Wood Construction in New England: A Firsthand Look

Presented by Marc Rivard, PE, SE
Regional Director
MA, CT, ME, NH, RI, VT

WoodWorks
September 22, 2022

The Canyons, Kaiser+Path, photo Jeremy Bittermann

Resources

New WOOD SOLUTION PAPER

CLT Diaphragm Design for Wind and Seismic Resistance

Using SDPWS 2021 and ASCE 7-22

New CASE STUDIES

Adidas East Village Expansion

Innovative mass timber designs meet ambitious construction timeline

Thomas Logan

Wood-frame urban podium project fills need for affordable downtown housing

Visit woodworks.org/publications-media

Upcoming Events

Mass Timber and the Future of Urban Multi-Family Development | October 12

1.0 AIA/CES HSW LUs, 1.0 PDH credit, 0.10 ICC credit

Fire and Structural Analysis for Mass Timber Buildings | November 9

1.5 AIA/CES HSW LUs, 1.5 PDH credits, 0.15 ICC credits

Visit woodworks.org/events

Mass Timber Business Case Studies

Real financial information on real deals

- Prepared by WoodWorks and Conrad Investment Management
- Include qualitative influences + quantitative data to examine investment success

PROPERTY SUB-TYPES:

For-Rent Institutional Housing • Institutional Offices • Industrial Buildings • Redevelopment/Additions • Purpose-Built Owner/Occupied (Student Housing)

« Scan the code to download the current package.

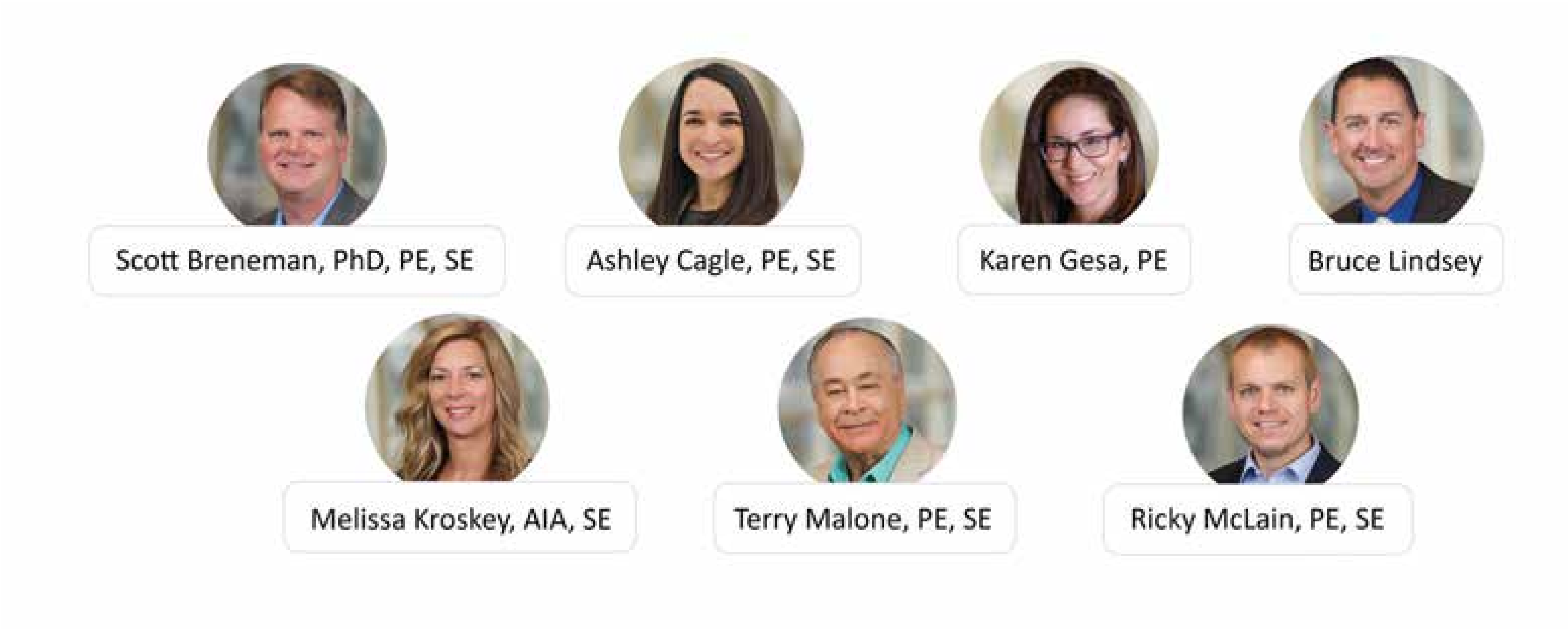
WOODWORKS
WOOD PRODUCTS COUNCIL

Design Professionals:
One-on-One Support & Assistance

PROJECT SUPPORT FIELD DIVISION

Find the Regional Director for your location:

Meet the **Help Desk**



Need technical assistance on a project?

Email: **help@woodworks.org**

NOW HIRING

REGIONAL DIRECTOR – CHICAGO, IL OR MINNEAPOLIS, MN METRO AREA

TECHNICAL DIRECTOR – REMOTE, US

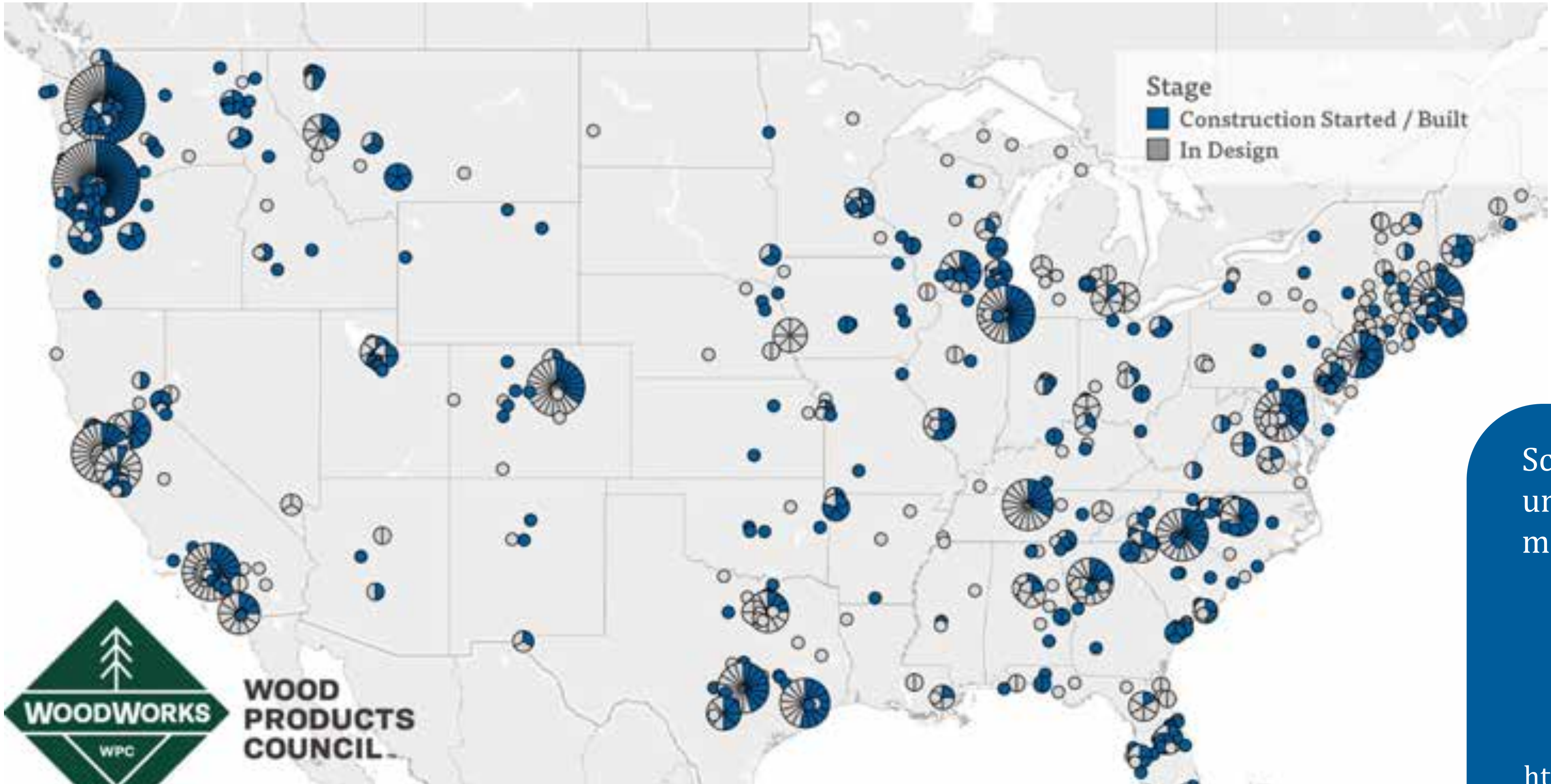
REGIONAL DIRECTOR – SEATTLE, WA METRO AREA

WOODWORKS

WOOD PRODUCTS COUNCIL

Current State of Mass Timber Projects

As of June 2022, in the US, **1,502** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



WOODWORKS WPC WOOD PRODUCTS COUNCIL

Source: WoodWorks, June 30, 2022

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

Scan this code or use the url to find the map and more details online.

https://www.woodworks.org/resources/u-s-mass-timber-projects/

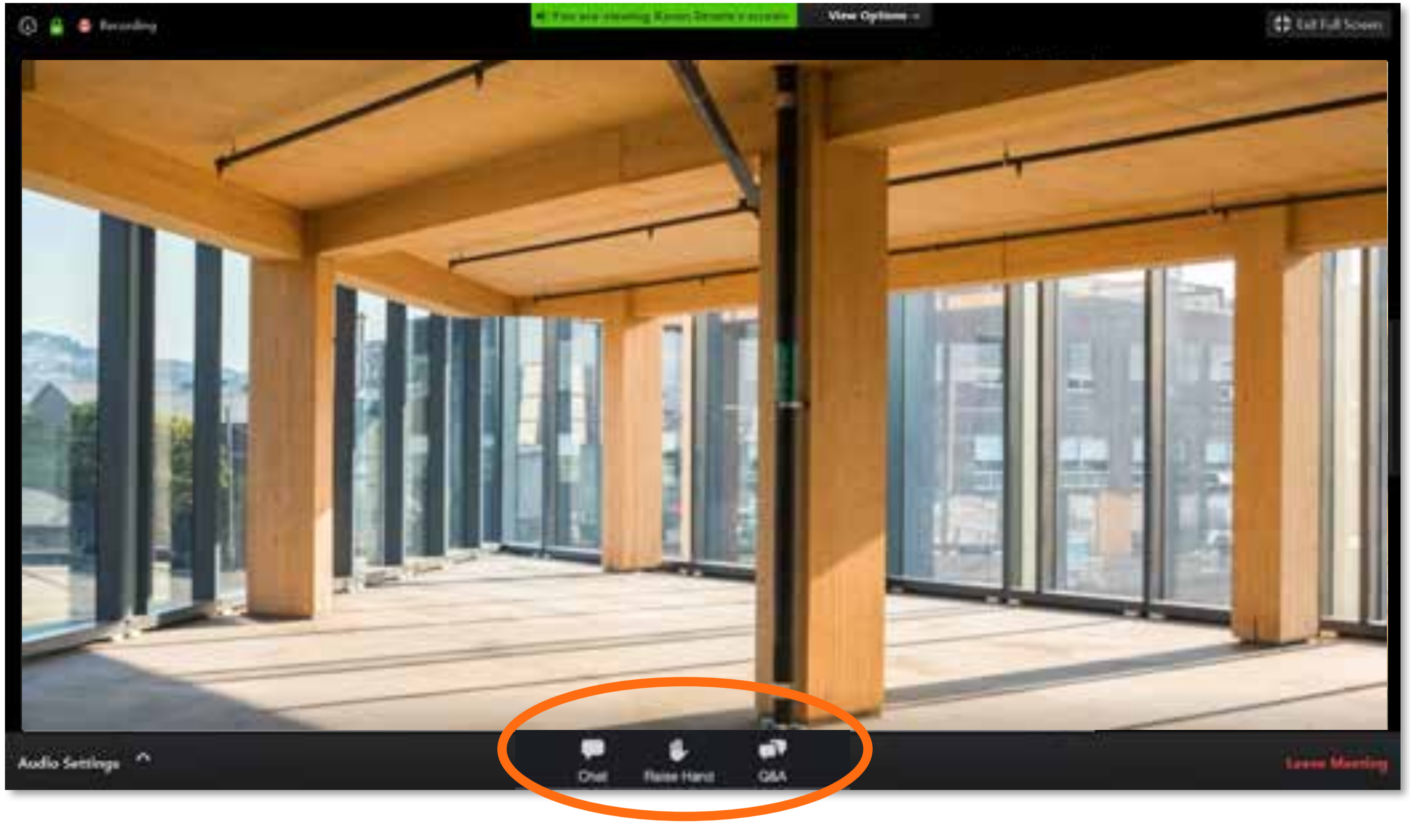
Continuing Education Credits

- Participants will receive a certificate of completion via email
- AIA credits will be processed by WoodWorks

- To receive credit and a certificate, attendees must stay on for the duration of the seminar.

Ask Questions through the Q&A Box

» Submit questions in the **Q&A** box at the bottom of your screen as they come up in the presentations. We will **get to as many questions as possible.**



AIA CES Course

"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.

Learning Objectives

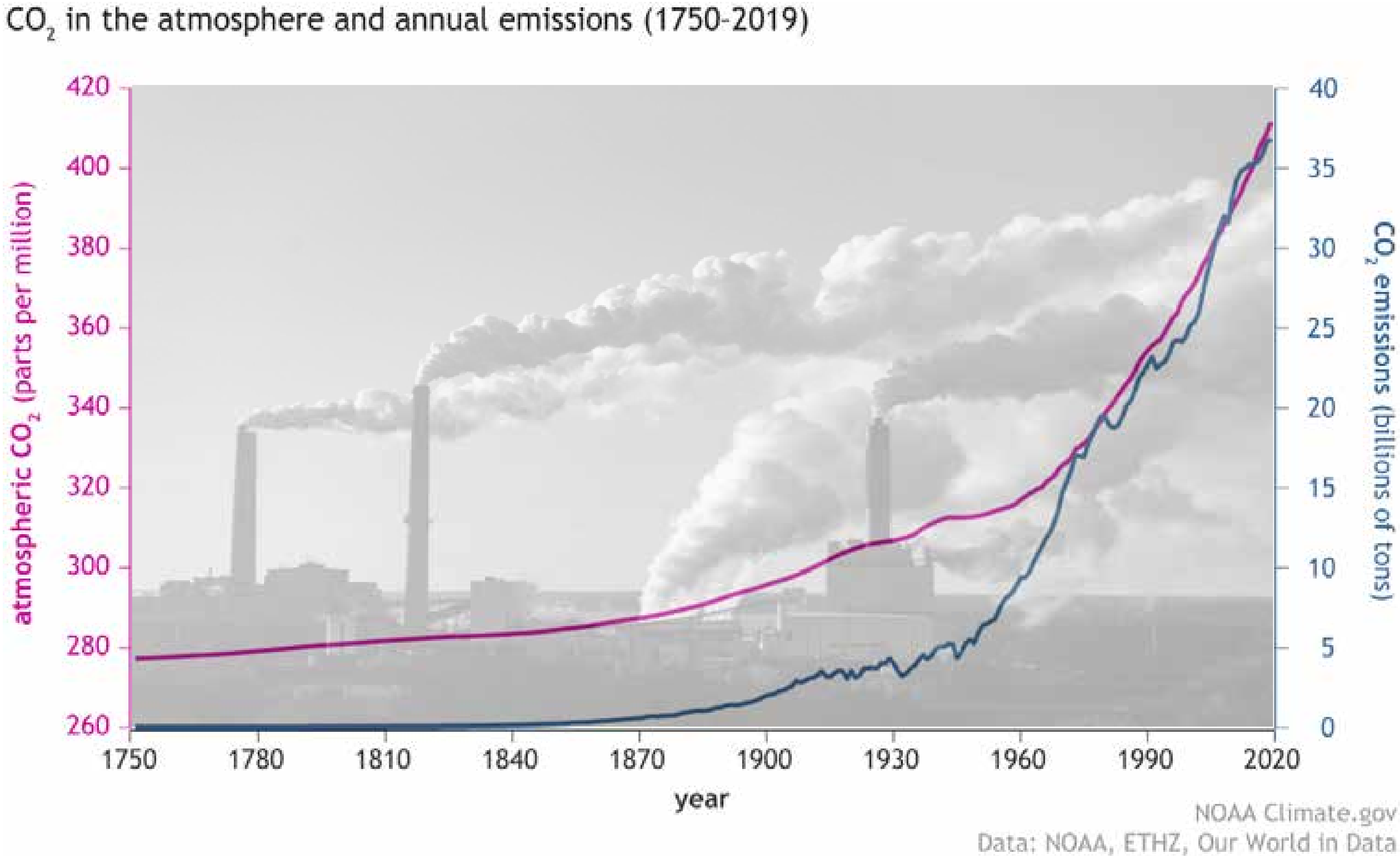
1. Review carbon basics and how material choice is related to sustainability.
2. Learn how wood products can be beneficial for the environment.
3. Identify mass timber products available in North America and consider how they can be used under current building codes and standards.
4. Discuss benefits of using mass timber products, including structural versatility, prefabrication, lighter carbon footprint, and reduced labor costs.

Climate Change Background

Rising Temperatures and Melting Glaciers

From Rising Waters to Catastrophic Wildfires

Carbon & Greenhouse Gas Emissions



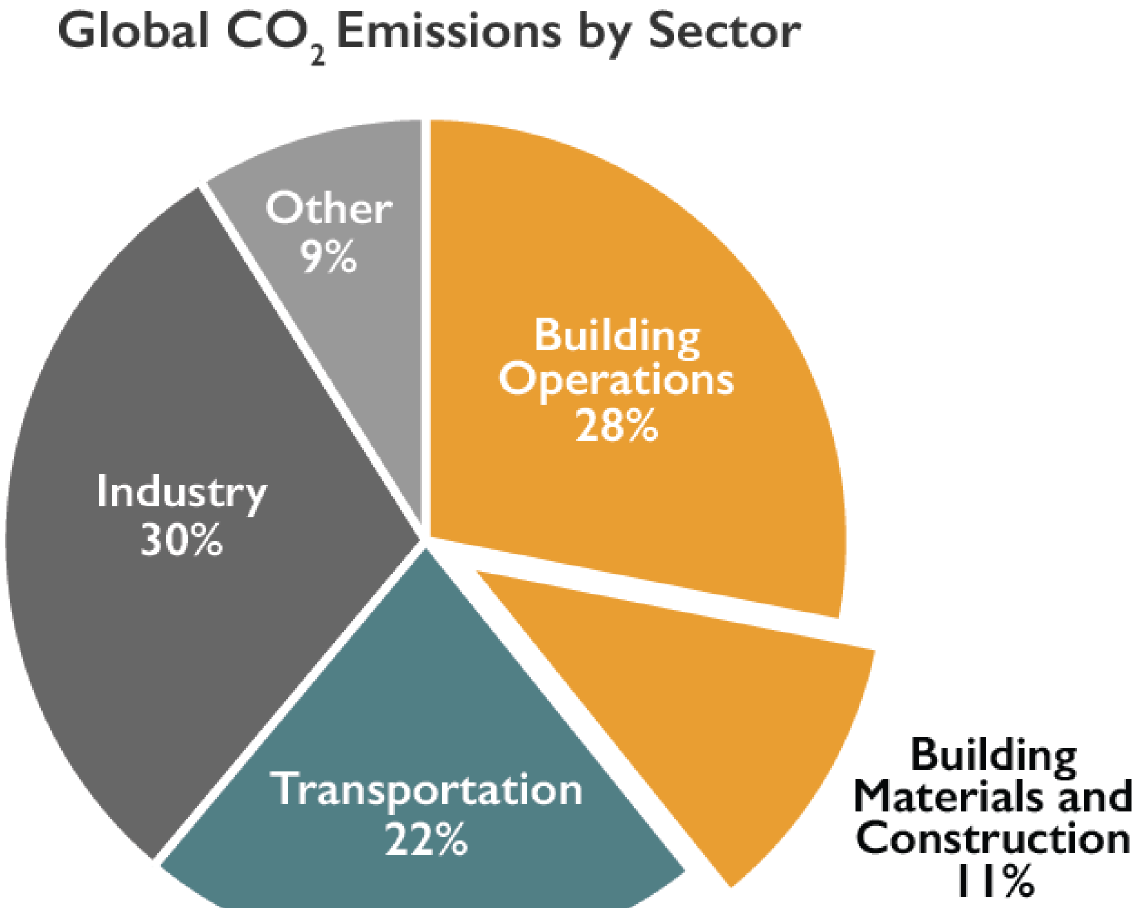
Global Population Increase

2020 = 7.8 billion people

2050 = 9.9 billion people

Source: www.prb.org

New Buildings & Greenhouse Gases



(Embodied Energy)

Buildings generate nearly **40%** of annual global greenhouse gas emissions (*building operations* + *embodied energy*)

Embodied energy: **11%**

Concrete, iron, steel **~9%**

Image: Architecture 2030

US Climate Policy

In the absence of strong Federal Policy, states and municipalities have adopted their own regulations

- CA: Buy Clean California – first US law to address embodied carbon in construction materials
  - GWP must not exceed set limits
  - Currently targets structural steel, steel rebar, glass, and mineral wool

Federal Policy is advancing under the Biden Administration:

- Rejoining the Paris Agreement
- Several first-week executive actions aimed at advancing zero-carbon technologies, increasing reforestation and carbon sequestration

Measuring Greenhouse Gases

Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The time period usually used for GWP's is 100 years. (EPA)

	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28-36
Nitrous Oxide (N_2O)	265-298
Fluorinated Gases	Thousands to Tens of Thousands

Carbon Dioxide Equivalents (CO_{2eq}) = International standard practice is to express greenhouse gases in terms of CO_2 equivalents

Carbon vs CO_2

+ 2 *

= 44 CO_2

1 ton Carbon ≠ 1 ton CO_2

1 ton Carbon = (44/12=) **<u>3.67</u> tons CO_2**

Carbon Terms

- **Embodied Carbon**: Carbon emissions associated with the entire life cycle of the building including harvesting, mining, manufacturing, transporting, installing, maintaining, decommissioning, and disposing/reuse of a material or product
- **Operational Carbon**: Carbon emissions associated with operating a building including power, heat, and cooling

Image: Boston Society for Architecture

Embodied vs. Operational Energy

Traditional Non-Wood Building

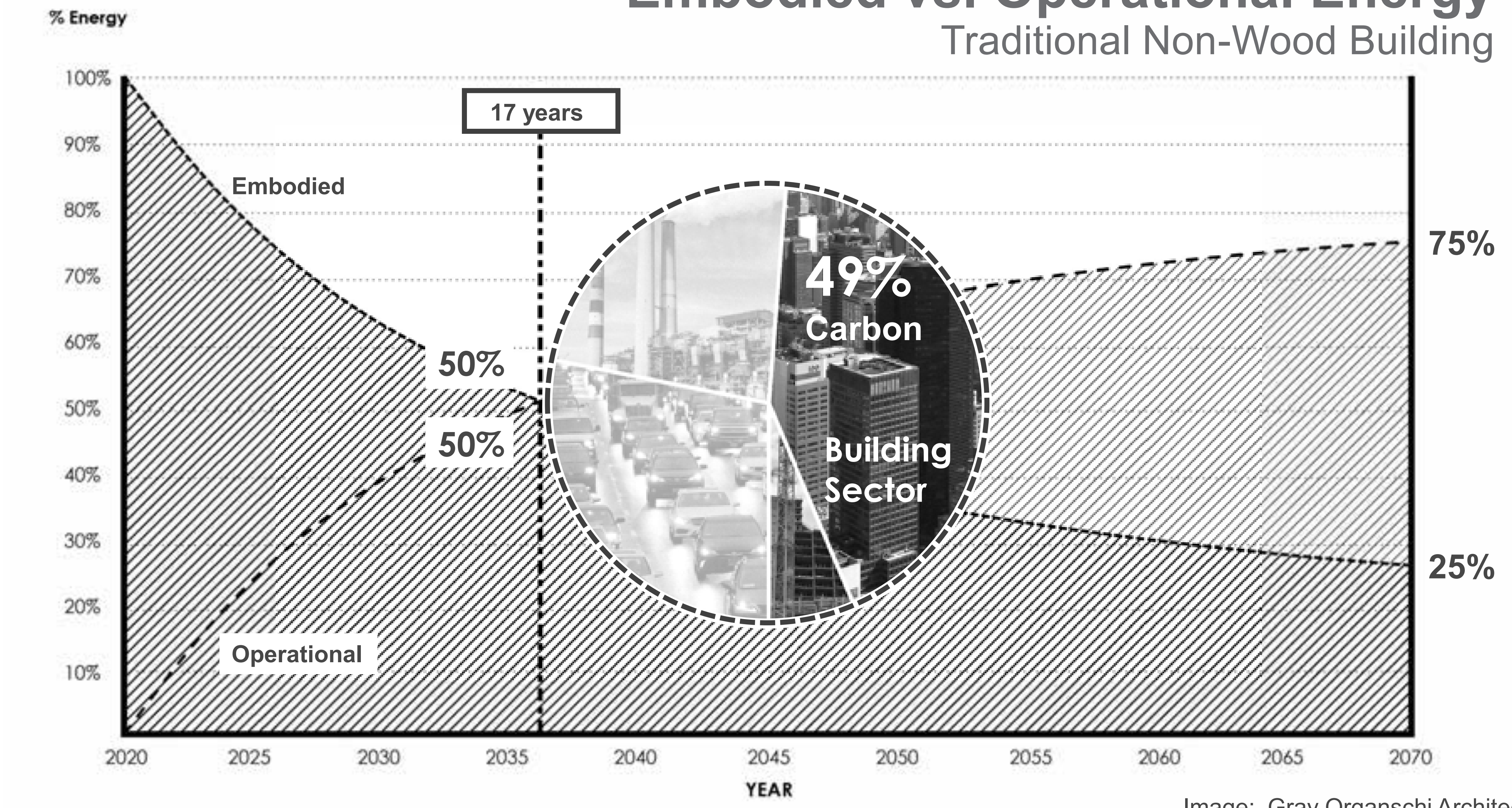


Image: Gray Organschi Architecture

How Does Wood Fit in?

