = 120 CF (32% of MT)
CLT volume = 258 CF (68% of MT)
Total volume = 0.51 CF / SF

Cost Implication of Design Choices

Which is the most efficient option?



Source: Fast + Epp, Timber Bay Design Tool

	Timber Volume Ratio
IIIA – Option 1	0.73 CF / SF
IIIA – Option 2	0.74 CF / SF
IV-HT	0.51 CF / SF

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF for up to a 1 hour rated structure (higher if 2 hour exposed timber in tall mass timber). Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

Expert Tips

Key Design Considerations for Mass Timber Projects

Important considerations related to construction type, fire ratings, panel thickness, member size and occupancy.

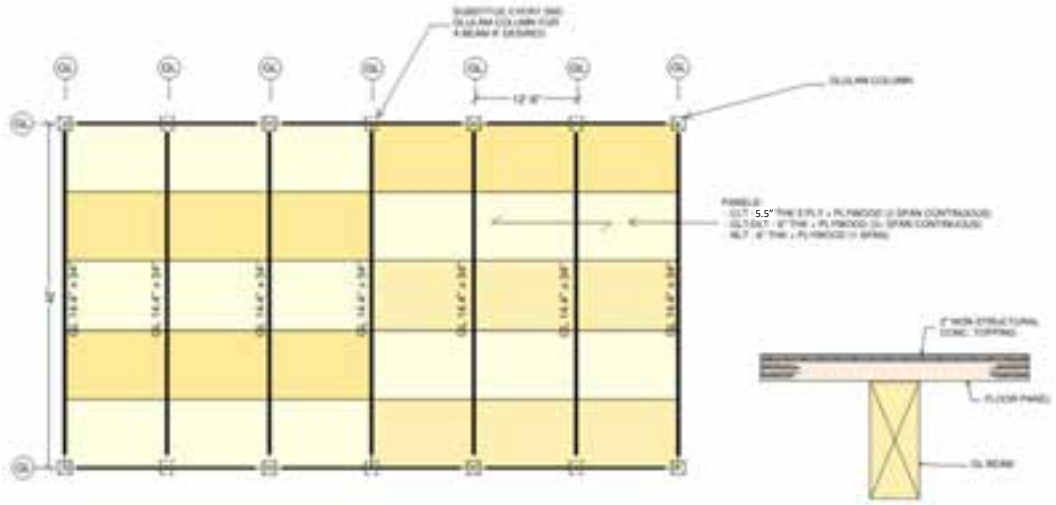
Share

Selecting a Construction Type

For mass timber projects, selection of construction type is one of the more significant design decisions. While it's common to choose construction type based on structural material—i.e., to assume that steel and concrete structures should be Type II, light-frame wood should be Type V, and exposed heavy/mass timber should be Type IV—this approach can lead to additional costs. While Type IV construction can be used for exposed


Photo: Swinerton

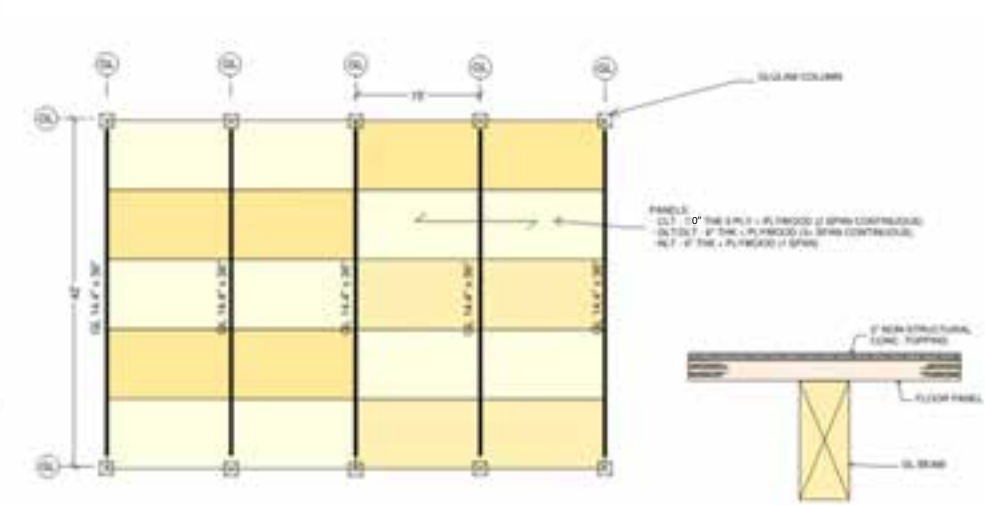
Cost: Structural System & Grid



Baseline

12’-6” Glulam Spacing

5.5” CLT



$ +5%

15’ Glulam Spacing

7” CLT

Source: Seattle Mass Timber Tower Book

Expert Tips

Creating Efficient Structural Grids in Mass Timber Buildings

Although a mass timber solution may work economically on grids created for other materials, a few modifications can increase efficiencies related to member sizing and manufacturer capabilities.

Share

Mass timber products such as cross-laminated timber (CLT), nail-laminated timber (NLT) and glue-laminated timber (glulam) are at the core of a revolution that is shifting how designers think about construction. At no time has materials selection been such an integral aspect of the building designer's daily responsibilities. In addition to its sustainability and light carbon footprint, mass timber has benefits that include enhanced aesthetics, speed of construction and light weight, all of which can positively impact costs. However, to convince building owners and developers that a mass timber solution is viable, the structural design must also be cost competitive. This requires a full understanding of both material properties and

Value Analysis

$$Value = \frac{\uparrow Function \quad + \uparrow Aesthetics}{\downarrow Cost}$$


Photo: RMW Architecture & Interiors

Value Analysis

$$Value\ Engineering = \frac{\downarrow Function\ + \downarrow Aesthetics}{\downarrow Cost}$$

Perimeter Glazing

Insurance Perspective on Mass Timber

- Lack of historic loss data = Unknowns
- Unknowns = Risk
- Risk = Higher Premiums
- Some take a ‘wood is wood’ approach

- Important to understand the significant differences in how mass timber performs in the event of a fire, etc. when compared to light wood-frame and all other building materials

