Photo: Jeremy Bittermann

WOODWORKS WOOD PRODUCTS COUNCIL

WHIRLWIND CONSULTANTS

The Financial Dynamics of Designing with Mass Timber

Ricky McLain, WoodWorks
Nicholas Sills, Whirlwind Consultants

"The Wood Products Council" is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

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

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

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

AIA Approved Continuing Education

Course Description

Teams working to maximize the benefits of mass timber while managing costs require a nuanced understanding of the design, procurement, fabrication, and construction process. For example, keeping mass timber volumes to a minimum is key to cost-effectiveness, but can it be to the detriment of other systems in the building? How should connections be designed and detailed with cost in mind while factoring in manufacturing and fabrication capabilities, constructability and tolerances, and code and design requirements? What influence should transportation, material handling, and on-site logistics (including construction schedule targets) have on building layout and design? Are there key performance indicators that can be applied to projects to evaluate whether they're in an appropriate range at first glance? This webinar will explore the financial implications of crucial design decisions, equipping architects, structural engineers, contractors, and real estate developers with the practical knowhow necessary to create cost-effective, environmentally friendly, and structurally sound mass timber buildings.

Learning Objectives

1. Identify construction types within the International Building Code (IBC) 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 metrics that can be applied to mass timber designs to evaluate cost-effectiveness as a function of material, labor, and other factors.
4. Highlight effective methods of integrating MEP services in a mass timber building and discuss the relative impacts of each on cost, aesthetics, and structural layout.

Disclaimer

The costs and metrics represented in this presentation are a function of previous projects and experience. Each project must evaluate its unique goals and constraints, and manufacturers should be consulted for current and accurate cost information.

WHAT'S THE #1 REASON THAT MASS TIMBER IS NOT USED?

Perception of costs, real costs,

\$\$

and expertise

What Impacts Mass Timber Costs?

Timber Volume

CLT glulam other

not all wood volume costs are equal

Timber Specs

species grade layup appearance

be careful what you “wish” for

Fabrication & Details

time complexity waste hardware tolerances

repetition, simplification and adjustability

What Impacts Mass Timber Costs?

Fire Rating

Piece Count Penetrations Crane Grid Size

Structural Loads Site Logistics Acoustics

Wood Volume Labor

Transportation Occupancy Complexity

Code Version Insurance Steel Volume

MEPF

Design Complexity Visual Finish

HOW CAN WE DESIGN FOR COST EFFICIENCY?

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

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

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…

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**

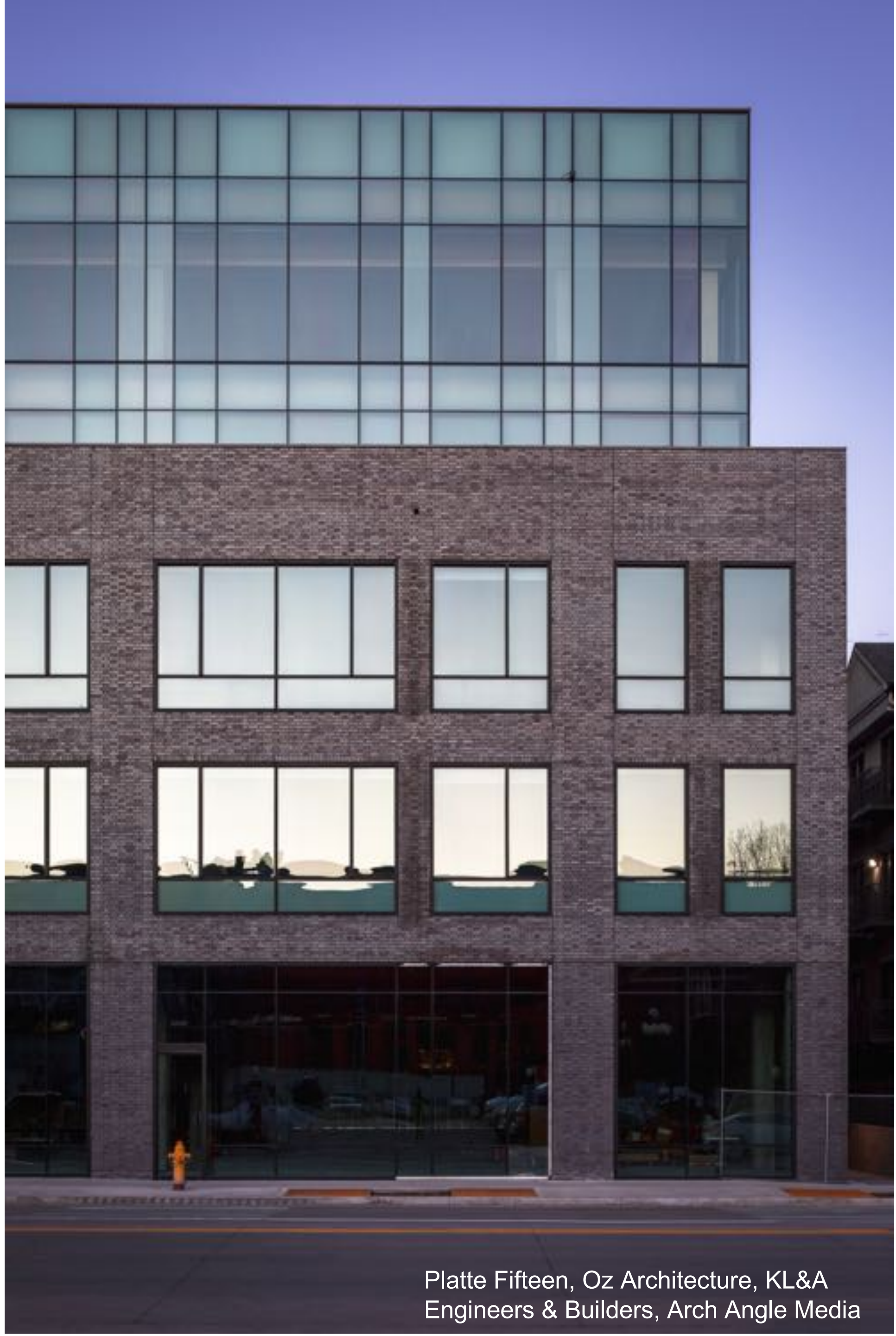
Miller Hull Partnership, photo: John Sta

