EFFICIENT STRUCTURAL DESIGNS FOR MASS TIMBER BUILDINGS: THE ENGINEER'S ROLE IN OPTIMIZATION

WoodWorks™
WOOD PRODUCTS COUNCIL

KL&A
Engineers & Builders

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Photo: Michael Green Architecture

KEY EARLY DESIGN DECISIONS

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

Grids & Spans
Construction Type
Fire-Resistance Ratings
Member Sizes
MEP Layout

Exposed Timber (where & how much)
Acoustics
Concealed Spaces
Connections
Penetrations

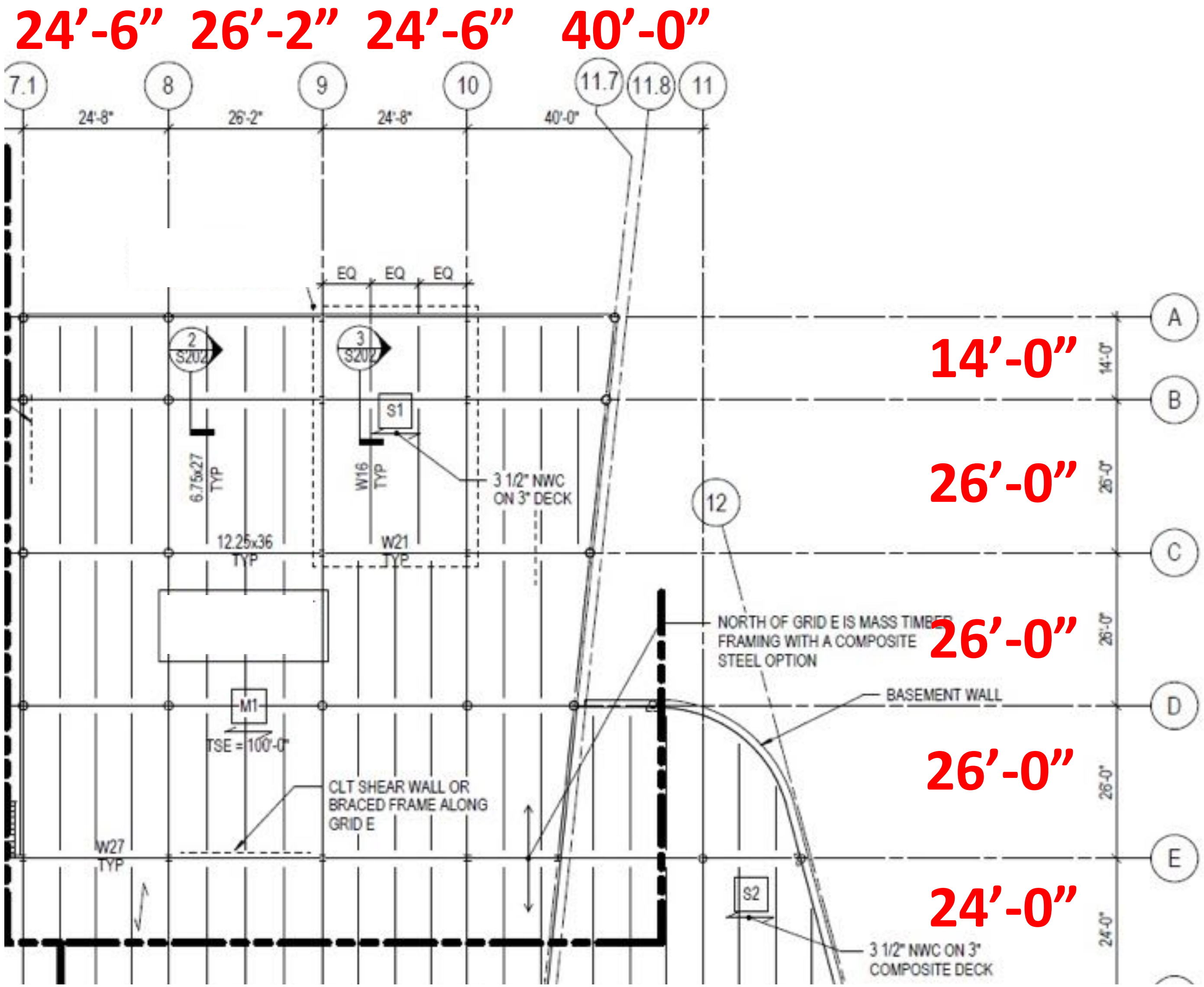
The Answer is…They All Need to Be Weighed (Plus Others)

Photo: Hickok Cole

KEY EARLY DESIGN DECISIONS

Grids & Spans

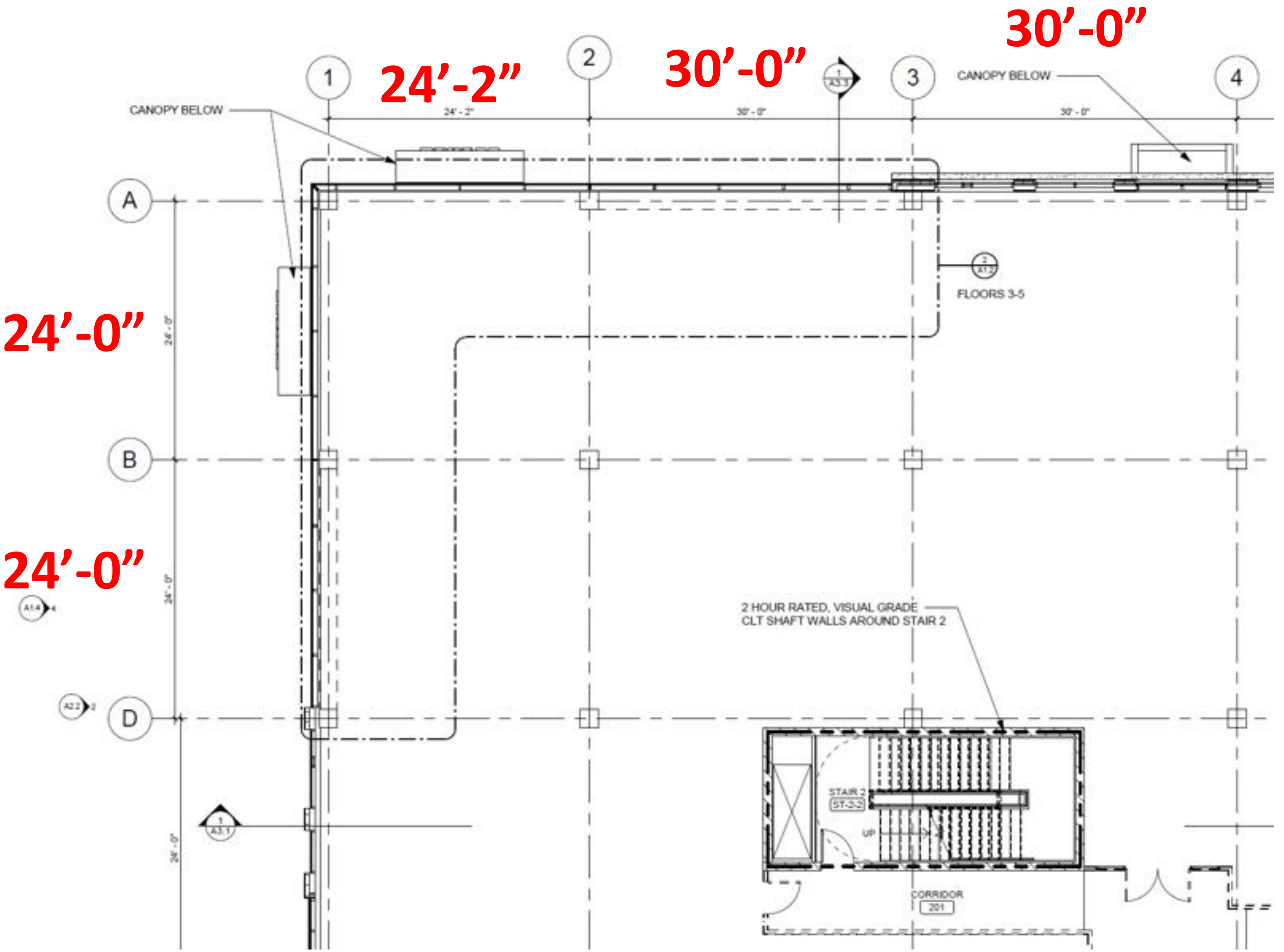
- Consider Efficient Layouts
- Repetition & Scale
- Cost and Volume of Timber
- Manufacturer Panel Sizing



KEY EARLY DESIGN DECISIONS

Grids & Spans

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



KEY EARLY DESIGN DECISIONS

Construction Type

	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
- Rated Structure or Not?
- Rating achieved through timber alone or non-com protection required?

