Early Design Decisions:
Priming Mass Timber Projects for Success

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Apex Plaza / Courtesy William McDonough + Partner

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Course Description

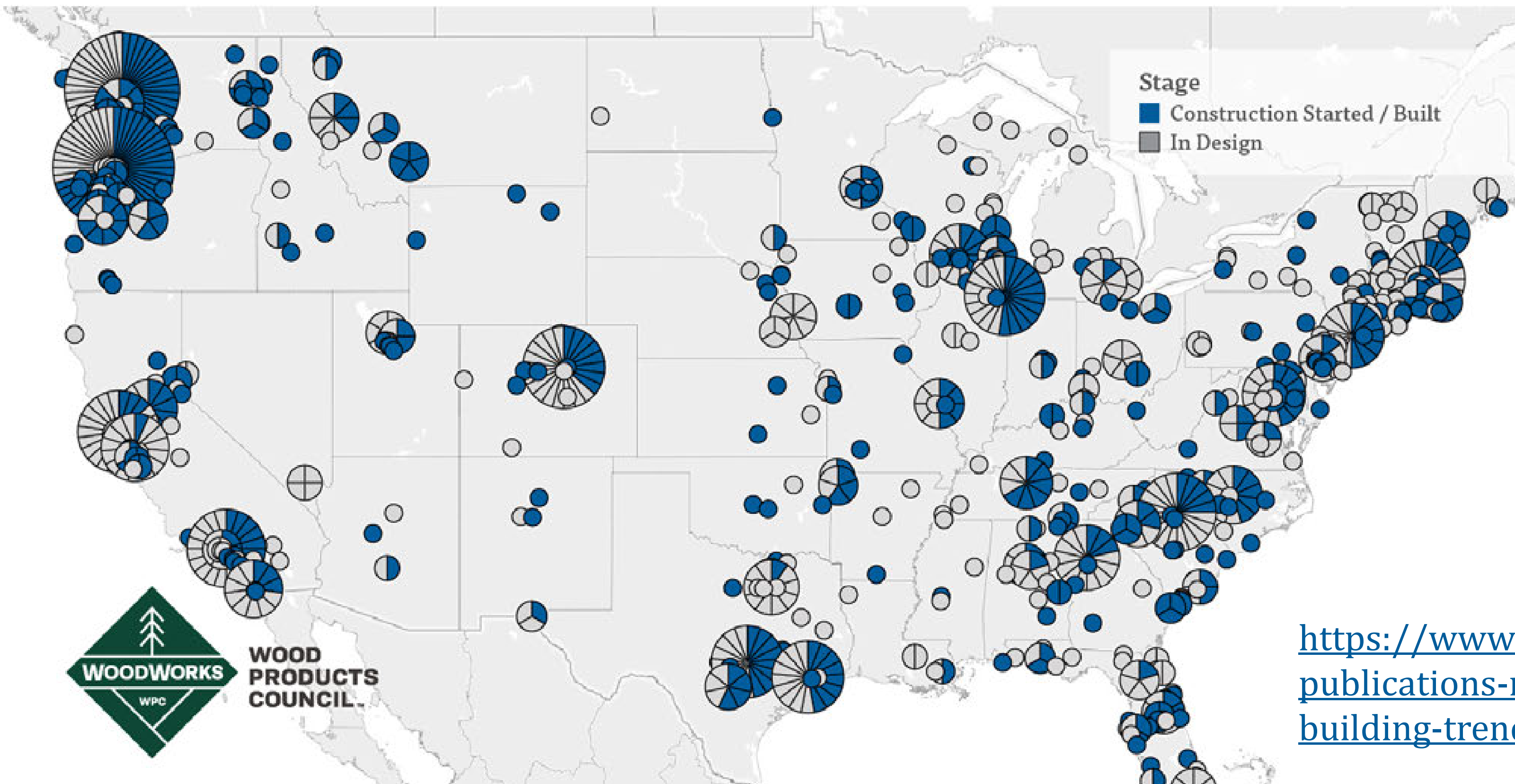
Mass timber is a unique, non-commodity building material and, to lay the groundwork for success, certain critical decisions must be made as early as possible. These decisions can have a big impact on cost and can either increase or limit opportunities later in design. There are many cases of project teams that want to realize the full benefits of mass timber, but, because they base their designs on traditional building practices instead of optimizing them for mass timber, end up with avoidable price premiums. This presentation will walk through early project decisions and design steps, focusing on how to optimize projects for mass timber and how one early decision can influence others. Topics will include construction types, fire ratings, column grids and beam/panel spans, acoustics and MEP integration. Completed mass timber projects will be used to illustrate the variety of viable options when navigating these key decisions.

Learning Objectives

1. Identify construction types within the International Building Code 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 code-compliance requirements for acoustics and primary frame connections, and provide solutions for meetings these requirements with tested mass timber assemblies.
4. Highlight effective methods of integrating MEP services in a mass timber building and discuss the relative impacts of each on cost, aesthetics, occupant comfort and future tenant renovations.

Current State of Mass Timber Projects

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



Source: WoodWorks, March 31, 2022

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

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

Glue Laminated Timber (Glulam)

Beams & columns

Photo: StructureCraft

Cross-Laminated Timber (CLT)

Solid sawn laminations

Photo: LendLease

Cross-Laminated Timber (CLT)

SCL laminations

Photo: Freres Lumber

Photo: LEVER Architecture

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

Significant Emphasis Placed on the Word Early

Early Because:

Avoids placing limitations due to construction norms or traditions that may not be efficient with mass timber

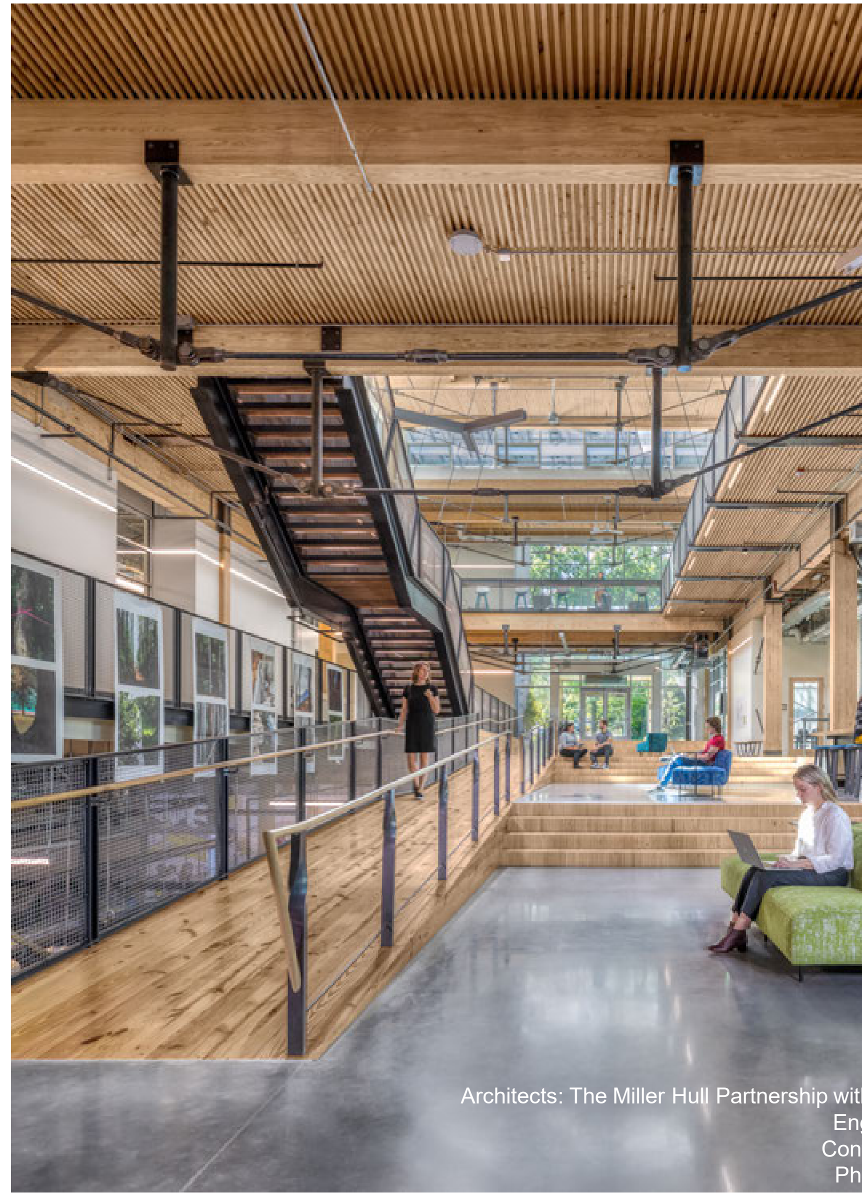
Allows greater integration of all building elements in 3D models, ultimately used throughout design, manufacturing and install

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:

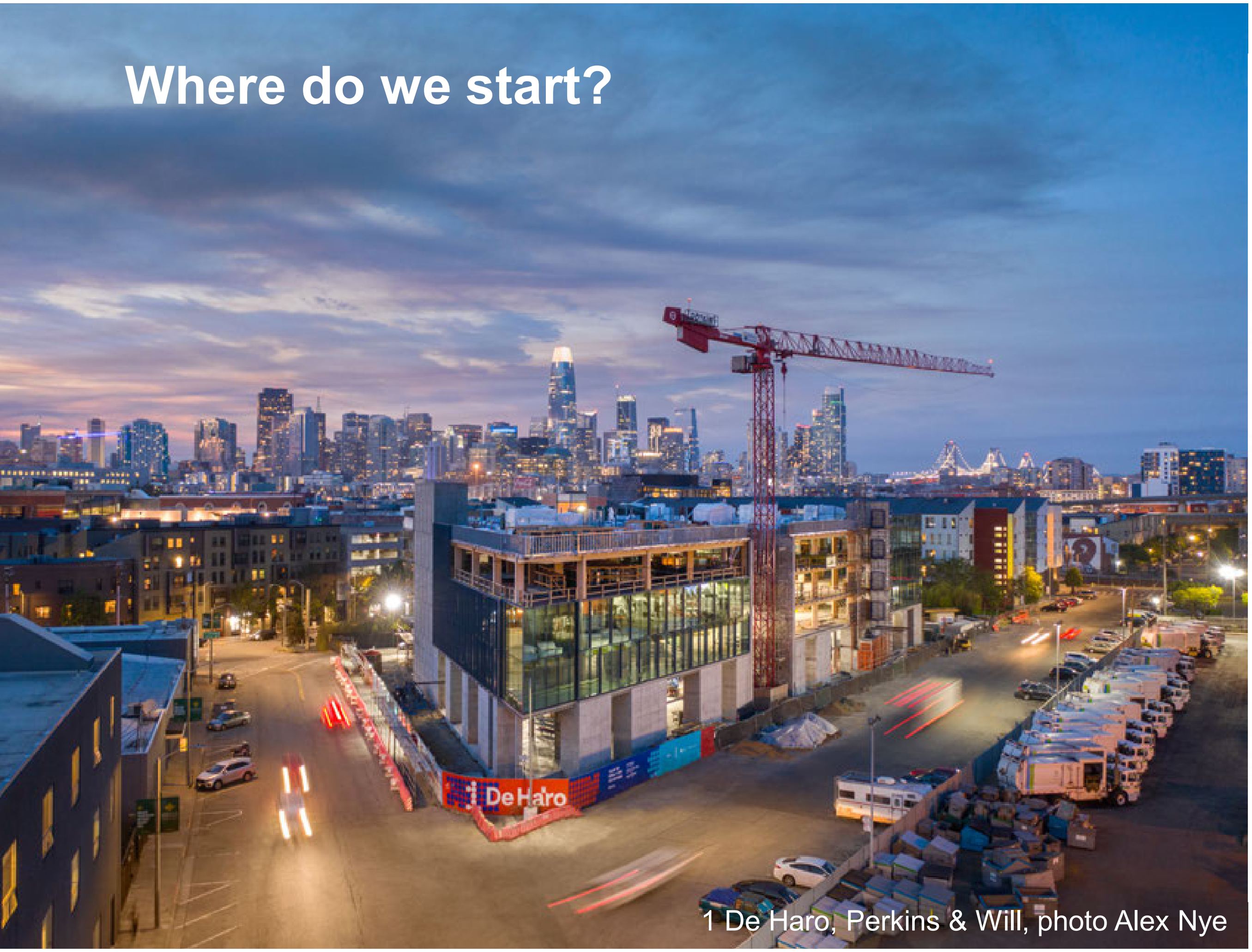
- **Grid informs efficient spans, MEP layout**
- **Manufacturer capabilities inform member sizes, grids & connections**
- **Lateral system informs connections, construction sequencing**

And more…

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

Key Early Design Decisions

Where do we start?



1 De Haro, Perkins & Will, photo Alex Nye

Key Early Design Decisions

Construction Type – Primarily based on building size & occupancy

	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

Construction Type – Primarily based on building size & occupancy

	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
	[illegible]							
A-2, A-3, A-4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	18	12	9	[illegible]	6	[illegible]	4	[illegible]
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

For low- to mid-rise mass timber buildings, there may be multiple options for construction type. There are pros and cons of each, don't assume that one type is always best.

Key Early Design Decisions

Fire-Resistance Ratings

- **Driven primarily by construction type**
- **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[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

Key Early Design Decisions

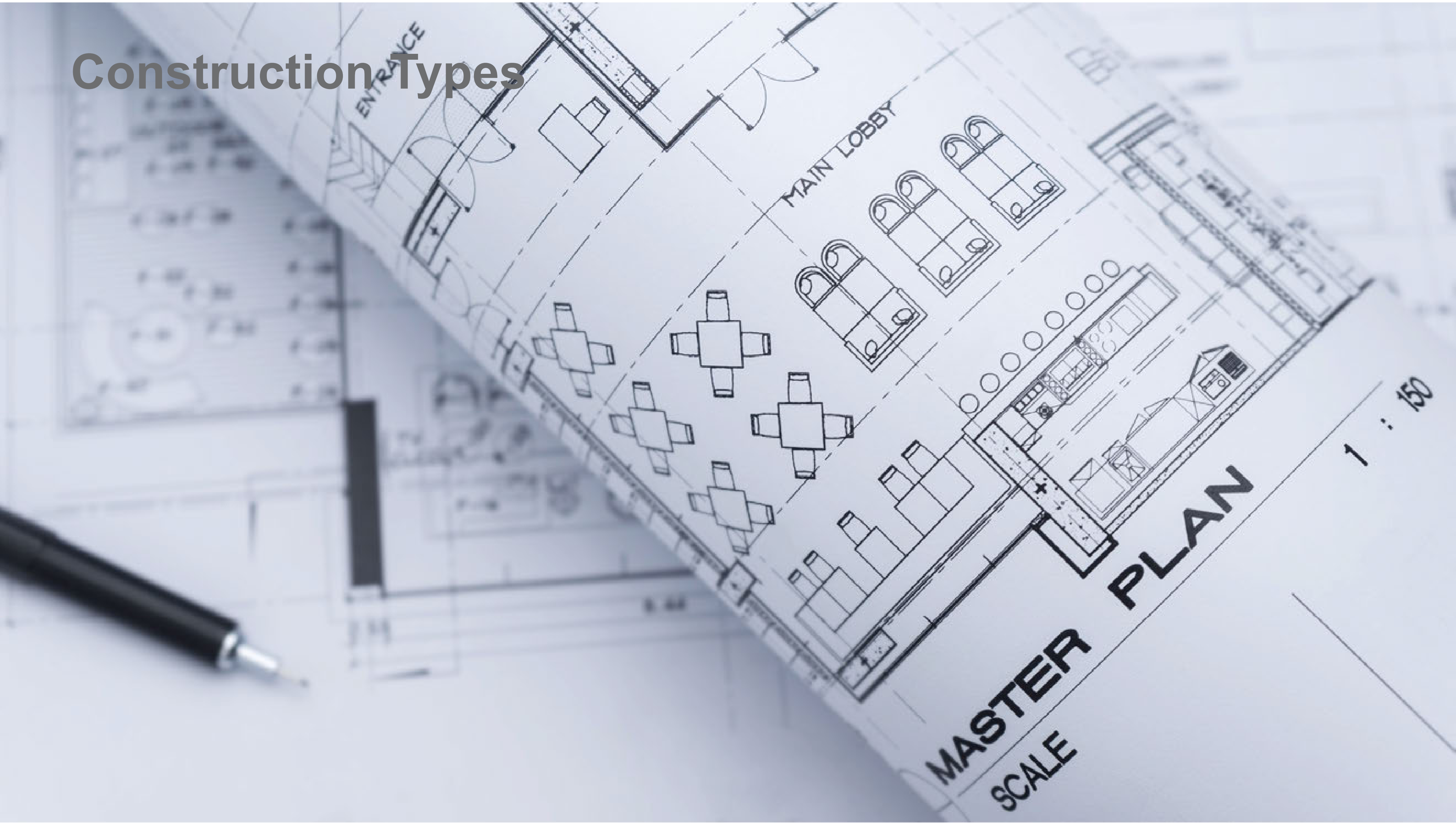
Fire-Resistance Ratings (FRR)

- 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

Construction Types

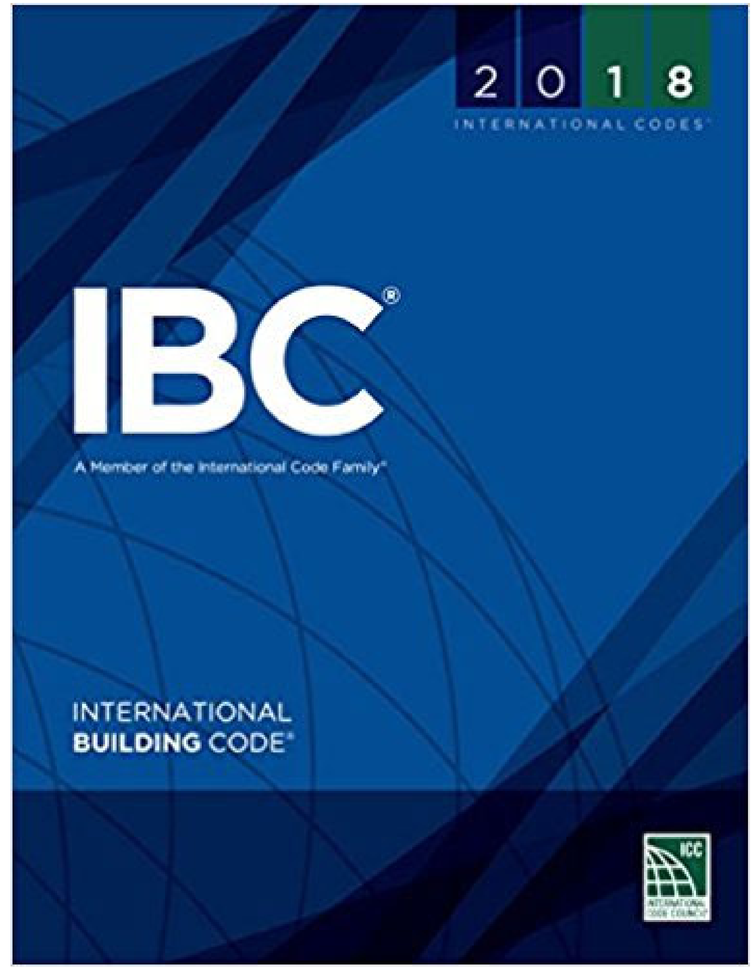


Construction Types

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

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?

- Type IB & II: Roof Decking

Construction Types

All wood framed building options:

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

Type V
All building elements are any allowed by code, including mass timber

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

Type IV (Heavy Timber)
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?

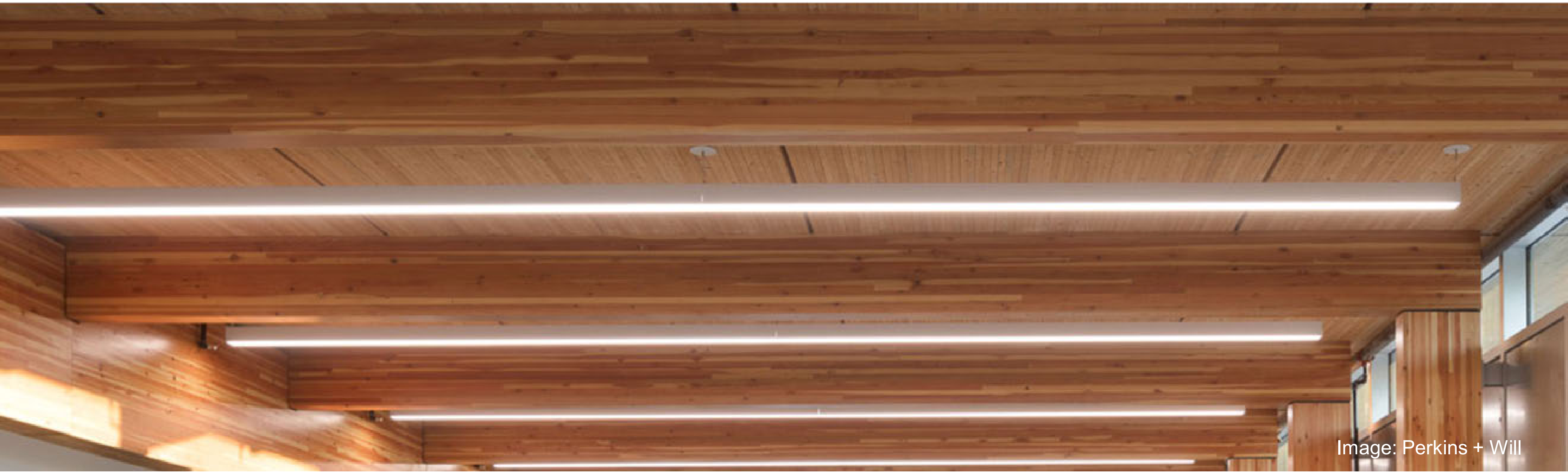
- Type V: All interior elements, roofs & exterior walls

Image: Christian Columbres 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

Construction Types

Type IV min. sizes:

<u>Interior Walls:</u>

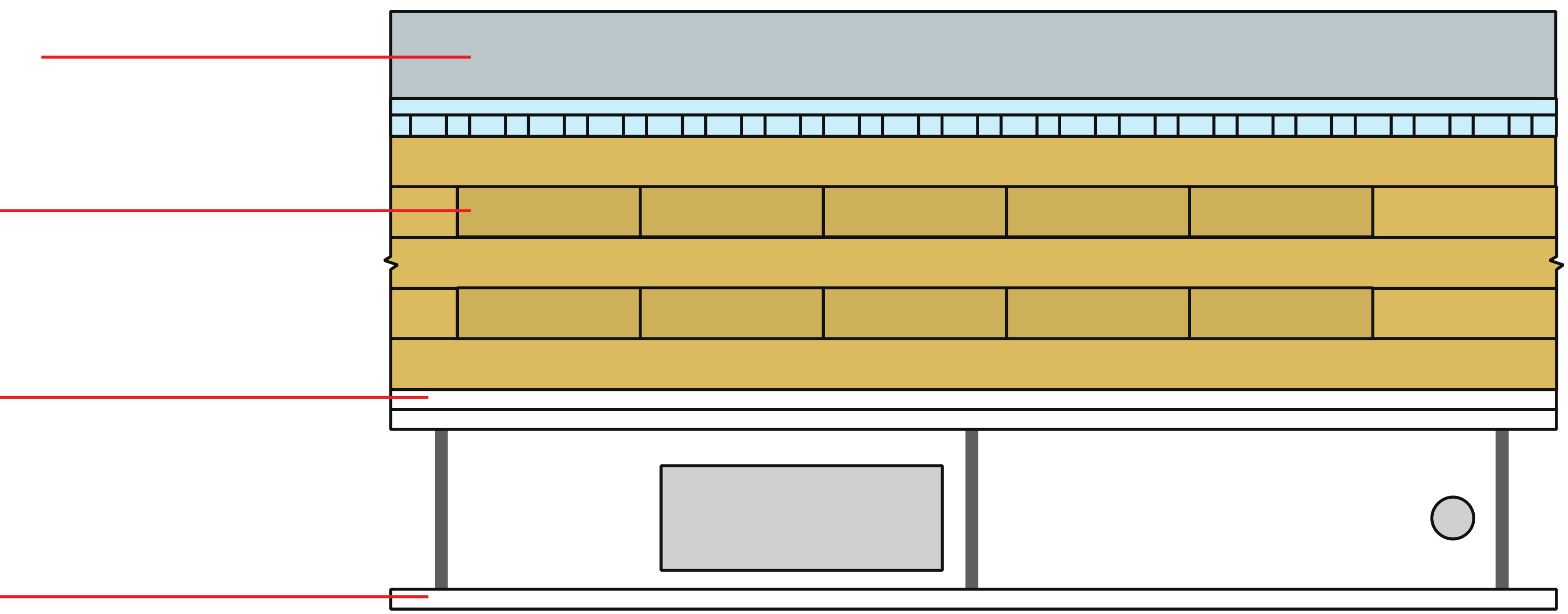
- Laminated construction 4” thick
- Solid wood construction min. 2 layers of 1” matched boards
- Wood stud wall (1 hr min)
- Non-combustible (1 hr min)

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

Construction Types

Type IV concealed spaces

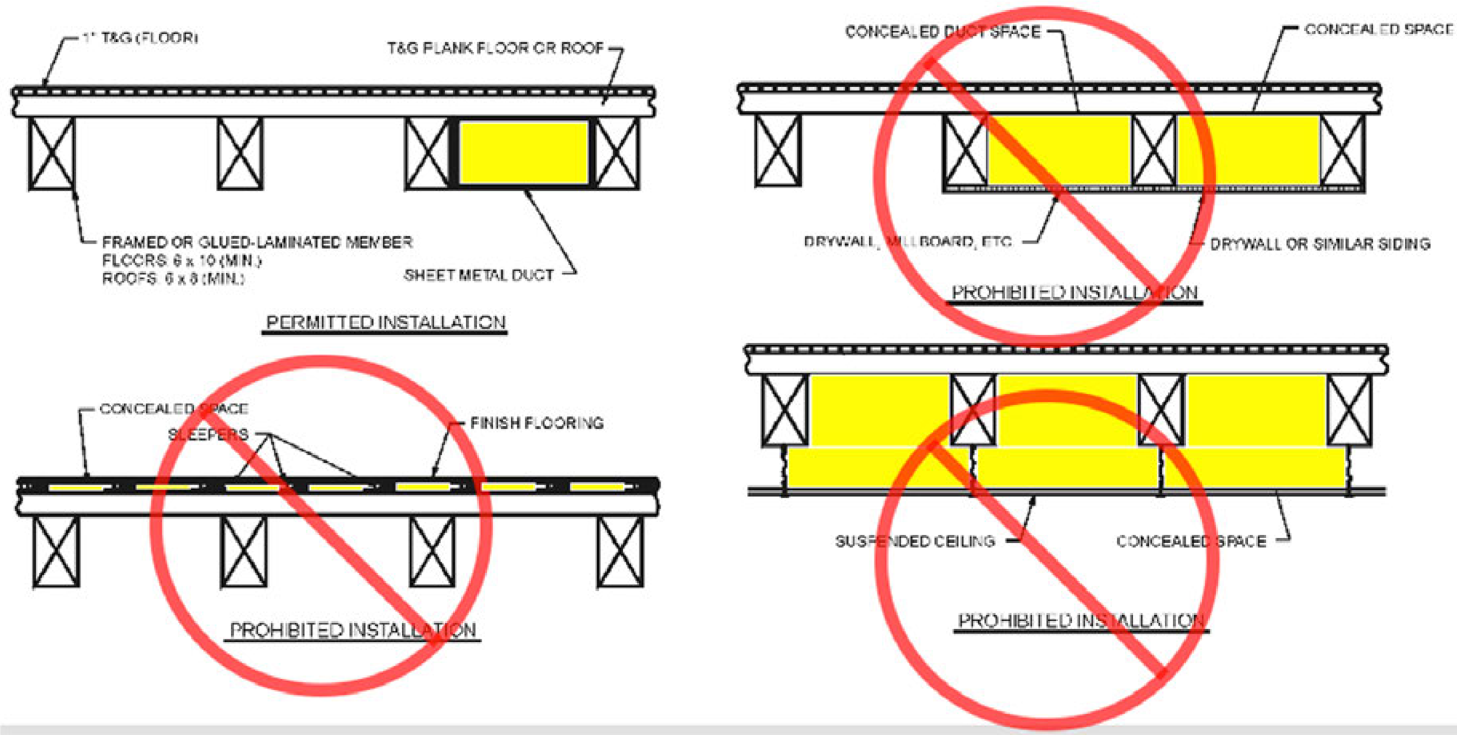
Can I have a dropped ceiling? Raised access floor?



