



Early Design Decisions: Priming Mass Timber Projects for Success

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WoodWorks – Wood Products Council

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



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 meeting 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.

Glue Laminated Timber (Glulam)
Beams & columns



Cross-Laminated Timber (CLT)
Solid sawn laminations



Cross-Laminated Timber (CLT)
SCL laminations



Photo: Freres Lumber



Photo: StructureCraft



Photo: LendLease



Photo: LEVER Architecture

Dowel-Laminated Timber (DLT)



Photo: StructureCraft

Nail-Laminated Timber (NLT)



Photo: Think Wood

Glue-Laminated Timber (GLT)
Plank orientation



Photo: StructureCraft



Photo: StructureCraft



Photo: Ema Peter



Photo: Manasc Isaac
Architects/Fast + Epp

Key Early Design Decisions

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

**Construction Type
Fire-Resistance Ratings
Member Sizes
Grids & Spans
Exposed Timber (where & how much)**

**MEP Layout
Acoustics
Concealed Spaces
Connections
Penetrations**

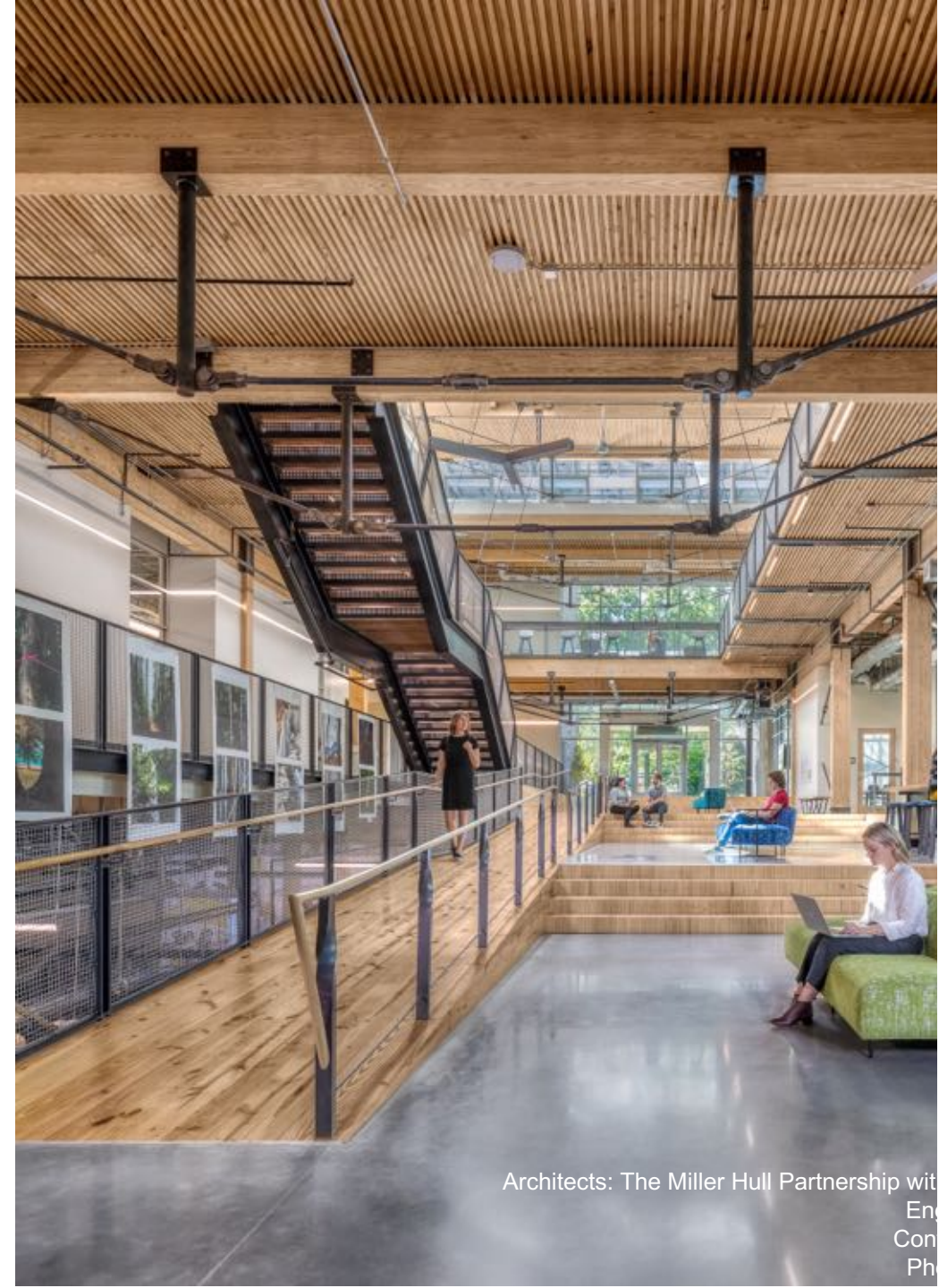
The Answer is...They All Need to Be Weighed (Plus Others)

Key Early Design Decisions

One *potential* design route:

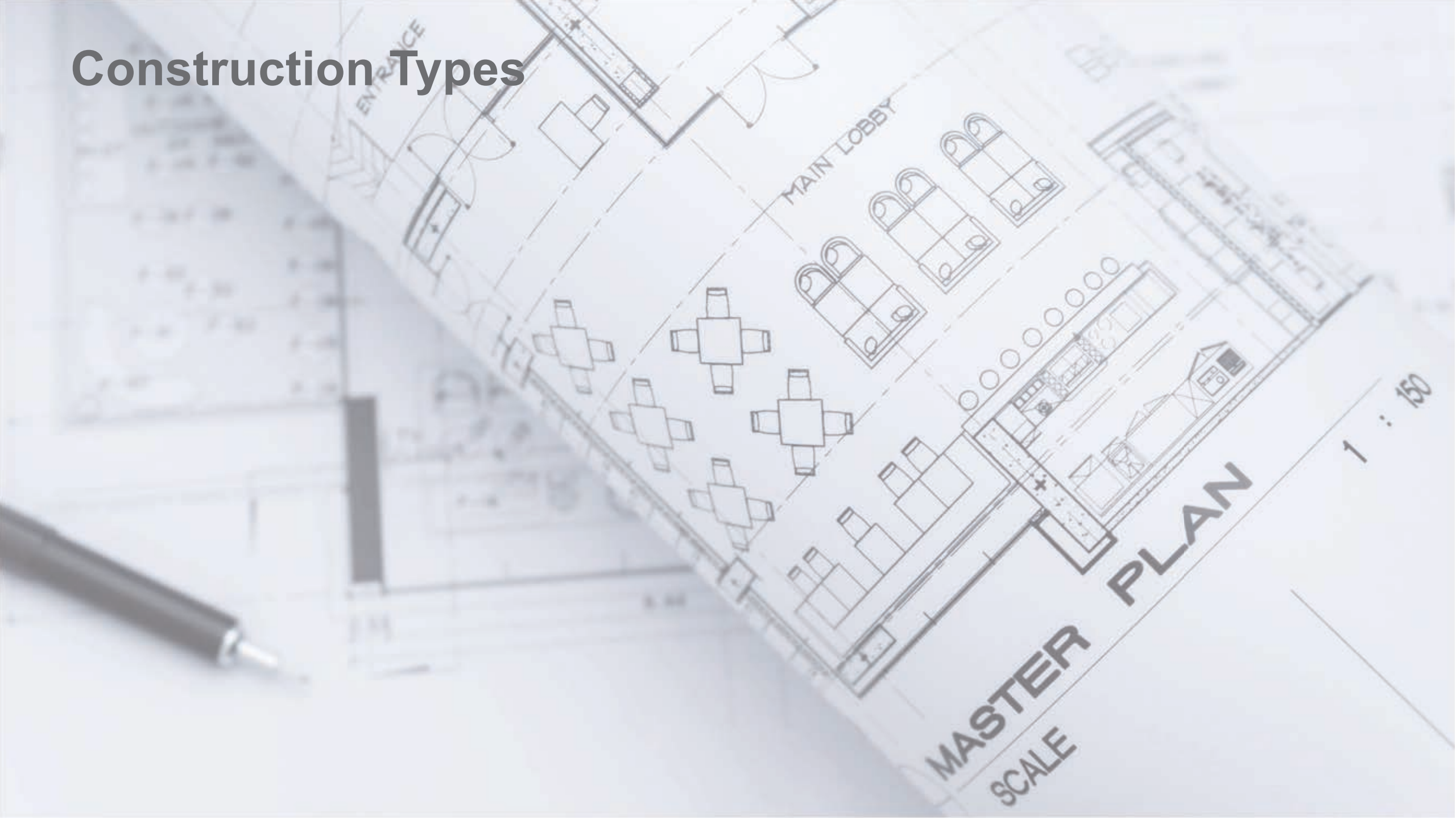
1. Building size & occupancy informs construction type & grid
2. Construction type informs fire resistance ratings
3. Grid & fire resistance ratings inform timber member sizes & MEP layout

But that's not all...



Architects: The Miller Hull Partnership with
Eng
Con
Ph

Construction Types



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
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.								
R-2	18	12	8	5	5	5	4	3
	Allowable Area Factor (At) for SM, Feet ² (IBC Table 506.2)							
A-2, A-3, A-4	135,000	90,000	56,250	45,000	42,000	28,500	34,500	18,000
B	324,000	216,000	135,000	108,000	85,500	57,000	54,000	27,000
R-2	184,500	123,000	76,875	61,500	72,000	48,000	36,000	21,000

Key Early Design Decisions

Fire-Resistance Ratings

- Driven primarily by construction type
- Rating achieved through timber alone or non-com protection required?

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

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame ^f (see Section 202)	3 ^{a, b}	2 ^{a, b, c}	1 ^{b, c}	0 ^c	1 ^{b, c}	0	3 ^a	2 ^a	2 ^a	HT	1 ^{b, c}	0
Bearing walls												
Exterior ^{a, f}	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3 ^a	2 ^a	1	0	1	0	3	2	2	1/HT ^g	1	0
Nonbearing walls and partitions Exterior					See Table 705.5							
Nonbearing walls and partitions Interior ^d	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1½ ^b	1 ^{b, c}	1 ^{b, c}	0 ^c	1 ^{b, c}	0	1½ ^b	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

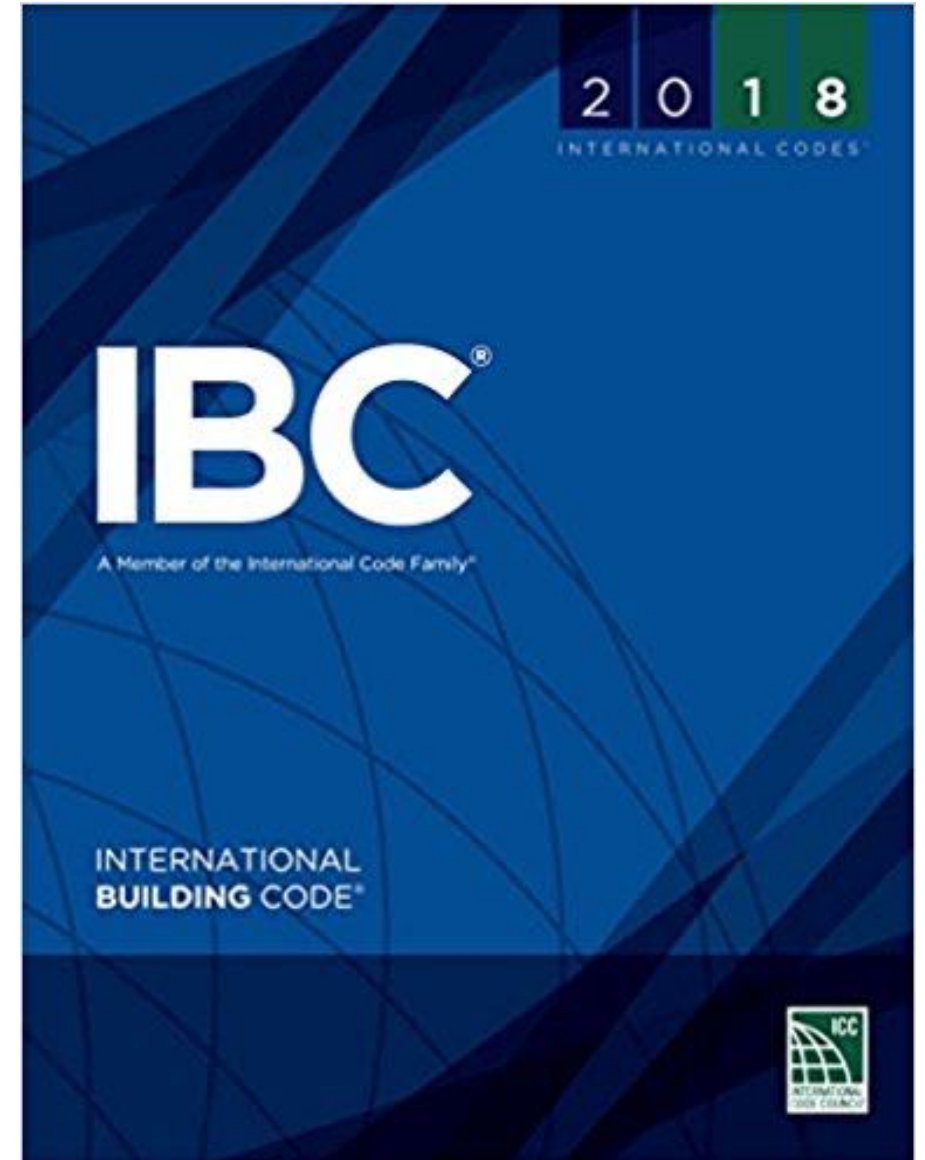


Construction Types

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

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)