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[a, 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

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

Panel	Example Floor Span Ranges
3-ply CLT (4-1/8" thick)	Up to 12 ft
5-ply CLT (6-7/8" thick)	14 to 17 ft
7-ply CLT (9-5/8")	17 to 21 ft
2x4 NLT	Up to 12 ft
2x6 NLT	10 to 17 ft
2x8 NLT	14 to 21 ft
5" MPP	10 to 15 ft


Credit: David Barber, ARUP

KEY EARLY DESIGN DECISIONS

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

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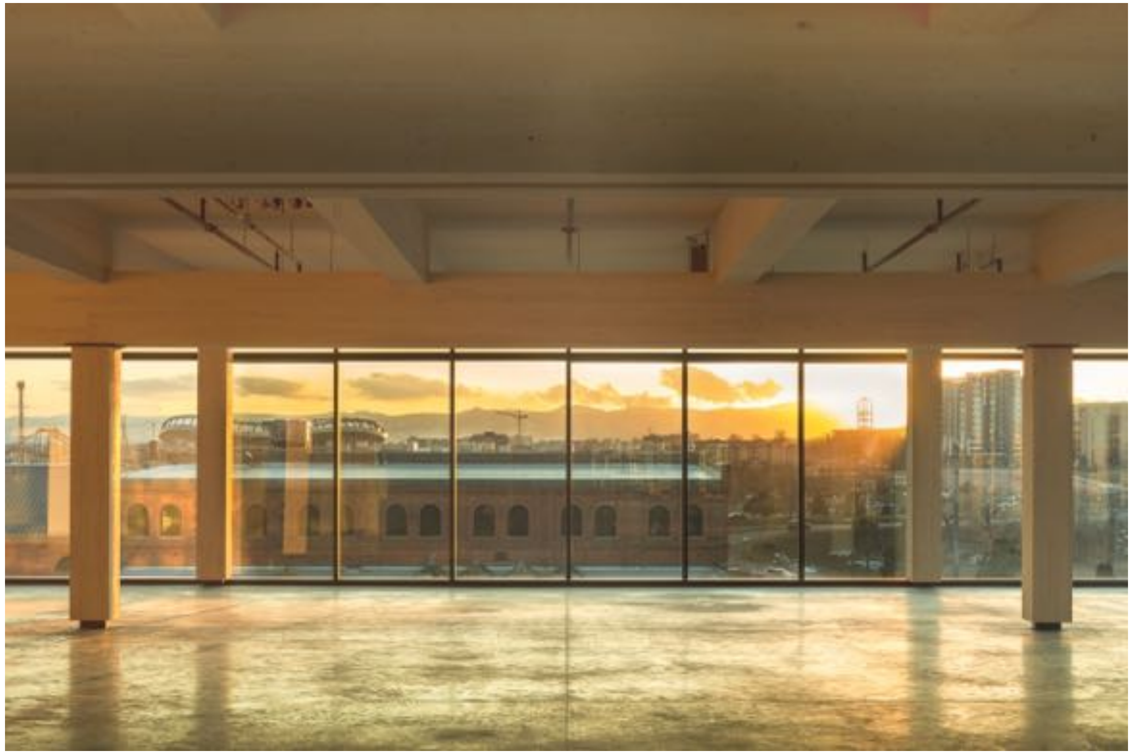

Platte Fifteen, Denver, CO
30x30 Grid, 2 purlins per bay
3-ply CLT
Image: JC Buck

KEY EARLY DESIGN DECISIONS

Member Sizes

- Impact of FRR on Sizing
- **Impact of Sizing on Efficient Spans**
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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

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

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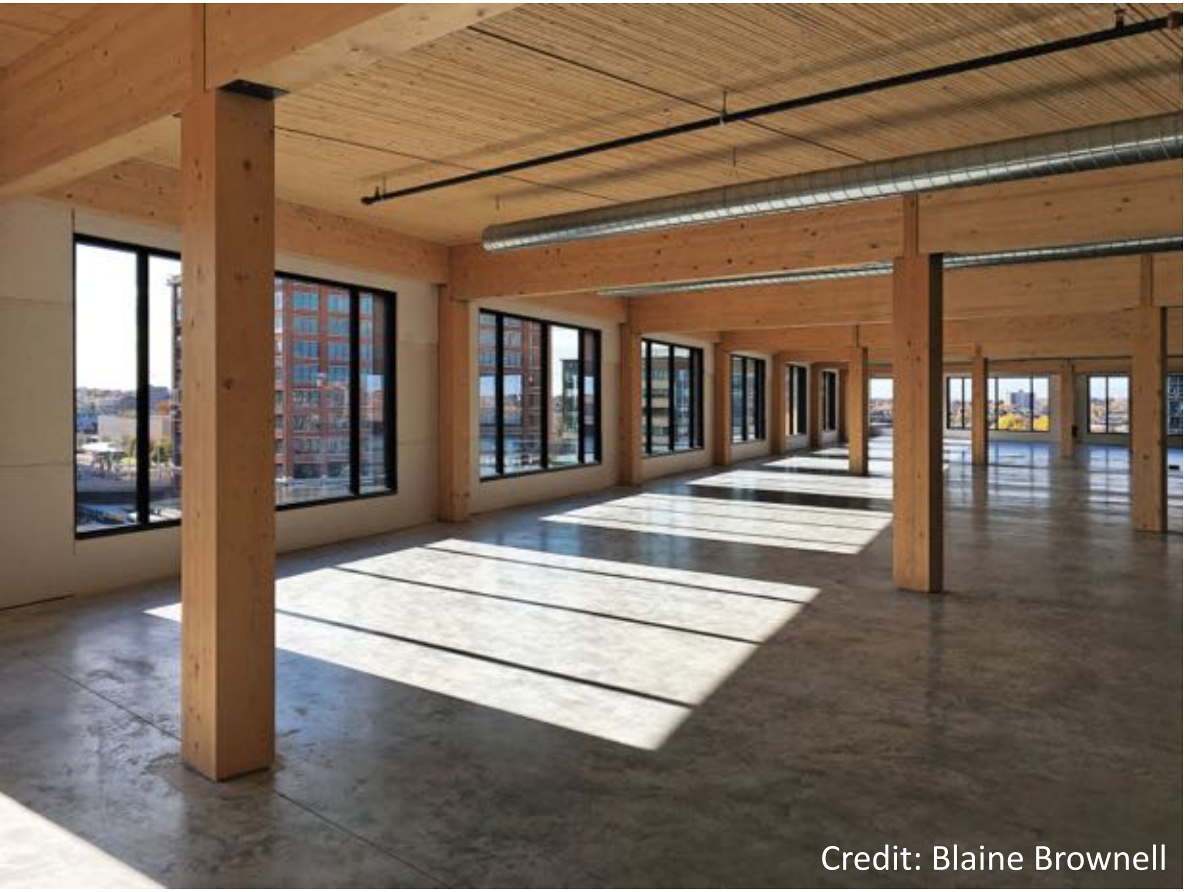
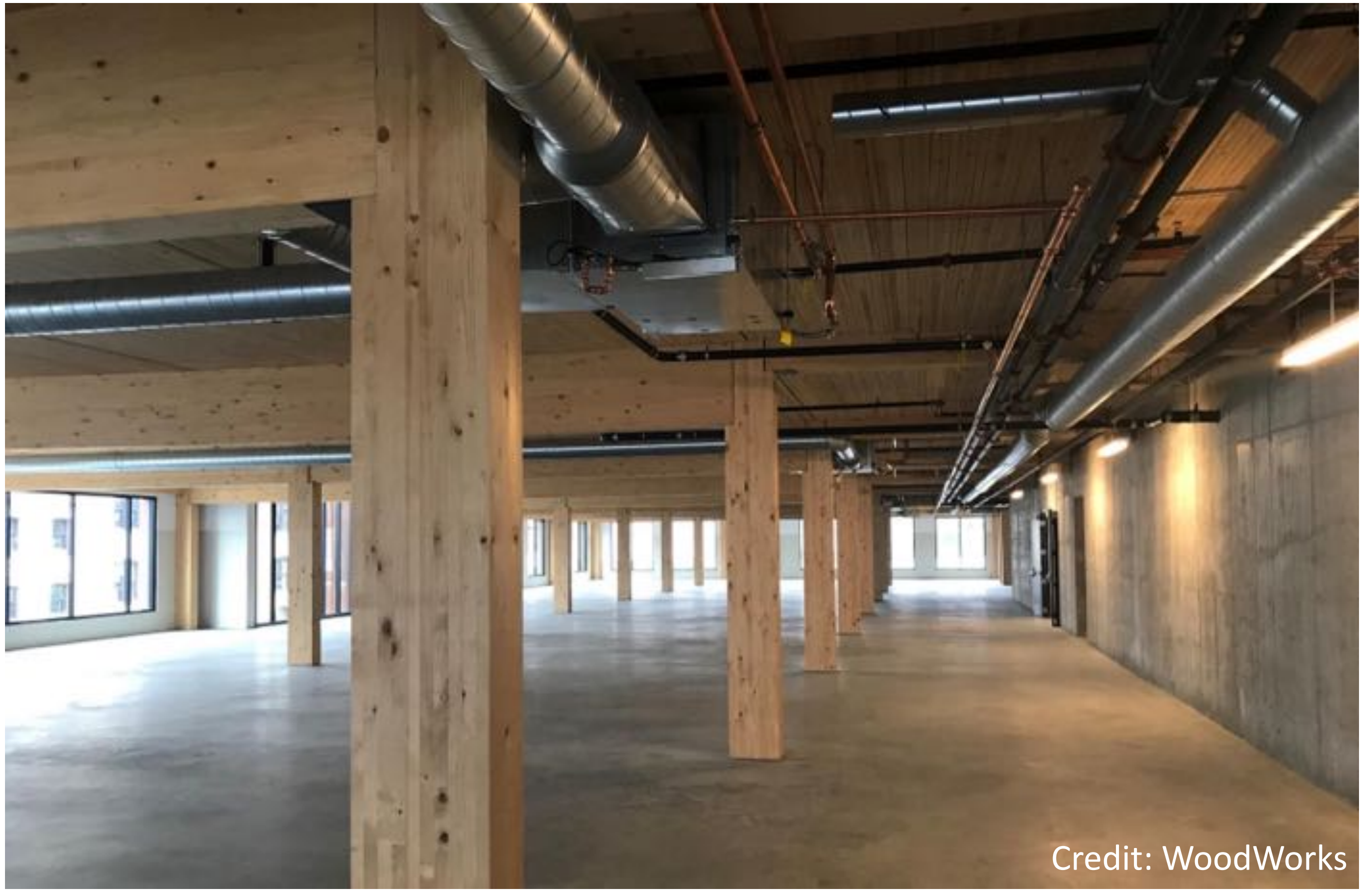
Clay Creative, Portland, OR
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie

KEY EARLY DESIGN DECISIONS

MEP Integration: Smaller Bay at Central Core, Branches in Exterior Bays





KEY EARLY DESIGN DECISIONS

MEP Integration: Dropped Below MT Framing


Credit: Alex Schreyer

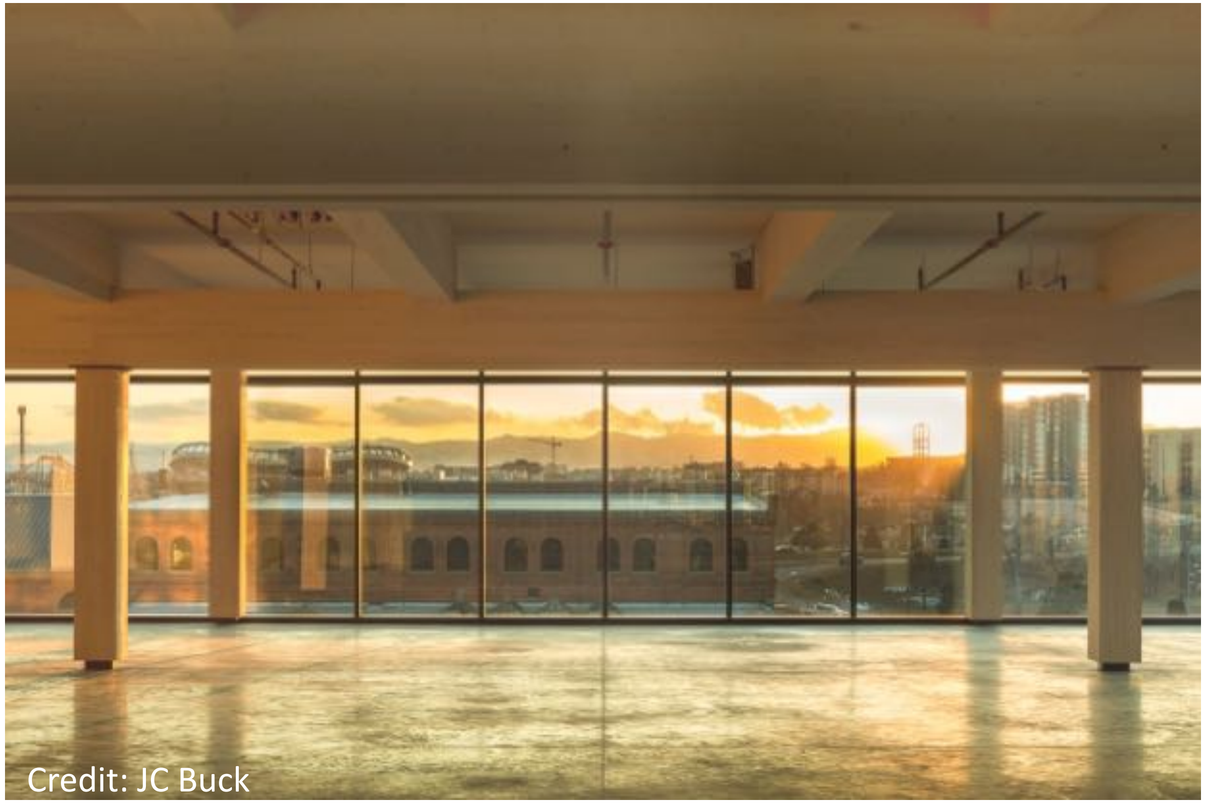

Credit: WoodWorks

KEY EARLY DESIGN DECISIONS

MEP Integration: Penetrations Through MT Framing

KEY EARLY DESIGN DECISIONS

MEP Integration: Under Slab, Through Chases



Credit: JC Buck

Credit: KL&A Engineers & Builders

KEY EARLY DESIGN DECISIONS

MEP Integration: In RAF Above MT Panels

World Conference on Timber Engineering

Efficient Structural Designs for Mass Timber Buildings:

The Engineer's Role in Optimization

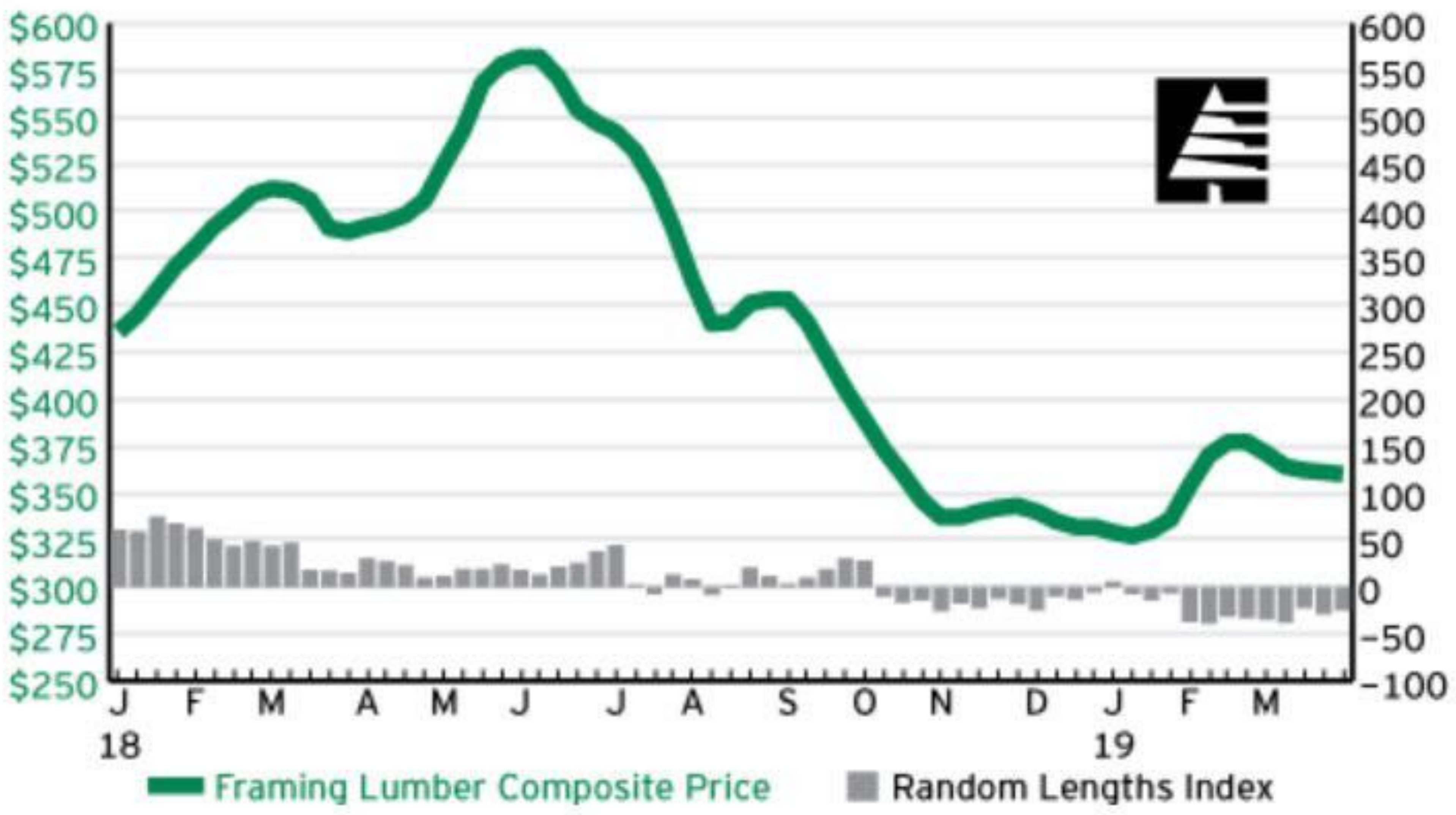
By Ricky McLain and Greg Kingsley

Part 2: Grid Cost Studies on Colorado Mass Timber Projects

KL&A Engineers & Builders

UNIT COSTS

MASS TIMBER COST DEPENDS ON THE PRICE OF LUMBER



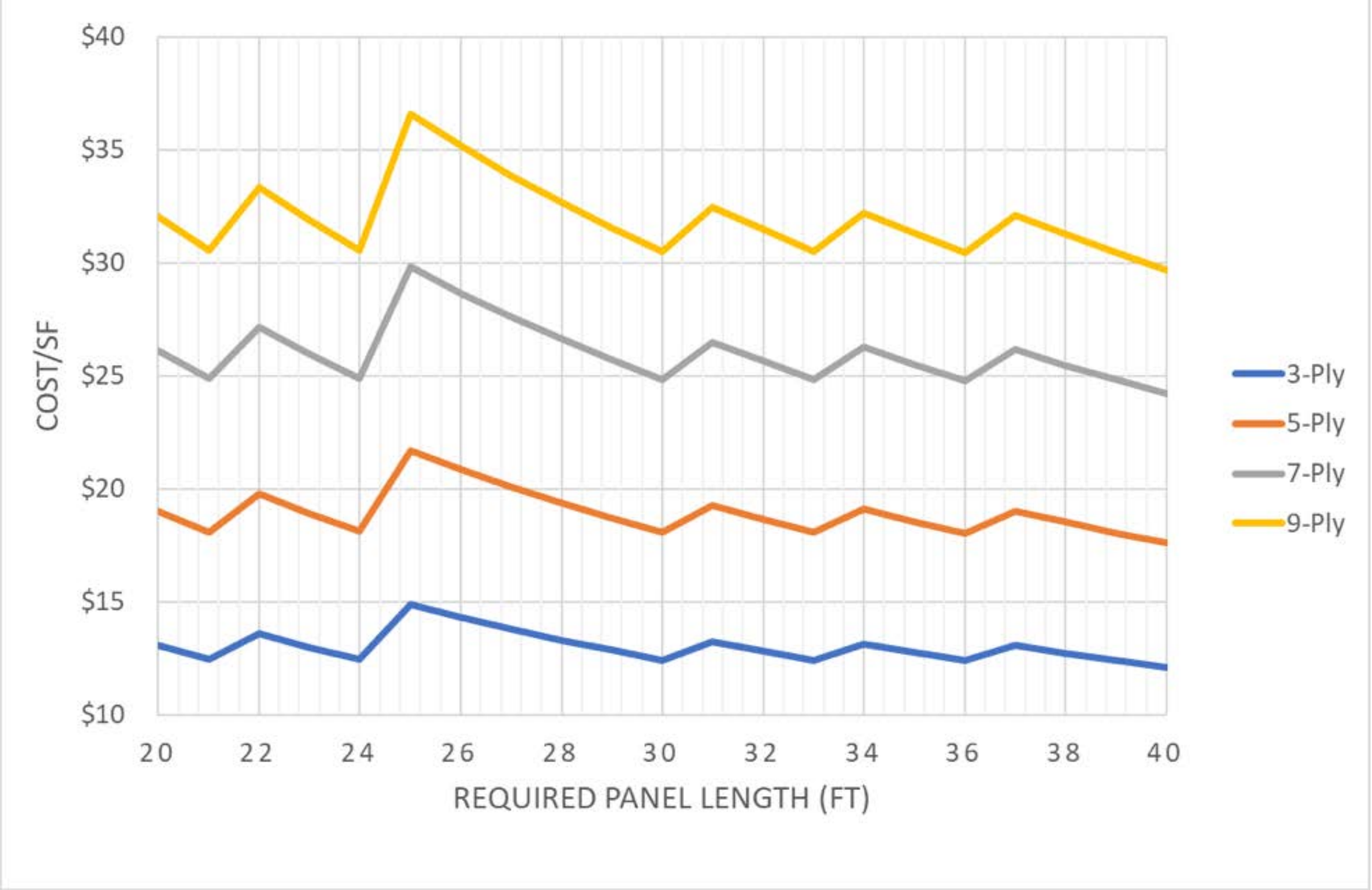
CLT COST DEPENDS ON VOLUME AND EFFICIENCY

Conceptual cost of CLT is intended to include:

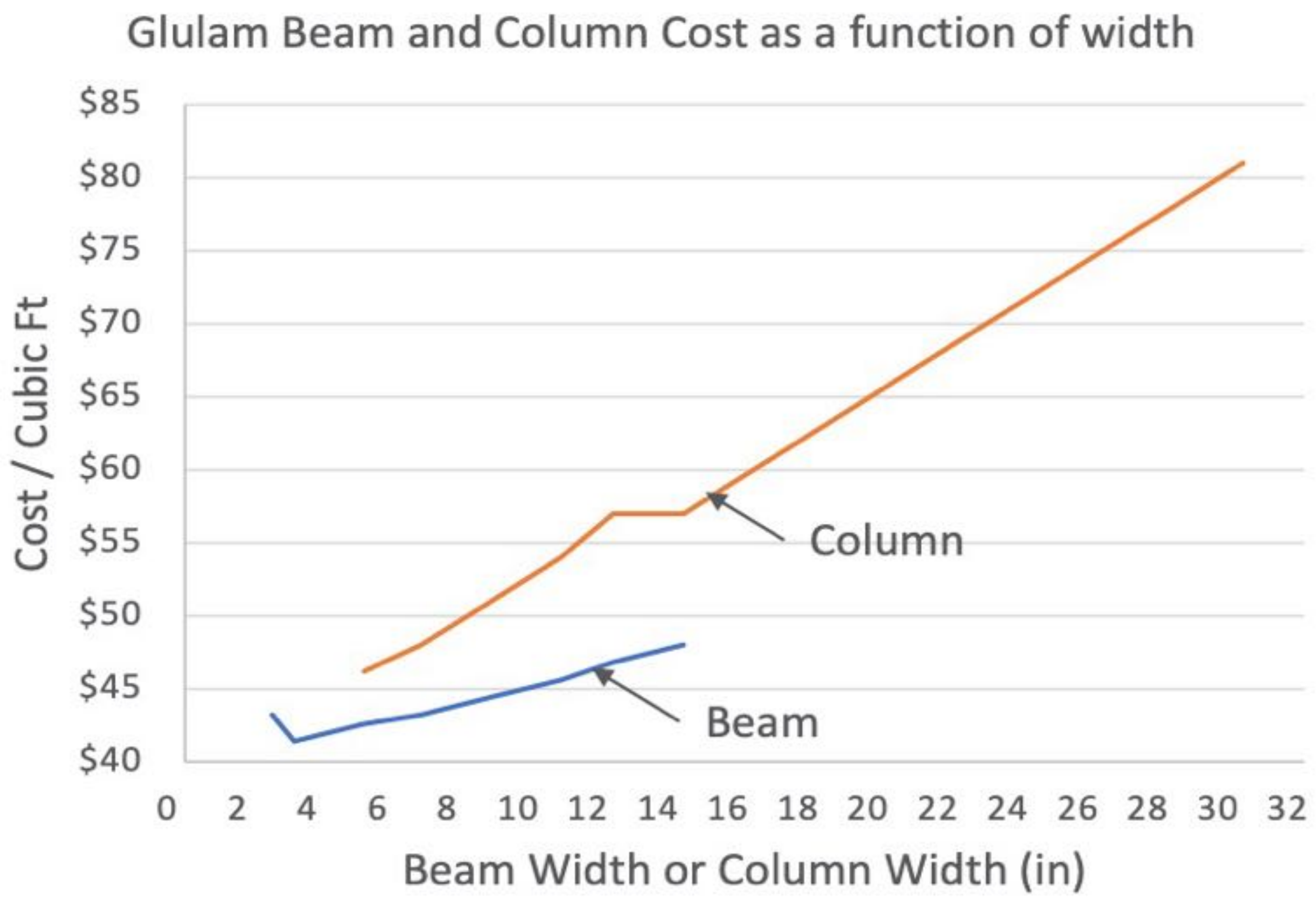
- CLT
- Shop fab
- Sanding
- Delivered
- Screws

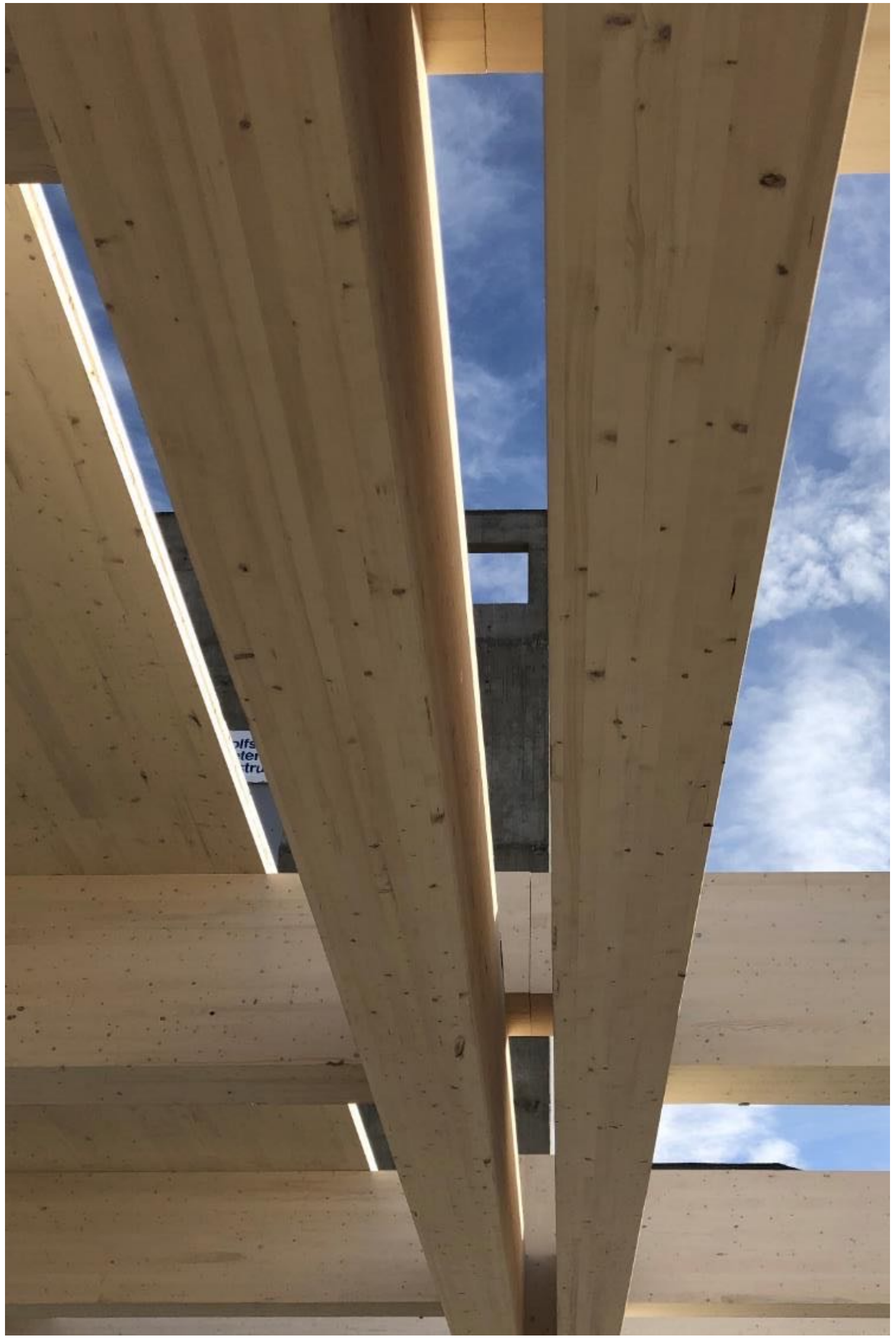
but does **not** include:

- Finishes

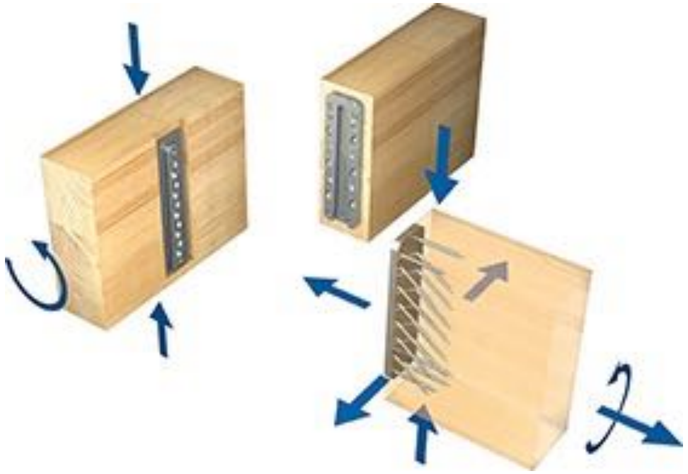


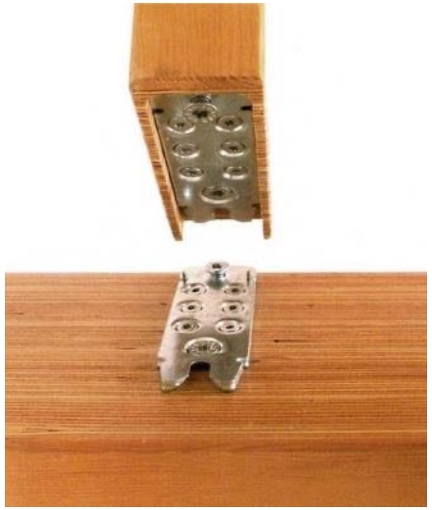
GLULAM BEAM AND COLUMN COST





Connection Cost – Different Connection “Classes”





Connection Cost based on “Connection Class”

Cost for each class is based on …

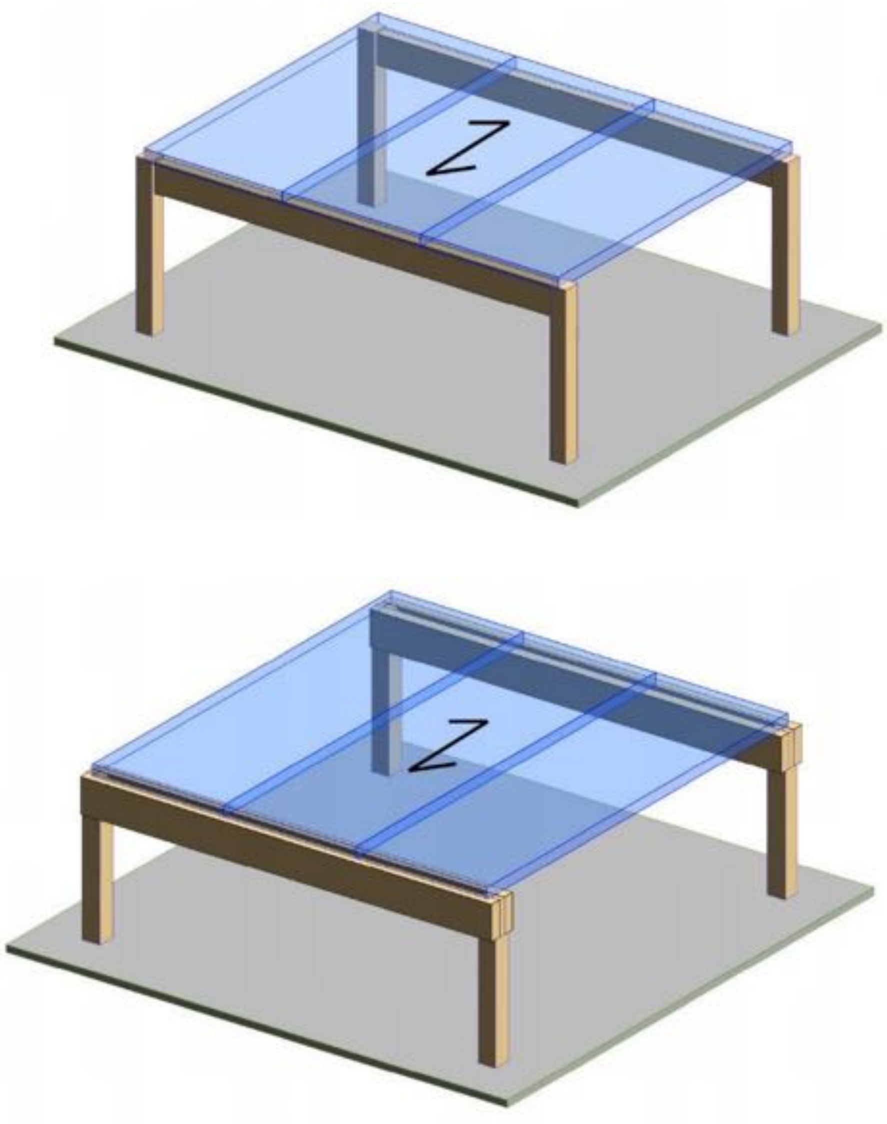
- Connection material
- Screws and bolts
- Beam end fabrication
- Girder fabrication
- Field Installation

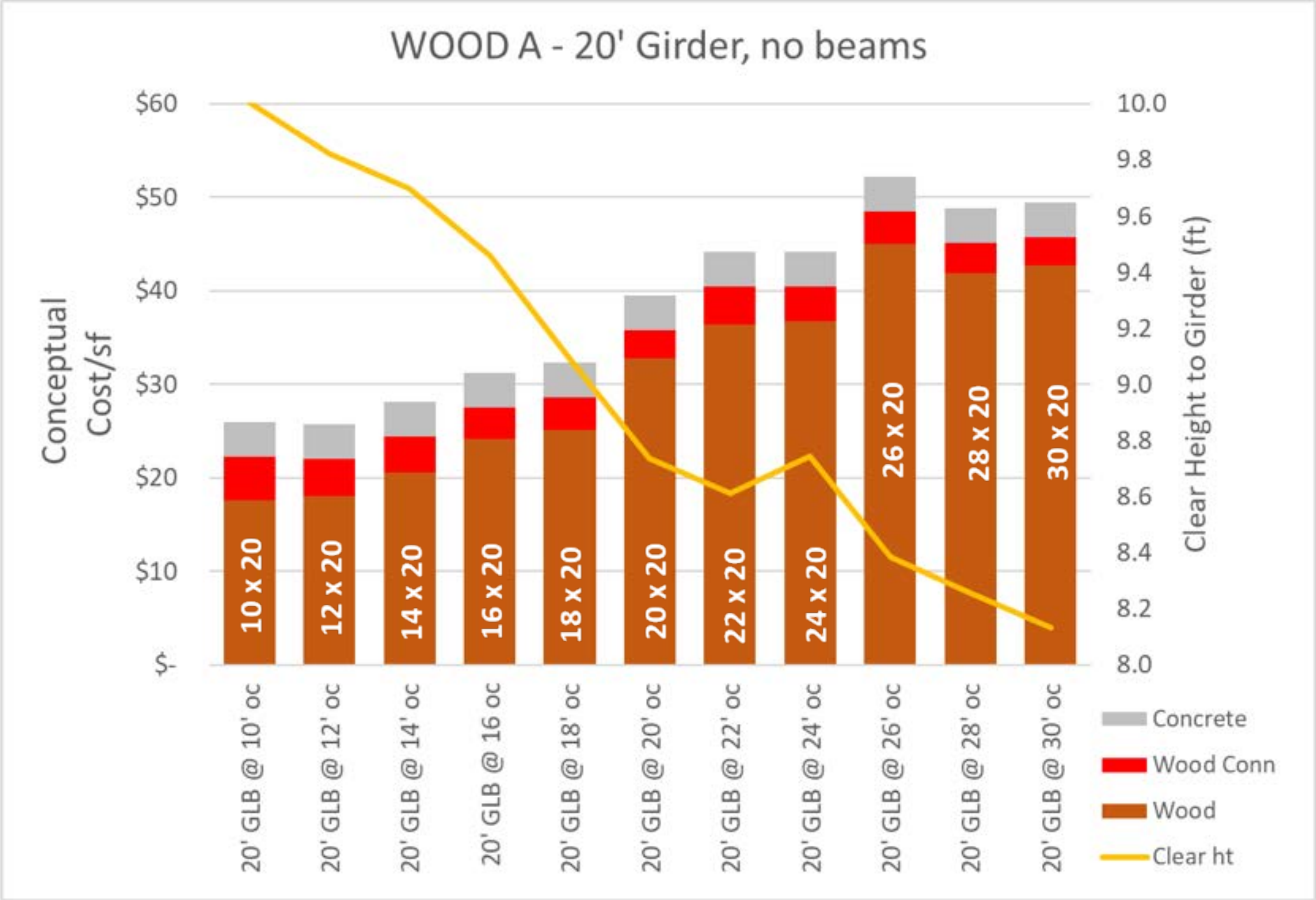
Cost increases with …

- Connection “Class”
  - Simple screws
  - Complex hidden custom connector
- Reaction carried

