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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 often attached to the stigma of being more expensive than other building materials. Because of this, some people assume it only makes sense for one-off projects where innovation is celebrated but repeatability is not. Is this true, or do its other benefits result in overall cost efficiency? If it is true, how can we expect to build the number of new housing units needed across our country in a sustainable and affordable manner? Typical multi-family housing developments are in the range of 4-6 stories, often utilizing podium or pedestal construction with 1-2 stories of steel and concrete topped with 3-5 stories of light wood framing. Beyond these heights, building codes have historically required steel or concrete framing and, to justify the added costs of these materials, projects often go much taller. This has created a critical gap in housing developments in the range of 6-12 stories. Can mass timber multi-family projects make financial sense in the 4-6 story range, used in conjunction with light wood-frame systems? What new opportunities will the 2021 International Building Code create for mass timber housing in the 6-18 story range? This presentation will answer these questions and much more.

Learning Objectives

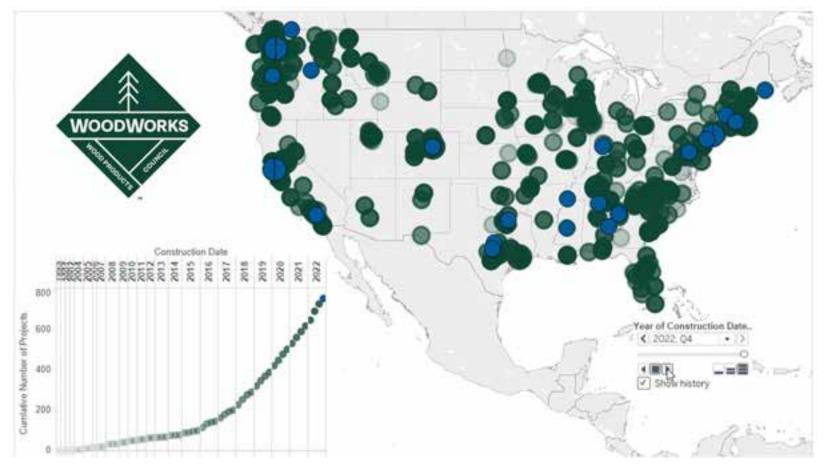
- 1. Evaluate the code opportunities for mass timber structures in residential mid-rise projects.
- 2. Discuss code-compliant options for exposing mass timber, where up to 2-hour fireresistance ratings are required, and demonstrate design methodologies for achieving these ratings.
- 3. Review code requirements unique to hybrid mass timber and light-frame housing projects, and emphasize solutions for criteria such as construction type, fire-resistance ratings and acoustics design.
- 4. Highlight the unique benefits of using exposed mass timber in taller multi-family buildings.

Is Mass Timber a Good Fit for Your Multi-Family Project?

Ascent, Milwaukee, WI Source: Korb & Associates Architects

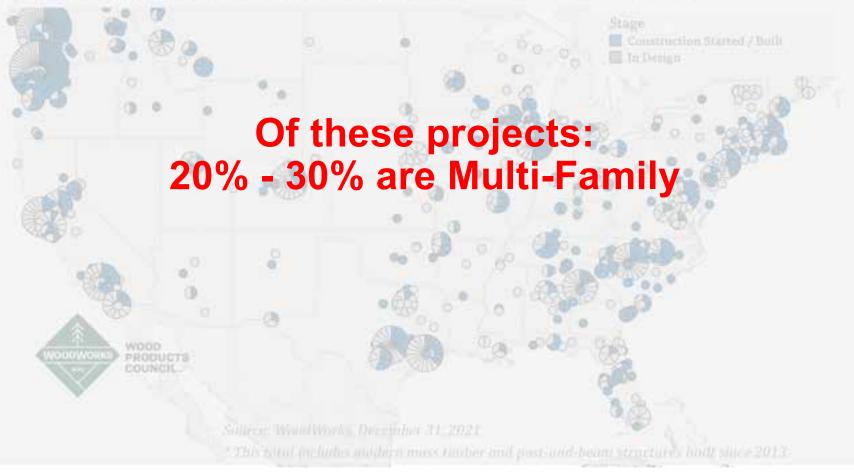
Current State of Mass Timber Projects

As of December 2022, in the US, **1,667** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



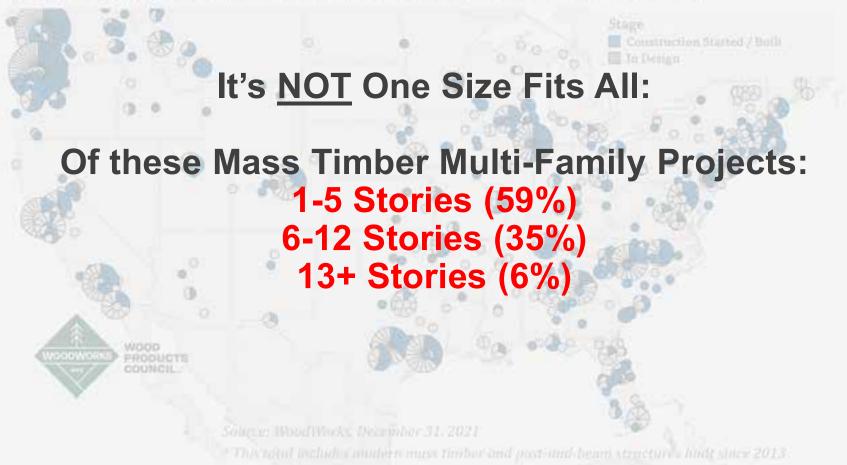
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MASS TIMBER IN MULTI-FAMILY EVOLUTION OR **REVOLUTION?**

