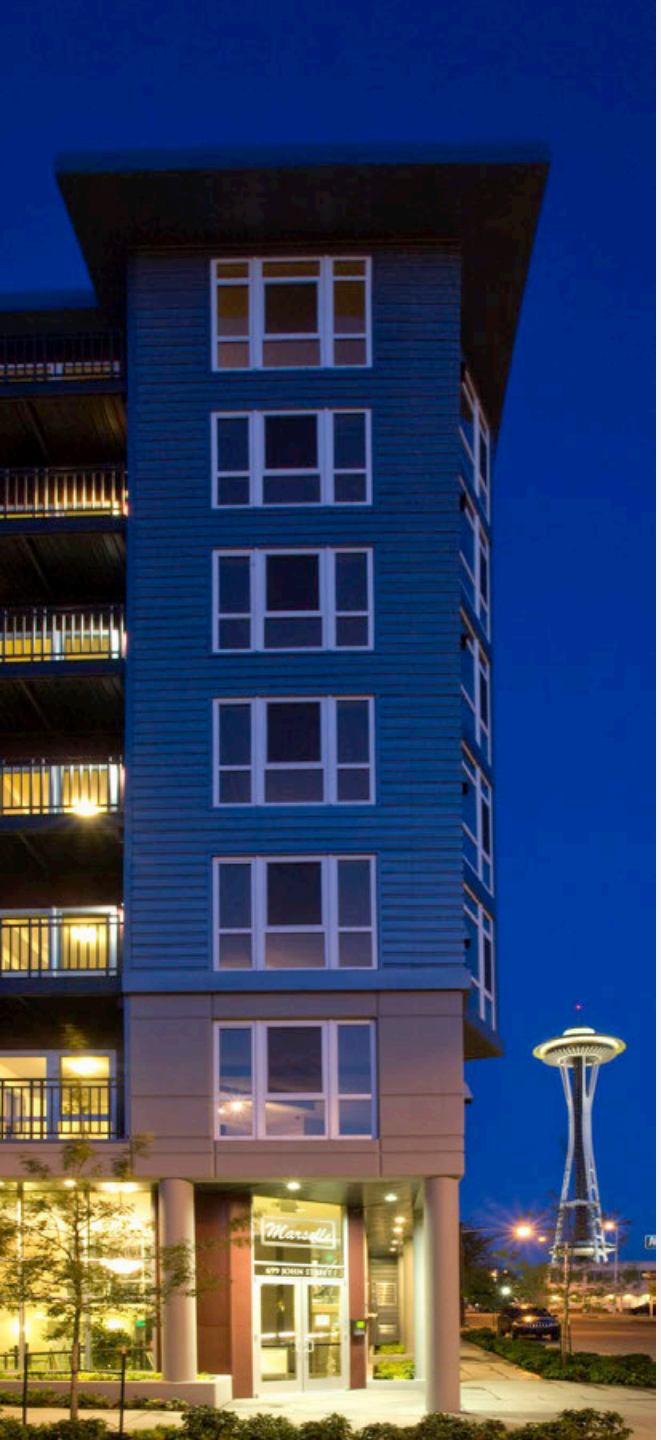
Mid-Rise Wood Design

May 7, 2025

Presented by
Shannon A. Williams, PE
WoodWorks

Image: Thomas Logan / Pivot North Architects / Axiom / Chad Case Visuals



Mid-Rise and Multi-Family Design

Optimizing Size, Maximizing Value

INTRODUCTION TO HEIGHTS AND AREAS
FOR MID-RISE WOOD FRAME BUILDINGS

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AIA Approved Continuing Education

Course Description

As cities seek increased density to address urban population growth, many building designers and developers are looking to mid-rise wood construction as a cost-effective, code-compliant and sustainable solution. This presentation will cover some of the design considerations associated with mid-rise wood-frame buildings, including how to maximize height and area through the use of sprinklers, open frontage, sloping sites, podiums and mezzanines. Construction types will be reviewed, with an emphasis on opportunities for wood use in types III and V.

Learning Objectives

1. In the context of a shift toward increased urban density, learn how mid-rise, wood-frame construction meets housing needs while contributing to vibrant and sustainable communities.
2. Discuss allowable construction types, occupancies, and building heights and areas for wood-frame mid-rise construction per the International Building Code.
3. Identify potential modifications to the IBC's base tabular heights and areas based on code provisions for building frontage, sprinklers, sloping sites, podiums and mezzanines.
4. Highlight constructed buildings that were designed using these code provisions to maximize density.

Outline

- Context for Mid-Rise Construction
- Mid-rise Building Types/Configurations
- Maximizing Height & Area

Landing Apartments, Russell Scott Steedle & Capione Architects, photo Gregory Folkins

Outline

- Context for Mid-Rise Construction
  - Mid-rise Building Types/Configurations
  - Maximizing Height & Area

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

Global Population Boom

Global Population

7.9 billion in 2022

9.7 billion by 2050

23% increase

Urban Population

6.4 billion by 2050

62% increase

Source: United Nations Department of Economic and Social Affairs

Sustainable Multi-Family & Mixed-Use Structures

Economically Meet
Urban Housing Needs

Increase Environmental
Responsibility

These 2 items don't need to be in opposition—
Wood-framing helps them work together!

Sustainable Multi-Family & Mixed-Use Structures

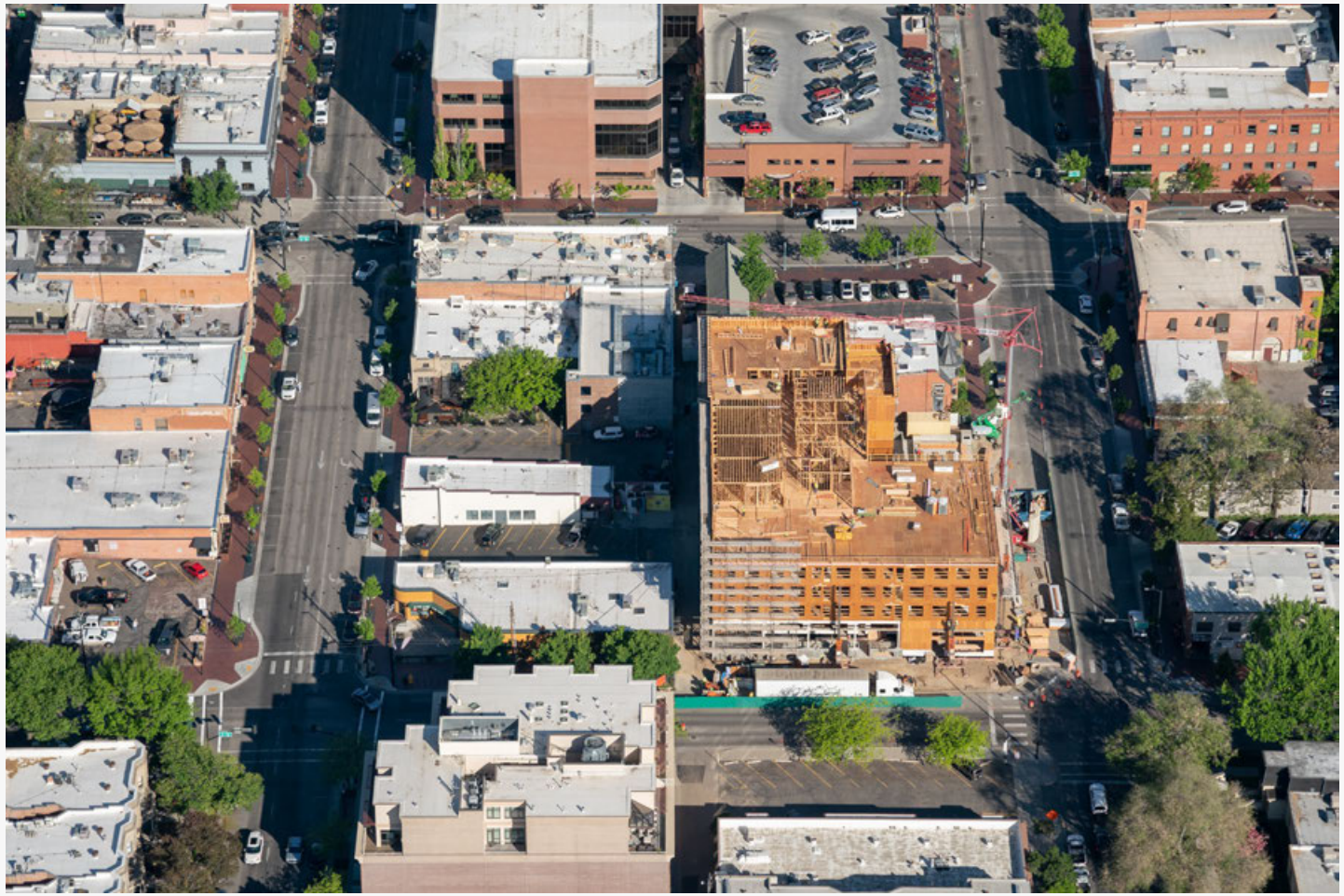
Mid-rise wood-frame construction provides a common ground for both

How?