Carbon Benefits of Wood

- **Less energy intensive** to manufacture than steel or concrete
- **Less fossil fuel consumed** during manufacture
- **Avoid process emissions**
- Carbon **storage in forests** and **promote forest health**
- Extended carbon **storage in products**

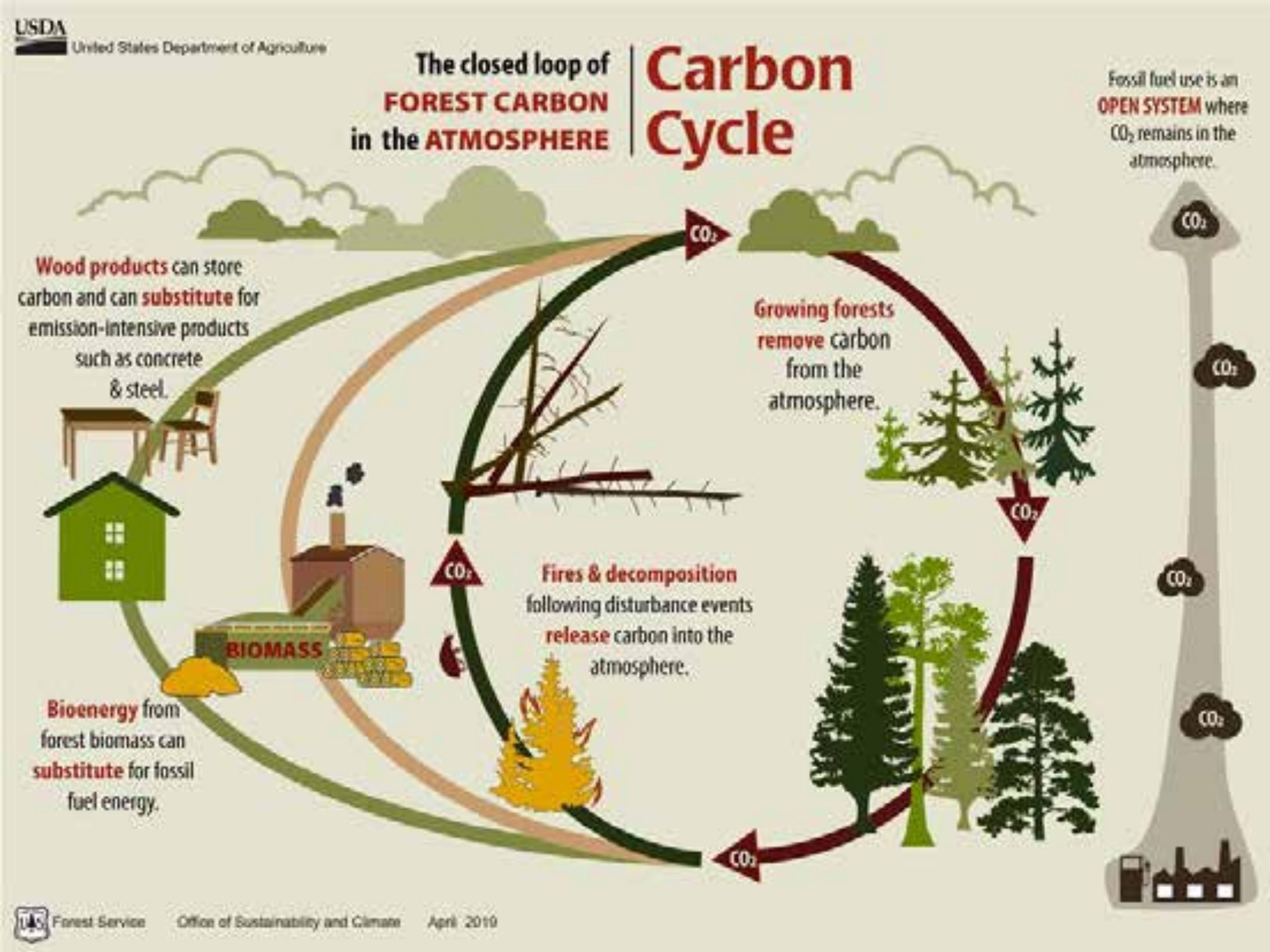


Image: USDA US Forest Service

More Carbon Terms

Carbon Sequestration: The process by which CO_2 is **removed** from the atmosphere and deposited in solid or liquid form in oceans, living organisms, or land.

Carbon Storage: Carbon is **stored as a solid** in the form of plant material: roots, trunks, branches, stems, and leaves. It can continue to be stored in **wood building materials**.

Image: Dovetail Partners, Inc.

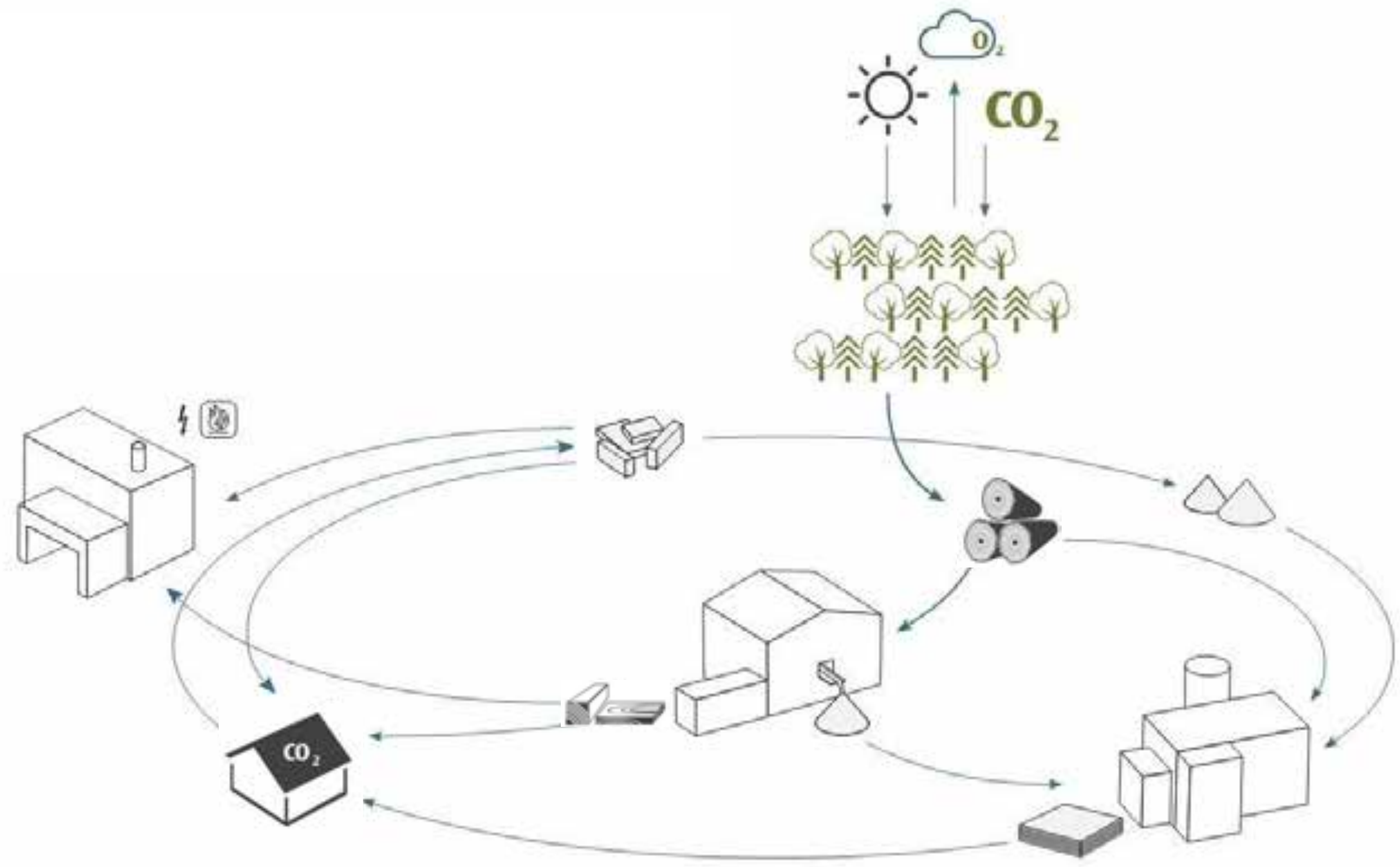
Carbon Storage
Wood ≈ 50% Carbon (dry weight)


Image: Kaiser + Path

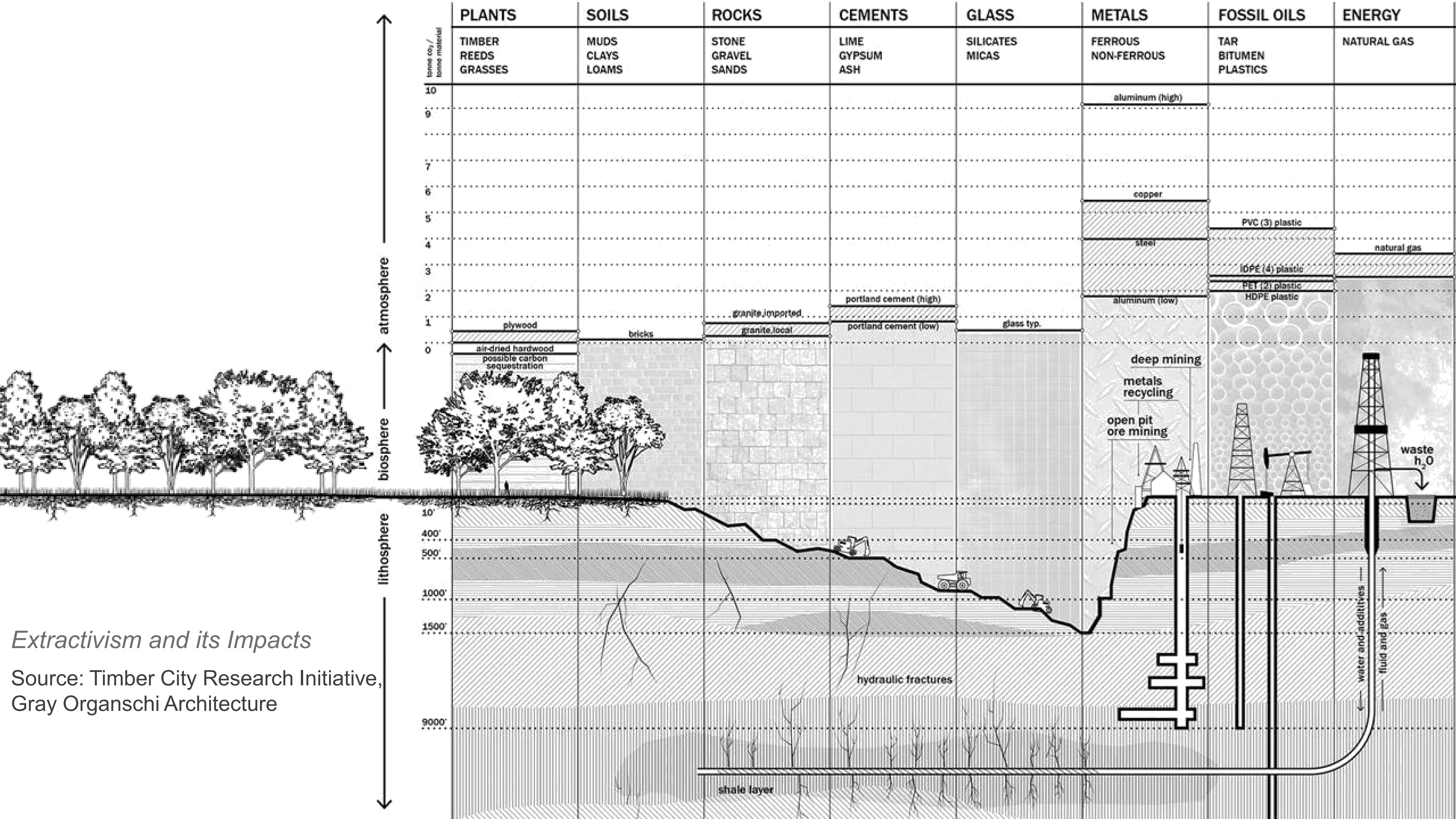

Image: Lever Architecture

Carbon Cycle

Renewable Resource | Carbon Sequestration



Source: Building with Wood – Proactive Climate Protection, Dovetail Partners, Inc.



Extractivism and its Impacts

Source: Timber City Research Initiative, Gray Organschi Architecture

Specifics of Carbon Storage

Where is Carbon Stored?

Harvested Wood Pools

- Harvested Wood Products
- Solid Waste Disposal Sites

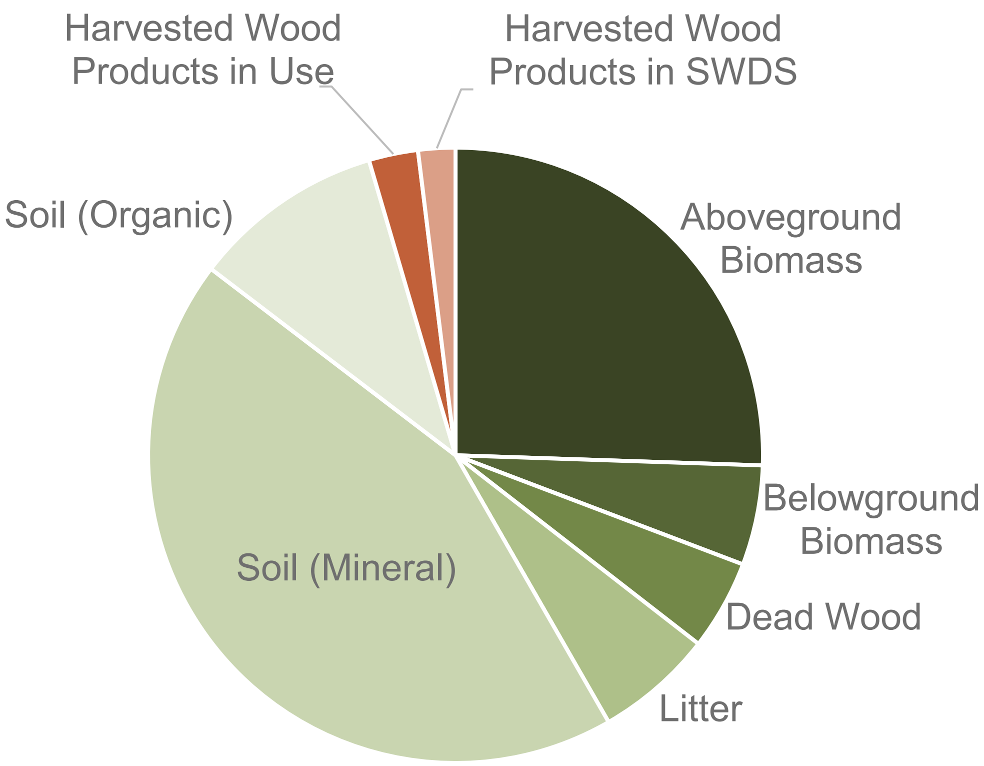
Forest Pools

- Aboveground Biomass
- Belowground Biomass
- Dead Wood
- Litter or Forest Floor
- Soil Organic Carbon

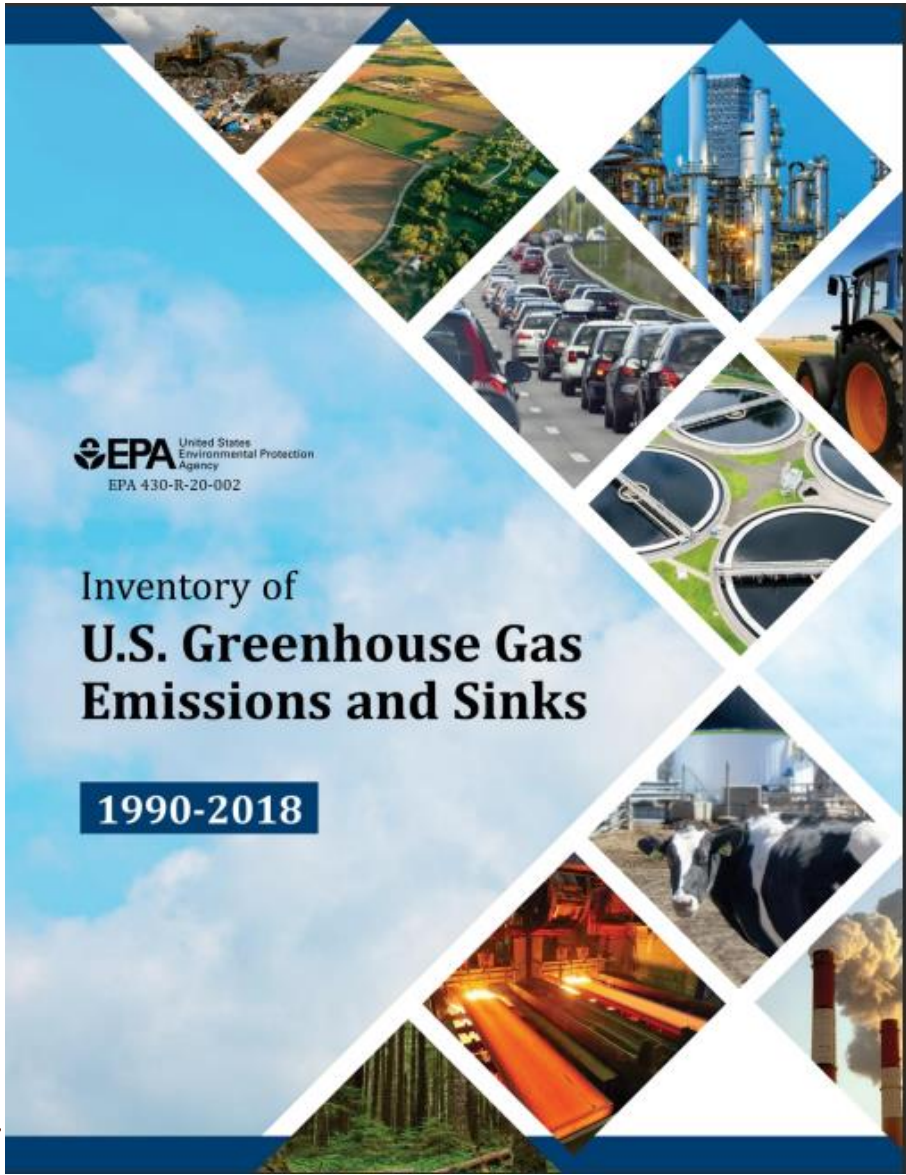
Source: https://usaforests.org/

Carbon Storage in Harvested Wood Products

As of 2019, the carbon stock for Harvested **Wood Products in Use** in the conterminous 48 states is estimated at **1,521 Million Metric Tons**.



Carbon Stocks in Forest Land and Harvested Wood Pools, 2019



https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Table 6-12: Forest Area (1,000 ha) and C Stocks in *Forest Land Remaining Forest Land* and Harvested Wood Pools (MMT C)

	1990		2005		2015	2016	2017	2018	2019
Forest Area (1,000 ha)	***279,748***		***279,749***		***280,041***	***280,041***	***279,893***	***279,787***	***279,682***
Carbon Pools (MMT C)									
Forest Ecosystem	**51,527**		**53,886**		**55,431**	**55,592**	**55,746**	**55,897**	**56,051**
Aboveground Biomass	11,833		13,484		14,561	14,672	14,780	14,884	14,989
Belowground Biomass	2,350		2,734		2,982	3,008	3,033	3,056	3,081
Dead Wood	2,120		2,454		2,683	2,707	2,731	2,753	2,777
Litter	3,662		3,647		3,638	3,639	3,639	3,640	3,641
Soil (Mineral)	25,636		25,639		25,640	25,640	25,637	25,637	25,638
Soil (Organic)	5,927		5,929		5,927	5,927	5,926	5,926	5,926
Harvested Wood	**1,895**		**2,353**		**2,567**	**2,591**	**2,616**	**2,642**	**2,669**
Products in Use	1,249		1,447		1,490	1,497	1,505	1,513	1,521
SWDS	646		906		1,076	1,094	1,112	1,129	1,148
Total C Stock	**53,423**		**56,239**		**57,998**	**58,183**	**58,362**	**58,539**	**58,720**

Notes: Forest area and C stock estimates include all *Forest Land Remaining Forest Land* in the conterminous 48 states

https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Harvested Wood Products

- **Solid sawn** wood products have the lowest level of embodied energy.
- Wood products requiring more processing steps (for example, plywood, engineered wood products, flake-based products) require more energy to produce but still require **significantly less energy** than their non-wood counterparts.