Photo Credit: StructureCraft

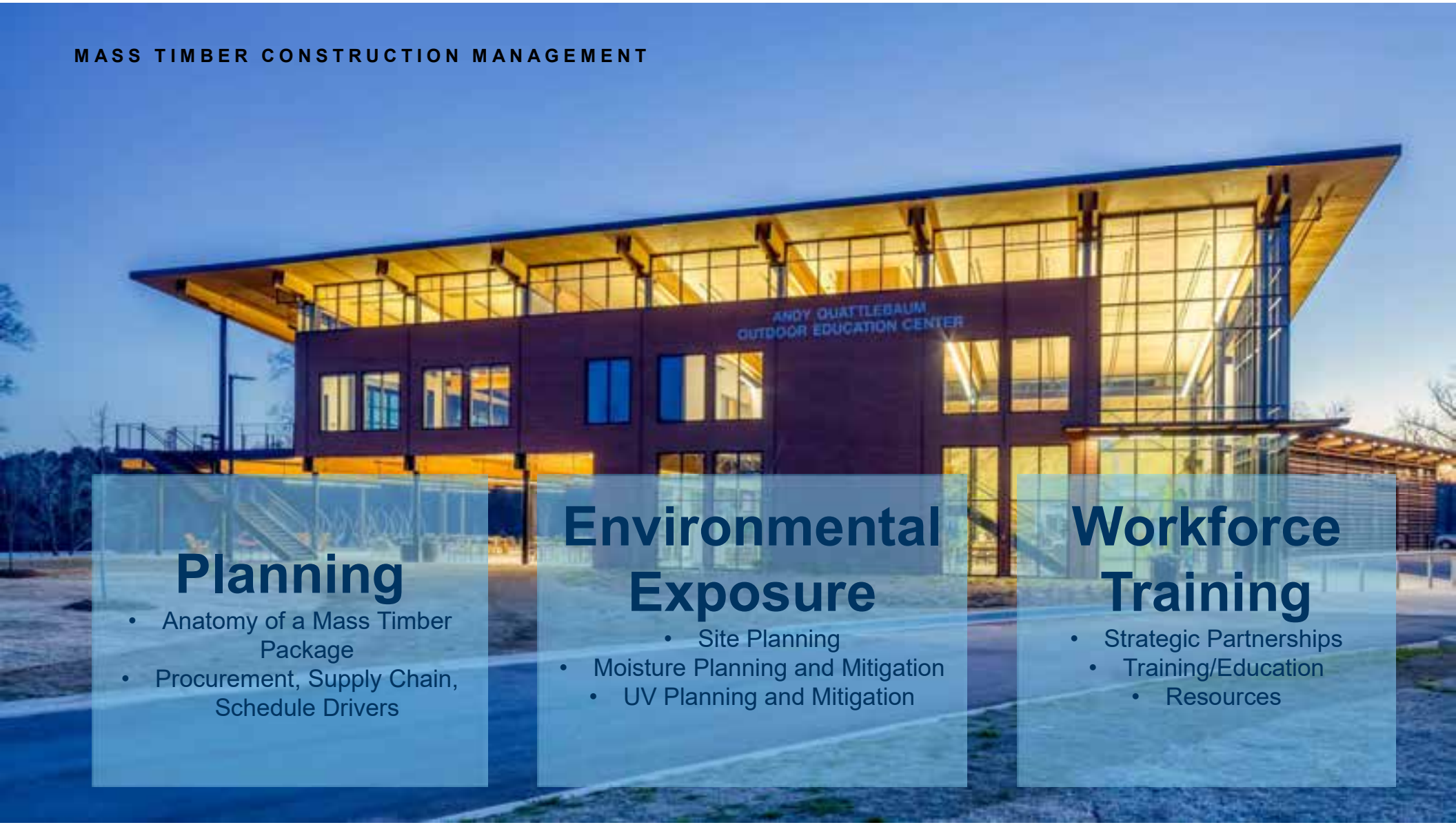
Photo Credit: GLI Partners

Insurance vs. Building Codes

- It is important to note the distinct difference between the primary concerns of insurers vs. primary concerns of building codes
- **Insurance** primarily concerned with **property loss**
- **Building codes** primarily concerned with **occupant safety**

- As such, code acceptance and associated testing may be helpful to insurers in evaluating a new product like mass timber, but it will not address all concerns

MASS TIMBER CONSTRUCTION MANAGEMENT



Planning

- Anatomy of a Mass Timber Package
- Procurement, Supply Chain, Schedule Drivers

Environmental Exposure

- Site Planning
- Moisture Planning and Mitigation
- UV Planning and Mitigation

Workforce Training

- Strategic Partnerships
- Training/Education
- Resources

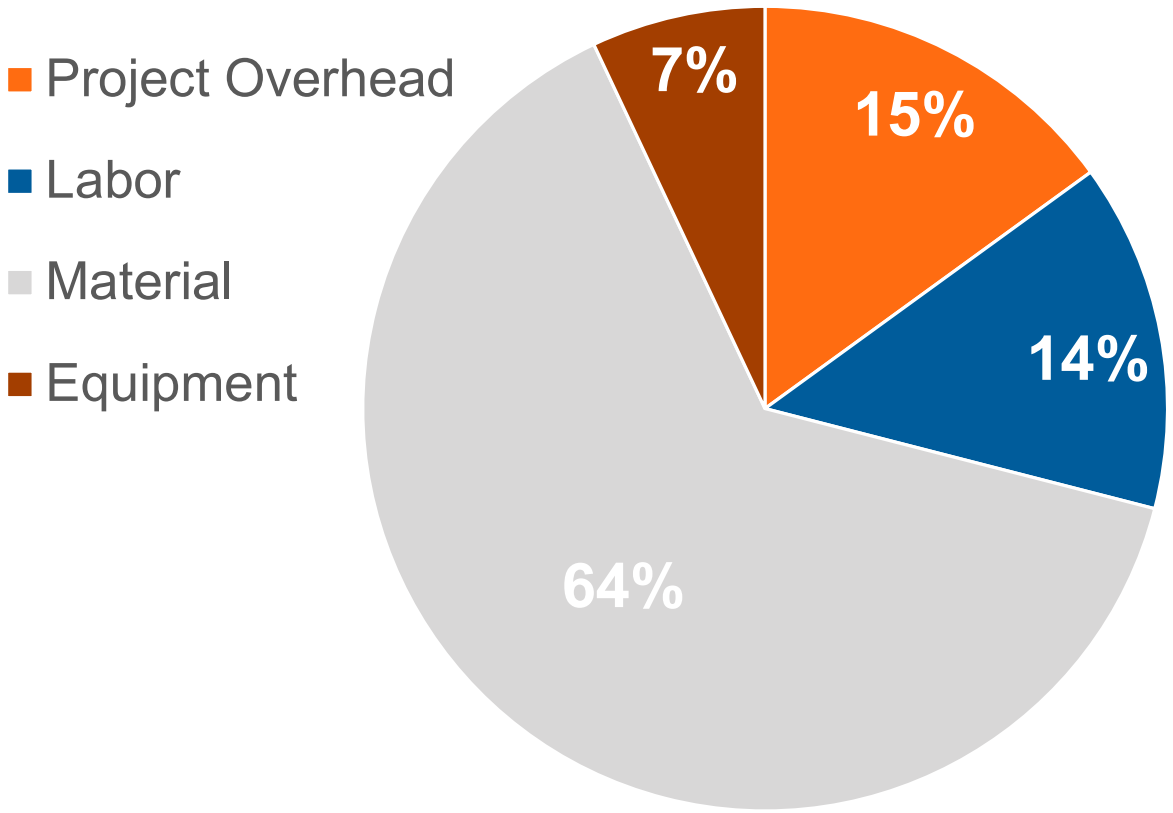
Holistic Costing

$/SF

$/SF

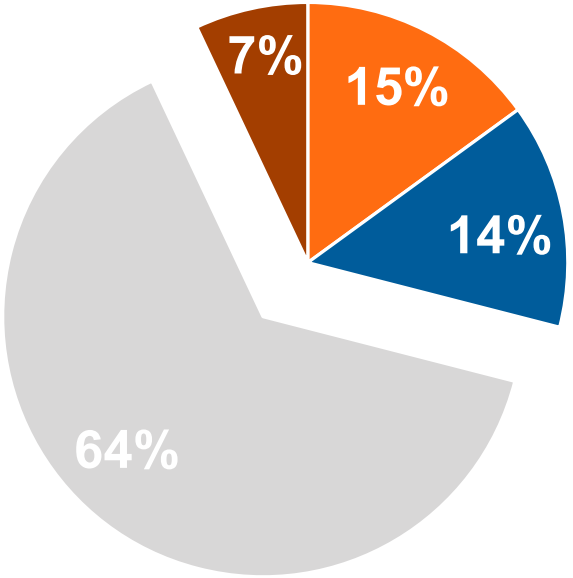
Image: GBD Architects

Anatomy of a Turnkey Mass Timber Package



Source: Swinerton

Material (Direct Cost)