Construction Types

Type IV concealed spaces

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



Credit: IBC

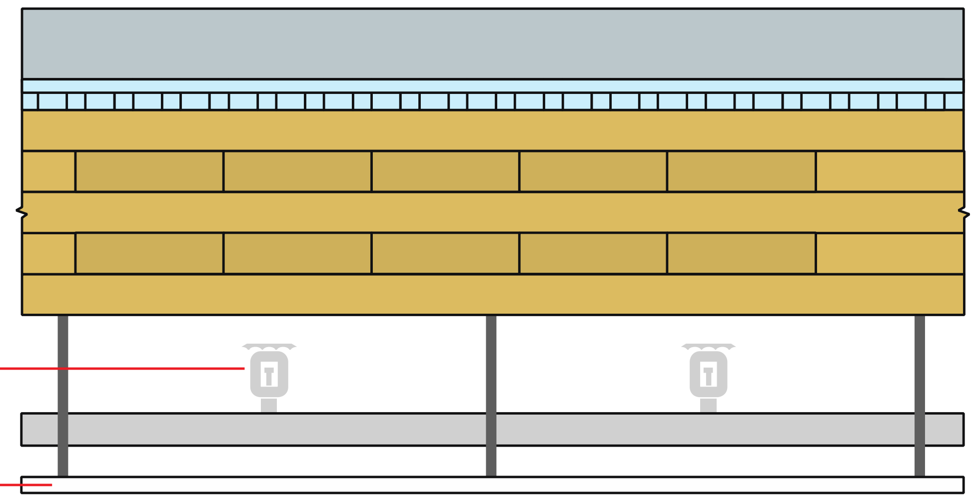
Construction Types

Type IV concealed space options within 2021 IBC

Option 1:

Sprinklers in concealed spaces

Dropped ceiling



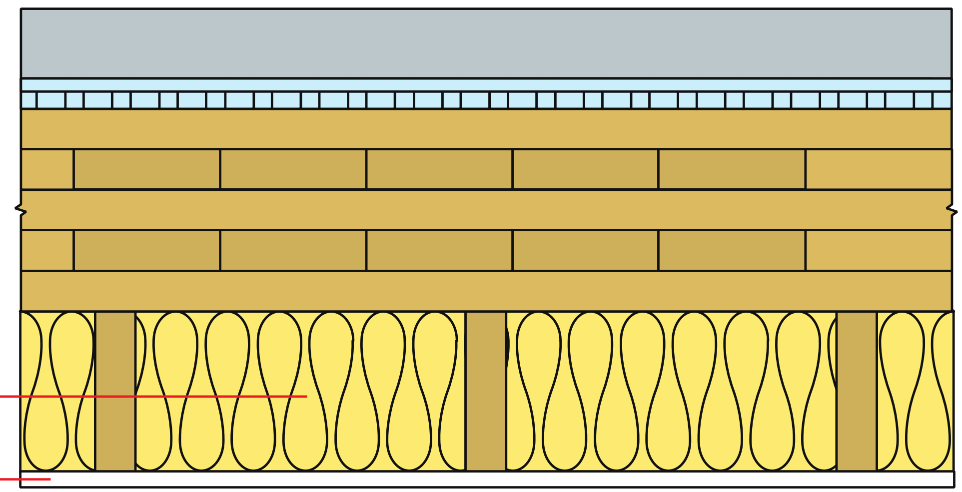
Construction Types

Type IV concealed space options within 2021 IBC

Option 2:

Noncombustible insulation

Dropped ceiling



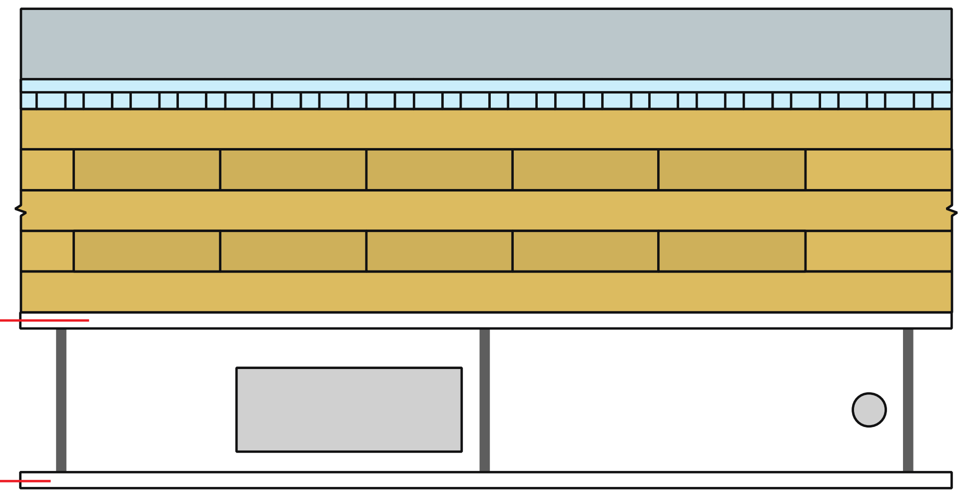
Construction Types

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

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?*[1]

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

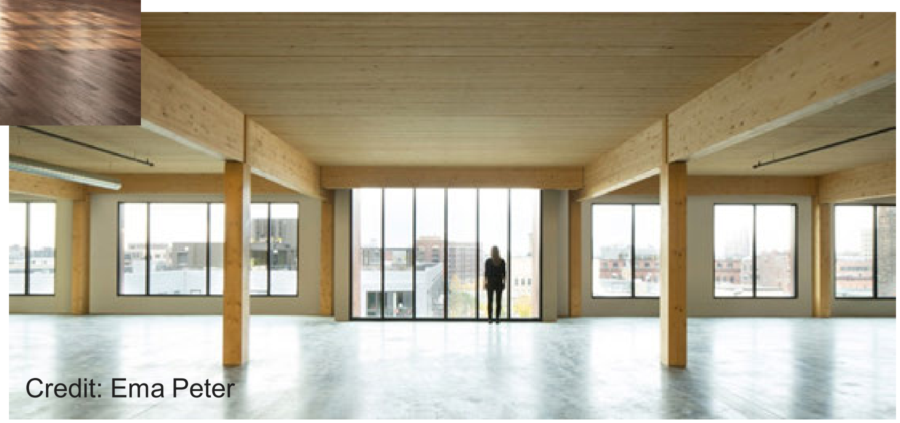
The John W. Olver Design Building at UMass Amherst includes exposed wood structure in some areas and dropped ceilings in others. Architect: Leers Weinzapfel Associates

https://www.woodworks.org/wp-content/uploads/wood_solution_paper-Concealed_Spaces_Timber_Structures.pdf

Construction Types

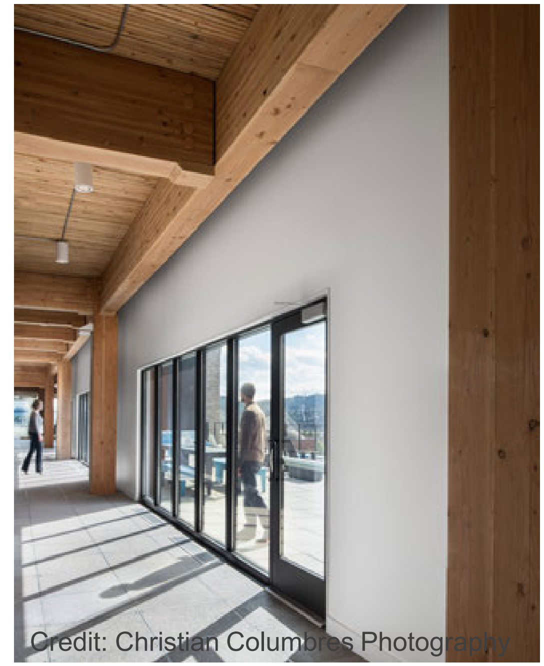
Type III: 6 stories

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



Credit: Ema Peter

Type IV: 6 stories

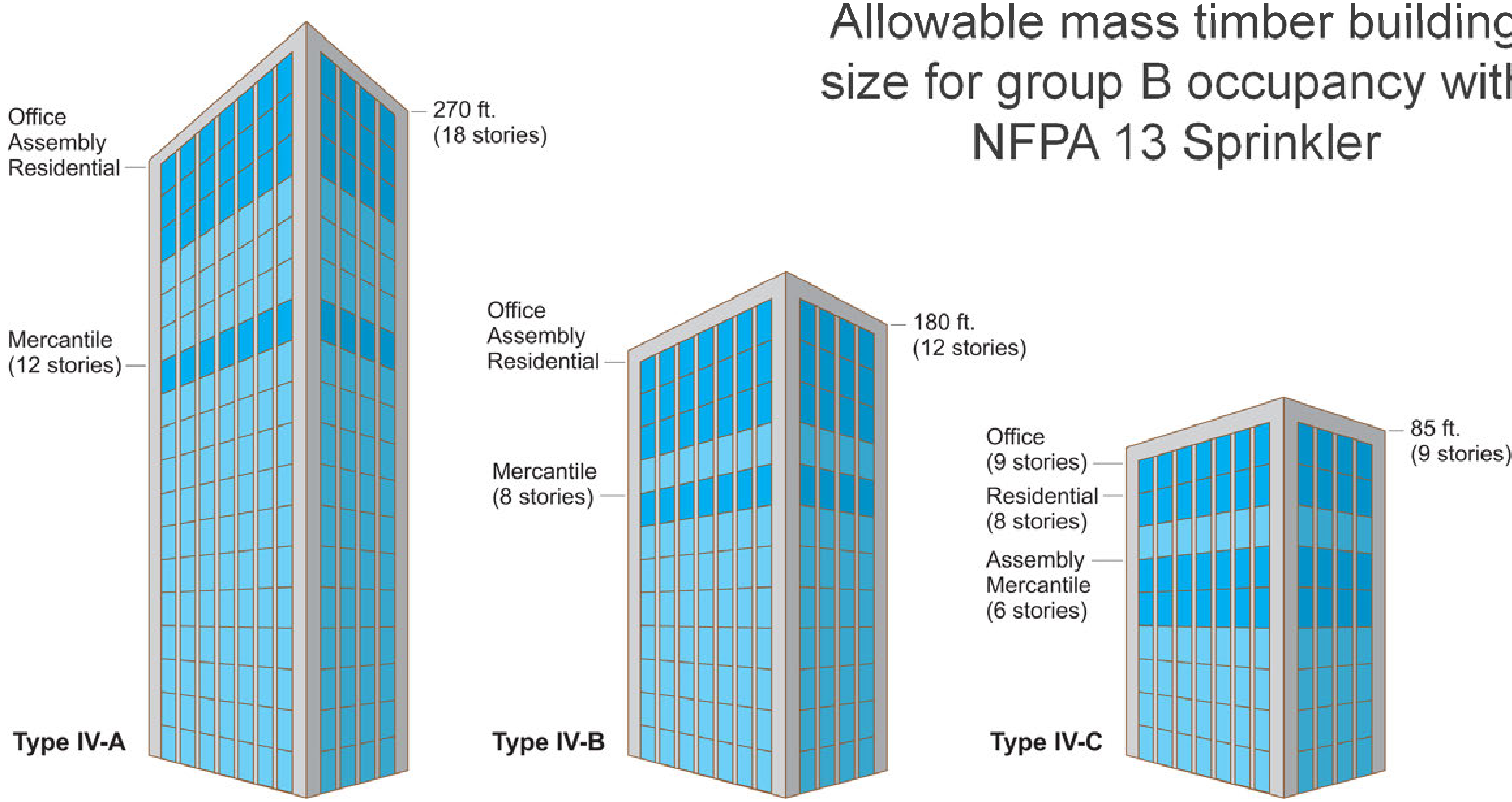


Credit: Christian Columbres Photography

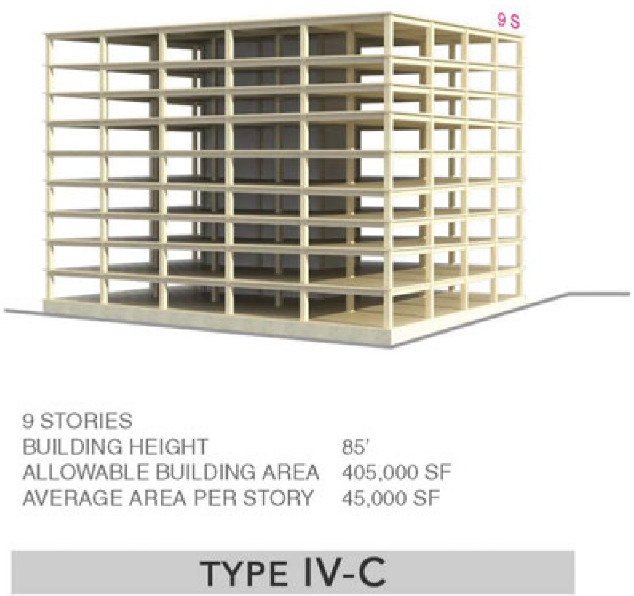
Type V: 4 stories

Construction Types

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

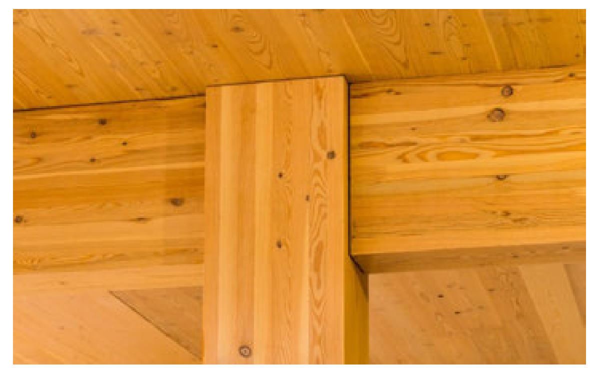


Type IV-C



Credit: Susan Jones, atelierjones

Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman

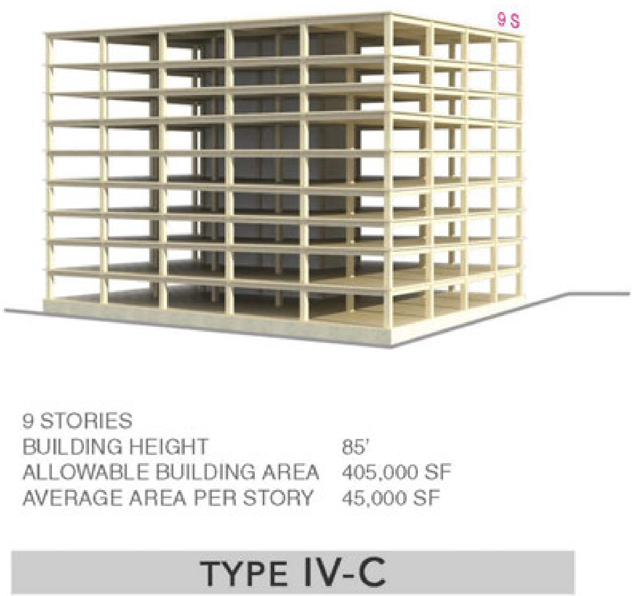


Type IV-C Height and Area Limits

IV-C

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	6	85 ft	56,250 SF	168,750 SF
B	9	85 ft	135,000 SF	405,000 SF
M	6	85 ft	76,875 SF	230,625 SF
R-2	8	85 ft	76,875 SF	230,625 SF

Areas exclude potential frontage increase



Credit: Susan Jones, atelierjones

In most cases, Type IV-C height allowances = Type IV-HT height allowances, but add'l stories permitted due to enhanced FRR

Type IV-C area = 1.25 * Type IV-HT area

IV-C

Type IV-C Protection vs. Exposed

9 STORIES
BUILDING HEIGHT 85'
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

TYPE IV-C

Credit: Susan Jones, atelierjones

Credit: Kaiser+Path, Ema Peter

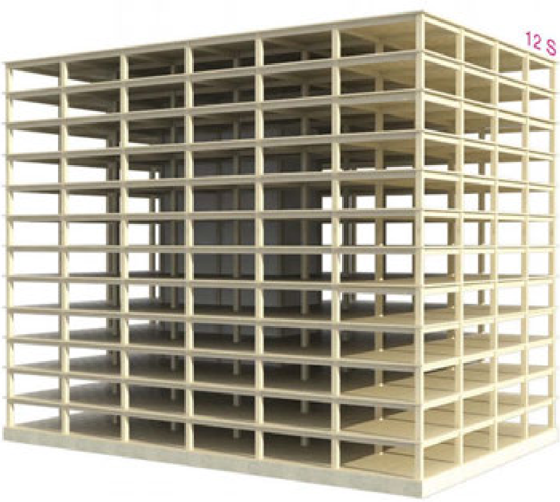
All Mass Timber surfaces may be exposed

Exceptions: Shafts, concealed spaces, outside face of exterior walls

IV-C

IV-C

Type IV-B



12 STORIES

BUILDING HEIGHT	180 FT
ALLOWABLE BUILDING AREA	648,000 SF
AVERAGE AREA PER STORY	54,000SF

TYPE IV-B

Credit: Susan Jones, atelierjones

Credit: LEVER Architecture

Type IV-B Height and Area Limits

IV-B

Credit: Susan Jones, atelierjones

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	12	180 ft	90,000 SF	270,000 SF
B	12	180 ft	216,000 SF	648,000 SF
M	8	180 ft	123,000 SF	369,000 SF
R-2	12	180 ft	123,000 SF	369,000 SF

Areas exclude potential frontage increase

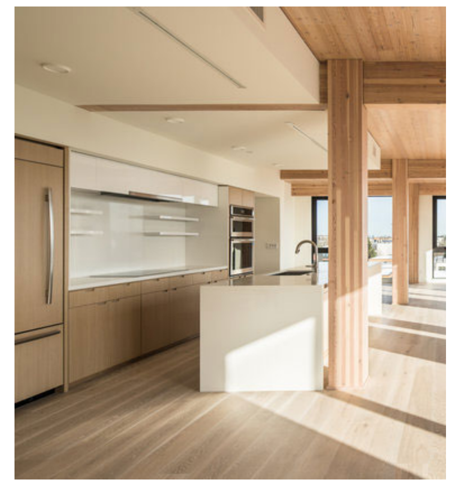
In most cases, Type IV-B height & story allowances = Type I-B height & story allowances

Type IV-B area = 2 * Type IV-HT area

Type IV-B Protection vs. Exposed

IV-B

Credit: Susan Jones, atelierjones



Credit: Kaiser+Path

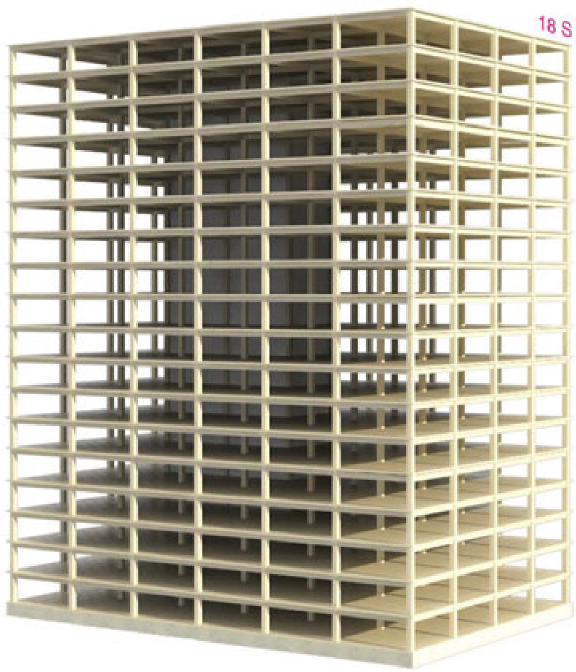
NC protection on all surfaces of Mass Timber except limited exposed areas

~20% of Ceiling or ~40% of Wall can be exposed

IV-B

IV-B

Type IV-A



18 STORIES
BUILDING HEIGHT 270'
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000SF

TYPE IV-A

Credit: Susan Jones, atelierjones

Photos: Structurlam, naturally:wood, Fast + Epp

IV-A

Type IV-A Height and Area Limits

Credit: Susan Jones, atelierjones

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	18	270 ft	135,000 SF	405,000 SF
B	18	270 ft	324,000 SF	972,000 SF
M	12	270 ft	184,500 SF	553,500 SF
R-2	18	270 ft	184,500 SF	553,500 SF

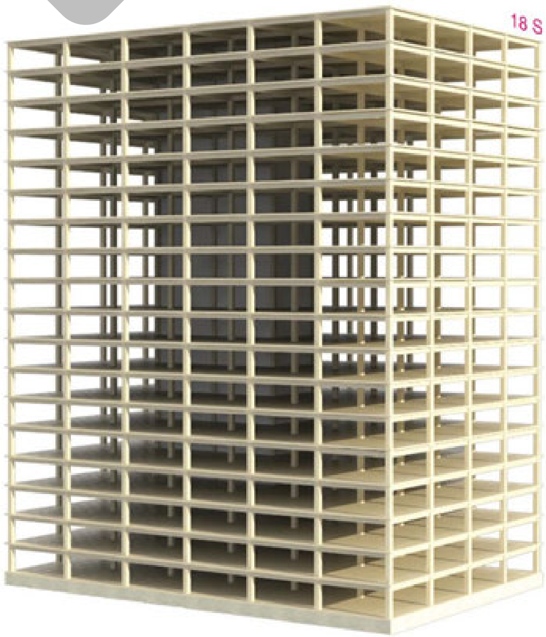
Areas exclude potential frontage increase

In most cases, Type IV-A height & story allowances = 1.5 * Type I-B height & story allowances

Type IV-A area = 3 * Type IV-HT area

IV-A

Type IV-A Protection vs. Exposed



18 STORIES
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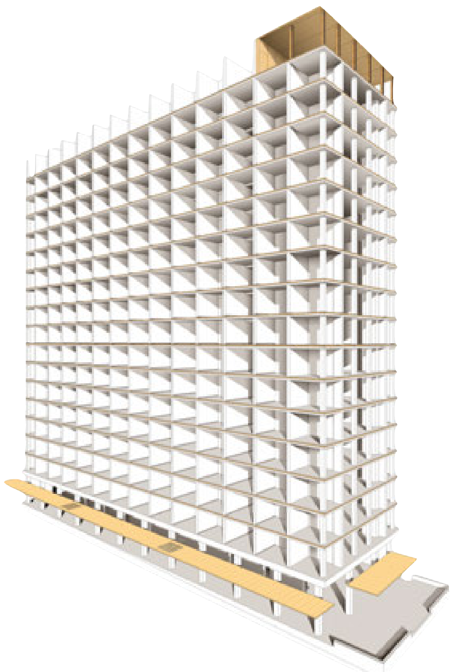
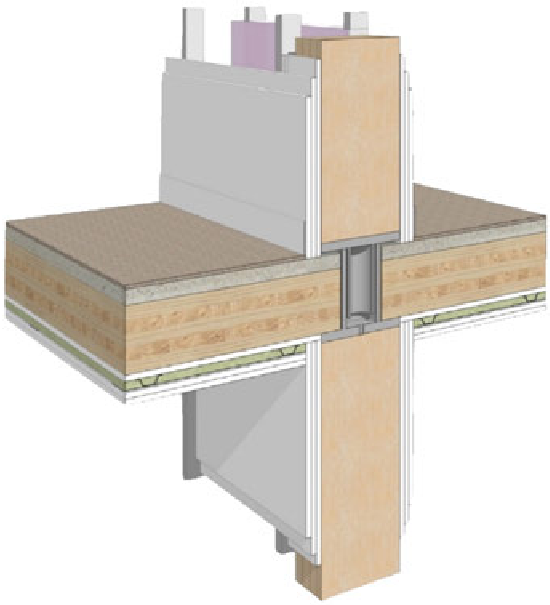
TYPE IV-A