Mid-Rise Construction

Where **wood** is a viable option,
it's likely the most appropriate choice.

- Senior Living
- Apartments/Condos
- Mixed Use
- Student Housing
- Affordable Housing
- Hotels



The Gibson, Hummel Architects, KPFF Consulting Engineers, photo Leo A. Geis

Why Wood?

Using wood helps reduce environmental impact
Wood products play significant role in modern economy

- Wood Costs Less
- Wood is Versatile
- Wood Meets Code
- Wood is Durable
- Wood is Renewable

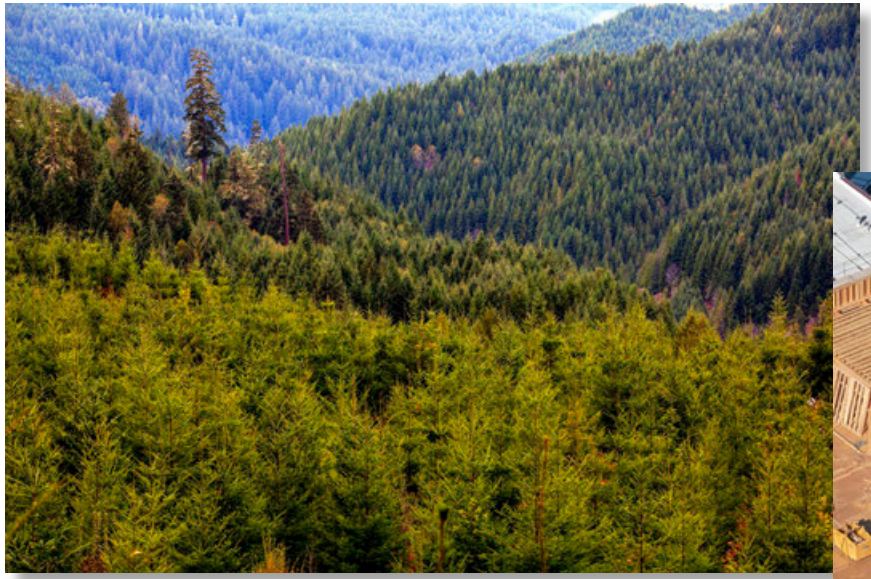
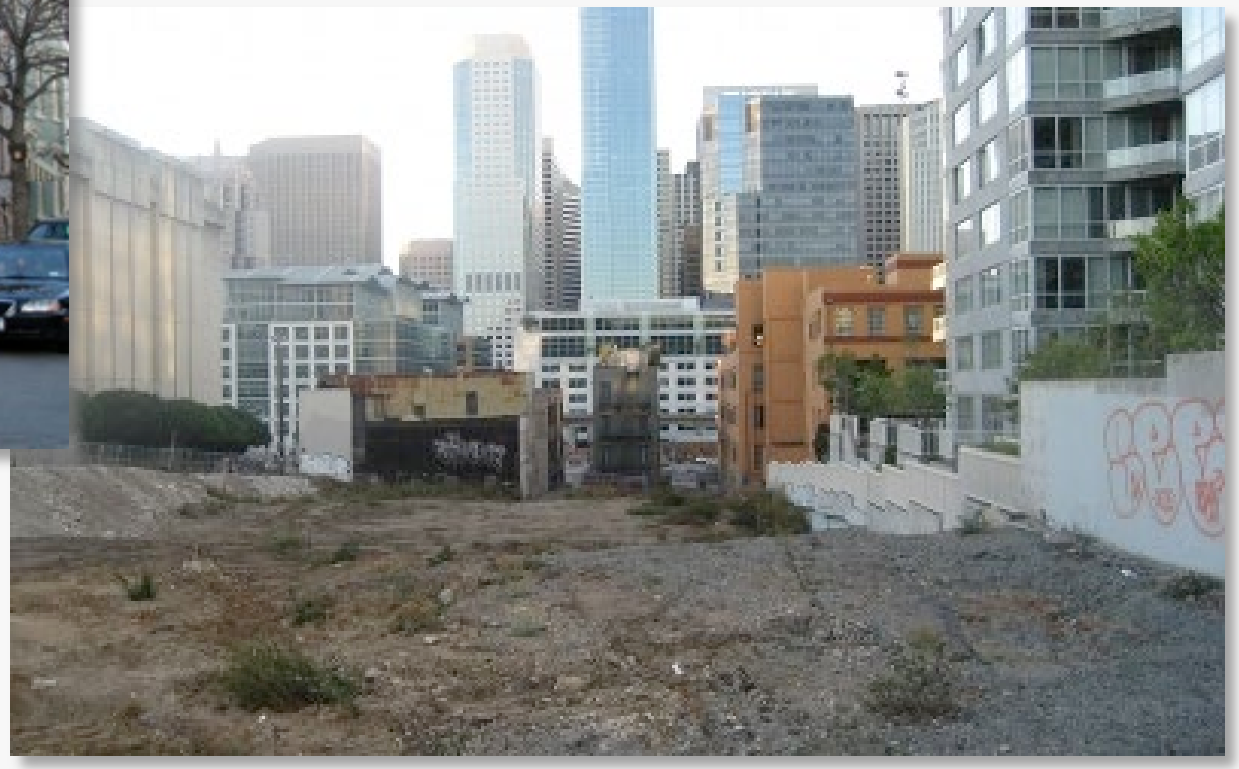


Photo courtesy OFRI

The Gibson, Hummel Architects, KPFF Consulting Engineers, photo Leo A. Geis

Urban Infill Development



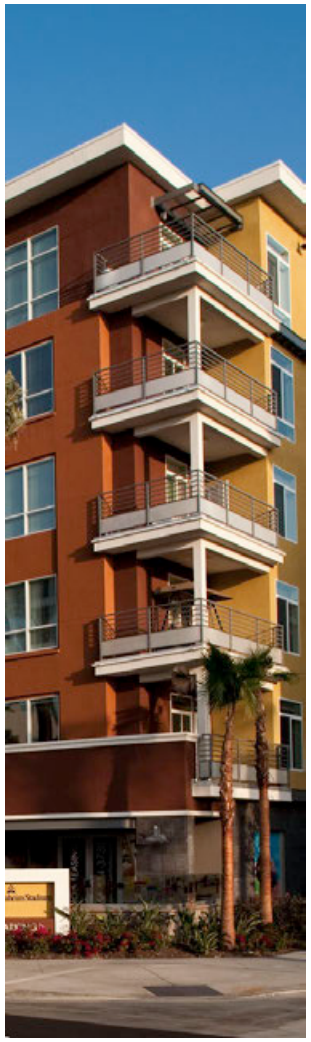
Case Study | Wood Buildings Aim High

AvalonBay Stadium

Location: Anaheim, CA
251 Apts., 13K sf retail/restaurant
Type III modified
50% of their projects are podium
Semi-balloon framed with 16" Open web trusses at exterior walls

Architect: Withee Malcolm Architects
Engineer: VanDorpe Chou Associates
Developer/Contractor: AvalonBay Communities
Photo credit: Arden Photography

Carbon Case Study | High Density



AvalonBay Stadium- Anaheim, CA

Climate Change Advantage:

Volume of wood used:
5,200 cubic meters / 183,600 cubic feet of lumber and sheathing

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

Carbon stored in the wood:
3,970 metric tons of CO_2

Avoided greenhouse gas emissions:
8,440 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
12,410 metric tons of CO_2

EQUIVALENT TO:

2,370 cars off the road for a year

Energy to operate a home for 1,050 years

Source: US EPA

For information on the calculations in this chart, visit woodworks.org
Note: CO_2 on this chart refers to CO_2 equivalent.

Outline

- Context for Mid-Rise Construction
- **Mid-rise Building Types/Configurations**
- Maximizing Height & Area

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

Seattle, WA

Photo: Matt Todd/PB Architects

College Park , MD

Photo: Matt Church

Normal, IL

Image: OKW Architects

Los Angeles, CA

Photo: Lawrence Anderson/Esto

Atlanta, GA

Image: Lord Aeck Sargent

Wood Mid-Rise Construction

How many stories can be wood framed in the IBC?