Multi-Housing Typologies

MT Floors & Roofs on LWF Bearing Walls



Credit: KL&A Engineers & Builders

MT Floors & Roofs on Post & Beam Framing

Credit: ADX Creative and Engberg Anderson

MT Floors & Roofs on MT Bearing Walls

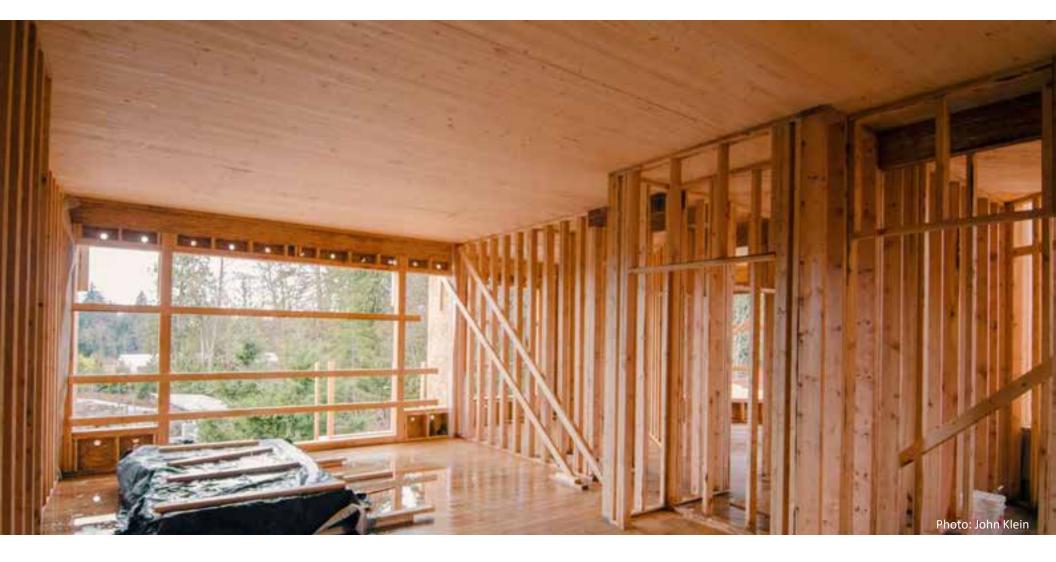


Credit: Grey Organschi Architecture and Spiritos Properties

EVOLUTION INCREMENTAL CHANGE

REVOLUTION TRANSFORMATIONAL CHANGE





HYBRID LIGHT-FRAME + MASS TIMBER

PROJECT ONE, OAKLAND, CA



Credit: Gurnet Point

CONDOS AT LOST RABBIT, MS



Credit: Everett Consulting Group

WESSEX WOODS, PORTLAND, ME



Credit: Avesta Housing



POST, BEAM + PLATE

360 WYTHE AVENUE, BROOKLYN, NY





Credit: Flank

BARRACUDA CONDOS, MADISON, WI



Credit: Populance Architecture and Development

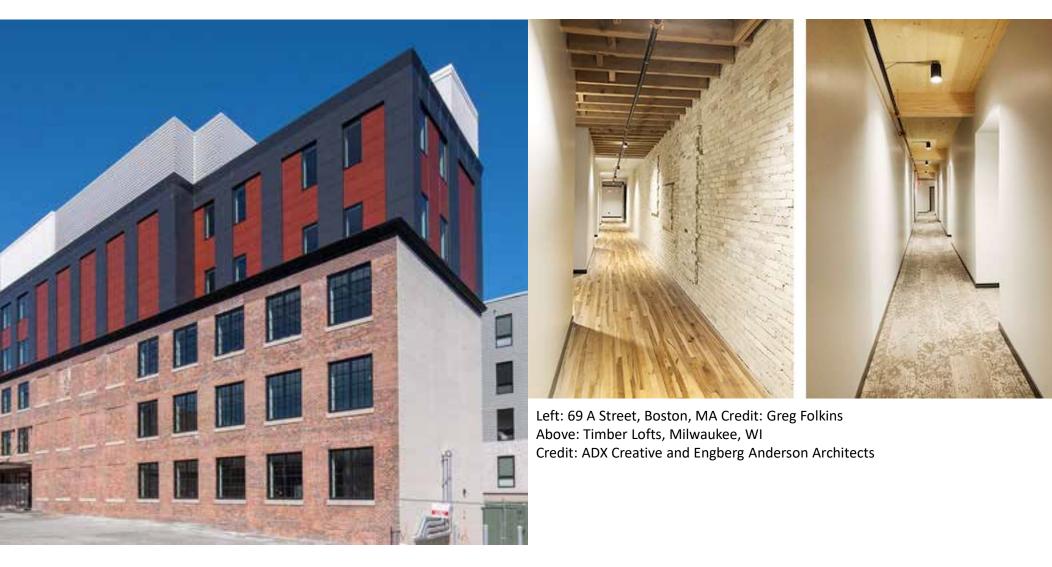


MASS TIMBER BEARING WALLS

Model C, Roxbury, MA



Credit: John Klein, Generate Architecture



VERTICAL ADDITIONS AND ADAPTIVE REUSE





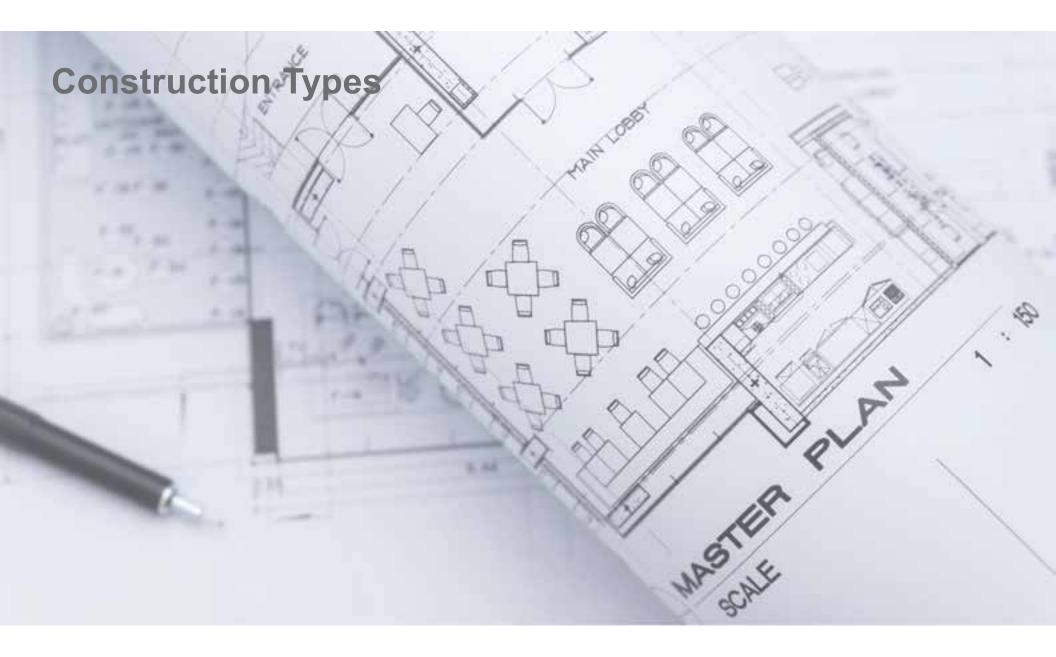
TIMBER LOFTS MILWAUKEE, WI

ANN PIEFIE LISENSEDWN OWNER/PRESIDENT | PIPER PROPERTIES

"Mass timber shaved 20% off our construction schedule. It's a renewable resource and also creates that warm look."

Source: ADX Creative and Engberg Anderson Architects

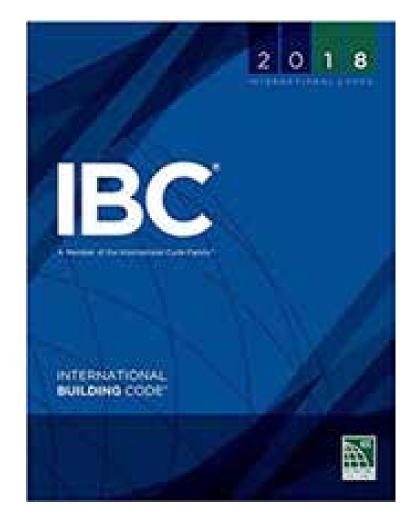
Source: Think Wood



When does the code allow mass timber to be used in low- and midrise multi-family projects?

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



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

Where does the code allow MT to be used?

• <u>Type III</u>: Interior elements (floors, roofs, partitions/shafts) and exterior walls if FRT



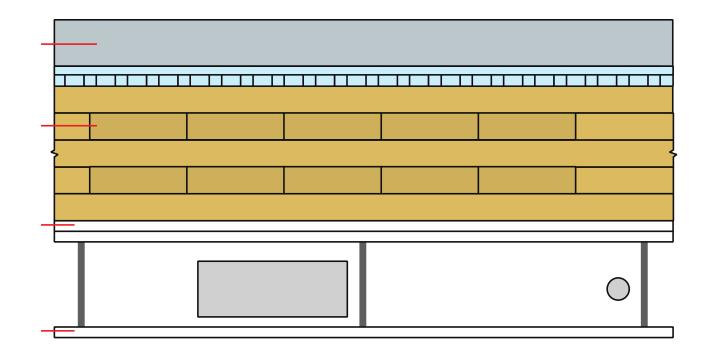
Where does the code allow MT to be used?

• <u>Type IV</u>: Any exposed interior elements & roofs, must meet min. sizes; exterior walls if CLT or FRT. Concealed space limitations (varies by code version)



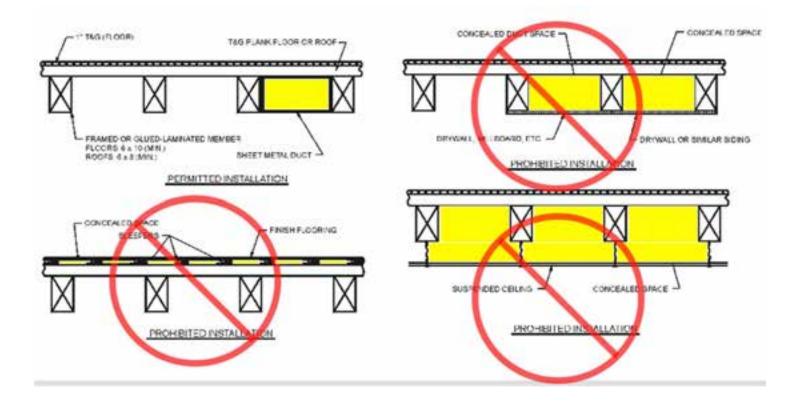
Type IV concealed spaces

Can I have a dropped ceiling? Raised access floor?



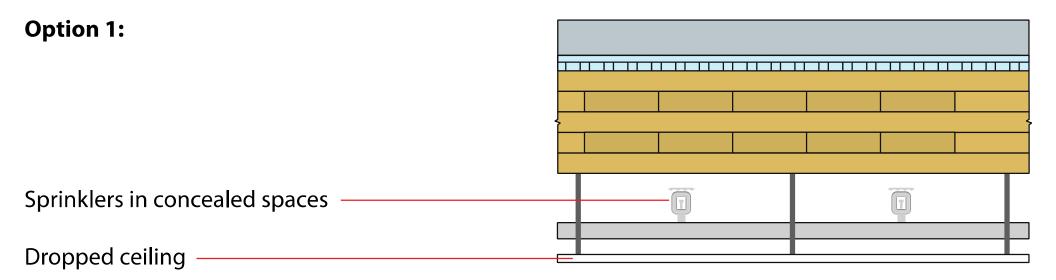
Type IV concealed spaces

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

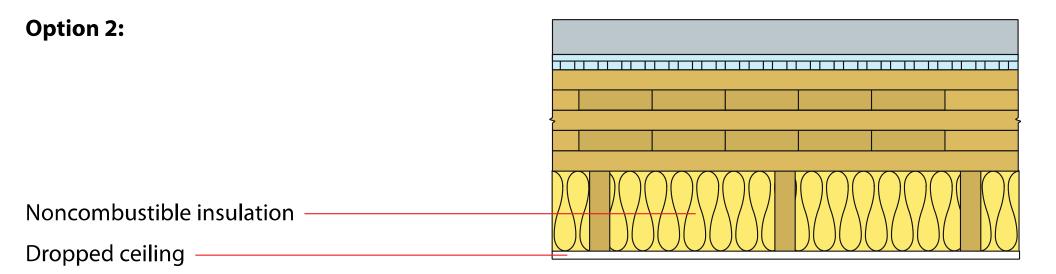


Credit: IBC

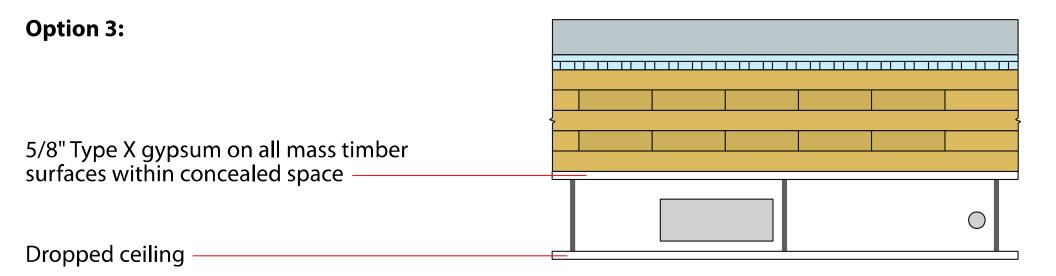
Type IV concealed space options within 2021 IBC



Type IV concealed space options within 2021 IBC



Type IV concealed space options within 2021 IBC



Concealed spaces solutions paper



Concealed Spaces in Mass Timber and Heavy Timber Structures

Remark Monary, PE, DC + Servey Terminal Director - Sal Dring Manufficher

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For mean timber building exempting, the obside of construction type can fast a significant impact on concentral disease responsements. Because an even tribler probability such as import laminated timber (CLT) are prescriptively recognized for Type IV construction, there is a communic measuremption that exposed wave tribler building exemption laminate used or executed in wave tribler. other communities righter. The is not the basis in addition to Tage NI buildings, processing mean britter elements – including CLT, global constants therein spulsars, coll-semanter tritter (HCR), processed composite lumiter (ECL), and torque and groups (TAG) decomposite lumiter (ECL), and torque and following constants righter, unlands and exposed in the following constants rights, unlands or loss a file-second and this exposed.