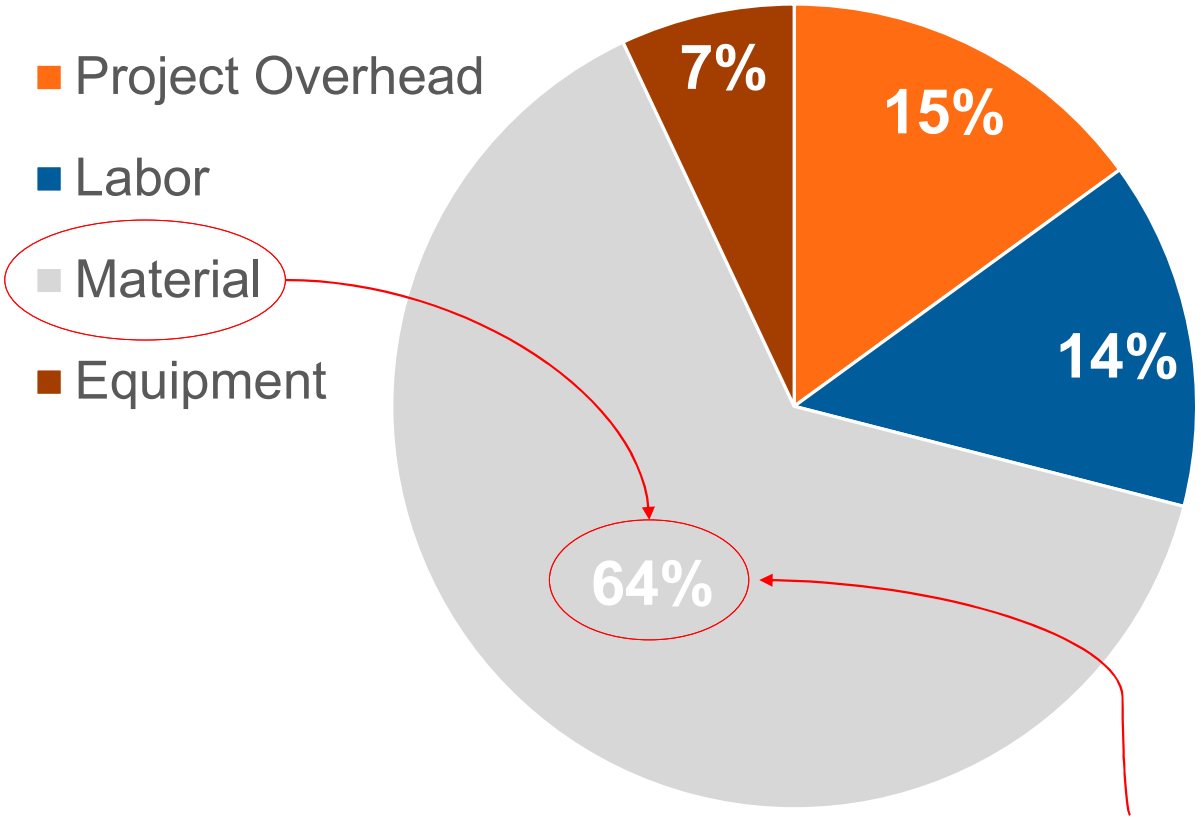


Turnkey Mass Timber Package

or

Source: Swinerton

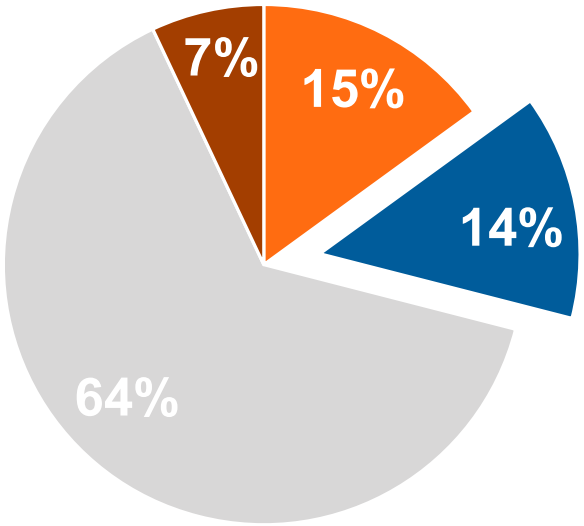
Mass Timber Package Costs



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

Source: Swinerton

Labor (Direct Cost)

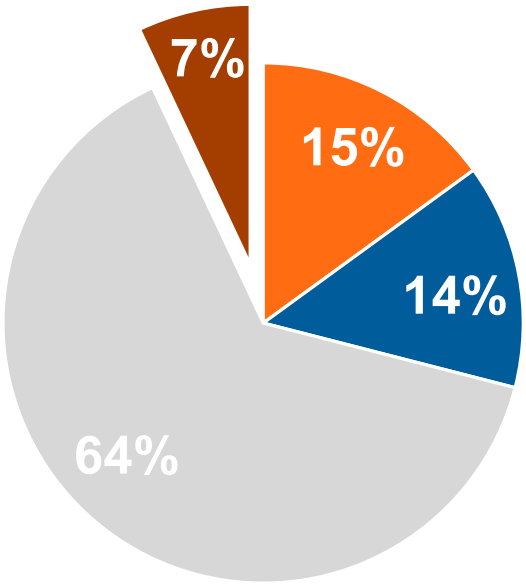


Turnkey Mass Timber Package

Photo: Swinerton

Source: Swinerton

Equipment (Direct Cost)



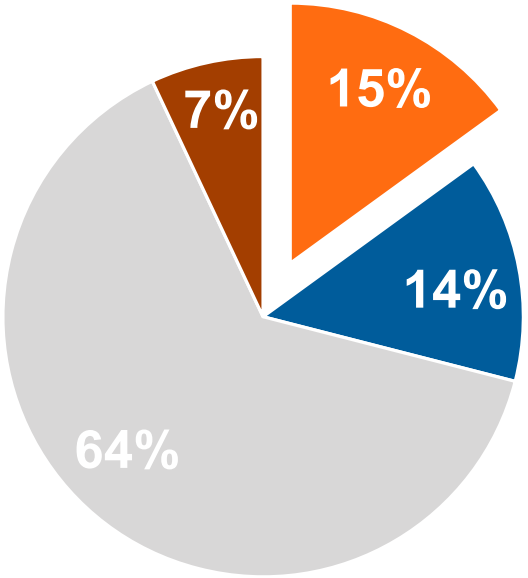
Turnkey Mass Timber Package

Photo: Swinerton

Photo: Alex Schreyer

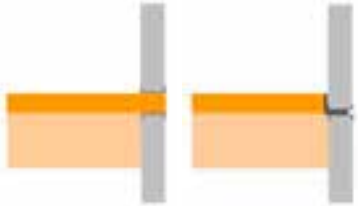
Source: Swinerton

Project Overhead



Turnkey Mass Timber Package

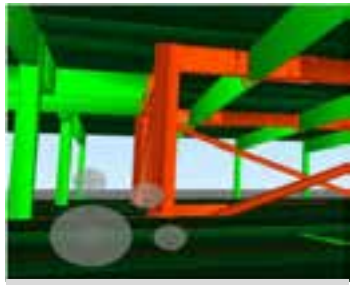
Cost Analysis



Design Refinement

System Integration

VD&C



Detail Optimization

Logistics Planning

Photos: Swinerton

Source: Swinerton

Total Project Cost Analysis

CONSIDERATIONS:

- Ceiling Treatment
- Floor Topping
- HVAC System & Route
- Foundation Size
- Material Savings
- Perimeter glazing
- Value of Time
- Completion Bonds/Insurance