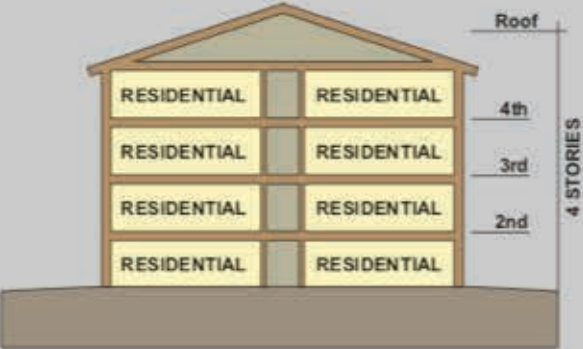
Type IV (Heavy Timber)

Exterior walls non-combustible (may be FRTW OR CLT)

Interior elements qualify as Heavy Timber (min. sizes, no concealed spaces except in 2021 IBC)

Mass Timber Construction Types

IBC Table 503: Base Height



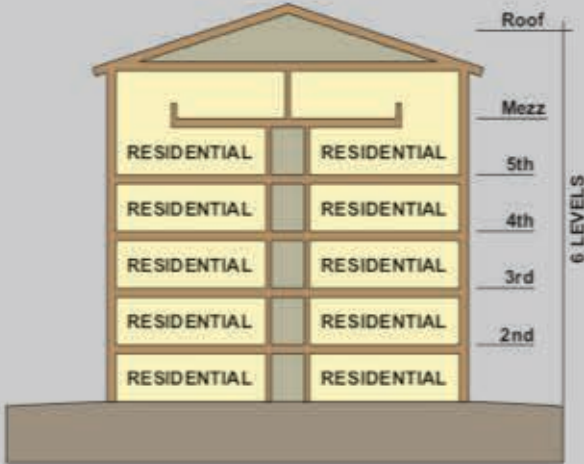
Type V
4 Stories

IBC Section 504: NFPA 13-Compliant Sprinkler System



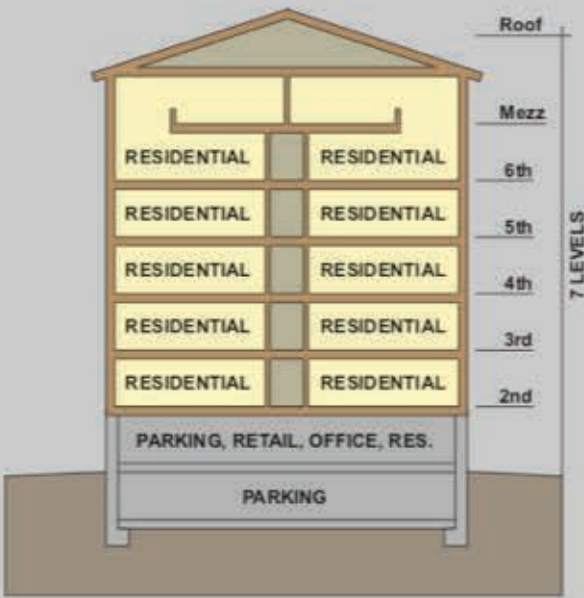
Type III & IV-HT
5 Stories

IBC Section 505: Mezzanine



Type III & IV-HT
5 Stories +
Mezz.

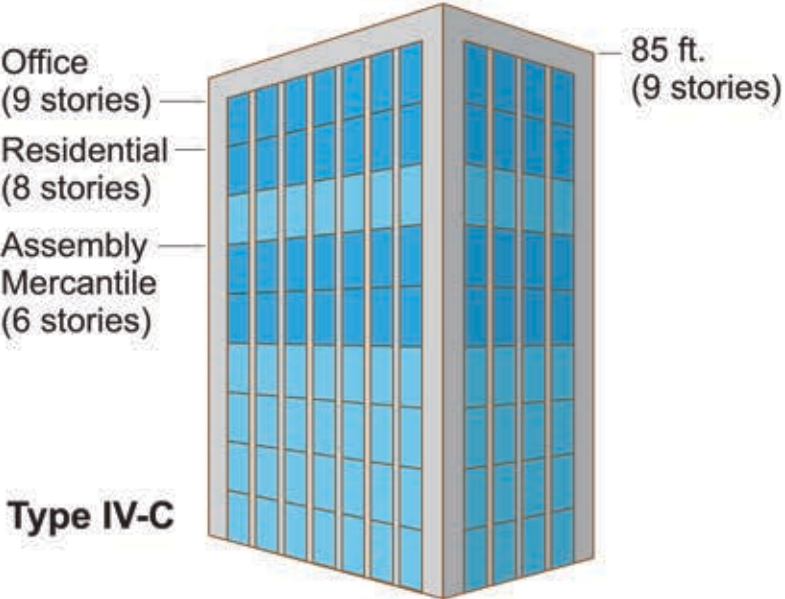
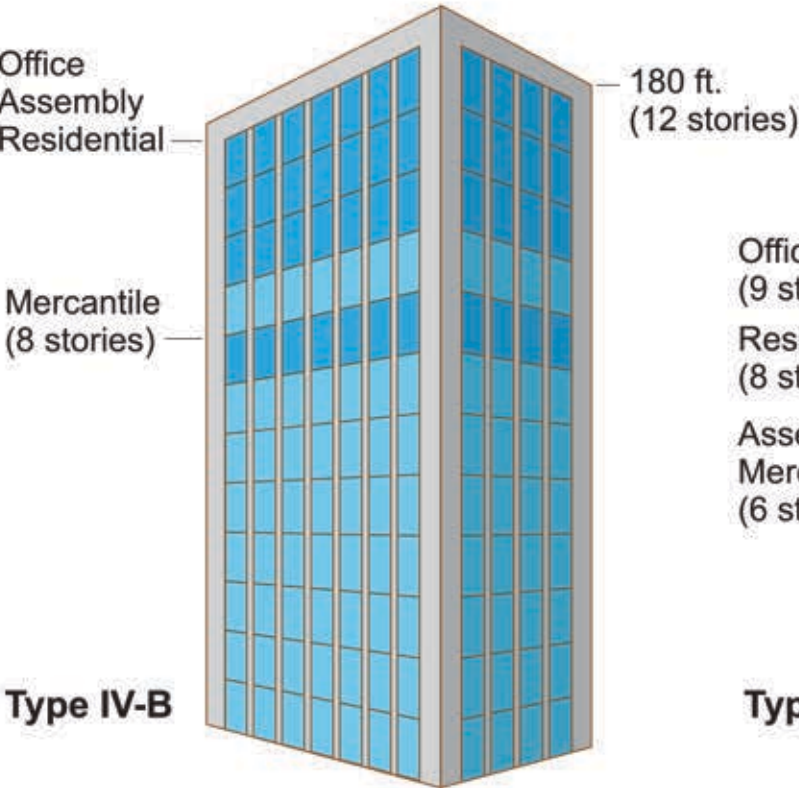
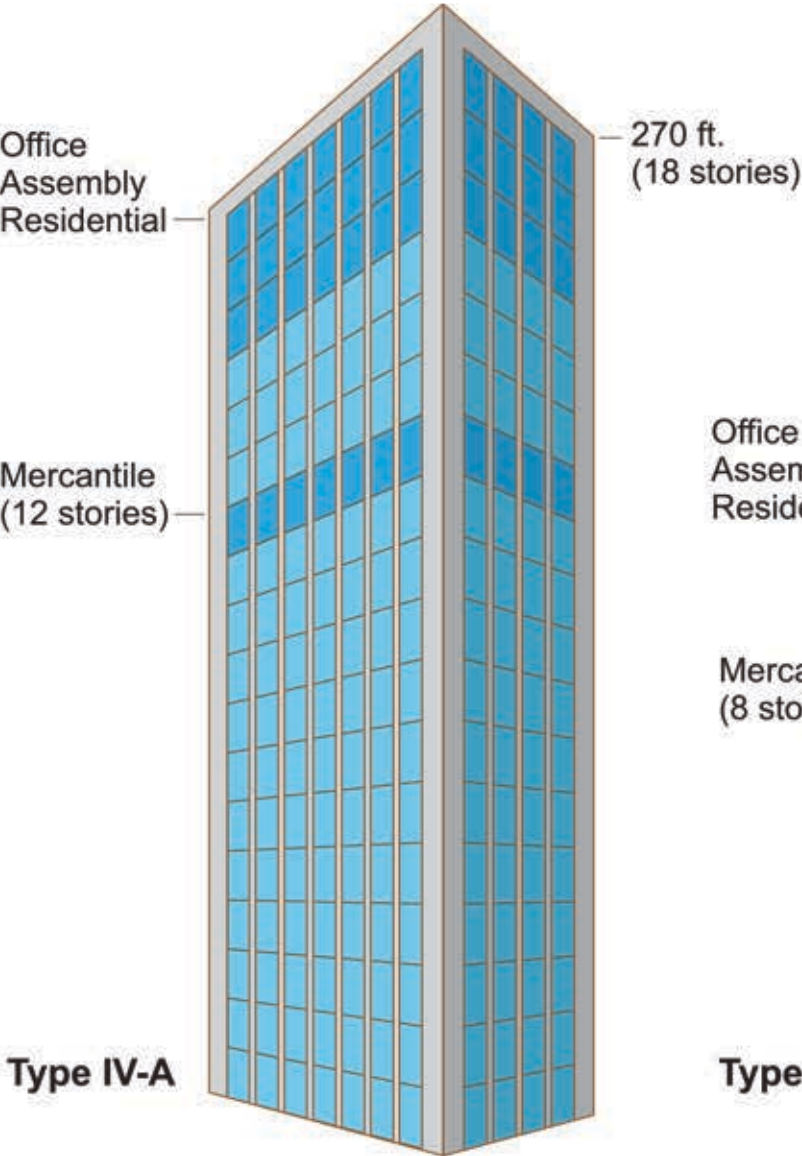
IBC Section 510.2: Podium



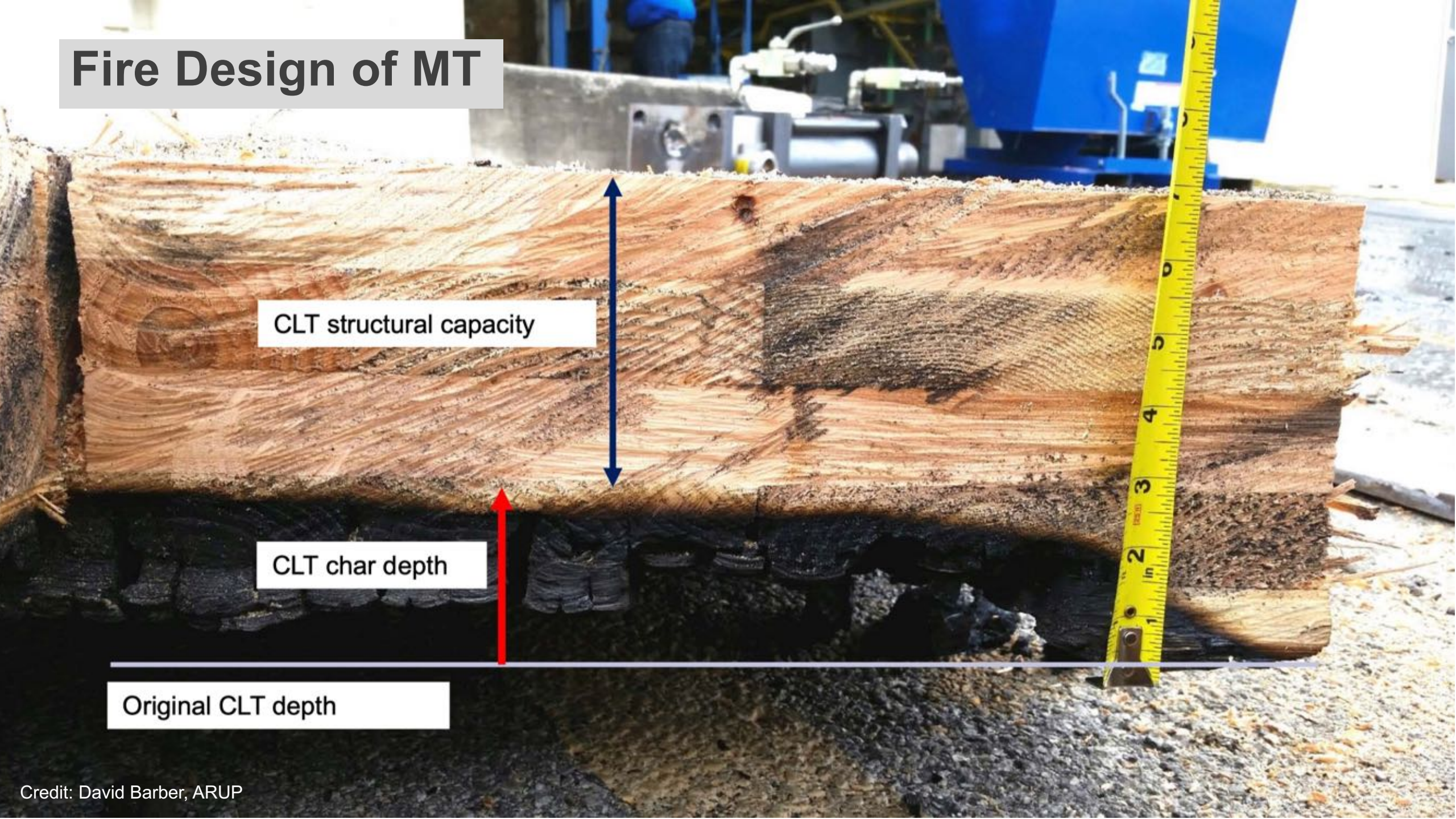
Type III & IV-HT
5 Stories +
Mezz. + Podium