Credit: Susan Jones, atelierjones



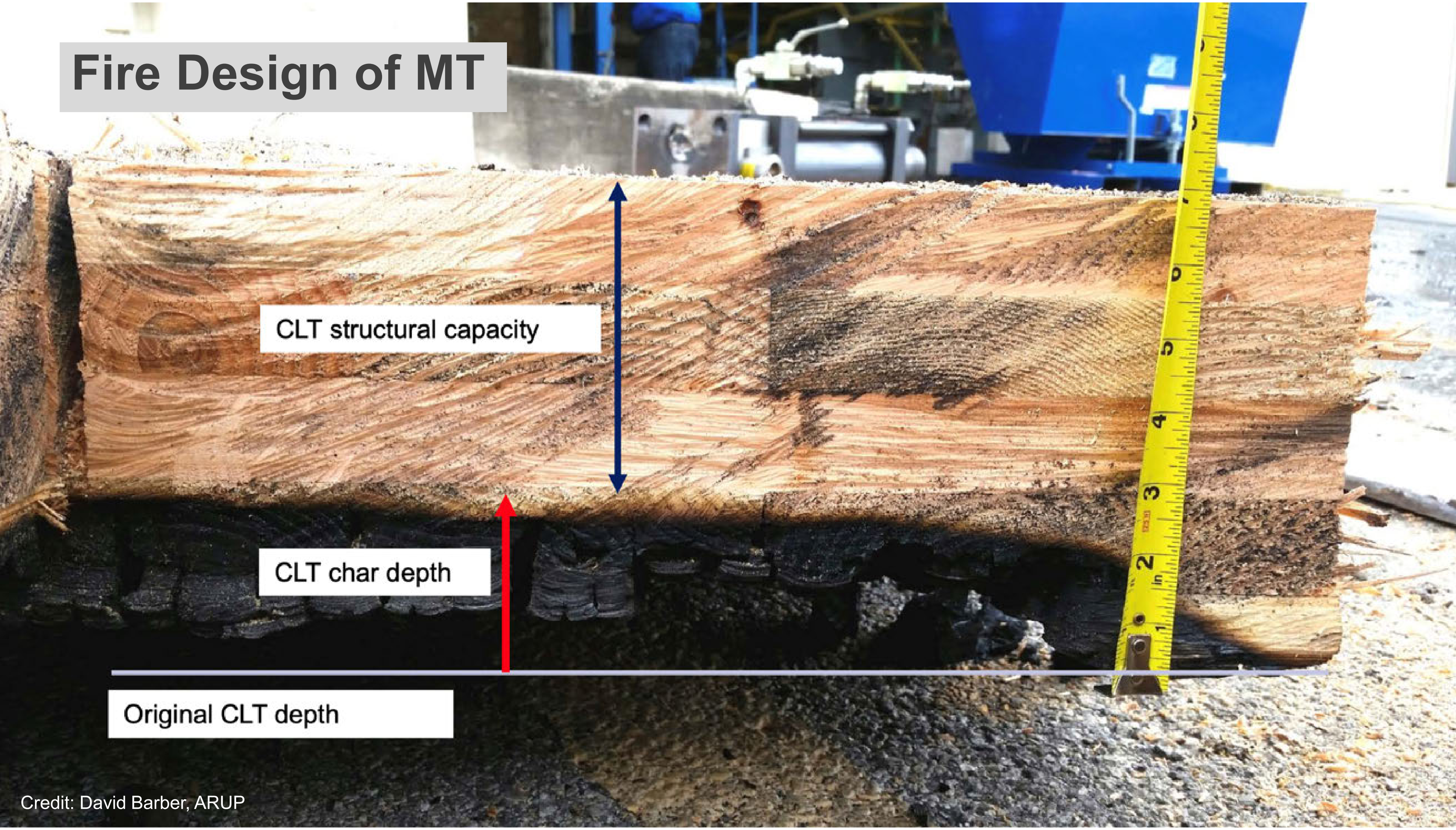


Credit: Acton Ostry Architects, Fast + Epp

100% NC protection on all surfaces of Mass Timber

IV-A

Fire Design of MT



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

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

Construction type influences FRR

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


Fire Testing Laboratory

NGC Testing Services

ACCREDITED Testing Laboratory TL-216

TEST REPORT

Page 1 of 53

for

American Wood Council

222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

Standard Methods of
Fire Tests of Building Construction and Materials
ASTM E 119 – 11a

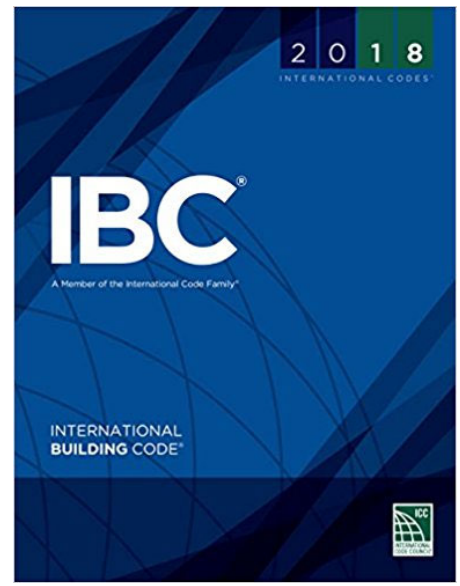
Test Report No: WP-1950
Assignment No: K-1089
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)
Test Date: October 4, 2012
Report Date: October 15, 2012

Prepared by: Michael J. Rizzo, Test Engineer

Reviewed by: Robert J. Marchetti, Director, Laboratory Facilities and Testing Services

The results reported in this document apply to specific samples submitted for measurement. No responsibility is assumed for performance of any other specimen. This report may not be reproduced, except in full, without the written approval of the laboratory. The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by this laboratory.

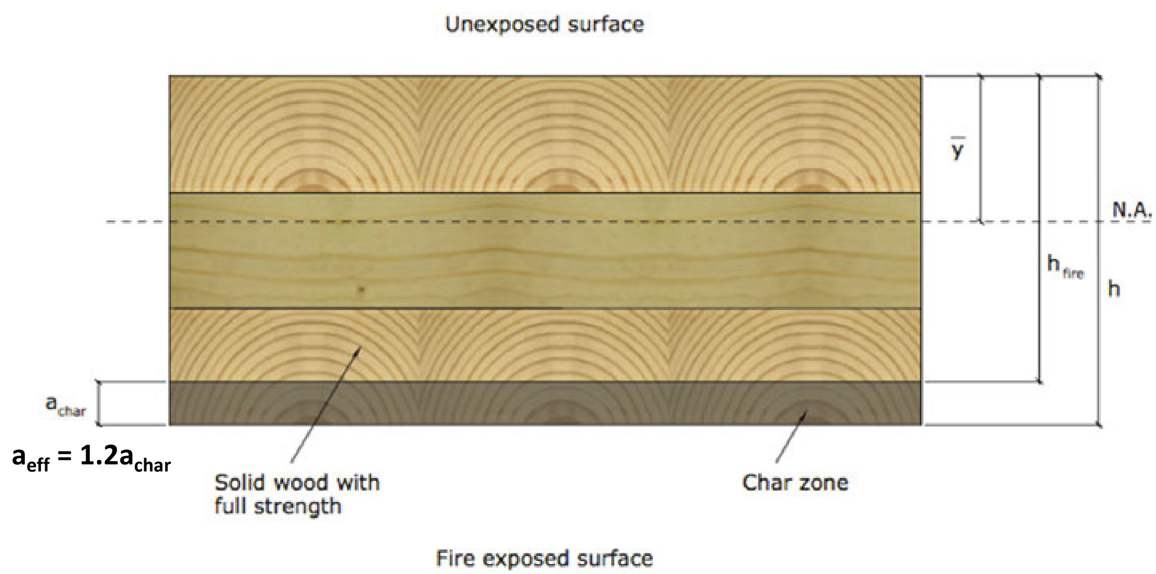
Method of demonstrating FRR (calculations or testing) can impact member sizing



Key Early Design Decisions

Which Method of Demonstrating FRR of MT is Being Used?

1. Calculations in Accordance with IBC 722 → NDS Chapter 16
2. Tests in Accordance with ASTM E119



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

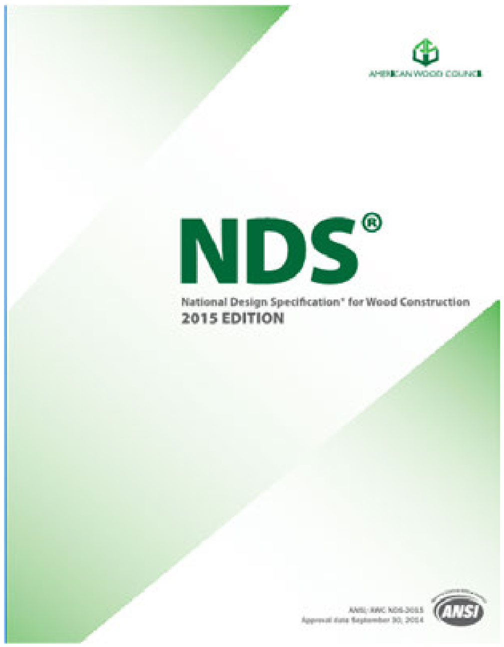
IBC 722
Calculated Fire Resistance

"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.)

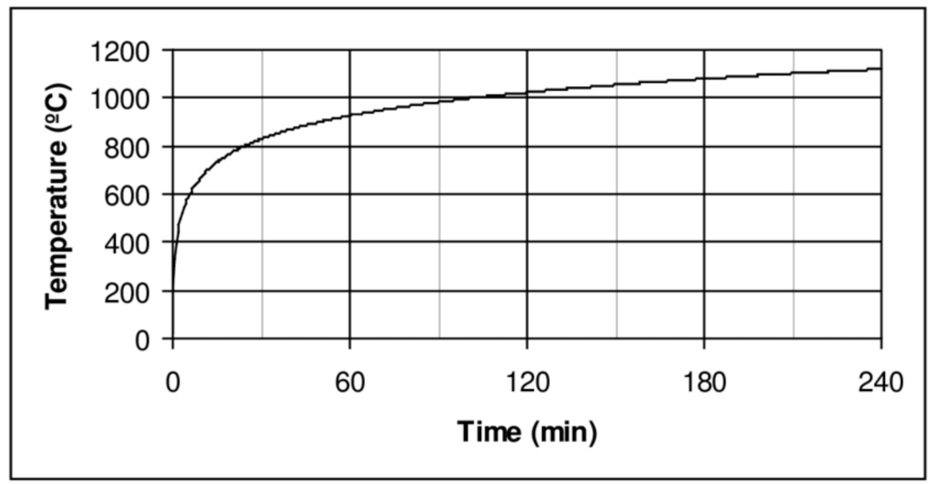
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

FRR Design of MT

Tested FRR of Exposed MT:

- IBC 703.2 notes the acceptance of FRR demonstration via testing in accordance with ASTM E119

703.2 Fire-resistance ratings. The *fire-resistance rating* of building elements, components or assemblies shall be determined in accordance with the test procedures set forth in ASTM E119 or UL 263 or in accordance with Section 703.3. The *fire-resistance rating* of penetrations and *fire-resistant joint systems* shall be determined in accordance Sections 714 and 715, respectively.

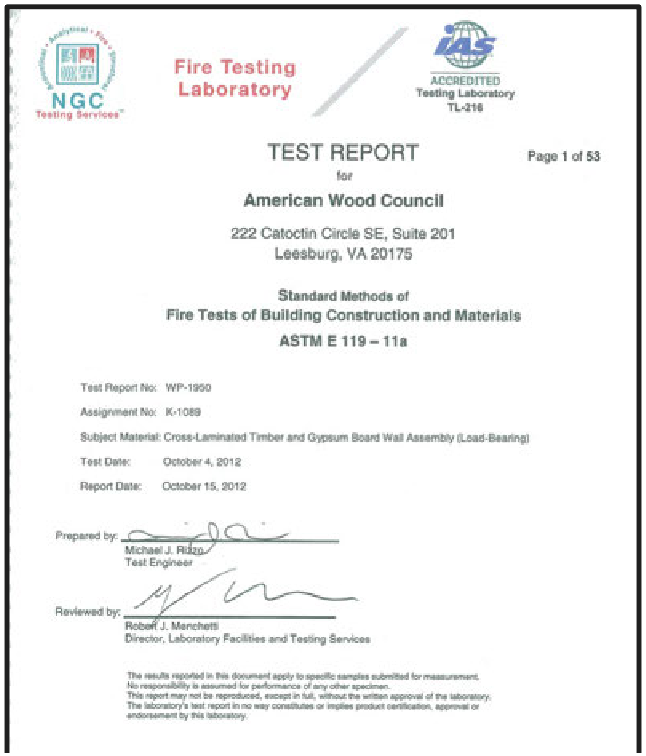


Standard ASTM E119 test time-temperature curve

FRR Design of MT

Tested FRR of Exposed MT:

- Many successful Mass Timber ASTM E119 fire tests have been completed by industry & manufacturers



NGC Testing Services

Fire Testing Laboratory

ACCREDITED Testing Laboratory TL-216

TEST REPORT

for

American Wood Council

Page 1 of 53

222 Catoctin Circle SE, Suite 201
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Standard Methods of
Fire Tests of Building Construction and Materials
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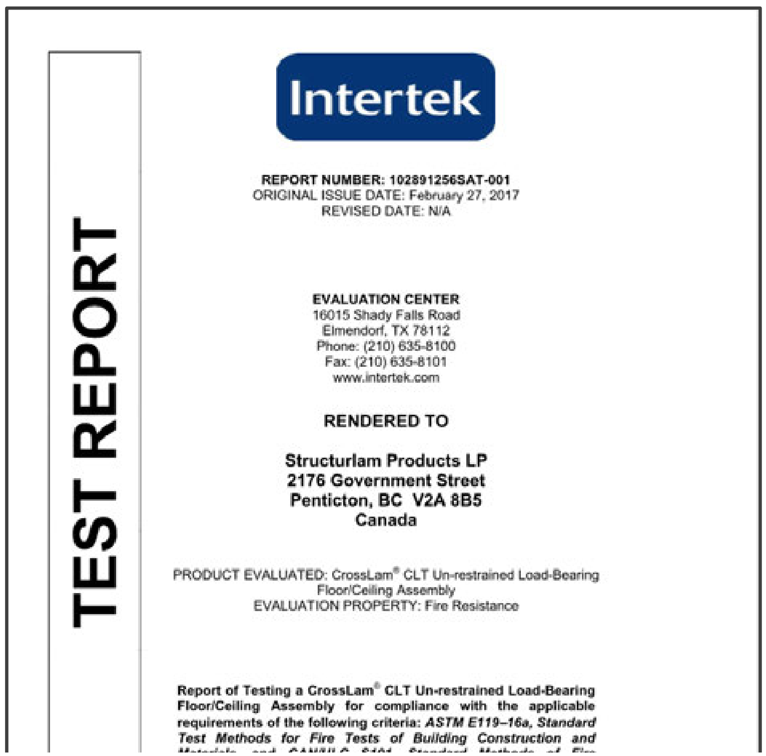


TEST REPORT

Intertek

REPORT NUMBER: 102891256SAT-001
ORIGINAL ISSUE DATE: February 27, 2017
REVISED DATE: N/A

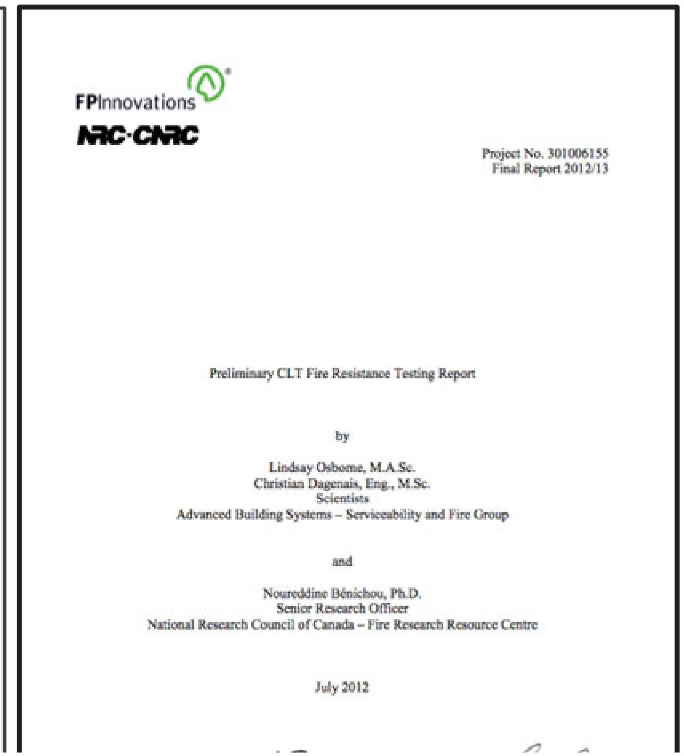
EVALUATION CENTER
16015 Shady Falls Road
Elmendorf, TX 78112
Phone: (210) 635-8100
Fax: (210) 635-8101
www.intertek.com

RENDERED TO

Structurlam Products LP
2176 Government Street
Penticton, BC V2A 8B5
Canada

PRODUCT EVALUATED: CrossLam® CLT Un-restrained Load-Bearing Floor/Ceiling Assembly
EVALUATION PROPERTY: Fire Resistance

Report of Testing a CrossLam® CLT Un-restrained Load-Bearing Floor/Ceiling Assembly for compliance with the applicable requirements of the following criteria: *ASTM E119–16a, Standard Test Methods for Fire Tests of Building Construction and*



FPInnovations

NRC·CNRC

Project No. 301006155
Final Report 2012/13

Preliminary CLT Fire Resistance Testing Report

by

Lindsay Osborne, M.A.Sc.
Christian Dagenais, Eng., M.Sc.
Scientists
Advanced Building Systems – Serviceability and Fire Group

and

Noureddine Bénichou, Ph.D.
Senior Research Officer
National Research Council of Canada – Fire Research Resource Centre

July 2012

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 Capactiy	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 Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X Gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool between Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1 M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-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 (160mm 6.3")	KLH	CV3M1	None	Half-Lap & Topside spline	None	Loaded, See Manufacturer	1	18	SwRI

FRR Design of MT

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

Each has unique benefits:

- **Testing:**
  - Can result in higher FRR for some assemblies when compared to calculations (i.e. 2-hr FRR with 5-ply CLT panel).
  - Seen as more acceptable by some building officials
- **Calculations:**
  - Can provide more design flexibility
  - Allows for project span and loading specific analysis

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

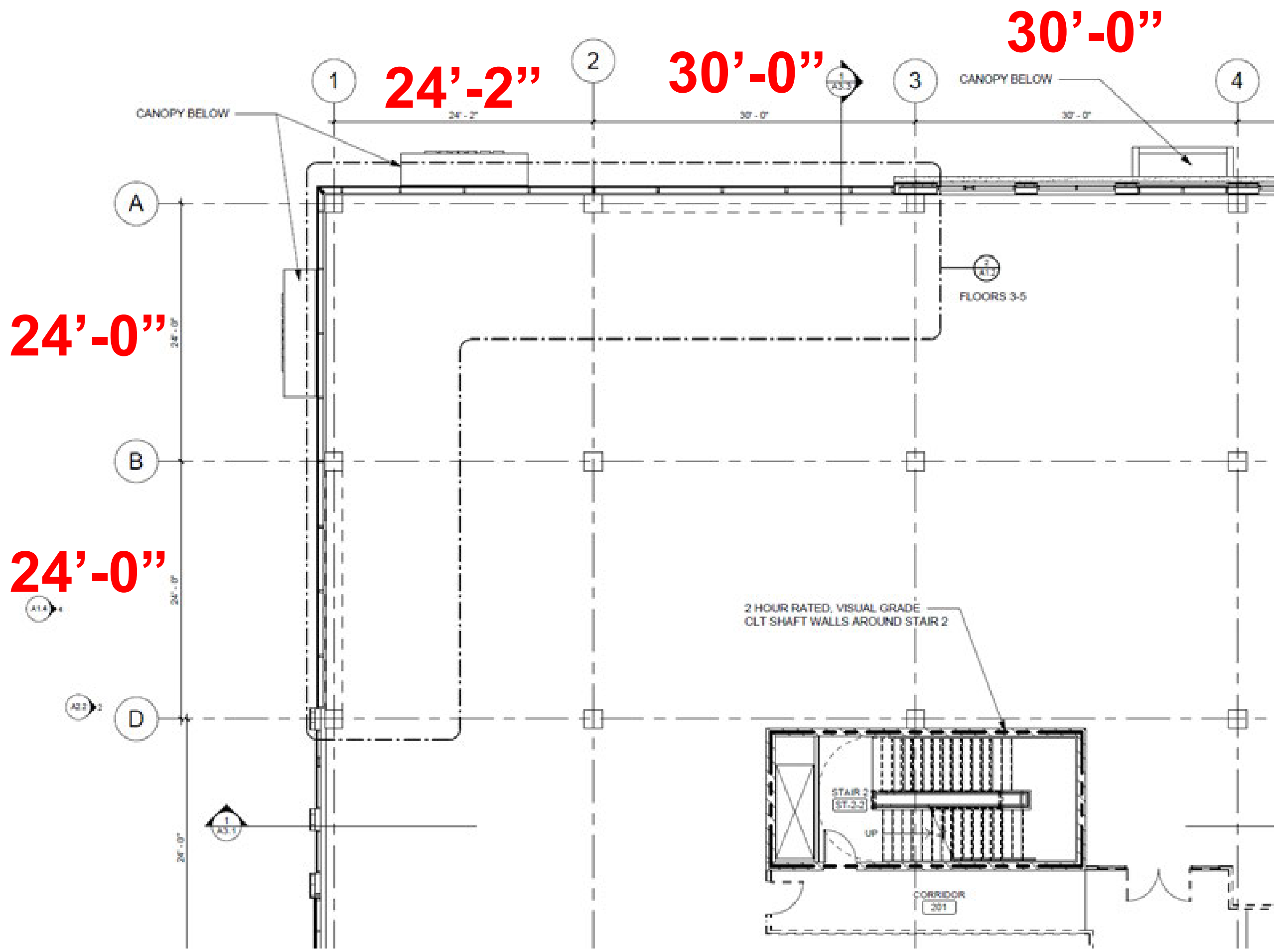
- Code compliance options for demonstrating FRR
- Free download at woodworks.org


Structural Grid

Structural Grid

Grids & Spans

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



Structural Grid

Grids & Spans

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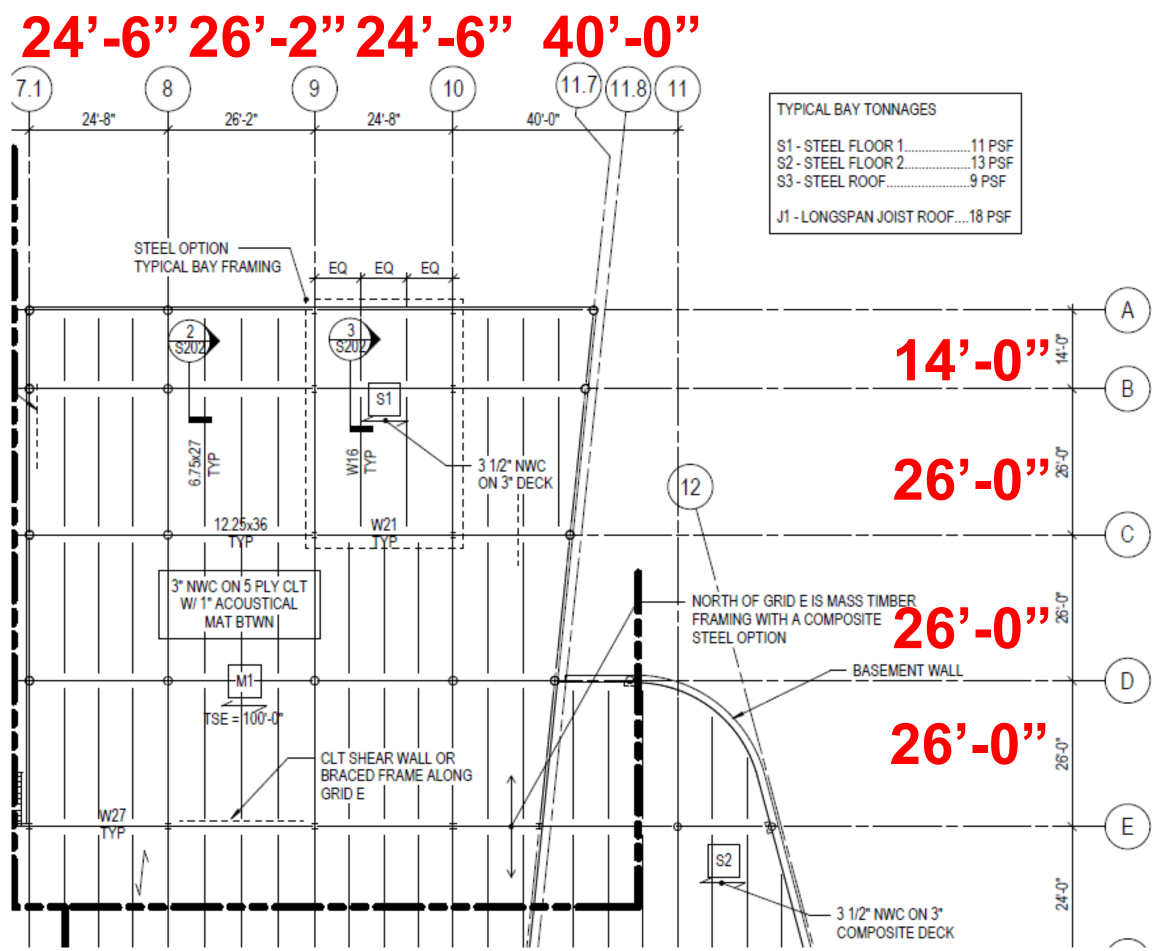


Structural Grid

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

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

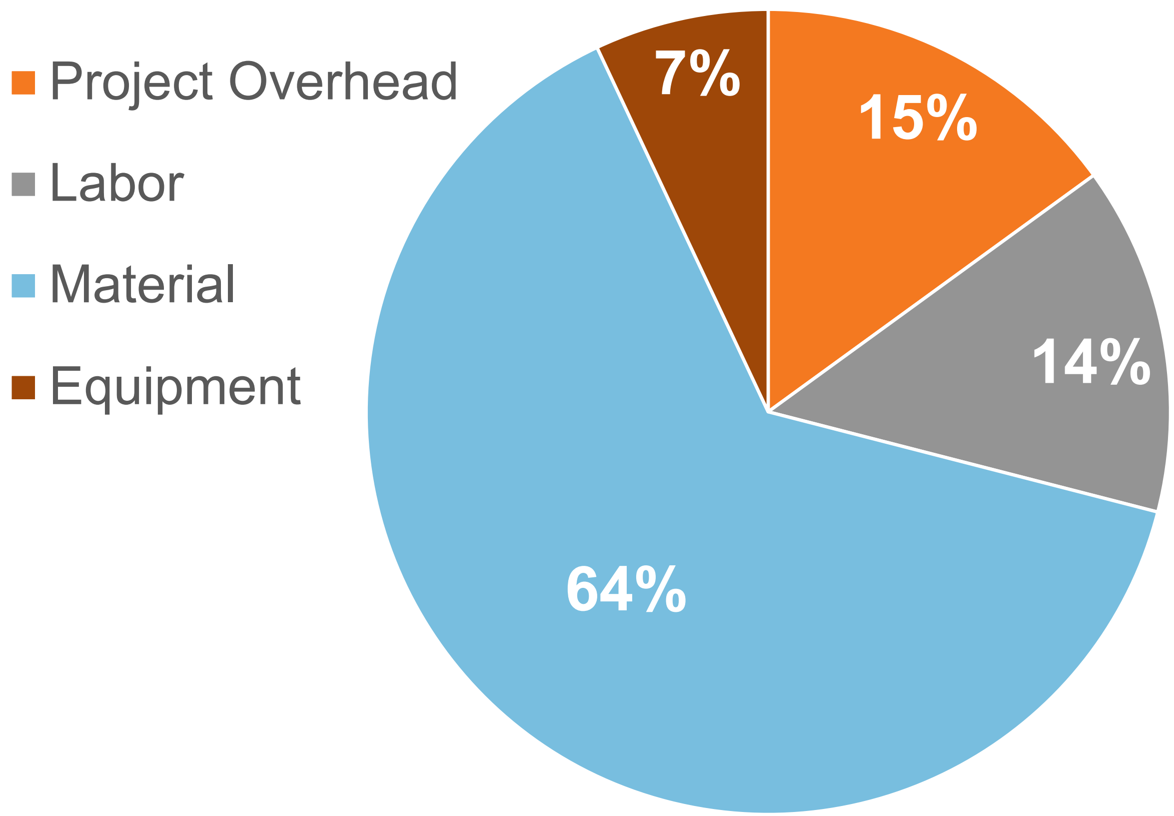
Clay Creative, Portland, OR
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie

Key Early Design Decisions

Why so much focus on panel thickness?