Credit: Hacker Architects

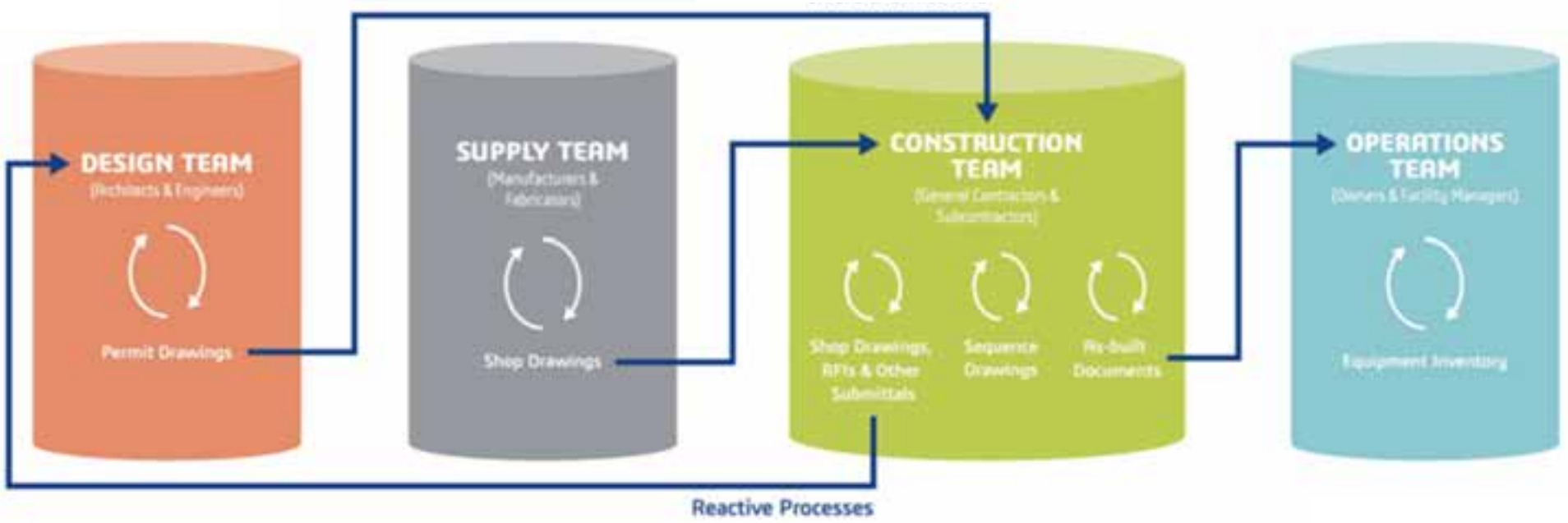
BB0

Sample Procurement Strategies

GC/CM Hires Turnkey Mass Timber Subcontractor	GC/CM Buys Material, Self-Performs Installation and Coordinates	GC/CM Buys Material, Subcontracts Labor and Coordinates
RISK SPECTRUM		
+ Hiring experience + Single point of responsibility	+ Hiring experience + Single point of responsibility + Financial security of strong GC/CM	+ Potential added mark-up
– Prequalify capacity of subs – Potential added mark-up	– Lack of familiarity with supply chain – Steep learning curve for coordination	– Multiple layers of coordination – Prequalify capacity of sub