- Type III Places, rocks and interior walks may be any meaning periodical by today, including mass timber; subject walks are required to be noncombucyble of the inspectant required wand.
- Type V Fours, touts, interior walls, and enterior walls (i.e., the entire structure) may be constructed of main forber.
- Types I and K Mass timber may be used in select citizenbarrow such as tool semistication—relating the genrary times in the 3201 IRC—in Types 14, II-A or 4.8, detailed selection and active when 20-bat or more of holizantia separation is presetting and balances, tempers and similar protections.

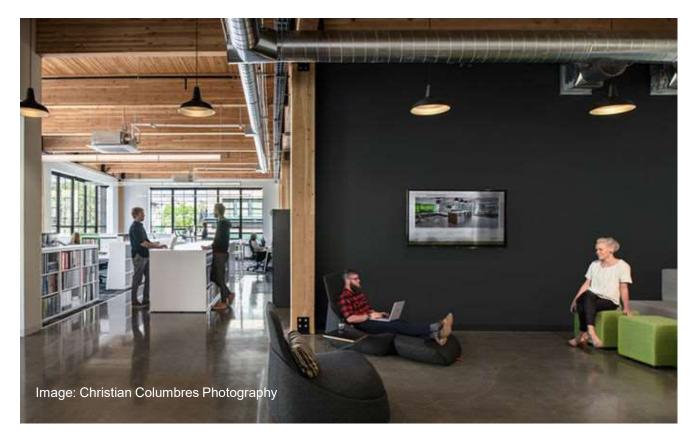




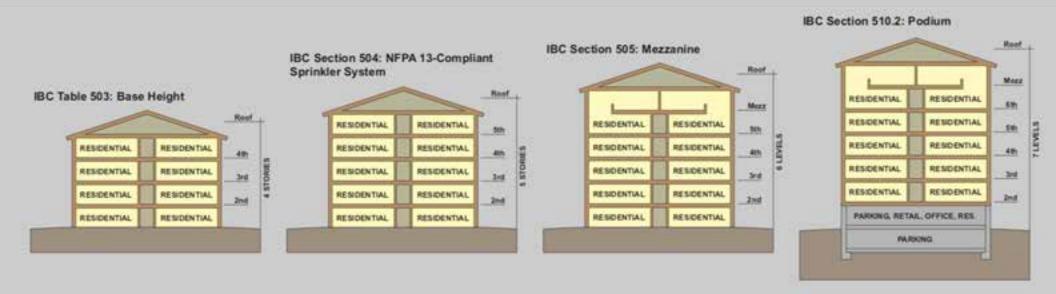
https://www.woodworks.org/wp-content/uploads/wood_solution_paper-Concealed Spaces Timber Structures.pdf

Where does the code allow MT to be used?

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

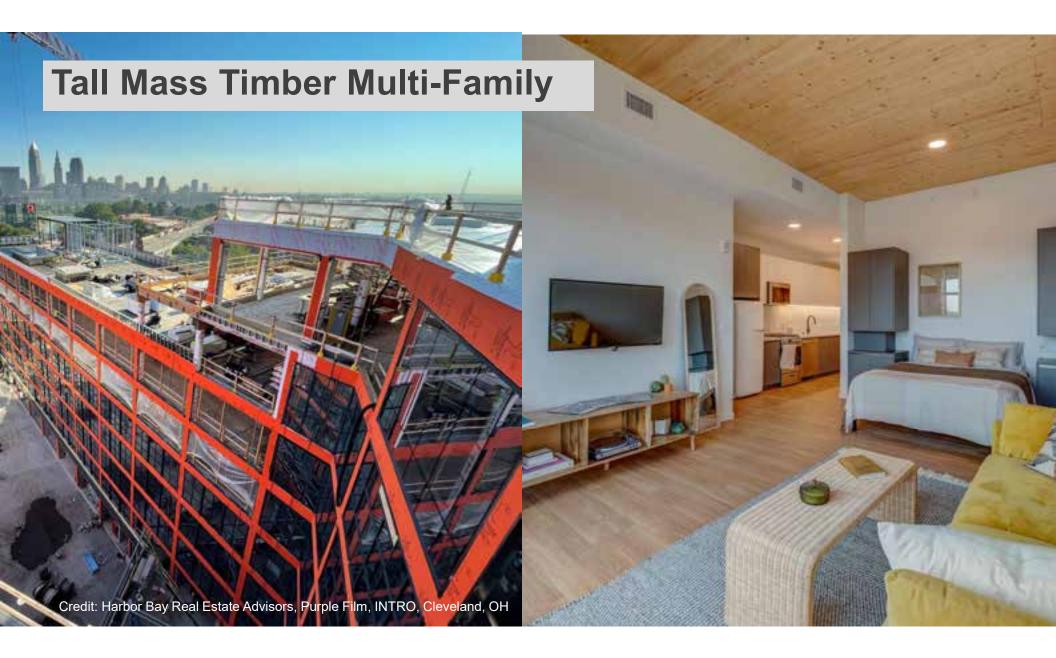


PRESCRIPTIVE BUILDING CODES



EVOLUTION INCREMENTAL CHANGE

REVOLUTIONAL CHANGE



CARBON 12, PORTLAND, OR



Credit: Baumberger Studio/PATH Architecture

INTRO, CLEVELAND

9 Stories | 115 ft 8 Timber Over 1 Podium

1005

512,000 SF 297 Apartments, Mixed-Use

Photo: Harbor Bay Real Estate Advisors, Purple Film | Architect: Hartshorne Plunkard Architecture

INTRO, CLEVELAND

9 Stories | 115 ft 8 Timber Over 1 Podium

Type IV-B Variance to expose ~50% ceilings

Photo: Harbor Bay Real Estate Advisors, Image Fiction | Architect: Hartshorne

ASCENT, MILWAUKEE



493,000 SF 259 APARTMENTS, MIXED-USE

ASCENT, MILWAUKEE

Tallest Mass Timber Building in the World



Photo: CD Smith Construction | Architect: Korb & Associates Architects

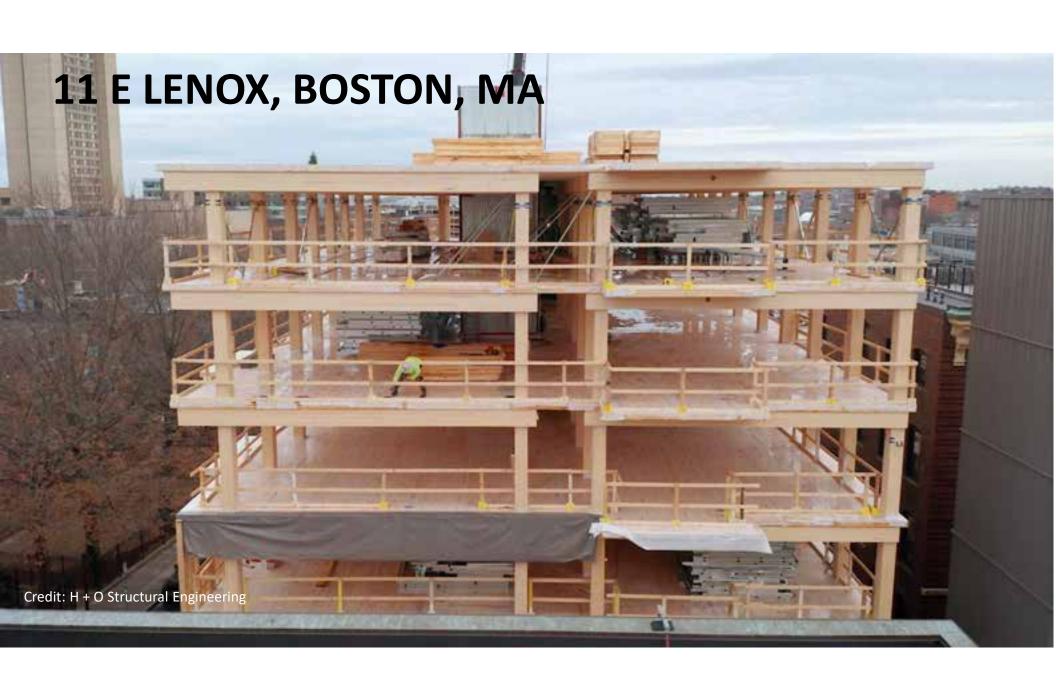
ASCENT, MILWAUKEE

25 STORIES

19 TIMBER OVER 6 PODIUM, 284 FT

Photo: Korb & Associates Architects | Architect: Korb & Associates Architects





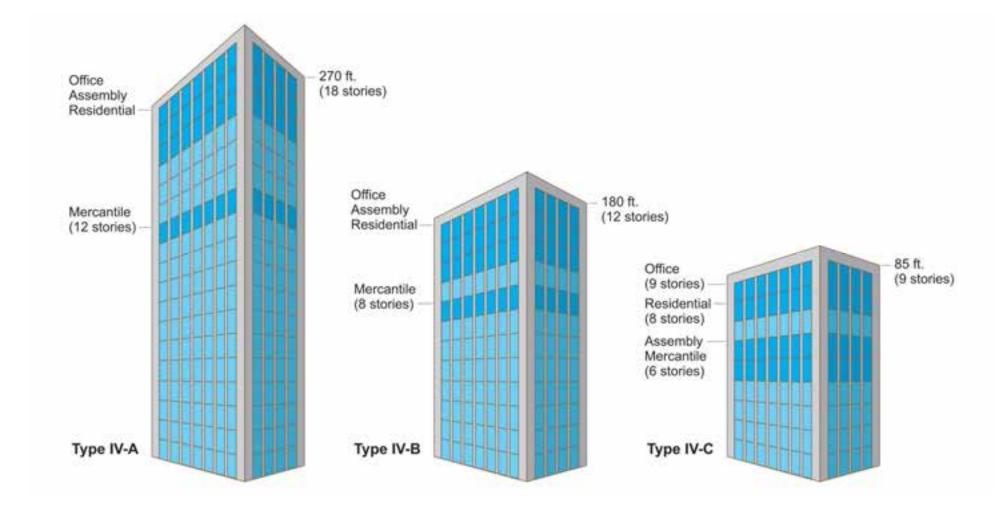
11 E LENOX, BOSTON, MA





Credit: H+O Structural Engineering

PRESCRIPTIVE BUILDING CODES



Type IV-C



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

TYPE IV-C





Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman







Type IV-C Height and Area Limits

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

IV-C

STORY 45,000 S

TYPE IV-C

Credit: Susan Jones, atelierjones

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	6	85 ft	56,250 SF	168,750 SF
В	9	85 ft	135,000 SF	405,000 SF
Μ	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