Image: Weyerhaeuser

Image: LP Building Solutions

Image: Structurecraft

Image: Georgia-Pacific

Source: USFPL Wood Handbook; Wood as a Sustainable Building Material

Tools to Evaluate Carbon Impact

Whole Building Life Cycle Analysis (WBLCA)

"Evaluation of the inputs, outputs, and potential environmental impacts… throughout its life cycle"

- WBLCA covers all stages in the life cycle of a building and its components
- Several tools available; various methodologies
- https://www.thinkwood.com/education/calculate-wood-carbon-footprint
- https://www.thinkwood.com/blog/understanding-the-role-of-embodied-carbon-in-climate-smart-buildings

WoodWorks Carbon Calculator

- Available at **woodworks.org**
- Estimates total wood mass in a building
- Relays **estimated** carbon impacts:
  - Amount of **carbon stored** in wood
  - Amount of **greenhouse gas emissions avoided** by choosing wood over a non-wood material

WoodWorks™ WOOD PRODUCTS COUNCIL

http://www.woodworks.org/carbon-calculator-download-form/

Case Studies

Bullitt Center
Seattle, WA

IV (HT)

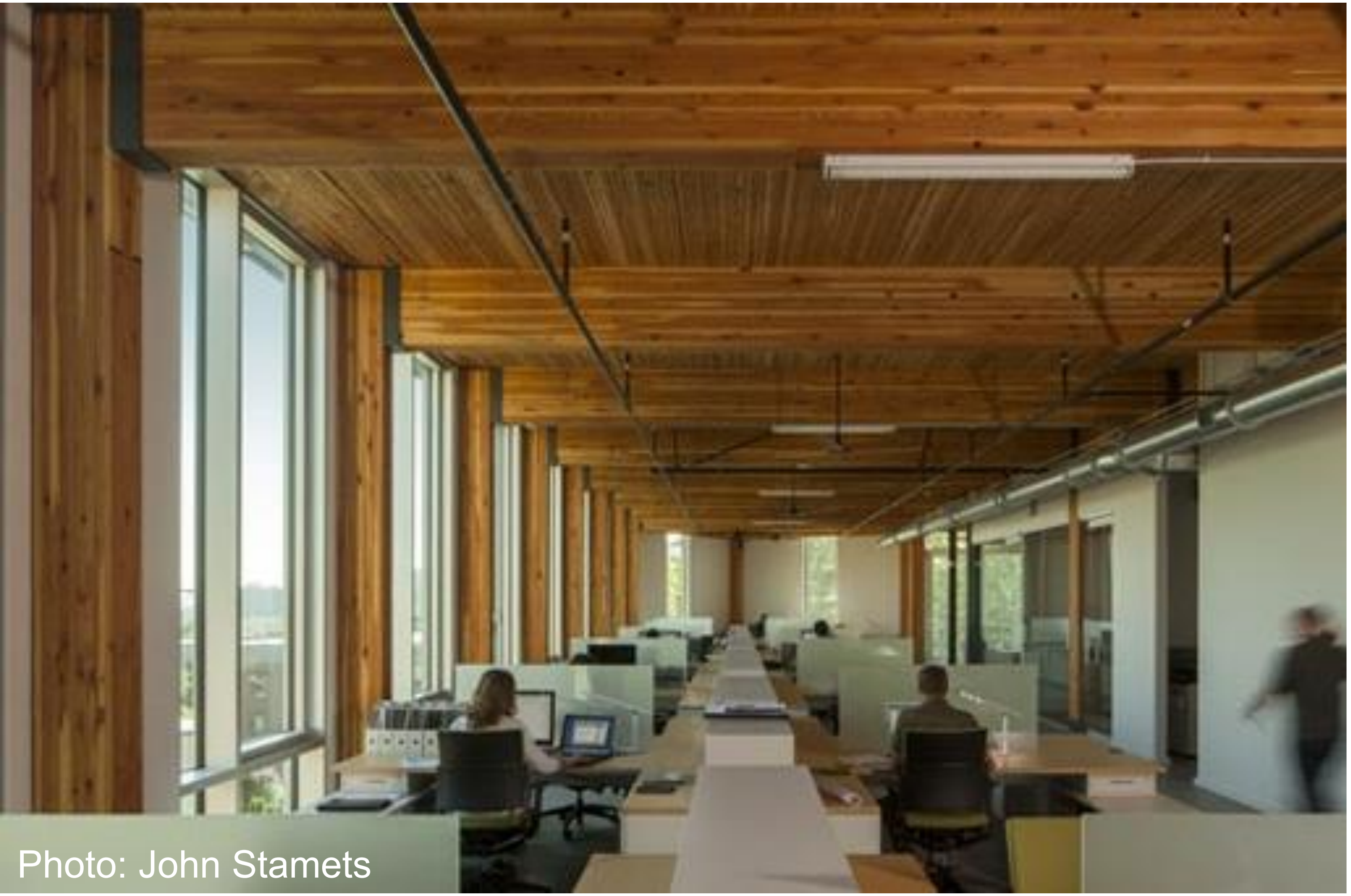


Photo: John Stamets

Architect: The Miller Hull Partnership
Structural Engineer: DCI Engineers

- Designed for a **250-year** life span
- Met criteria for **Living Building Challenge 2.0**
- Rooftop photovoltaic cells generate electricity for the building; building recycles its own water
- 6 over 2 design; 52,000 sf
- Heavy timber frame: glulam and NLT panels

Bullitt Center
Seattle, WA

Volume of wood used:
24,526 cubic feet

U.S. and Canadian forests grow this much wood in:
2 minutes

Carbon stored in the wood:
545 metric tons of CO_2

Avoided greenhouse gas emissions:
1,158 metric tons of CO_2

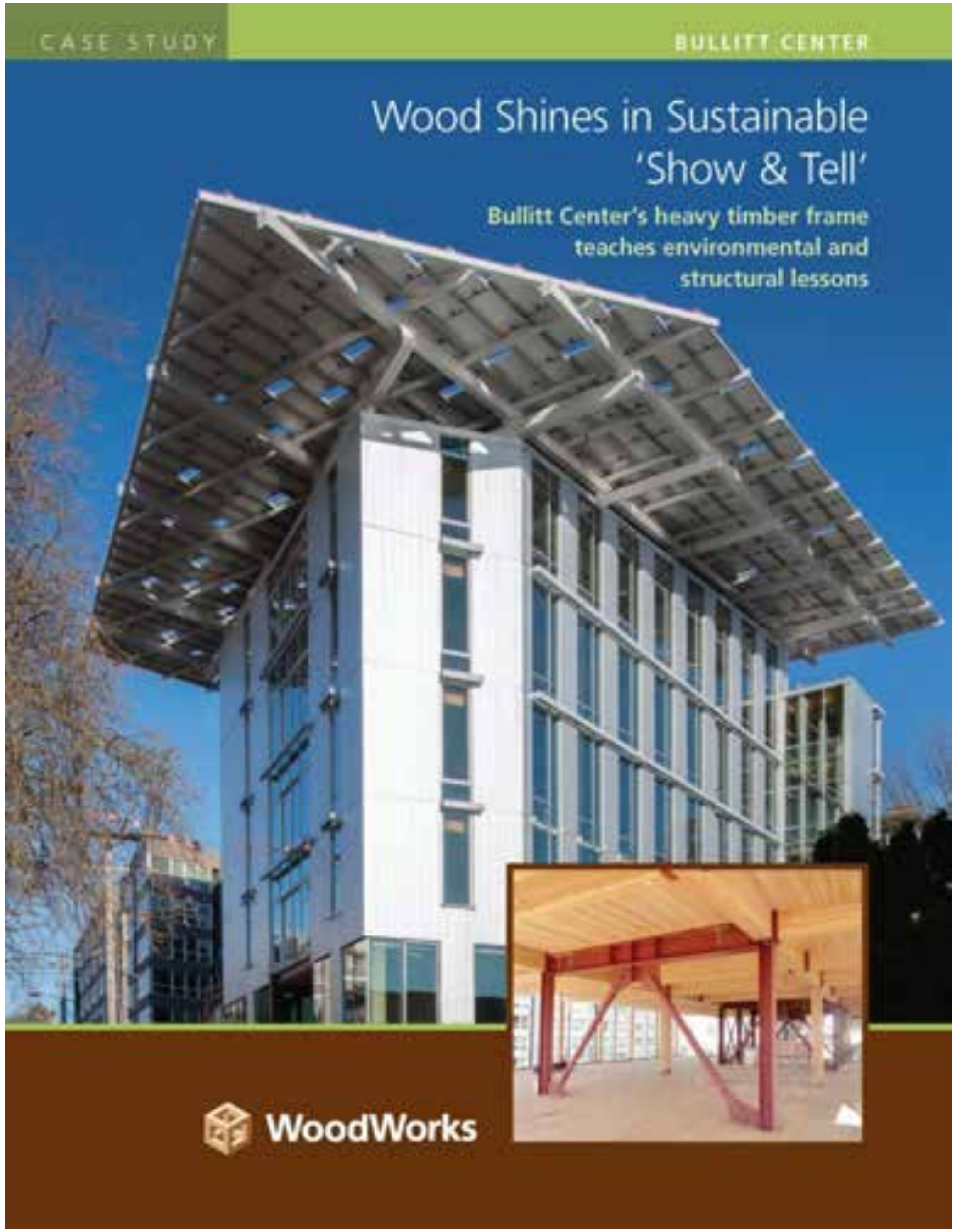
TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO_2

EQUIVALENT TO:

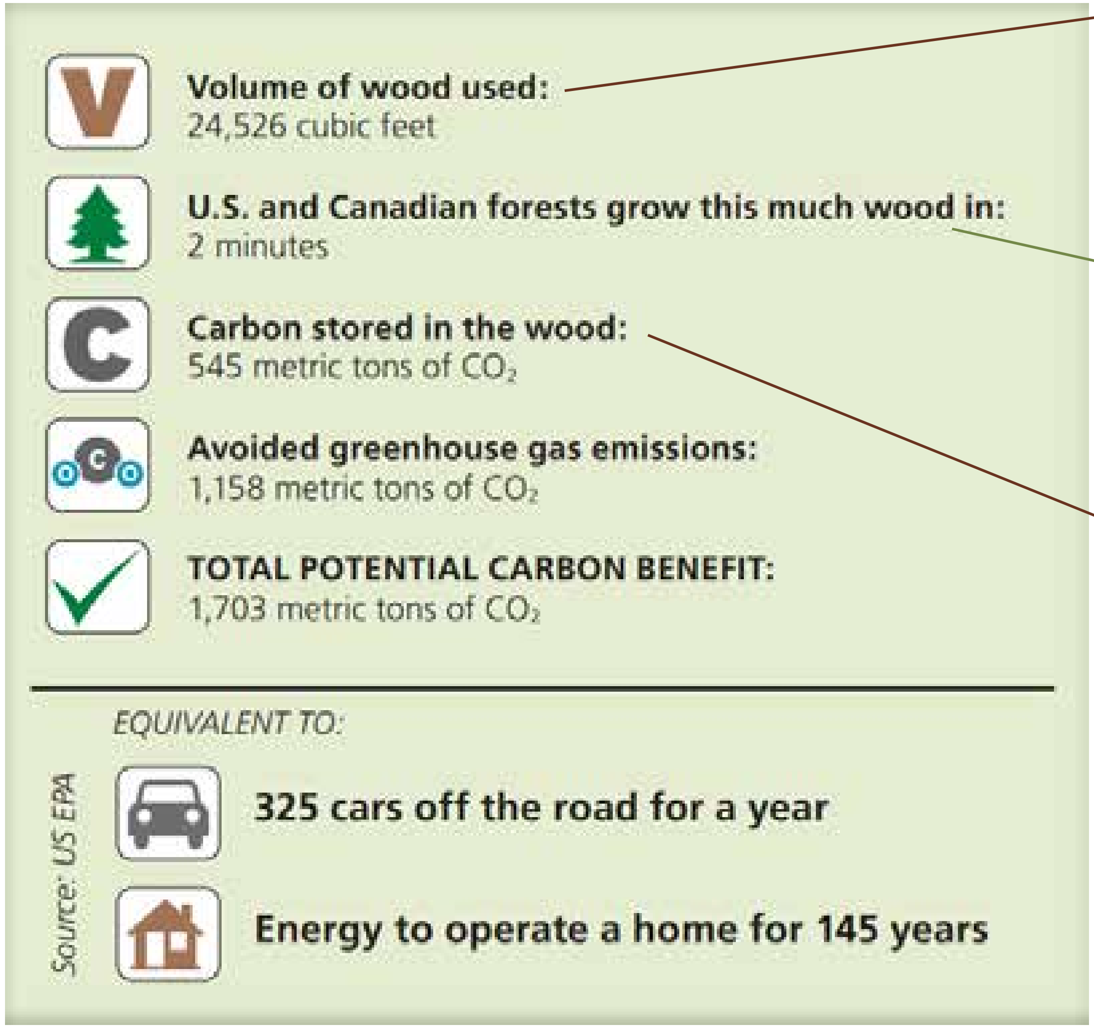
325 cars off the road for a year

Energy to operate a home for 145 years

Source: US EPA



Bullitt Center
Seattle, WA



Volume of wood:
Based on user inputs

Volume of Wood → Volume of Logs → Volume of Trees → Tree Growth Rate

Volume of Wood → Mass of Wood → Mass of Carbon (50% of wood) → Mass of CO_2 (3.67 x mass of Carbon)

Candlewood Suites
Redstone Arsenal, AL


Photo: IHG Army Hotels, Lendlease

Architect: Lendlease
Project Engineer: Schaefer Structural Engineers

IIIB

- 4 stories; 62,688 sf
- **First CLT hotel** in USA
- **37% faster** overall construction
- 40% fewer construction workers
- Trained unemployed veterans

Candlewood Suites

Redstone Arsenal, AL

Photo: IHG Army Hotels, Lendlease

Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed by the tree while growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood products used:
935,696 board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,276 metric tons of CO_2

Avoided greenhouse gas emissions:
494 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,770 metric tons of CO_2

EQUIVALENT TO:

374 cars off the road for a year

Energy to operate 187 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Candlewood Suites
Redstone Arsenal, AL

Emissions avoided by choosing wood over alternative building material based on building type

Total Potential Carbon Benefit = Carbon Stored + Emissions Avoided

Convert Total Potential Carbon Benefit to laymen's terms like emissions from operating a car or a home

Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed by the tree while growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood products used:
935,696 board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,276 metric tons of CO_2

Avoided greenhouse gas emissions:
494 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,770 metric tons of CO_2

EQUIVALENT TO:

374 cars off the road for a year

Energy to operate 187 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Crescent Terminus
Atlanta, GA

Project Architect: Lord Aeck Sargent
Structural Engineer: SCA Consulting Engineers

IIIA

- 5 stories wood over 3 stories of concrete parking (Type IA podium)
- Savings by using wood could be spent on **luxury amenities**
- Dedication to **sustainable investments**
- Flexibility in design
- **Rooftop gardens** supported by wood trusses

Crescent Terminus

Atlanta, GA

Photo: Crescent Communities

Project Architect: Lord Aeck Sargent
Structural Engineer: SCA Consulting Engineers

Volume of wood products used:
3.1 million board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
16 minutes

Carbon stored in the wood:
4,327 metric tons of CO_2

Avoided greenhouse gas emissions:
9,196 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
13,523 metric tons of CO_2

EQUIVALENT TO:

2,583 cars off the road for a year

Energy to operate a home for 1,149 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

El Dorado High School

El Dorado, AR

IIIA


Photo: Dennis Ivy

- 322,500 square feet
- **$2.7 million savings** by switching from steel and masonry to wood
- **Exposed wood** to acknowledge Arkansas landscape and provide enriching educational space
- Barrel-vaulted roof with exposed **glulam bowstring trusses** in the arena

Architect: CADM Architecture, Inc.
Structural Engineer: Engineering Consultants, Inc.

El Dorado High School

El Dorado, AR

Photo: W.I. Bell

Architect: CADM Architecture, Inc.
Structural Engineer: Engineering Consultants, Inc.

Carbon Benefits

For more information on the calculations below, visit woodworks.org.

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed during the tree's growing cycle, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and used elsewhere. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood used:
4,340 cubic meters / 153,140 cubic feet of lumber, panels and engineered wood

U.S. and Canadian forests grow this much wood in:
13 minutes

Carbon stored in the wood:
3,660 metric tons of CO_2

Avoided greenhouse gas emissions:
7,780 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
11,440 metric tons of CO_2

EQUIVALENT TO:

2,100 cars off the road for a year

Energy to operate a home for 970 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent

1430 Q
Sacramento, CA

IIIA

- **6 stories of wood + mezzanine** over 2-story concrete podium (IIIA over IA)
- 63,000 square feet
- **First** of its kind in USA
- Needed 6 floors of residential units to make the project viable
- Concrete and steel were too expensive

Architect: HRGA, The HR Group Architects
Structural Engineer: Buehler

1430 Q
Sacramento, CA

Photo: Gary Folkins

1430 Q

Volume of wood products used:
1,708 cubic meters (60,334 cubic feet)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,426 metric tons of CO_2

Avoided greenhouse gas emissions:
3,031 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
4,457 *metric tons of* CO_2

EQUIVALENT TO:

942 cars off the road for a year

Energy to operate 471 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 *on this chart refers to* CO_2 *equivalent.*

Tallhouse, Boston

Source: Generate Architecture

Tallhouse Boston

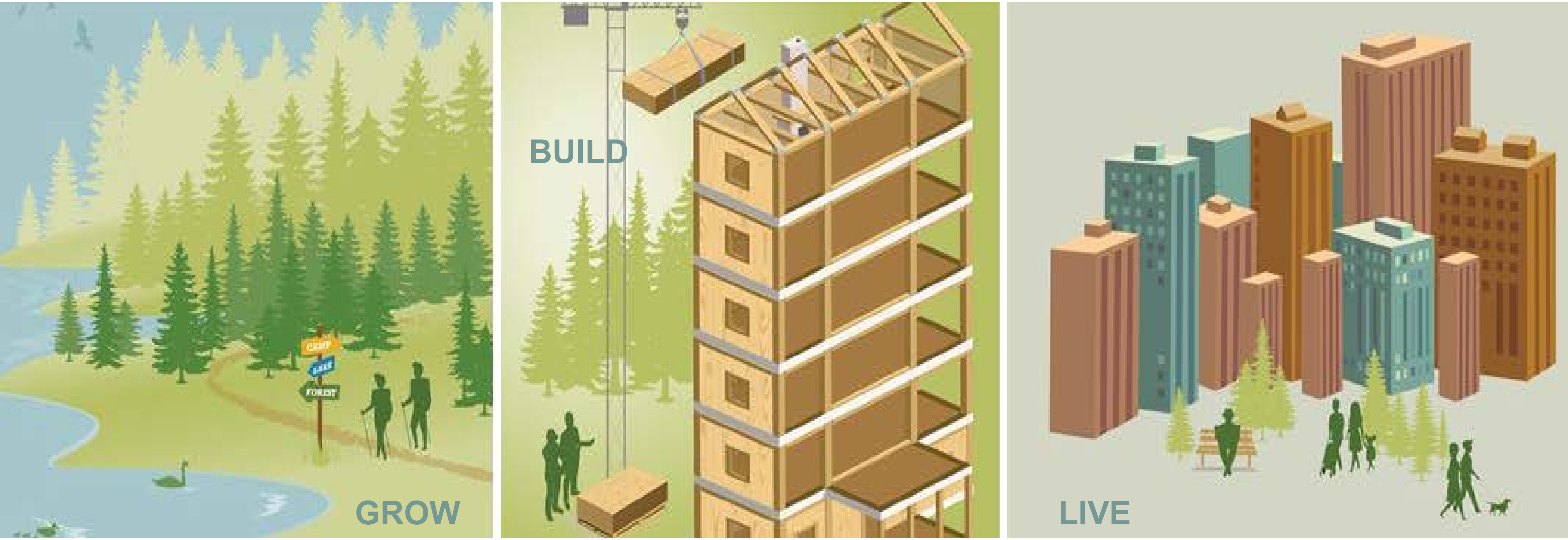
GLOBAL WARMING POTENTIAL & MATERIAL MASS
(PER BUILDING ASSEMBLY)

Source: Generate Architecture

The total global warming potential (GWP) of each option is shown with a breakdown by building assembly. The Concrete With Steel Frame and Concrete Flat Slab options have the highest GWP, with the bulk of the impact embedded in the floor slabs. The Timber Use 1 (Floor Slabs; Steel Frame) option offers a slight reduction in GWP, with the most of the savings also embedded in the floor slabs. The Timber Use 2 (Post, Beam, and Plate) option offers a relatively typical approach to building with timber, showing savings in floor slabs, beams and columns. Since Timber Use 3 and 4 are cellular approaches with load-bearing walls, these options included steel podiums to accommodate the ground floor program. Timber Use 3 shows how a hybrid approach with light gauge metal yields GWP savings in structural walls and exterior walls, despite the addition of the podium. Lastly, Timber Use 4 emphasizes how a completely cellular CLT

Forest to Cities

A Systemic Solution in Action



www.ForesttoCities.org

WoodWorks Online Event

Kendeda Building for Innovataive Sustainable Design, The Miller Hull Partnership with Lord Aeck Sargent, photo Jonathan Hillyer

1430 Q, The HR Group Architects, Buehler Engineering, Greg Folkins Photography

T3 Minneapolis, MGA, DLR Group, Magnusson Klemencic Associates, StructureCraft, photo Ema Peter

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

Early = Efficient

Realize Efficiency in:

- Cost reduction
- Material use (optimize fiber use, minimize waste)
- Construction speed
- Trade coordination
- Minimize RFIs

Commit to a mass timber design from the start

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 wit
Eng
Con
Ph

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:

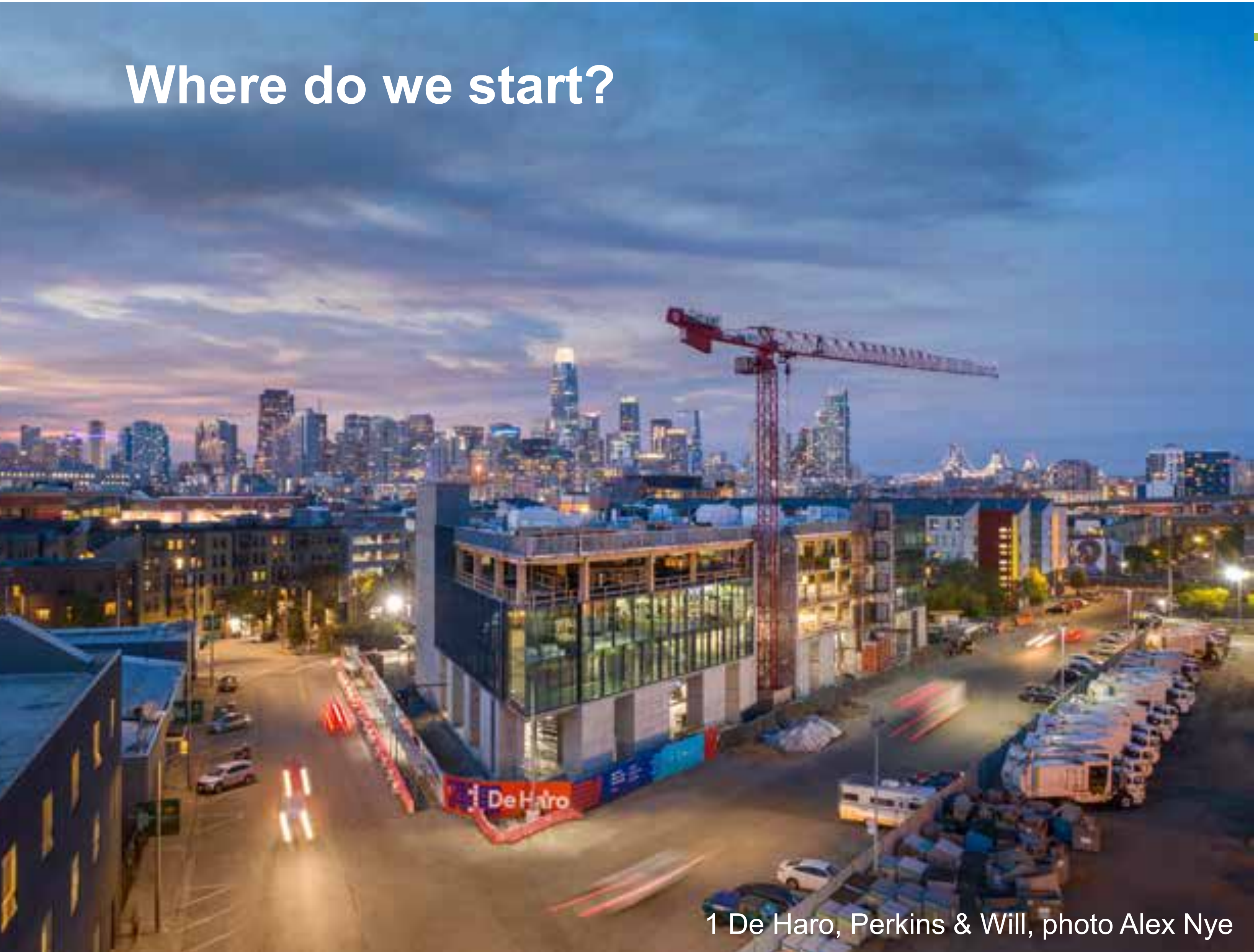
- **Grid** informs efficient spans, MEP layout
- **Manufacturer capabilities** inform member sizes, grids & connections
- **Lateral system** informs connections, construction sequencing