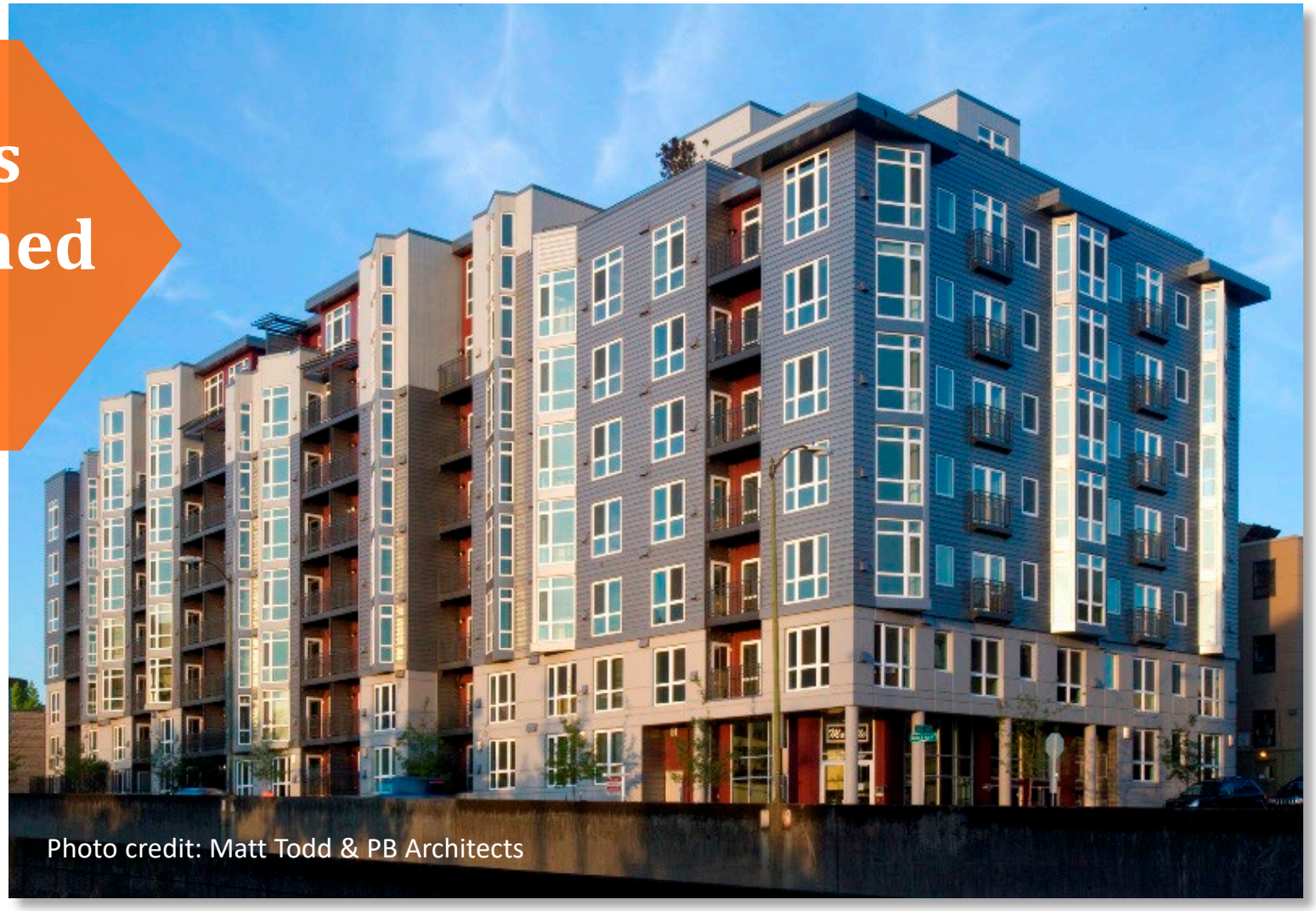


Photo credit: Matt Todd & PB Architects

Wood Mid-Rise Construction

6 stories for Offices,
5 stories for Residential
+ Mezzanine
+ Multi-Story Podium

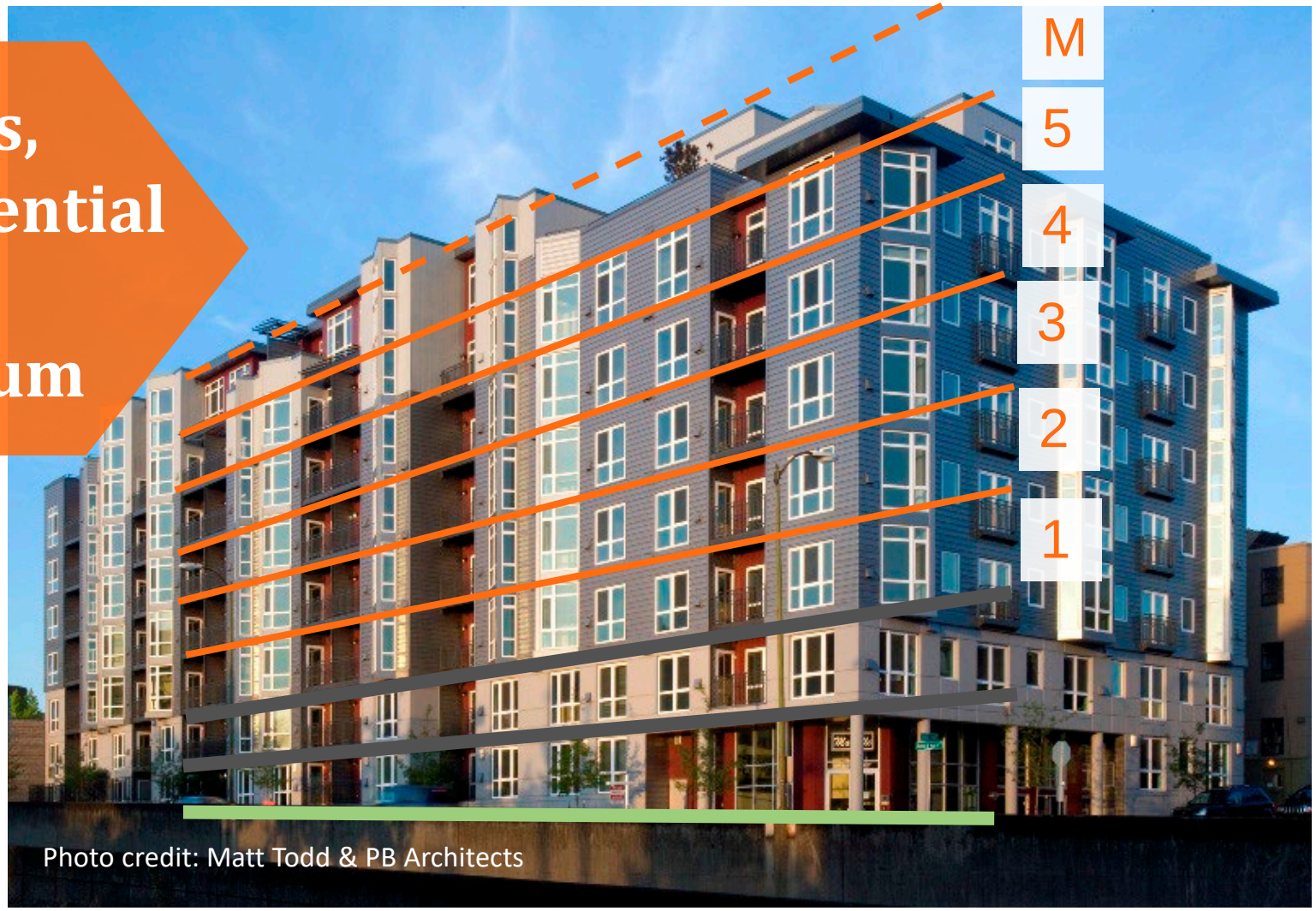
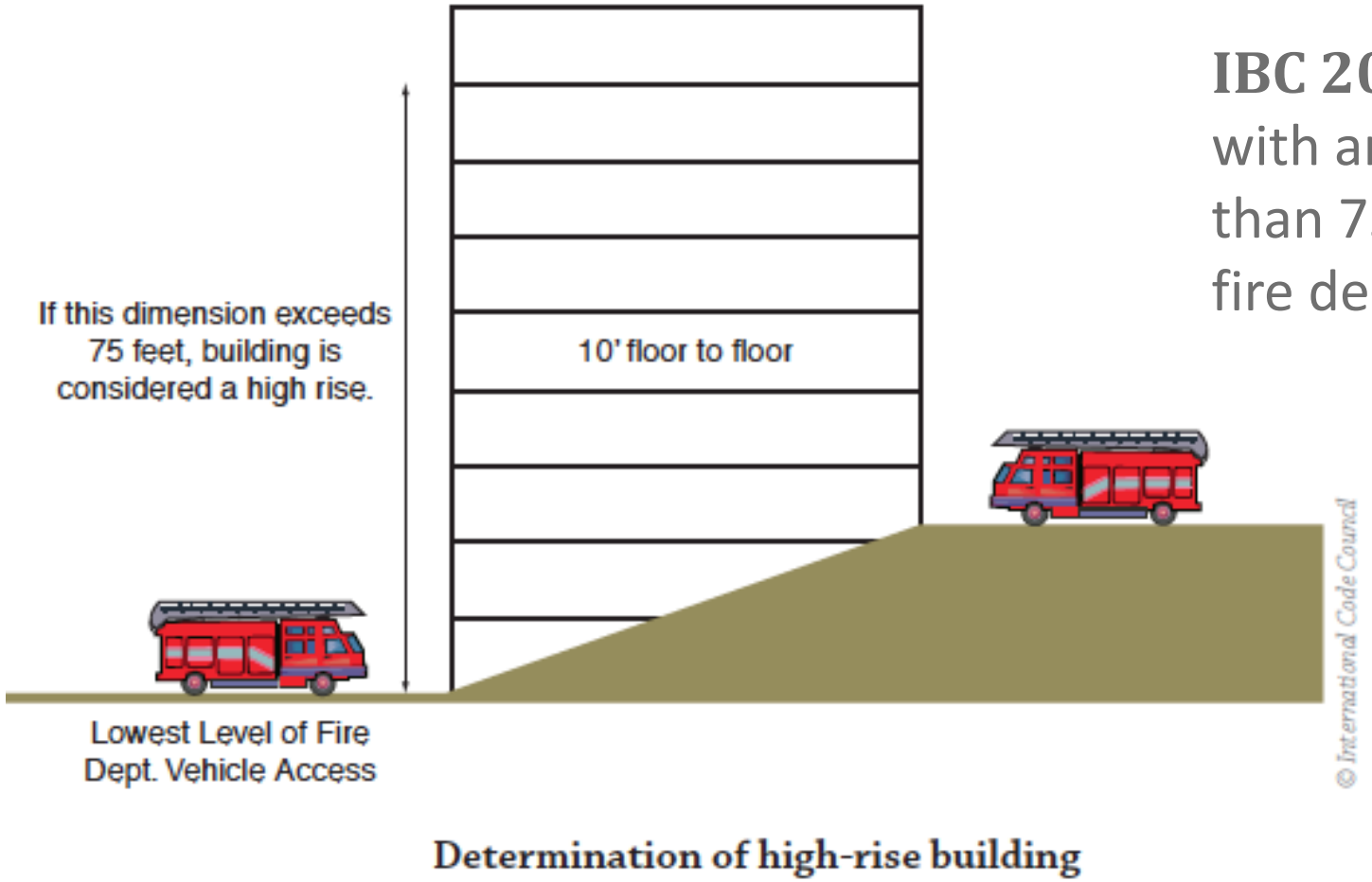