In most cases, Type IV-C height allowances = Type IV-HT height allowances, but add'I stories permitted due to enhanced FRR Type IV-C area = 1.25 * Type IV-HT area



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

IV-C

TYPE IV-C

Credit: Susan Jones, atelierjones



All Mass Timber surfaces may be exposed

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





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

IV-B



12 STORIES NG HEIGHT 180 FT ABLE BUILDING AREA 648,000 SF ERAGE AREA PER STORY 54,000SF

TYPE IV-B

Credit: Susan Jones, atelierjones

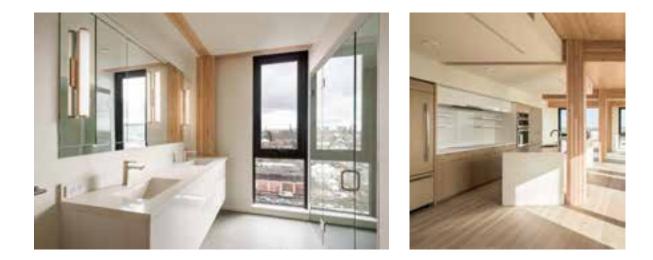
Type IV-B Height and Area Limits

Occupancy	# of Stories	Height	Area per Story	Building Area		
A-2	12	180 ft	90,000 SF	270,000 SF		
В	12	180 ft	216,000 SF	648,000 SF		
Μ	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



NC protection on all surfaces of Mass Timber except limited exposed areas ~20% of Ceiling or ~40% of Wall can be exposed



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

Limited Exposed MT allowed in Type IV-B for:

- MT beams and columns which are not integral part of walls or ceilings, no area limitation applies
- MT ceilings and beams up to 20% of floor area in dwelling unit or fire area, <u>or</u>
- MT walls and columns up to 40% of floor area in dwelling unit or fire area, <u>or</u>
- Combination of ceilings/beams and walls/columns, calculated as follows:



IV-B

Credit: Kaiser+Path

Mixed unprotected areas, exposing both ceilings and walls:

In each dwelling unit or fire area, max.
unprotected area =

 $(\mathrm{U_{tc}}/\mathrm{U_{ac}}) + (\mathrm{U_{tw}}/\mathrm{U_{aw}}) \leq 1.0$

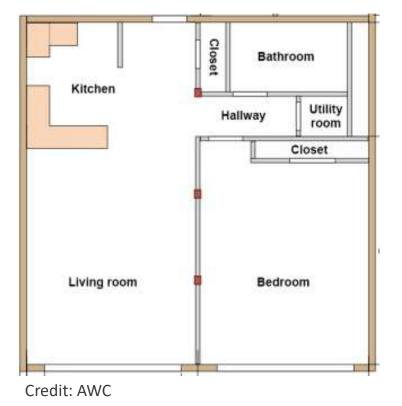
- U_{tc} = Total unprotected MT ceiling areas
- U_{ac} = Allowable unprotected MT ceiling areas
- U_{tw} = Total unprotected MT wall areas
- U_{aw} = Allowable unprotected MT wall areas



IV-B

Credit: Kaiser+Path

Design Example: Mixing unprotected MT walls & ceilings



800 SF dwelling unit

- U_{ac} = (800 SF)*(0.20) = 160 SF
- U_{aw} = (800 SF)*(0.40) = 320 SF
- Could expose 160 SF of MT ceiling, <u>OR</u> 320 SF of MT Wall, <u>OR</u>

IV-B

• If desire to expose 100 SF of MT ceiling in Living Room, determine max. area of MT walls that can be exposed

Design Example: Mixing unprotected MT walls & ceilings



- $\begin{array}{l} (U_{tc}/U_{ac}) + (U_{tw}/U_{aw}) \leq 1.0 \\ (100/160) + (U_{tw}/320) \leq 1.0 \\ U_{tw} = 120 \; \text{SF} \end{array}$
- Can expose 120 SF of MT walls in dwelling unit in combination with exposing 100 SF of MT ceiling

IV-B

Credit: AWC







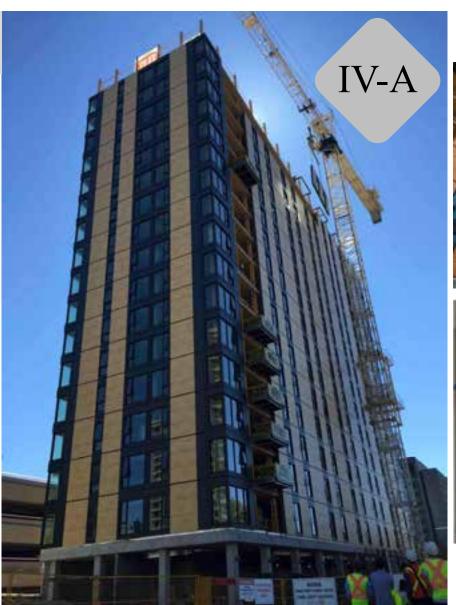
Type IV-A



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



18 STORIES BUR, DING HEIGHT 270⁴ ALLOWABLE BUR, DING AREA 972,000 SF AVERAGE AREA PER STORY 54,000SF

TYPE IV-A

Credit: Susan Jones, atelierjones

Occupancy	# of Stories	Height	Area per Story	Building Area
A-2	18	270 ft	135,000 SF	405,000 SF
В	18	270 ft	324,000 SF	972,000 SF
Μ	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

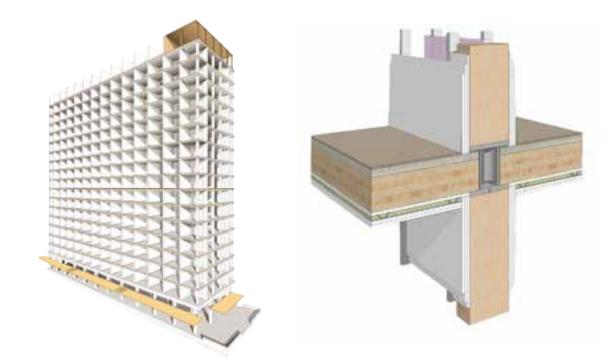
Type IV-A Protection vs. Exposed



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

TYPE IV-A

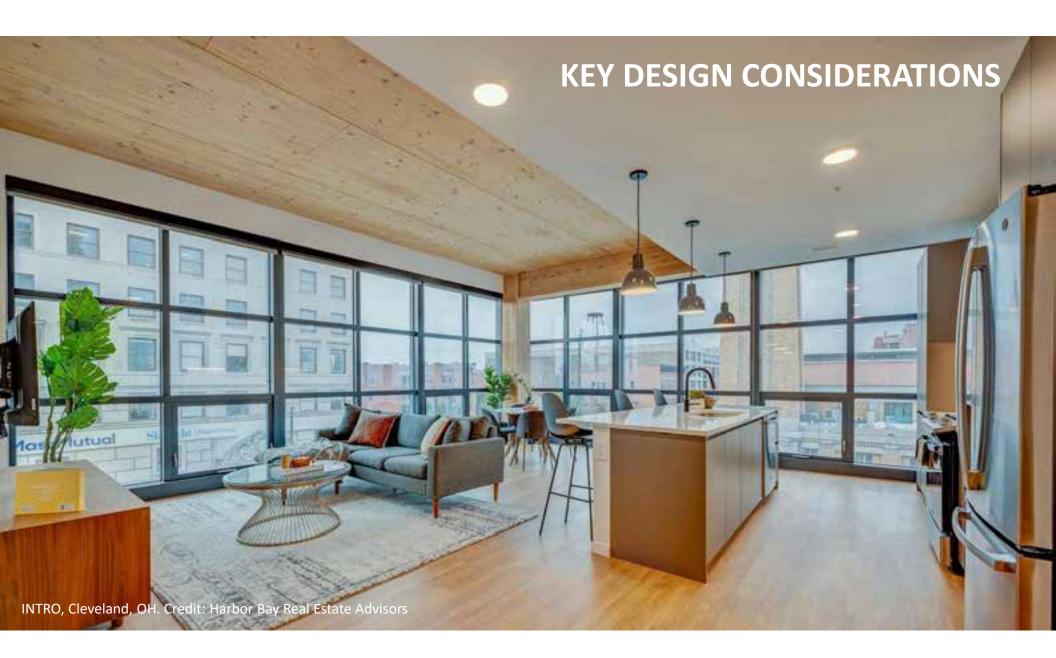
Credit: Susan Jones, atelierjones



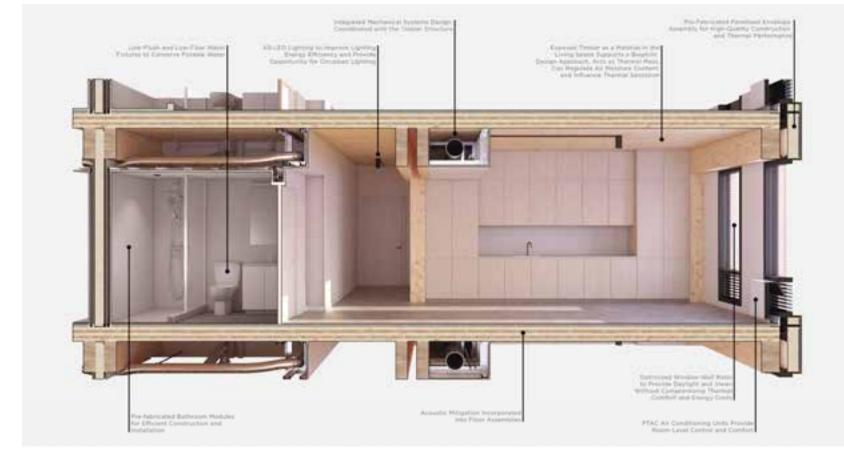
100% NC protection on all surfaces of Mass Timber







MEP SYSTEMS, ROUTING, INTEGRATION



INTEGRATED SYSTEMS

Credit: John Klein, Generate Architecture

The Talihouse building system prioritizes the integration of design, engineering, and construction. This results in a high performance building finely tuned to meet energy, comfort, acoustic, and design orberta that has been vetted by constructability expects to ensure fast, efficient production.