And more…

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

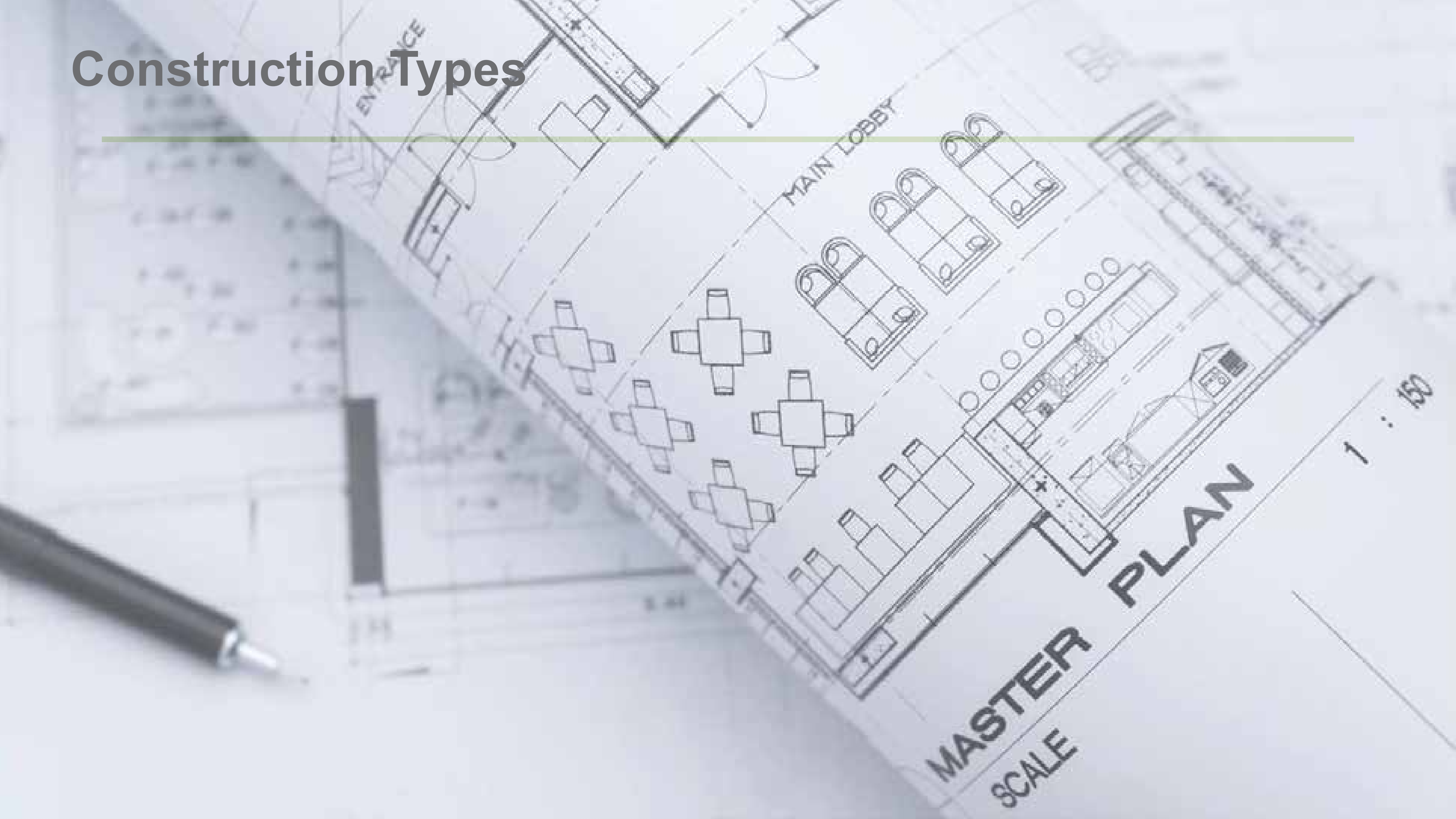
Key Early Design Decisions

Where do we start?



1 De Haro, Perkins & Will, photo Alex Nye

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?

- <u>Type IB & II</u>: Roof Decking

Photo Credit: DeStafano & Chamberlain, Inc, Robert Benson Photography

Image: StructureCraft Builders

Construction Types

All wood framed building options:

<u>Type III</u>
Exterior walls non-combustible (may be FRTW)
Interior elements any allowed by code, including mass timber

<u>Type V</u>
All building elements are any allowed by code, including mass timber

Types III and V are subdivided to A (protected) and B (unprotected)

<u>Type IV (Heavy Timber)</u>
Exterior walls non-combustible (may be FRTW OR CLT)
Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)

Photo Credit: Hacker Architects, Jeremy Bittermann

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)

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

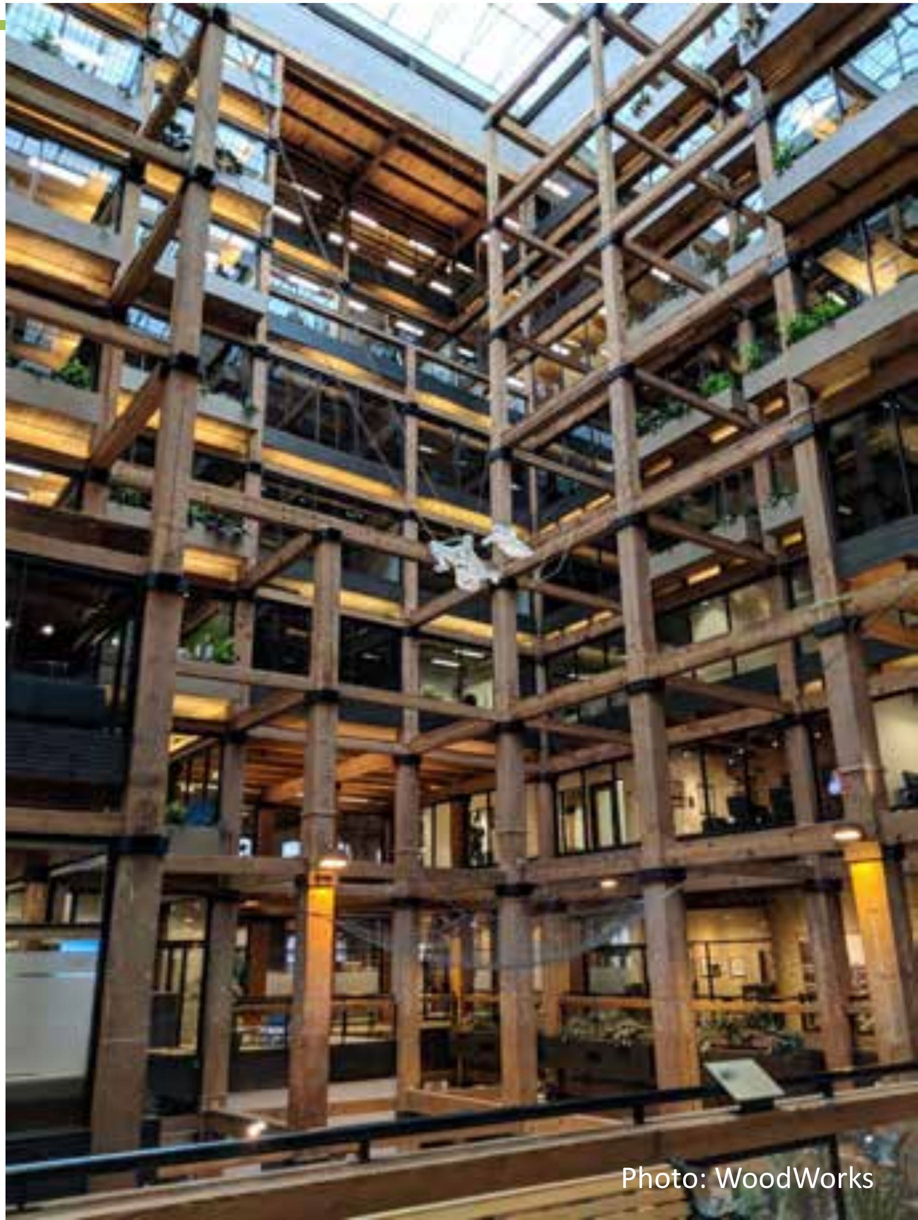


Photo: WoodWorks

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

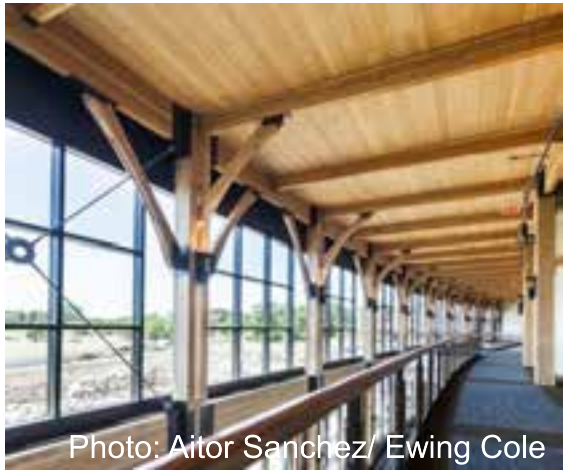


Photo: Aitor Sanchez/ Ewing Cole


Photo: WoodWorks

Construction Types

Type IV min. sizes:

Interior Walls:

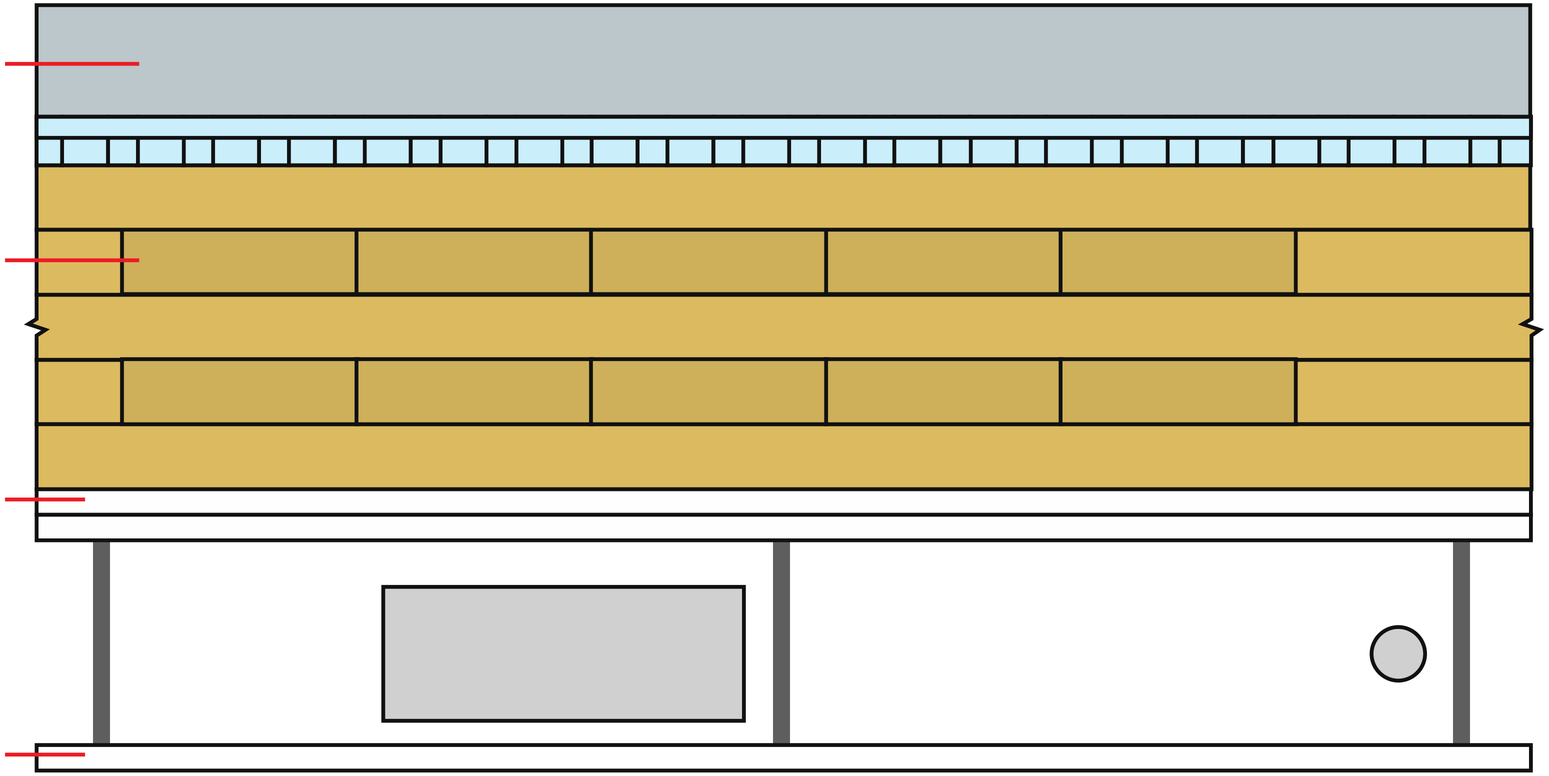
- Laminated construction 4” thick
- Solid wood construction min. 2 layers of 1” matched boards
- Wood stud wall (1 hr min)
- Non-combustible (1 hr min)

Verify other code requirements for FRR (eg. interior bearing wall; occupancy separation)

Construction Types

Type IV concealed spaces

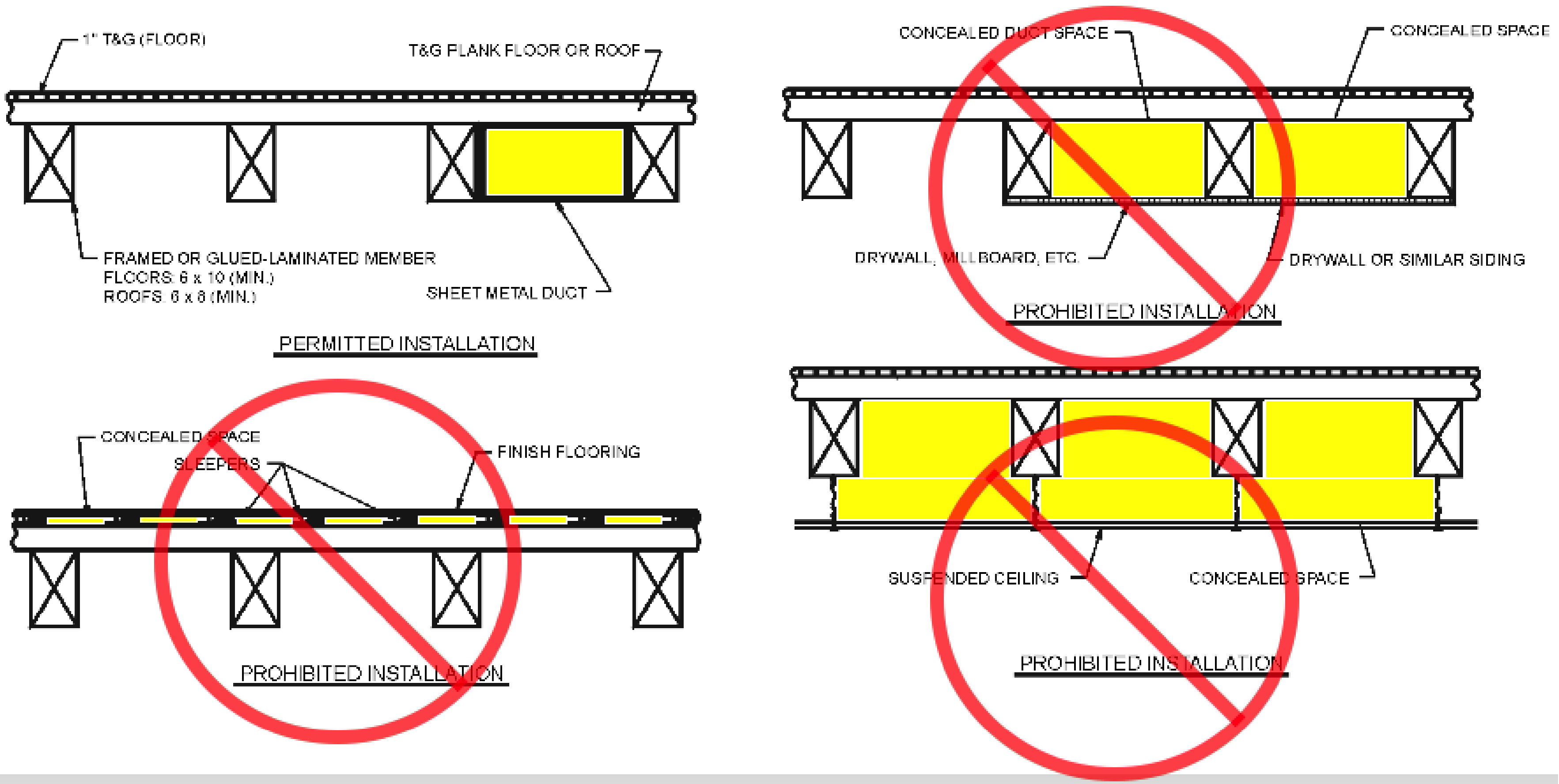
Can I have a dropped ceiling? Raised access floor?



Construction Types

Type IV concealed spaces

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



Credit: IBC

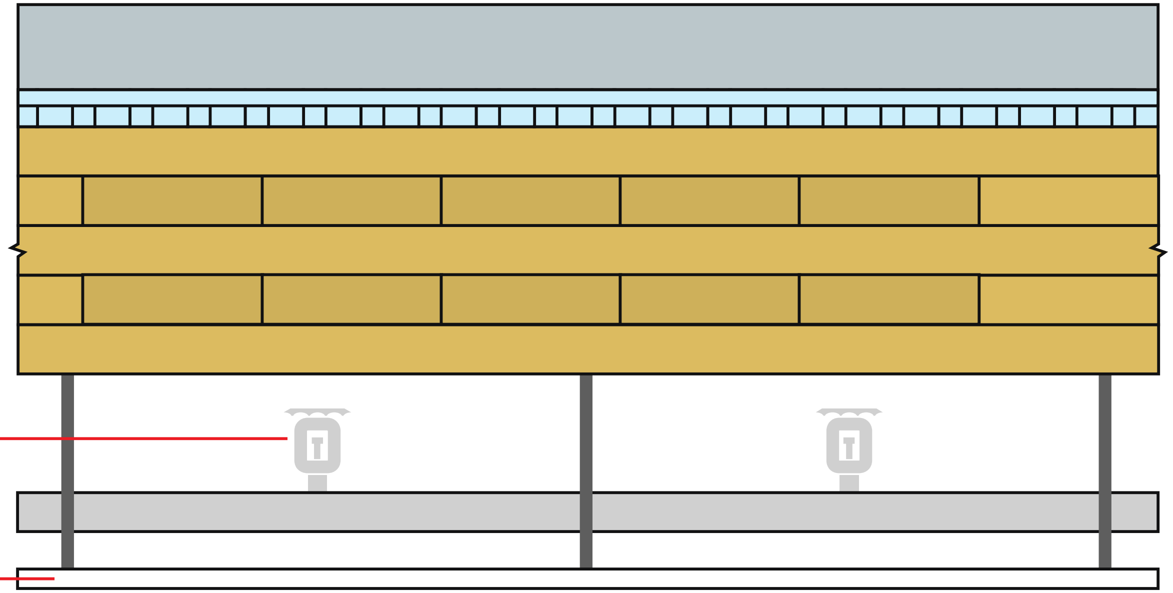
Construction Types

Type IV concealed space options within 2021 IBC

Option 1:

Sprinklers in concealed spaces

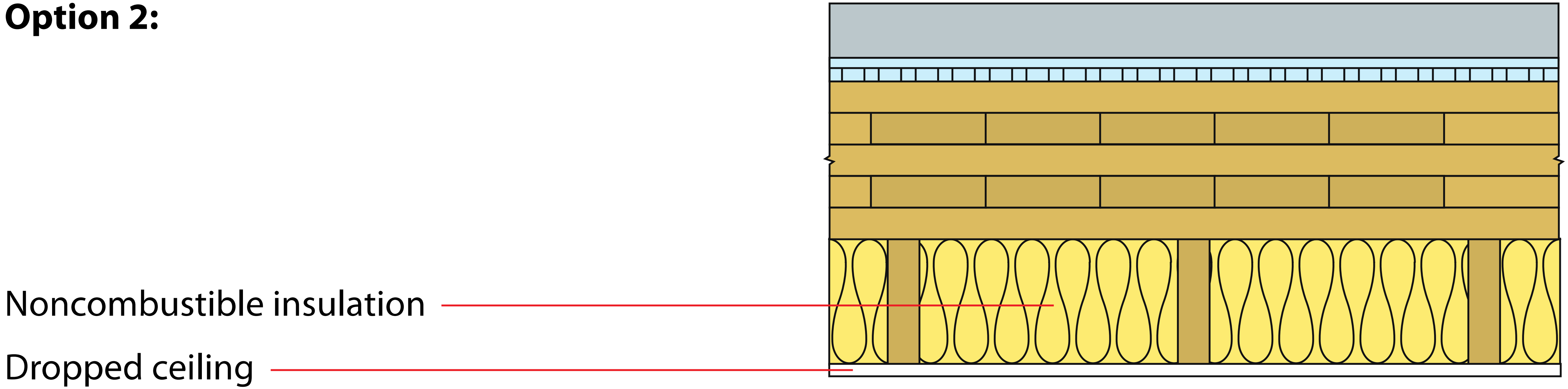
Dropped ceiling



Construction Types

Type IV concealed space options within 2021 IBC

Option 2:



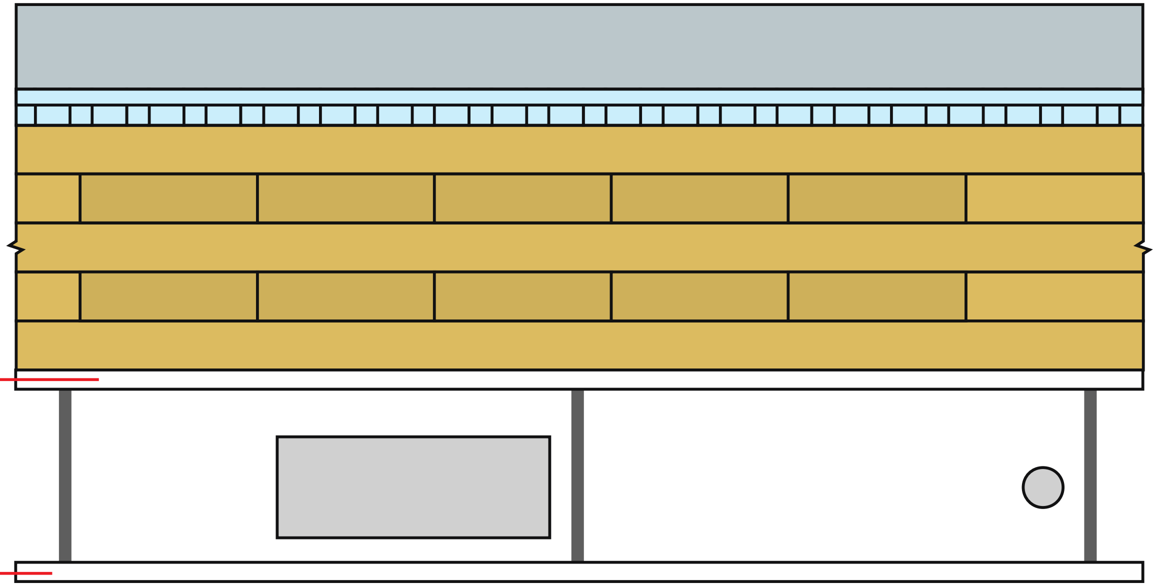
Construction Types

Type IV 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

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?*

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?