Source: Timberlab

Potential Cost Impacts:
Design-Bid-Build Procurement



Alternate Procurement Option:
Trade Partner/Master Builder Approach

Procurement Strategy is Key to Success

5% Savings

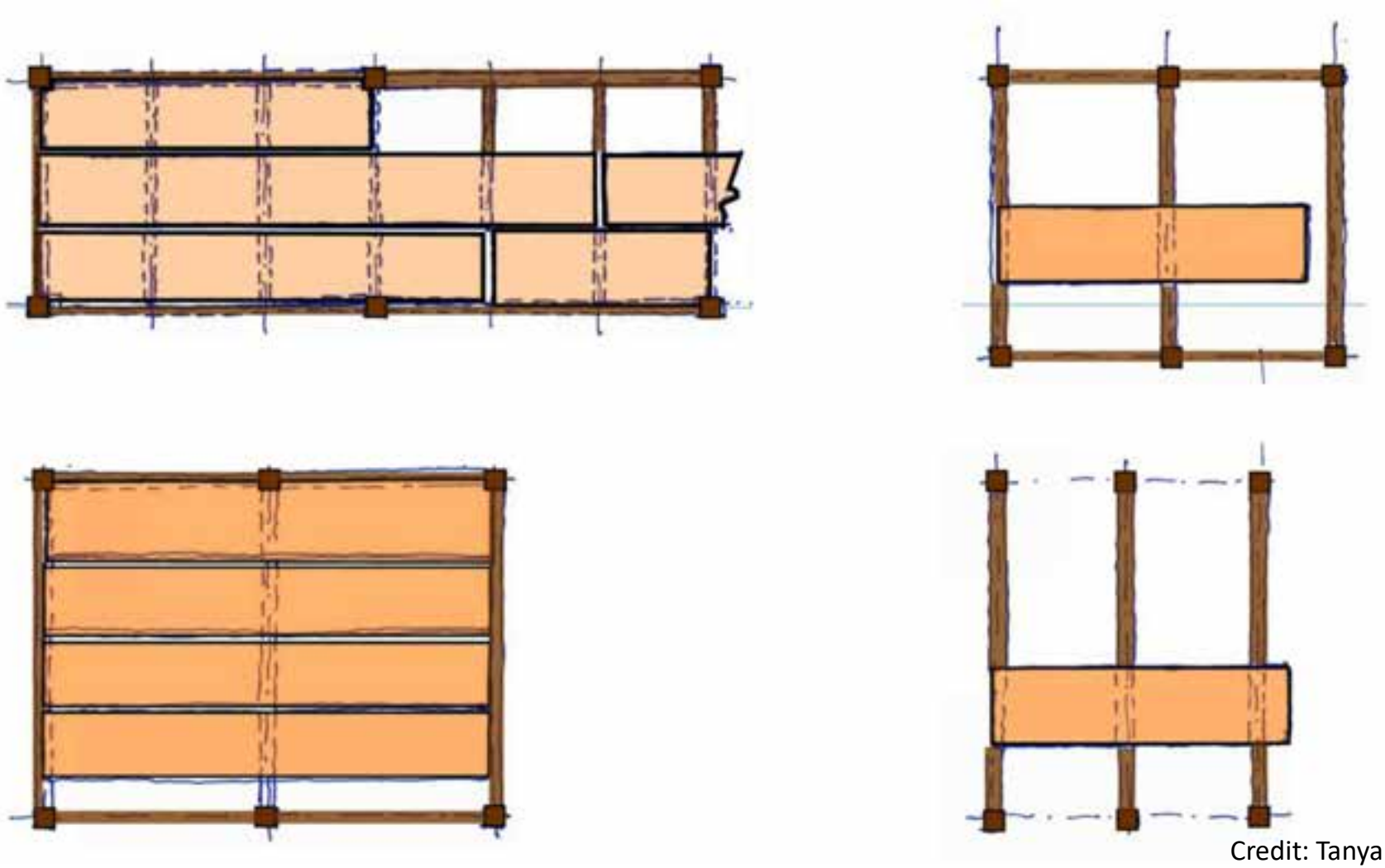
Neutrality

10% Premium

Material Fabrication Planning

Understand the Supply Chain

Photo: Swinerton

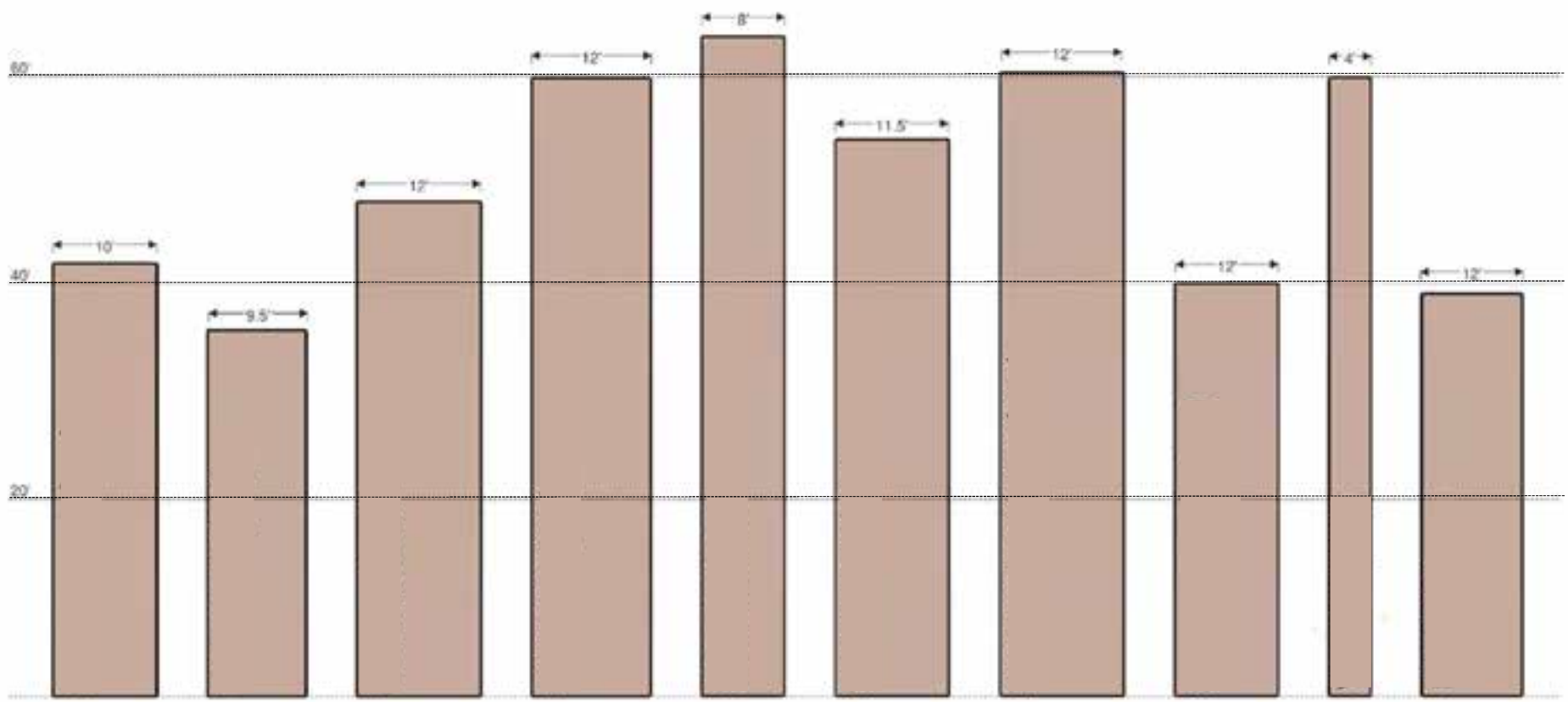


Credit: Tanya Luthi, Entuitive

Understand Manufacturer's Capabilities

BB0

Understand Manufacturer's Capabilities



Credit: TimberLab


Embrace the
Prefab Advantage
Photo: Swinerton

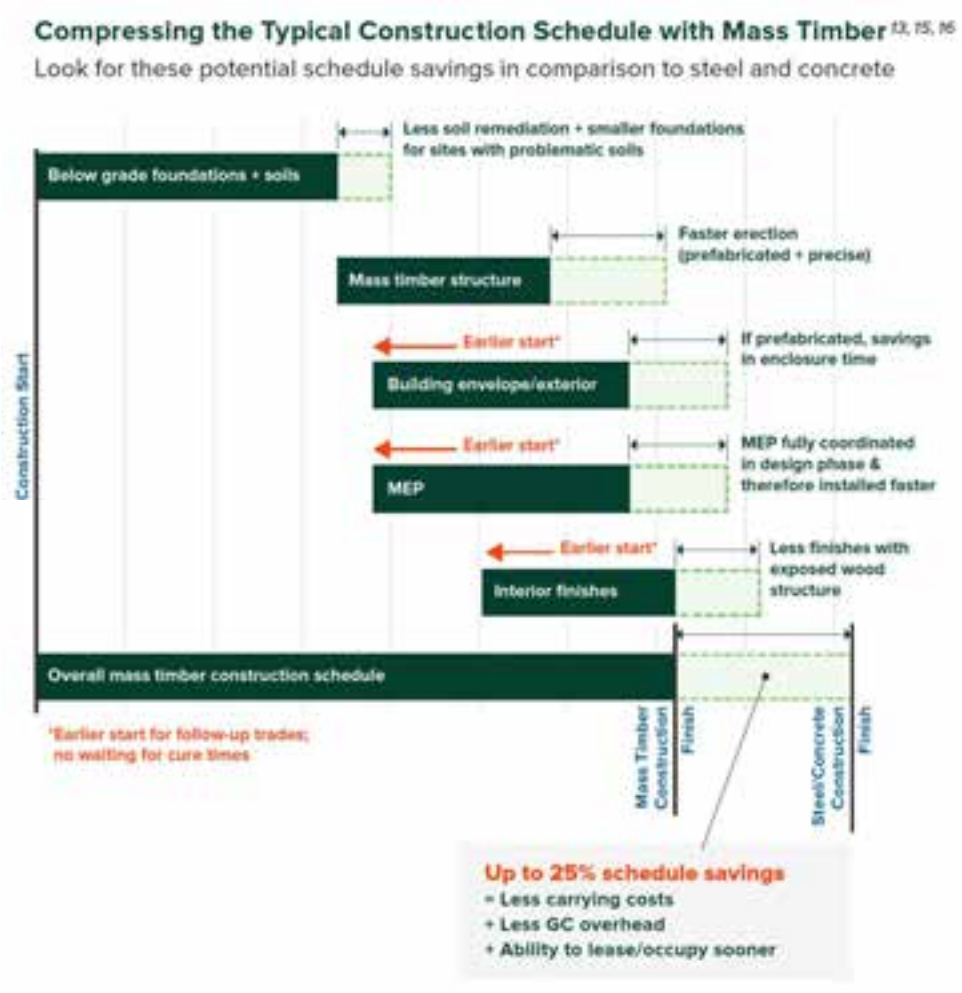
Tolerances: Interface with Other Structural Materials