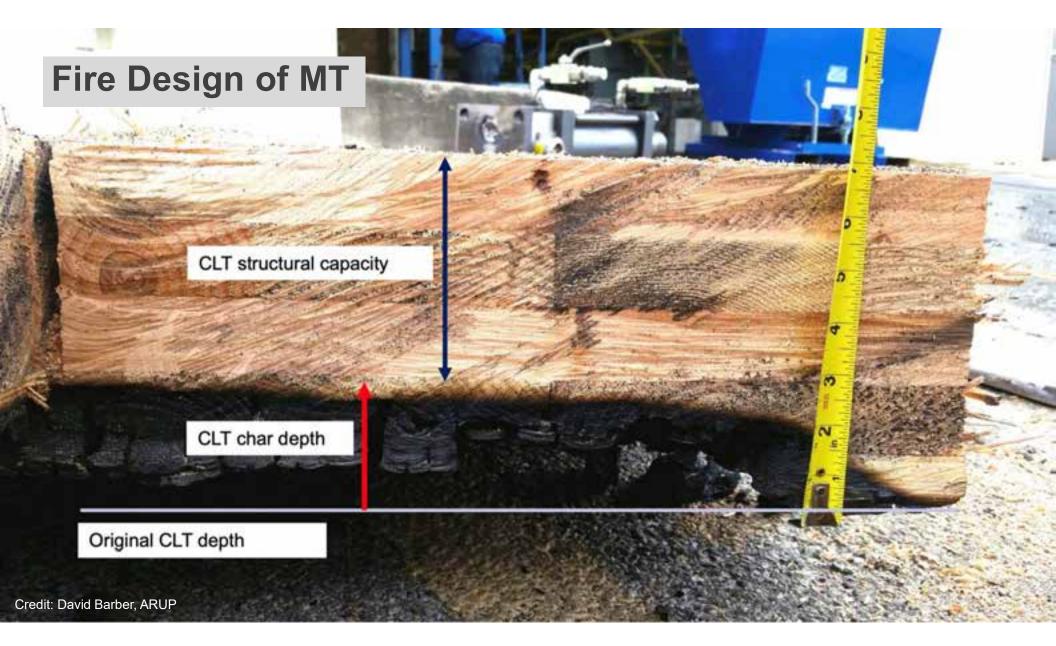
Utilizing Pre-Fabricated Facede Fanels and Bathroom Hodules that are manufactured off-site in factories allows for reducing construction time on-site. higher quality control practices, and safer labor conditions for construction workers. Efficient routing of duct-work conserves material, and associated embodied carbon, allowing more exposed timber all while providing the air quality needed for healthy living. Water conserving fixtures reduce potable water use as a precision shore, while maintaining initialite performance.

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





Key Early Design Decisions

Fire-Resistance Ratings

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

BUILDING ELEMENT		TYPEI		TYPE II		TYPE III		TYPE IV			TYPE V	
BOILDING ELEMENT	A	B	A	В	A	В	A	В	C	HT	A	B
Primary structural frame ¹ (see Section 202)	34.6	2a, b. c	16.0	0°	Ib.c.	0	3*	2ª	2*	HT	1he	0
Bearing walls												_
Exterior*1	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3*	2*	1	0	1	0	3	2	2	1/HT*	1	0
Nonbearing walls and partitions Exterior					See Table 705.5							
Nonbearing walls and partitions Interior ⁴	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)	11/2 b	18,0	18,0	0 ^e	1 ^{h,c}	0	11/2	1	1	HT	1 ^{b,c}	0

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 2hour 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 type influences FRR

BUILDING ELEMENT	TY	PEI	TYPE II		TYPE III			T	YPE IV	k	TYP	PE V
BUILDING ELEMENT	A	В	A	В	A	В	A	В	С	HT	A	В
Primary structural frame ^f (see Section 202)	3 ^{a,b}	2 ^{a,b,c}	1 ^{b, c}	0°	$1^{h,c}$	0	31	2*	2*	HT	$1^{b,c}$	0
Bearing walls												
Exterior*.f	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3*	2*	1	0	1	0	3	2	2	1/HT ^g	1	0
Nonbearing walls and partitions Exterior						See	Table 70	5.5				
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)	$1^{1/\frac{b}{2}}$	1 ^{b,c}	I ^{b,c}	0 ^e	$1^{b,\varepsilon}$	0	$1^{3}/_{2}$	1	1	HT	$1^{b,c}$	0

Source: 2021 IBC

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



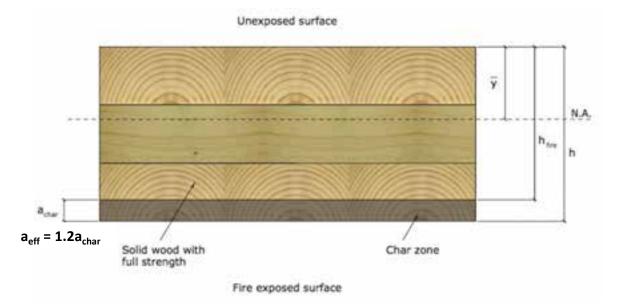




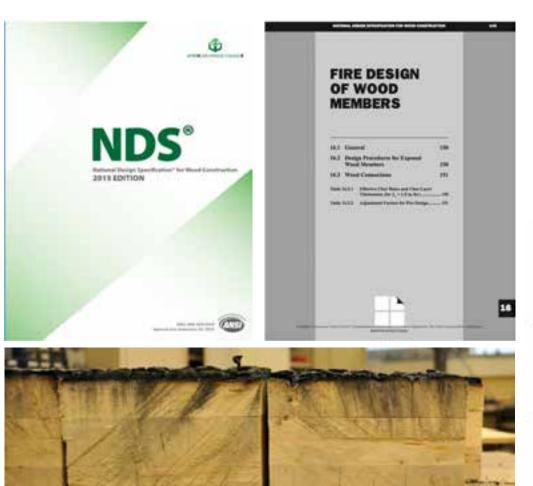
Which Method of Demonstrating FRR of MT is Being Used?

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





Credit: FPInnovations



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 $\beta_n = 1.5 in./hr.$)

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			

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



Table 16.2.1AChar Depth and Effective CharDepth (for $\beta_n = 1.5$ in./hr.)

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

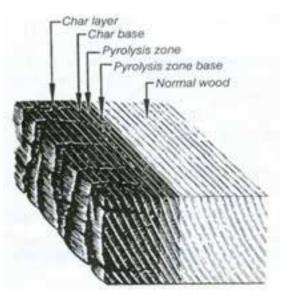


with $\beta_n = 1.5 in./hr.$)

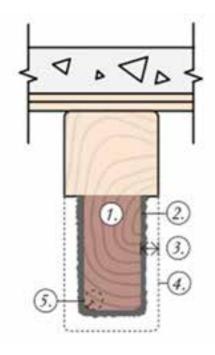
Required Fire Endurance (hr.)		Effective Char Depths, a _{thar} (in.) lamination thicknesses, h _{lam} (in.)										
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2			
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8			
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6			
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6			

Two structural capacity checks performed:

- 1. On entire cross section neglecting fire effects
- 2. On post-fire remaining section, with stress increases



Credit: Forest Products Laboratory

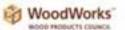


 $a_{char} = \beta_{t} t^{0.813}$ Solid Sawn, Glulam, SCL $a_{char} = n_{lam} h_{lam} + \beta_{t} \left(t - (n_{lam} t_{gl}) \right)^{0.813}$ CLT

a_{eff} = 1.2a_{char} Effective Char Depth

WoodWorks Inventory of Fire Tested MT Assemblies

Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies



CLT Pand	Menefacturer	CLT Gesde er Major x Maser Grade	Colling Prototion	Panel Connection in Test	Fluor Topping	Loud Robert	Fire Resistance Addressed (Bloom)	Neme	Tening Lab
3 y ly C32 (1) Hom 4 AUT (a)	Sedic	679 (n in Fi-1.56,MSR 4.679 (n)	2 Japan I (7° Type X gyprom	Half-Lag-	None	Rotural MCManat Capacity		1 (fee 1)	NRC Fee Laboratory
3-pth CGI (107-cm 4.133-ia)	Instation	509 KL K2 5 MH KL K2	1 August 3 W" Type X 430 com	Half Log	Name	Rolmod 13% Monitor Ceptury	1	1 (Tast 5)	NRC Fee Labor mery
3-ptp-CE7 (TT7mm4.873*)	Nets	.0.	Not	Topside Splitter	2 singpoord layers of 1-2* crowint brands	Londord, Num Menufacturist		2.1	NRC Fee Laboratory Match 2016
3-p1/2237 (375minut 273*)	Nels		1 Input of 3.5° Type Agypoint and at 2- chattach and farring stype with 3.5.5° therein a two	Signide Splitte	2 stagg and layers of 1.2° scenario basels.	Eralid, But Manalacturat	а.		NRC Fire Laboratory Nov 2014
5+9 CUT (175mm#.479*)	Needia	.0	Nov.	Tophile Splitte	1943a populatary gypointa averMaicon penaritari me	Builsial 10% Moniori Capacity	1.1	÷.	UL.
5 giş Ci.T (1*5mm+ #77*)	Northe	R.	3 Japan J.W. normal gyprose.	Topolde Nellino	314 in propriatory pygenter inter Marine accordinal and or proprietary waved for and	Relwood 14% Manuer Capacity	2	-40	u.
3490C03 (125mm43/127)	Nordic	в.	Hyper SV-2cpt S-10pt under Real-Reachangel ander TTP's Links with 3-12" Manual Ward Network Joan.	Hall-Lap	Nate	Kataded, Rais Manufactured		zi	Interick 8/24/2012
P-phy ELT. (C75mmik/8797)	Secularitate -	ELMO MER 2100 + NPF +2	New	Yopeide Ny Sides	1-1-2" Main of Cyp-Onto 2000 nine Main on Relationing Mash	Existed. Not Medical and	20	1.	Setertek, 2-22/2016
5-ph/CE7 (11fmm4.811*)	DR Johnson	. 90	New	Hall Lap & Tage site Splana	2. Warmentabut	for adv-0. Ken Minimi art area	2	623	SwRI (May 2016)
5-pty IL3 (175mm5.671*)	Nedic	SPE LEVEL For NEW + SPE KE	Sile	Half Lap	Nav	Related 19% Monitol Copacity	(66)	1 (Sec.1)	NRC Fee Laboratory
1.995 (0.7 (17)mm4.871*)	Emuladam	507 FL92 x 507 FL92	Line DP Type Xgypnin	Half Lap	Note	Executional (1075 Monium) Capacity	3	1 (Saile)	NEC Fee Laboratory
7.935 (0.3 ()45mm7417	Structure	589 91.92 x 529 91.92	New	HuitLap	Nine	Danabasii Dith Monistri Capacity	2.6	1 (Part 2)	NRC Fee Laboratory
5-pi) CKI (1*5min+6.877*)	Soutas	SL/Ve	New	Hall Lap	anned 12* phymed with Manie	Karindudi. Kasi Mantafant anyi	1	12(Tet 4)	Western Fire Center 10/26/2016
54% CE7 (117maid.811*)	imari(an	390	Sein	Helf kap	accornal 12" physical with Manada.	Erialică, Rus Massal acturei		11(Tat 5)	Wotorn Fire Center 10/28/2016
3-ptp-03.7 (175mm+-877*)	SH Julyison	NI.	Not	thatfiling	mining 12*ply word with 62 mails	Eralid, Bur Manafaitute	÷	12(Secto	Wedem Fire Center 11/01/2016
549-032	ALC: Y	CV3Mi	New	Thill Lig 4	New	Loakd, Key Manufatana	N.	314	SwRJ