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**

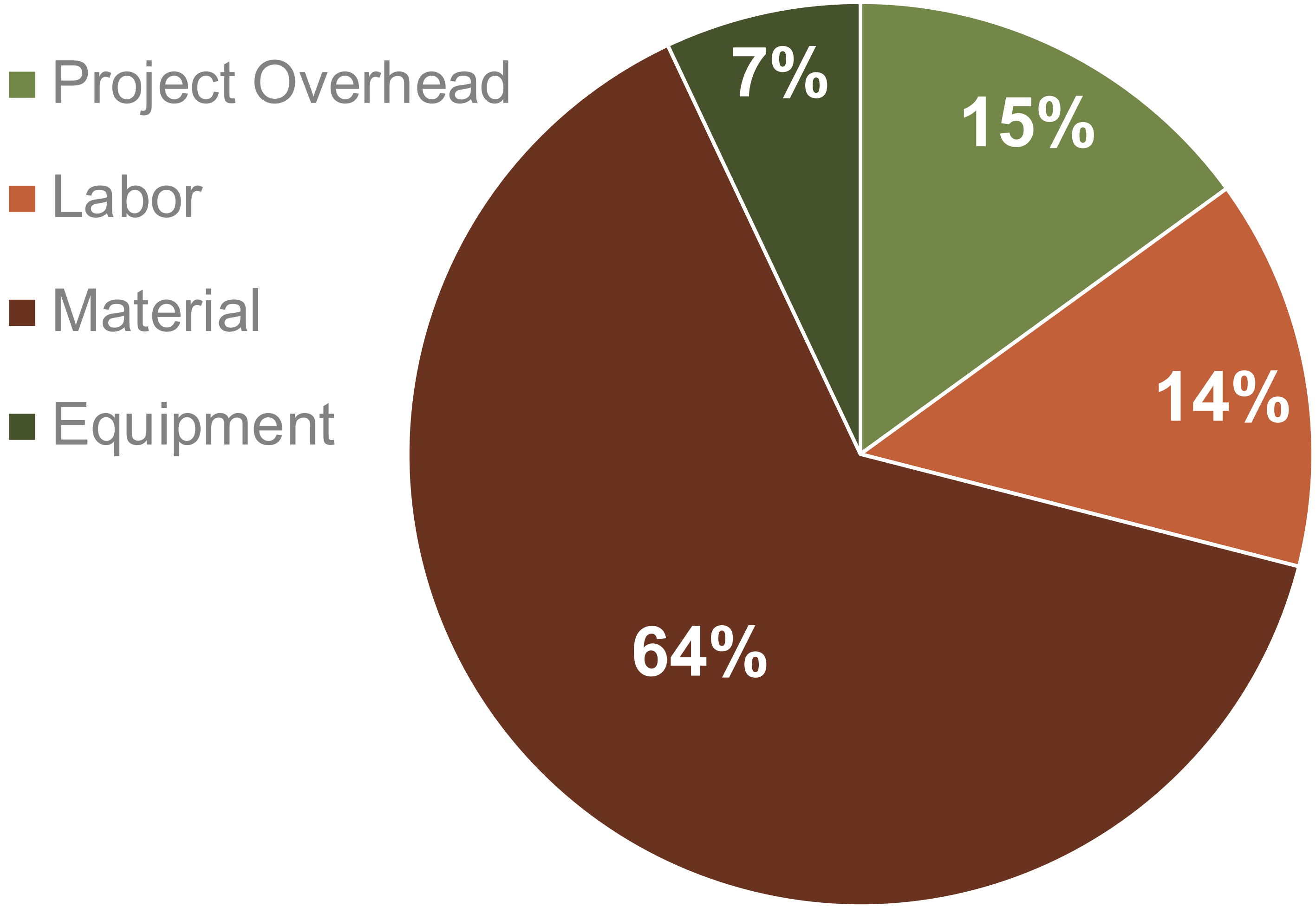
And more…



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

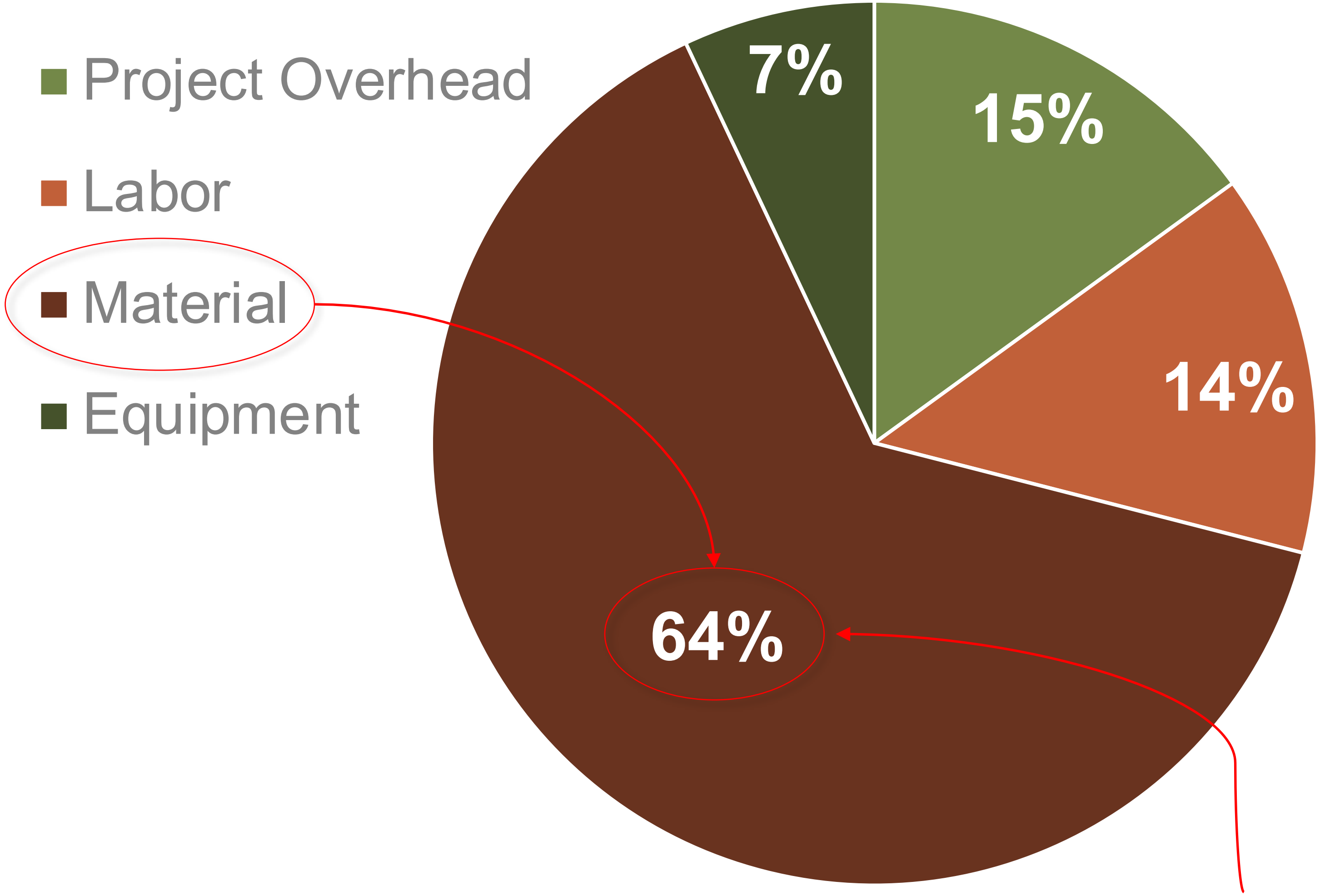
Mass Timber Costs

Typical MT Package Costs



Source: Swinerton

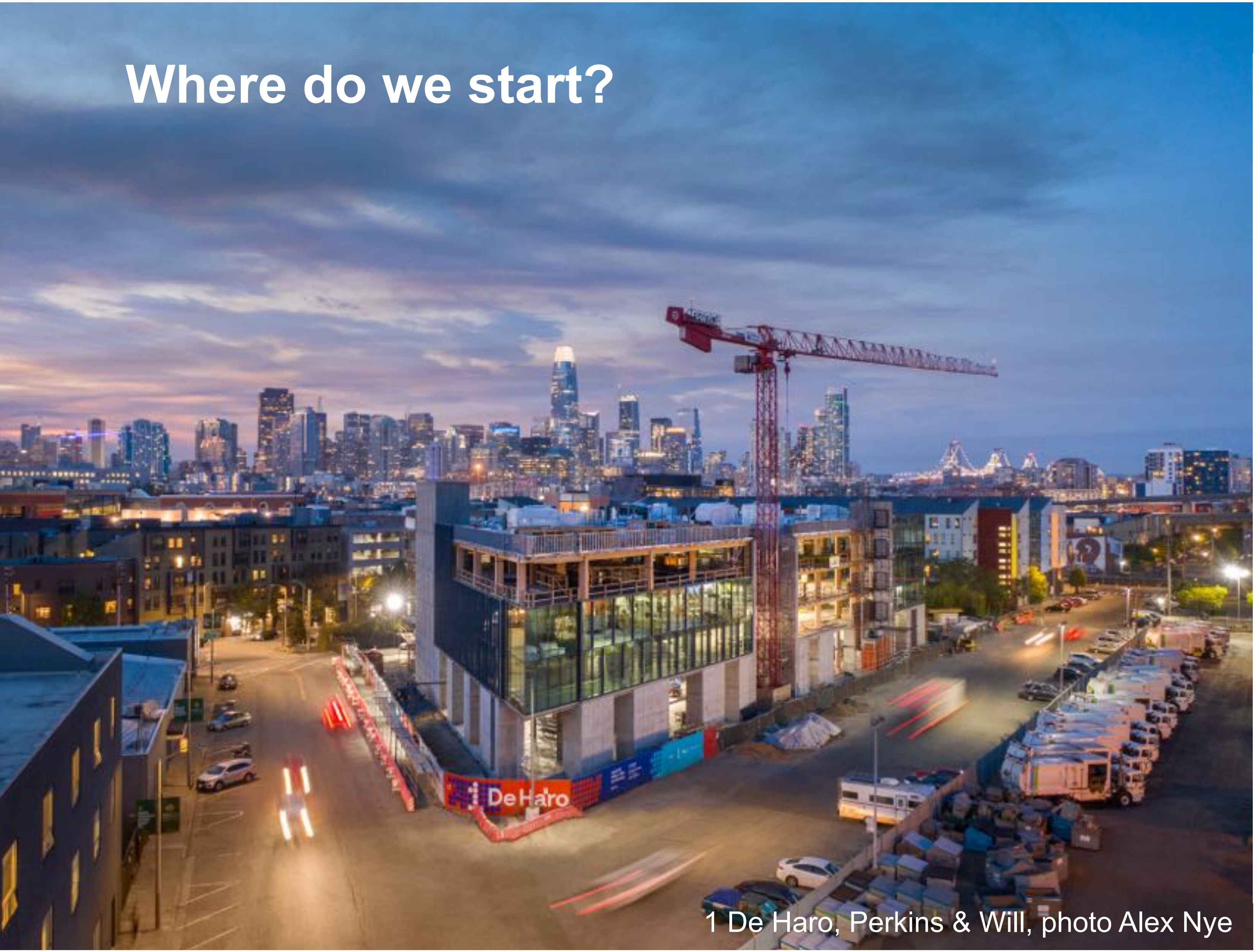
Key Early Design Decisions



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

Source: Swinerton

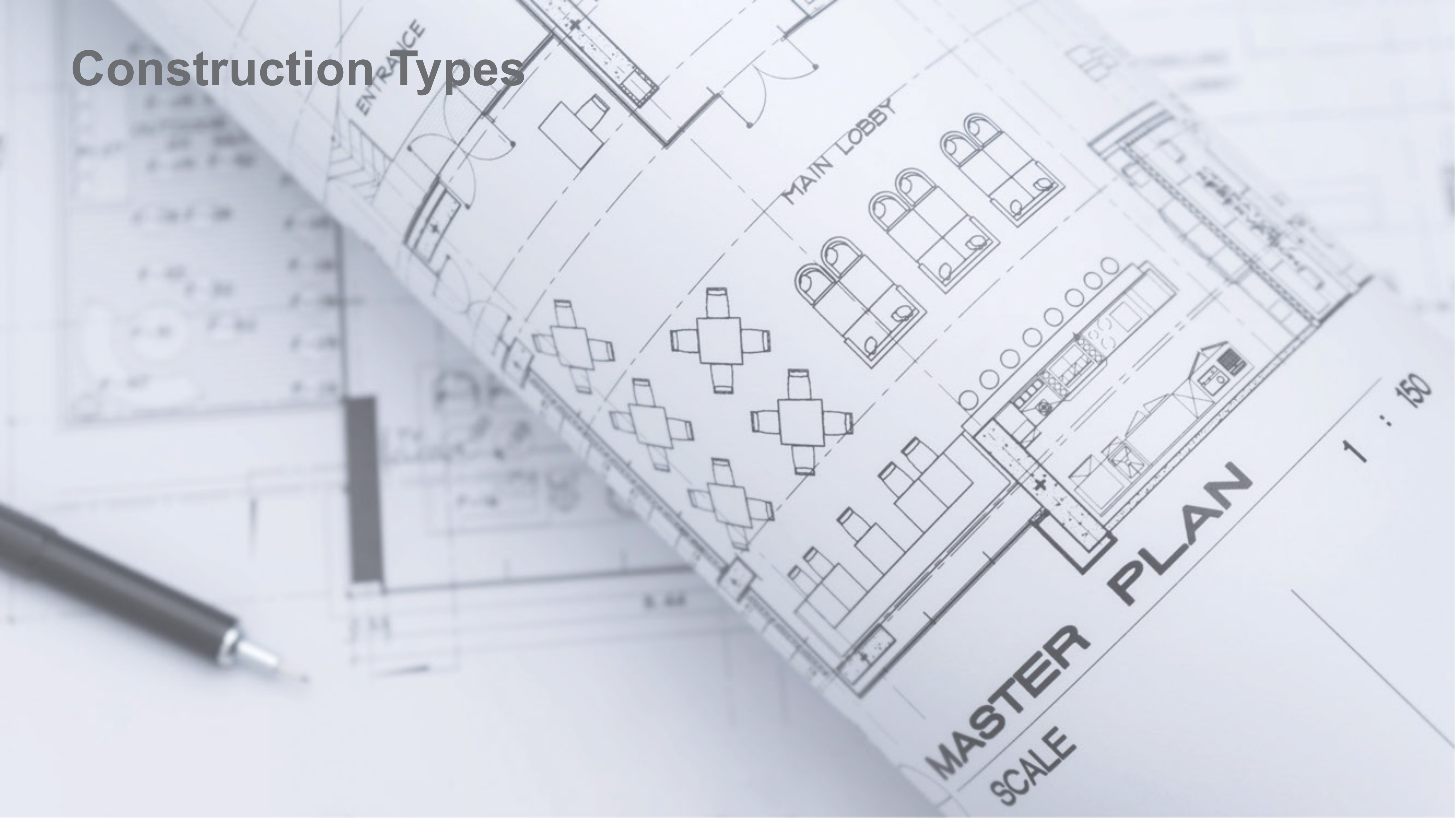
Key Early Design Decisions



1 De Haro, Perkins & Will, photo Alex Nye

MASS TIMBER IN THE CODE

Construction Types

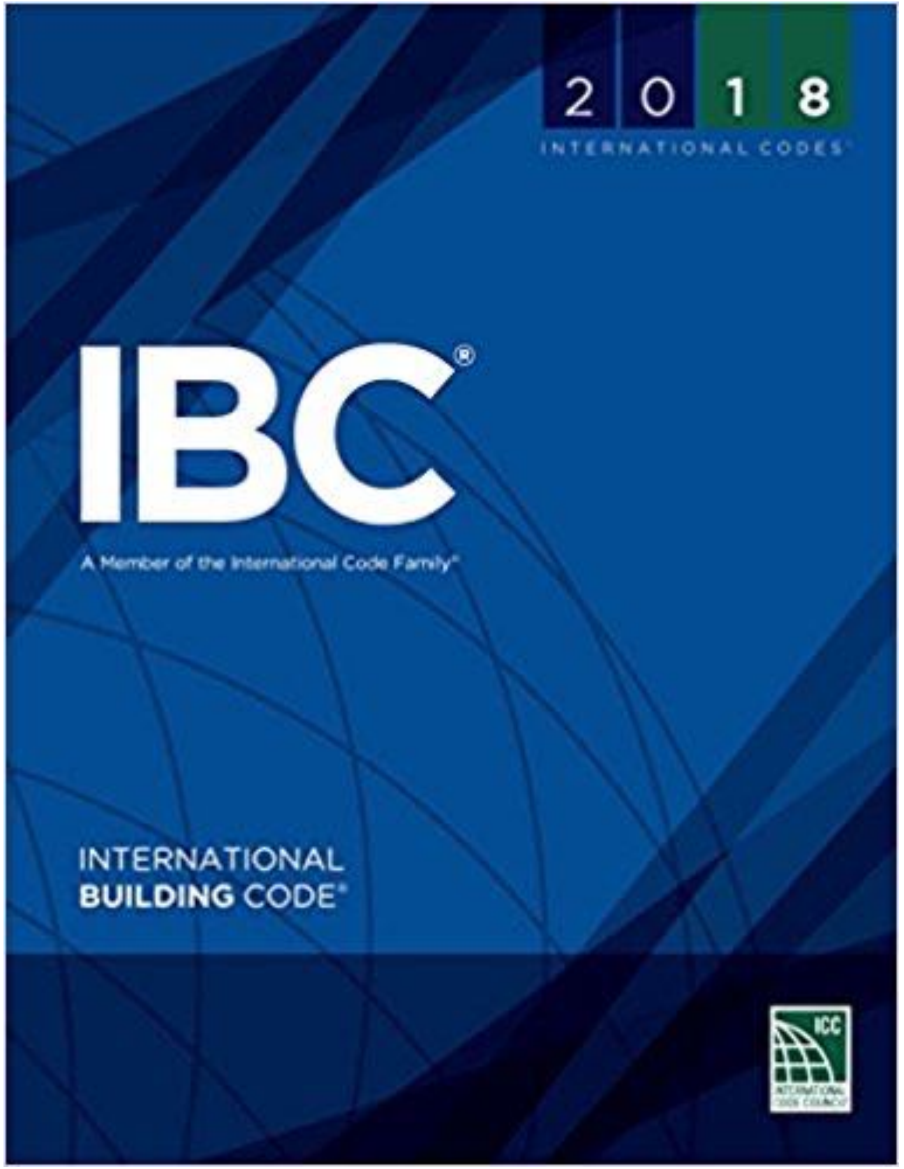


Construction Types

When does the code allow mass timber to be used?

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

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



Construction Types

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

8 Mass Timber Construction Types

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

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