- <u>Type V</u>: All interior elements, roofs & exterior walls

Image: Christian Columbres Photography

Construction Types

Type III: 6 stories

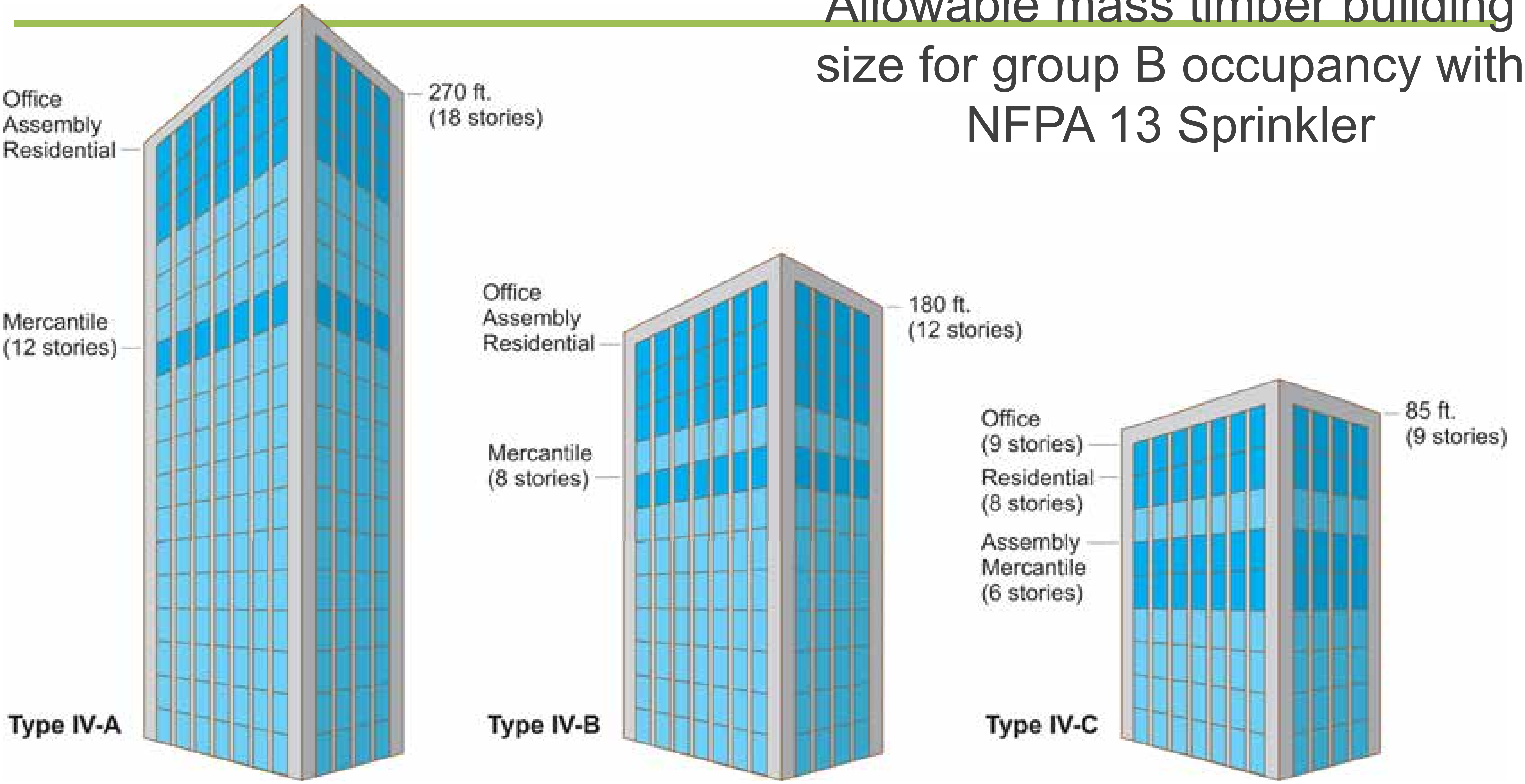
Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler

Type IV: 6 stories

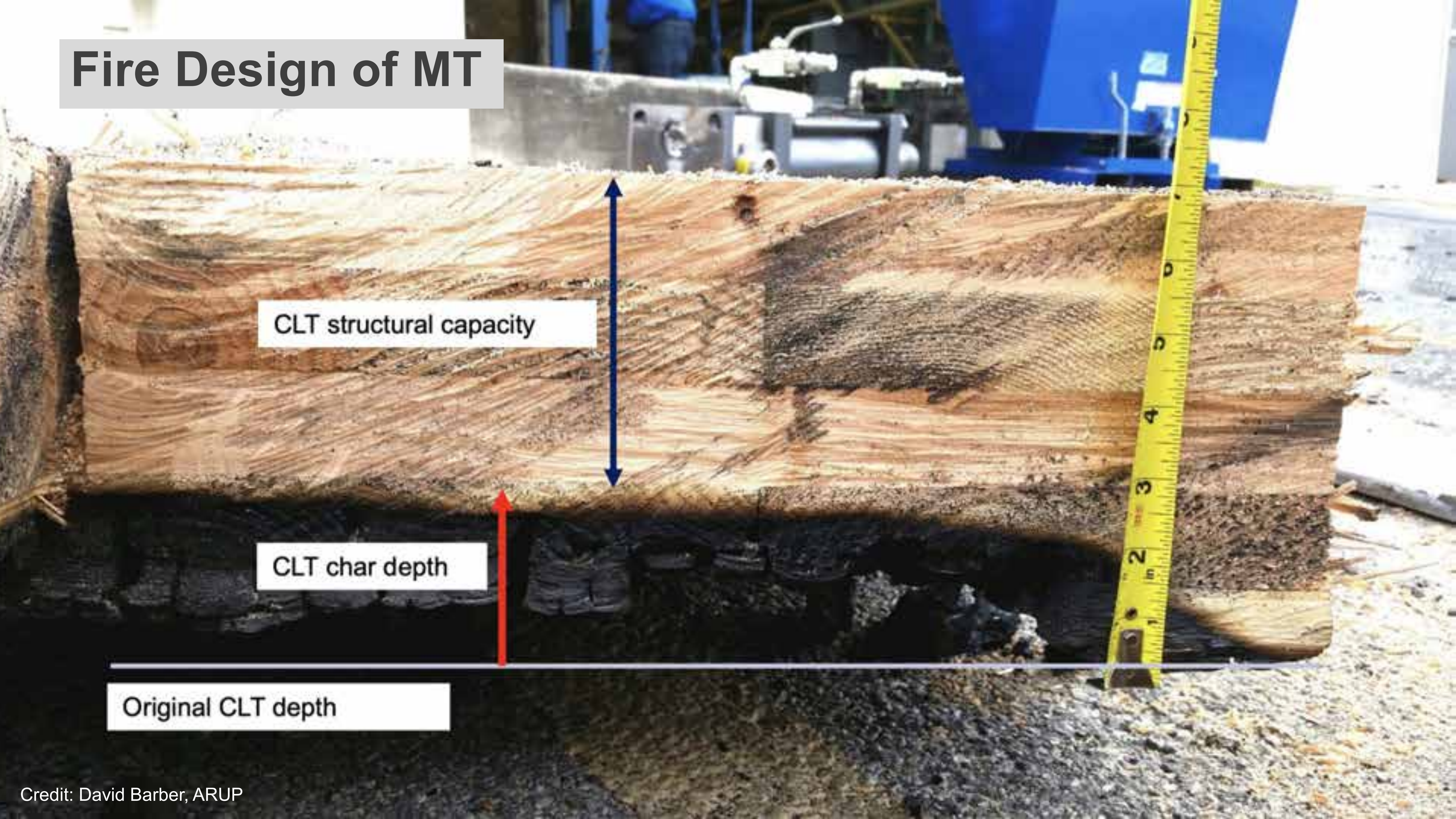
Type V: 4 stories

Construction Types

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



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

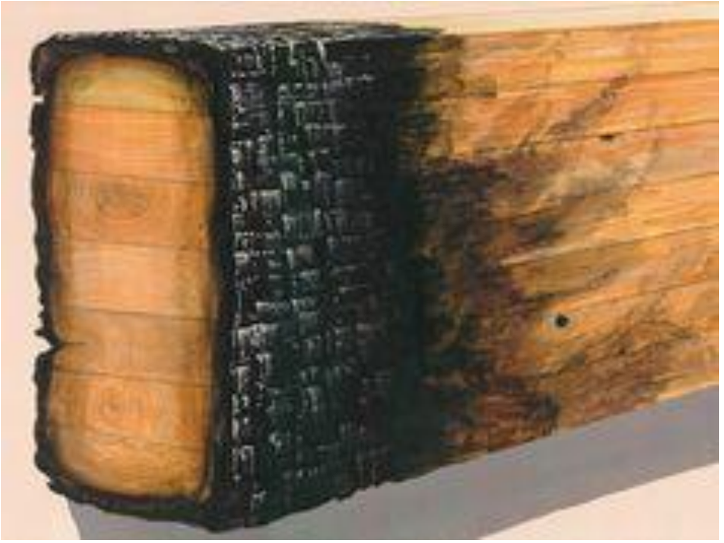
Source: 2018 IBC

Key Early Design Decisions

Construction type influences FRR

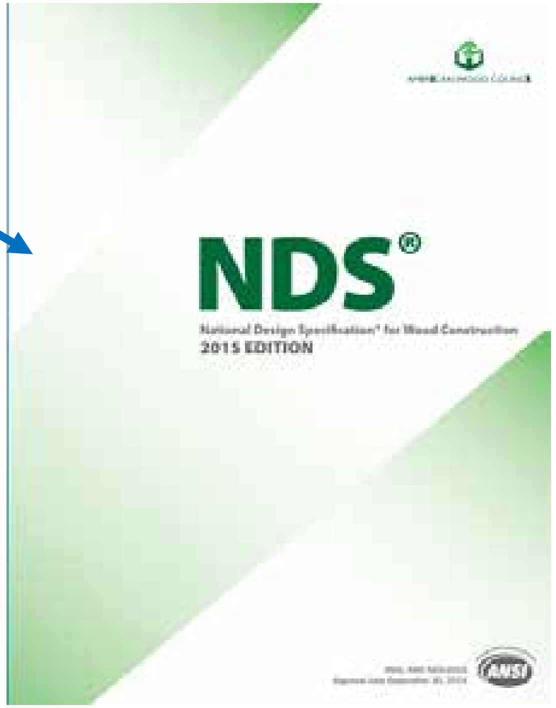
- Type IV-HT Construction (minimum sizes)
- **<u>Other than type IV-HT</u>**: Demonstrated fire resistance

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



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

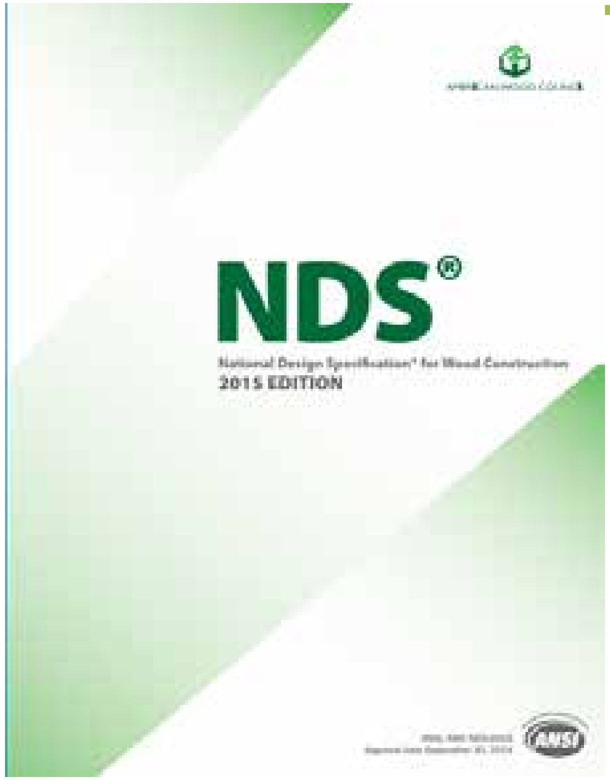
IBC 722
Calculated Fire Resistance

"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



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


Credit: FPInnovations

FRR Design of MT

NDS Table 16.2.2 Design stress adjustment factors applied to adjust to average ultimate strength under fire design conditions

Table 16.2.2 Adjustment Factors for Fire Design[1]

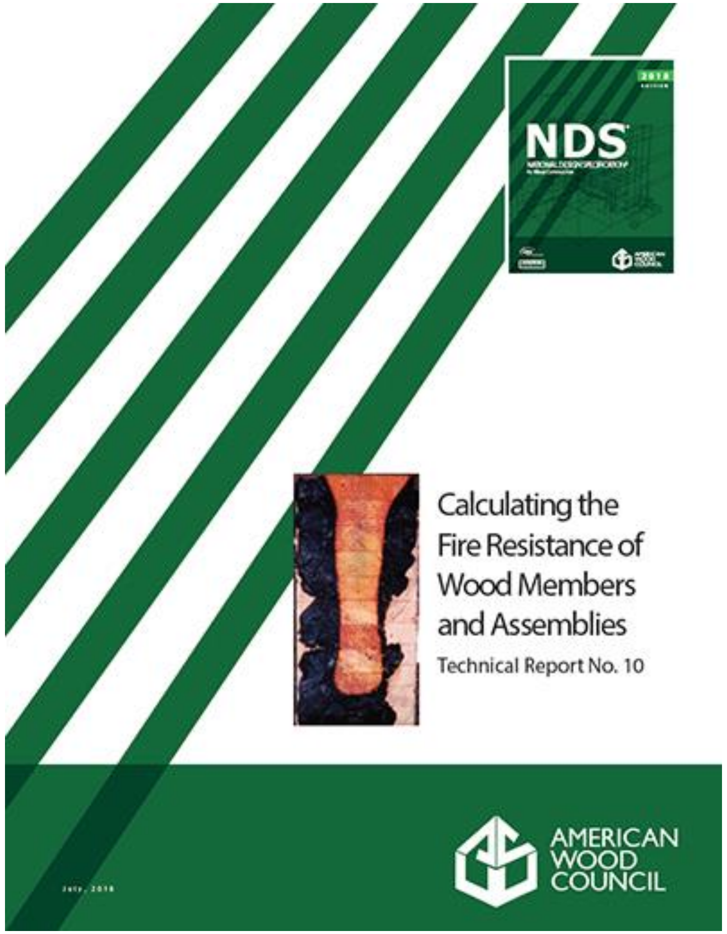
			ASD					
			Design Stress to Member Strength Factor	Size Factor[2]	Volume Factor[2]	Flat Use Factor[2]	Beam Stability Factor[3]	Column Stability Factor[3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-	-	-

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.

Source: AWC's NDS

FRR Design of MT

AWC's TR10 is a technical design guide, aids in the use of NDS Chapter 16 calculations



Example 5: Exposed CLT Floor - *Allowable Stress Design*

Simply-supported cross-laminated timber (CLT) floor spanning L=18 ft in the strong-axis direction. The design loads are q_{live}=80 psf and q_{dead}=30 psf including estimated self-weight of the CLT panel. Floor decking, nailed to the unexposed face of CLT panel, is spaced to restrict hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a 1-hour structural fire resistance time when subjected to an ASTM E119 fire exposure.

For the structural design of the CLT panel, calculate the maximum induced moment.

Calculate panel load (per foot of width):

$W_{load} = (q_{dead} + q_{live})$ = (30 psf +80 psf)(1ft width) =110 plf/ft of width

Calculate maximum induced moment (per foot of width):

$M_{max} = w_{load} L^2 / 8 = (110)(18^2)/8$ = 4,455 ft-lb/ft of width

From PRG 320, select a 5-ply CLT floor panel made from 1-3/8 in x 3-1/2 in. lumber boards (CLT thickness of 6-7/8 inches). For CLT grade V2, tabulated properties are:

Bending moment, $F_b S_{eff,0}$ = 4,675 ft-lb/ft of width (PRG 320 Annex A, Table A2)

Calculate the allowable design moment (assuming C_D=1.0: C_M=1.0: C_t=1.0: C_L=1.0)

$M_s' = F_b(S_{eff})(C_D)(C_M)(C_t)(C_L)$ = 4,675 (1.0)(1.0)(1.0) = 4,675 ft-lb/ft of width (NDS 10.3.1)

Structural Check: $M_s' \geq M_{max}$ **4,675 ft-lb/ft > 4,455 ft-lb/ft** √

(note: serviceability check is not performed to simplify the design example, but should be done in typical structural design).

Source: AWC's TR10

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	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	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete 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 gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capacity	2	4	UL
3-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	E1 M5 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 & Topside spline [illegible]	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

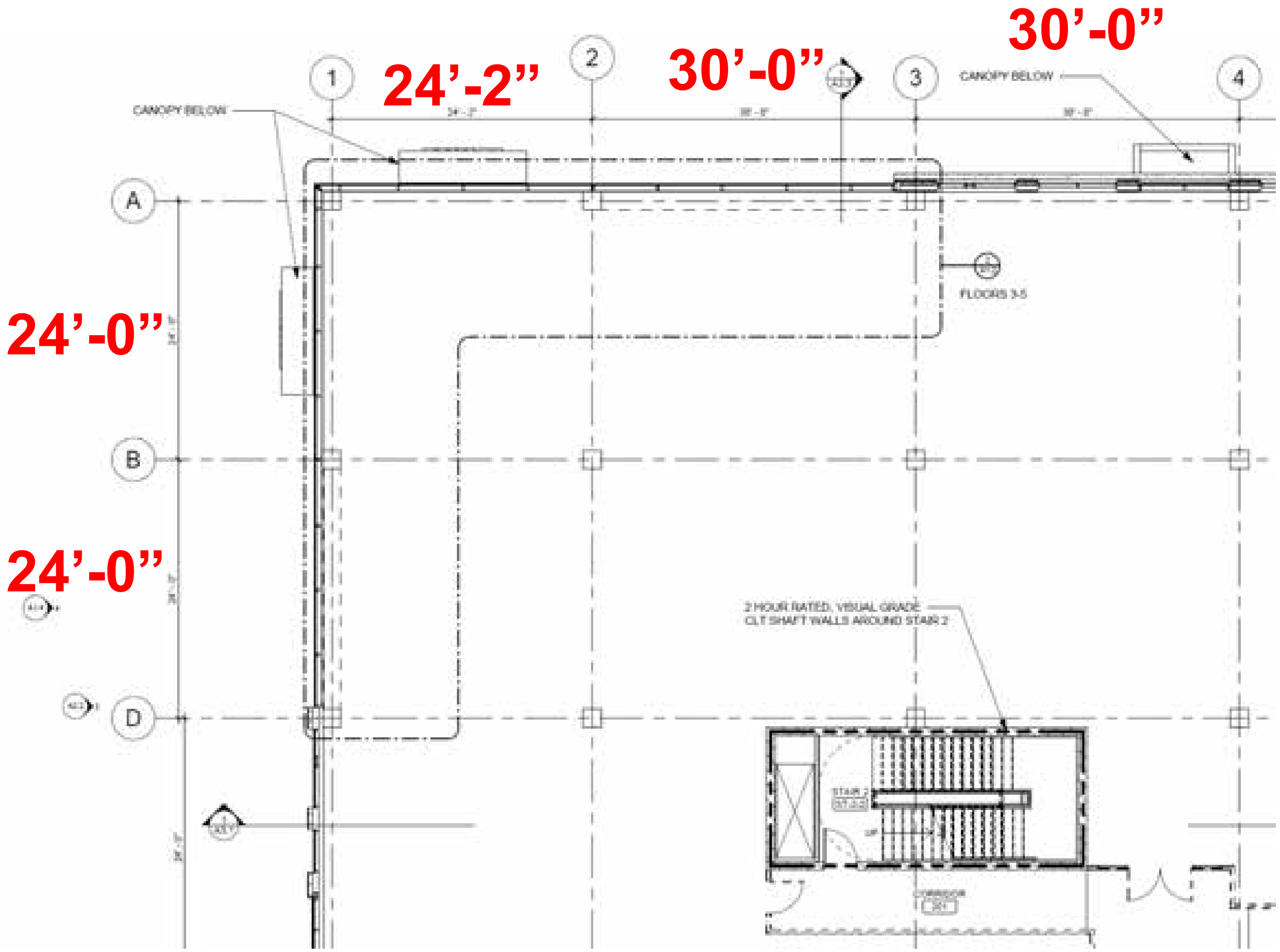
- Code compliance options for demonstrating FRR
- Free download at woodworks.org

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

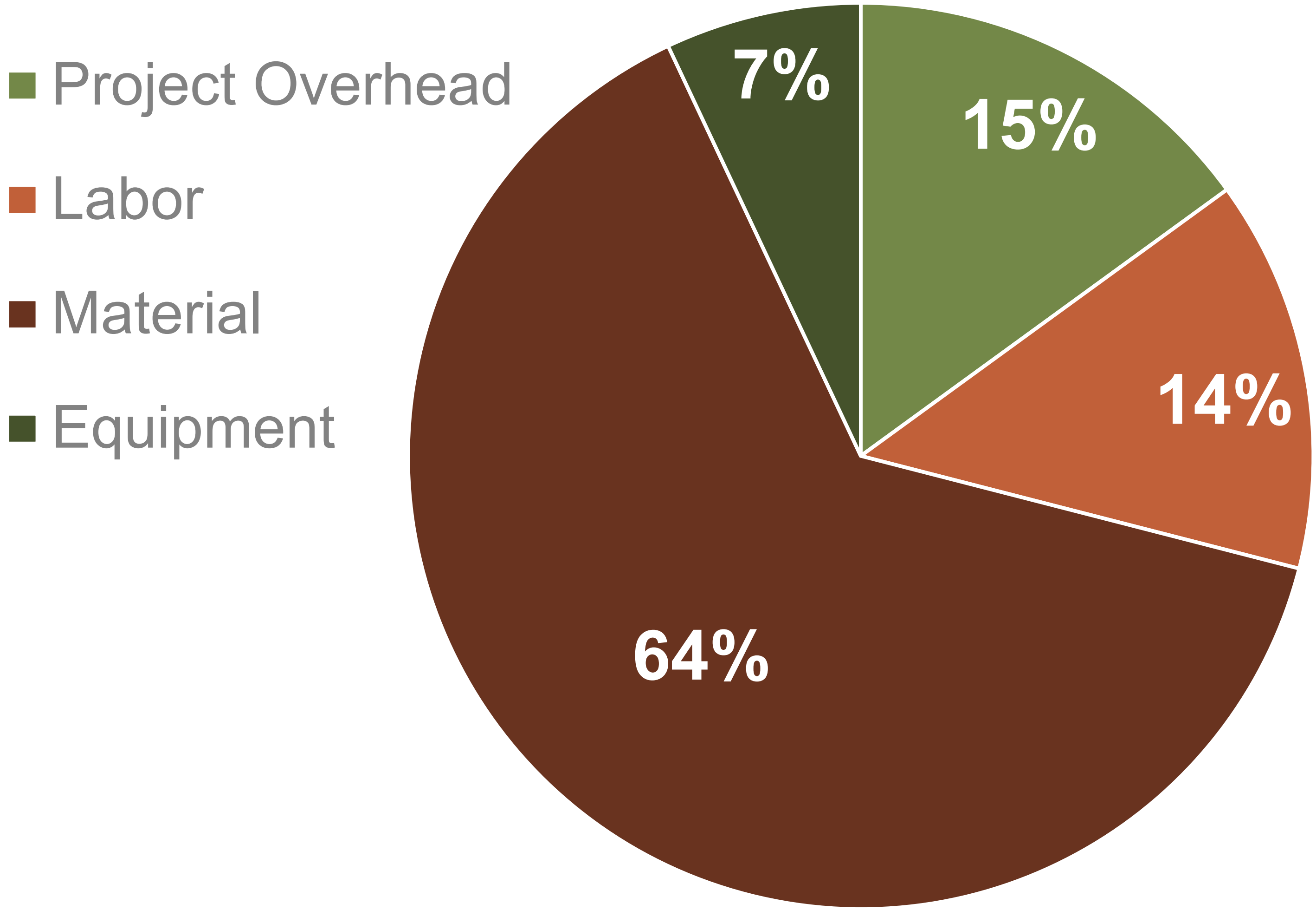
First Tech Credit Union, Hillsboro, OR
12x32 Grid, One-Way Beams
5-ply (5.5”) CLT
Image: Swinerton

Key Early Design Decisions

Why so much focus on panel thickness?