Construction Types

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



Fire Design of MT



CLT structural capacity

CLT char depth

Original CLT depth

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

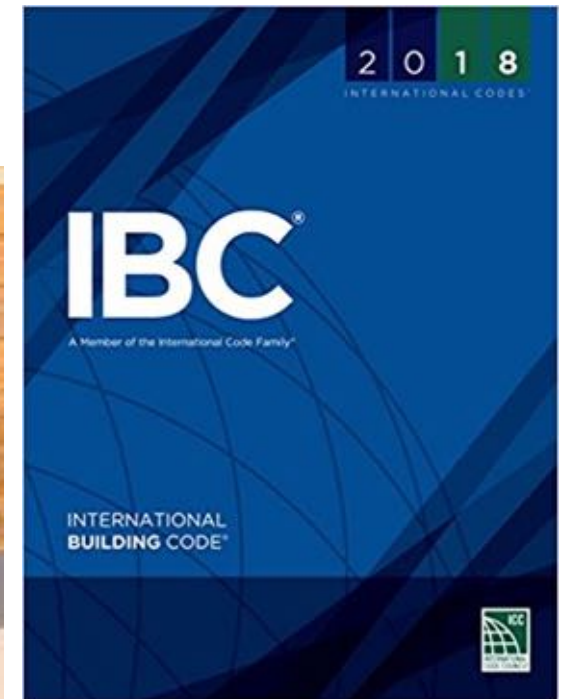
Source: 2021 IBC

Key Early Design Decisions

Construction type influences FRR

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

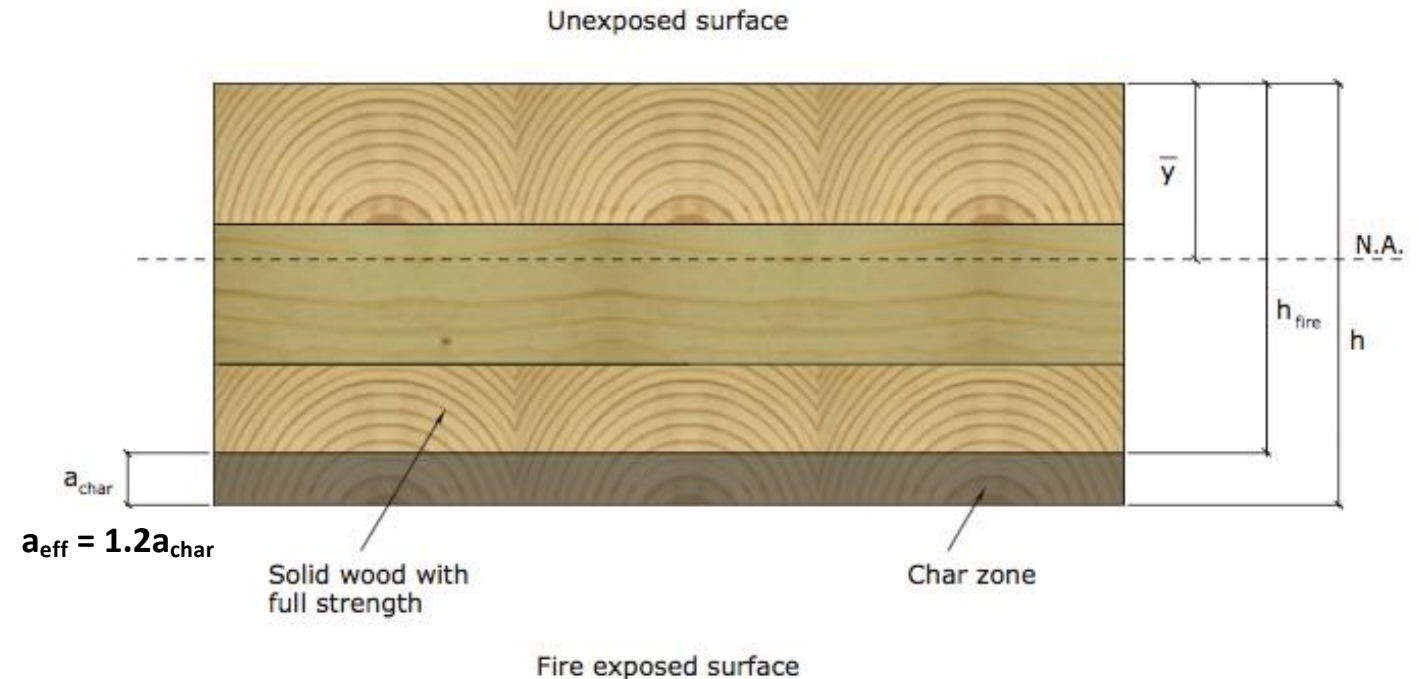
Method of demonstrating FRR (calculations or testing)
can impact member sizing



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



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)**

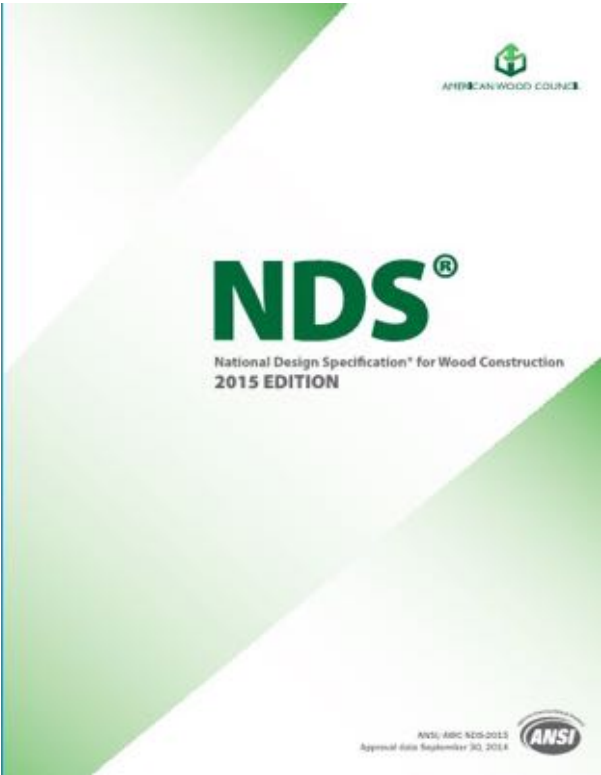


NDS Chapter 16

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 $\beta_n=1.5\text{in./hr.}$)

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

Nominal char rate of 1.5"/HR is recognized in NDS. Effective char depth calculated to account for duration, structural reduction in heat-affected zone



Credit: ARUP

Table 16.2.1A Char Depth and Effective Char Depth (for $\beta_n = 1.5 \text{ in./hr.}$)

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



Table 16.2.1B Effective Char Depths (for CLT with $\beta_n=1.5\text{in./hr.}$)

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:


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


 **Fire Testing Laboratory** 

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. Rizko
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 specimens. 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.

Intertek

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


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

TEST REPORT

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 Materials, and CANULC S104, Standard Methods of Fire

FPInnovations 
NRC-CNRC

Preliminary CLT Fire Resistance Testing Report

Project No. 301006155
Final Report 2012/13

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



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 1.5 EMSR 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	EI	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	EI	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fibrous lath	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	EI	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	EI	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
5-ply CLT (175mm 6.875")	Nordic	EI	1 layer 5/8" Type X Gyp under Resilient Channel under 7 7/8" J-Joints with 3 1/2" Mineral Wool between Joins	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	EI MS MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Grete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	VI	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	VI	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	VI	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 (175mm 6.875")	KLH	CV3M1	None	Half-Lap & Topside Spline	None	Loaded, See Manufacturer	1	18	SwRI 11/10/2016