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

Where does the code allow wood to be used?

» Mass Timber Roof Construction

Wellesley College, Wellesley, MA

Wellesley College Science Complex / Skidmore, Owings & Merrill / Le Messurier / Photo Dave Burk © SOM

Construction Types III-A, III-B

Type III Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - FRTW light-frame walls
  - FRTW mass timber (NLT, DLT)
    - Note: CLT not allowed

The Canyons, Portland, OR

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

Construction Types V-A, V-B

Type V Construction:

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

Star Lofts, Des Moines, IA

Image: Cutler Development

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

Type IV-HT Construction:

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

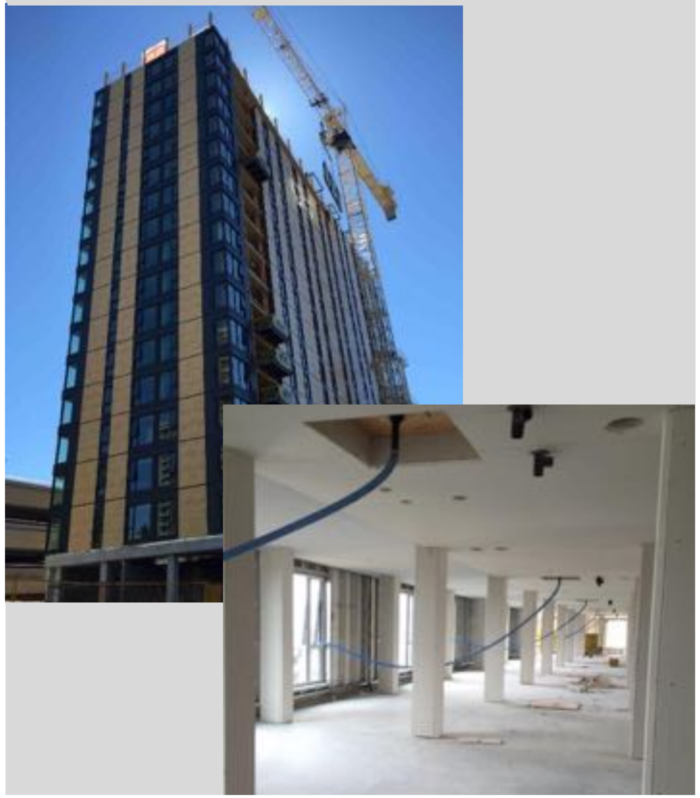
The Soto, San Antonio, TX

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

Construction Types IV-A, B, and C

» Business Occupancy (Group B) Size Limits:

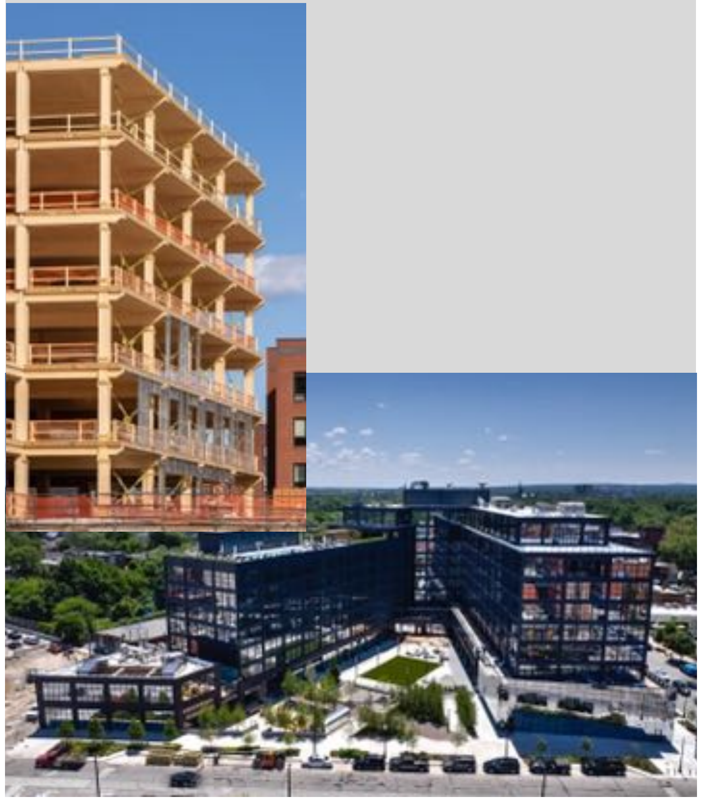
Type IV-A



Photos: Flor Projects

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

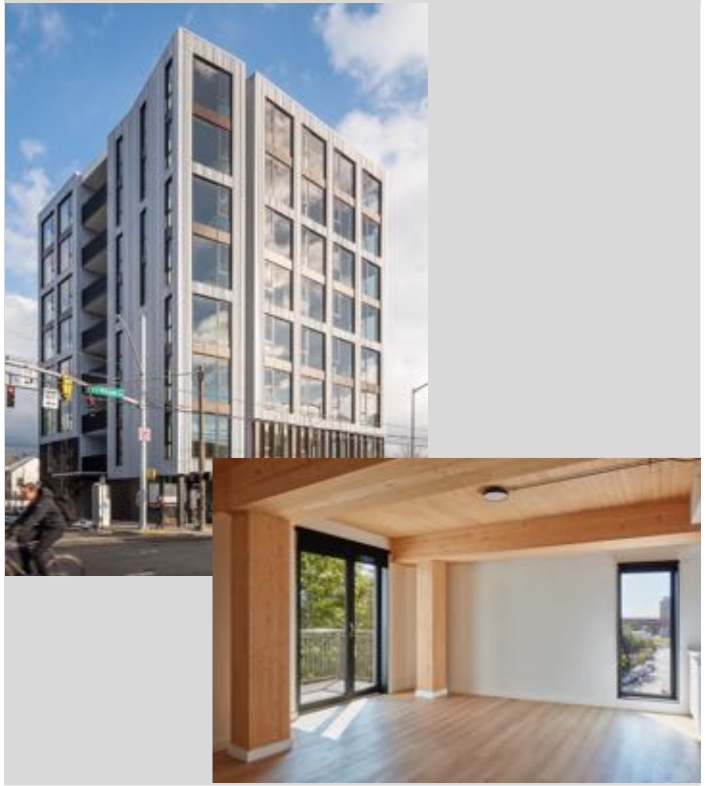
Type IV-B



Photos: ©Prakash Patel

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

Type IV-C



Monte French Design Studio, Photos: Jane Messinger

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

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

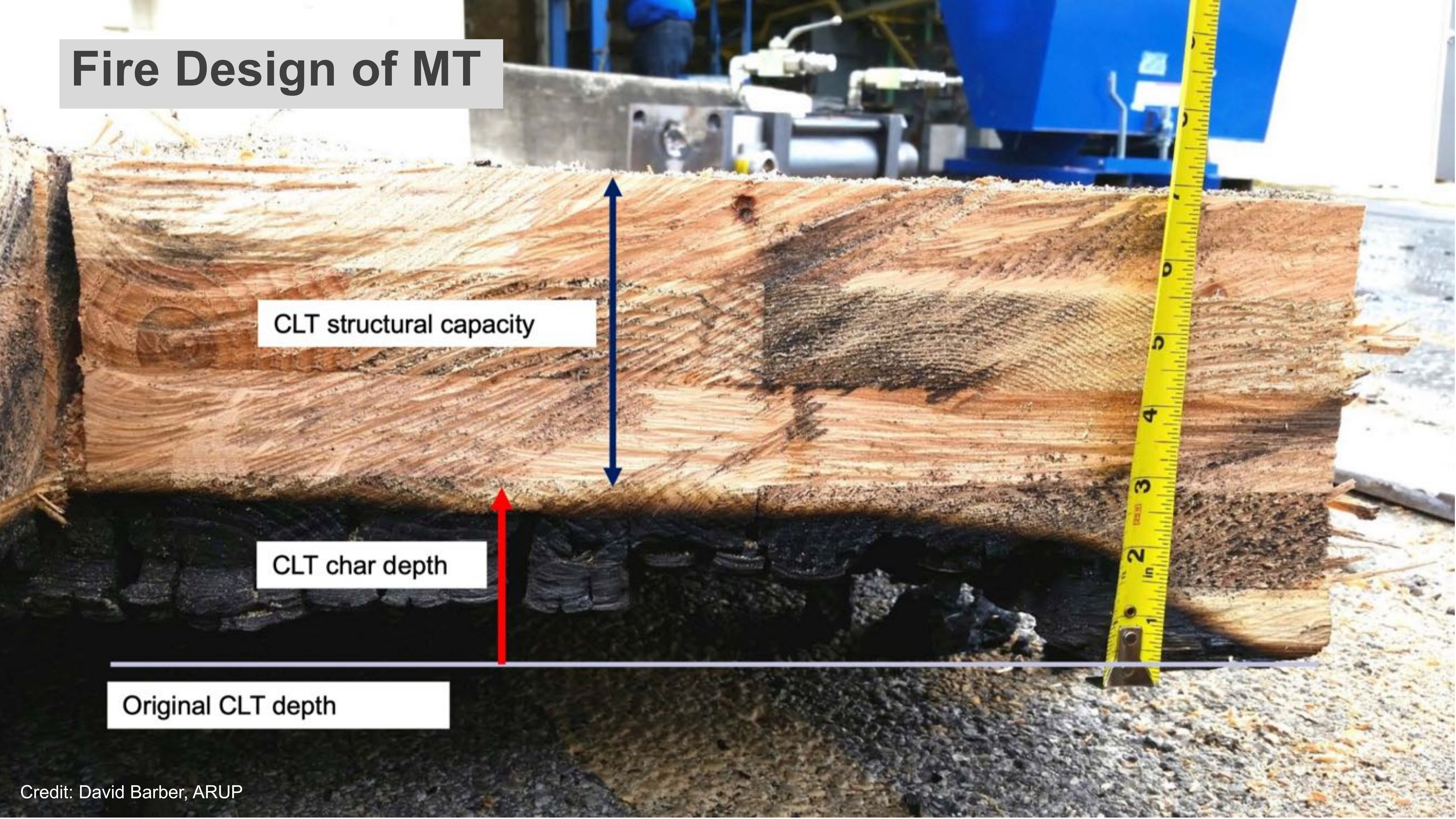
Type IV-A, B, and C Construction:

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

Heartwood, Seattle, WA

Heartwood, Atelier Jones, DCI Engineers, rendering Atelier Jones

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	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

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

GENERAL COST IMPACTS

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

Volume of Material

- Ensure you are using the right units!
  - Ft^3 or m^3, not BF as there are nominal, and net board feet.
- Ratio of material to enclosed floor area
  - 0.3 - 0.8 ft^3 / ft^2 general ratio
  - 1 hr FRR 0.5 – 0.65 ft^3 / ft^2
  - 2 hr FRR 0.65 – 0.7 ft^3 / ft^2
  - 3 hr FRR 0.72 – 0.8 ft^3 / ft^2
- Floor Plate to Gravity Frame:
  - 30% - 40% skeleton to 60 - 70% floor plate
  - IE: 35% Glulam, 65% CLT

GBC LIMBERLOST– PCL, MORIYAMA TESHIMA, ACTON OSTRY, FAST + EPP, NORDIC STRUCTURES,

To Purlin, or Not to Purlin?