Schedule Drivers

Photo: Swinerton

BB0

Procurement Approach Determines Schedule



Source: WoodWorks

Procurement Logic for Scheduling

Source: Swinerton

Example 6 Story Type IIIA Project

Procurement Approach Determines Schedule

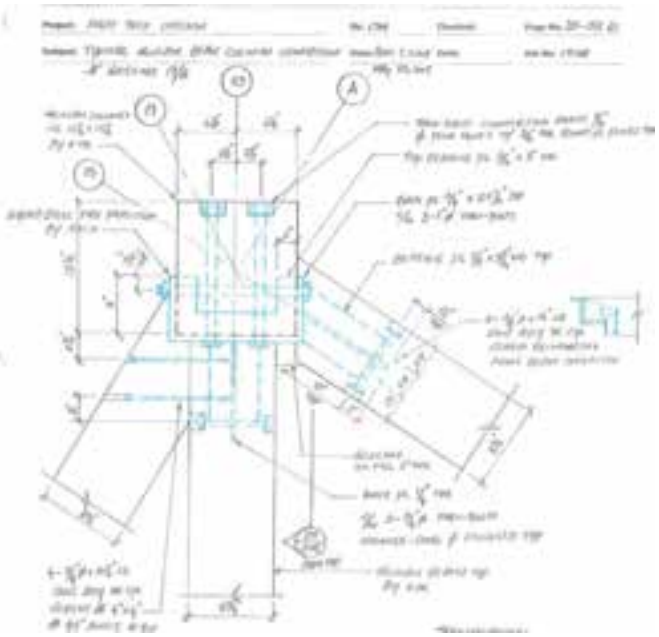
Schedule Comparison

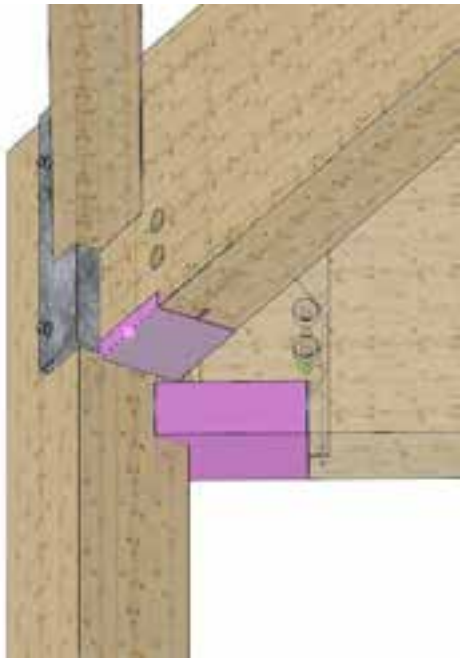
Image: Swinerton

Photo: WoodWorks

Schedule Drivers

BIM/Digital Twins





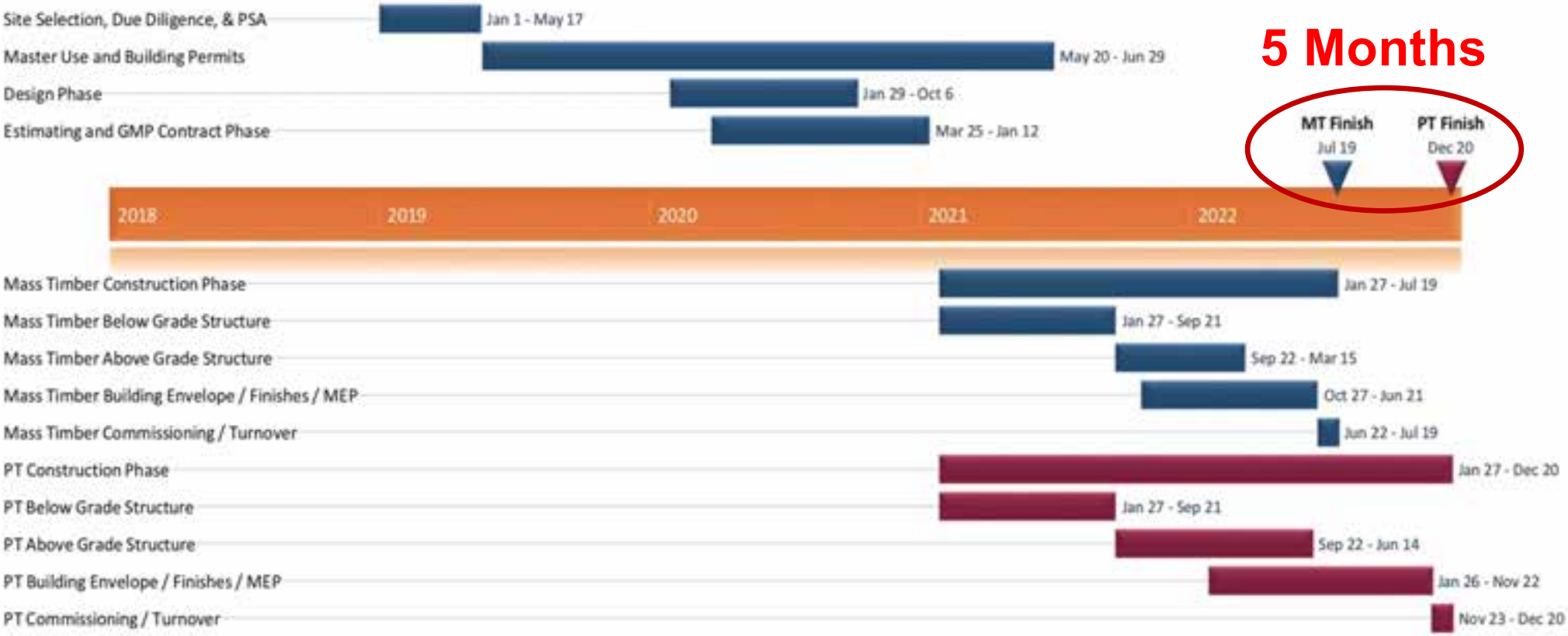
Photos: Swinerton

Schedule Impacts: Hybrid Structures

Photos: Swinerton


Look At Schedule Holistically
Photo: StructureCraft Builders

Overall Project Schedule Analysis: 12 Story Type IV-B



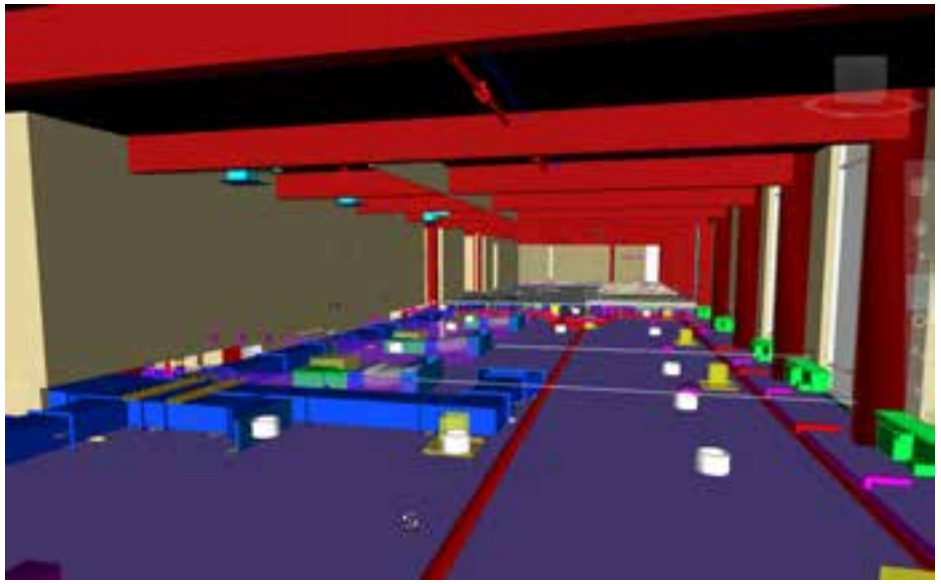
Source: Swinerton

Schedule Impact on Cost | Value of Time

Early Move-In for Rough-In Trades.