Photo credit: Matt Todd & PB Architects

Mid-Rise vs. High-Rise Definition – 2018/2021 IBC 202



Determination of high-rise building

IBC 202: High-Rise Building: A building with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access.

Walk-up / Tuck Under

First floor walk up units with private garage

Benefits:

- Eliminates need for S-2 parking garage
- Can be all wood
- Least expensive overall but lowest densification rates (20-35 units/acre)

Wrap-Around

Walk up units surround parking structure

Benefits:

- Enhanced security
- Centralized access to parking
- Visual appeal from street
- More expensive than walk/up tuck-under
- 5 story yields 60-80 units/acre

Podium

Multiple stories of wood over an elevated concrete deck

Benefits:

- Increased number of stories
- Accommodates Mixed-use occupancies
- Most expensive but can allow increased density

Podium

4 stories of residential over podium (parking or retail)

- 60–80 units/acre

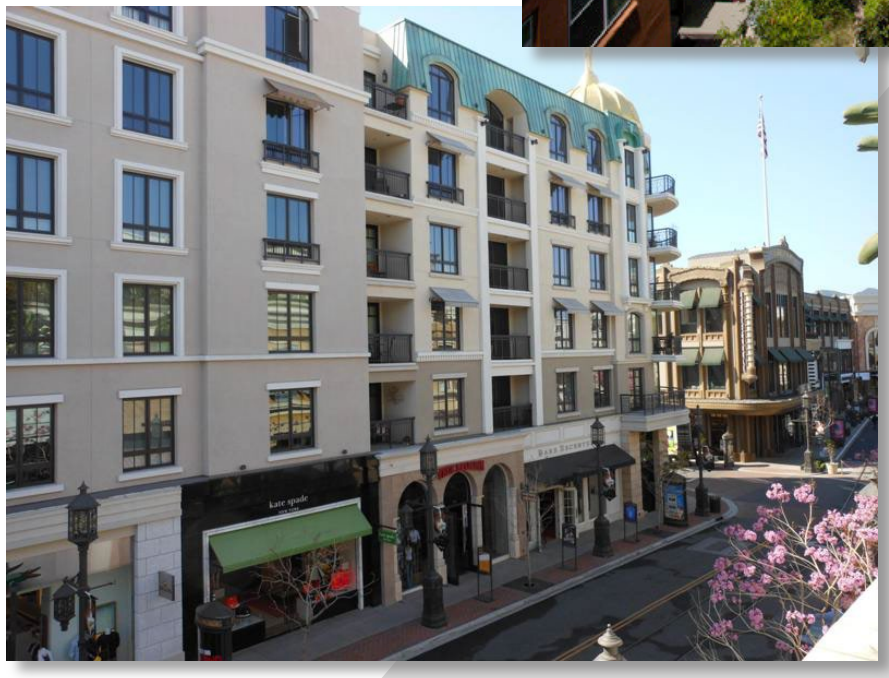
Inman Park Condos, Atlanta, GA
Davis & Church

Podium

5 stories over retail

» 100–120 units/acre

AvalonBay Stadium, Anaheim, CA
VanDorpe Chou Associates



Inman Park Condos, Atlanta, GA
Davis & Church

Podium

5 stories over residential podium

» 120–140 units/acre

16 Powerhouse, Sacramento, CA
D&S Development
LPA Sacramento

Mezzanine & Podium

5 stories with mezzanine + residential podium

» 125–145 units/acre

120 Union, San Diego, CA
Togawa Smith Martin

Outline

- » Context for Mid-Rise Construction
- » Mid-rise Building Types/Configurations
- Maximizing Height & Area
  1. Construction Types
  2. Tabulate Areas & Stories
  3. Allowable increases
  4. Mezzanine & Special Design Provisions

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

Typical Mid-rise Occupancy

Hotels (R-1)

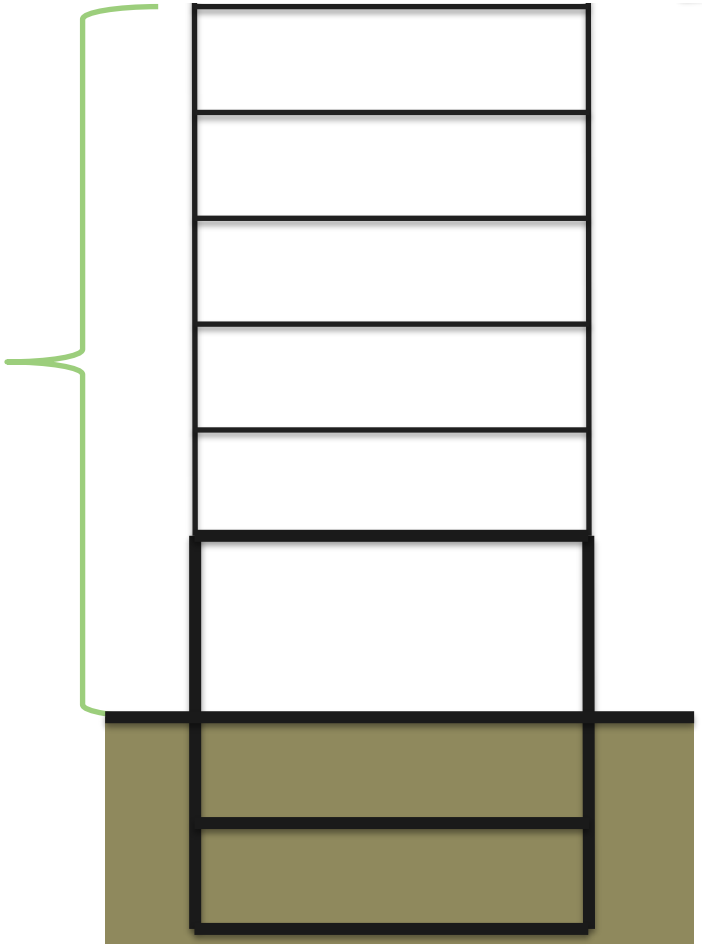
Apartments (R-2)

Condominiums (R-2)

Student housing (R-2)

Live/work units (R-2)

Assisted living (R-4)



(A-2) Restaurants/cafeterias

(A-3) Workout facilities

(A-3) Meeting rooms

(B) Offices

Nursing homes (I-2)

(M) Shops

(S-2/U) Parking

(S-1) Storage

Mid-Rise Construction Types

Type III

- Exterior walls non-combustible (may be light frame FRTW)
- Interior elements any allowed by code

Type V

- All building elements any allowed by code

Types III and V can be subdivided:

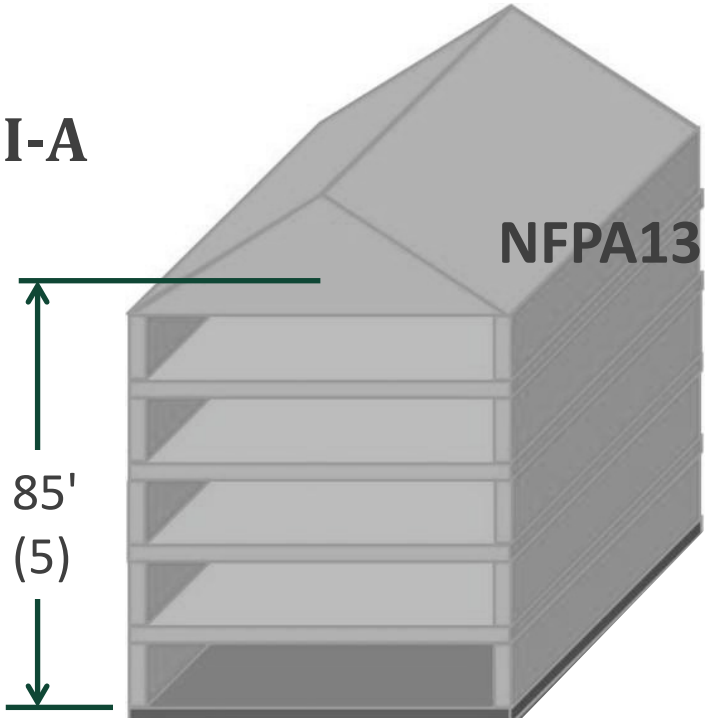
- A (protected)
- B (unprotected)

Type IV (C & HT)

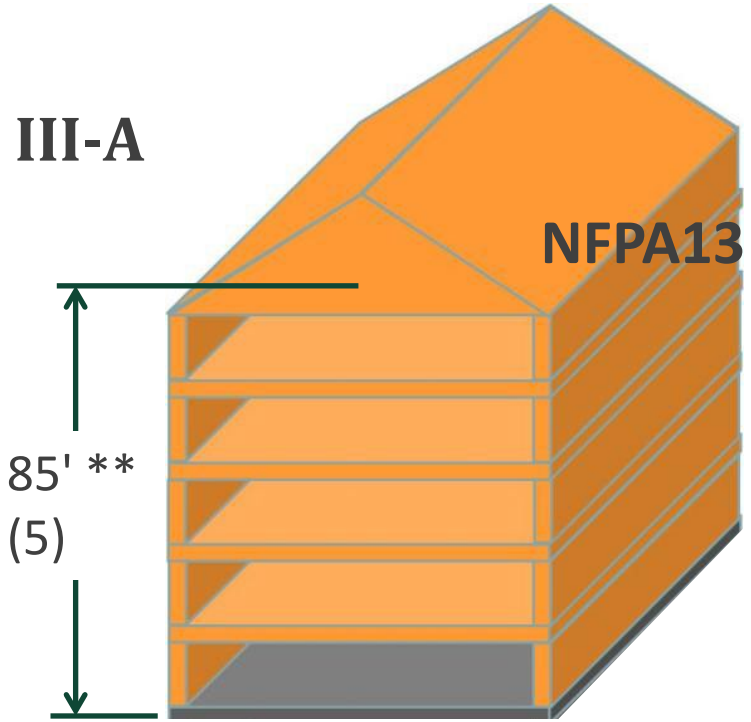
- All building elements mass timber (covered CLT) or non-combustible
  - For IV-HT, interior elements may also be 1-hour FRR light frame
  - For IV-HT, exterior walls may also be FRTW, including light frame walls)

Increased Height & Story Area: Residential Occupancy

Type II-A



Type III-A

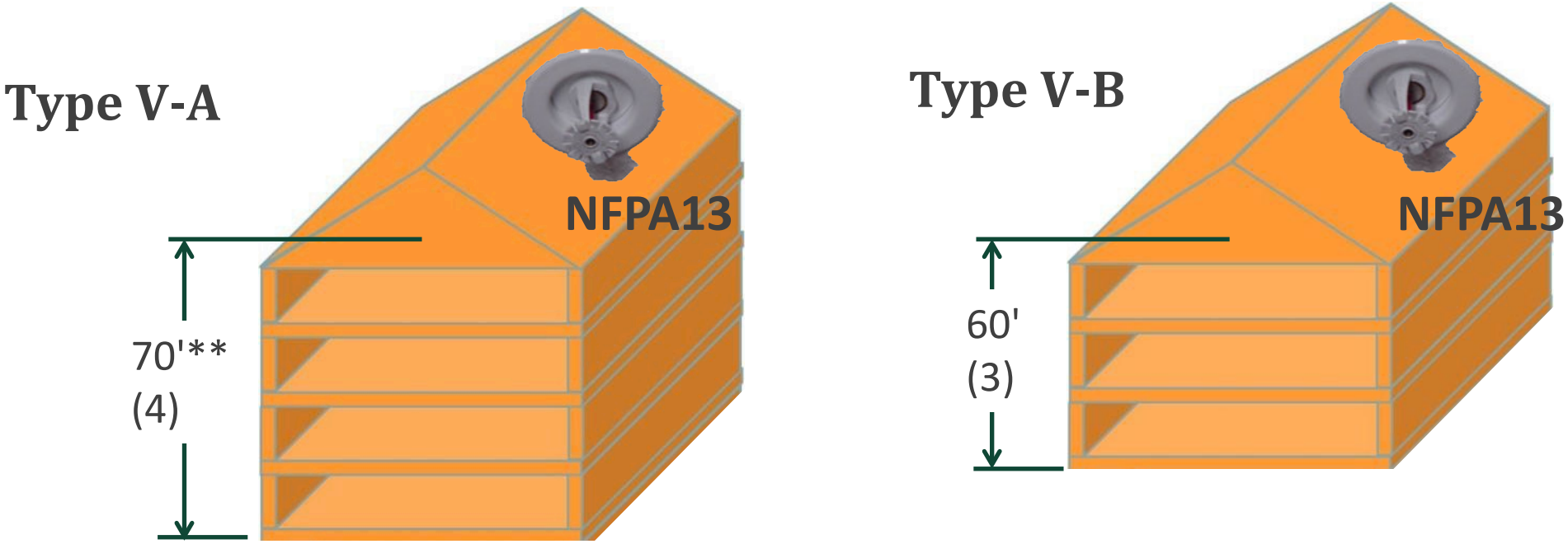


Occupancy	II-A (ft^2)*	III-A (ft^2)*
R-1	72,000 +18,000 (max frontage)	72,000 +18,000 (max frontage)
R-2	72,000 +18,000 (max frontage)	72,000 +18,000 (max frontage)

* Areas reflect PER STORY max. Total building max may limit area further.

** ASCE7-16 Table 12.2-1 limits wood shear wall seismic systems to 65' in height in SDC D,E,F

Increased Height & Story Area: Residential Occupancy

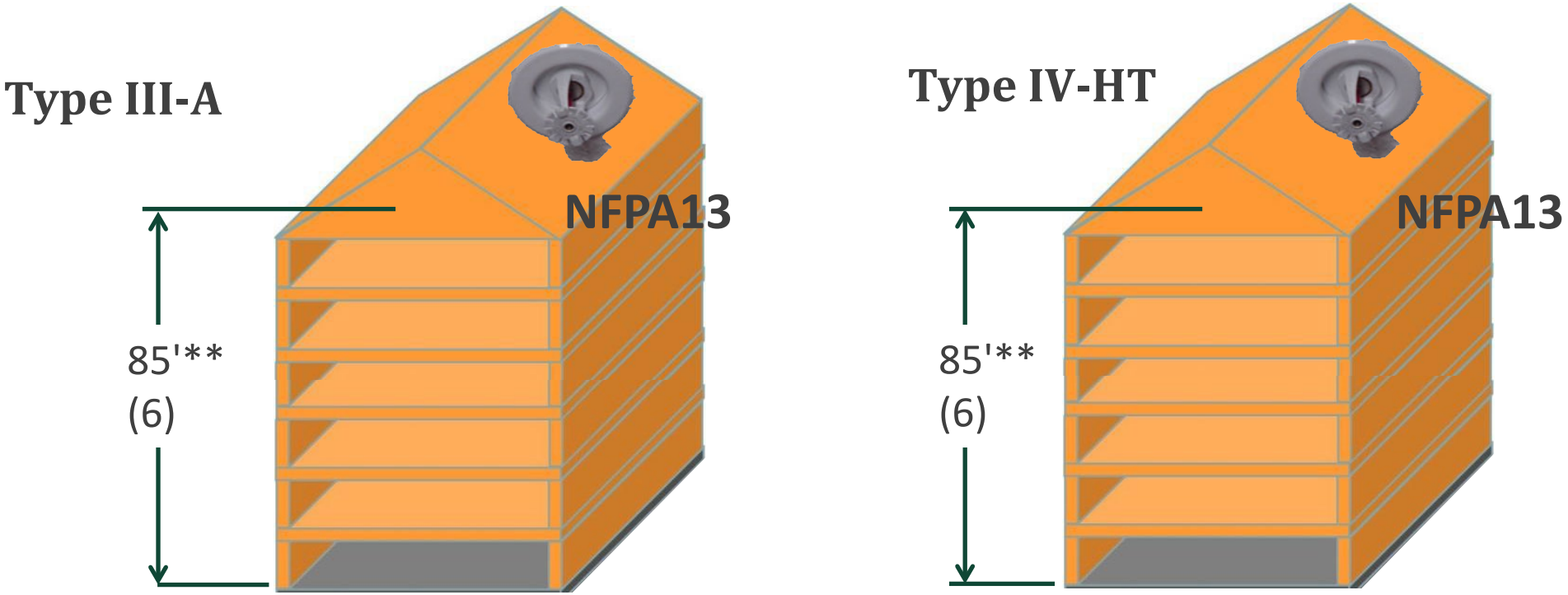


Occupancy	V-A (ft^2)*	V-B (ft^2)
R-1	36,000 +9,000 (max frontage)	21,000 +5,250 (max frontage)
R-2	36,000 +9,000 (max frontage)	21,000 +5,250 (max frontage)

* Areas reflect PER STORY max. Total building max may limit area further.