FRR Design of MT



Fire-Resistive Design of Mass Timber Members

Code Applications, Construction Types and Fire Ratings

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

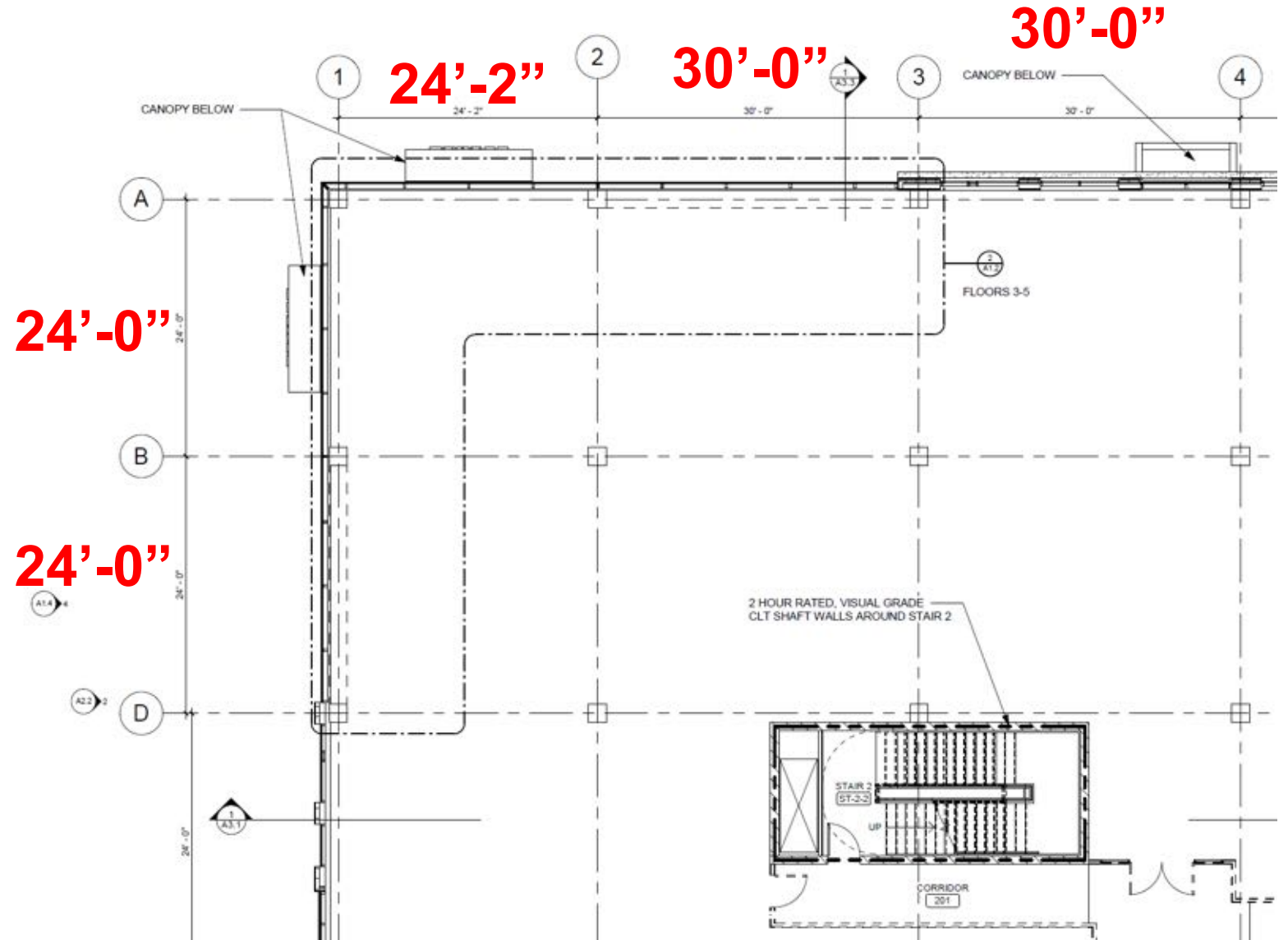
Structural Grid



Structural Grid

Grids & Spans

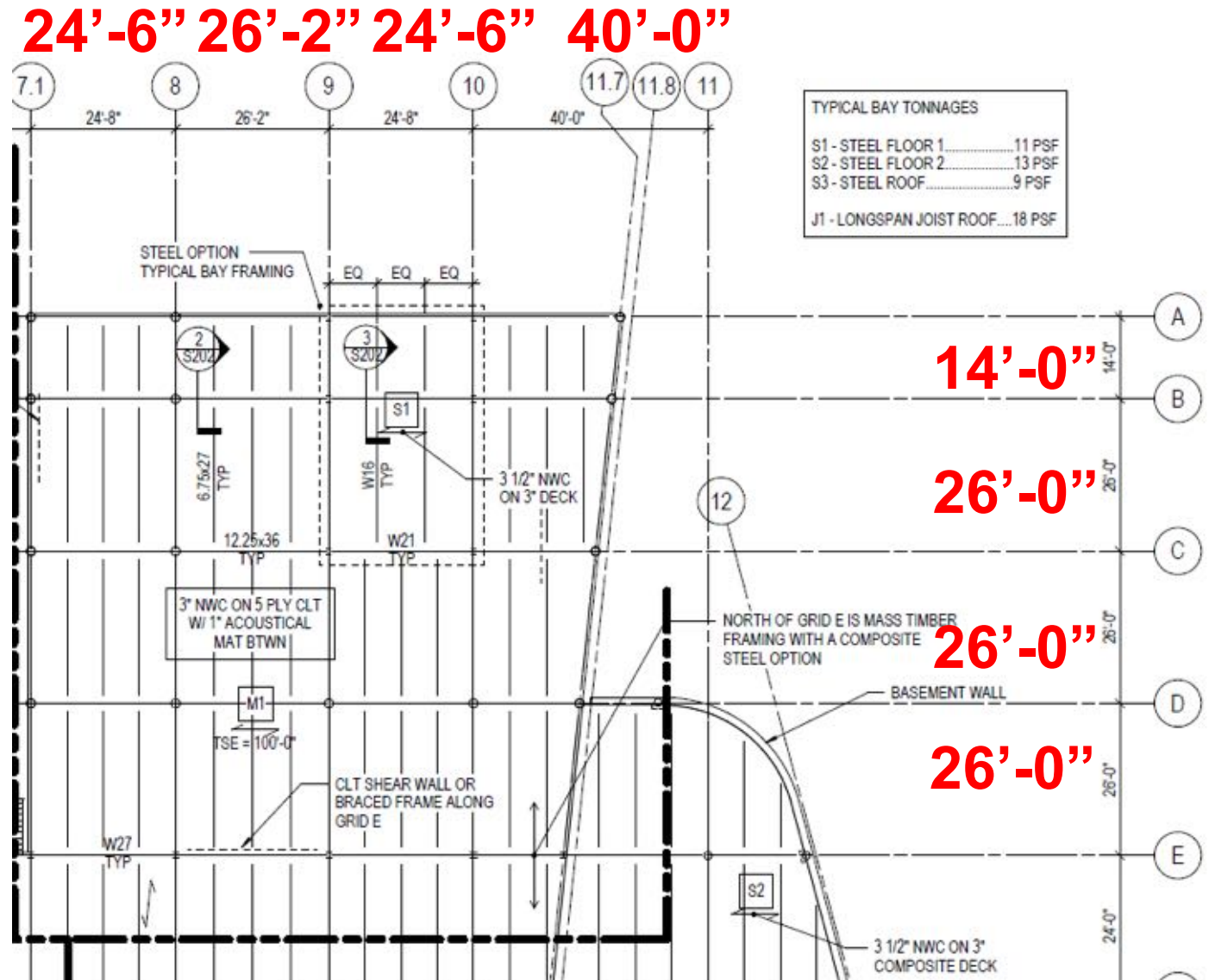
- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation



Structural Grid

Grids & Spans

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



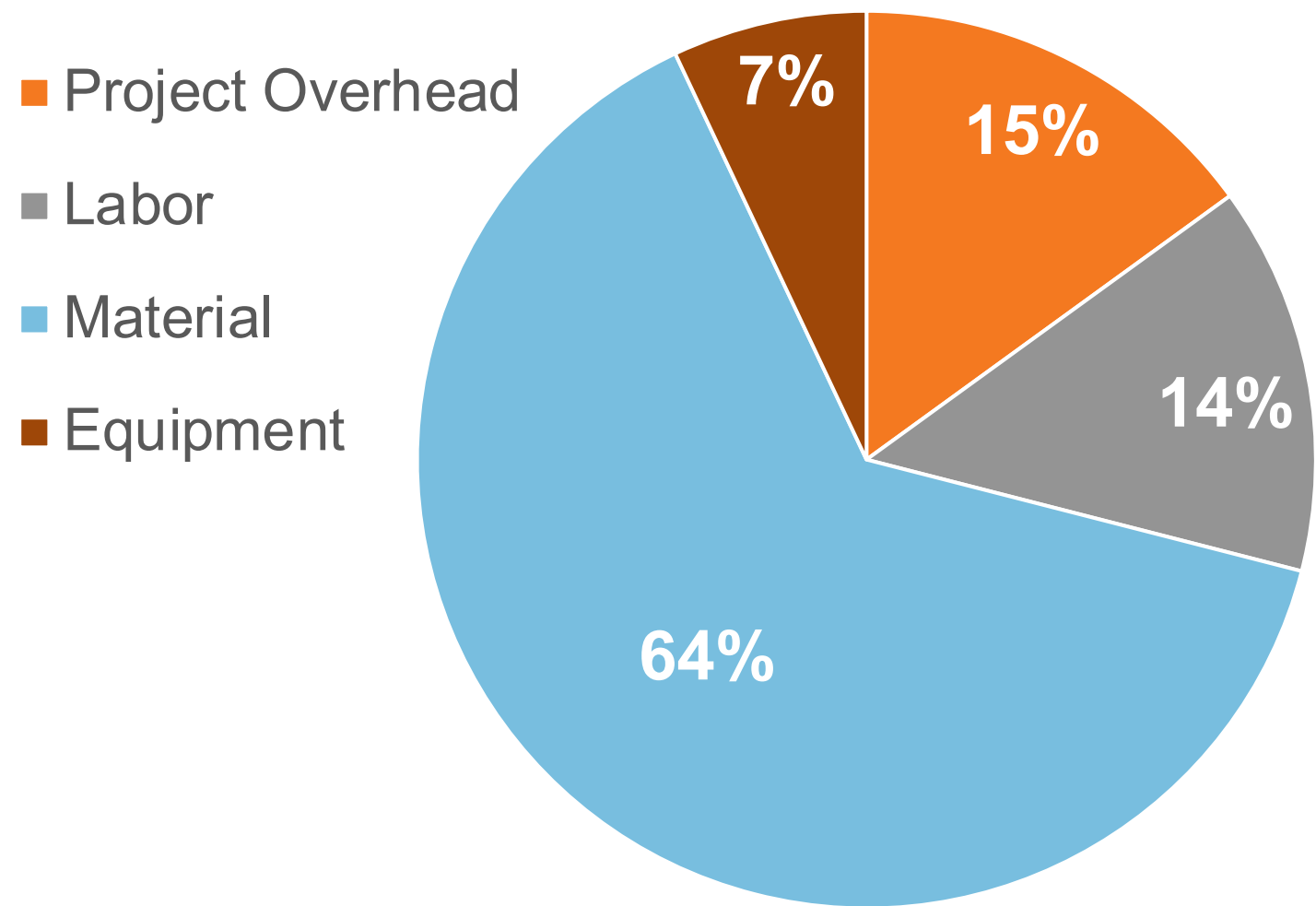
Key Early Design Decisions

Why so much focus on panel thickness?

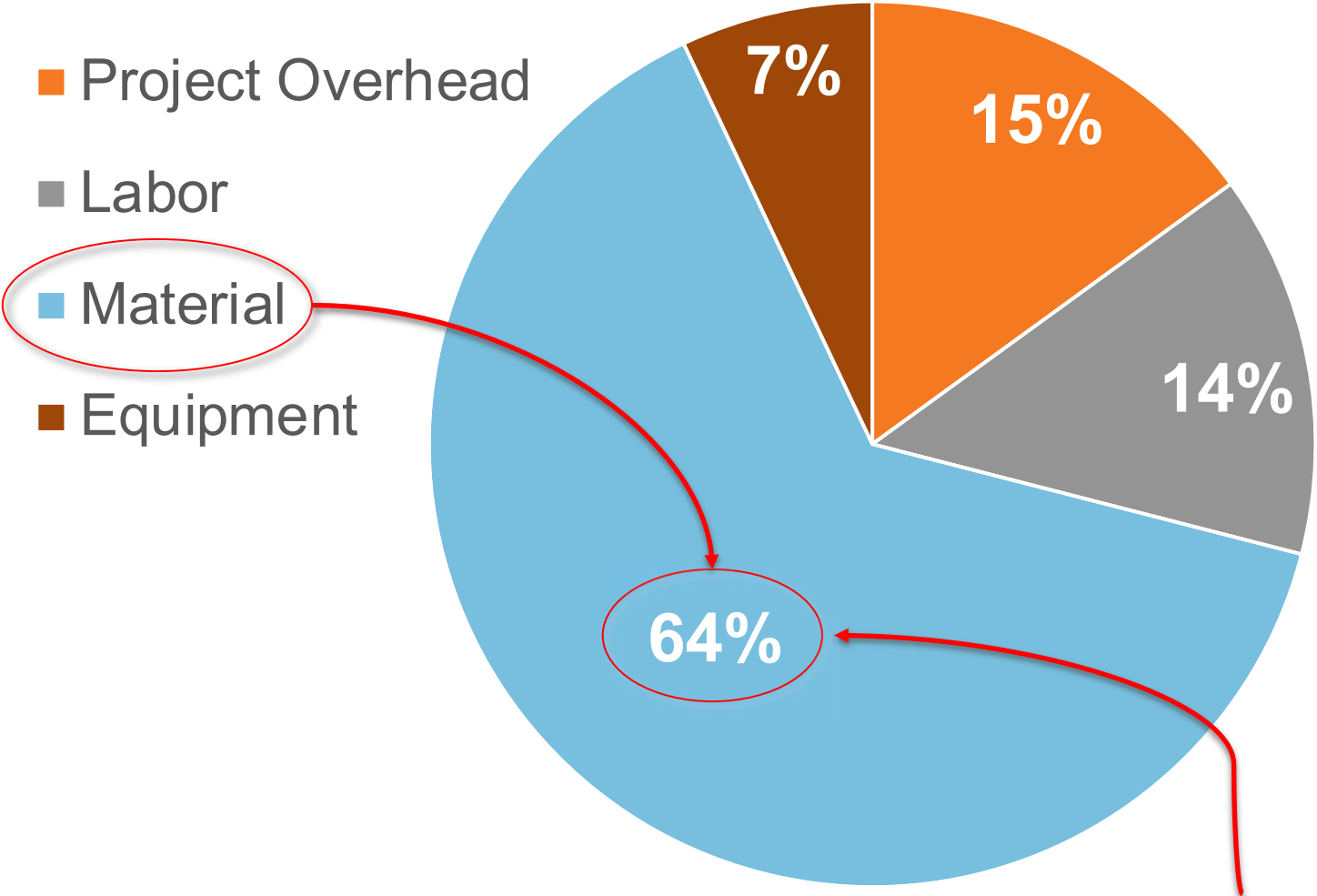


Key Early Design Decisions

Typical MT Package Costs



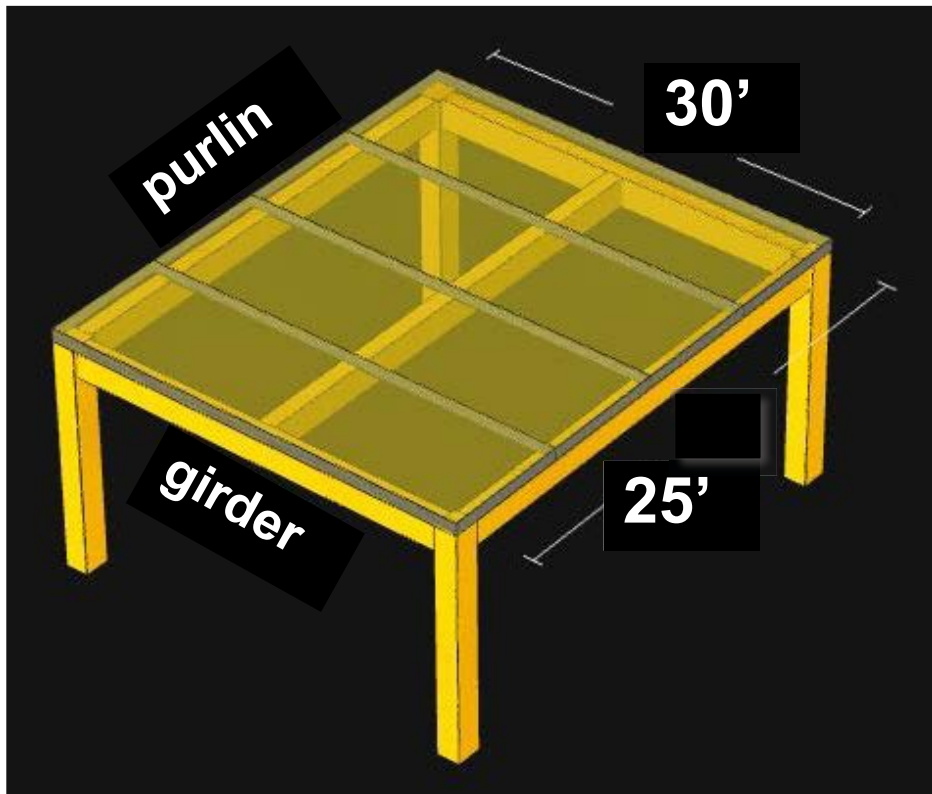
Key Early Design Decisions



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

Key Early Design Decisions

Panel volume usually 65-80% of MT package volume



Type IIIA option 1

1-hr FRR

Purlin: 5.5"x28.5"