Fire-Resistive Design

of Mass Timber Members Code Applications, Construction Types and Fire Ratings

Andread Medium, Phil. 58 - Januar Santonica Consultar - Honodonicas Andread Medium (NC) 10 - Daniel Santonica Consultar - Honodonicas

For many years, exposed heavy timber framing elements have been parentitied in U.S. buildings due to their element fre-instance properties. The predictability of exods, char rate her been well established for docable and her long been manyorised in fluiding codes and interdemis

Tables, one of the exciting trends to building design is the growing use of must techni-La., targat still wood panel products such as more-living transition of the UCT and salterinated tender (HCT)—for those wail and not outstructure. Use heavy tender, mass tender products have interart the instruction that allows them to be life as exposed and pall anteres a the meantance rating. Because of their tempts and dimensional statistics, these tenders also of the interrupt and dimensional statistics, because and massing the tempts absorbed to the tested, concrete, and massing the ratio tempts that developest and designers some the formation tempts that developest and designers some the country. are teveraging to cleate increative decigns with a warm yet modern aesthetic, often for projects that go bayond traditional nome of wood design.

This paper has been written to support profilects and angineers exploring the use of makes limber for communitie and multi-beneficients. It focuses to have to meet the-executions is equipaments in the limbertained Rudding Code (RC), including calculates and testing-based methods. Unless otherwise stretut, internetional testing-based methods. Unless otherwise stretut, internetional testing-based methods.

Mass Timber & Construction Type

Before demonstrating the instructions railings of exposed mass bindler elements, the important to understand under what occurrentances the code currentle allows the use of mass timber in commercial and multi-family comprisedow.



A faileding's assigned construction type is the next indicate of where and where all wood enstreme can be used. (IKC Section RE2) indexes the main address (Type I through V), with all but Type (V having subcategories A and II: Types II and V permit the use of wood having throughout much of the structure and both and used extension for moder model. tothe set used extension for moder model.

WoodWorks"

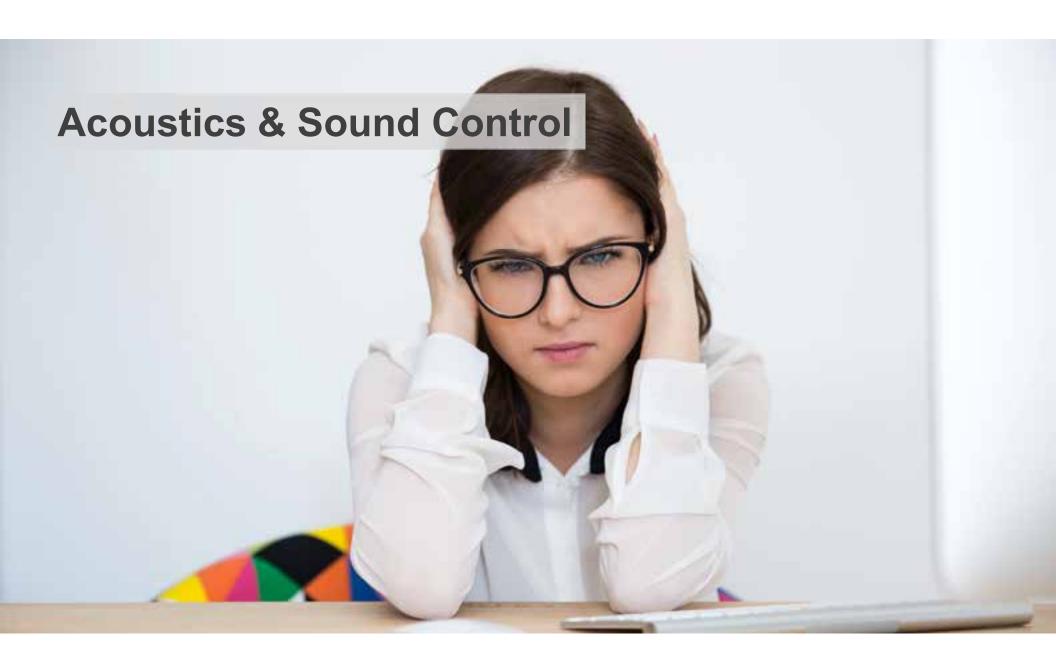
New BYIEC 602 31 – Timber elements cal be used in form, nich and interior wale. Fra-standart-bested wind (FBW) having is permitted in educior walk with a frementation uting of 2 hours or less.

Type V /IOC 602.0 - Tentar elements can be used throughout the structure, including fluors, mofs and both-markor and extensor walk.

Rose Nº 15C 602 Al - Commonly referred to as "Heavy Timbe" construction, this option

Mass Timber Fire Design Resource

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



Consider Impacts of:

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





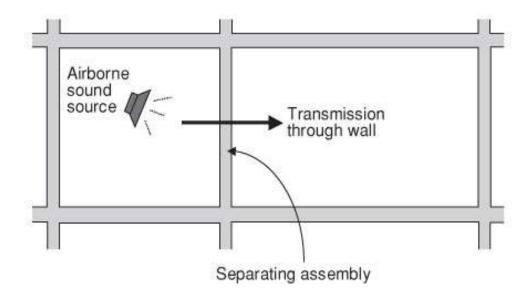


Finish Floor if Applicable	-	 	 		 	
Concrete/Gypsum Topping						
Acoustical Mat Product						
CLT Panel						
No direct applied or hung ceiling				-		

Air-Borne Sound:

Sound Transmission Class (STC)

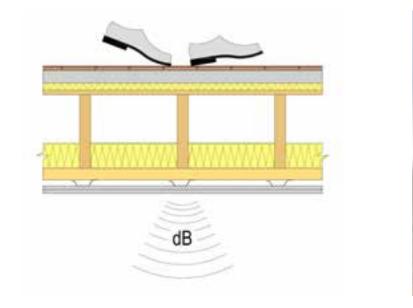
- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies





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





Code requirements only address residential occupancies:

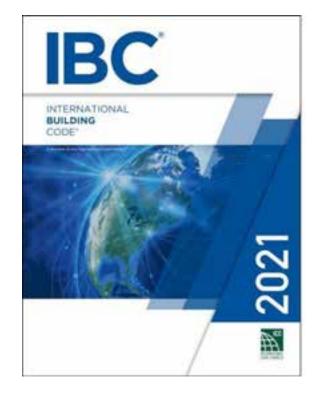
For unit to unit or unit to public or service areas:

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



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

MT: Structure Often is Finish



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

But by Itself, Not Adequate for Acoustics



TABLE 1:

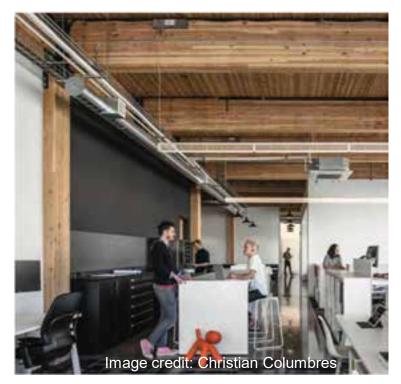
Examples of Acoustically-Tested Mass Timber Panels

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	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
6 NLT floor + 1/2" plywood ²	6" with 1/2" plywood	34	33

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks?