** ASCE7-16 Table 12.2-1 limits wood shear wall seismic systems to 65' in height in SDC D,E,F

Increased Height & Story Area: Office Occupancy



Occupancy	III-A (ft^2)*	IV-HT (ft^2)*
B	85,500 +21,375 (max frontage)	108,000 +27,000 (max frontage)

* Areas reflect PER STORY max. Total building max may limit area further.

** ASCE7-16 Table 12.2-1 limits wood shear wall seismic systems to 65' in height in SDC D,E,F

Height – 2021/2024 IBC Table 504.3

- IBC 2021: Table 504.3 provides base & increased heights

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION												
	See Footnotes	Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S13D	60	60	60	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	270	180	85	85	70	60

NS = Buildings not equipped throughout with an automatic sprinkler system

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

S13D = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.3 (NFPA 13D)

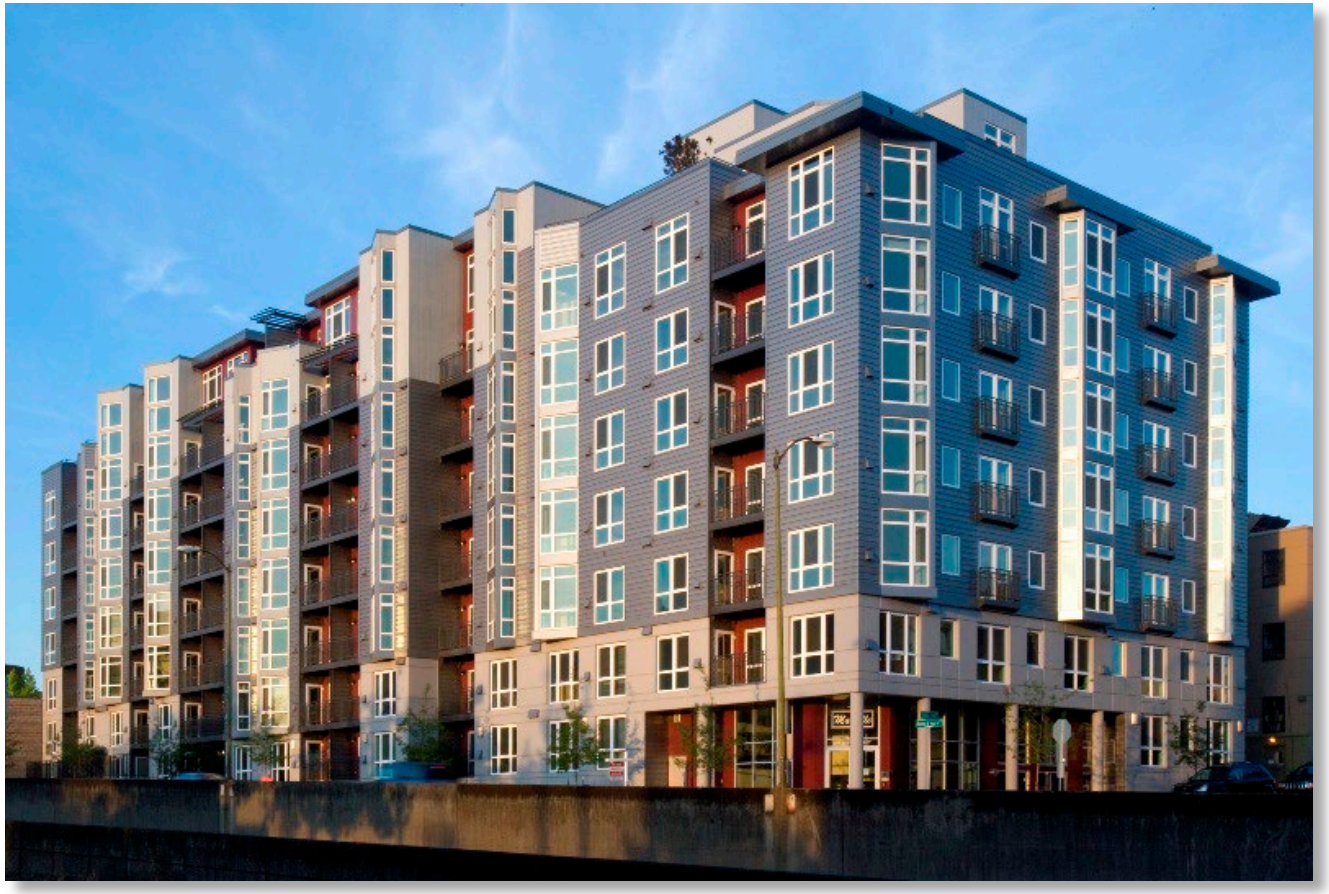
Stories – 2021/2024 IBC Table 504.4

TABLE 504.4
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE[a, b]

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-2	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-3	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
B	NS	UL	11	5	3	5	3	5	3	2
	S	UL	12	6	4	6	4	6	4	3
R-1[h]	NS[d]	UL	11	4	4	4	4	4	3	2
	S13R	4	4						4	3
	S	UL	12	5	5	5	5	5	4	3
R-2[h]	NS[d]	UL	11	4	4	4	4	4	3	2
	S13R	4	4	4					4	3
	S	UL	12	5	5	5	5	5	4	3
S-1	NS	UL	11	4	2	3	2	4	3	1
	S	UL	12	5	3	4	3	5	4	2

Sloped Sites

Fashion Valley, CA
AvalonBay Communities



Seattle, WA
PB Architects

Sloped Sites – Chapter 2 Definitions

HEIGHT, BUILDING. The vertical distance from *grade plane* to the average height of the highest roof surface.

GRADE PLANE. A reference plane representing the average of finished ground level adjoining the building at *exterior walls*. Where the finished ground level slopes away from the *exterior walls*, the reference plane shall be established by the lowest points within the area between the building and the *lot line* or, where the *lot line* is more than 6 feet (1829 mm) from the building, between the building and a point 6 feet (1829 mm) from the building.

626 Dekalb Avenue, Atlanta, GA
Matt Church - Davis Church Structural Engineers

Basements –IBC 506.1.3

A basement is not included in the total allowable building area if it doesn't exceed the area permitted for a building with no more than one story above grade plane.

"Basement" is defined as "not a story above grade plane" and has a finished floor surface of the next floor above:

- Less than 6 feet above grade plane; or
- Less than 12 feet above the finished ground level at any point

Fashion Valley, CA
AvalonBay Communities

Summary of Building Heights

Building Heights and Stories by Building Type With NFPA 13 Sprinklers				
Occupancy	III-A	III-B	V-A	V-B
	85 ft	75 ft	70 ft	60 ft
R-1/R-2/R-4	5	5	4	3
A-2/A-3	4	3	3	2
B	6	4	4	3
M	5	3	4	2
S-2	5	4	5	3
S-1	4	4	4	2

**ASCE7 12.2-1 limits wood shear wall seismic systems to 65’ in height in SDC D,E,F

Sprinkler Systems: IBC 903.2

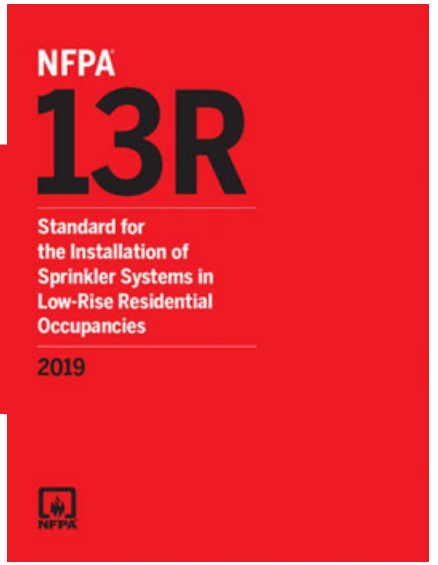
In some cases, sprinklers are required by code depending on occupancy

- Most new Group R fire areas
- Group A, E, M, S-1, I fire areas exceeding 1-12k sf

Stella Apartments, DesignARC, Taylor and Syfan, photo Lawrence Anderson

Commercial Sprinkler Systems – IBC 903.3.1

- NFPA 13
  Standard for Commercial Construction 903.3.1.1
- NFPA 13R
  Residential Occupancies (One- and Two-Family or Low-Rise Multi-Family and Commercial) 903.3.1.2
- NFPA 13D
  Standard for One- and Two-Family Residences (but allowed in a few commercial occupancies) 903.3.1.3