Girder: 8.75"x33"

Column: 10.5"x10.75"

Floor panel: 5-ply

Glulam volume = 118 CF (22% of MT)

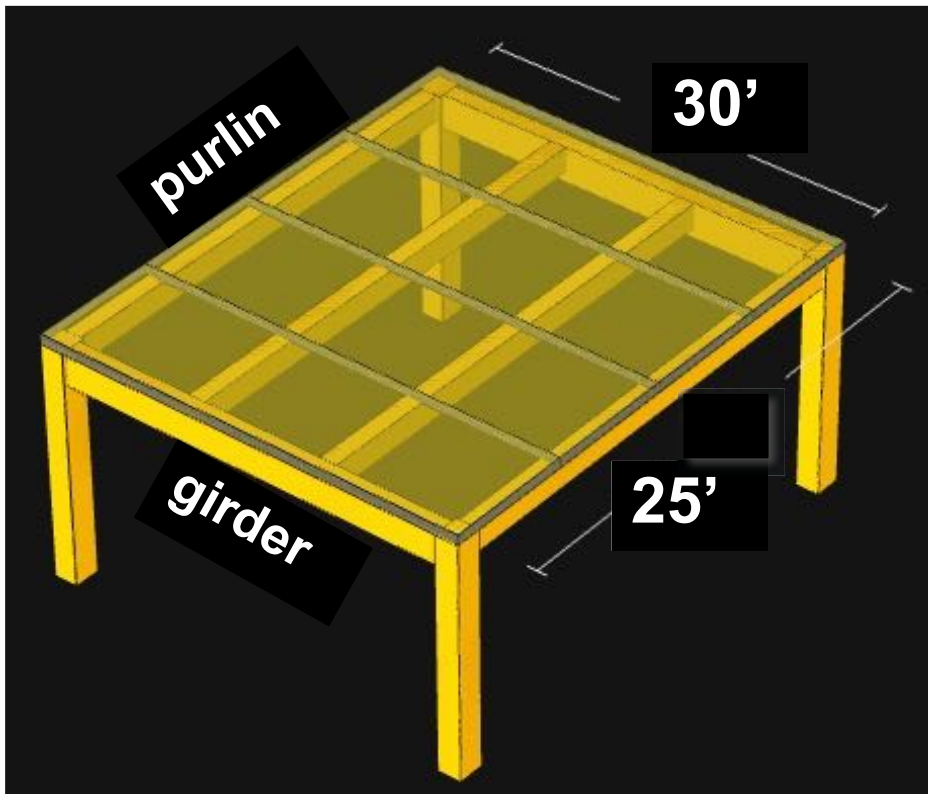
CLT volume = 430 CF (78% of MT)

Total volume = 0.73 CF / SF

Source: Fast + Epp, Timber Bay Design Tool

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)

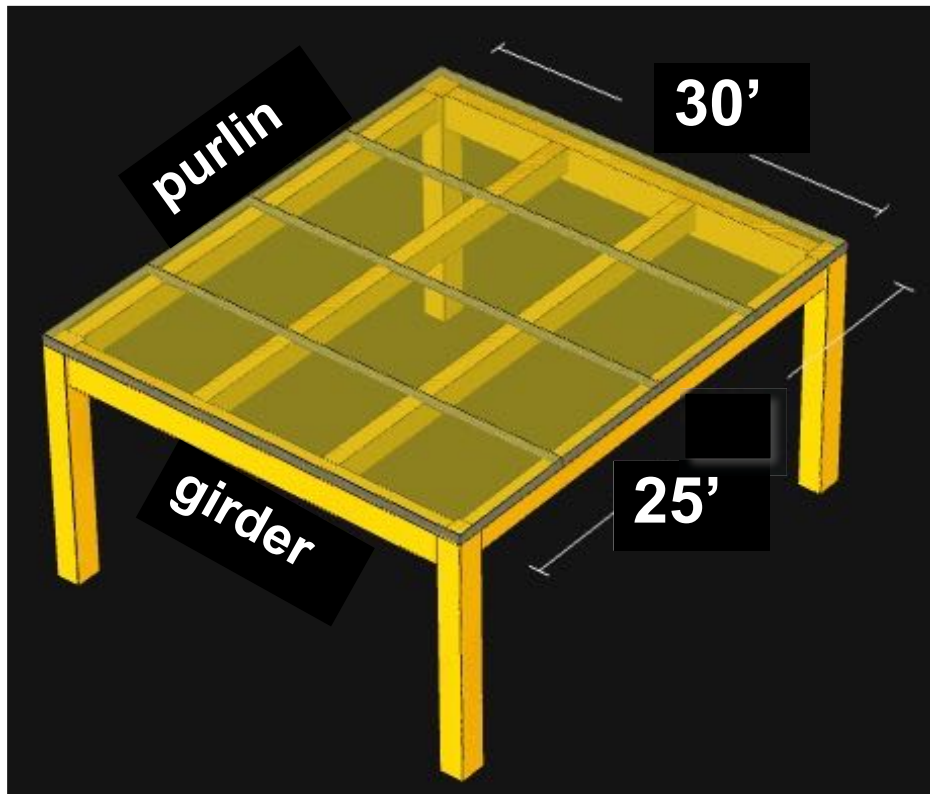
CLT volume = 430 CF (78% of MT)

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)

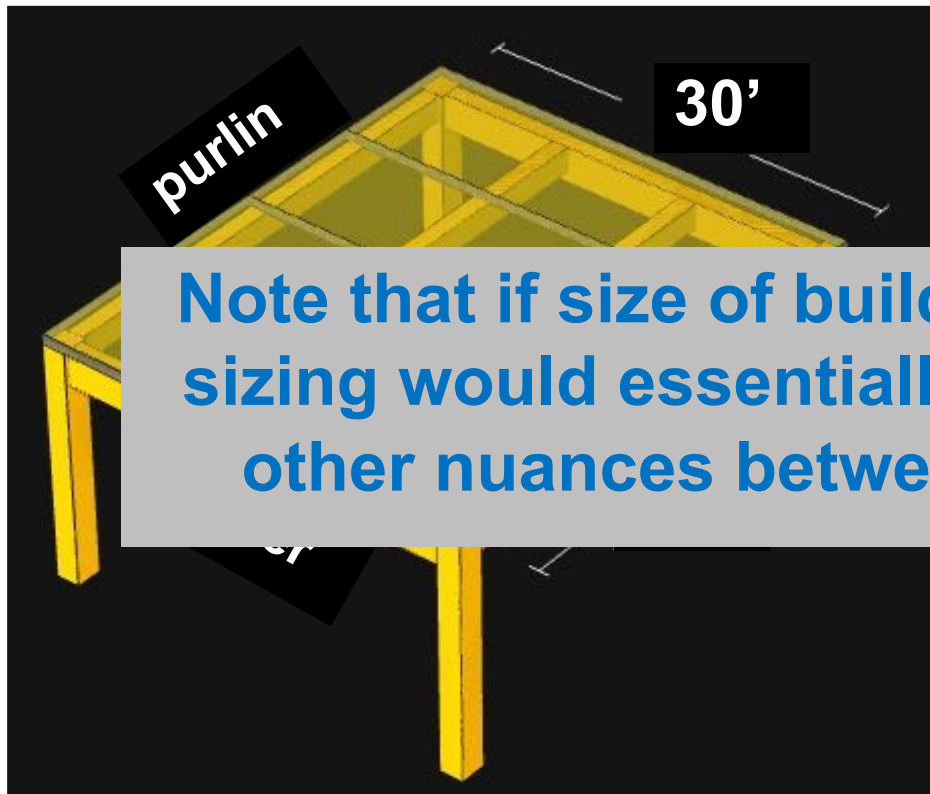
Glulam volume = 120 CF (32% of MT)

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



Type IV-HT

0-hr FRR (min sizes per IBC)

Purlin: 5.5"x24" (IBC min = 5"x10.5")

Note that if size of building had permitted Type IIIB, member sizing would essentially be the same as IV-HT. But there are other nuances between III and IV, we'll cover that later... (25")

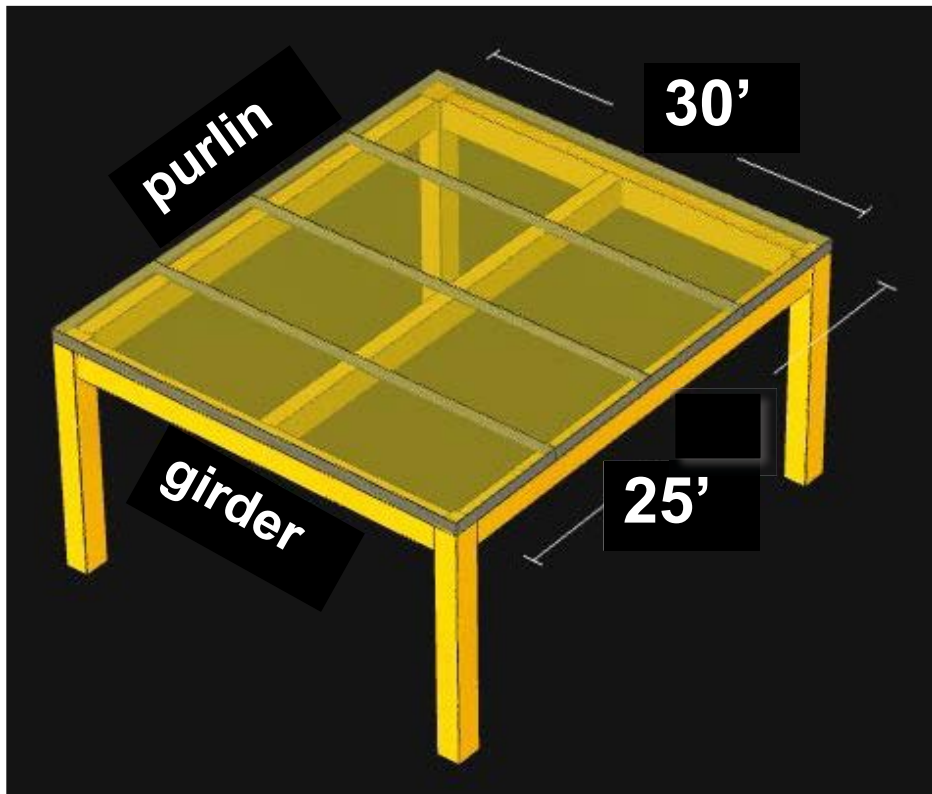
Glulam volume = 120 CF (32% of MT)

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



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)

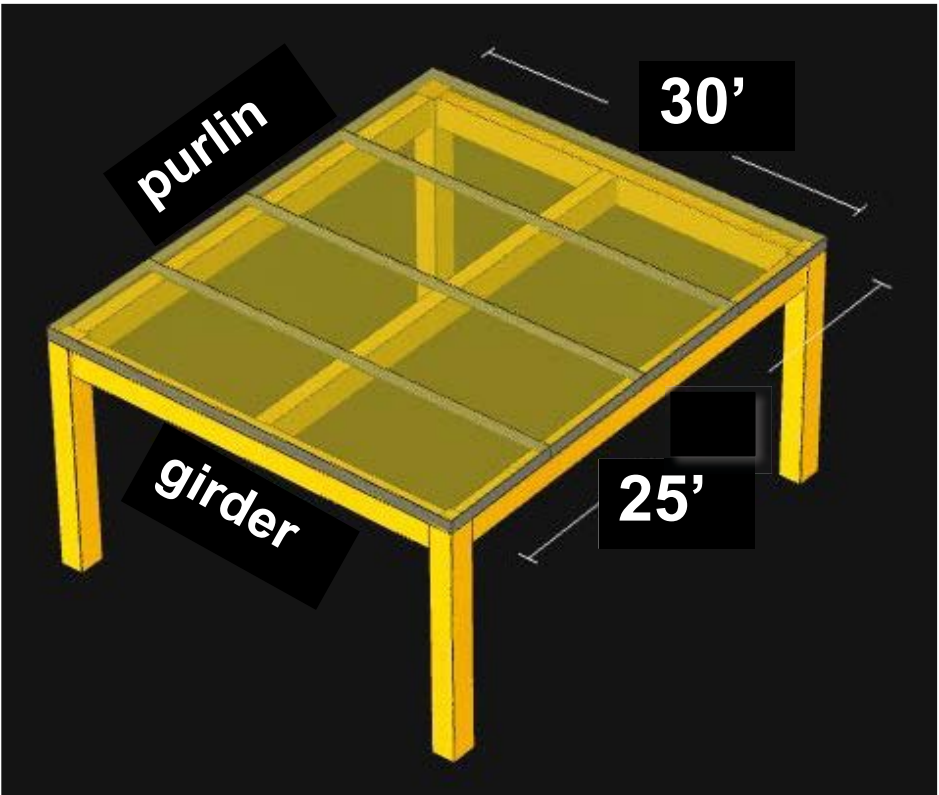
CLT volume = 430 CF (70% of MT)

Total volume = 0.82 CF / SF

Source: Fast + Epp, Timber Bay Design Tool

Key Early Design Decisions

Which is the most efficient option?