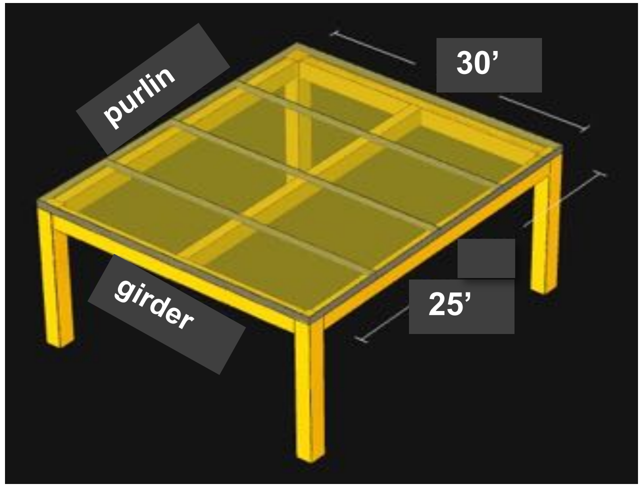
- Ratio of floor plate thickness to sqft of floor area
- There are many ways to reduce overall costs
    - Reduce floor plate thickness by:
        - Reducing grid size
          (shrink grid)
        - Reducing fire rating of wood
          (encapsulation)
        - Reducing plate span by adding purlins
          (add purlins)
    - 8-15 mins install per purlin
    - Install labor = ~15% costs, with 15% increase per grid for each purlin
    - Material = potential 40% material savings
        - Total costs = Materials (.65)*(1-.4)+(.15*1.15)+(.20) = 76% of cost for design without purlin, potential 24% savings.

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

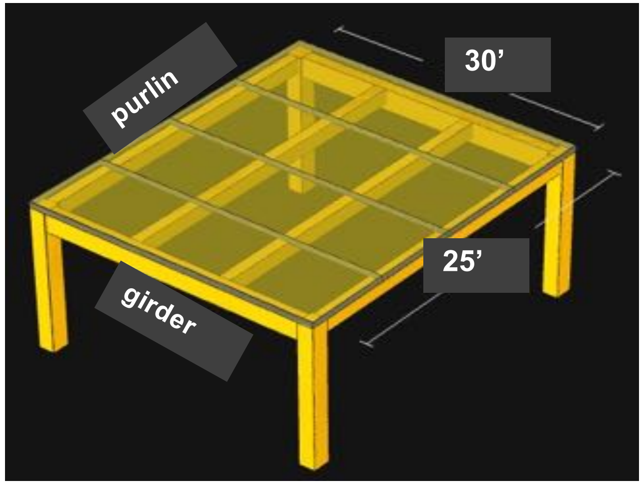
Type IIIA option 1
1-hr FRR
Purlin: 5.5”x28.5”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

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



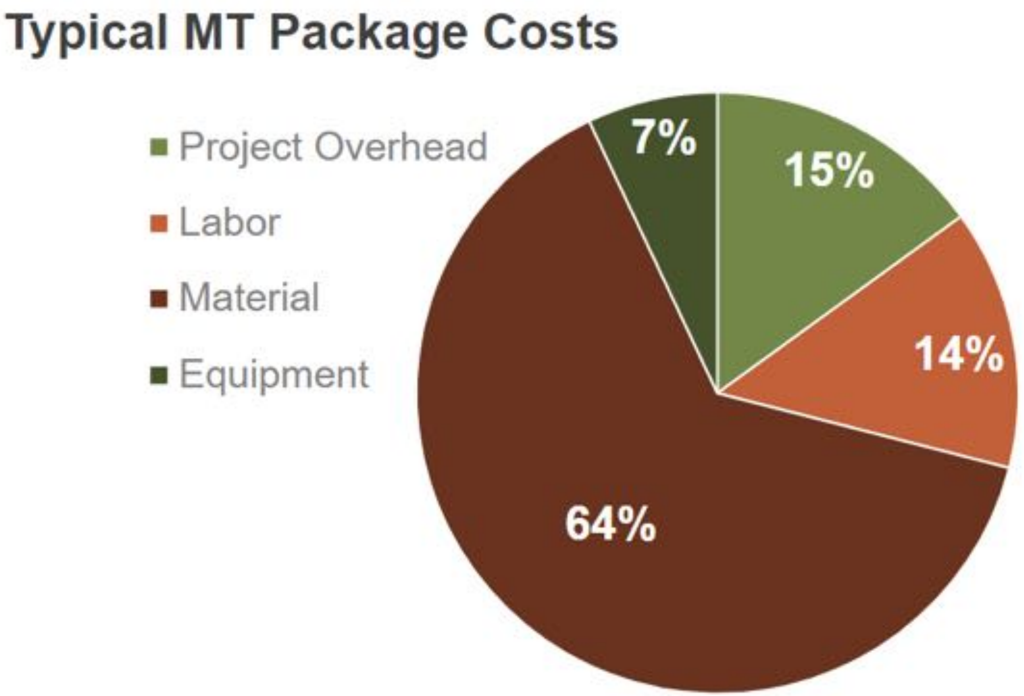
Type IV-HT
0-hr FRR (min sizes per IBC)
Purlin: 5.5”x24” (IBC min = 5”x10.5”)
Girder: 8.75”x33” (IBC min = 5”x10.5”)
Column: 10.5”x10.75” (IBC min = 6.75”x8.25”)
Floor panel: 3-ply (IBC min = 4” CLT)

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



Source: Fast + Epp, Timber Bay Design Tool

Handling and Install



- Mins per piece install

• Column	10 - 20
• Beam	8 - 15
• Brace/Frame	20 - 30
• Panel	8 – 10

- Example: With loaded labour rates at $150/ hr and a four person install crew the addition of one purlin would save 38% on the material + install package, and the addition of two purlins 45% based on shrinking material volume, but added labour time.
- Key is to ensure simple connections for smooth install.

Framing Complexity Factors

- Mass Timber pricing based on material volume, connection complexity, scope adders.
- Subject to CNC machine specifications but generally:

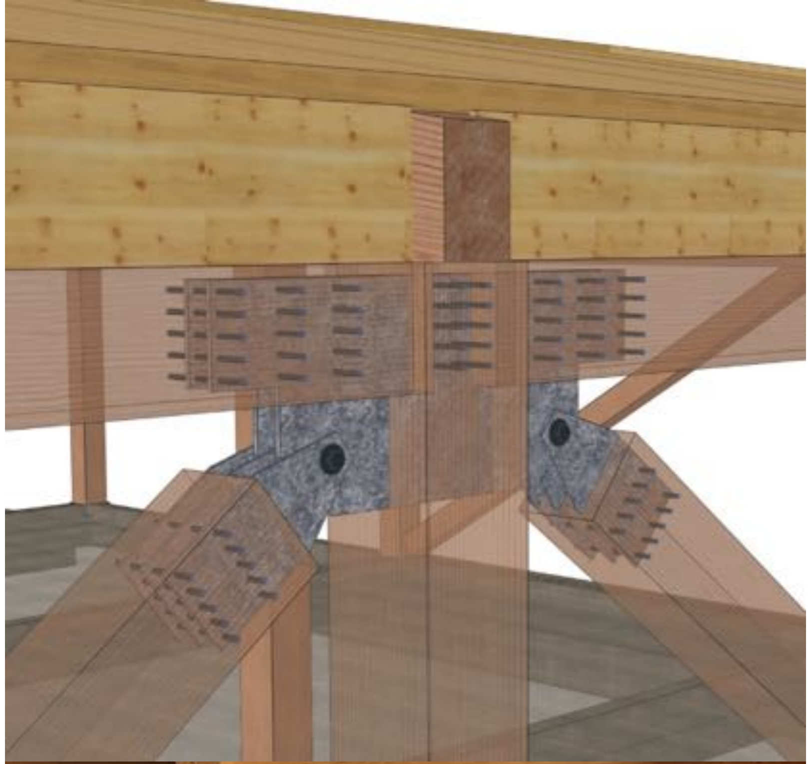
Glulam

2 mins: Trim to Length
10 mins: Simple
15 mins: Simple + Drillings
20 mins: Simple Knife Slots
30 mins: Medium
45 mins: Complex
60 mins: Big + Complex
90 mins: Difficult
120 mins: Weird Stuff

CLT

10 mins: Billet Trim
15 mins: Edge+ Spline
20 mins: Edge + Spline (Large)
30 mins: Nested Squares
45 mins: Nested Shapes
60 mins: Awkward Shapes
90 mins: Weird Stuff

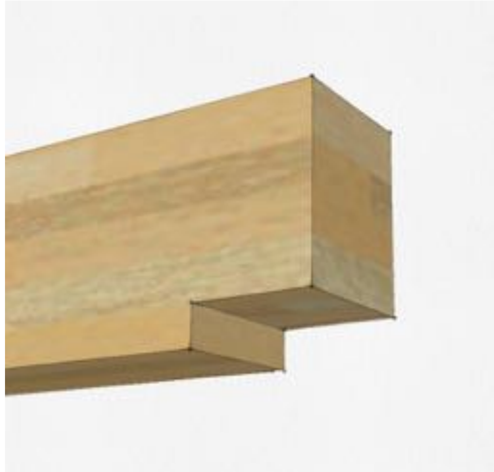
- CNC time charge anywhere from $150 – 1000 / hr
- Poor production throughput may result in a company charging a higher markup for risk, difficulty, and loss of production output.
- Complexity also correlates to 3D BIM design time, likely number of issues and overall schedule. BIM time at $60 - 175 / hr.