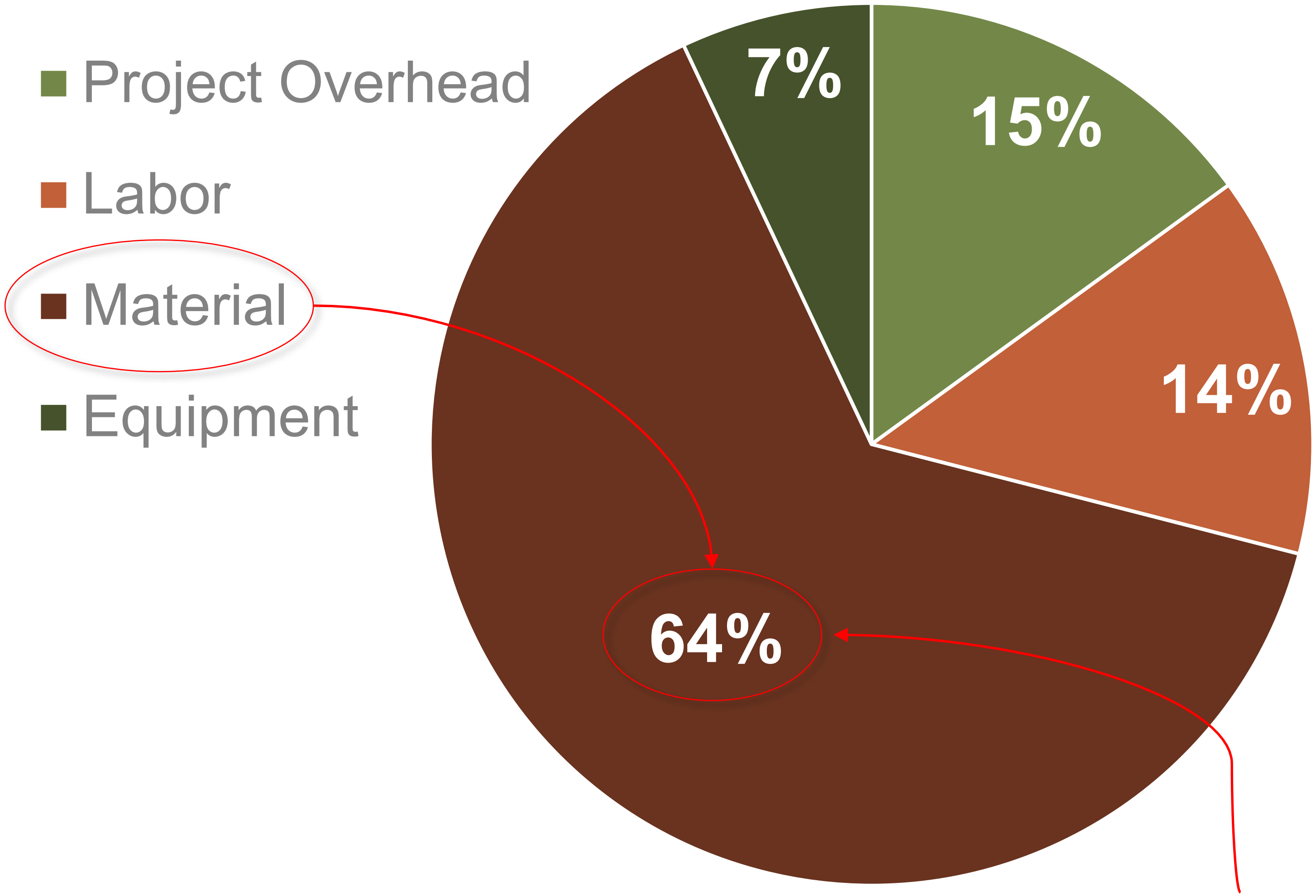
Key Early Design Decisions

Typical MT Package Costs



Source: Swinerton

Key Early Design Decisions

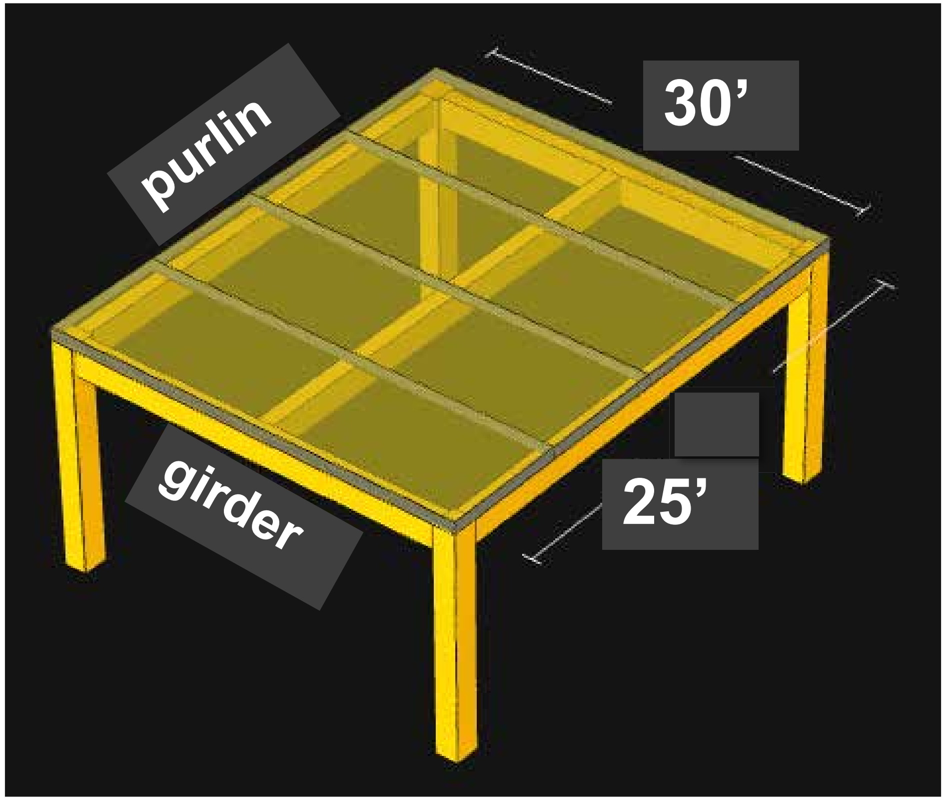


Panels are the biggest part of the the biggest piece of the cost pie

Source: Swinerton

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

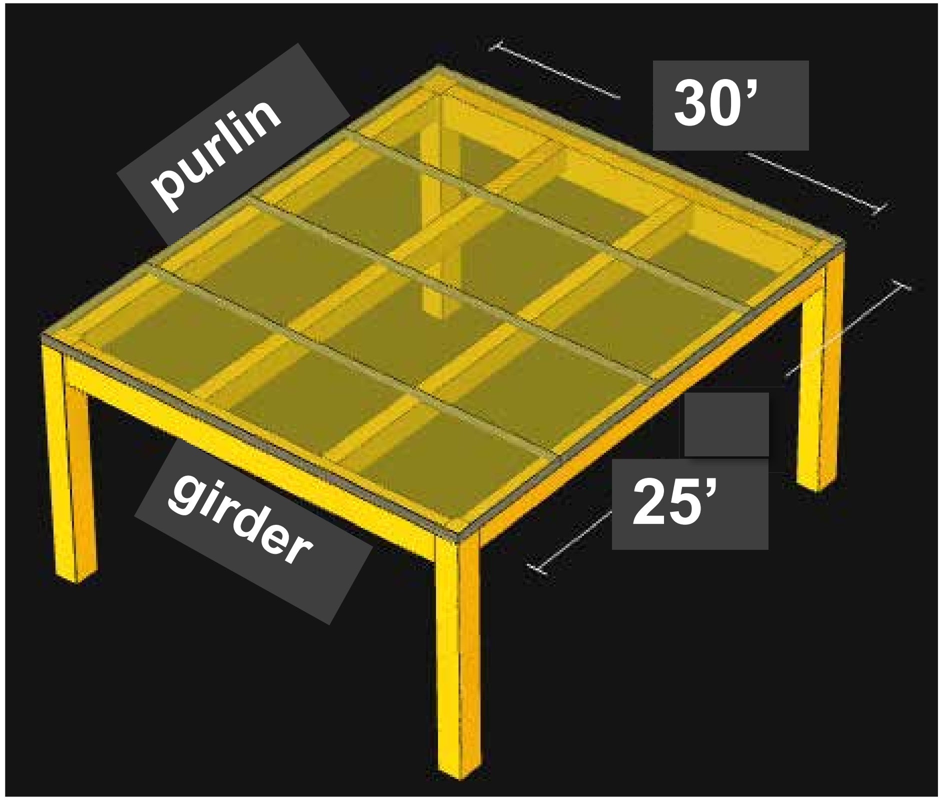
Type IIIA option 1

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

Key Early Design Decisions

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)

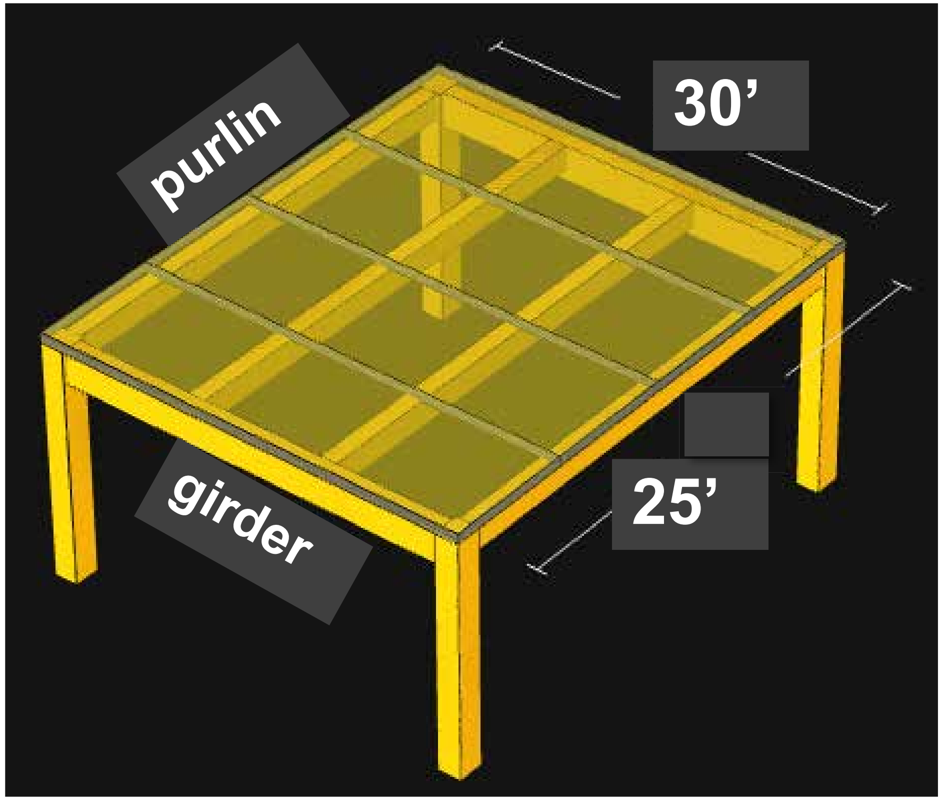
CLT volume = 430 CF (78% of MT)

Total volume = 0.74 CF / SF

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

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

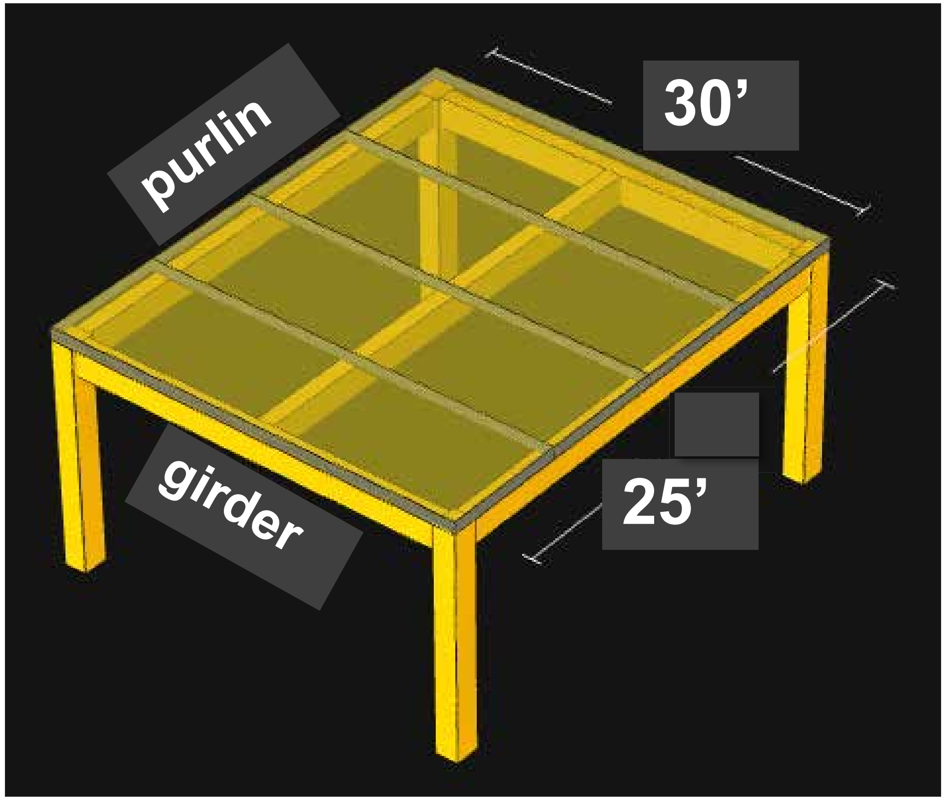
Type IV-HT

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

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

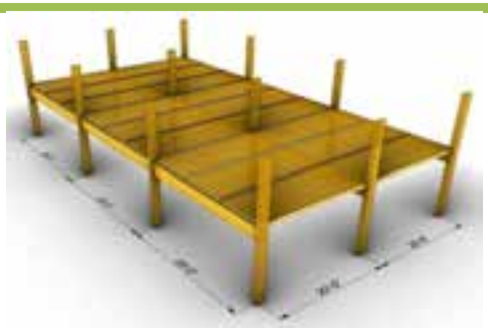
Type IV-C

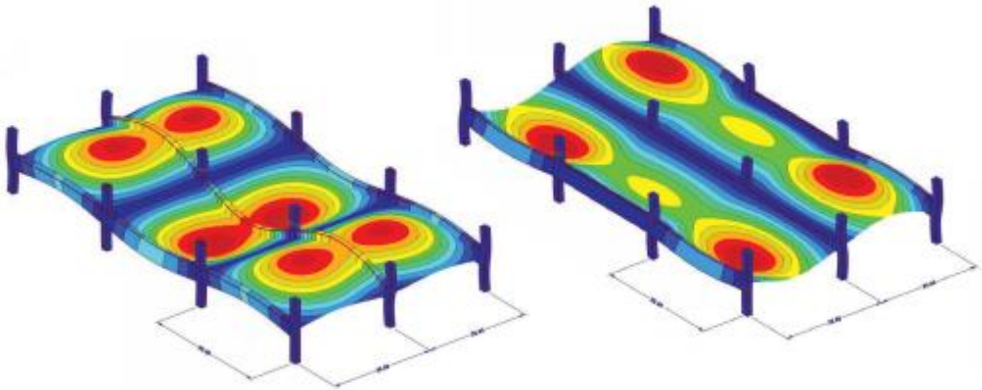
2-hr FRR
Purlin: 8.75”x28.5”
Girder: 10.75”x33”
Column: 13.5”x21.5”
Floor panel: 5-ply

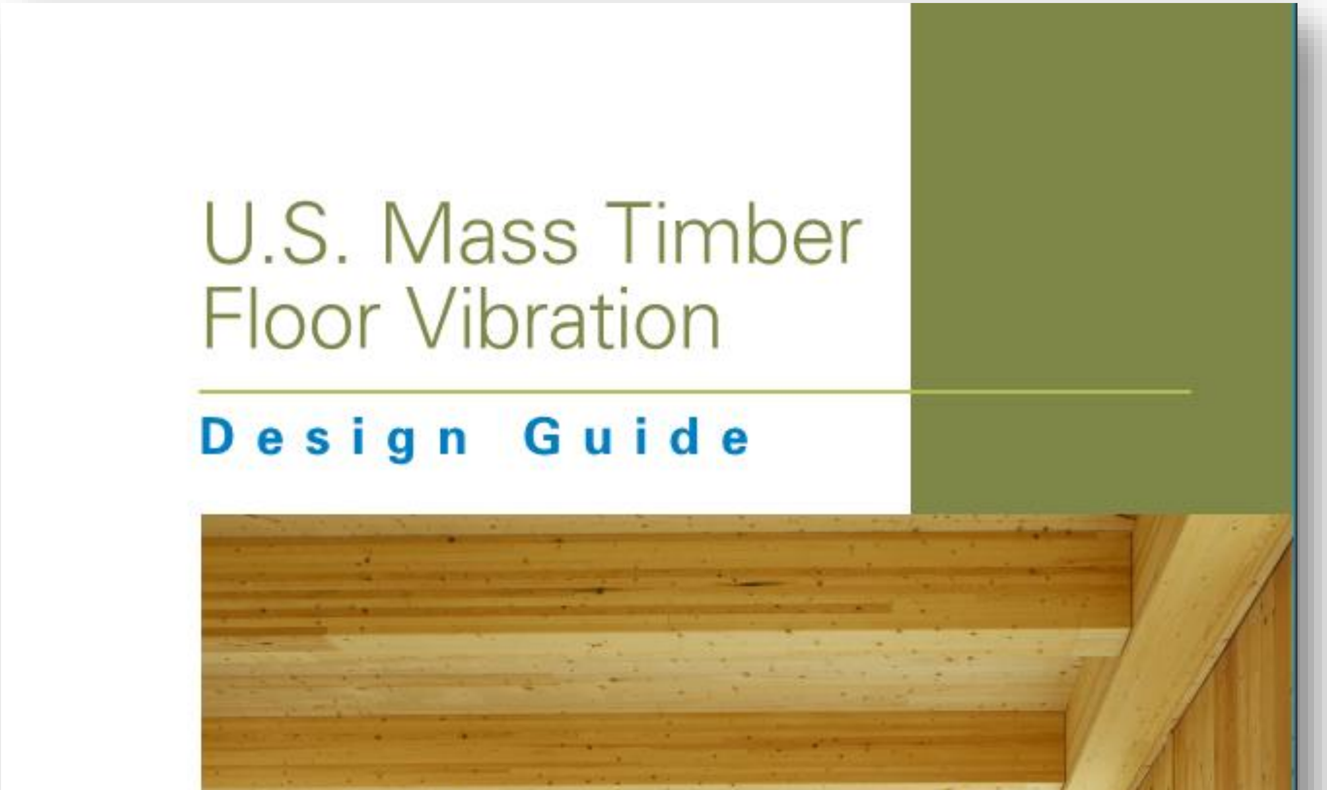
Glulam volume = 183 CF (30% of MT)
CLT volume = 430 CF (70% of MT)
Total volume = 0.82 CF / SF