NFPA 13 vs. NFPA 13R

NFPA 13	NFPA 13R
Goal: Provide life safety and property protection	Goal: Provide life safety only
Fully sprinklered system throughout entire building even in unoccupied spaces (closets, attics)	Partially sprinklered system; unoccupied spaces often don't require sprinklers
Can cost more	Lower levels of water discharge, shorter water supply time can result in smaller pipe sizes, reduce need for storage & pumps
Permitted for many occupancies, buildings of many sizes, allows greater building size increases	Limited applications, mainly for multi-family up to 4 stories, 60 feet

Area Increases – 2021/2024 IBC Table 506.2

TABLE 506.2

ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, S13D or SM, as applicable) IN SQUARE FEET[a, b]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION											
		Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
R-1[h]	NS[d]	UL	UL	24,000	16,000	24,000	16,000	61,500	41,000	25,625	20,500	12,000	7,000
	S13R												
	S1	UL	UL	96,000	64,000	96,000	64,000	246,000	164,000	102,500	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	184,500	123,000	76,875	61,500	36,000	21,000

**Can still increase these areas by the Frontage Factor of Section 506.3

NS = Buildings not equipped throughout with an automatic sprinkler system

S1 = Buildings a maximum of one story above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

SM = Buildings two or more stories above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

Single Occupancy – IBC 506.2.1

$$A_a = A_t + [NS \times I_f]$$

(Equation 5-1)

A_a = Allowable area per story (sq. ft.)

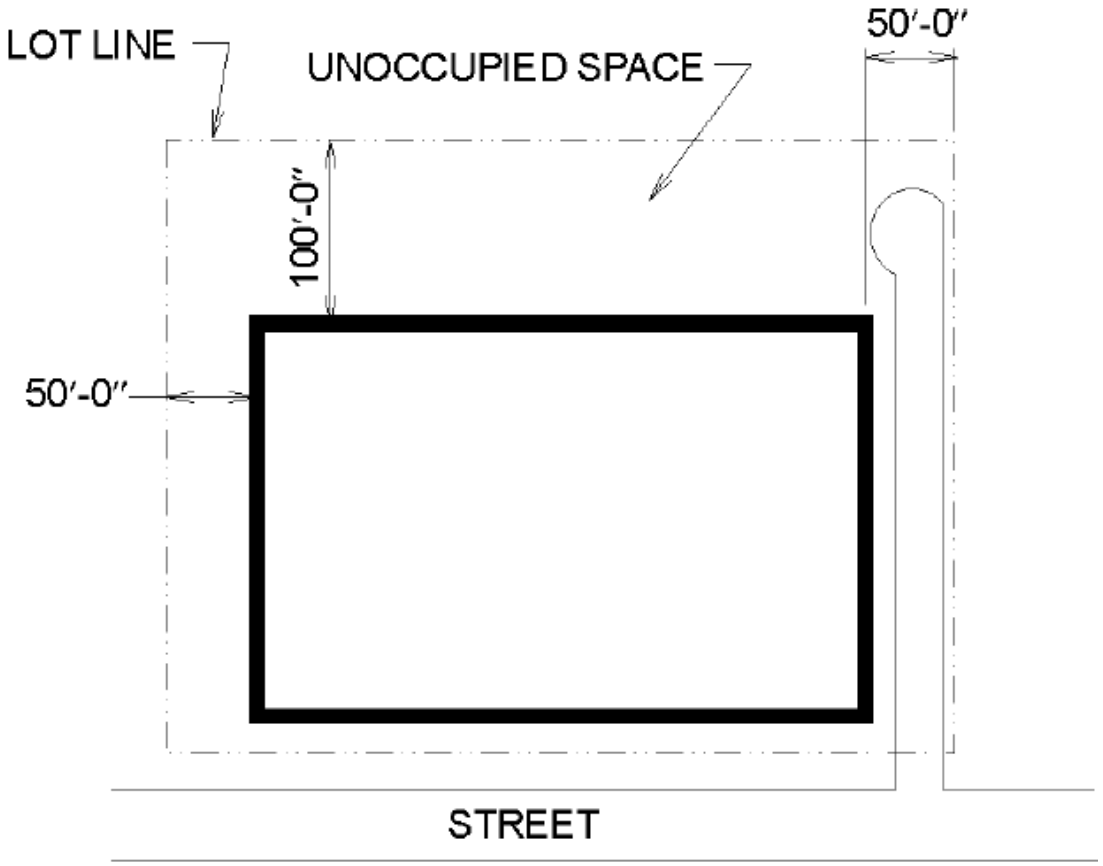
A_t = Tabular allowable area per story per Table 506.2 for NS, S1 or S13R (sq. ft.)

NS = Tabular allowable area per story per Table 506.2 for non-sprinklered building (sprinklered or not)

I_f = Area increase factor due to frontage per 506.3
$I_{f,\ max} = 0.75$

Area Modification – Frontage IBC 506.3

- Allowable area increase for frontage
  - Streets (public ways)
  - Open Spaces
- Frontage provides:
  - Access by fire service personnel
  - Temporary refuge for occupants
  - Reduced exposure to/from adjacent structures



Frontage Increases – 2021/2024 IBC 506.3.3

I_f = Area factor increase due to frontage

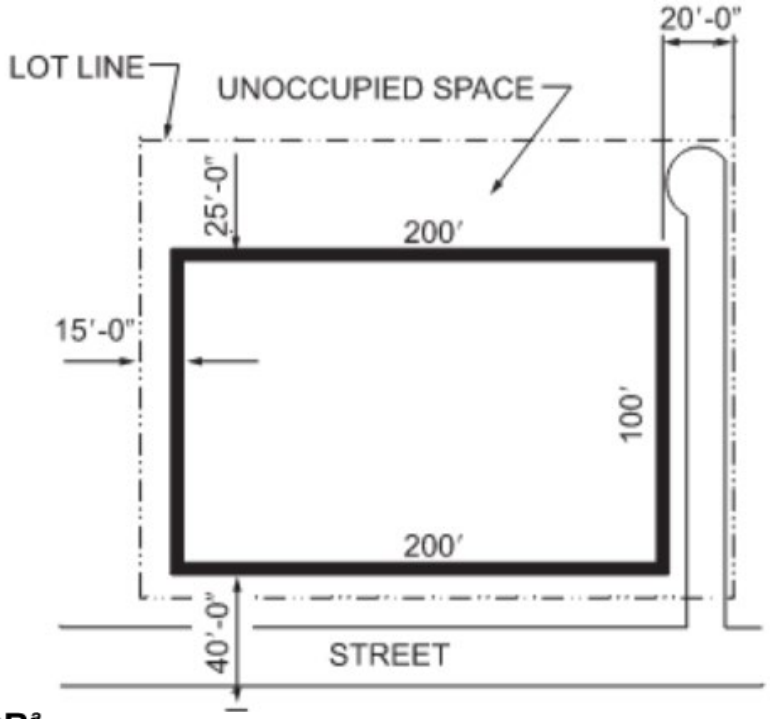


TABLE 506.3.3
FRONTAGE INCREASE FACTOR[a]

PERCENTAGE OF BUILDING PERIMETER	OPEN SPACE (feet)			
	0 to less than 20	20 to less than 25	25 to less than 30	30 or greater
0 to less than 25	0	0	0	0
25 to less than 50	0	0.17	0.21	0.25
50 to less than 75	0	0.33	0.42	0.50
75 to 100	0	0.50	0.63	0.75

Area Modification – Frontage IBC 506.3

MINIMUM QUALIFICATIONS

25% min of building perimeter is on a public way or open space 20' min distance from building face to:

- Closest interior lot line
- Entire width of street, alley, or public way
- Exterior face of adjacent building

EXCEPTIONS

Where building meets Unlimited requirements of IBC 507

And W > 30'