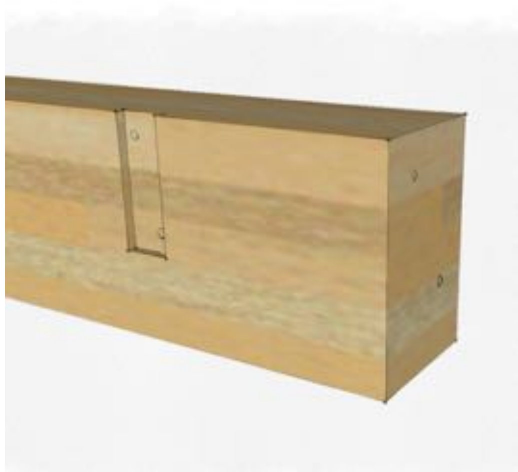
Glulam Beam CNC Time Samples

End connections, assumed the same on each end (x2)

PRECISION END TRIM
2 MINS

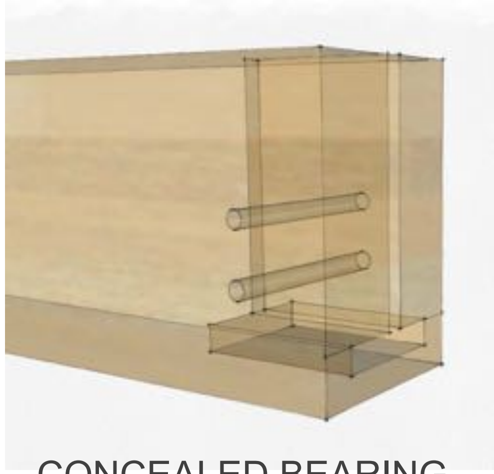


SIMPLE KNOTCH
8 MINS



PRE-ENG HANGER +
PURLIN HANGERS
15 MINS

SIMPLE KNIFE &
BEARING
20 MINS



CONCEALED BEARING
25 MINS

KNIFE SLOT + TIGHT FIT
PINS ARRAY
25 MINS

General scale of CNC framing time assuming Hundegger k2 style machine.

- There are key tooling limitations for slot depths, that greatly affect process time to understand some framing supplier.

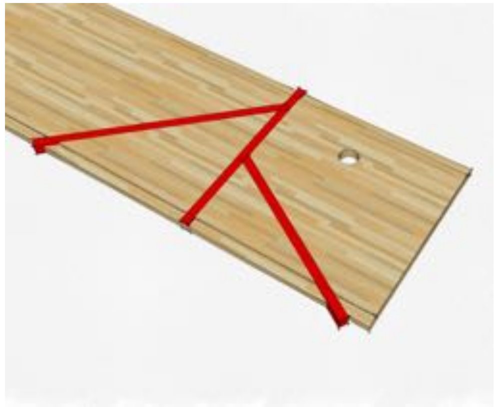
2 mins: Trim to Length
10 mins: Simple
15 mins: Simple + Drillings
20 mins: Simple Knife Slots
30 mins: Medium
45 mins: Complex
60 mins: Big + Complex
90 mins: Difficult
120 mins: Weird Stuff

CLT CNC Time Samples

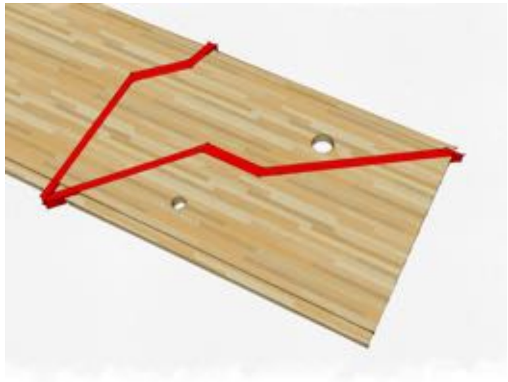
BILLET TRIM
10 MINS

EDGE + SPLINE
15-20 MINS

NESTED SQUARES
30 MINS



NESTED SHAPES
45 MINS



AWKWARD SHAPES
60 MINS

WEIRD STUFF
90+ MINS

General scale of CNC framing time assuming Hundegger PBA style machine.

- There are key tooling limitations for many tool heads and specific machines. Each supplier will vary +/- 20%
- Manufacture controls how nesting will occur.

10 mins: Billet Trim
15 mins: Edge+ Spline
20 mins: Edge + Spline (Large)
30 mins: Nested Squares
45 mins: Nested Shapes
60 mins: Awkward Shapes
90 mins: Weird Stuff

Cost & Schedule Savings

- Minimized site labor – Crew of 3-8 for install typical
- Scheduled overhead costs reduced (4 months to 2 months)
- Early occupancy
    - Reduced Insurance
    - Reduced Financing fees
    - Time value for occupancy

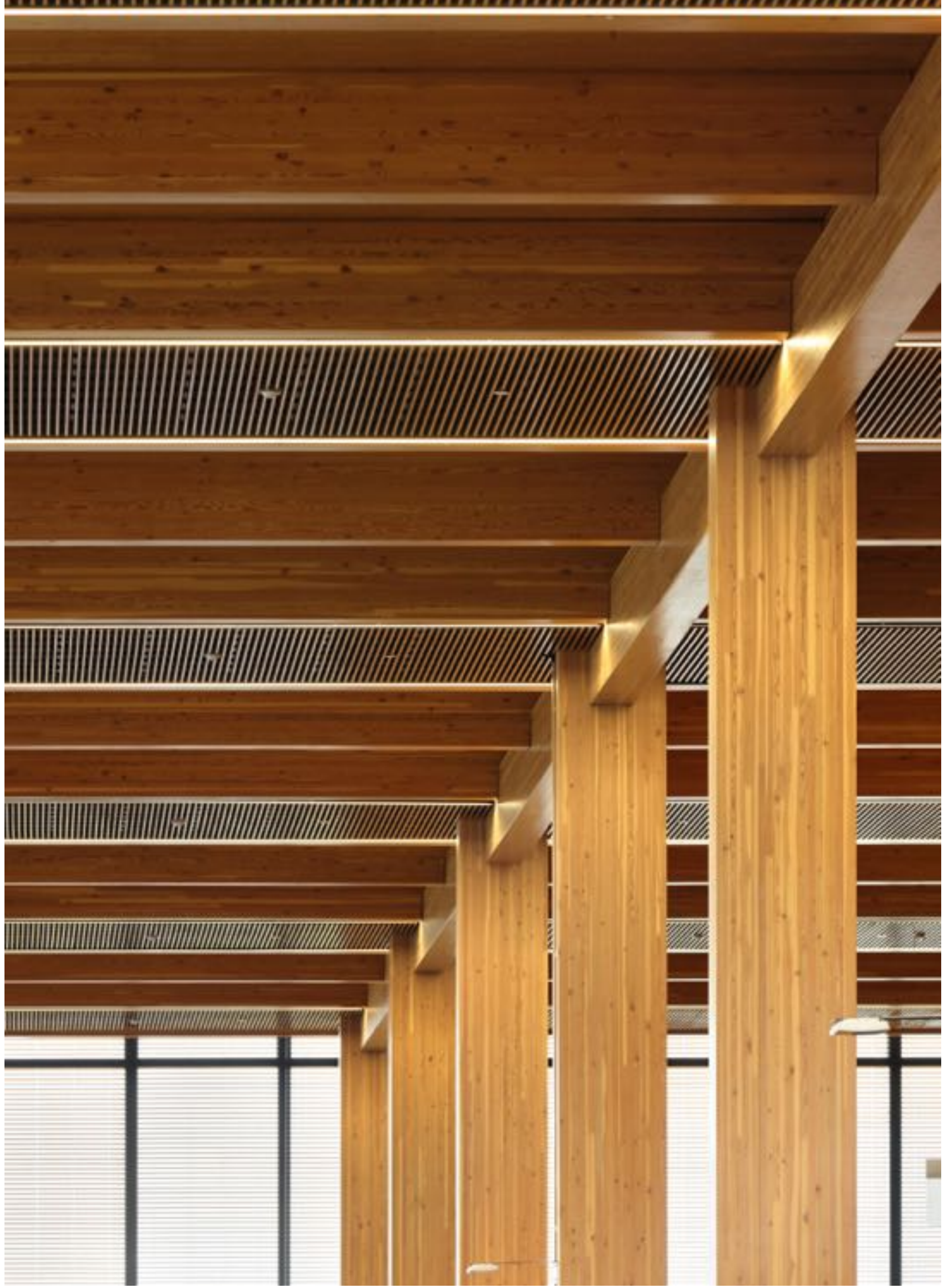
= Total potential savings

* Ensure other trades are prepared to capitalize on schedule and ensure time savings are holistically understood and executed upon

LTC ONE – DORNBIRN, AUSTRIA - CREE

Acoustics

- Potentially governing factor for building height
  - Can add significant material volumes to expensive cladding.
  - Can push building beyond regional building allowances.
- Potentially governing factor for foundation design
  - Dead load of concrete topping can be significant in both member sizing and foundation design sizes.
  - Topping slabs can be double used for diaphragm / composite systems, likely has construction schedule implications.
- Potentially governing factor for fire
  - Acoustics should be considered as part of fire resistance rating system; smoke penetration, and thermal transfers.