Photos: Swinerton

Embracing BIM for Fabrication



Photos: Swinerton

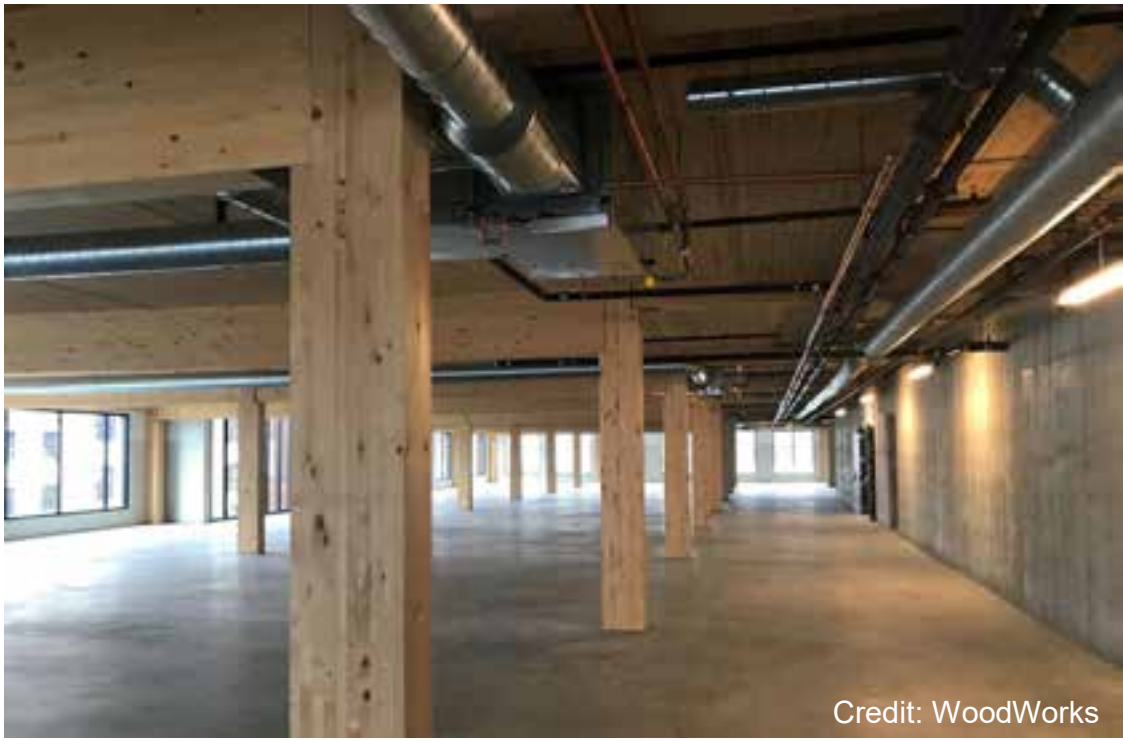
MEP Layout & Integration

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

Dropped below MT framing

- Can simplify coordination (fewer penetrations)
- Bigger impact on head height


Credit: Alex Schreyer


Credit: WoodWorks

MEP Layout & Integration

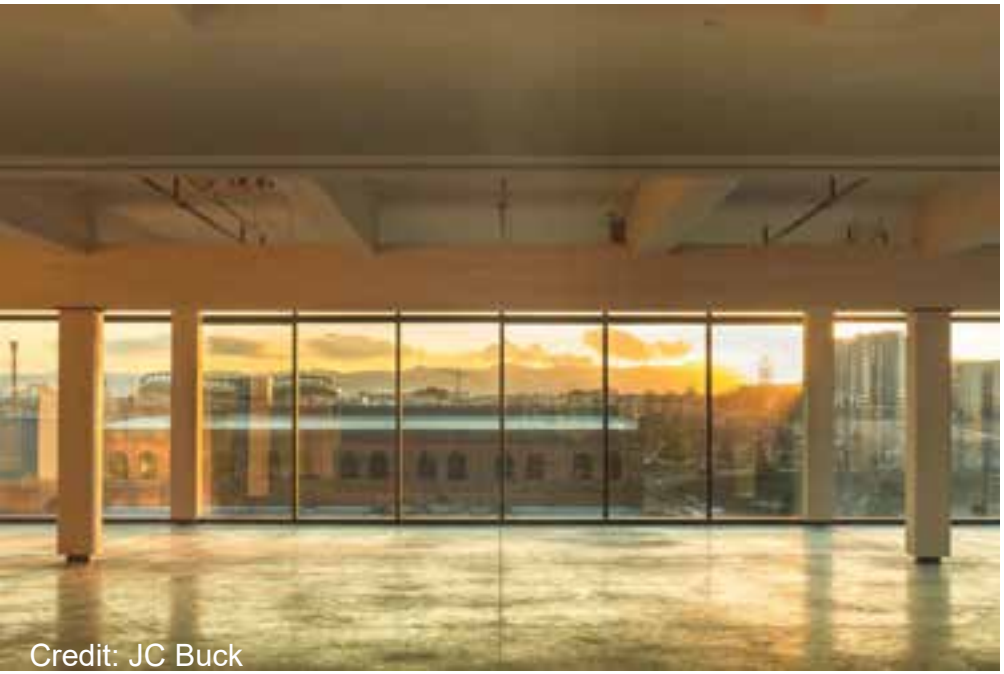
In penetrations through MT framing

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

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 raised access floor (RAF) above MT

- Impact on head height
- Concealed space code provisions

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

SITE PLANNING

Photo: Swinerton

QA/QC

Photo: Swinerton

SITE INSPECTIONS

Photo: H+O Structural Engineering, Kure Creative

Tall Mass Timber Special Inspections

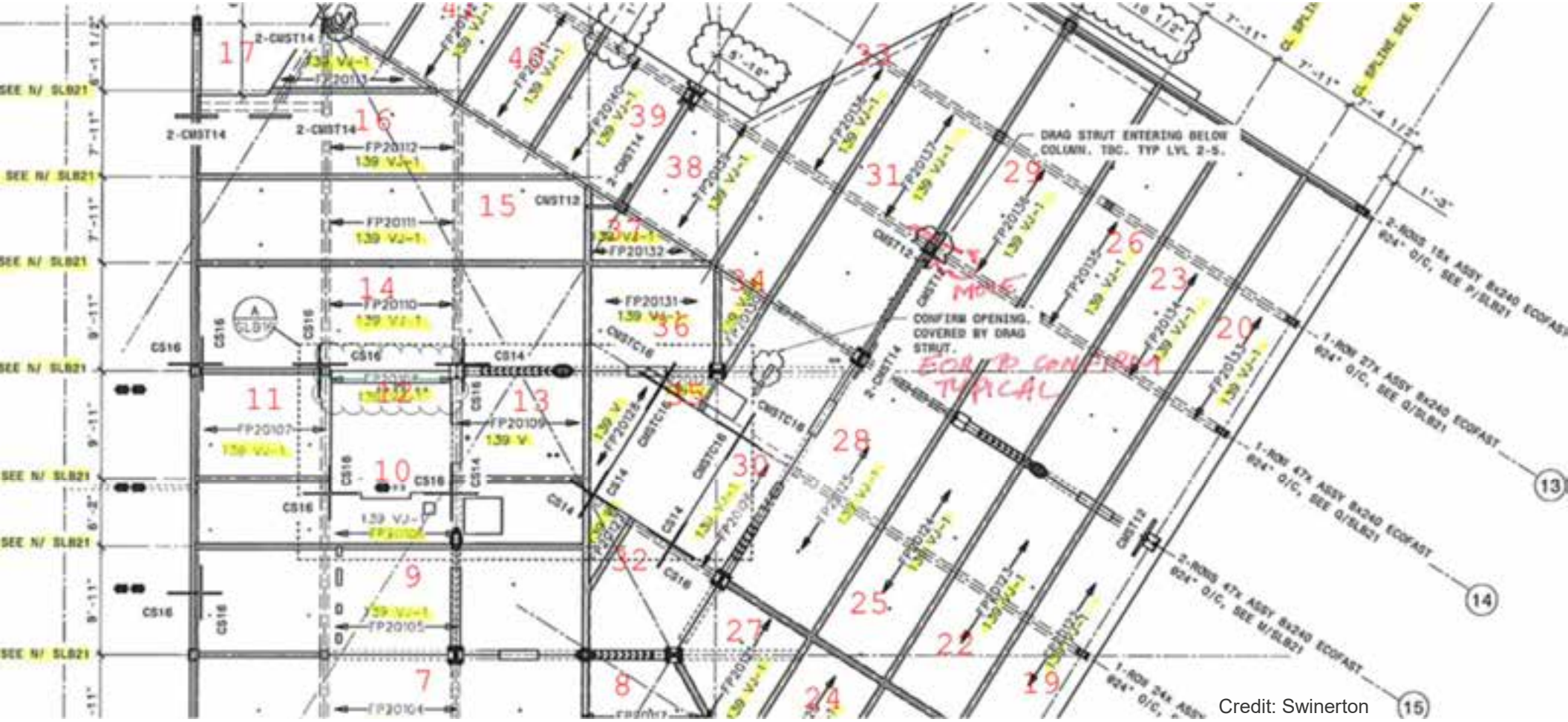
TABLE 1705.5.3
REQUIRED SPECIAL INSPECTIONS OF MASS TIMBER CONSTRUCTION

Type	Continuous Special Inspection	Periodic Special Inspection
1. Inspection of anchorage and connections of mass timber construction to timber deep foundation systems.		X
2. Inspect erection of mass timber construction		X
3. Inspection of connections where installation methods are required to meet design loads		
3.1. Threaded fasteners		
3.1.1. Verify use of proper installation equipment.		X
3.1.2. Verify use of pre-drilled holes where required.		X
3.1.3. Inspect screws, including diameter, length, head type, spacing, installation angle, and depth.		X
3.2. Adhesive anchors installed in horizontal or upwardly inclined orientation to resist sustained tension loads	X	
3.3. Adhesive anchors not defined in 3.2.		X
3.4. Bolted connections		X
3.5. Concealed connections		X

Source: International Building Code

Table is only required for Type IV-A, IV-B, and IV-C

Sequencing


DRAG STRUT ENTERING BELOW COLUMN. TBC. TYP LVL 2-5.
CONFIRM OPENING. COVERED BY DRAG STRUT.
TYPICAL
Credit: Swinerton

PICK PLAN

Photo: Swinerton

MATERIAL DELIVERY

Photo: Swinerton

Photo: Swinerton

STAGING

Planning for Environmental Exposures

- Plan Early
- Risk Evaluation
- Develop Construction
- Phase Plan
- Execute the Design and Moisture Management Plan
- Monitor