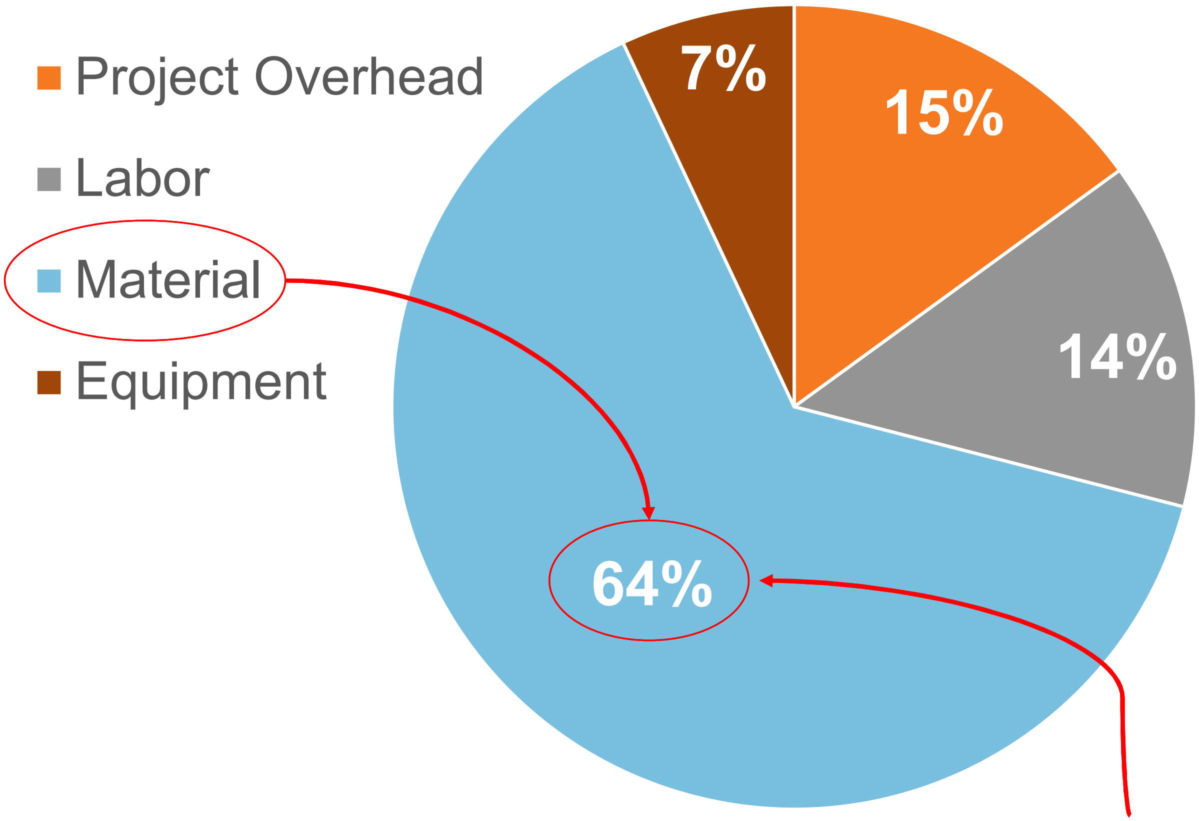
Key Early Design Decisions

Typical MT Package Costs



Source: Swinerton

Key Early Design Decisions



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

Source: Swinerton

Key Early Design Decisions

Construction Type Early Decision Example

7-story building on health campus

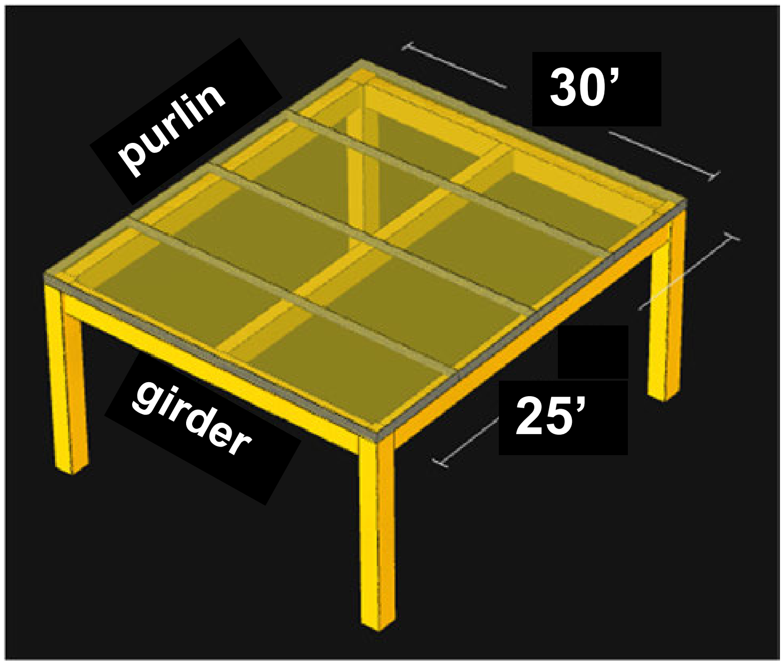
- Group B occupancy, NFPA 13 sprinklers throughout
- Floor plate = 22,300 SF
- Total Building Area = 156,100 SF

MT Construction Type Options:

- **If Building is < 85 ft**
  - **7 stories of IV-C**
  - **6 stories of IIIA or IV-HT over 1 story IA podium**
- **If Building is > 85 ft**
  - **7 stories of IV-B**

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Source: Fast + Epp, Timber Bay Design Tool

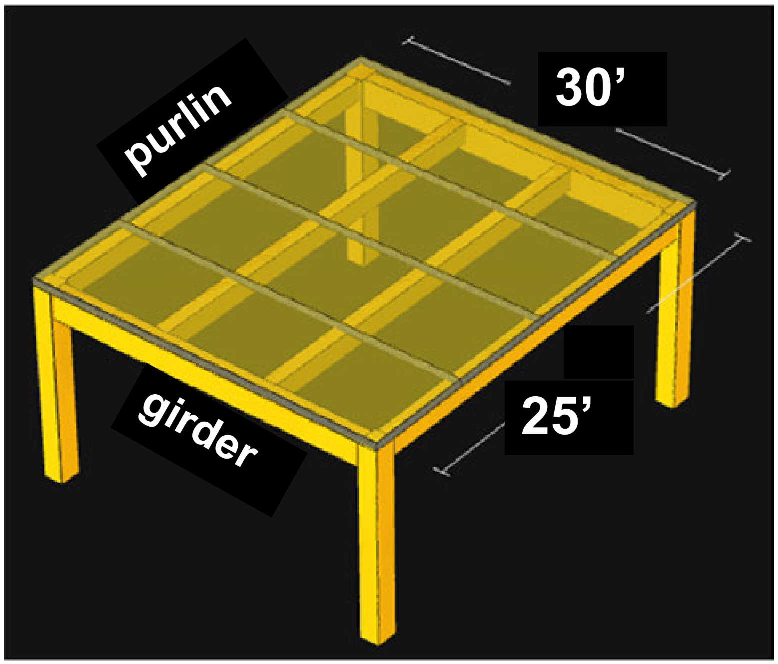
Type IIIA option 1

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

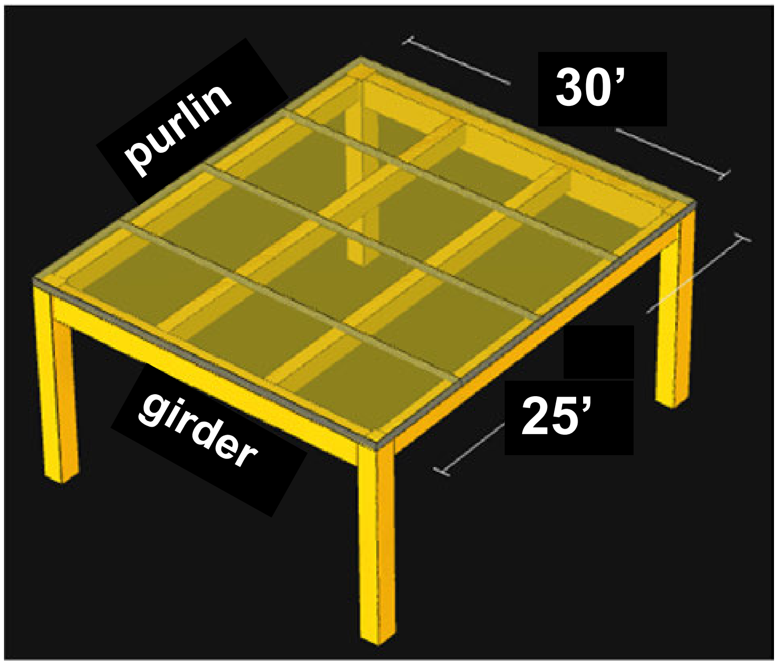
Type IIIA option 2
1-hr FRR
Purlin: 5.5”x24”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

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

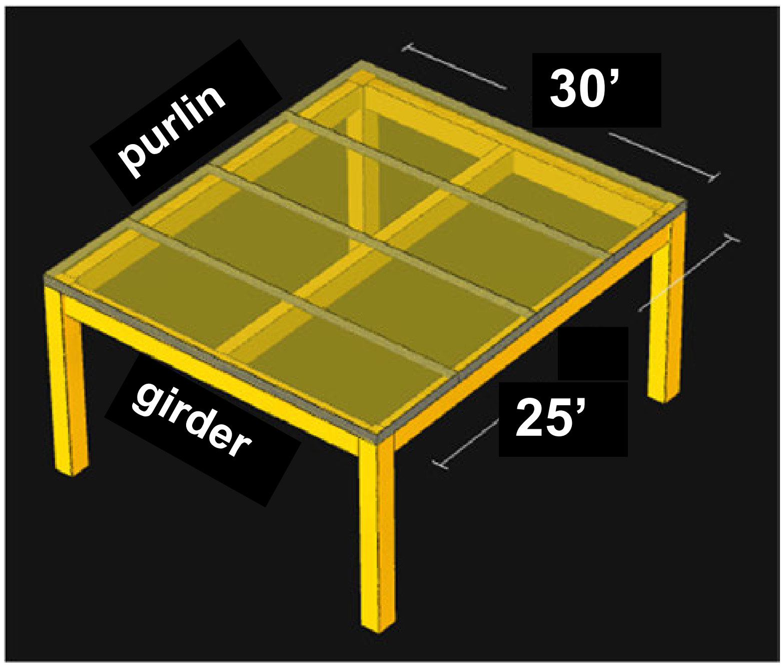
Type IV-HT

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

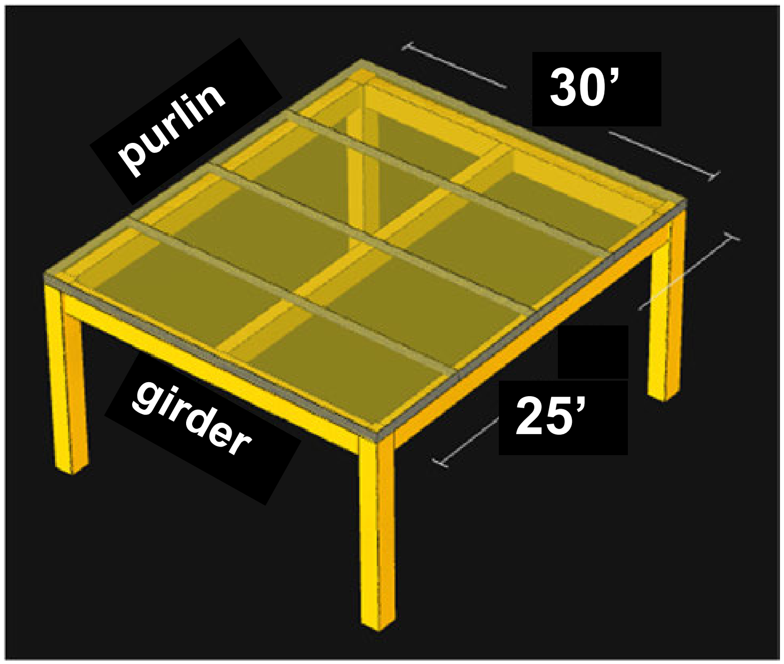
Glulam volume = 183 CF (30% of MT)

CLT volume = 430 CF (70% of MT)

Total volume = 0.82 CF / SF

Key Early Design Decisions

Which is the most efficient option?



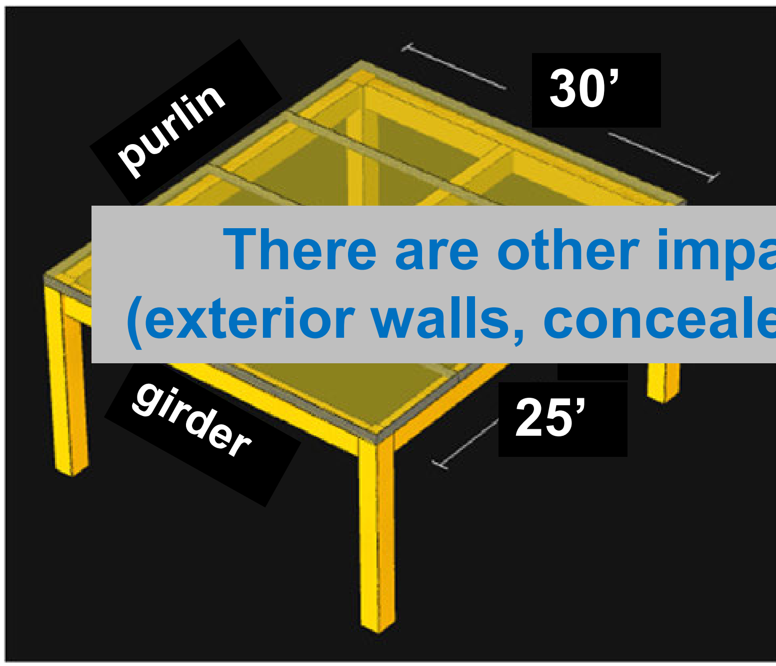
Source: Fast + Epp, Timber Bay Design Tool

	Timber Volume Ratio	Podium on 1st Floor?
IIIA – Option 1	0.73 CF / SF	Yes
IIIA – Option 2	0.74 CF / SF	Yes
IV-HT	0.51 CF / SF	Yes
IV-C	0.82 CF / SF	No

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

Key Early Design Decisions

Which is the most efficient option?



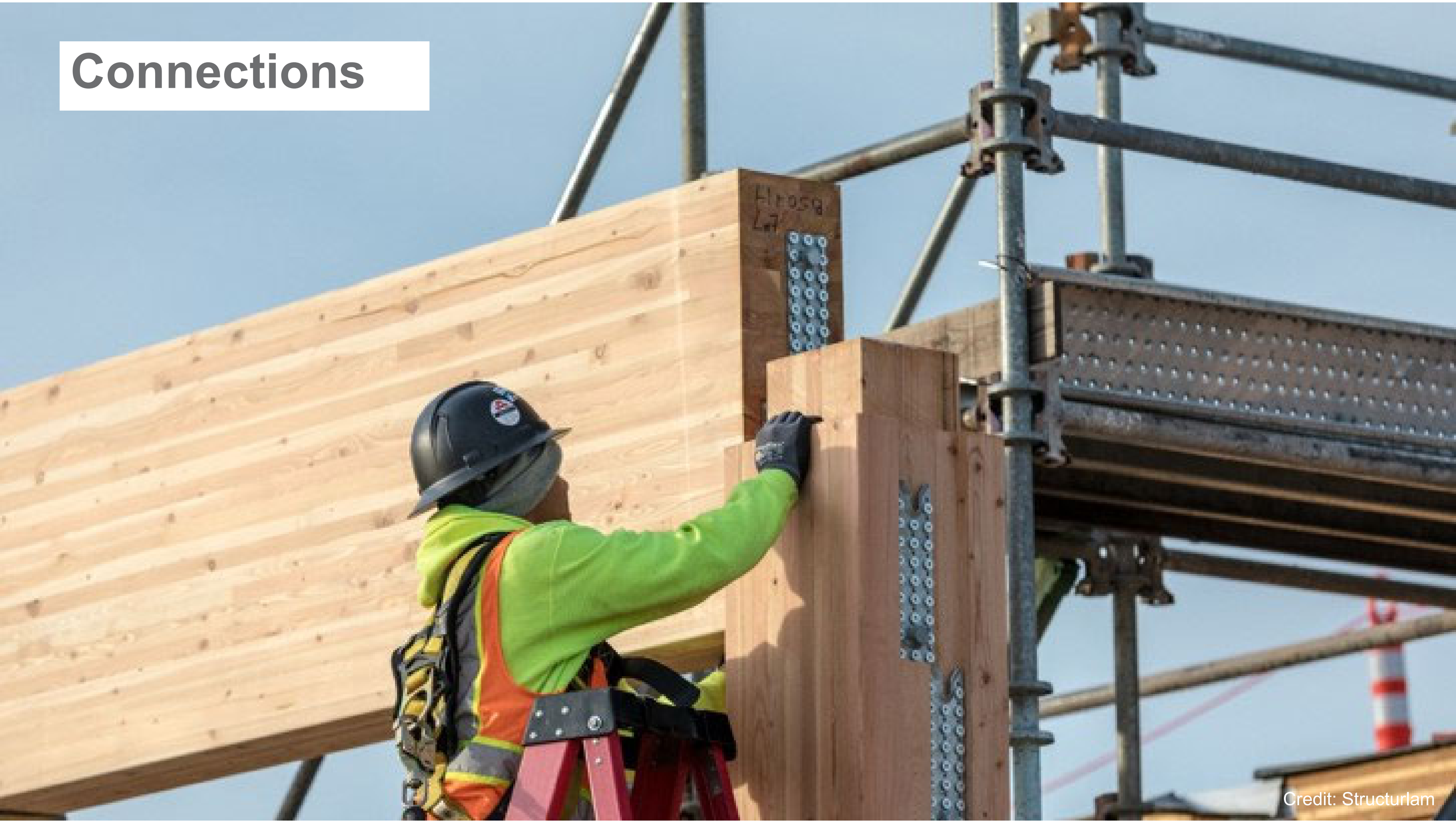
Source: Fast + Epp, Timber Bay Design Tool

	Timber Volume Ratio	Podium on 1st Floor?
IIIA – Option 1	0.73 CF / SF	Yes
IV-C	0.82 CF / SF	No

There are other impacts of constriction type selection (exterior walls, concealed spaces) that should be considered

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive

Connections



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

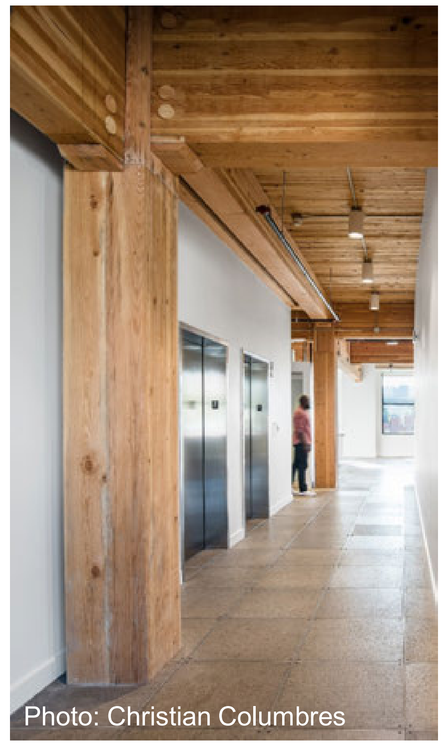


Photo: Christian Columbres

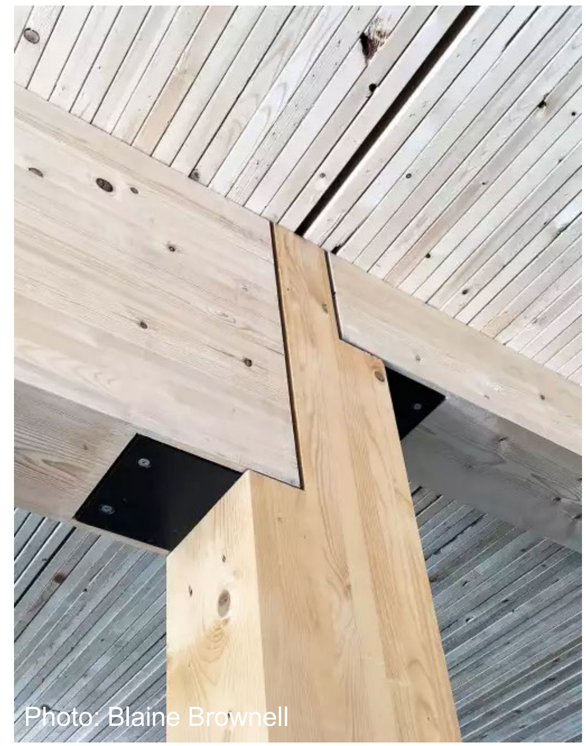
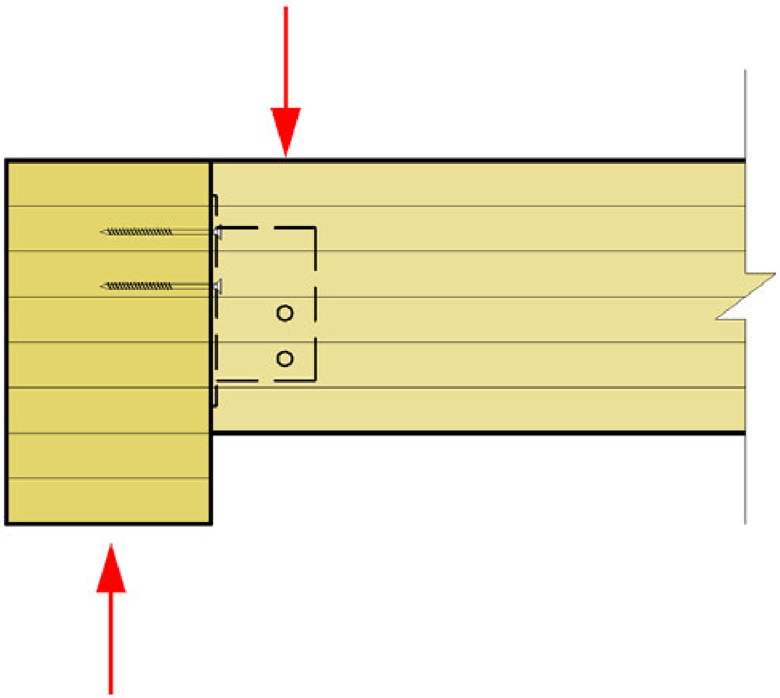


Photo: Blaine Brownell

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

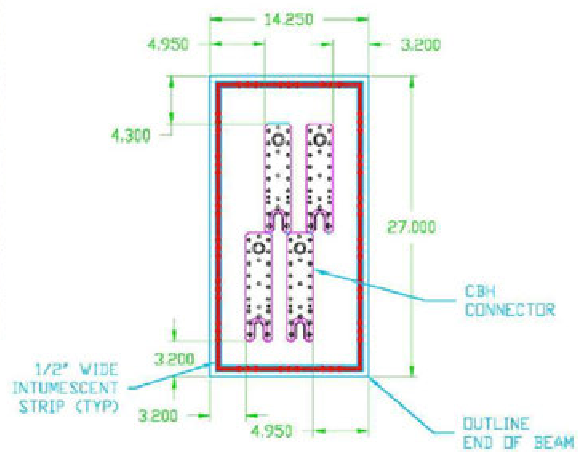


Photo: LEVER Architecture

Key Early Design Decisions

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

Key Early Design Decisions

Fire Test Results

Test	Beam	Connector	Applied Load	FRR
1	8.75” x 18” (222mm x 457mm)	1 x Ricon S VS 290x80	3,905lbs (17.4kN)	1hr
2	10.75” x 24” (273mm x 610mm)	Staggered double Ricon S VS 200x80	16,620lbs (73.9kN)	1.5hrs
3	10.75” x 24” (273mm x 610mm)	1 x Megant 430	16,620lbs (73.9kN)	1.5hrs

Key Early Design Decisions

Softwood Lumber Board

Glulam Connection Fire Test

Summary Report

Issue | June 5, 2017

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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION

FIRE TECHNOLOGY DEPARTMENT
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FIRE PERFORMANCE EVALUATION OF A LOAD BEARING GLULAM BEAM TO COLUMN CONNECTION, INCLUDING A CLT PANEL, TESTED IN GENERAL ACCORDANCE WITH ASTM E119-16a, *STANDARD TEST METHODS FOR FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS*

FINAL REPORT
Consisting of 32 Pages

Full Report Available at:

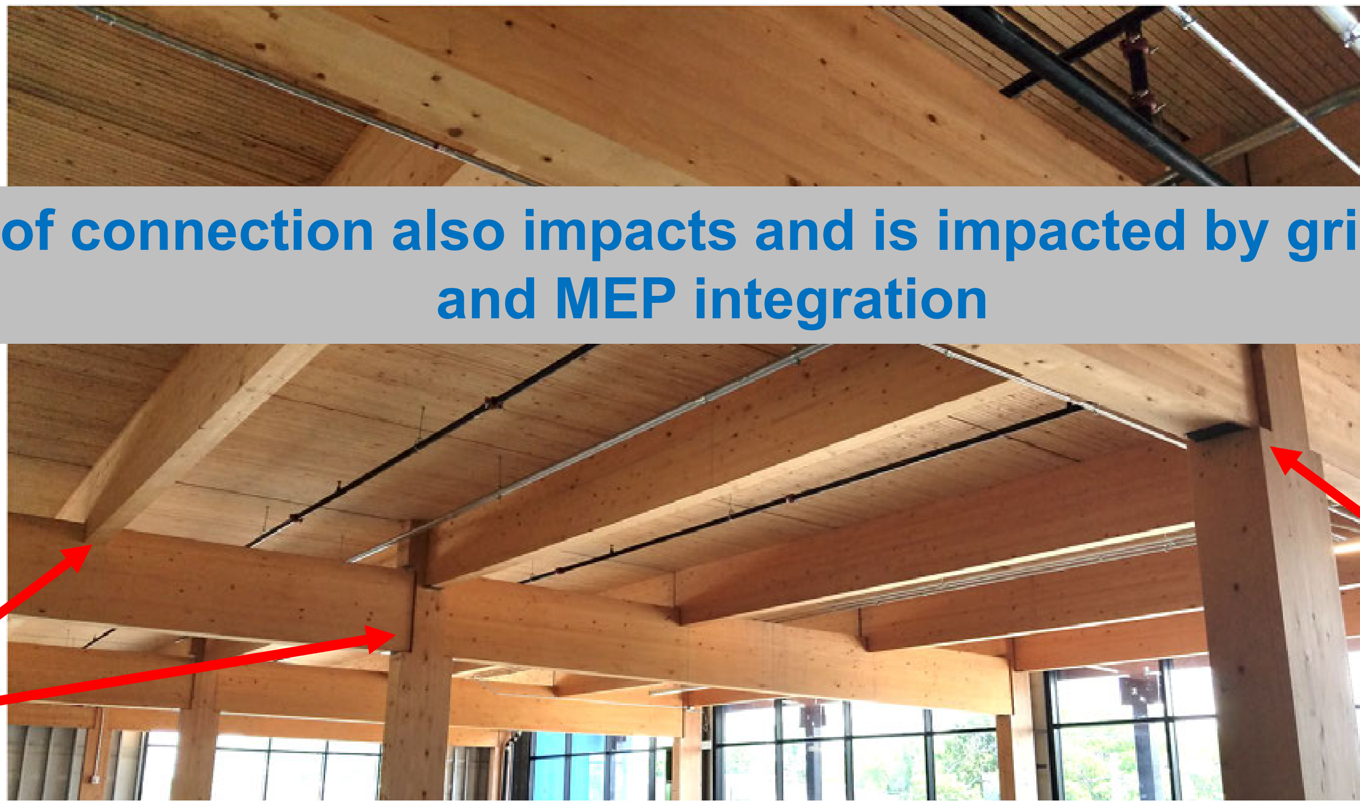
https://www.thinkwood.com/wp-content/uploads/2018/01/reThink-Wood-Arup-SLB-Connection-Fire-Testing-Summary-web.pdf

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

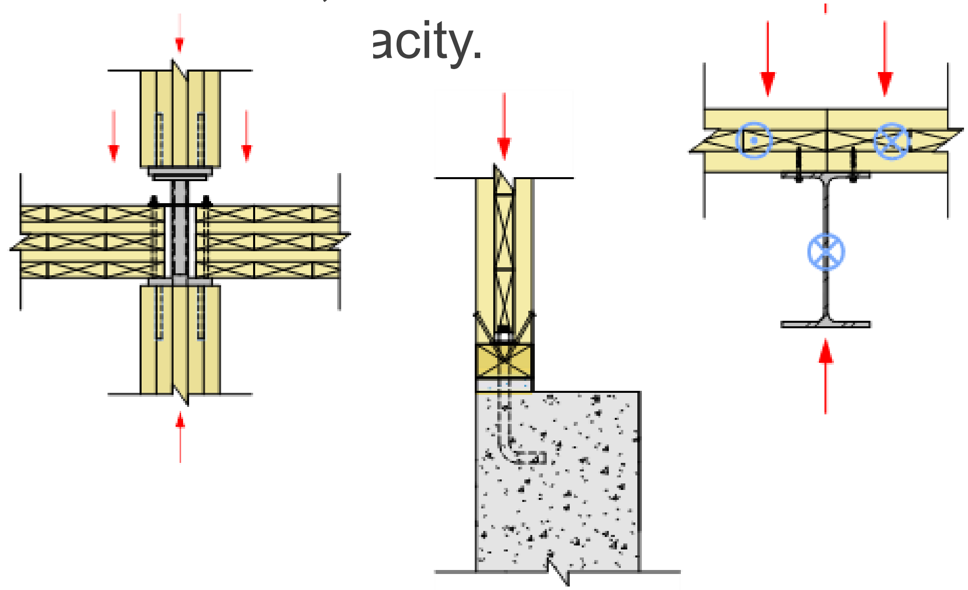


Style of connection also impacts and is impacted by grid layout and MEP integration

Key Early Design Decisions

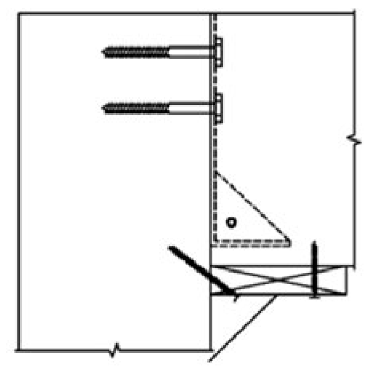
MASS TIMBER CONNECTIONS INDEX

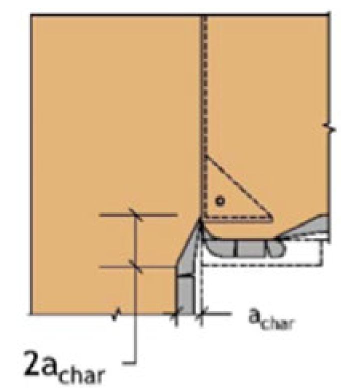
A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load-
acity.



Key Early Design Decisions

2304.10.1 Connection fire resistance rating. Fire resistance ratings in Type IV-A, IV-B, or IV-C construction shall be determined by one of the following:


Source: AWC's TR 10



1. Testing in accordance with Section 703.2 where the connection is part of the fire resistance test.
2. Engineering analysis that demonstrates that the temperature rise at any portion of the connection is limited to an average temperature rise of 250° F (139° C), and a maximum temperature rise of 325° F (181° C), for a time corresponding to the required fire resistance rating of the structural element being connected. For the purposes of this analysis, the connection includes connectors, fasteners, and portions of wood members included in the structural design of the connection.

Connections

Other connection design considerations:

- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost


Credit: Alex Schreyer

Penetrations & Firestopping

Photo: Alex Schreyer

Penetrations & Firestopping

Construction Type Impacts FRR | FRR impacts penetration firestopping requirements

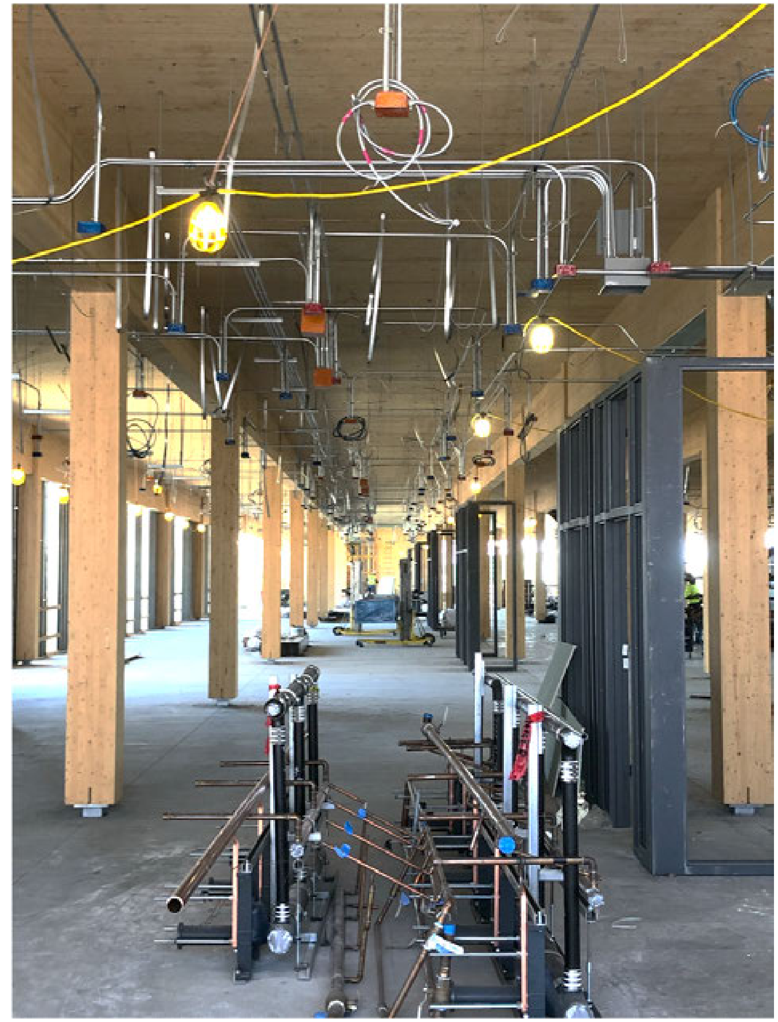
714.1.1 Ducts and air transfer openings. Penetrations of fire-resistance-rated walls by ducts that are not protected with *dampers* shall comply with Sections 714.3 through 714.4.3. Penetrations of *horizontal assemblies* not protected with a shaft as permitted by Section 717.6, and not required to be protected with *fire dampers* by other sections of this code, shall comply with Sections 714.5 through 714.6.2. Ducts and air transfer openings that are protected with *dampers* shall comply with Section 717.

Penetrations & Firestopping

Code options for firestopping through penetrations

714.4.1.1 Fire-resistance-rated assemblies. *Through penetrations* shall be protected using systems installed as tested in the *approved* fire-resistance-rated assembly.

714.4.1.2 Through-penetration firestop system. *Through penetrations* shall be protected by an *approved penetration firestop* system installed as tested in accordance with ASTM E814 or UL 1479, with a minimum positive pressure differential of 0.01 inch (2.49 Pa) of water and shall have an *F rating* of not less than the required *fire-resistance rating* of the wall penetrated.



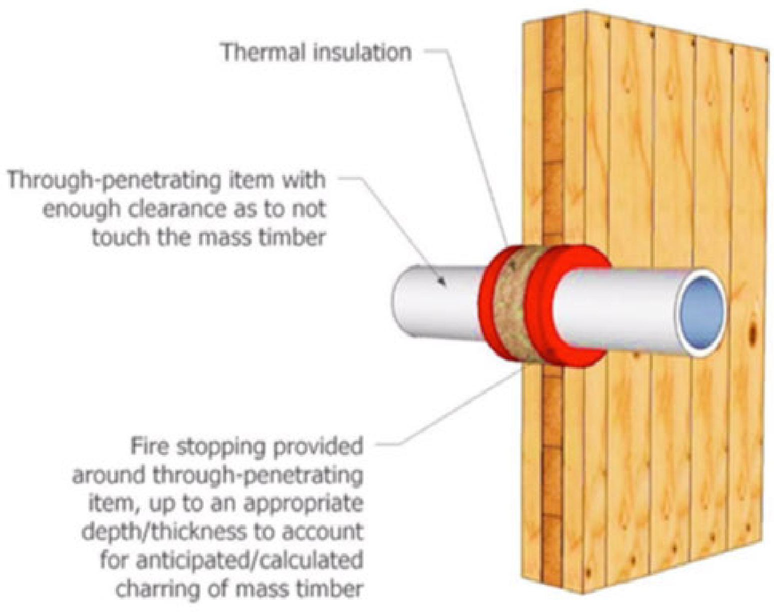
Penetrations & Firestopping

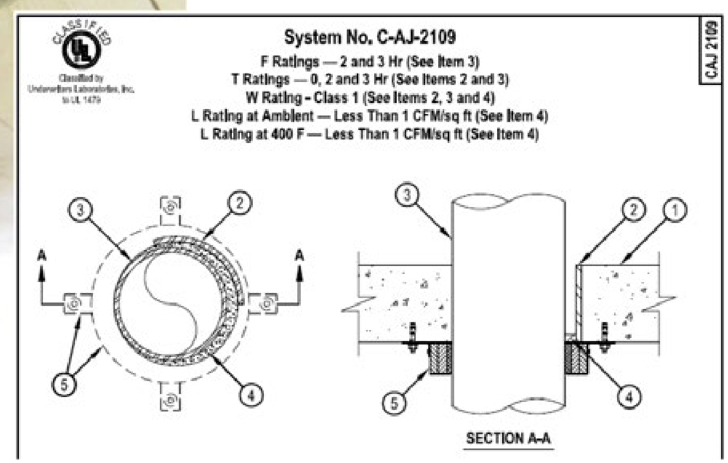
Option 1: MT penetration firestopping via tested products

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

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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
2018 World Conference on Timber Engineering
August 20 - 23, 2018 | Seoul, Republic of Korea

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

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

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, wh
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, s
tall wood buildings. Construction details are outlined which ensure adequate fire performance of these

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

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FIRESTOPPING TEST WITNESS REPORT

for

NORDIC STRUCTURES

Penetrations & Firestopping

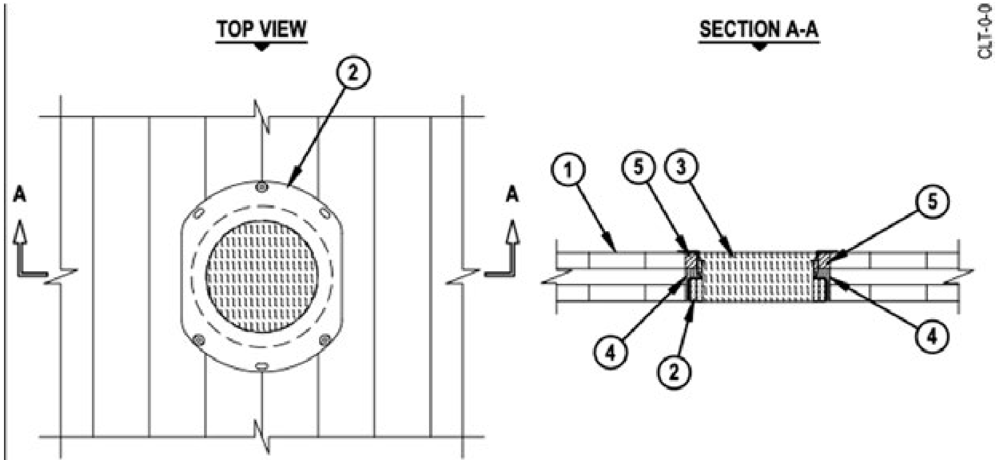
Inventory of Fire Tested Penetrations in MT Assemblies

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

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 – 5/64 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.	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 – 5/64 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.	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

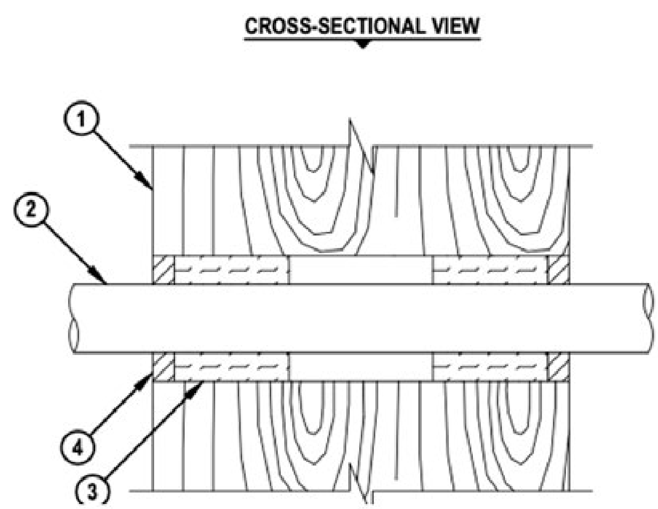
Penetrations & Firestopping

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)

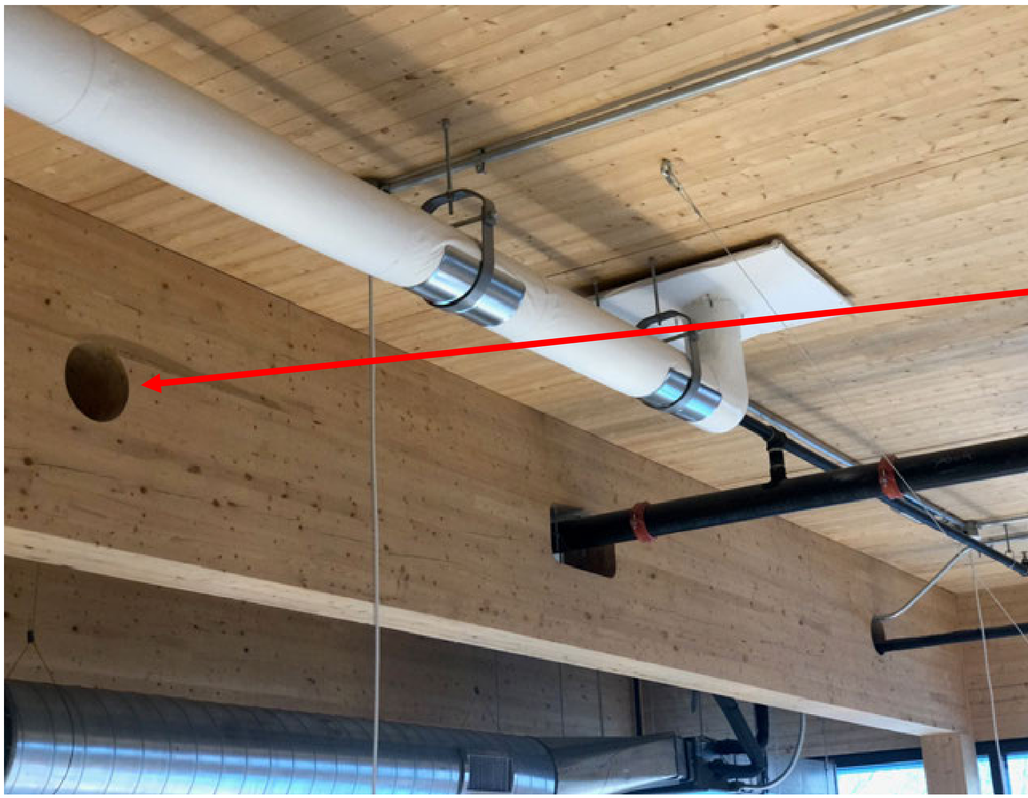


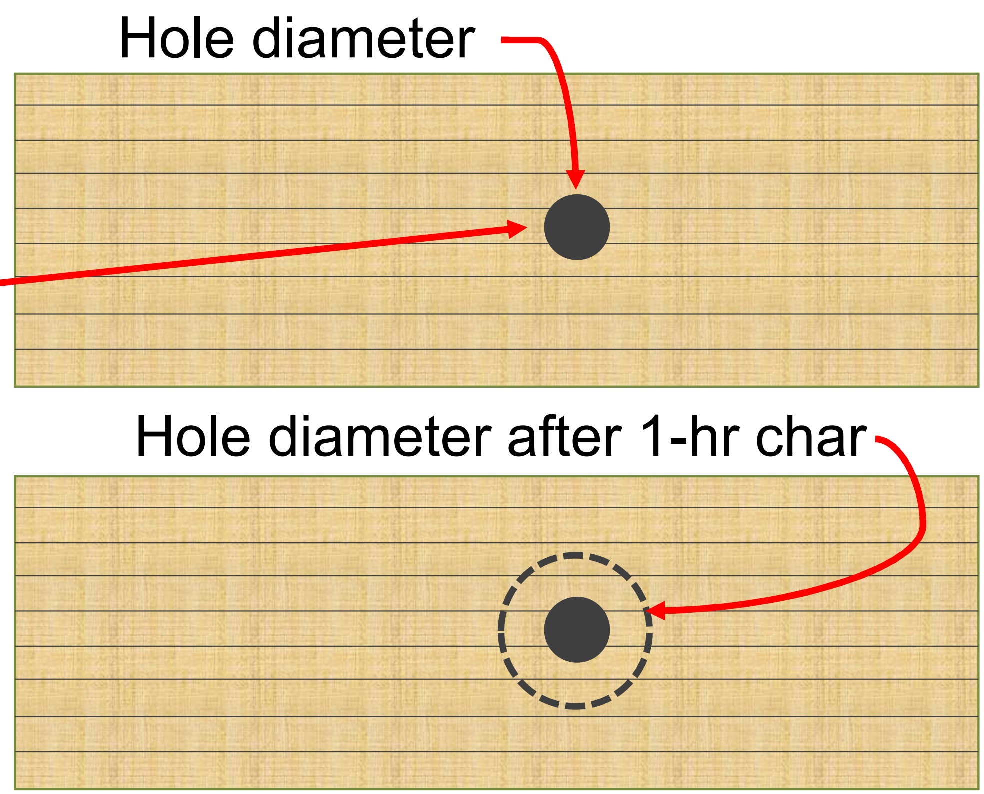
1. MASS TIMBER WALL ASSEMBLY (MINIMUM 12" THICK) (1-HR. OR 2-HR. FIRE-RATING).
2. MAXIMUM 2" NOMINAL DIAMETER PVC PLASTIC PIPE (SCH 40).
3. MINIMUM 4" THICKNESS MINERAL WOOL (MIN. 4 PCF DENSITY) TIGHTLY PACKED AND RECESSED TO ACCOMMODATE SEALANT.
4. MINIMUM 3/4" DEPTH HILTI FS-ONE MAX INTUMESCENT FIRESTOP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



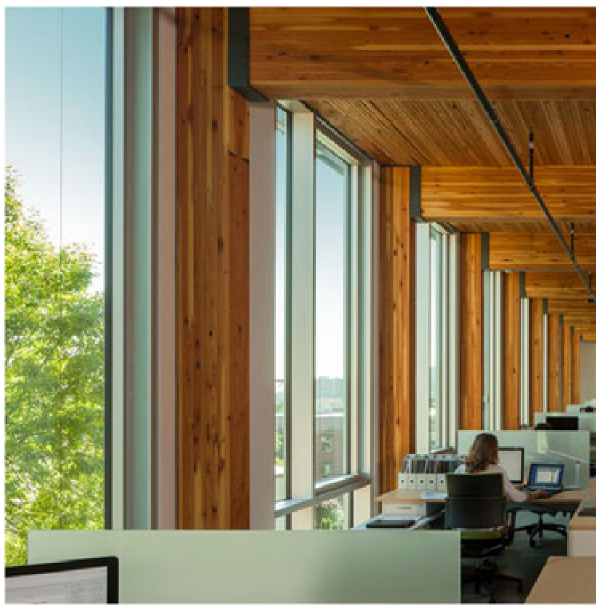


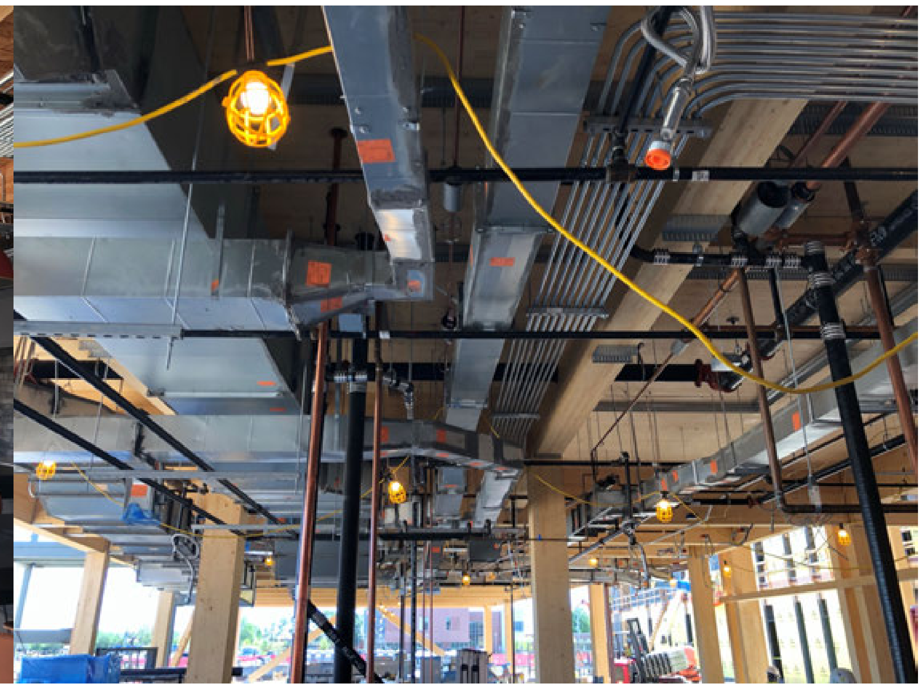
MEP Layout & Integration

MEP Layout & Integration

Set Realistic Owner Expectations About Aesthetics

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





MEP Layout & Integration

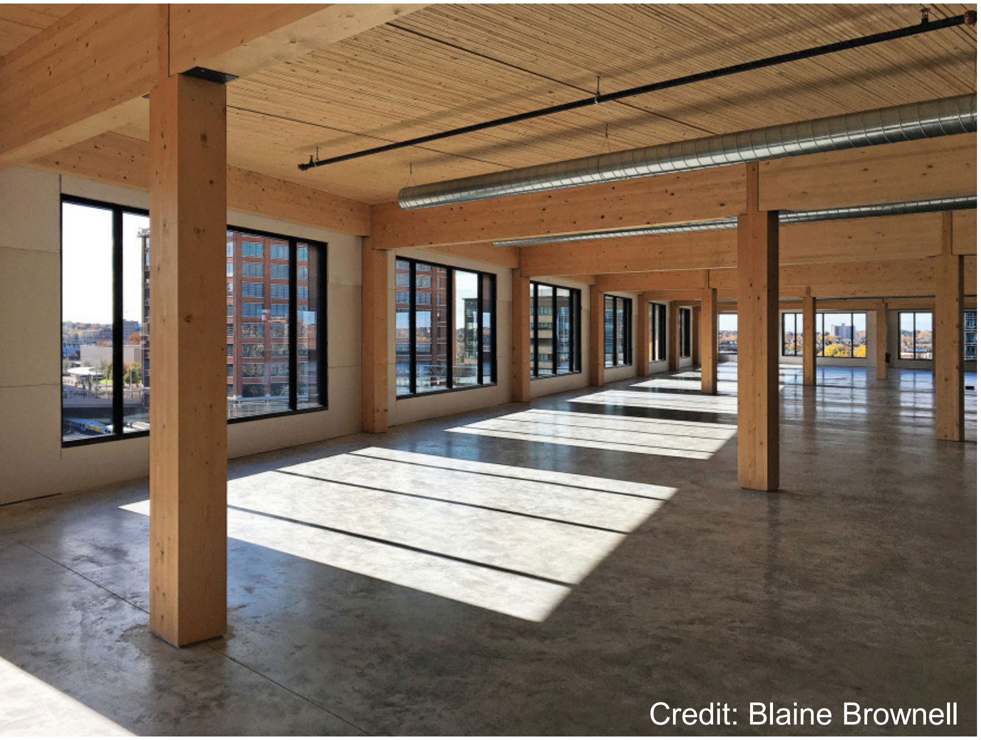
Key considerations:

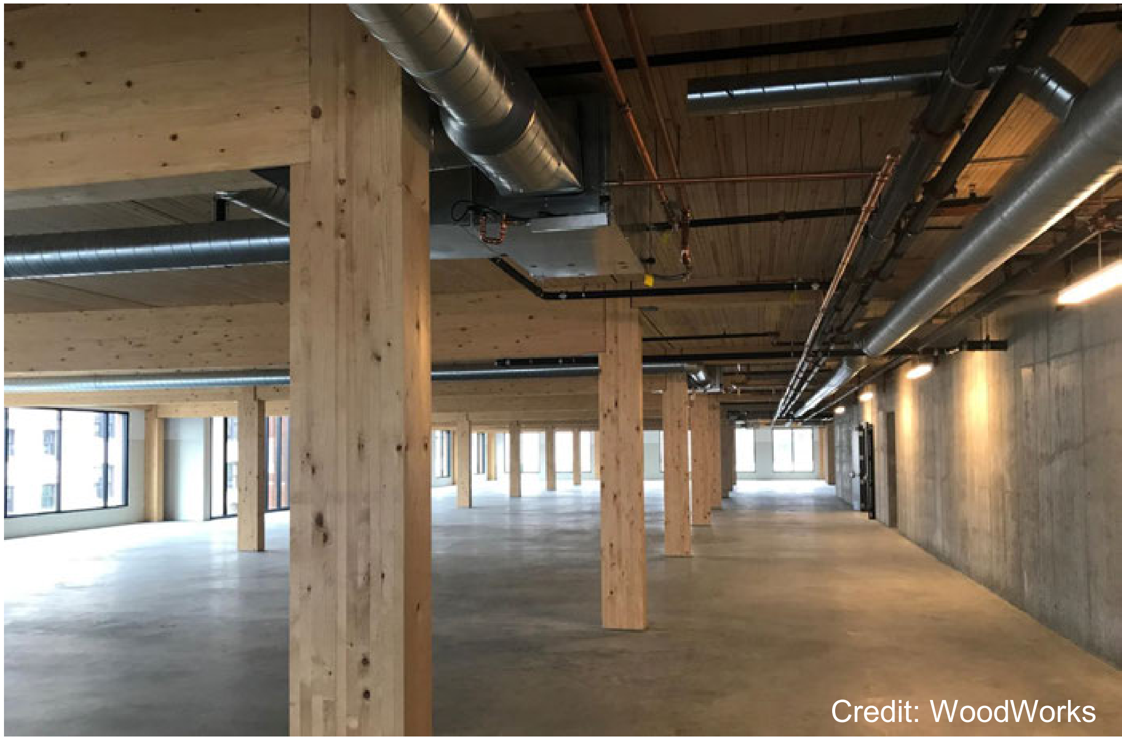
- Level of exposure desired
- Floor to floor, structure depth & desired head height
- Building occupancy and configuration (i.e. central core vs. double loaded corridor)
- Grid layout and beam orientations
- Need for future tenant reconfiguration
- Impact on fire & structural design: concealed spaces, penetrations

MEP Layout & Integration

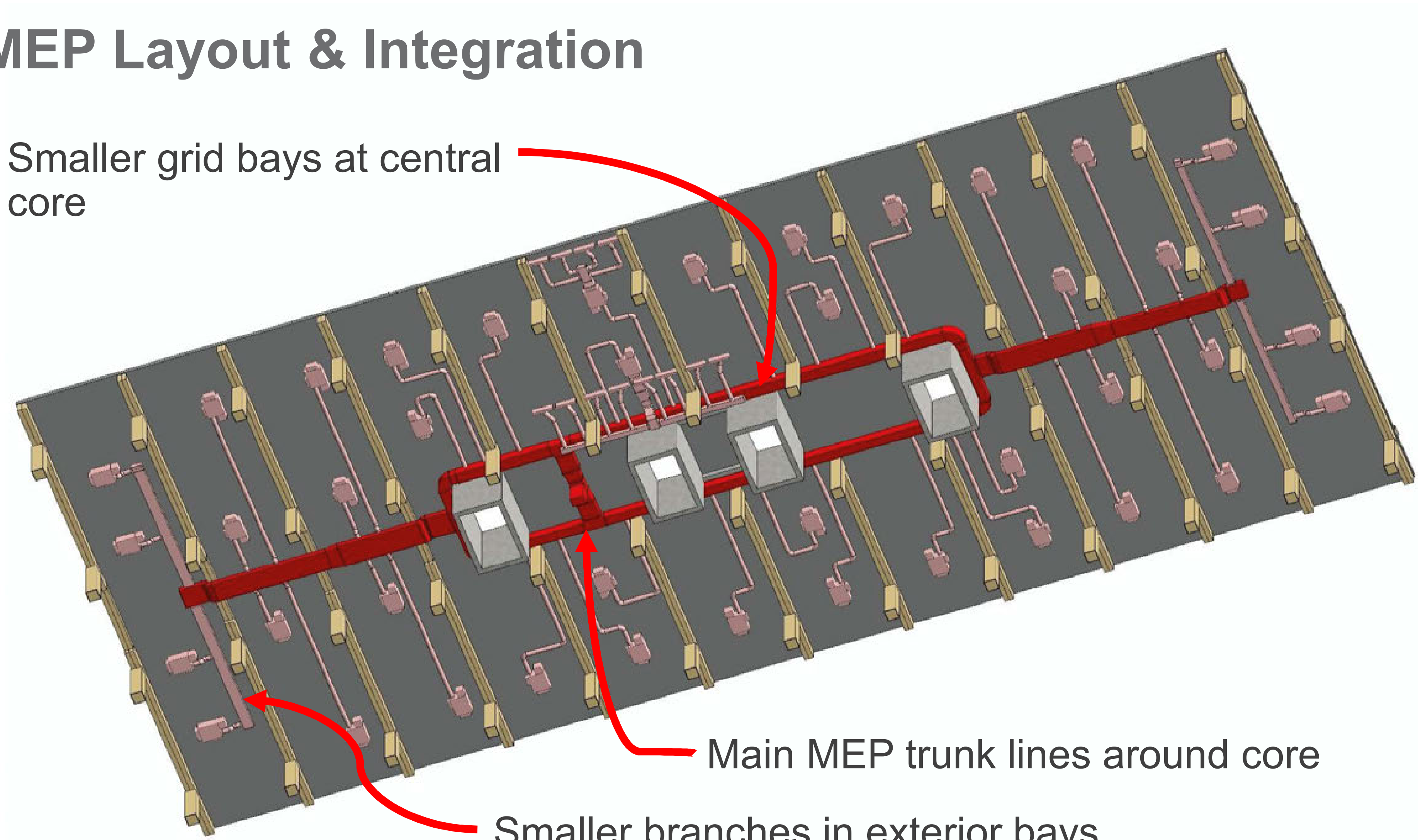
Smaller grid bays at central core (more head height)

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





MEP Layout & Integration



Credit: ARUP

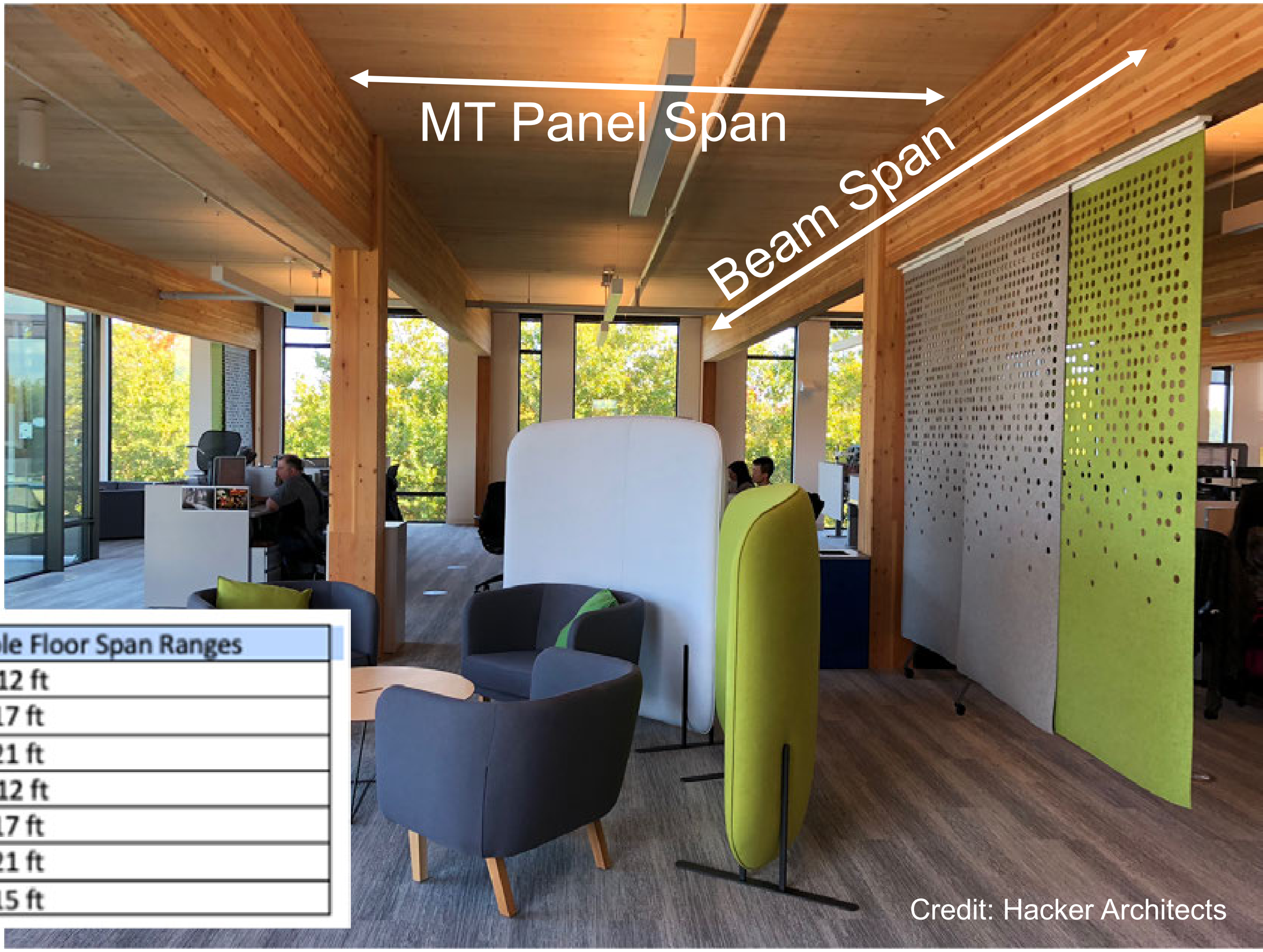
MEP Layout & Integration

Grid impact: Relies on one-way beam layout. Columns/beams spaced at panel span limits in one direction.

Beam penetrations are minimized/eliminated

Recall typical panel span limits:

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

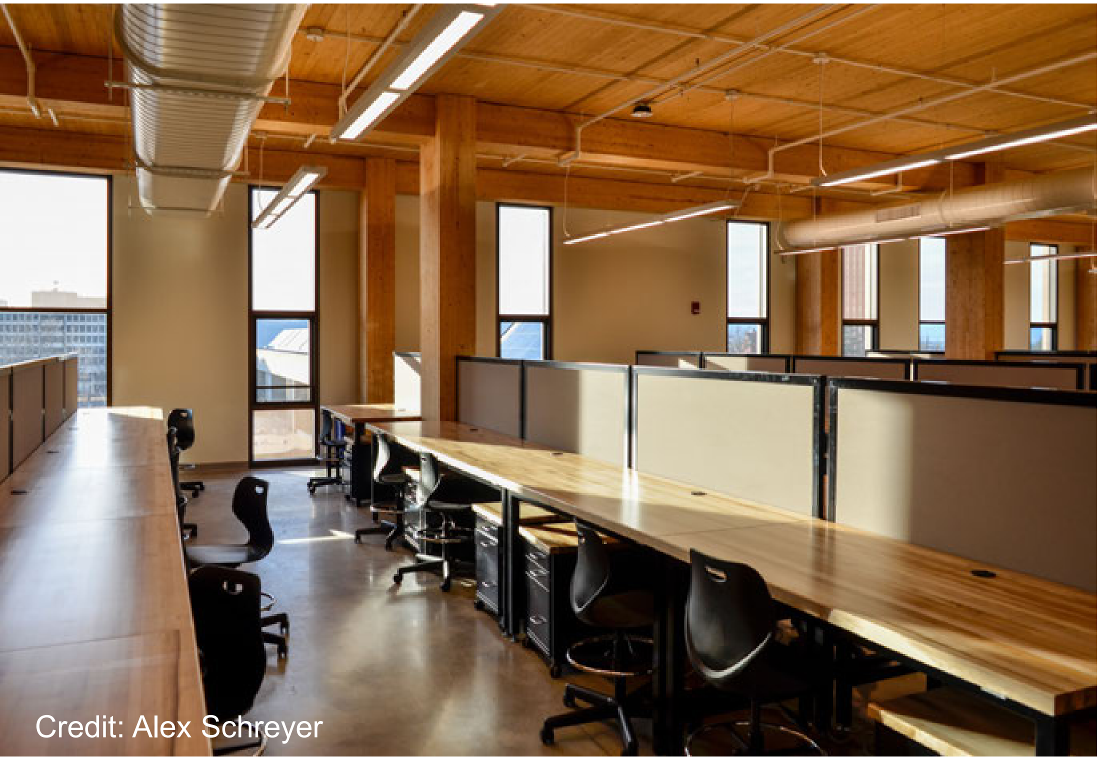


Credit: Hacker Architects

MEP Layout & Integration

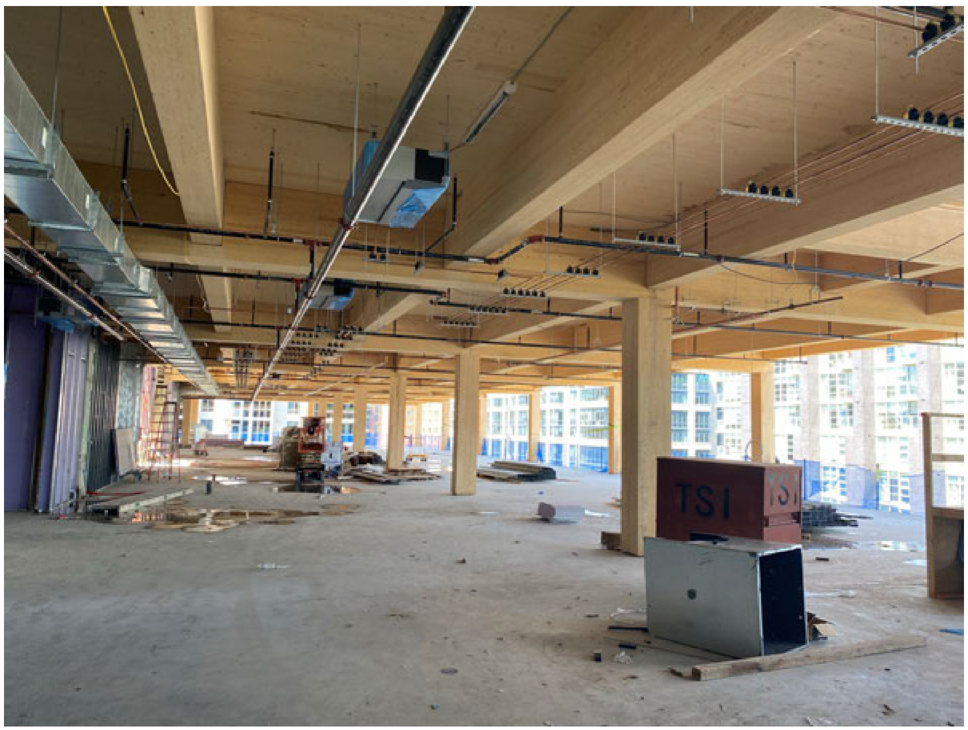
Dropped below MT framing

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



MEP Layout & Integration

Grid impact: Usually more efficient when using a square-ish grid with beams in two directions



Credit: SOM Timber Tower Report

MEP Layout & Integration

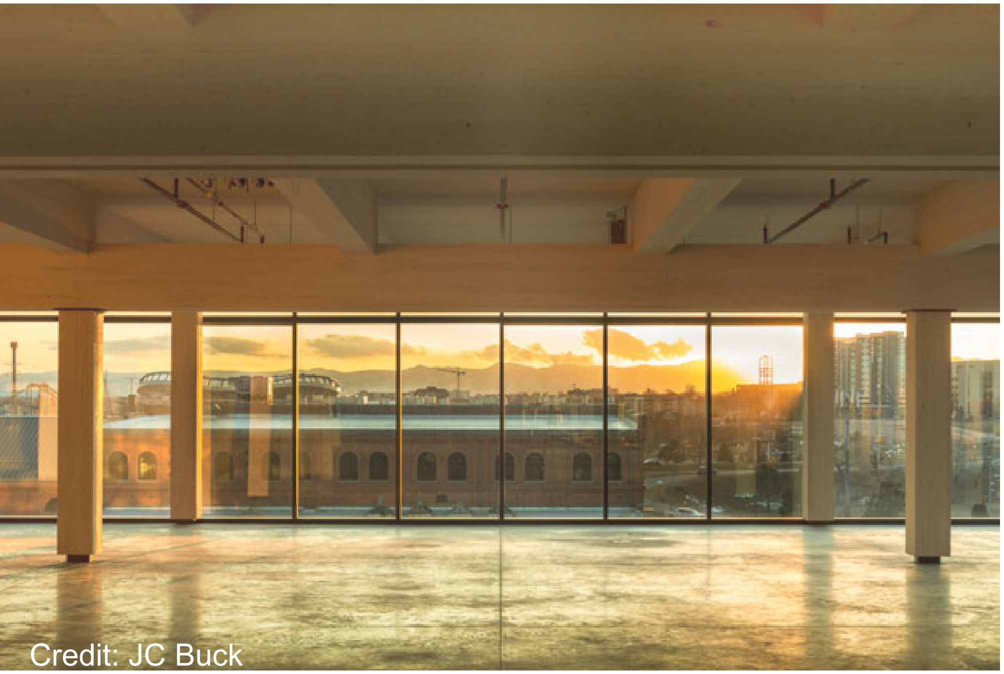
In penetrations through MT framing

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

MEP Layout & Integration

In chases above beams and below panels

- Fewer penetrations
- Bigger impact on head height (overall structure depth is greater)
- FRR impacts: top of beam exposure



MEP Layout & Integration

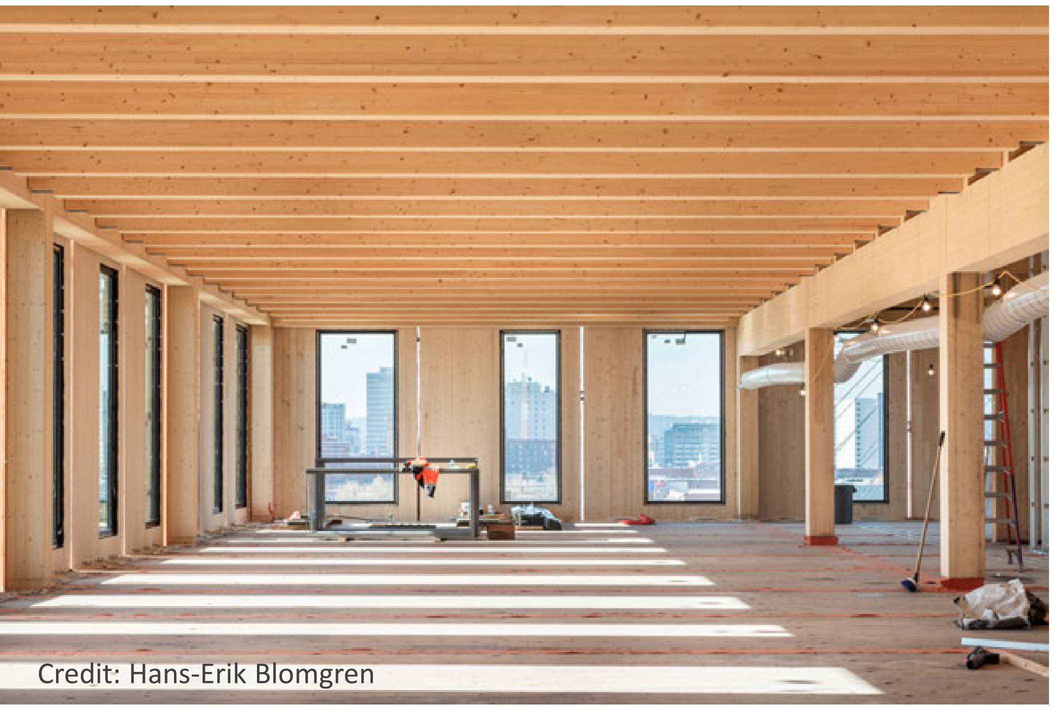
In chases above beams and below panels at Platte 15

- 30x30 grid, purlins at 10 ft, 3-ply CLT

MEP Layout & Integration

In chases above beams and below panels at Catalyst

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



MEP Layout & Integration

In gaps between MT panels

- Fewer penetrations, can allow for easier modifications later

Credit: Ema Peter/MGA

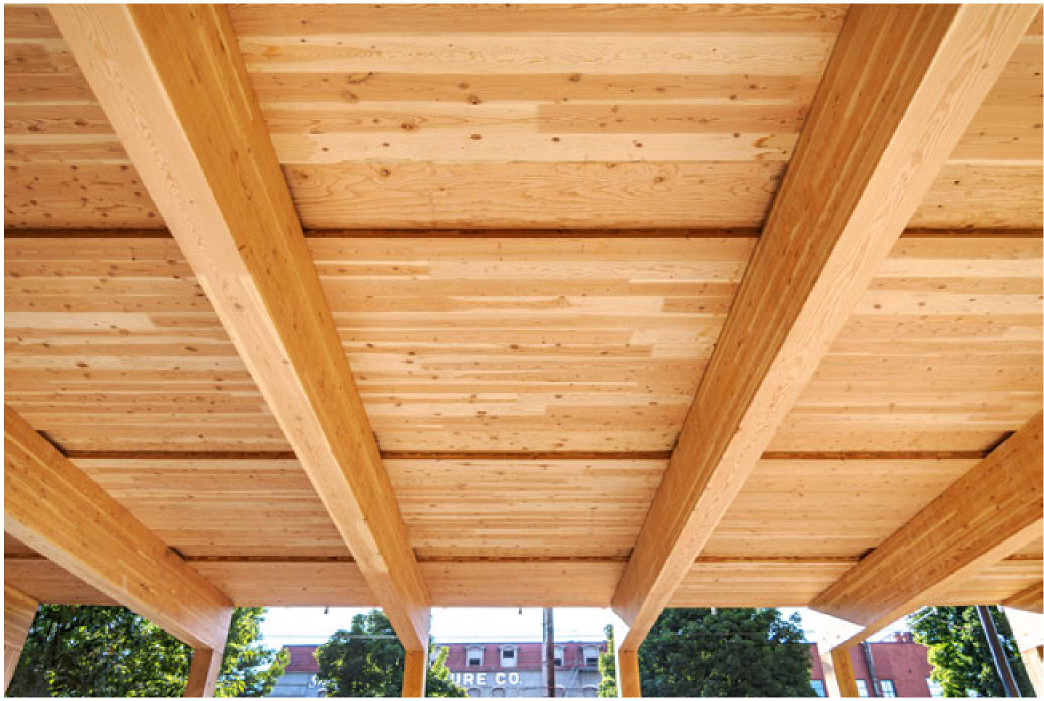
Credit: Hacker Architects

MEP Layout & Integration

In gaps between MT panels
- FRR impacts: generally topping slab relied on for FRR