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

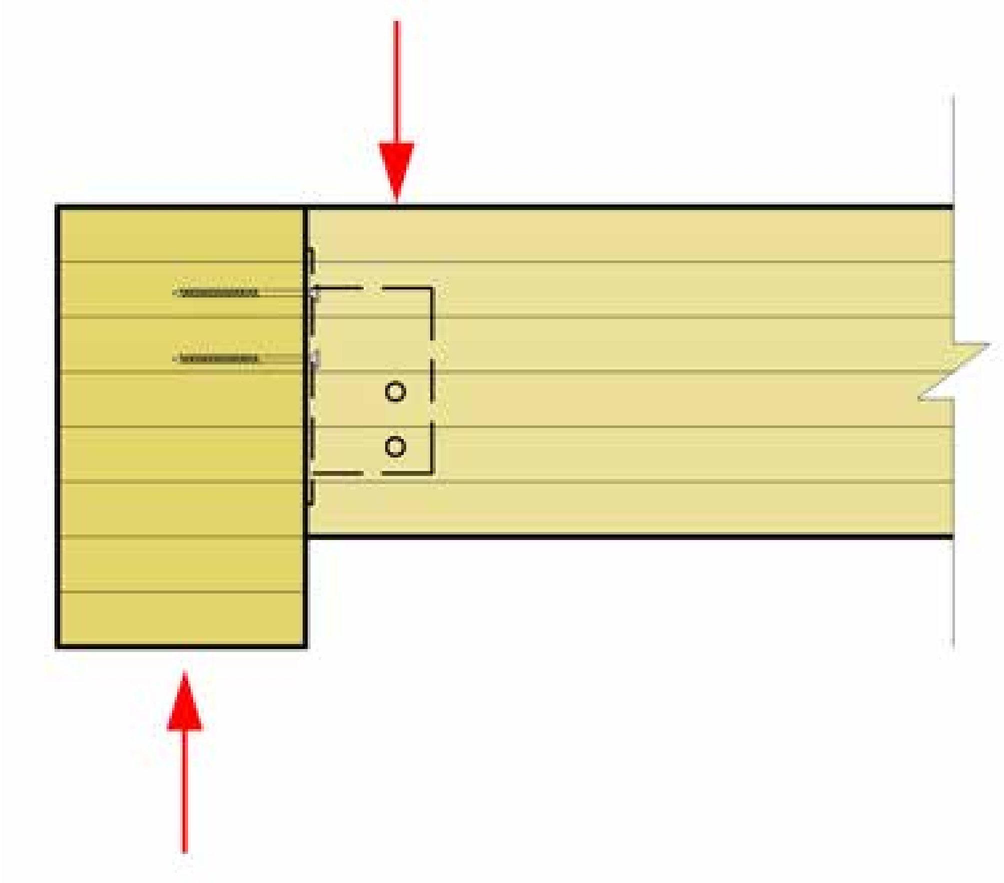

Photo: Josh Partee


Photo: Christian Columbres


Photo: Blaine Brownell

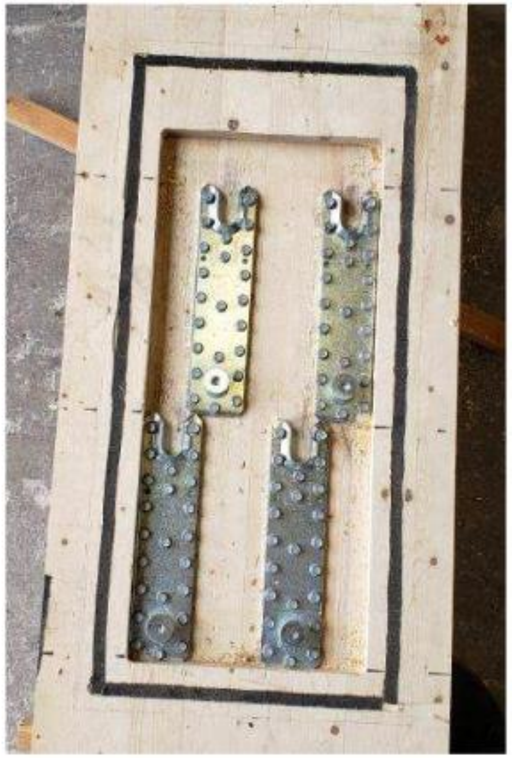
Key Early Design Decisions

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



Key Early Design Decisions

Connection FRR and beam reactions could impact required beam/column sizes



Photos: Simpson Strong-Tie

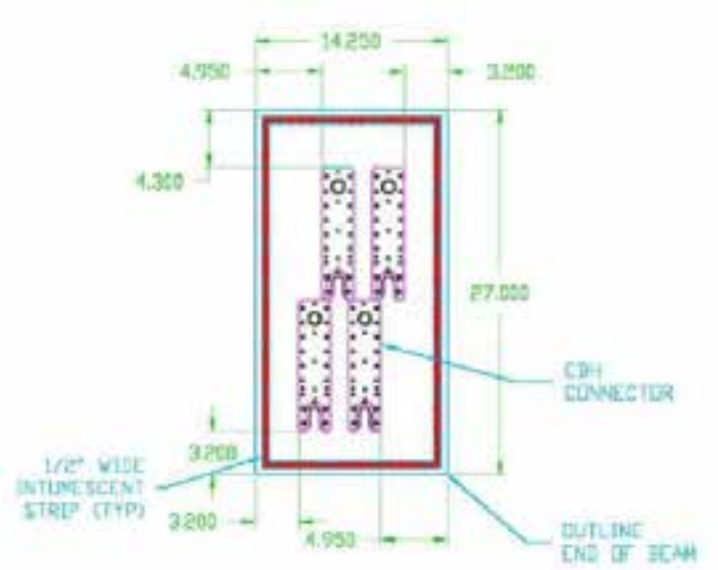


Photo: LEVER Architecture

Key Early Design Decisions

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


Photo: ARUP/SLB

Key Early Design Decisions

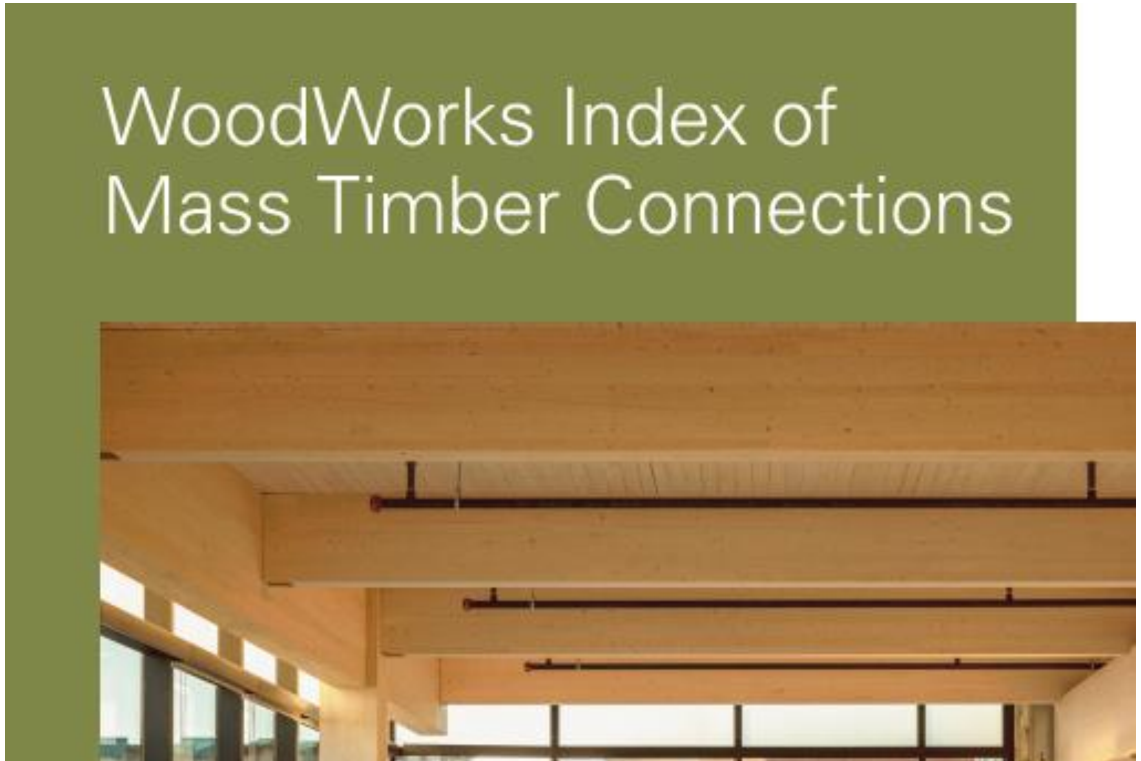
Member to member bearing also commonly used, can avoid some/all steel hardware at connection

Key Early Design Decisions

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

Style of connection also impacts and is impacted by grid layout and MEP integration

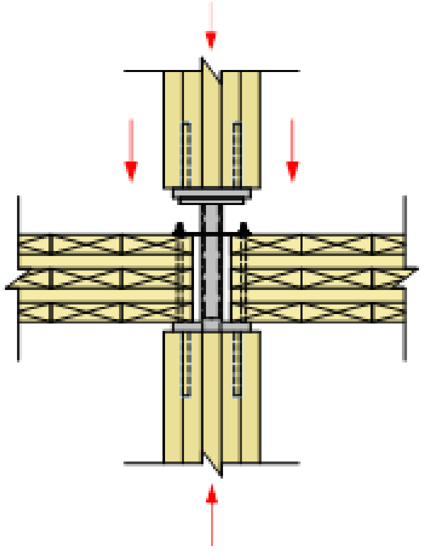
Key Early Design Decisions

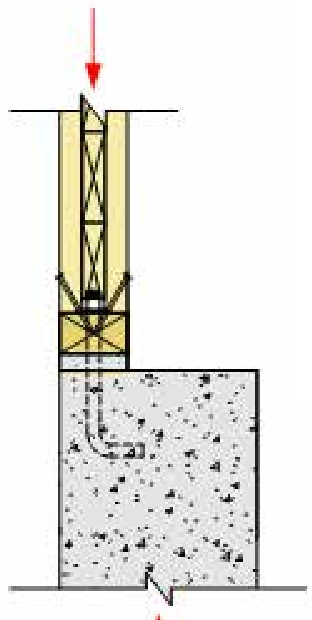


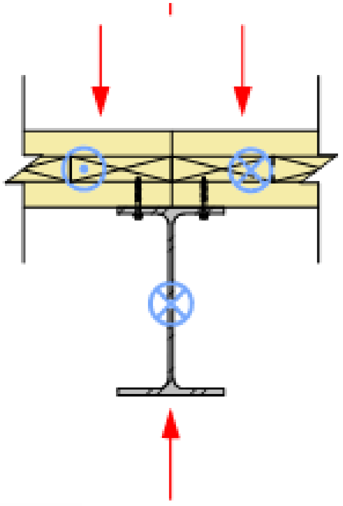
MASS TIMBER CONNECTIONS INDEX

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

Credit: Alex Schreyer

Penetrations & Firestopping

Photo: Alex Schreyer

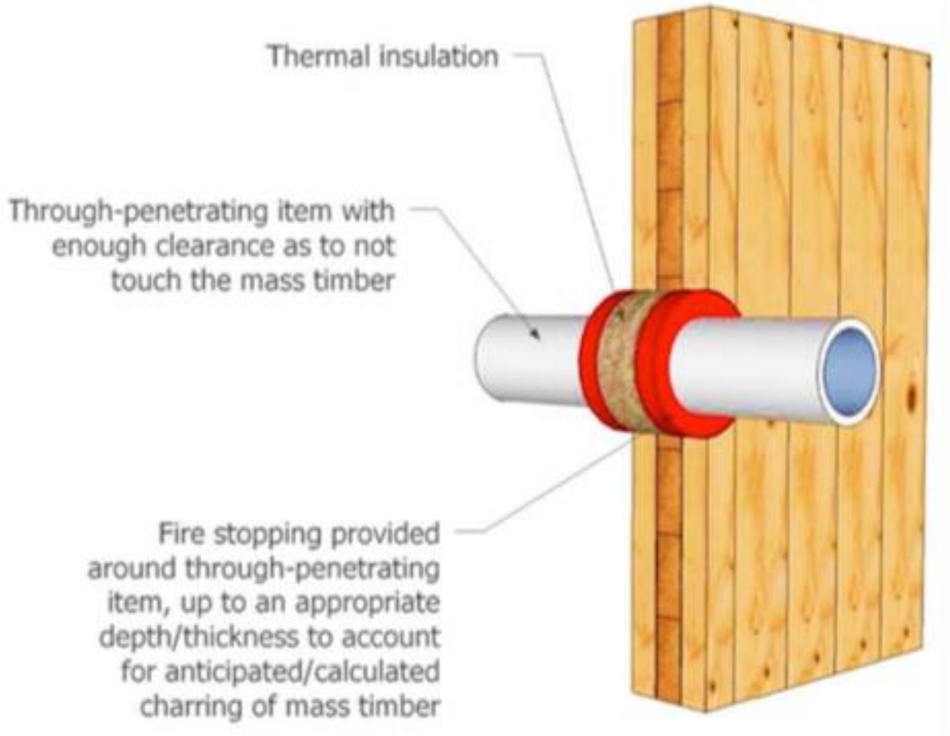
Penetrations & Firestopping

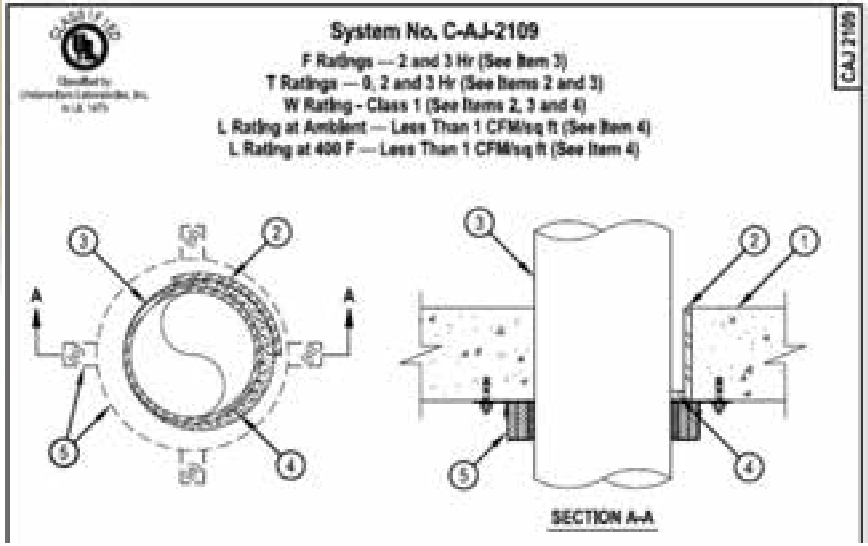
Option 1: MT penetration firestopping via tested products


Photos: AWC/FPInnovations

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

SOUTHWEST RESEARCH INSTITUTE®

CHEMISTRY AND CHEMICAL ENGINEERING DIVISION

FIRE RESISTANCE PERFORMANCE EVALUATION OF A PENETRATION FIRESTOP SYSTEM TESTED IN ACCORDANCE WITH ASTM E814-13A, *STANDARD TEST METHOD FOR FIRE TESTS OF PENETRATION FIRESTOP SYSTEMS*

FINAL REPORT
Consisting of 18 Pages

SwRI® Project No. 01.21428.01.001a
Test Date: September 30, 2015
Report Date: October 22, 2015

Prepared for:

American Wood Council
222 Catoctin Circle SE
Leesburg, VA 20175

WCTE 2018

FIRE PERFORMANCE OF FIRESTOPS, PENETRATIONS, AND FIRE DOORS IN MASS TIMBER ASSEMBLIES

Lindsay Ranger [1], Christian Dagenais [1], Conroy Lum[1], Tony Thomas[2]

ABSTRACT: Integrity and continuity must be maintained for fire separations required to provide f… prevent passage of hot gases or increased temperature on the unexposed side. Vulnerable locations, whe… are introduced into mass timber systems, are susceptible to fire spread. Service and closure penetra… timber fire separation have been investigated. Many of the fire stop systems were able to achieve 1-½… accordance with CAN/ULC-S115, which would be required for 2-hr fire resistance rated assemblies, u… tall wood buildings. Construction details are outlined which ensure adequate fire performance of these p…

KEYWORDS: Firestop, through-penetrations, fire rated door, mass timber, cross-laminated tim… buildings, fire resistance

1 INTRODUCTION

Many tall wood buildings using mass timber are planned or are currently being designed for construction around the world. A few have been built in Canada, including an 18 storey cross-laminated timber (CLT) and glulam building in British Columbia. The prescriptive requirements in the National Building Code of Canada (NBCC) [1] do not (yet) permit the construction of wood buildings taller than six stories, however an alternative solutions approach can be used to demonstrate equivalent performance to prescriptive acceptable …

construction, as well as in several alte… building designs.

Although the general fire performance … well documented, there are still seve… warrant further investigation to ensur… safety levels are met and a number … available for designers to use. Generatin… generic assemblies will reduce the need … completed on an individual constructio… which will help ease the approvals proce… widespread adoption of tall wood buildin…

GHL CONSULTANTS LTD

FIRESTOPPING TEST WITNESS REPORT

for

NORDIC STRUCTURES

Penetrations & Firestopping

Inventory of Fire Tested Penetrations in MT Assemblies

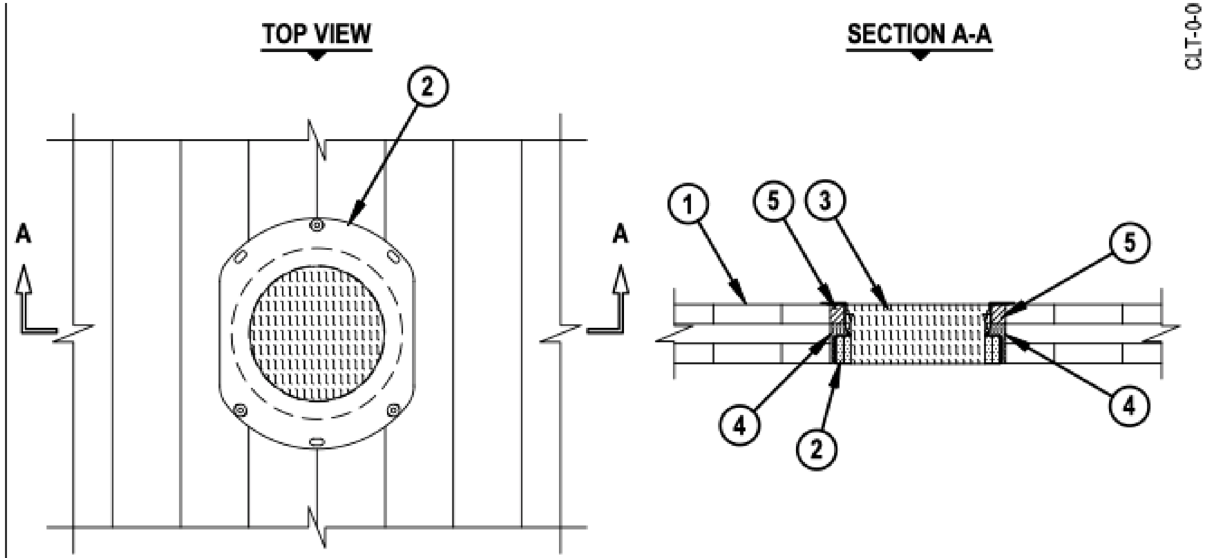
Table 3: North American Fire Tests of Penetrations and Fire Stops in CLT Assemblies

WoodWorks WOOD PRODUCTS COUNCIL

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	CAN ULC 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.	CAN ULC 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.	CAN ULC 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.	CAN ULC 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	CAN ULC 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 1 in. 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	CAN ULC 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.	CAN ULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	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 4 – 5/32 in. 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.	2 hours	0.5 hour	CAN ULC S115	26	Intertek March 30, 2016
5-ply CLT (131mm 5.16")	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 4 – 5/32 in. 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.	2 hours	N.A.	CAN ULC S115	26	Intertek March 30, 2016
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	CAN ULC 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

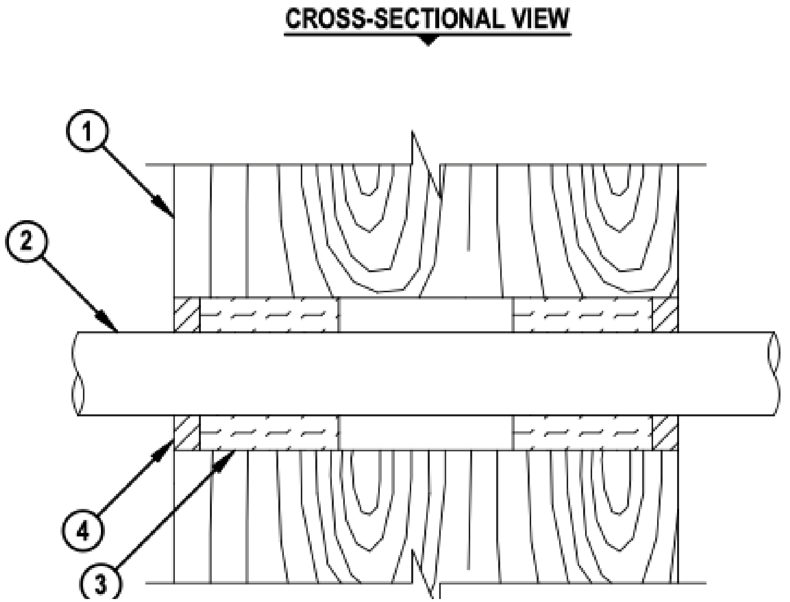
Penetrations & Firestopping

Option 2: MT penetration firestopping of penetrations via engineering judgement details (contact firestop manufacturer)



1. 3-PLY CROSS LAMINATED TIMBER FLOOR ASSEMBLY (MINIMUM 3" THICK) (1-HR. FIRE-RATING).
2. HILTI CFS-DID FIRESTOP DROP-IN DEVICE INSERTED INTO OPENING (SEE TABLE BELOW) AND SECURED TO TOP SURFACE OF CROSS LAMINATED TIMBER FLOOR ASSEMBLY WITH THREE 1/4" x 1" LONG STEEL WOOD SCREWS WITH WASHERS.
3. MINIMUM 3" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED, AND FLUSH WITH TOP AND BOTTOM SURFACE OF CFS-DID FIRESTOP DROP-IN DEVICE.
4. MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED, RECESSED TO ACCOMMODATE SEALANT, AND COMPLETELY FILLING SPACE BETWEEN CFS-DID FIRESTOP DROP-IN DEVICE AND PERIPHERY OF OPENING.
5. MINIMUM 1" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP SEALANT BETWEEN CFS-DID FIRESTOP DROP IN DEVICE AND PERIPHERY OF OPENING.

F-RATING = 1-HR. OR 2-HR. (SEE NOTE NO. 3 BELOW)

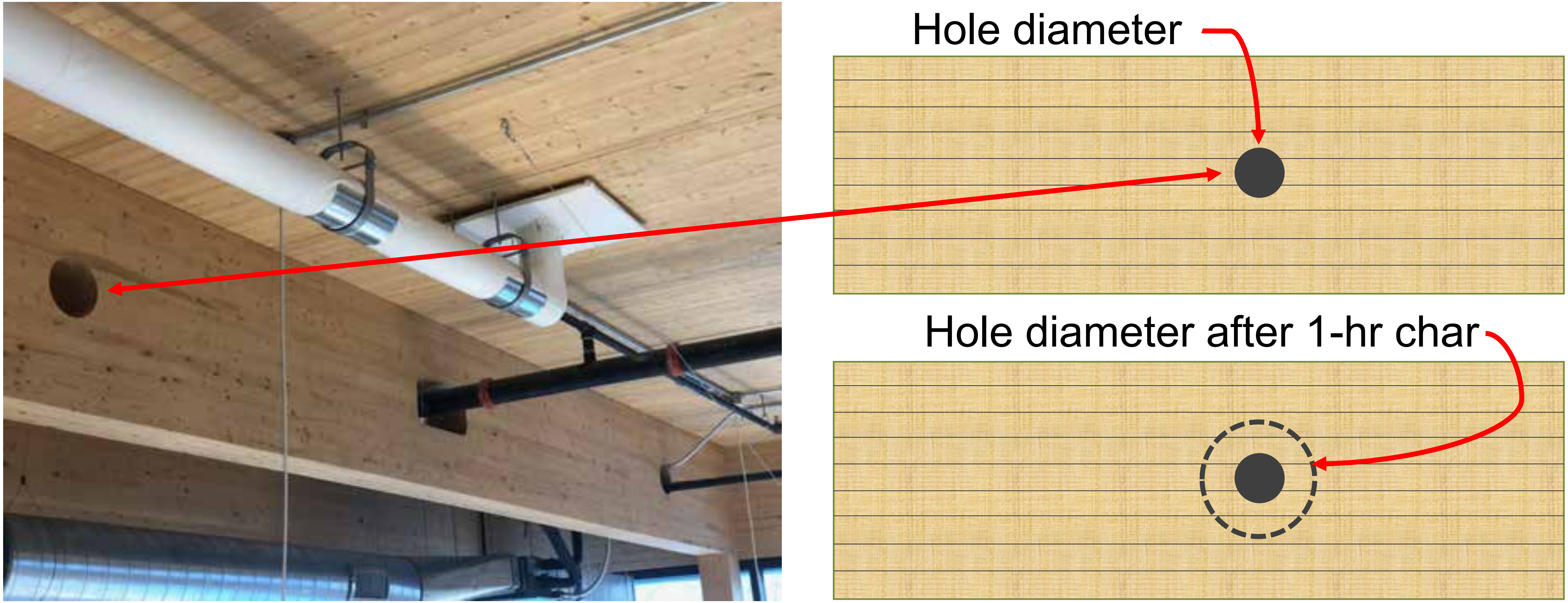


1. MASS TIMBER WALL ASSEMBLY (MINIMUM 12" THICK) (1-HR. OR 2-HR. FIRE-RATING).
2. MAXIMUM 2" NOMINAL DIAMETER PVC PLASTIC PIPE (SCH 40).
3. MINIMUM 4" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED AND RECESSED TO ACCOMMODATE SEALANT.
4. MINIMUM 3/4" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP SEALANT.

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

Set Realistic Owner Expectations About Aesthetics

- MEP fully exposed with MT structure, or limited exposure?