RDH Moisture Management Guide 1st Ed

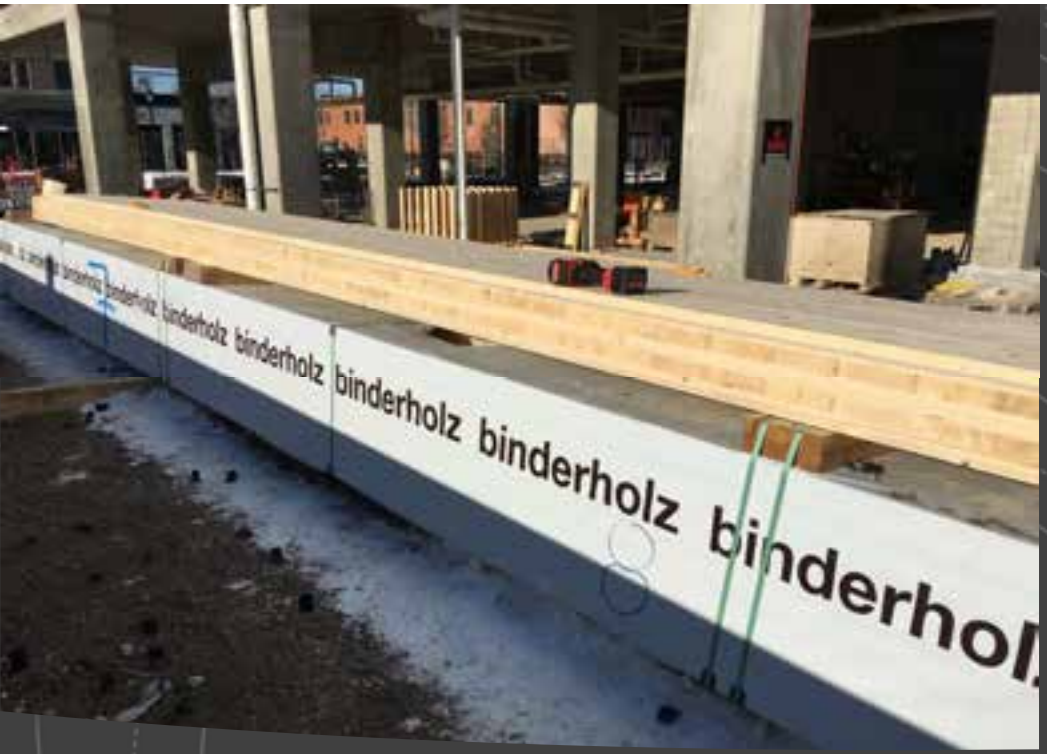
BB0

Photo: Swinerton

Material Environmental Exposure and Moisture Management

Enroute
Onsite
Post-Install
Other Material

Photo: Alex Schreyer



Enroute Exposure

On Site Considerations

On Site Considerations

BBO

Onsite Considerations

Other Materials

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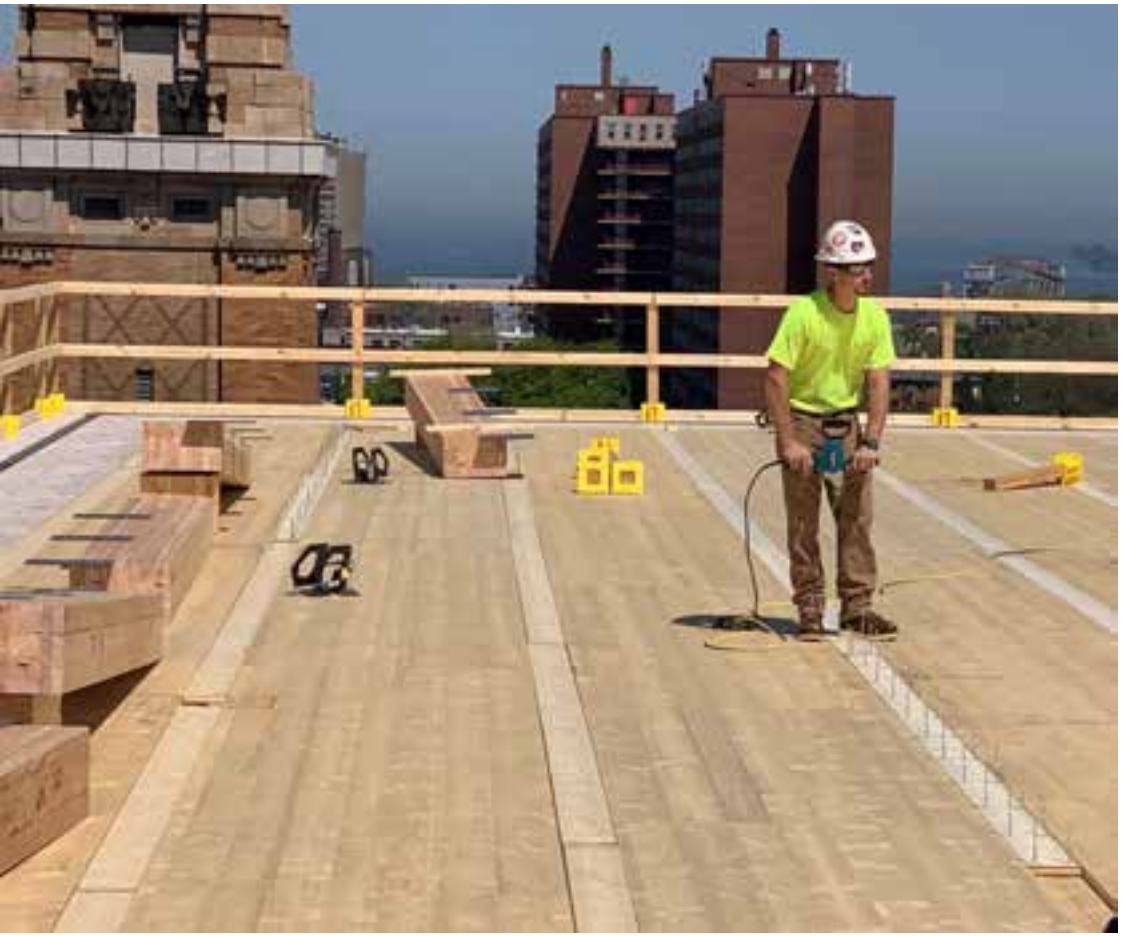


Workforce Development

- Training is the key to efficiency
- Training takes time and money

Training versus Education

Resources available to all

- MT Construction Manual
- Installer Curriculum
- Other WW Resources
- CM Workshops
- Previous recorded versions
- Learning Management System

Mass Timber Construction Management Program

MASS TIMBER CONSTRUCTION MANUAL

8- & 16-HOUR INSTALLER TRAINING PACKAGE AND TRAINING CENTERS

COMMUNITY COLLEGE AND UNIVERSITY CM PROGRAMS

VIRTUAL AND/OR IN-PERSON WORKSHOPS

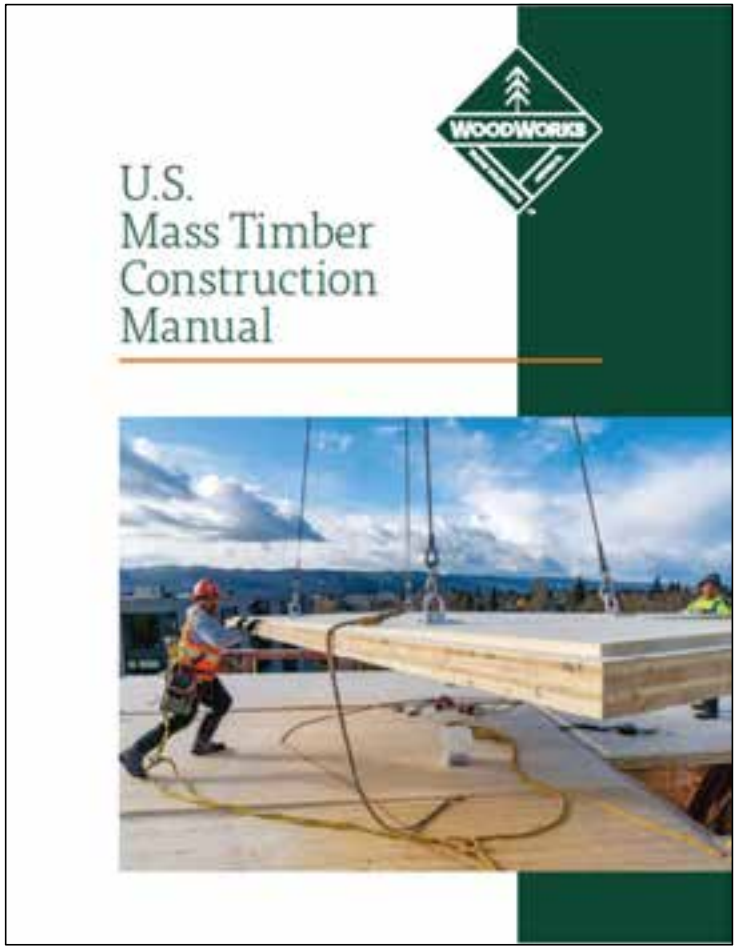
PARTNER WITH CONSTRUCTION ASSOCIATIONS

PROJECT TOURS

ENGAGE WITH GENERAL CONTRACTORS ACROSS THE US

Released on 20 October 2021

https://www.woodworks.org/mass-timber-construction-management-program/



The Loading Dock, OZ Architecture, KL&A, photo Joe Anastasi

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John W. Olver Design Building at UMass Amherst
Leers Weinzapfel Associates, Equilibrium Consulting
photo © Albert Vecerka / Esto

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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

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