BAY STUDIES

20 ft timber bents, no beams, CLT of varying span





BOULDER LOADING DOCK

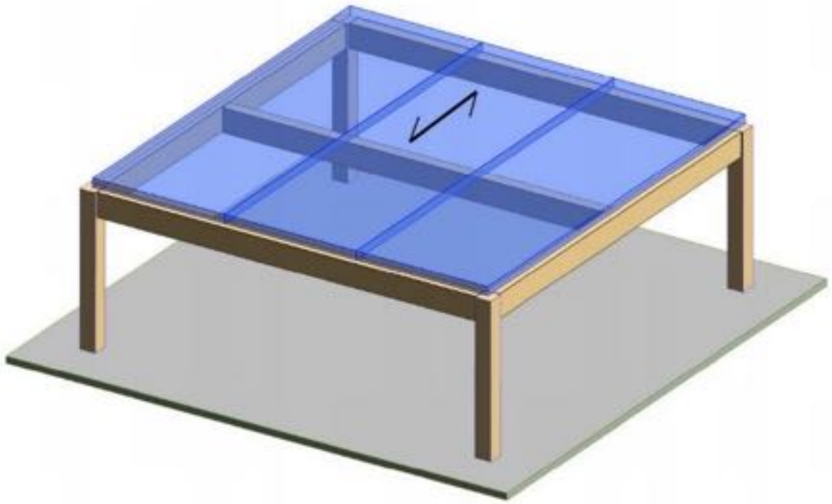
- 25 x 30 Grid
- 7-ply 5-layer CLT Floors