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

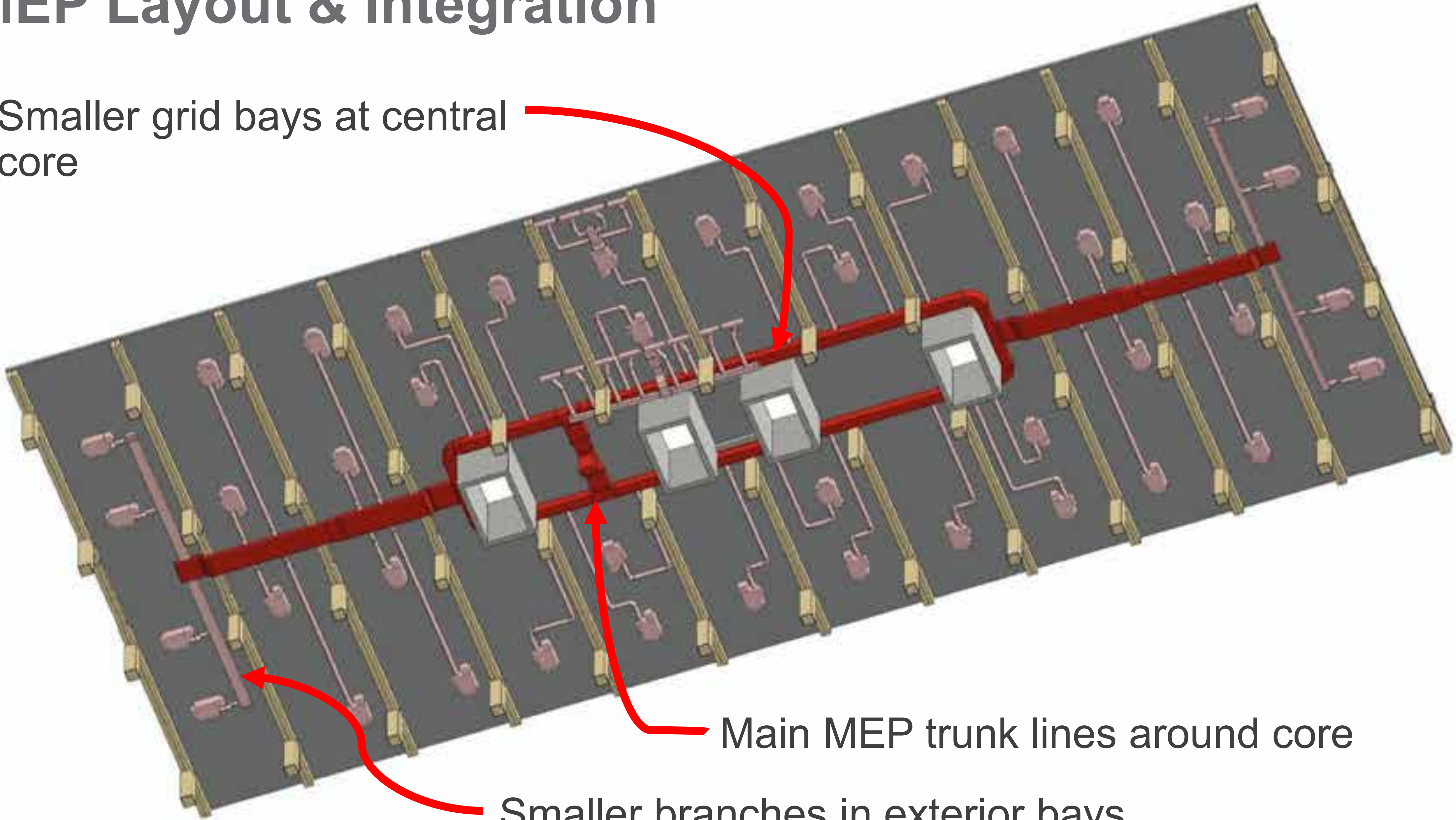
Credit: WoodWorks

MEP Layout & Integration

Smaller grid bays at central core (more head height)

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

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

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 at Catalyst

- 30x30 grid, 5-ply CLT ribbed beam system


Credit: Hans-Erik Blomgren

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

- 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

Steel Braced Frame

Photos: Marcus Kauffmann, ODF

Lateral System Choices

Wood-Frame Shearwalls


Credit: KL&A Engineers & Builders

Lateral System Choices

Wood-frame Shearwalls:

- Code compliance
- Standard of construction practice well known
- Limited to 65 ft shearwall height, 85 ft overall building height (Type IIIA construction)


Credit: Jeremy Bittermann & Kaiser + Path

Lateral System Choices

MT Shearwalls

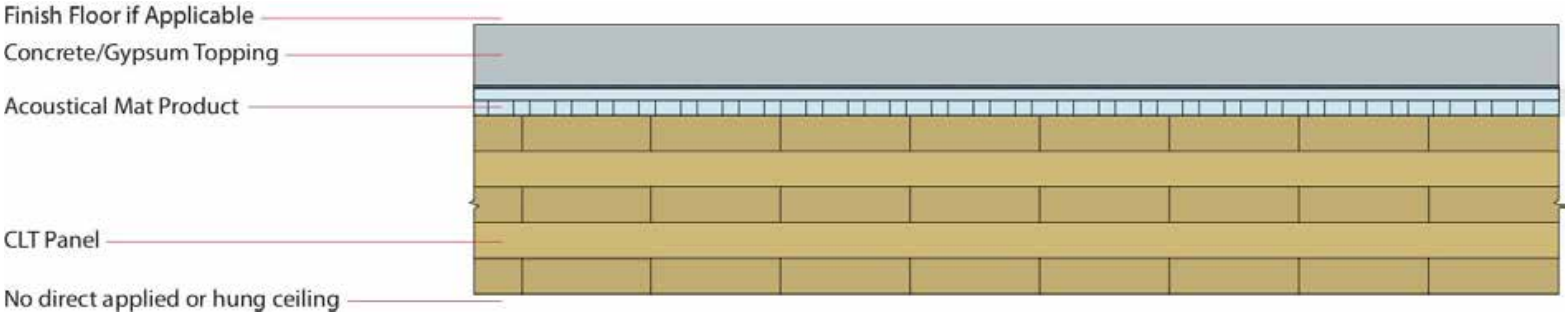
Lateral System Choices

Timber Braced Frame

Acoustics & Sound Control

Acoustics & Sound Control

Images: Maxxon

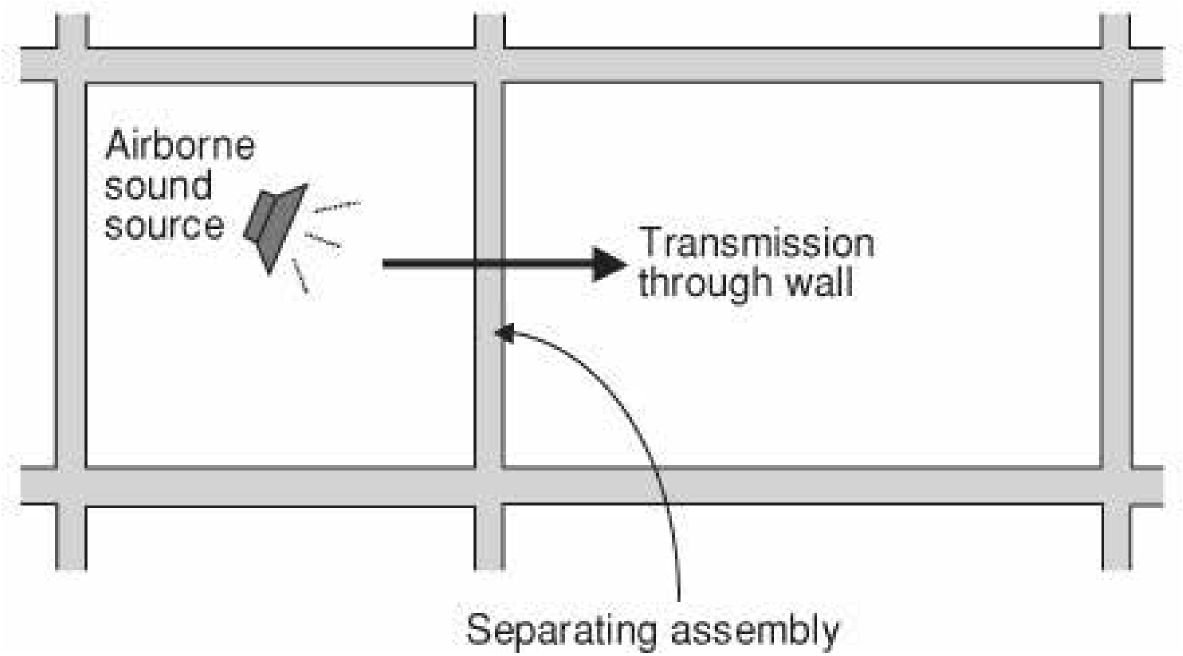


Acoustics & Sound Control

<u>Air-Borne Sound:</u>

Sound Transmission Class (STC)

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies

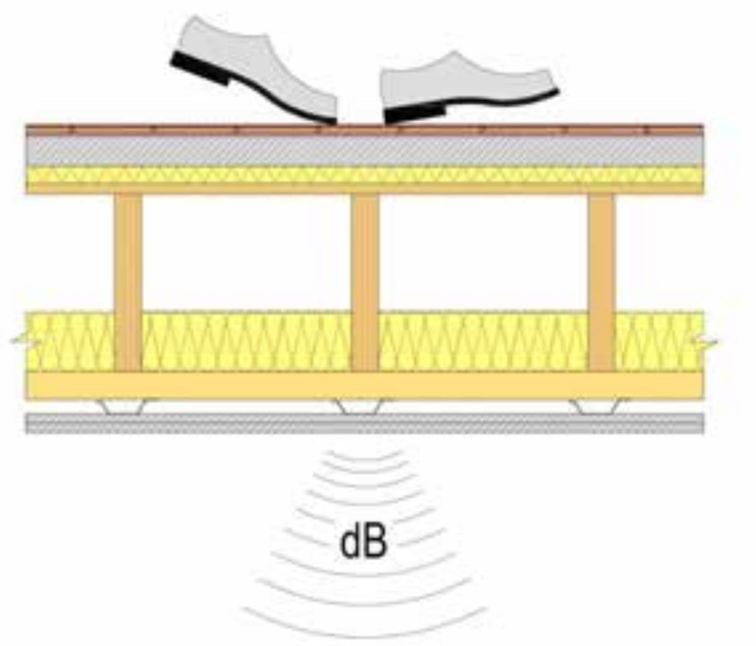


Acoustics & Sound Control

Structure-borne sound:

Impact Insulation Class (IIC)

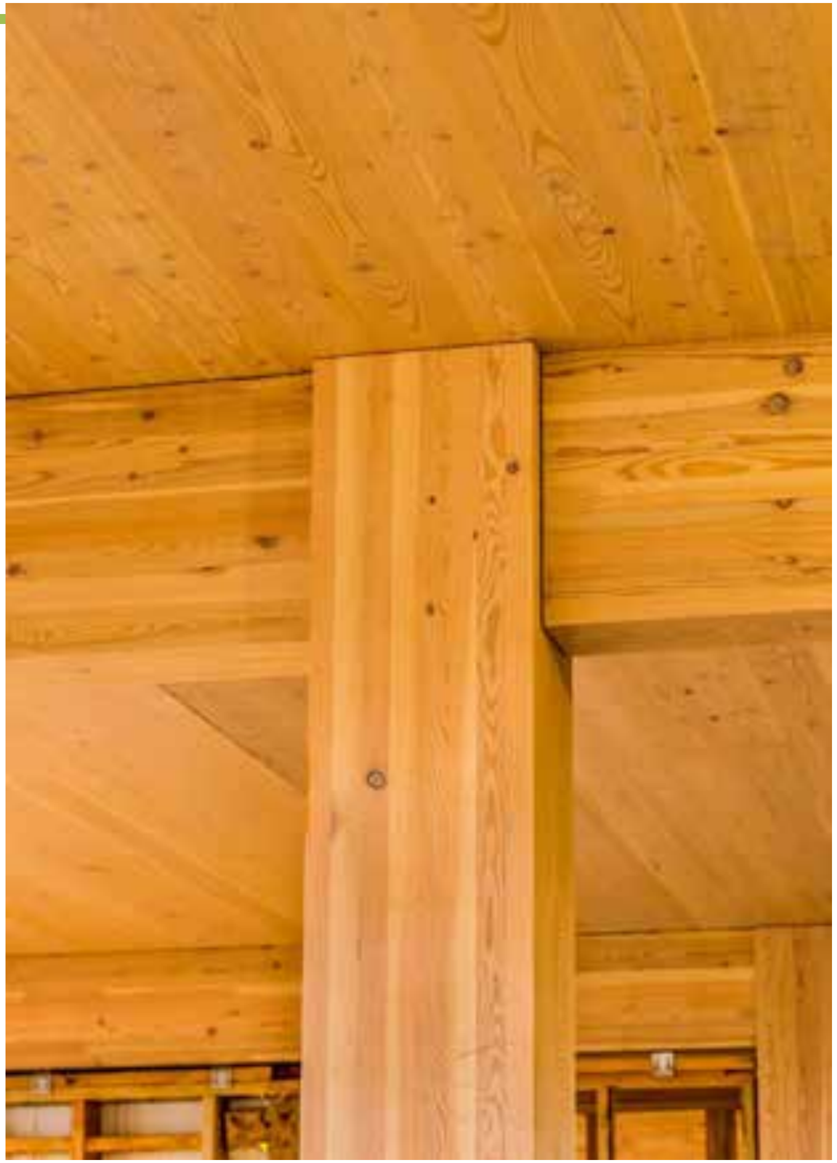
- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies



Acoustics & Sound Control

MT: Structure Often is Finish





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

Acoustics & Sound Control

But by Itself, Not Adequate for Acoustics

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

Mass timber has relatively low "mass"
Recall the three ways to increase acoustical performance:

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


Credit: Christian Columbres

Acoustics & Sound Control

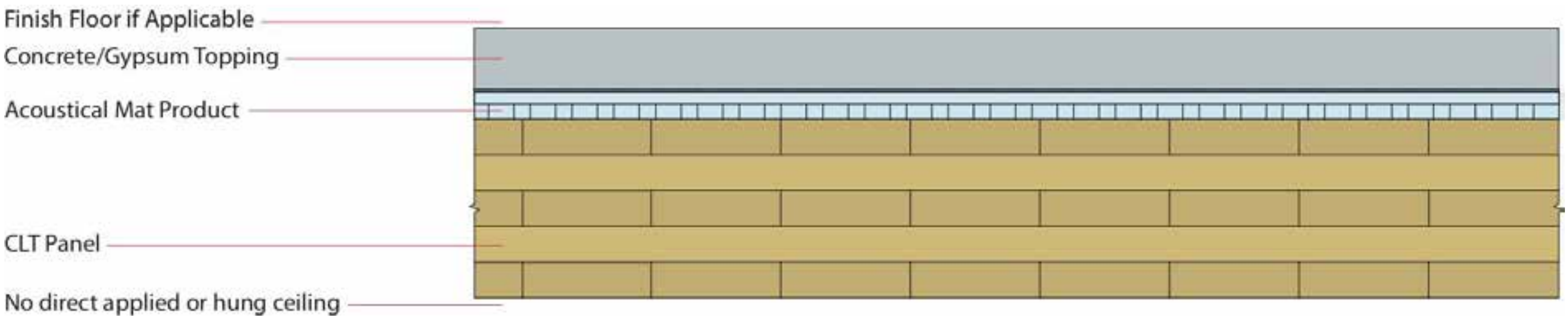
<u>Concrete Slab:</u>
6” Thick
80 PSF
STC 53

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

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

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

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

Acoustical Mat:

- Typically roll out or board products
- Thicknesses vary: Usually ¼" to 1"+

Credit: Maxxon

Acoustics & Sound Control

Acoustical floor underlayments

Photo: AcoustiTECH[10]

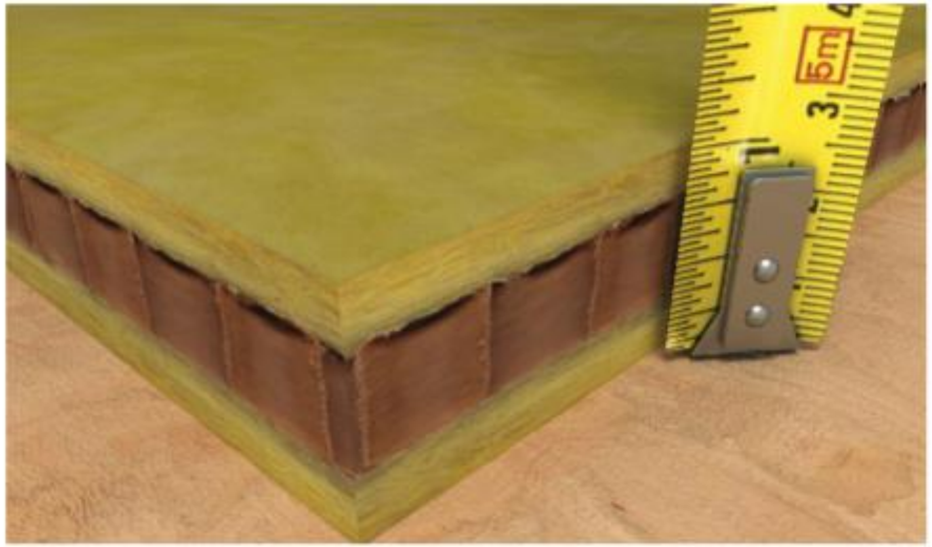


Photo: Kinetics Noise Control, Inc.,[11]

Photo: Maxxon Corporation

Photo: Pliteq Inc.,[12]

Acoustics & Sound Control

Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5” to 4” thick concrete/gypcrete topping
- Acoustical mat
- WSP (if applicable)
- Mass timber floor panels

Credit: AcoustiTECH

Acoustics & Sound Control

Solutions Paper

WoodWorks
WOOD PRODUCTS COUNCIL

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

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

Acoustics & Sound Control

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:

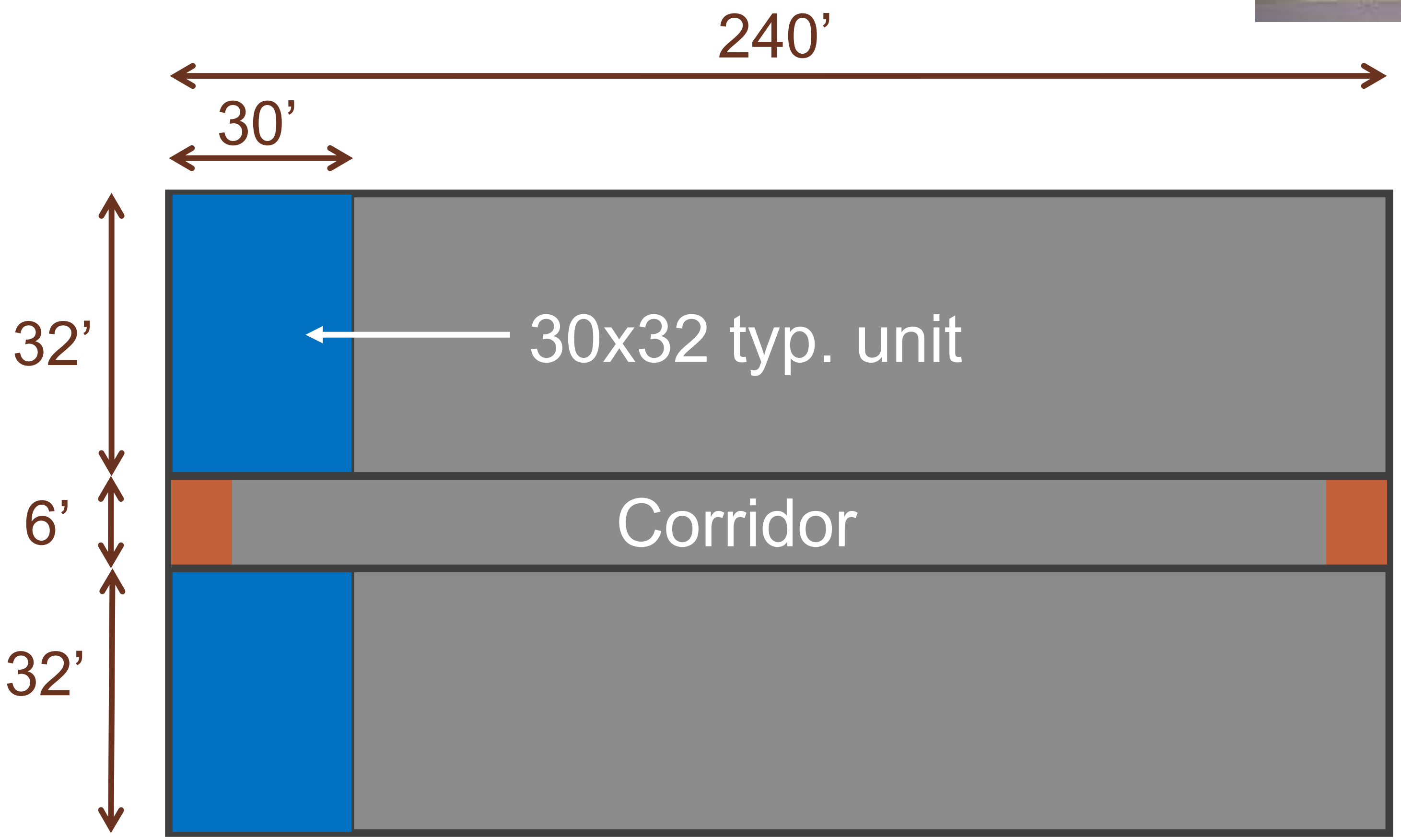
http://bit.ly/mass-timber-assemblies

Key Early Design Decisions

Early Design Decision Example

7-story, multi-family building, typ. floor plan:

Credit: Monte French Design Studio



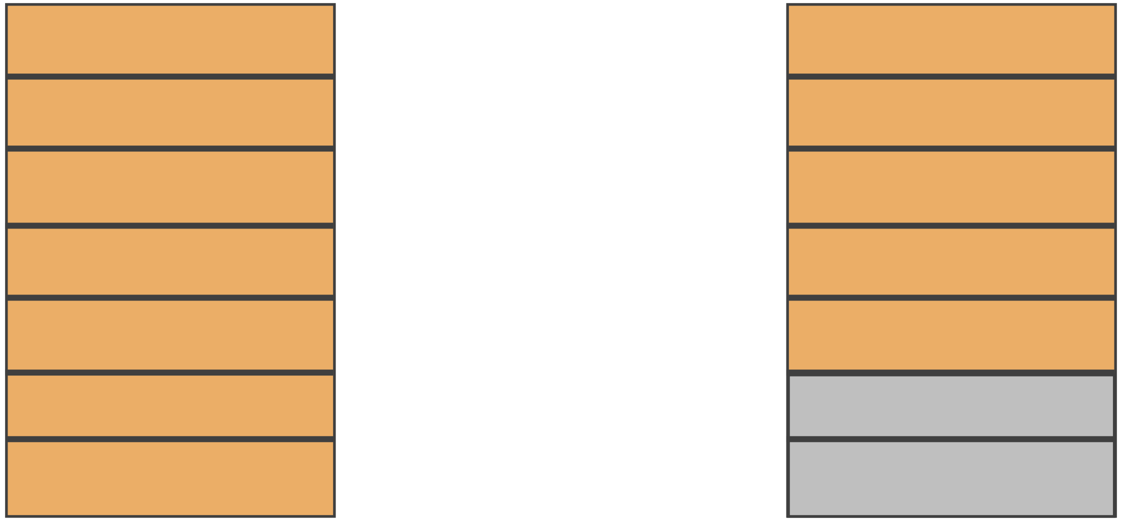
Key Early Design Decisions

Early Design Decision Example

Credit: Monte French Design Studio

MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium



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

WoodWorks™
WOOD PRODUCTS COUNCIL

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.

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

First Tech Federal Credit Union

ARCHITECT

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? Ask me anything.

Marc Rivard, PE, SE
Regional Director | MA, CT, ME, NH, RI, VT

(617) 997-3890
marc.rivard@woodworks.org

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