MEP Layout & Integration

In gaps between MT panels
- Impact on assembly acoustics performance



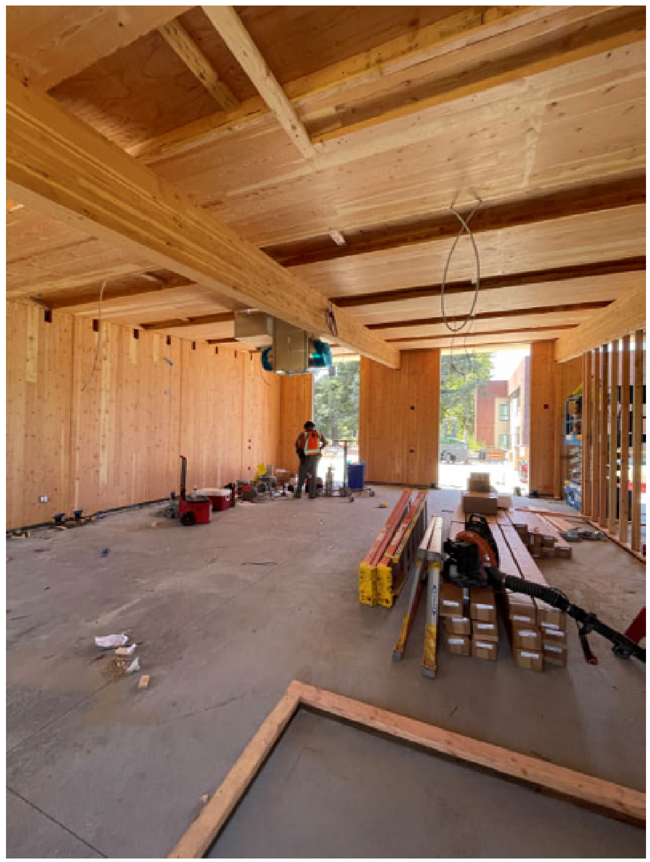
Credit: KPFF

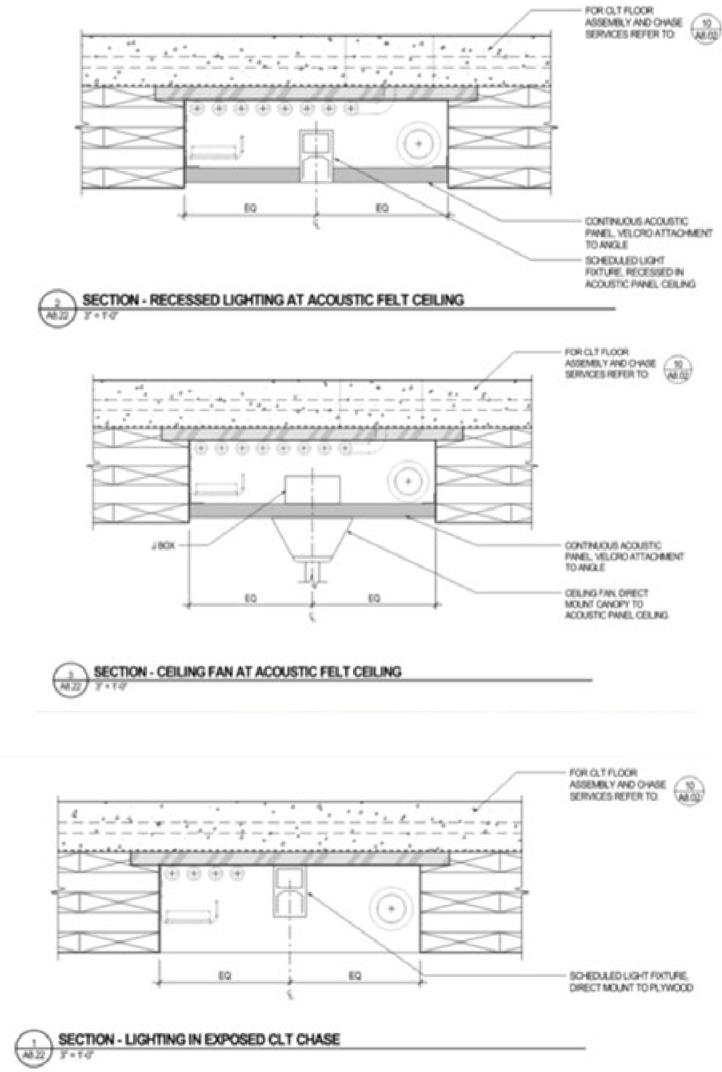
MEP Layout & Integration

In gaps between MT panels

- Greater flexibility in MEP layout

Credit: WoodWorks



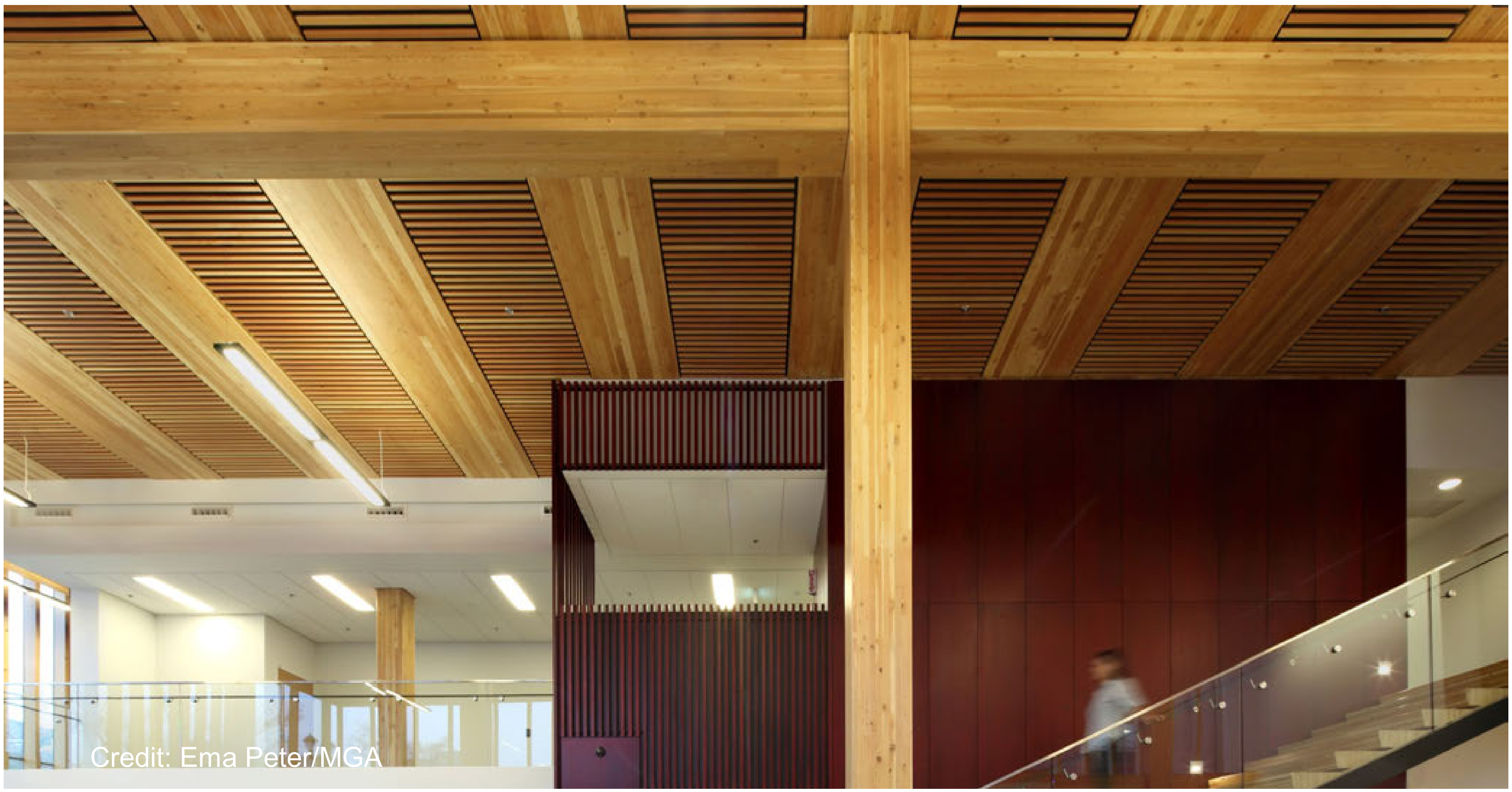


Credit: PAE Consulting Engineers

MEP Layout & Integration

In gaps between MT panels

- Aesthetics: often uses ceiling panels to cover gaps



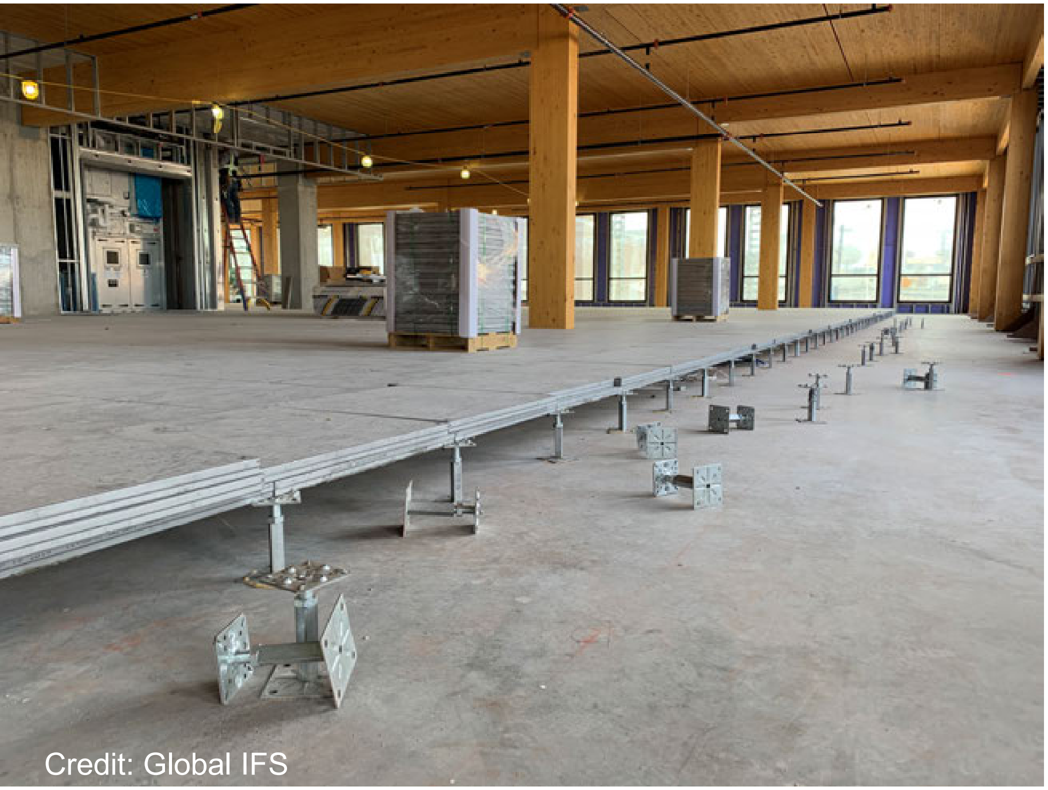
MEP Layout & Integration

In raised access floor (RAF) above MT

- Aesthetics (minimal exposed MEP)

MEP Layout & Integration

In raised access floor (RAF) above MT
- Impact on head height
- Concealed space code provisions


Credit: Global IFS

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

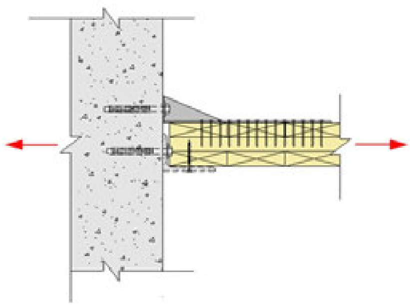
Lateral System Choices

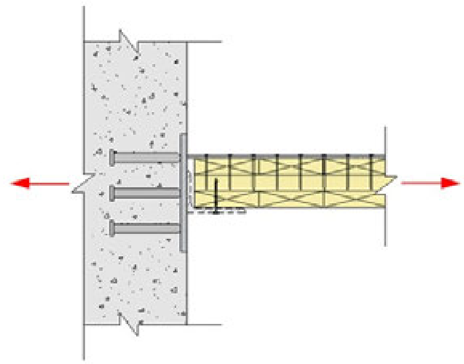
Connection to concrete core

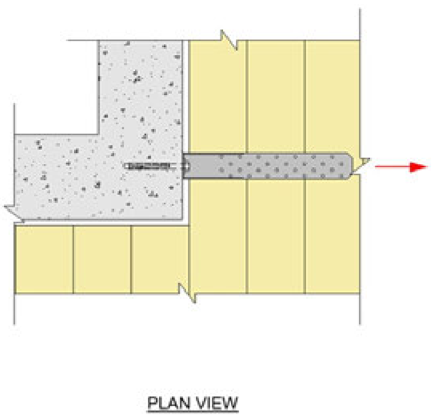
Lateral System Choices

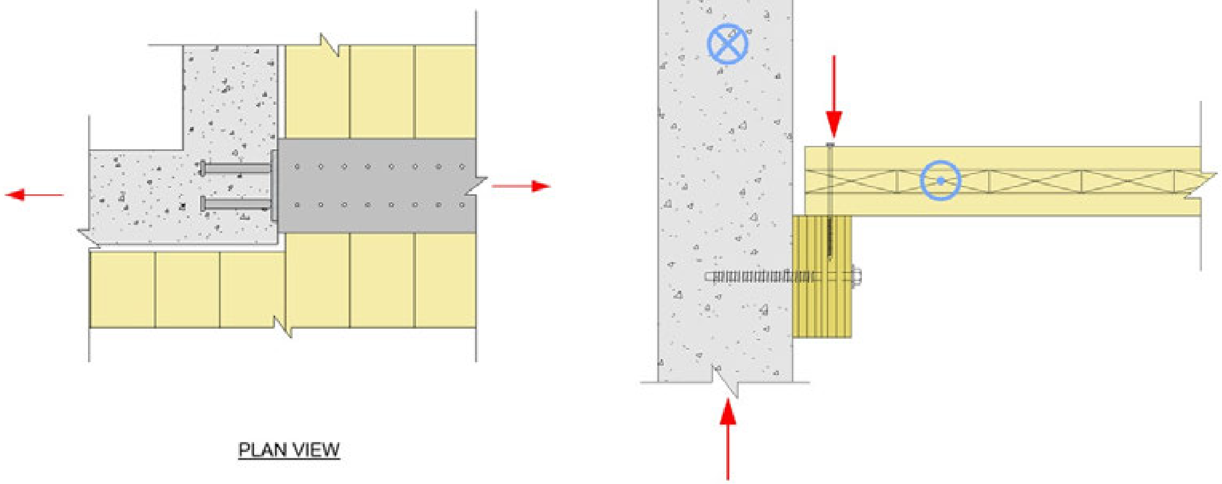
Connections to concrete core

- Tolerances & adjustability
- Drag/collector forces









Lateral System Choices

Steel Braced Frame

Photos: Marcus Kauffmann, ODF

Lateral System Choices

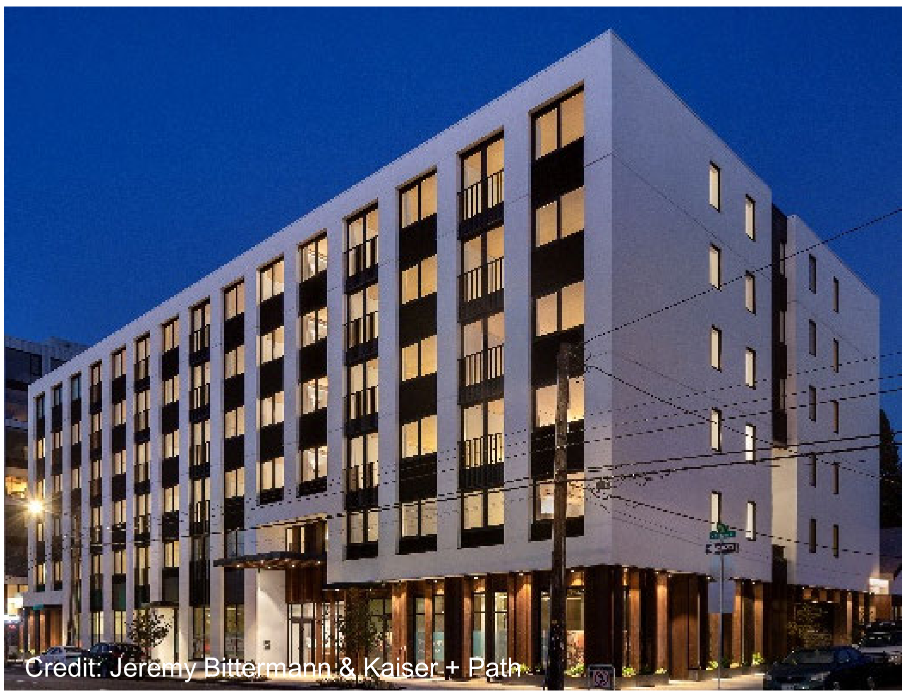
Wood-Frame Shearwalls


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

Photo: Alex Schreyer

Lateral System Choices

MT Rocking Shearwalls


Photo: WoodWorks

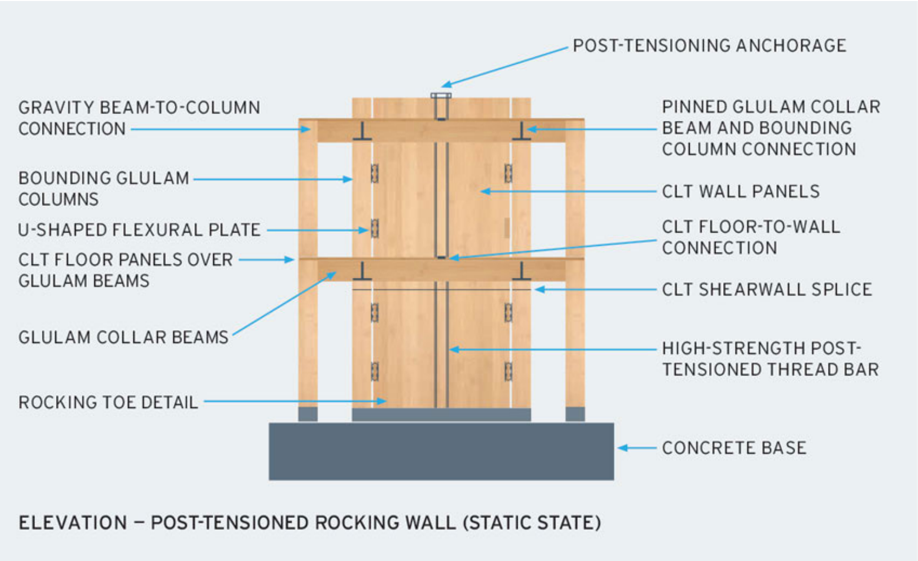


Image: KPFF

Lateral System Choices

Timber Braced Frame

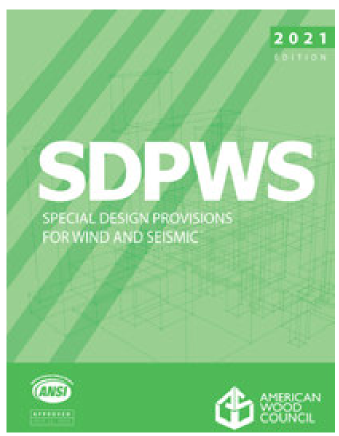

Credit: Alex Schreyer

Lateral System Choices

<u>Prescriptive Code Compliance</u>

Concrete Shearwalls ✓
Steel Braced Frames ✓
Light Wood-Frame Shearwalls ✓
CLT Shearwalls ✓
CLT Rocking Walls ✗
Timber Braced Frames ✗

2021 SDPWS
ASCE 7-22



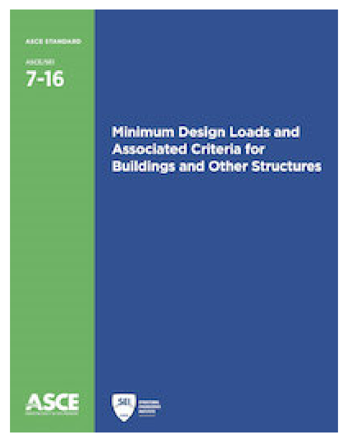



Photo: WoodWorks

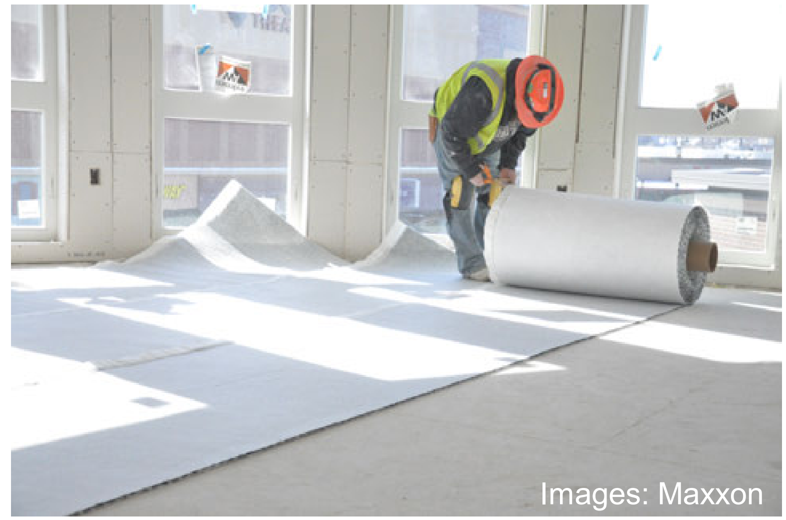
Acoustics & Sound Control

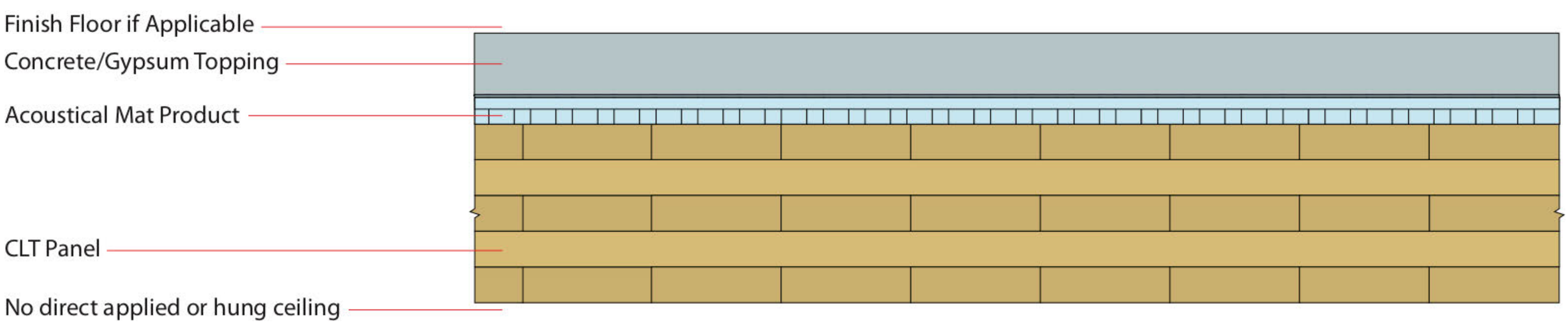
Acoustics & Sound Control

Consider Impacts of:

- Timber & Topping Thickness
- Panel Layout
- Gapped Panels
- Connections & Penetrations
- MEP Layout & Type

Acoustics & Sound Control



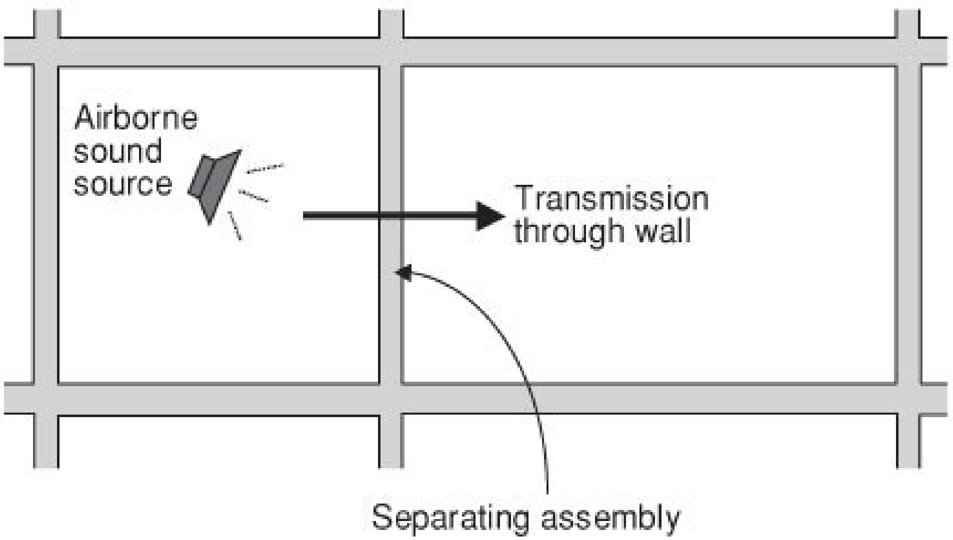


Acoustics & Sound Control

<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

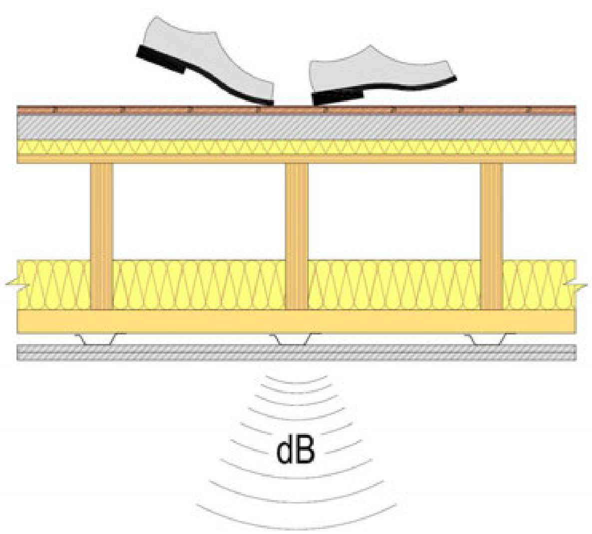


Acoustics & Sound Control

<u>Structure-borne sound:</u>

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

Code requirements only address residential occupancies:

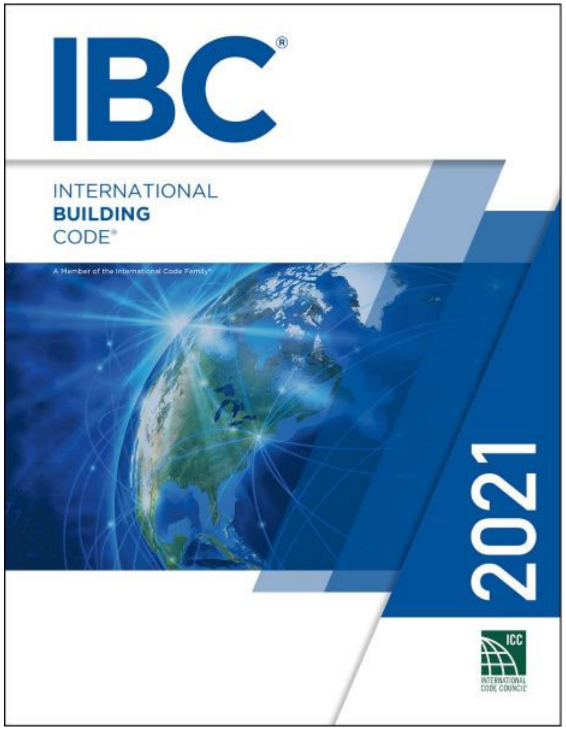
For unit to unit or unit to public or service areas:

Min. STC of 50 (45 if field tested):

- Walls, Partitions, and Floor/Ceiling Assemblies

Min. IIC of 50 (45 if field tested) for:

- Floor/Ceiling Assemblies

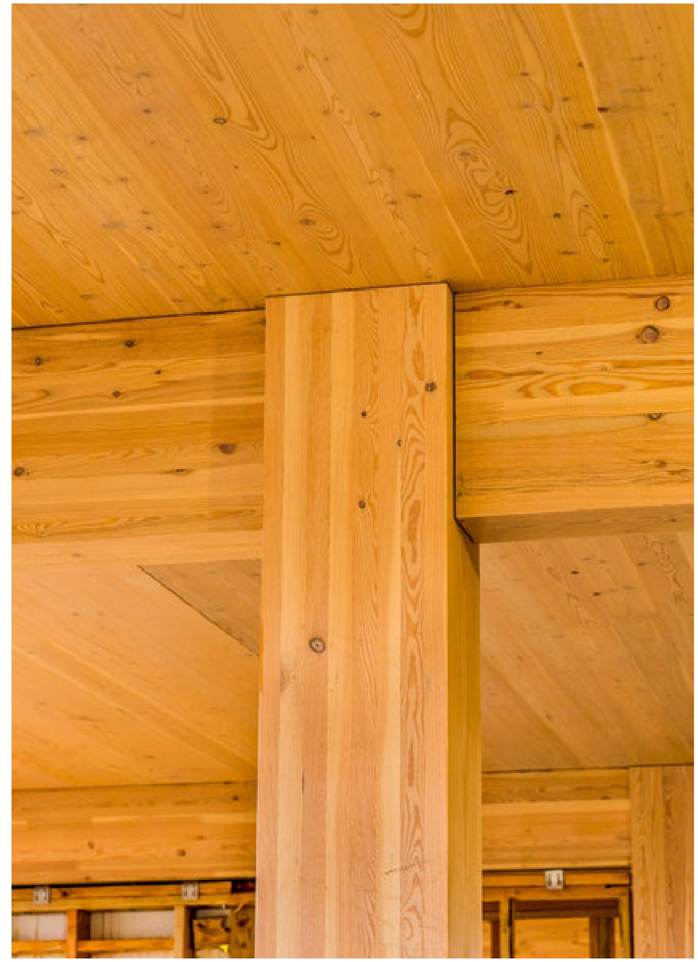


Acoustics & Sound Control

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

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

Photo: Corey Gaffer courtesy Perkins + Will

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:

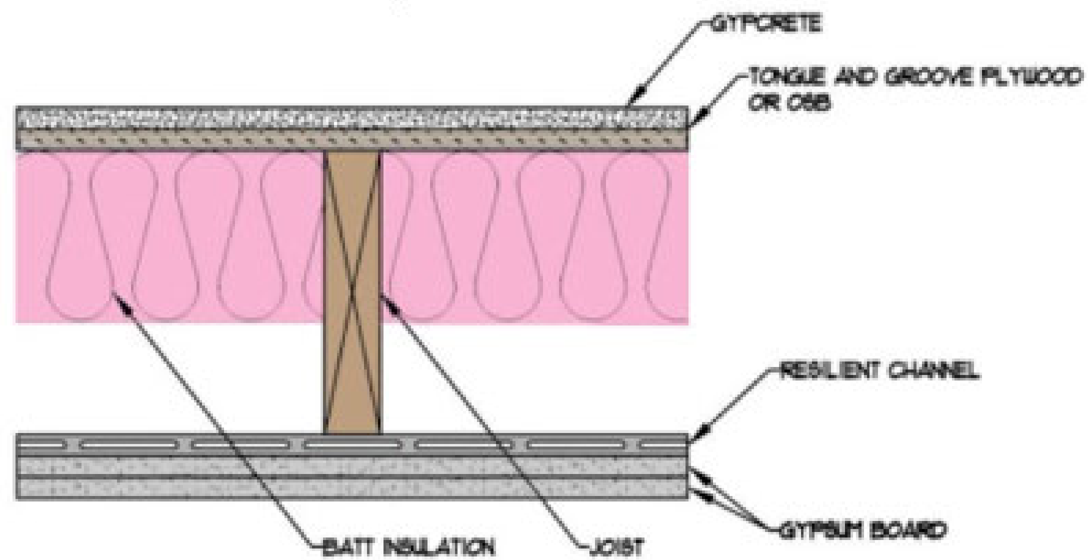
1. Add mass
2. Add noise barriers
3. Add decouplers


Image credit: Christian Columbres

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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

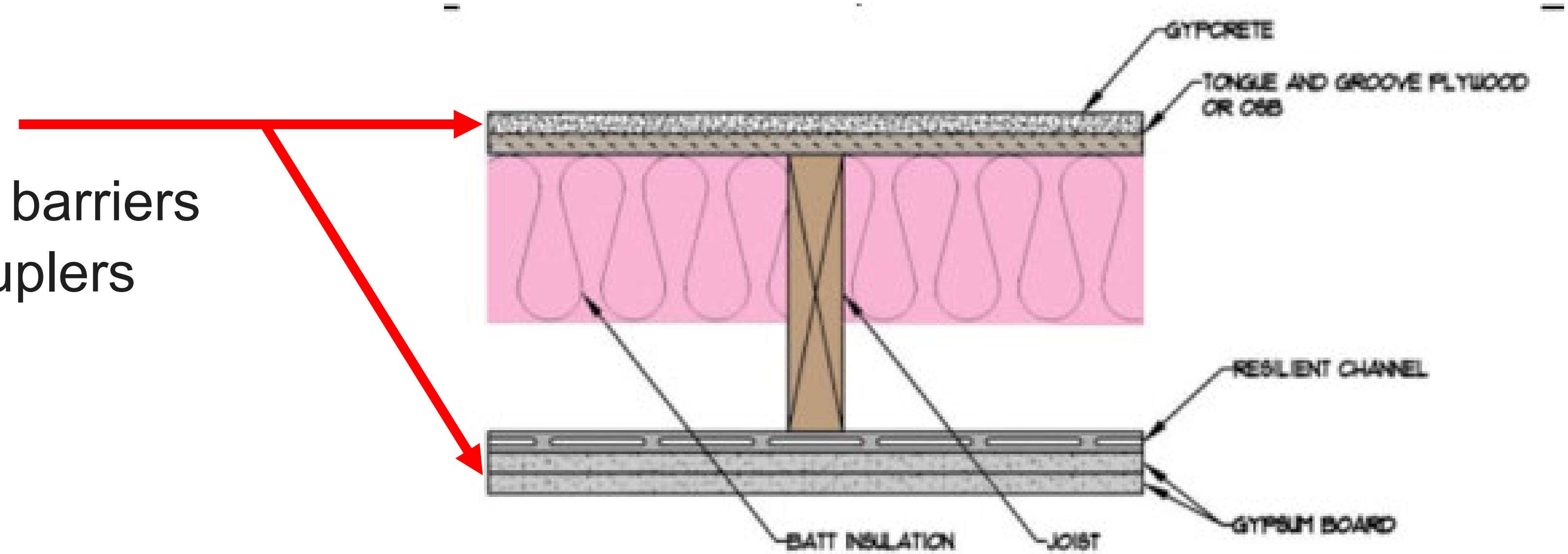


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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

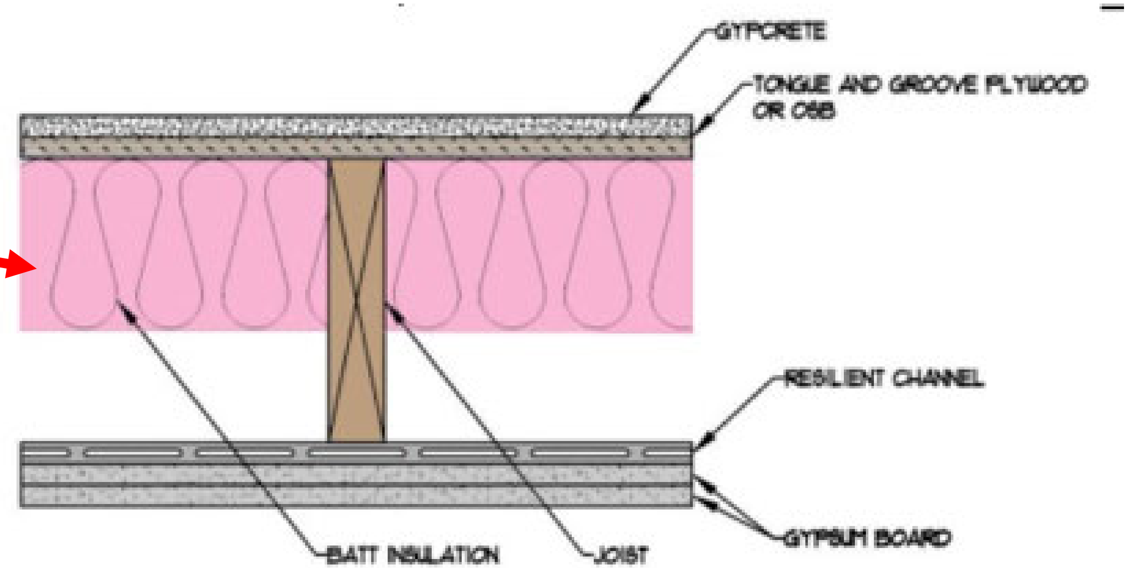


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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

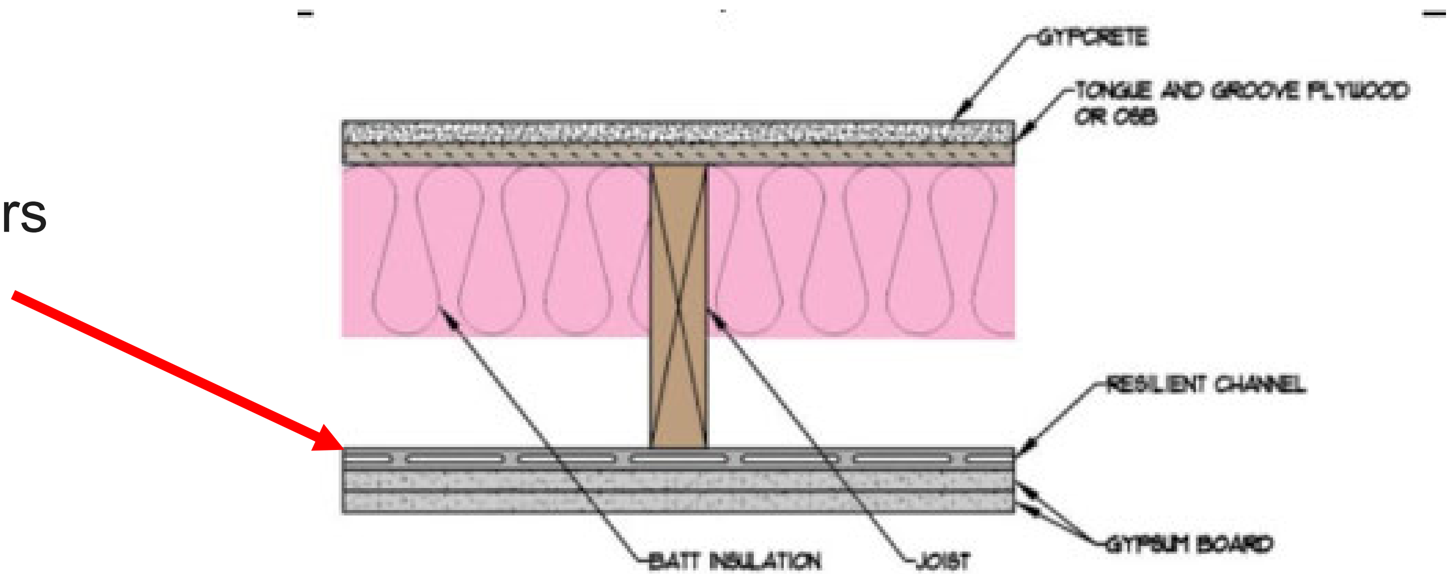


STC 62

Acoustics & Sound Control

What does this look like in typical wood-frame construction:

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

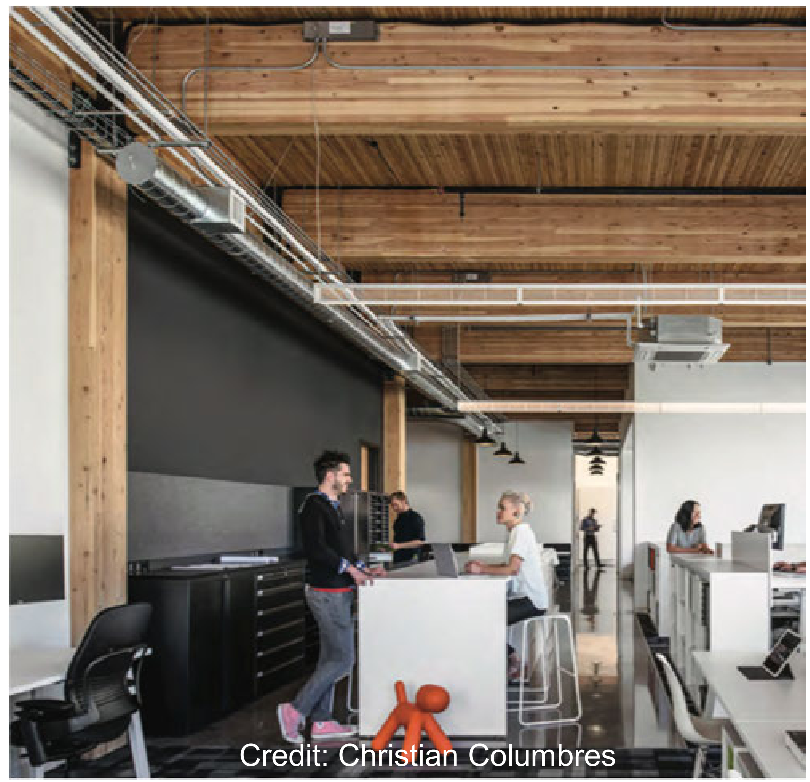


STC 62

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

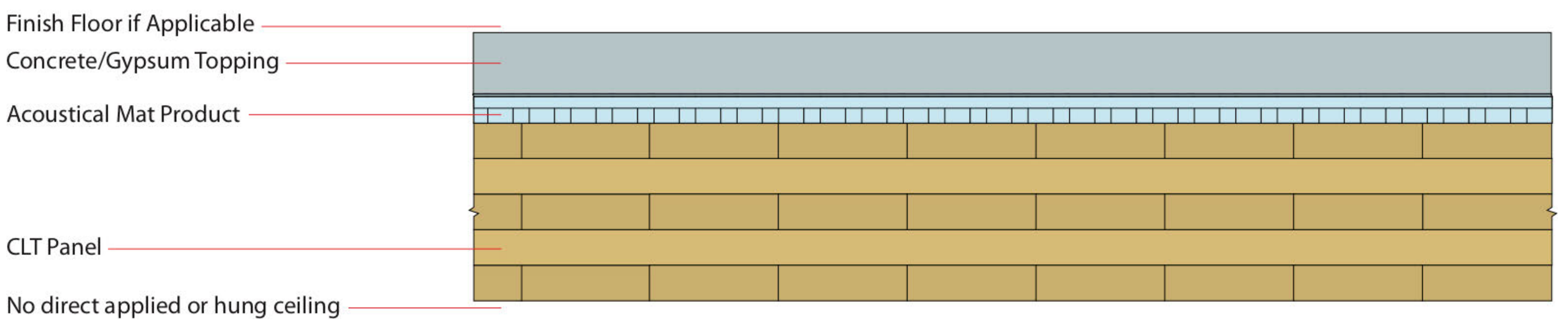
<u>Concrete Slab:</u>
6" Thick
80 PSF
STC 53

<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]

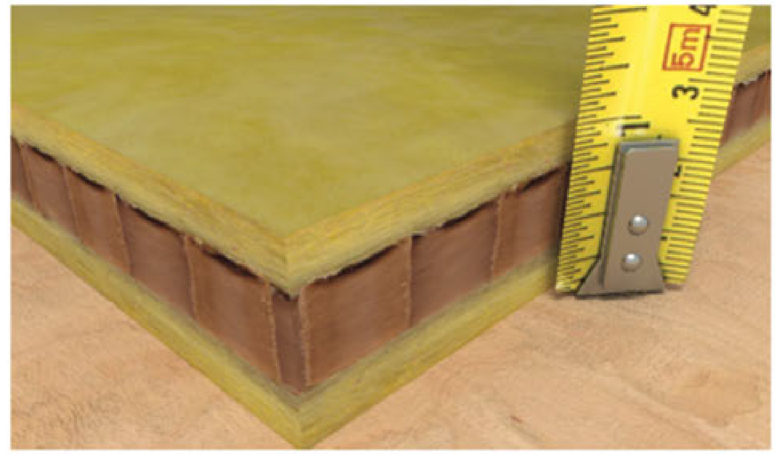


Photo: Kinetics Noise Control, Inc.,[11]

Photo: Maxxon Corporation

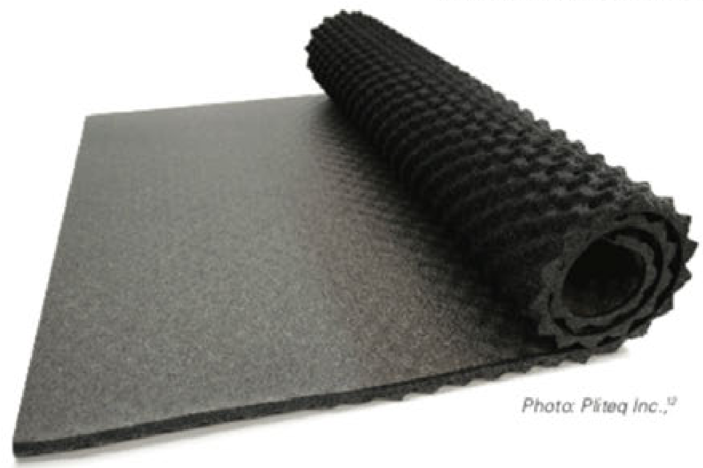


Photo: Pliteq Inc.,[12]

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

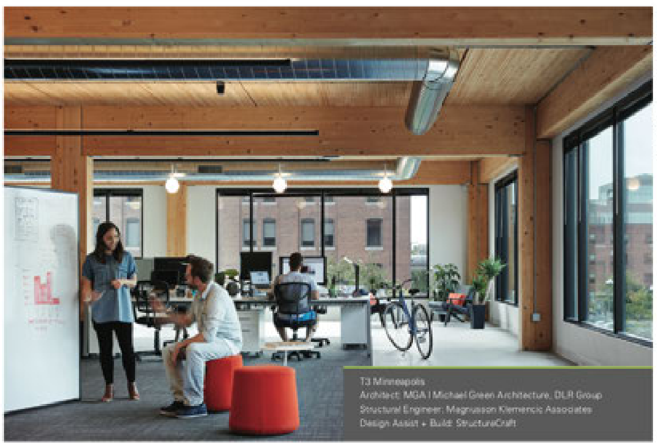
Acoustics & Sound Control

Solutions Paper

WoodWorks
WOOD PRODUCTS COUNCIL

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

Richard McLain, PE, SE • Senior Technical Director • WoodWorks



T3 Minneapolis
Architect: MGA | Michael Green Architecture, DLR Group
Structural Engineer: Magnusson Klemencic Associates
Design Assist + Build: StructureCraft

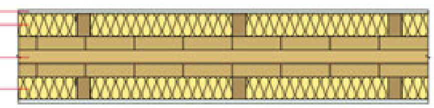
The growing availability and code acceptance of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction has given designers a low-carbon alternative to steel, concrete, and masonry for many applications. However, the use of mass timber in multi-family and commercial buildings presents unique acoustic challenges.

While laboratory measurements of the impact and airborne sound isolation of traditional building assemblies such as light wood-frame, steel and concrete are widely available, fewer resources exist that quantify the acoustic performance of mass timber assemblies. Additionally, one of the most desired aspects of mass timber construction is the ability to leave a building's structure exposed as finish, which creates the need for asymmetric assemblies. With careful design and detailing, mass timber buildings can meet the acoustic performance expectations of most building types.

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

FIGURE 3:
Interior CLT partition wall with chase walls on both sides

Example Mass Timber Wall Assembly, STC 58
Plan View



Source: US CLT Handbook

Mass Timber Assembly Options: Walls

Mass timber panels can also be used for interior and exterior walls—both bearing and non-bearing. For interior walls, the need to conceal services such as electrical and plumbing is an added consideration. Common approaches include building a chase wall in front of the mass timber wall or installing gypsum wallboard on resilient channels that are attached to the mass timber wall. As with bare mass timber floor panels, bare mass timber walls don't typically provide adequate noise control, and chase walls also function as acoustical improvements. For example, a 3-ply CLT wall panel with a thickness of 3.07" has an STC rating of 33.[4] In contrast, Figure 3 shows an interior CLT partition wall with chase walls on both sides. This assembly achieves an STC rating of 58, exceeding the IBC's acoustical requirements for multi-family construction. Other examples are included in the inventory of tested assemblies noted above.

Acoustical Differences between Mass Timber Panel Options

The majority of acoustically-tested mass timber assemblies include CLT. However, tests have also been done on other mass timber panel options such as NLT and dowel-laminated timber (DLT), as well as traditional heavy timber options such as tongue and groove decking. Most tests have concluded that CLT acoustical performance is slightly better than that of other mass timber options, largely because the cross-orientation of laminations in a CLT panel limits sound flanking.

For those interested in comparing similar assemblies and mass timber panel types and thicknesses, the inventory noted above contains tested assemblies using CLT, NLT, glued-laminated timber panels (GLT), and tongue and groove decking.

Improving Performance by Minimizing Flanking

Even when the assemblies in a building are carefully designed and installed for high acoustical performance, consideration of flanking paths—in areas such as assembly intersections, beam-to-column/wall connections, and MEP penetrations—is necessary for a building to meet overall acoustical performance objectives.

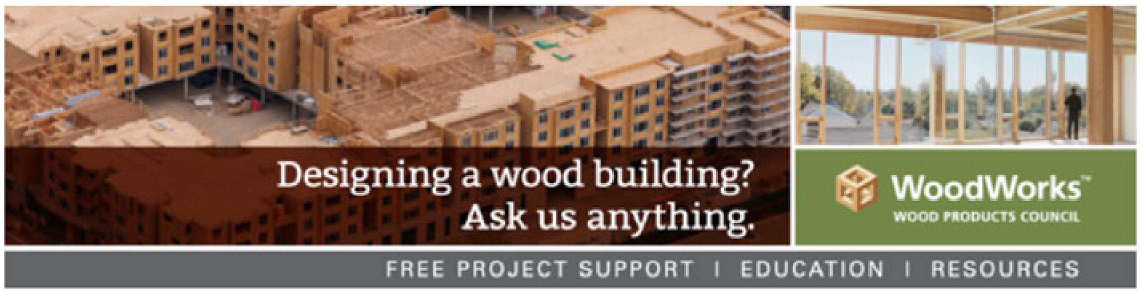
One way to minimize flanking paths at these connections and interfaces is to use resilient connection isolation and sealant strips. These products are capable of resisting structural loads in compression between structural members and connections while providing isolation and breaking hard, direct connections between members. In the context of the three methods for improving acoustical performance noted above, these strips act as decouplers. With airtight connections, interfaces and penetrations, there is a much greater chance that the acoustic performance of a mass timber building will meet expectations.

Acoustical isolation strips *Photos: Rothoblaas*

Acoustics & Sound Control

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:

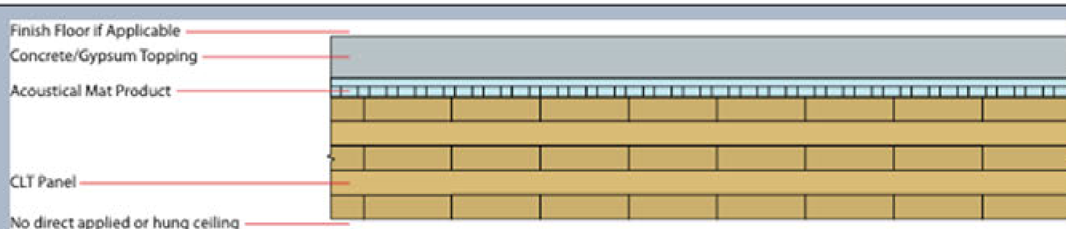
http://bit.ly/mass-timber-assemblies

Acoustics & Sound Control

Inventory of Tested Assemblies

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

WoodWorks WOOD PRODUCTS COUNCIL



CLT Panel	Concrete/Gypsum Topping	Acoustical Mat Product Between CLT and Topping	Finish Floor	STC[1]	IIC[1]	Source
CLT 5-ply (6.875″)	1-1/2″ Gyp-Crete®	Maxxon Acousti-Mat® 3/4	None	47[2] ASTC	47[2] AIIC	1
			LVT	-	49[2] AIIC	
			Carpet + Pad	-	75[2] AIIC	
			LVT on Acousti-Top®	-	52[2] AIIC	
			Eng Wood on Acousti-Top®	-	51[2] AIIC	
		Maxxon Acousti-Mat® ¾ Premium	None	49[2] ASTC	45[2] AIIC	
			LVT	-	47[2] AIIC	
			LVT on Acousti-Top®	-	49[2] AIIC	
	1-1/2″ Levelrock®	USG SAM N25 Ultra	None	45[6]	39[6]	15
			LVT	48[6]	47[6]	16
			LVT Plus	48[6]	49[6]	58
			Eng Wood	47[6]	47[6]	59
			Carpet + Pad	45[6]	67[6]	60
			Ceramic Tile	50[6]	46[6]	61
			None	45[6]	42[6]	15
			LVT	48[6]	44[6]	16

Reduce Risk

Optimize Costs

- For the entire project team, not just builders
- Lots of reference documents

Download Checklists at

www.woodworks.org

www.woodworks.org/wp-content/uploads/wood_solution_paper-Mass-Timber-Design-Cost-Optimization-Checklists.pdf

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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 – Hillsboro, OR
ARCHITECT: Hacker
ENGINEERS: Kramer Gehlen & Associates, Equilibrium Consulting
CONTRACTOR: Swinerton

Keys to Mass Timber Success:

Know Your WHY
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 us anything.

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

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