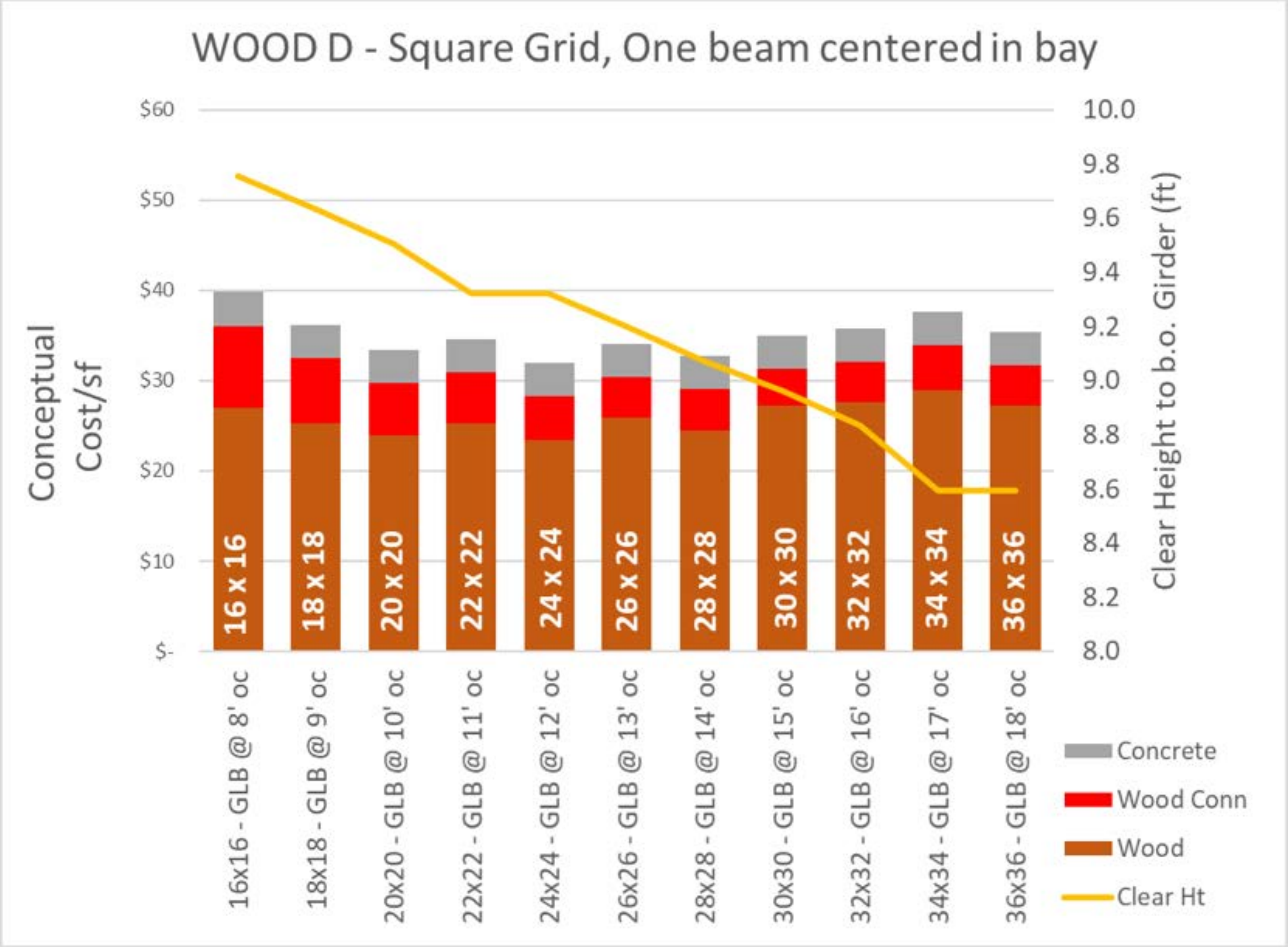
OZ Architecture

Quinlan

KL&A

Square bay, CLT with 2 equal (varying) spans



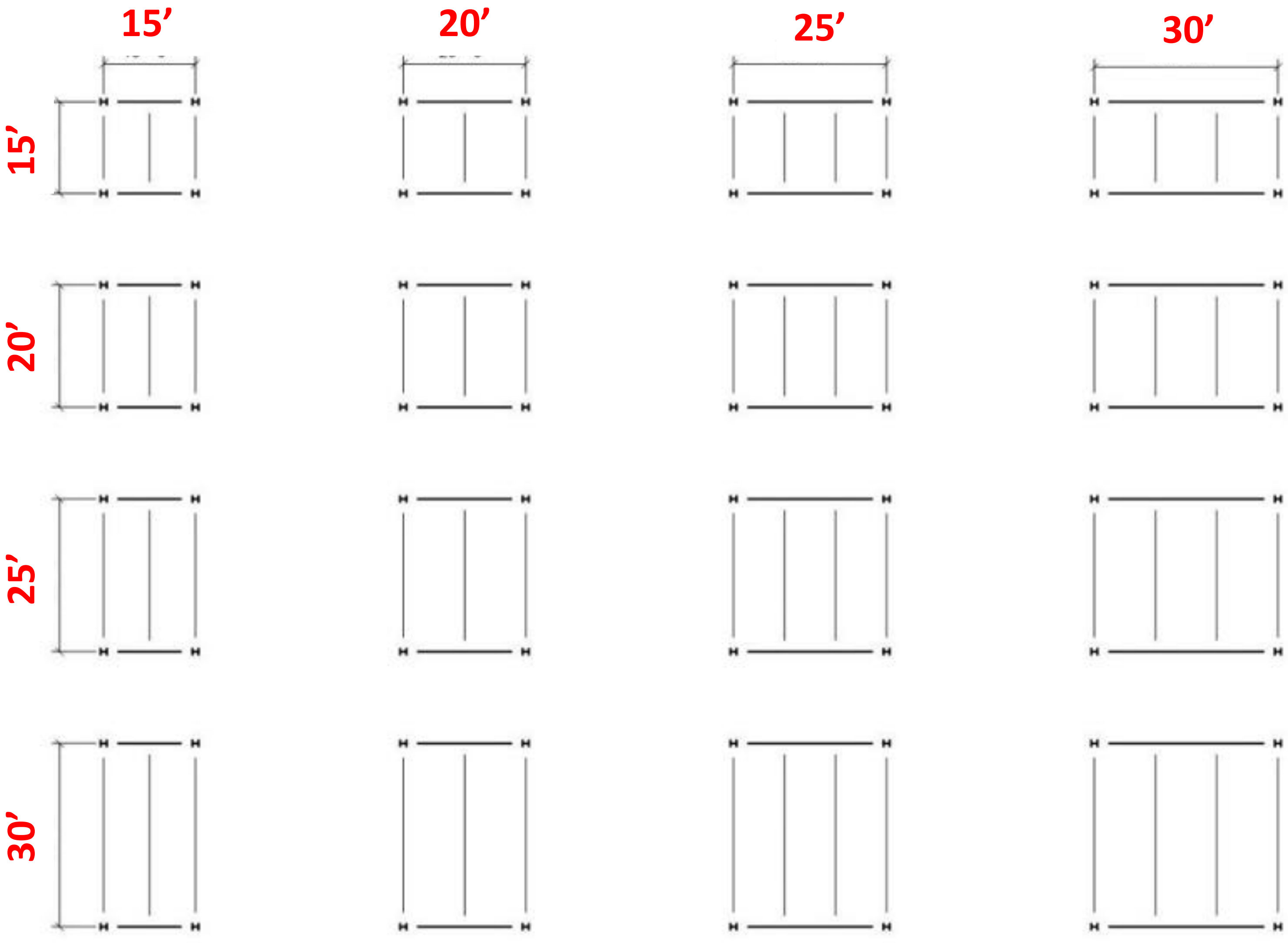


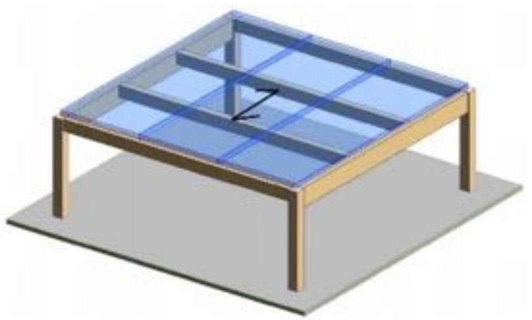
PLATTE FIFTEEN

- 30 x 30 Grid
- 3-ply CLT Floors

Photo Credit: JC Buck

Wood Bay Study: 15x15 up to 30x30





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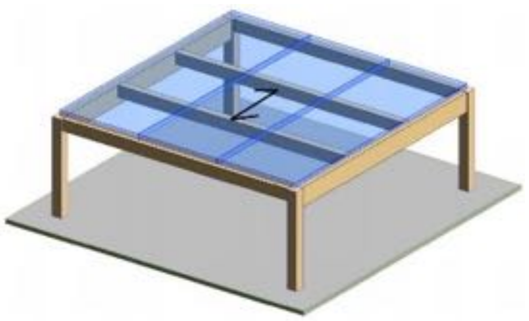
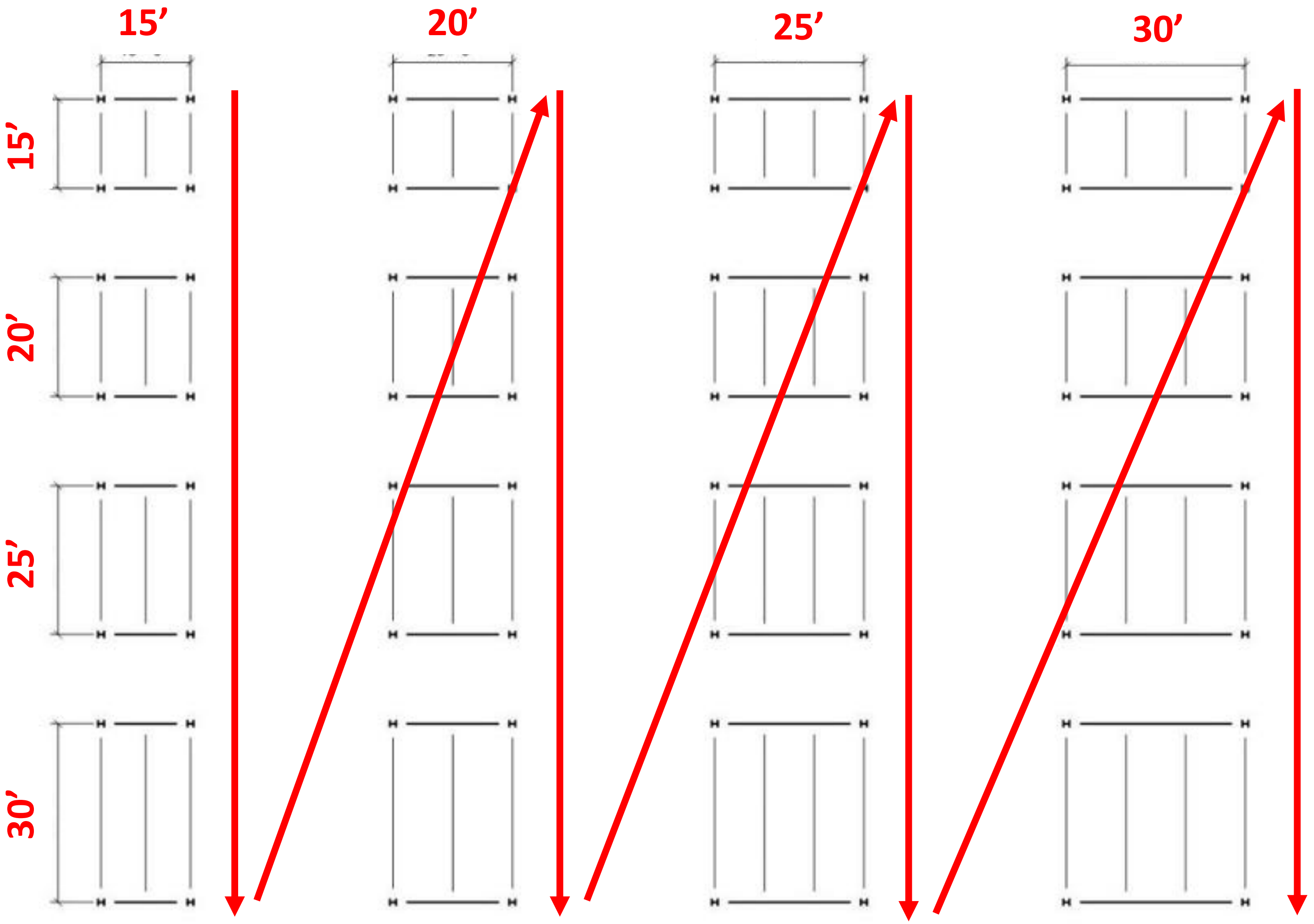
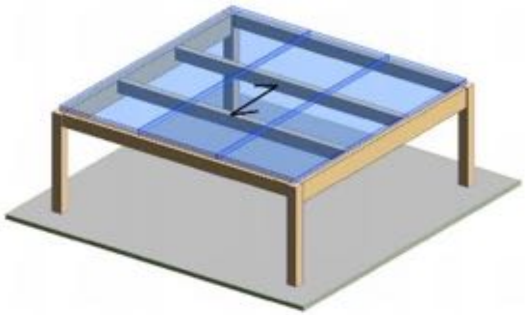
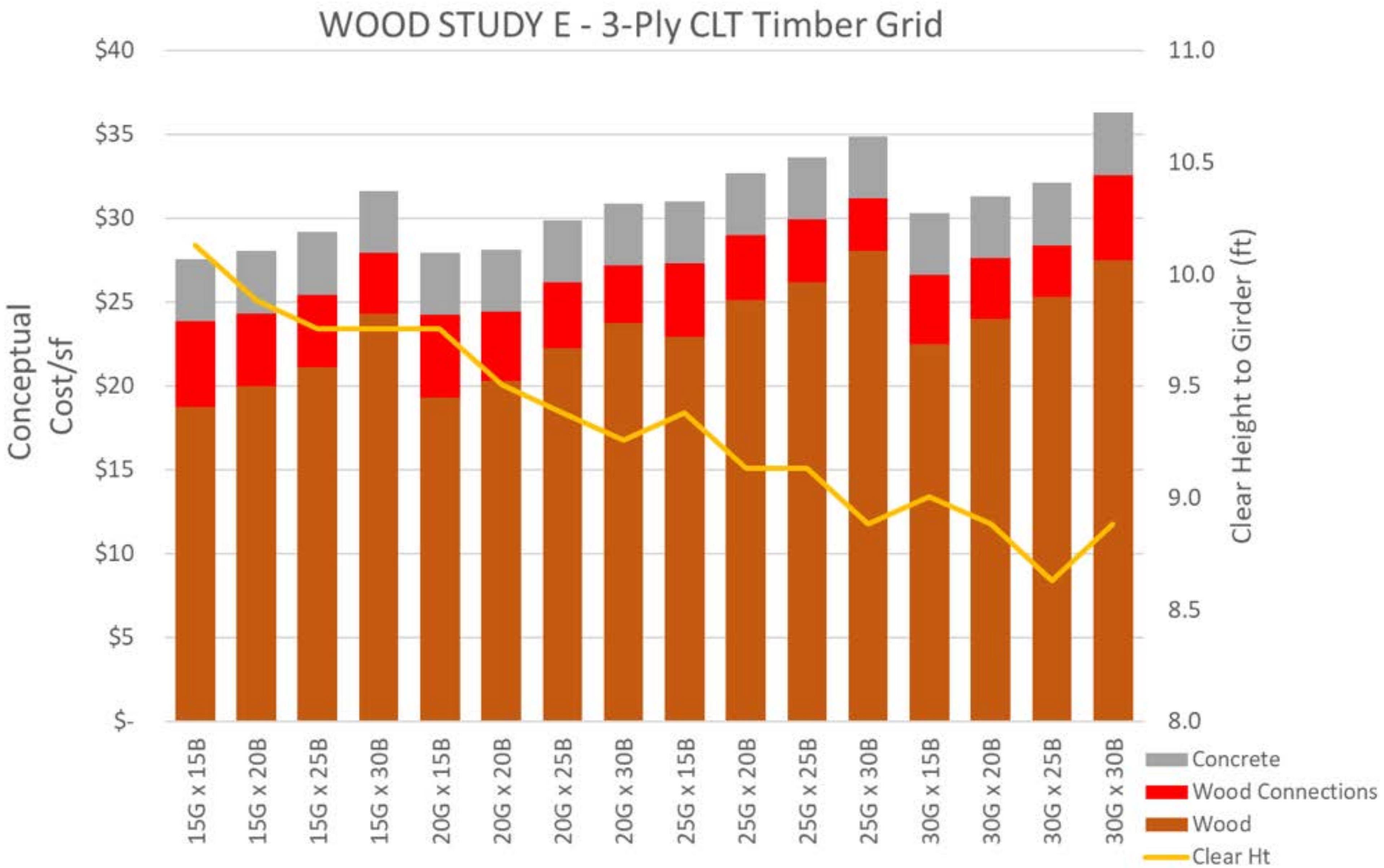