GOOGLE MT1 – MGA, XL CONSTRUCTION, EQUILIBRIUM, STRUCTURLAM

Penetrations

- Pre-coordinate
  - Bets done by Architect or GC, must be in BIM scope
  - Supply 3D model of penetrations to Engineer and MT supplier
- Each hole is usually not too hard to cut if less than 8” deep
- Rule of thumb, 4 penetrations per panel is a good target
  - Roughly 2 mins per hole
  - Think of implications for many holes to CNC time.
  - Target holes under 6” diameter.

FIRST TECH CREDIT UNION –SWINERTON, HACKER ARCHITECTS, EQUILIBRIUM, STRUCTURLAM,

Finished Surfaces

- Potentially governing for acoustics
  - Exposed vs. concealed
  - Estimated 50% increase in acoustic system costs for exposed underside of CLT
- Potentially governing for fire
  - Exposed vs. concealed
  - Each sheet of ½” Type X = 30 mins FRR
- Coatings: when and where?
  - Top side for moisture protection
  - Edges for moisture and checking
  - Bottom side for finished surface? How does this work during transport damages and course of construction?

CARBON 12 – KAISER GROUP, STRUCTURLAM, PATH ARCHITECTURE

Effective Design Rules of Thumb

- **Visuals**
  - Is the mass timber exposed or not?
    - Dictates large part of fire strategy
    - Dictates large part of acoustic system
- **Acoustics**
  - Top or bottom side? Dry or wet system?
- **Grid size**
  - Smaller can save material, or rectangular and remove perimeter beams and provide great options
- **Connection complexity**
  - Minimize fasteners, simple cut outs, fire protected, wood to wood when possible
- **Install sequencing**
  - Plan crane positions, and truck load arrivals of material sequenced to job site with installer
  - Coordinate during “Offered for Approval” drawing review with MT supplier

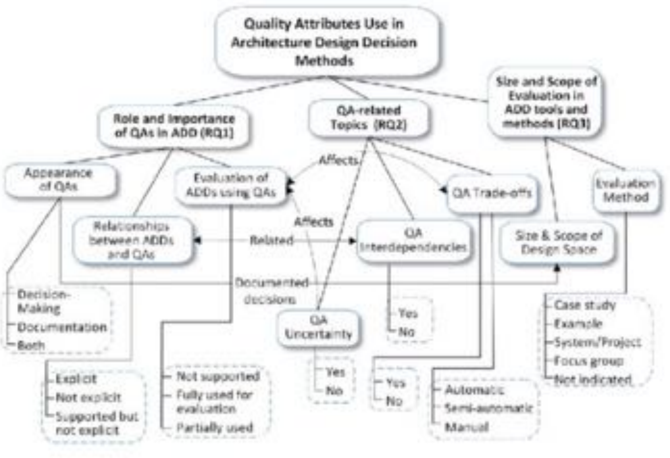
oN5– HEMSWORTH ARCHITECTURE, TIMBER ENGINEERING, NAIKOON, KATERRA

Sample Synchronized Relationships

- Visual → Acoustics
  → Fire → Dead load → Member sizes → Foundation sizes

- MEP strategy → Purlins → Grid size → Panel thickness
  → Envelop & ceiling heights → Acoustics

- Acoustics → Concrete topping → Dead load → Fire Performance → Panel Thickness
  → Foundation sizes



Complex set of interactions, but which are the best to focus on?

MASS TIMBER DESIGN CORRELATION MATRIX

BASE SYSTEM DECISION

		Fire Strategy	Purlins	Grid size	Visual Exposure	MEP	Acoustic System	Foundation Design
AFFECTED SYSTEMS RELATIONSHIPS	Fire Strategy	X	3	3	5	2	4	0
	Purlins	3	X	4	0	5	0	0
	Grid Size	3	2	X	1	2	0	3
	Visual Exposure	5	0	1	X	4	5	0
	MEP	2	5	2	4	X	2	0
	Acoustic System	4	0	0	5	2	X	0
	Foundation Design	0	2	3	0	0	0	X
IMPACTS ONLY	Panel Thickness	4	5	4	4	0	2	1
	Concrete Topping	2	0	1	0	1	4	5
	Building Height	4	4	3	1	2	3	1
	Structural Size	4	5	5	4	2	1	3
	Overall Impact:	**3.1**	**2.6**	**2.6**	**2.4**	**2.0**	**2.1**	**1.3**