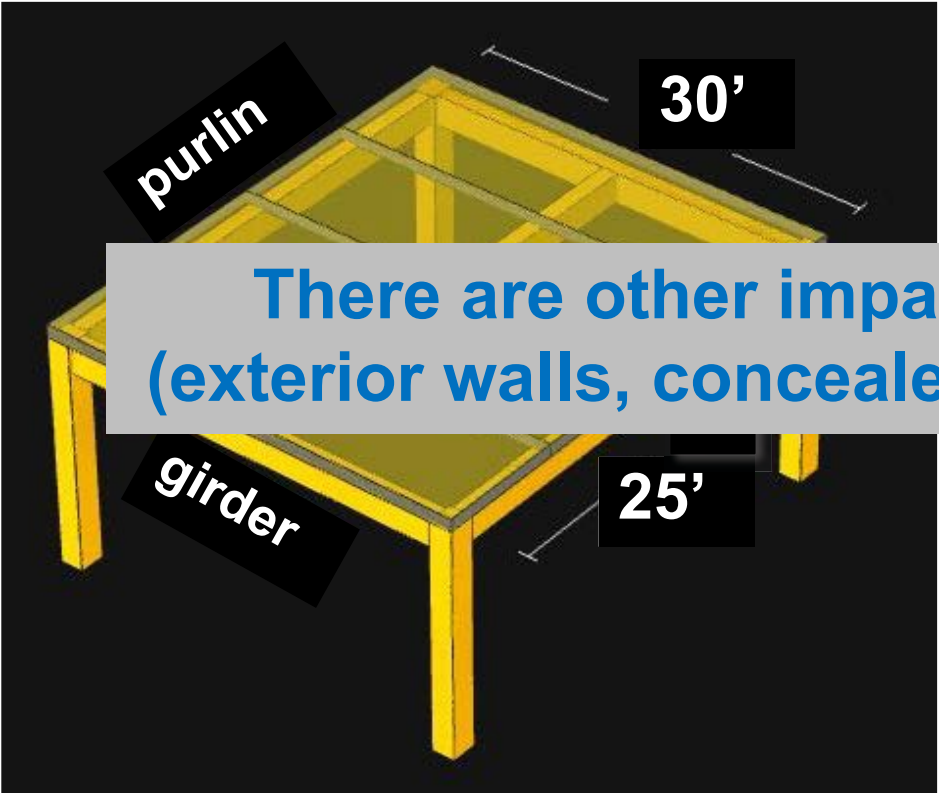
Source: Fast + Epp, Timber Bay Design Tool

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

There are other impacts of construction 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

Lateral System Choices & Impacts



Lateral System Choices

Concrete Shearwalls

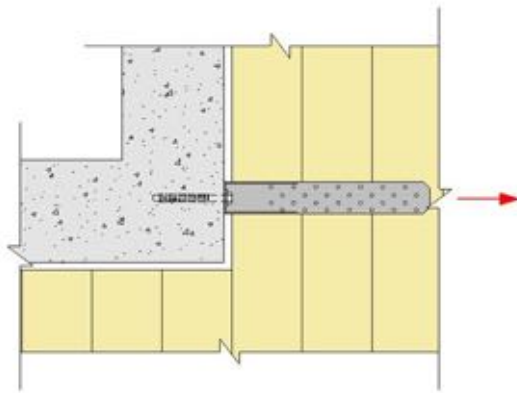
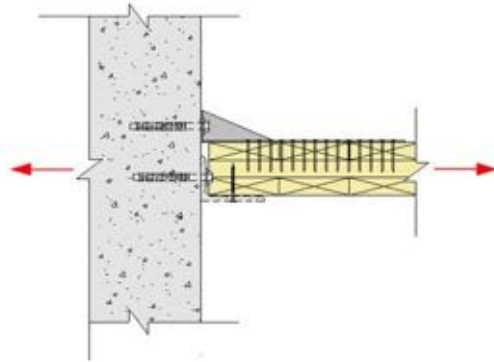


Credit: Hacker Architects

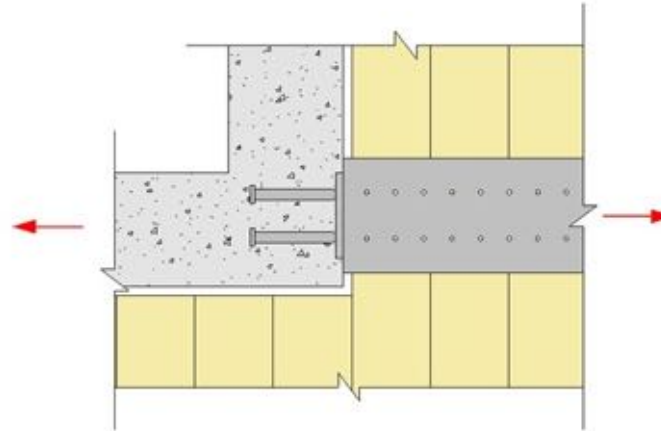
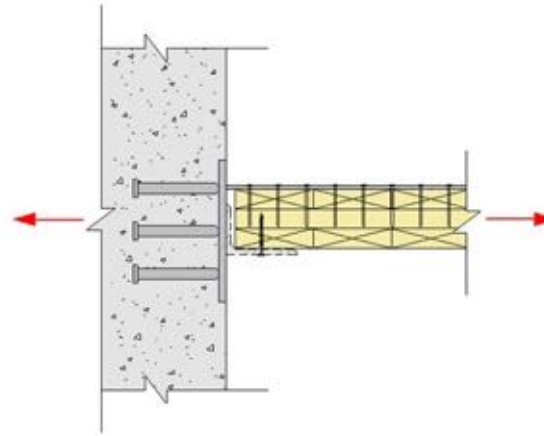
Lateral System Choices

Connections to concrete core

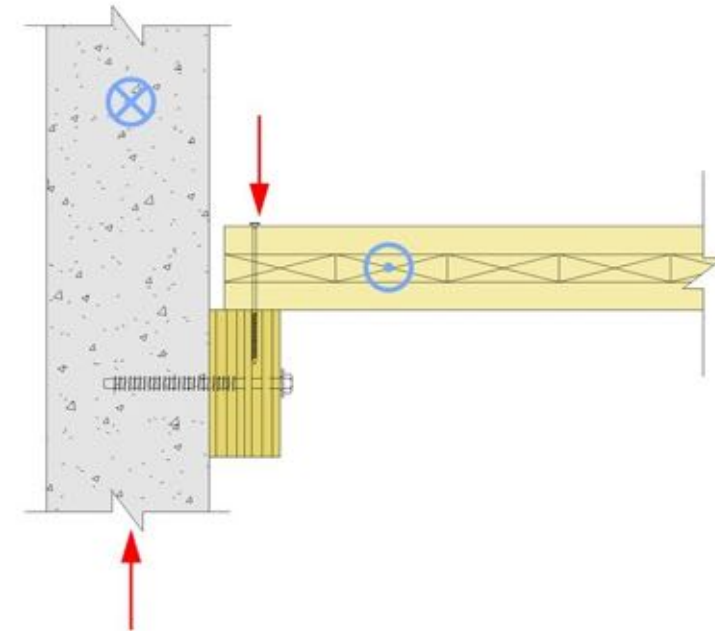
- Tolerances & adjustability
- Drag/collector forces



PLAN VIEW



PLAN VIEW



Lateral System Choices

Steel Braced Frame

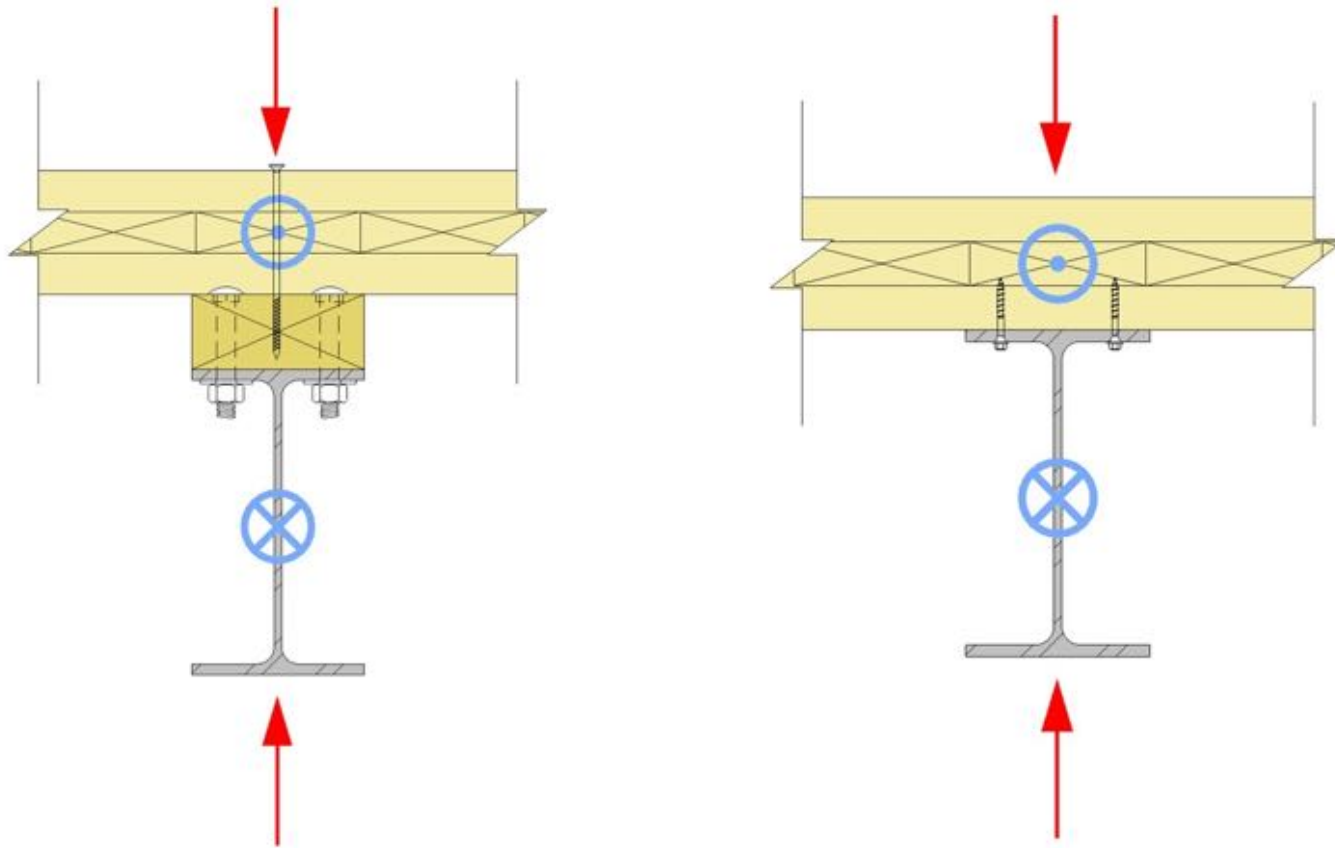


Photos: Marcus Kauffmann, ODF

Lateral System Choices

Connections to steel frame

- Tolerances & adjustability
- Consider temperature fluctuations
- Ease of installation



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)