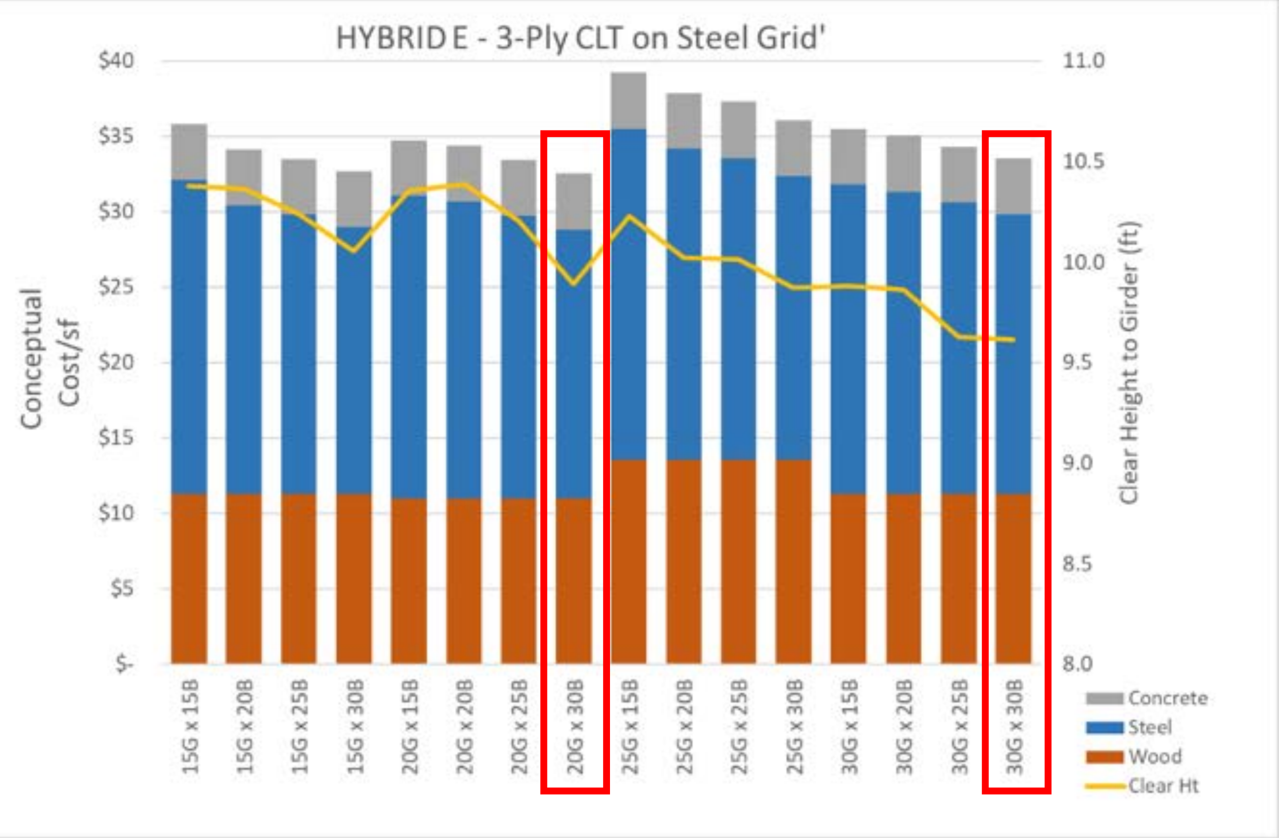


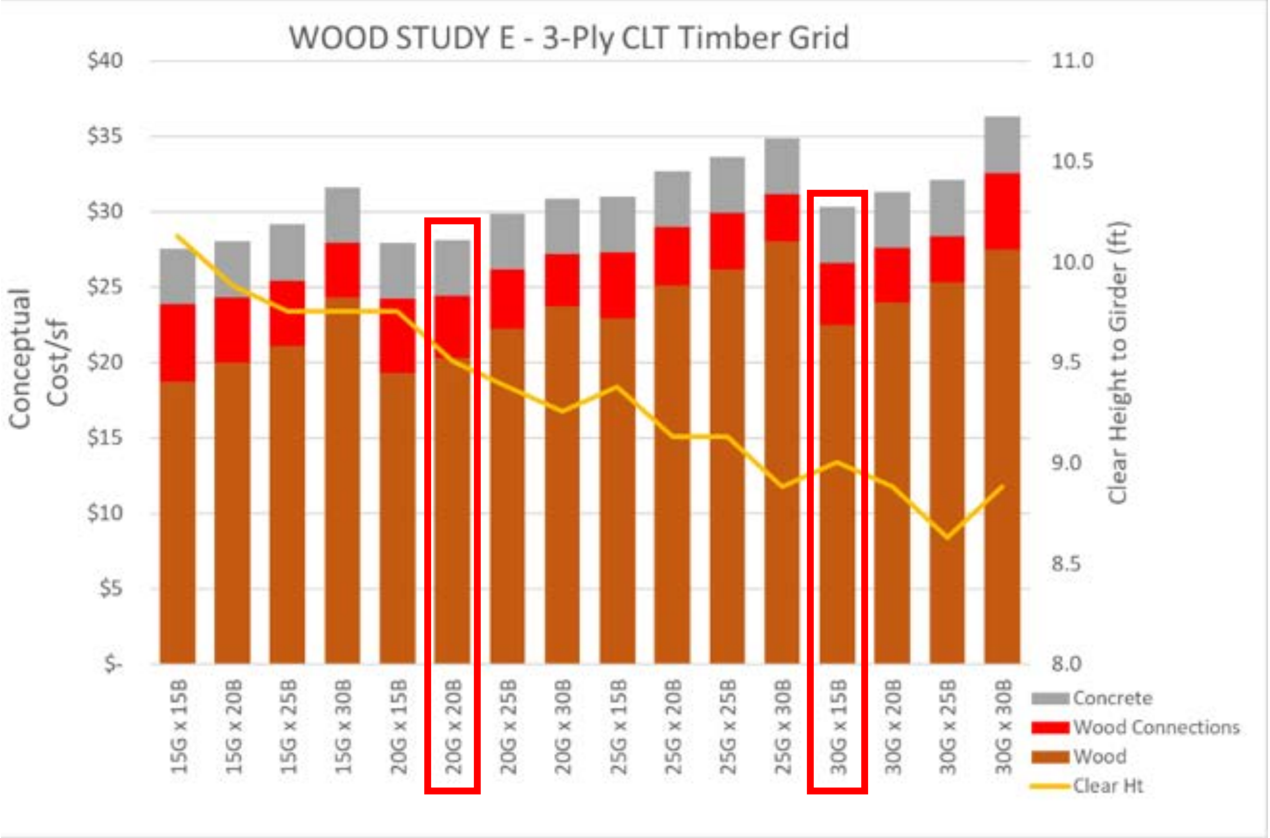
Wood Bay Study

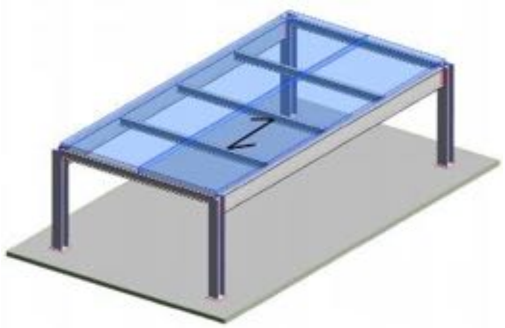


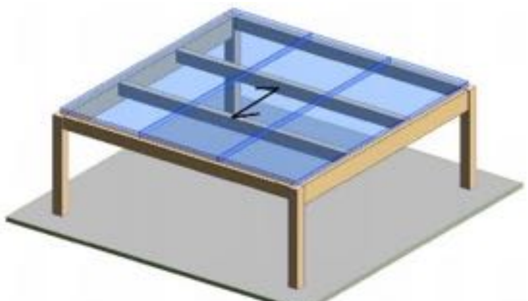


Hybrid Steel and Wood vs Wood









Some conclusions

- Timber is not the same as steel
  - When establish grid, remember:
    - Timber: Wood volume is key — Cost usually goes up with span
    - Steel: Number of pieces is key — Cost usually goes down with span
- Collaboration and coordination is critical
  - Engage all stakeholders early!
  - Architects, engineers, contractors, fabricators, erectors all have a part to play in optimizing systems
- After grids are set, don't forget other factors
  - Connection cost
  - Constructability
  - Interface with other materials

THANK YOU

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Photo Credit: JC Buck

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