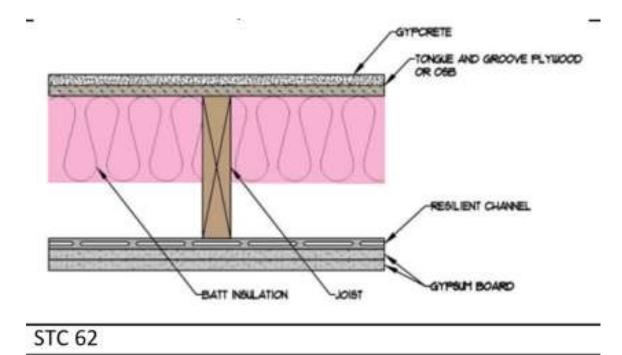
Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:

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



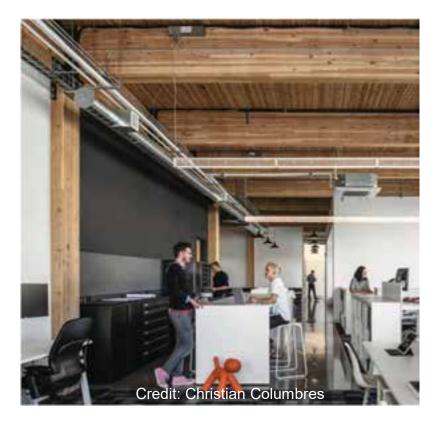
What does this look like in typical wood-frame construction:

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



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

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









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

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

Finish Floor if Applicable —		 			 	
Concrete/Gypsum Topping						
Acoustical Mat Product	TET,					
	7					
	2					
CLT Panel		17	14	45		
No direct applied or hung ceiling						

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"+











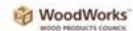
Common mass timber floor assembly:

- 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

Solutions Paper



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

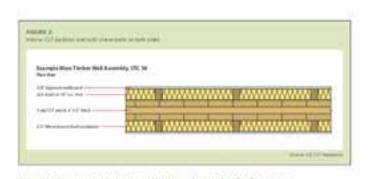
Schericky, P. Science Science Course Conditions



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Which information is remeasurementation of the inspaced and advanced in transmit conduction of Pachtinesia Including presentations in such an Applie scored threads and the inspaced and the inspace to the inspaced and the inspaced by the inspace animal sequence of their paced installation and the inspace animal sequence of their paced installation in the installation inspace a building's structure legisland all firsts: which the inspace animal sequences of the inspaced installation in the installation inspace a building's structure legisland all firsts: which the inspace and making inspace to their building is not from the inspaced and thermostation approximation. Which is a from the inspaced and thermostation approximation is approximate them.

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



Mass Timber Assembly Options: Walte

Many rivides, parally belt also the used by inferior and evidence walls-both basing ald ton klaznig. Fol intellar walls, this hand to contrait safet to such as also not providing a at added consideration. Converses approached trillade Building a chess out a fract of the mass timbs wall or an art develop realize to tradice running princes attached in the men pinker well, for with how must inclu-Bur strais, have want trains with don't typically provide antiquate montal control, and chairs walls also furnement as accusting memoryly. He apprint a long ft 7 and appliwheth a reliable to the first have an STE maning of 2014 to contribut. Figure 3 shows an interce IDF pertine coal with china systeor both soles. This asserting advances on \$72 ming of \$8. assessing the ICCLE sold of magnetized by multileville tabletuiter. Other exercises are initiated in the maintain of banked briggetering screek advance.

Accountical Differences between Mass Timber Panel Options

This is sparting of a scattalingly distance means from the paper-relation includes CDT transmoster basis basis and an extent data of the scattal distance of infrared technological constraints and the DLT and DLT a

For those interested on informing service assemblies and must be that given hyper and the lowership with modulation consists are leaded assemblies using CLT, NCT, given any wave transmission (CLT), and transmission graves declaring

Improving Performance by Minimizing Flanking

Even server the assumptions or a training and concludy and great and head the high soundary preformance. Investigations of develop performance in the examption programmers and develop performance and the perpendition of the example of a statement of the period and the training of the training to main mean assumption performance in dependition.

One way to extension tension parts a first-a constructions and interfaced at the sum markets presentation mentions and extension maps. These products are sampled of raiseting structures limits to congression bulk weak creations methods and onesettation into provide chains and these interfaces and simulation of data between creations on the sampled data structures that between sentences. In the provide data way these results, for interprove

scoutil of performance needs dense; those sings all as dense; those sings all as dense; there is a much prove dense; there is a much prove dense; there is a performance that the accusing performance of a much performance.



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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:

Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed	
Table 2: CLT Floor Assemblies without Concrete/Gypsum Topping, Ceiling Side Exposed	
Table 3: CLT Floor Assemblies without Concrete/Gypsum Topping, with Wood Sleepers, Ceiling Side Exposed	
Table 4: NLT, GLT & T&G Decking Floor Assemblies, Ceiling Side Exposed	
Table 5: Mass Timber Floor Assemblies with Ceiling Side Concealed	
Table 6: Single CLT Wall	
Table 7: Single NLT Wall	
Table 8: Double CLT Wall	
Sources	
Disclaimer	
http://bit.ly/mass_timbor_assomblies	1

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

Inventory of Tested Assemblies

	Concrete/C	# Applicable		-		
		optied or hung setting				
CLT Panel	Concrete/Gypsum Topping	Acoustical Mat Product Between CLT and Toppin	Finish Floor	STC ¹	IIC ¹	Source
			None	47º ASTC	47º AliC	
			LVT		49 ² AllC	1
		Carpet + Pad		75 ² AliC	1	
		Maxion Acousti-Mat* 3/4	LVT on Acousti-Top*		52 ² AliC	1
	1-1/2" Gyp-Crete*		Eng Wood on Acousti- Top*	-	51 ² AliC	1
			None	49 [±] ASTC	45 ² AIIC	5 ² AIIC
		Maxxon Acousti-Mat* % Premium	LVT	- 47º A		
			LVT on Acousti-Top*	1	49 ^z AliC	
	-		None	454	394	15
			LVT	485	474	16
CLT5-ply			LVT Plus	48%	49*	58
(6.875")		USG SAM N25 Ultra	Eng Wood	474	474	59
House and			Carpet + Pad	456	674	60
			Ceramic Tile	50*	464	61
			None	45*	424	15
	1-1/2" Levelrock*		IVT	481	444	16

Mass Timber in Multi-Family

Early Design Decision Example



7-story, 84 ft tall multi-family building

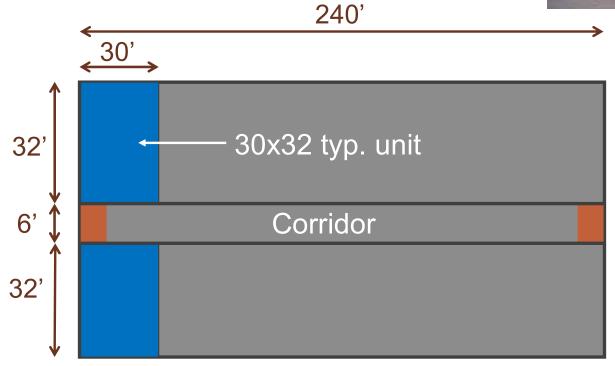
- Parking & Retail on 1st floor, residential units on floors 2-7
- NFPA 13 sprinklers throughout
- Floor plate = 18,000 SF
- Total Building Area = 126,000 SF



Early Design Decision Example

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

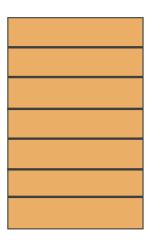


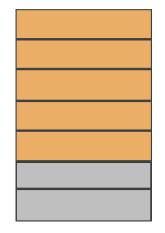


Early Design Decision Example

MT Construction Type Options:

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







Early Design Decision Example

MT Construction Type Options:

- <u>7 stories of IV-C</u>
- 5 stories of IIIA over 2 stories of IA podium
- 5 stories of IV-HT over 2 stories of IA podium

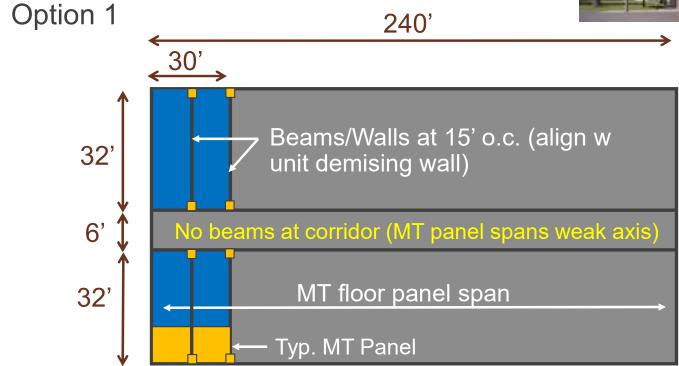
Implications of Type IV-C:

- 2 hr FRR, all exposed floor panels, beams, columns
- Likely will need at least 5-ply CLT / 2x6 NLT/DLT
- Efficient spans in the 14-17 ft range
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
- CLT exterior walls permitted



Early Design Decision Example

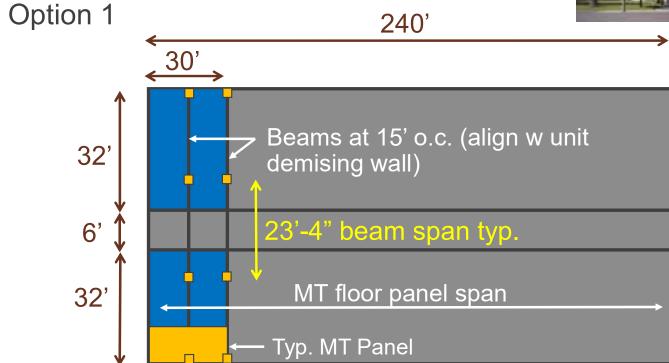
Type IV-C Grid Options





Early Design Decision Example

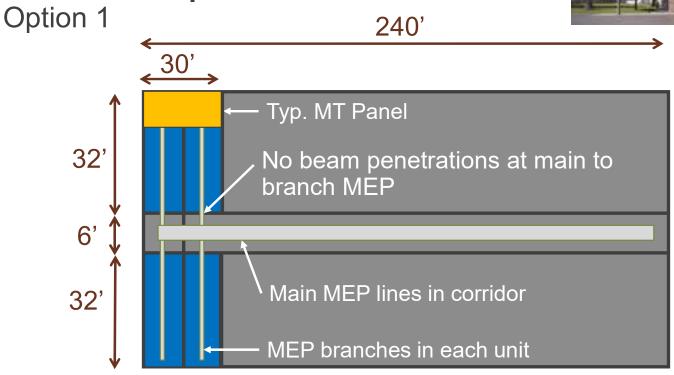
Type IV-C Grid Options





Early Design Decision Example

Type IV-C Grid Options

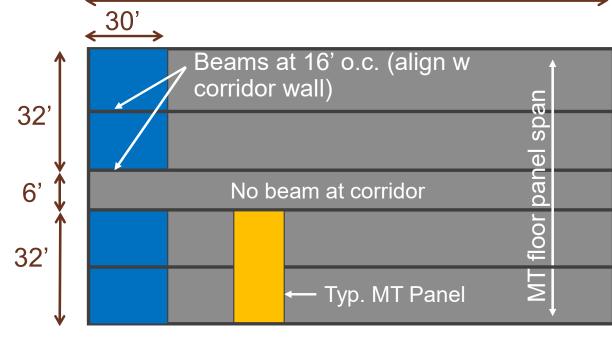




Early Design Decision Example

Type IV-C Grid OptionsOption 2



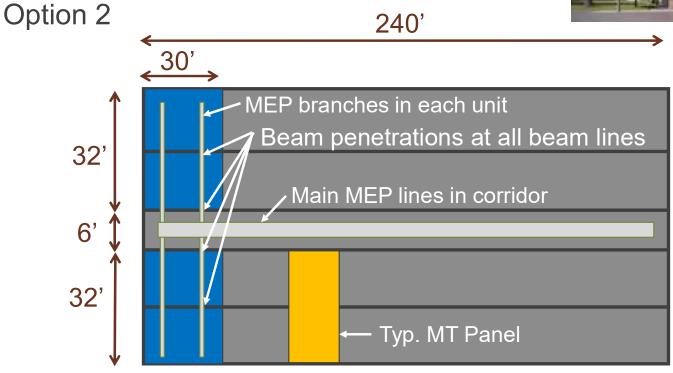


240'