Lateral System Choices

MT Shearwalls



Photo: Alex Schreyer



Lateral System Choices

Timber Braced Frame



Credit: Alex Schreyer

Lateral System Choices

Prescriptive Code Compliance

Concrete Shearwalls

Steel Braced Frames

Light Wood-Frame Shearwalls

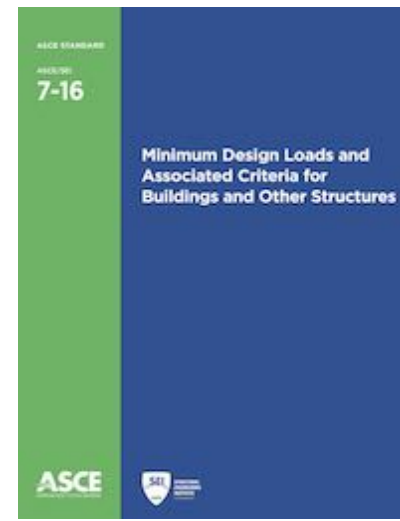
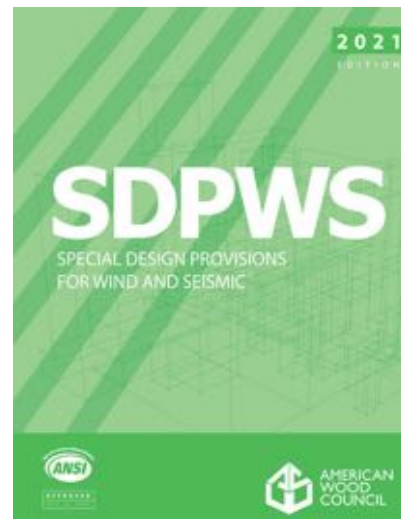
CLT Shearwalls

CLT Rocking Walls

Timber Braced Frames



**2021 SDPWS
ASCE 7-22**



MEP Layout & Integration



MEP Layout & Integration

Set Realistic Owner Expectations About Aesthetics

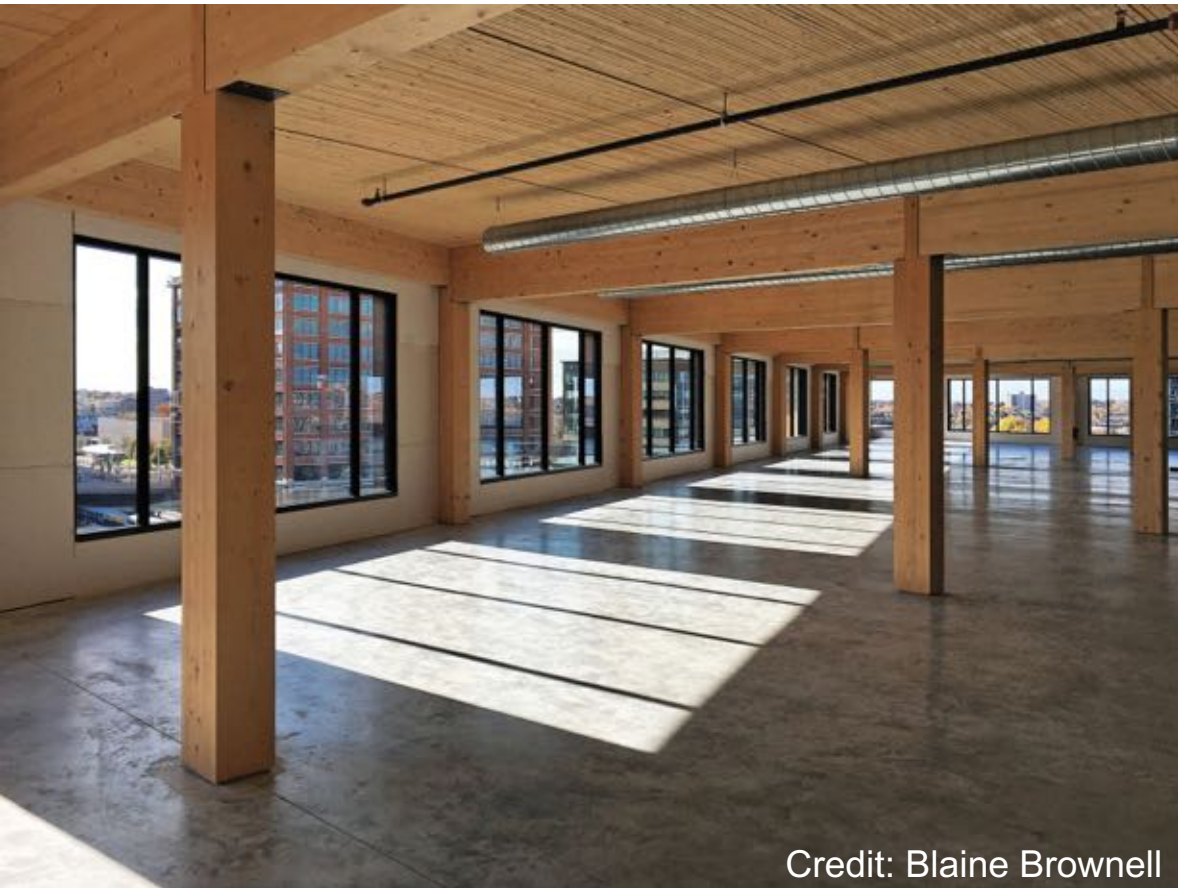
- MEP fully exposed with MT structure, or limited exposure?



MEP Layout & Integration

Smaller grid bays at central core (more head height)