Structural Grid

Uni-directional beams

Duda|Paine Architects
Thornton Tomasetti
Photo: WoodWorks

Bi-directional beams

Powell Studio Architecture
Gutherman Structural
Photo: WoodWorks

Stacked purlins on girders

Handel Architects
StructureCraft
Photo: StructureCraft

Double beams

Monte French Design Studio
H+O Structural Engineers
Photo Jane Messinger

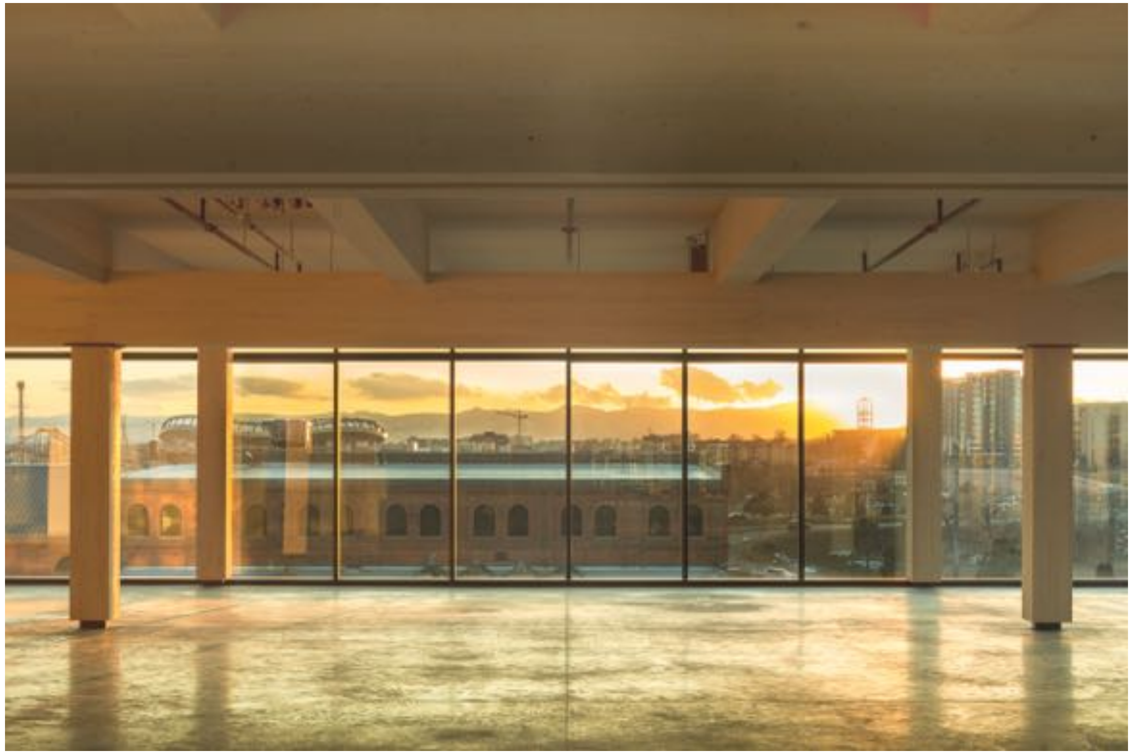
Structural Grid

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



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

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

Structural Grid

Member Sizes

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

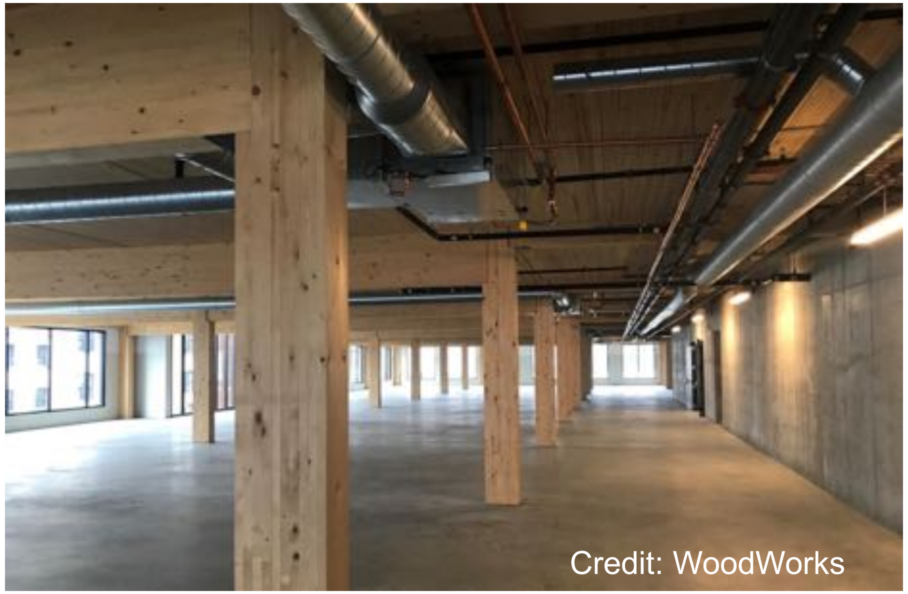
1 or 2 HR FRR: Likely 5-ply Panel

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

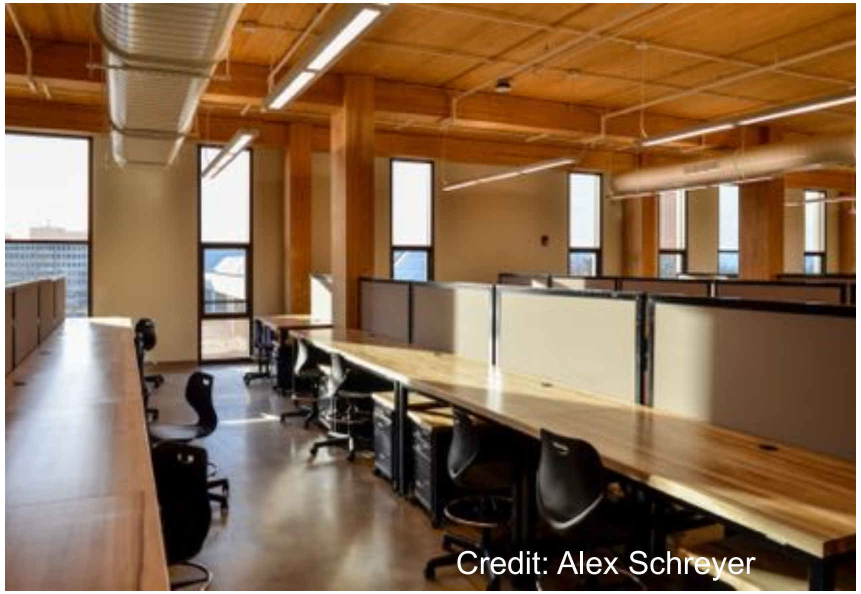
Clay Creative, Portland, OR
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie

MEP Layout & Integration

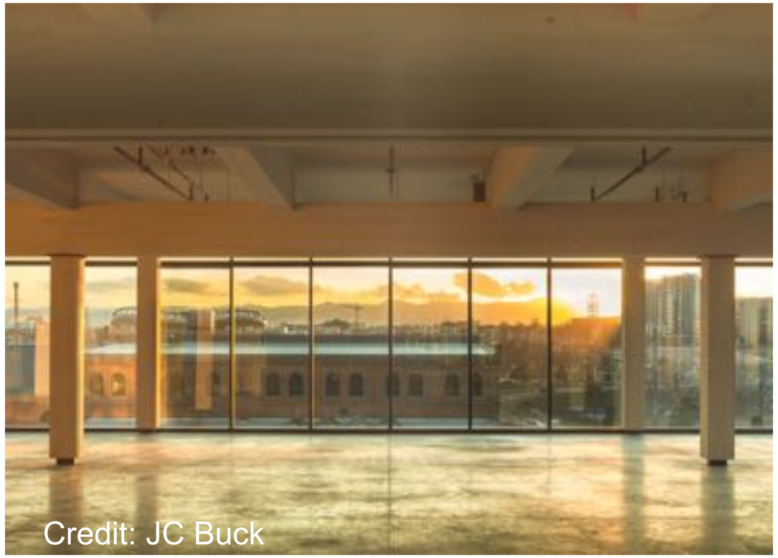
MEP Layout & Integration


Credit: WoodWorks


Credit: Global IFS

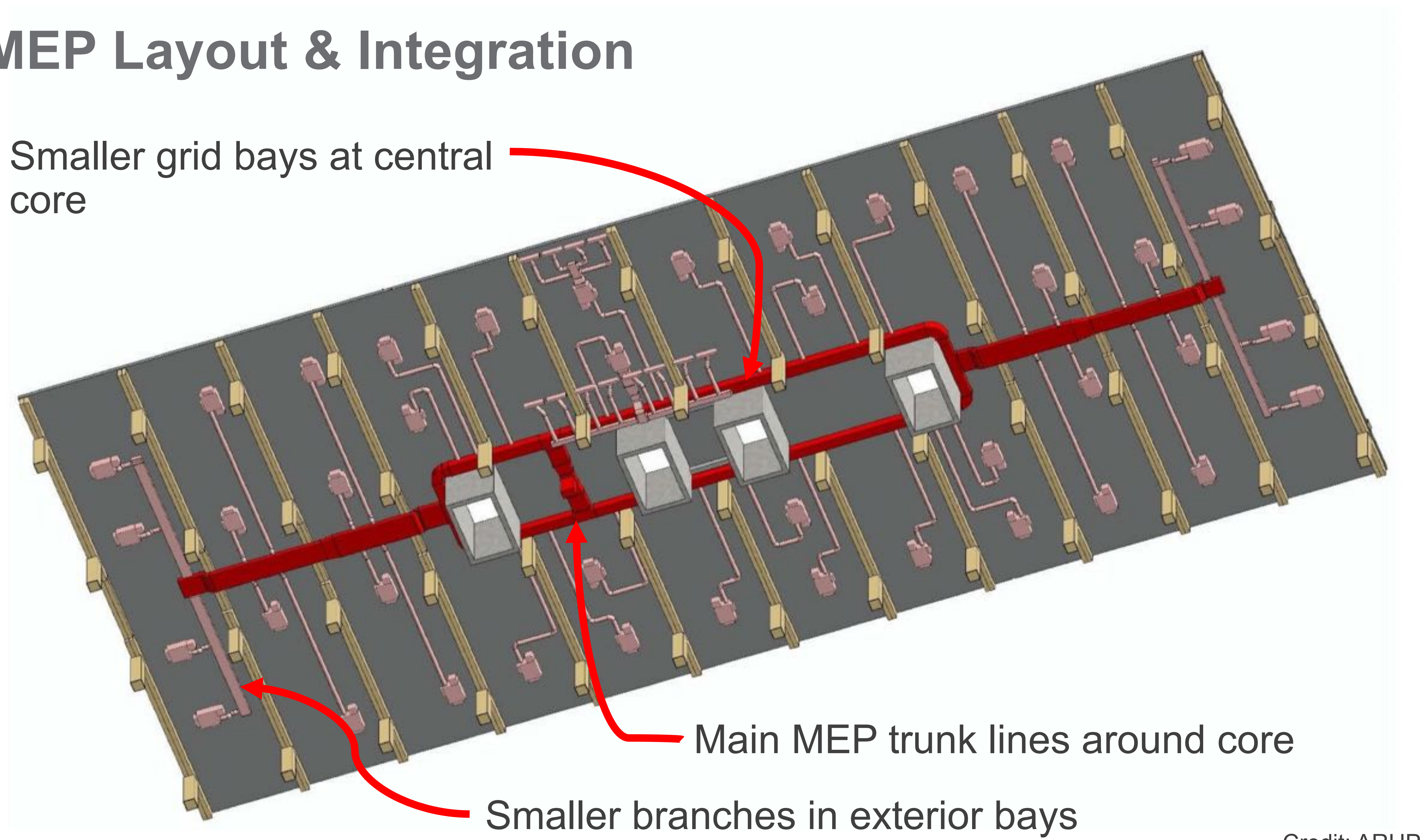

Credit: Alex Schreyer


Credit: WoodWorks


Credit: JC Buck


Credit: Hacker Architects

MEP Layout & Integration



Credit: ARUP

What Impacts Mass Timber Costs?

Fire Rating
Piece Count Penetrations Crane Grid Size
Structural Loads Site Logistics Acoustics
Wood Volume Labor
Transportation Occupancy Complexity
Code Version Insurance Steel Volume
MEPF
Design Complexity Visual Finish

Questions?

Nicholas Sills

Whirlwind Consultants

250.551.2735

[nsills@whirlwindconsultants.com]

Ricky McLain, PE, SE

WoodWorks

(802)498-3310

[Ricky.mclain@woodworks.org]

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

Funding provided in part by the Softwood Lumber Board