Early Design Decision Example

Type IV-C Grid Options





Key Early Design Decisions Early Design Decision Example

Type IV-C Floor Assembly Options



Finish Floor if Applicable	_		 		 		
Concrete/Gypsum Topping							
Acoustical Mat Product	- Internet				 TT IT IT.		n n n
				6	 	-	
CLT Panel		-			 		
No direct applied or hung ceiling							

- 2-hr FRR: 5-ply CLT (tested assembly) or 7-ply CLT (char calculations)
- STC & IIC 50 min: 2" topping (5-ply CLT) or 1.5" topping (7-ply CLT) Note: many other acoustic mat and topping options exist, one example shown here Note: 5-ply is most efficient for the 15-16 ft panel spans shown

Early Design Decision Example

Credit: Monte French Design Studio

MT Construction Type Options:

- 7 stories of IV-C
- <u>5 stories of IIIA over 2 stories of IA podium</u>
- 5 stories of IV-HT over 2 stories of IA podium

Implications of Type IIIA:

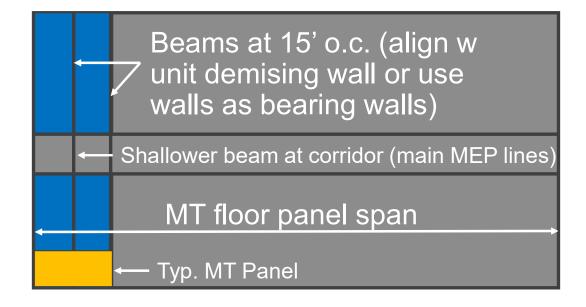
- 1 hr FRR
- Potential to use 3-ply or thin 5-ply CLT
- Efficient spans vary with panel thickness
- Efficient grids of that or multiples of that (i.e. 20x25, etc)
- 1 story Type IA podium required
- CLT exterior walls not permitted

Early Design Decision Example

Type IIIA Grid Options

Option 1



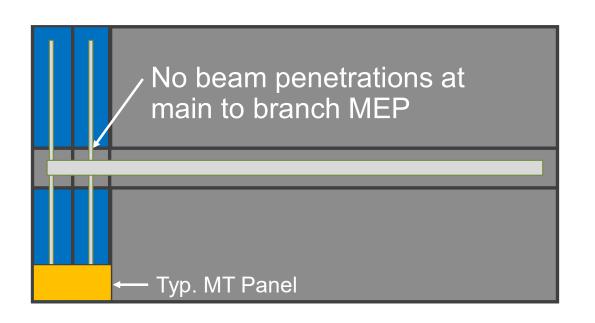


Early Design Decision Example

Type IIIA Grid Options

Option 1





Early Design Decision Example

MT Construction Type Options:

- 7 stories of IV-C
- 5 stories of IIIA over 2 stories of IA podium
- <u>5 stories of IV-HT over 2 stories of IA podium</u>

Type IV-HT in Group R Occupancy:

- Separation walls (fire partitions) and horizontal separation (horizontal assemblies) between dwelling units require a 1-hour rating.
- Floor panels require a 1-hour rating in addition to minimum sizes
- Essentially the same panel and grid options as IIIA

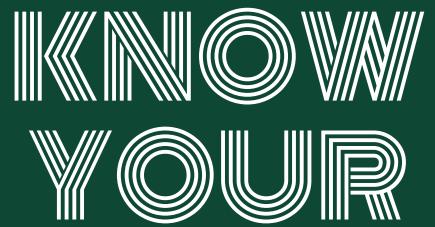
Ref. IBC 420.2, 420.3, 708.3, 711.2.4.3



Speed of Construction

Market Distinction

Sustainability





Leasing Velocity

Cost

Urban Density

Seattle Mass Timber Tower: Detailed Cost Comparison Fast Construction



- Textbook example done by industry experts
- Mass timber vs. PT conc
- Detailed cost, material takeoff & schedule comparisons

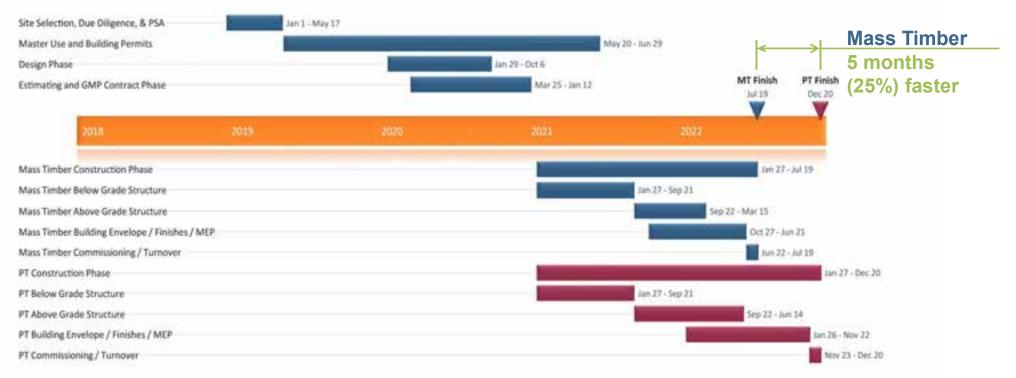
"The initial advantage of Mass Timber office projects in Seattle will come through the

leasing velocity

that developers will experience." - Connor Mclain, Colliers

Seattle Mass Timber Tower Fast Construction

Construction Schedule:



Source: Tall With Timber A Seattle Mass Timber Tower Case Study by DLR Group¹

Seattle Mass Timber Tower

Faster Construction + Higher Material Costs = Cost Competitive

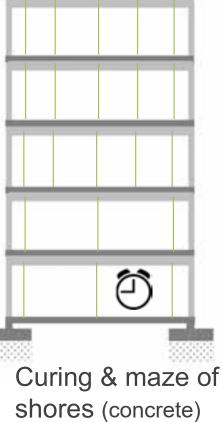
System	Mass Timber Design	PT Concrete Design	Mass Timber Savings	
Direct Cost of Work	\$86,997,136	\$85,105,091	2.2%	
Project Overhead	\$ 9,393,750	\$11,768,750	-20.2%	
Add-Ons	\$ 8,387,345	\$ 8,429,368	-0.5%	
Total	\$104,778,231	\$105,303,209	-0.5%	

Source: DLR Group | Fast + Epp | Swinerton Builders

Schedule Savings for Rough-In Trades Fast Construction



(mass timber)





Holistic Cost Assessment – 8 Stories in Boston



Reference 1 Concrete Slabs on Steel Deck; Steel Frame; Concrete Cores



Reference 2 Concrete Flat Slab, Concrete Cores



Timber Use 1 Timber Floors: Steel Frame: Concrete Cores



Timber Use 2 Timber Post, Beam, & Plate; Concrete Cores



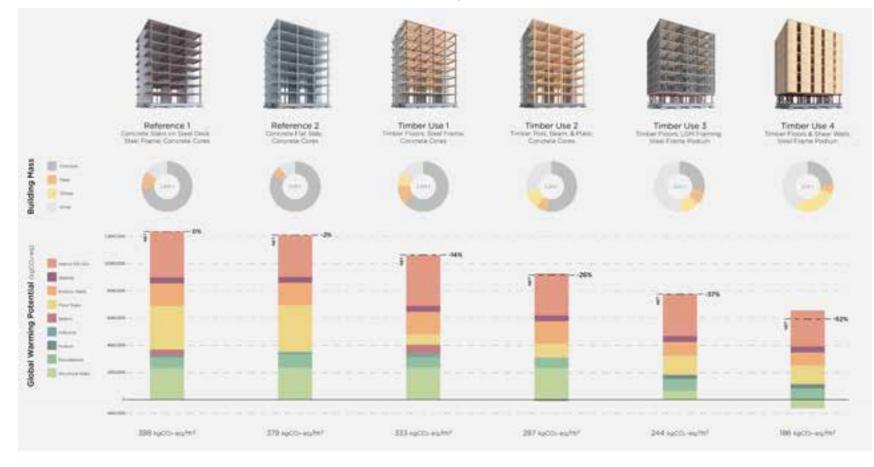
Timber Use 3 Timber Floors: LGM Framing: Steel Frame Podium



Timber Use 4 Timber Floors & Shear Walls: Steel Frame Podium

Source: Generate Architecture + Technologies

Sustainability Impacts



GLOBAL WARMING POTENTIAL & MATERIAL MASS (PER BUILDING ASSEMBLY)

Source: Generate Architecture + Technologies

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Reduce Risk Optimize Costs

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

WoodWorks

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 farchitects 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.

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



www.woodworks.org

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

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

Mass Timber in Multi-Family Housing: Is it a Good Fit for Your Project?

There's a good chance it is...Let's talk about it!

Credit: D/O Architects

Questions? Ask us anything.



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



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