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



Credit: Blaine Brownell



Credit: WoodWorks

MEP Layout & Integration

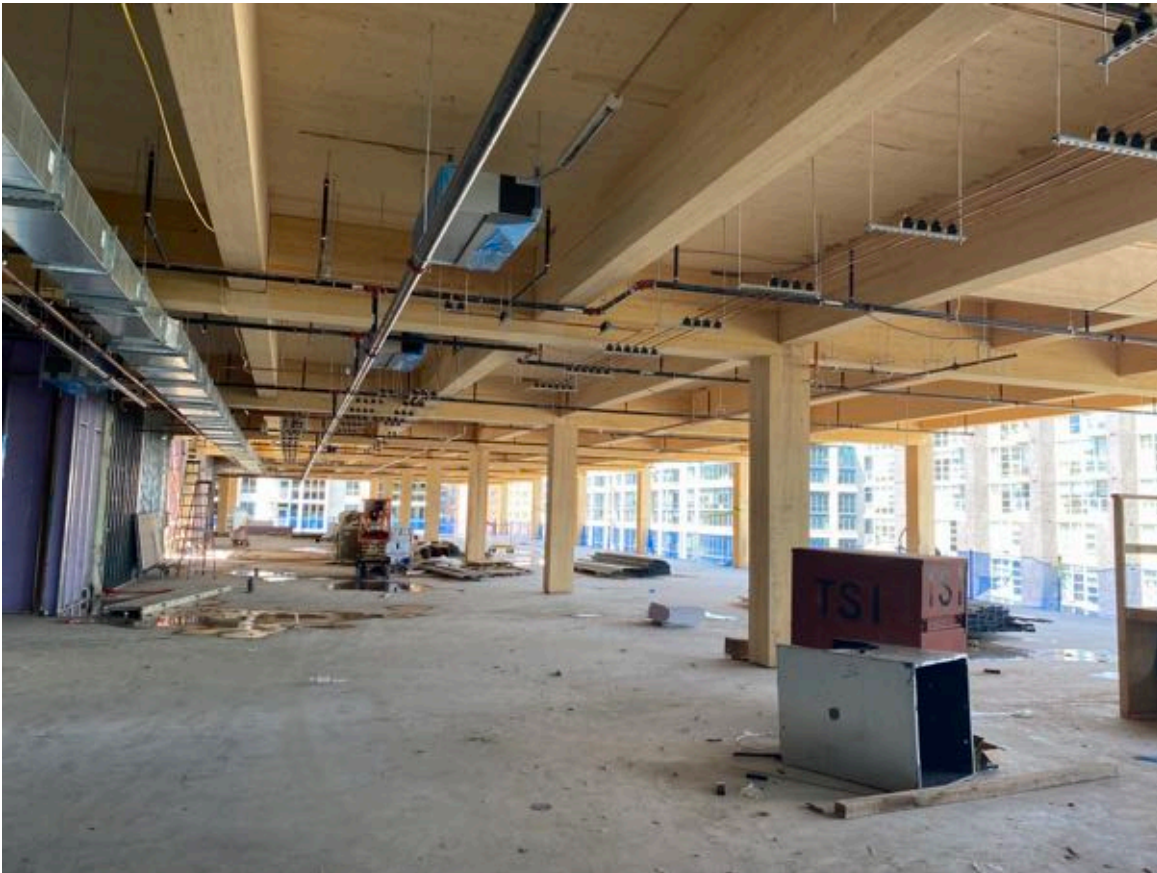
Dropped below MT framing

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



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



Credit: WoodWorks

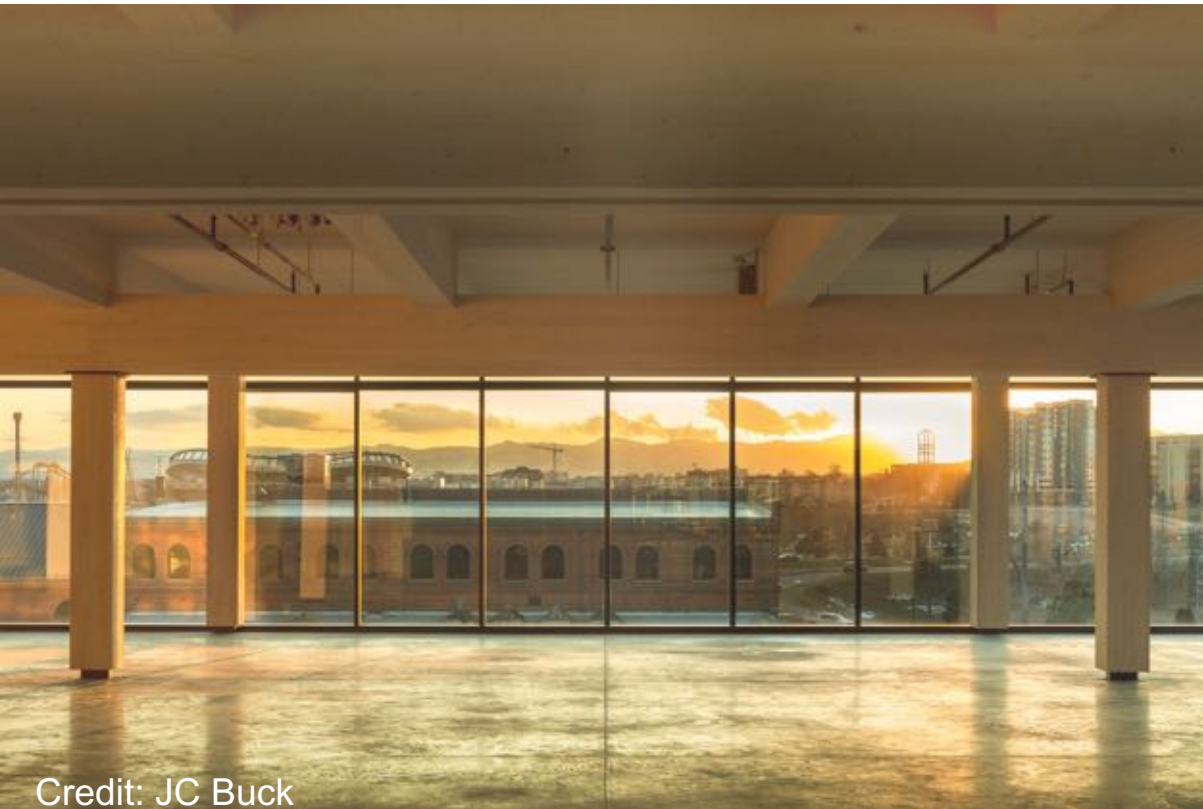


Credit: WoodWorks

MEP Layout & Integration

In chases above beams and below panels

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



Credit: JC Buck



Credit: KL&A Engineers & Builders

MEP Layout & Integration

In gaps between MT panels

- Fewer penetrations, can allow for easier modifications later



Credit: Ema Peter/MGA

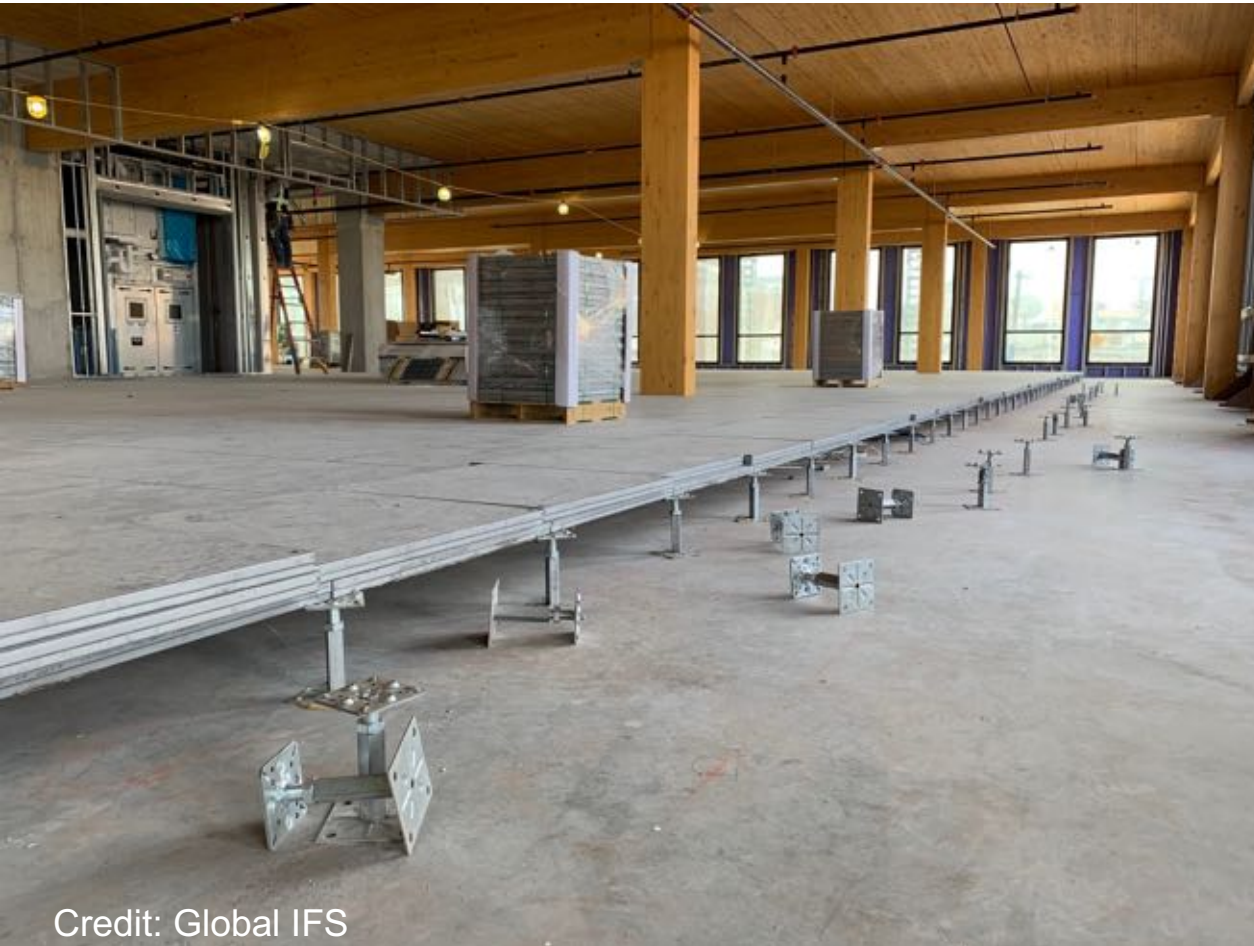


Credit: Hacker Architects

MEP Layout & Integration

In raised access floor (RAF) above MT

- Impact on head height
- Concealed space code provisions



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



Acoustics & Sound Control

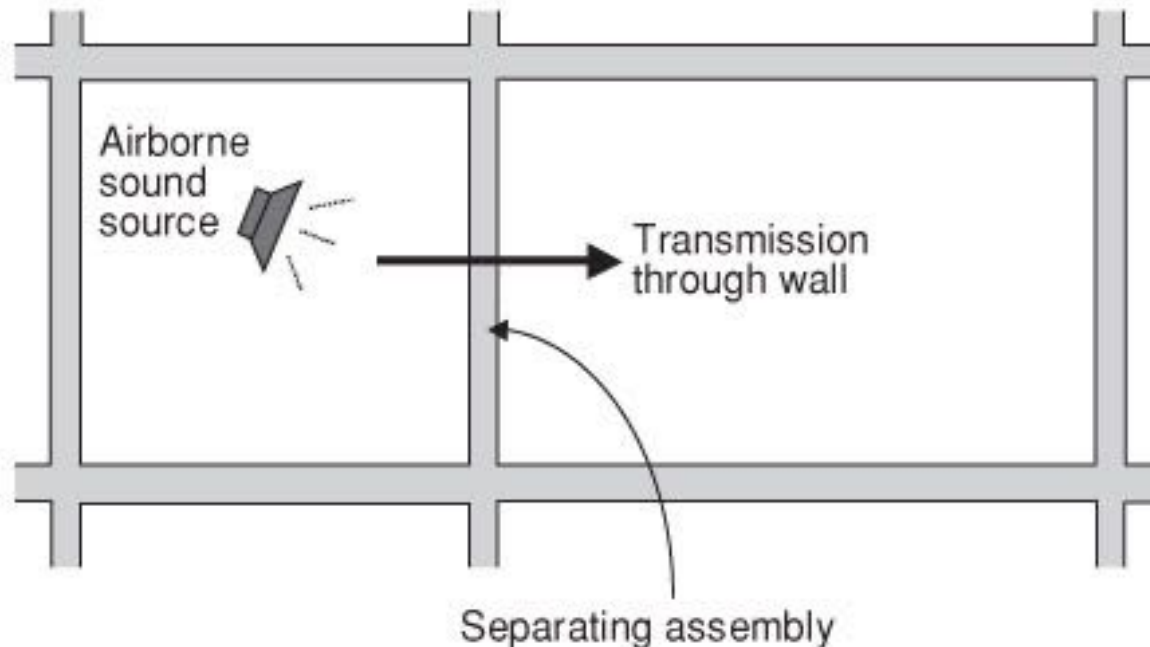


Acoustics & Sound Control

Air-Borne Sound:

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

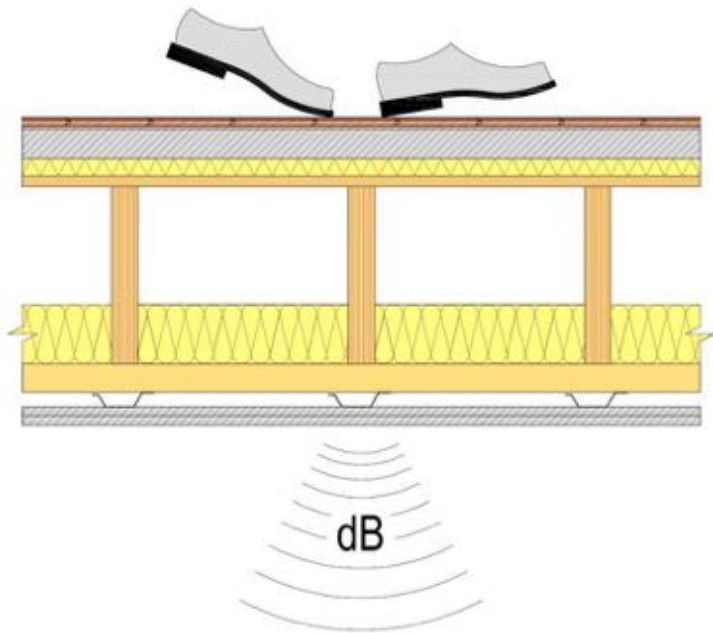


Acoustics & Sound Control

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

Code requirements only address residential occupancies:

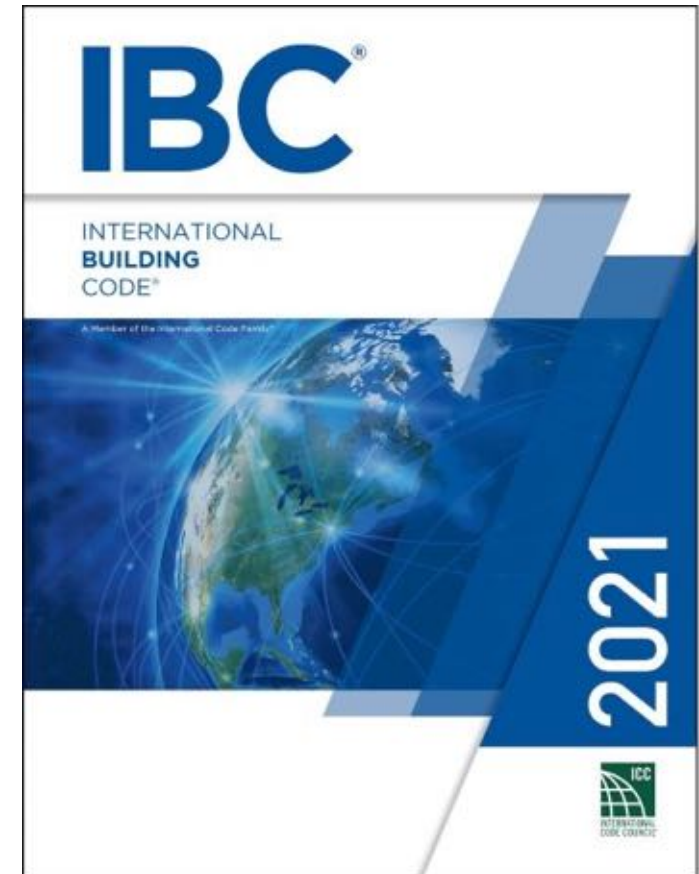
For unit to unit or unit to public or service areas:

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

- Walls, Partitions, and Floor/Ceiling Assemblies

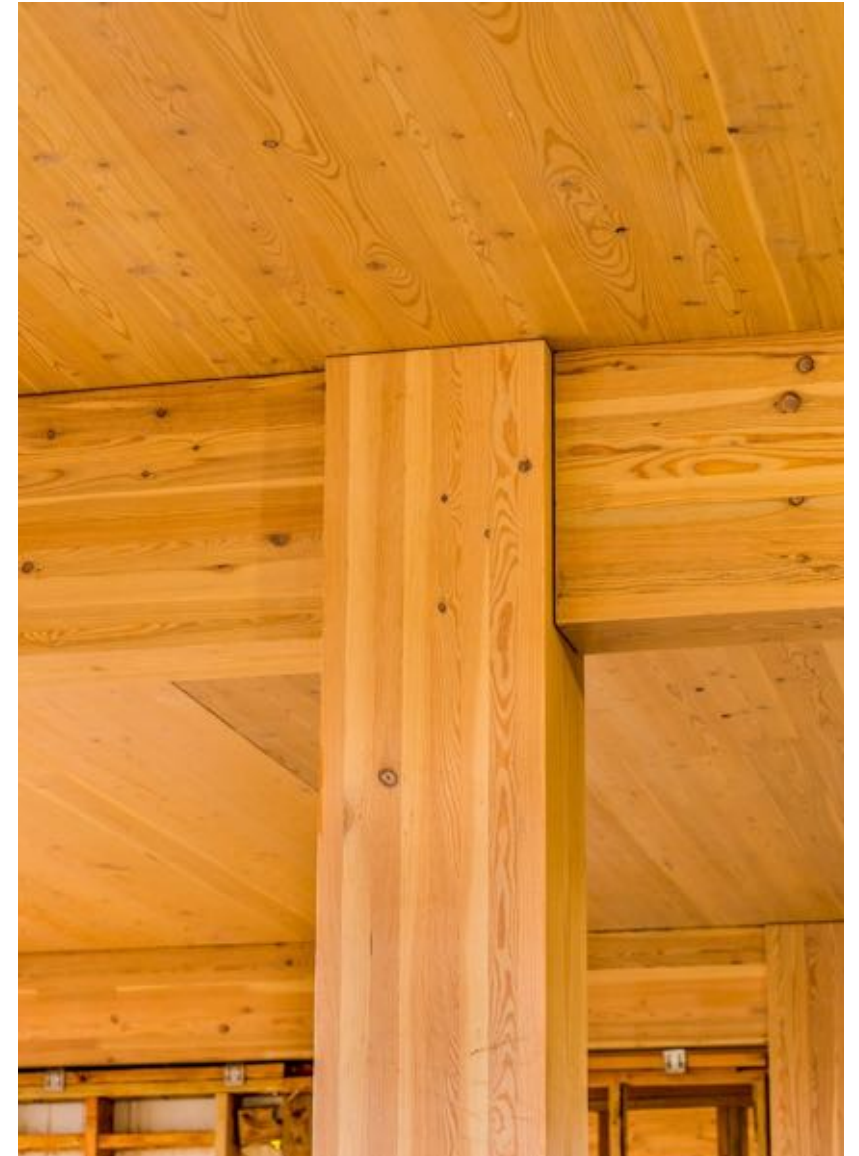
Min. IIC of 50 (45 if field tested) for:

- Floor/Ceiling Assemblies



Acoustics & Sound Control

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, WoodWorks⁷

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



Concrete Slab:

6" Thick

80 PSF

STC 53



CLT Slab:

6-7/8" Thick

18 PSF

STC 41



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



Acoustics & Sound Control

Solutions Paper



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: StructuralCraft

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.

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

Example Mass Timber Wall Assembly, STC 58

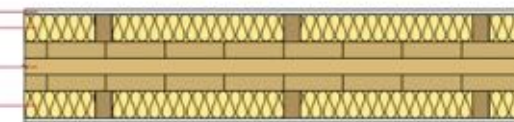
Plan View

5/8" Gypsum wallboard

2x3 studs @ 16" o.c. min.

3-ply CLT panel, 4-1/2" thick

2.5" Mineral wool batt insulation



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: Romuldas

Acoustics & Sound Control

Inventory of Tested Assemblies

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



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	
	1-1/2" Levelrock®	USG SAM N25 Ultra	LVT on Acousti-Top®	-	49 ² AIIC	
			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	None	45 ⁶	42 ⁶	15
			LVT	48 ⁶	44 ⁶	16

Questions?

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



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Funding provided in part by the Softwood Lumber Board

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