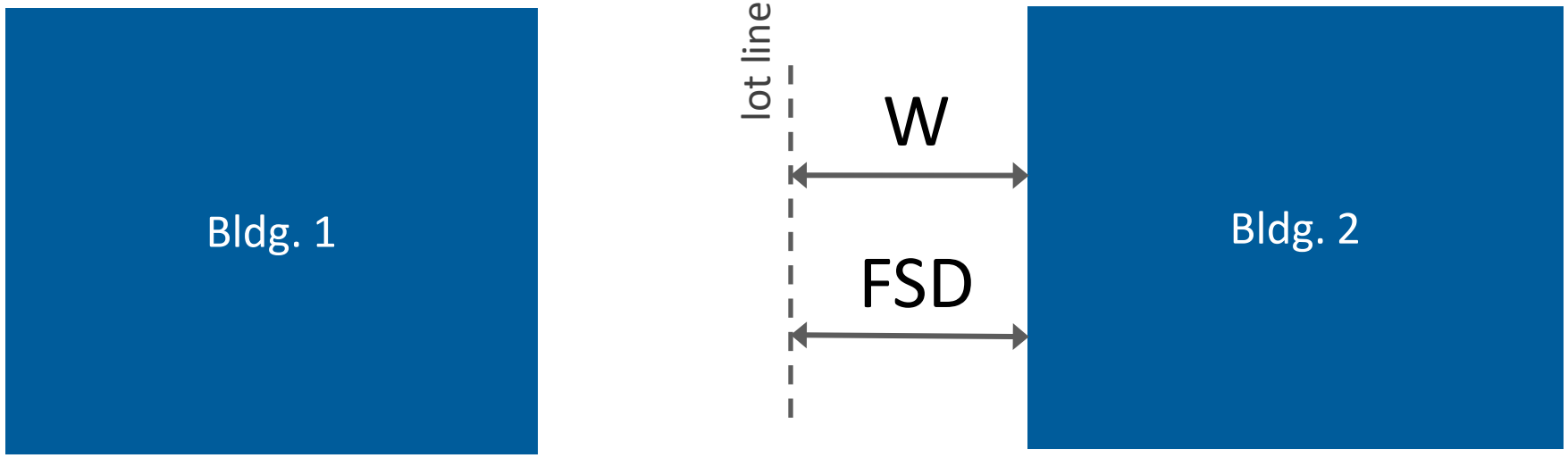
W_{max} = 60'

Frontage Increases – IBC 506.3

"W" for area increases NOT always the same as Fire Separation Distance (FSD) for purposes of fire resistance ratings of walls and openings

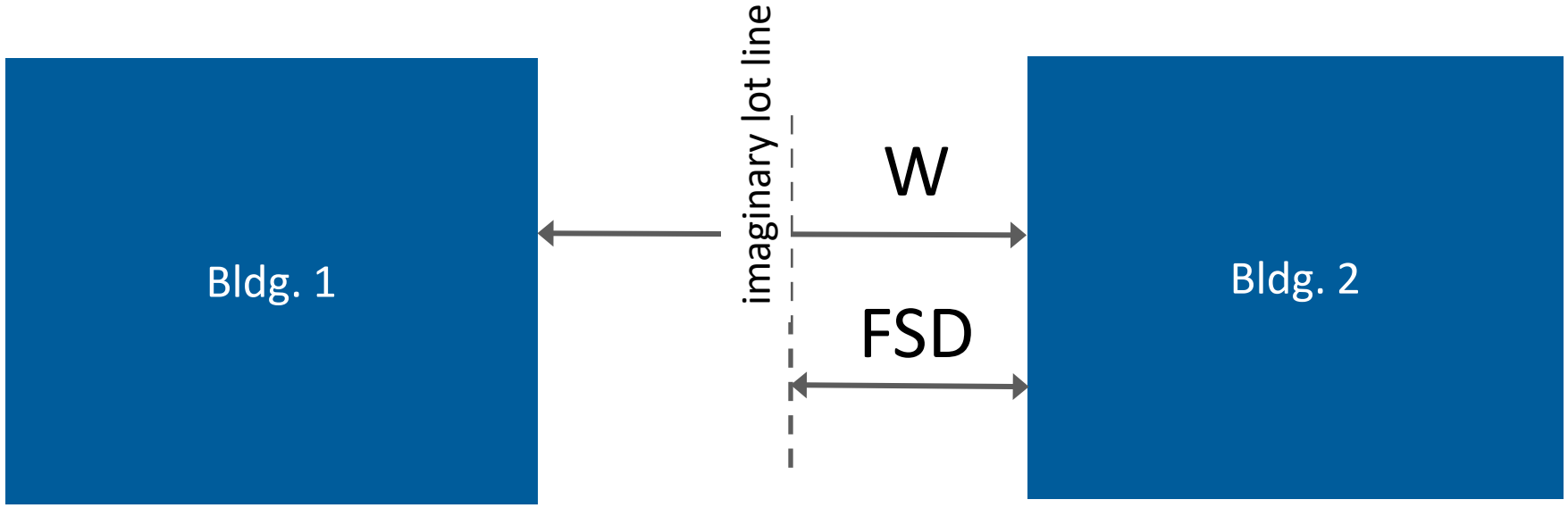
Frontage Increases – IBC 506.3

Two buildings on DIFFERENT lots



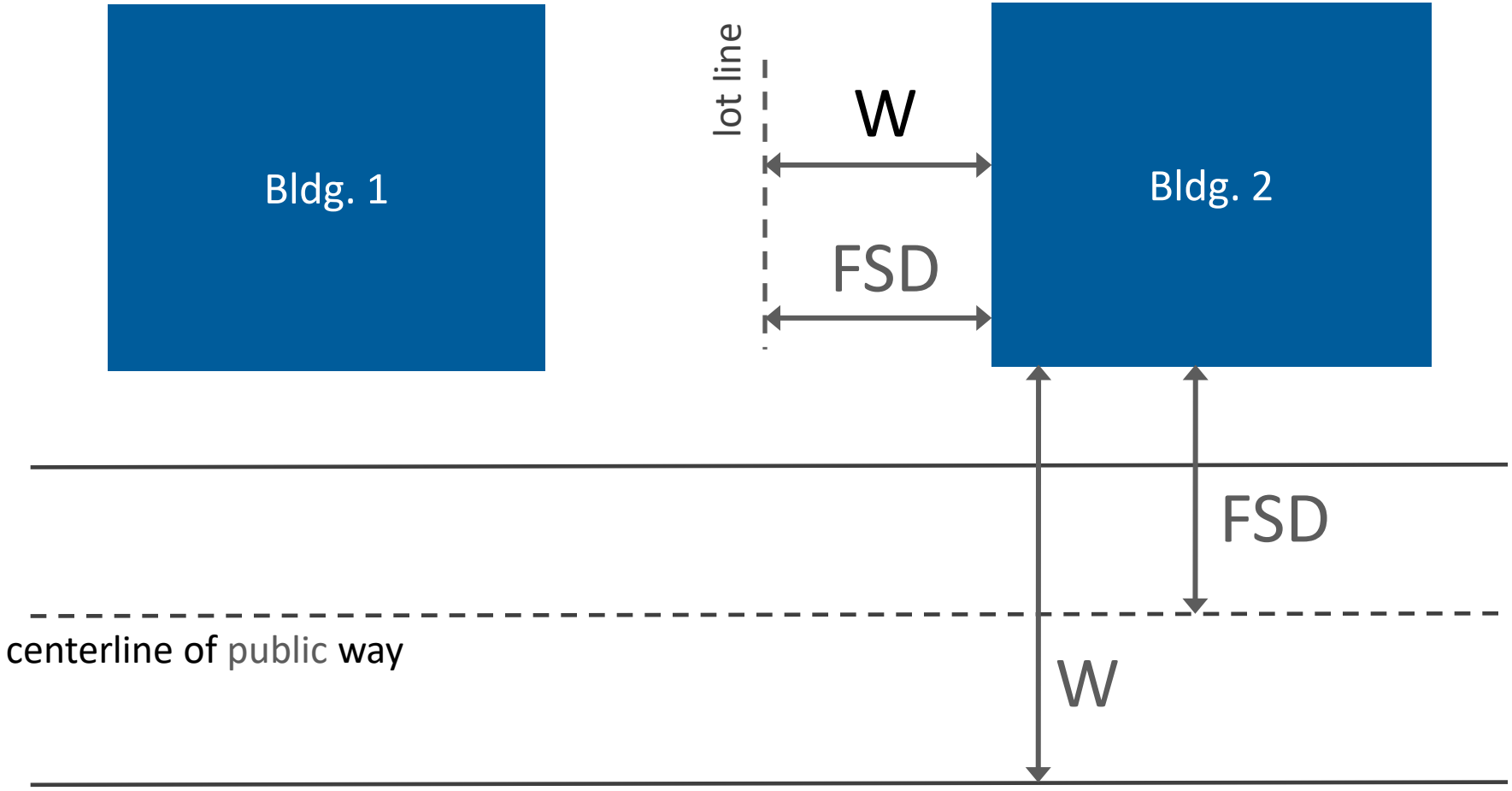
Frontage Increases – IBC 506.3

Two buildings on SAME lot



Frontage Increases – IBC 506.3

Buildings near public right of ways:



Total Building Area – IBC 506.2

$$A_a = [A_t + (NS \times I_f)] \times S_a$$

(Equation 5-2)

A_a = Allowable area, total (sq. ft.)

A_t = Tabular allowable area per story per Table 506.2 for NS, S1 or S13R (sq. ft.)

NS = Tabular allowable area per story per Table 506.2 for non-sprinklered building (sprinklered or not)

I_f = Area increase factor due to frontage per 506.3
I_f, max = 0.75

S_a = Actual number of building stories above grade

$S_{a,\ max}$ = 3 for non-sprinklered buildings and those w/ NFPA13

$S_{a,\ max}$ = 4 for buildings w/ NFPA 13R

Total Building Area –IBC 506.2

1 story building (Type III-A)

» Total Area is 1 x A_a

R-2
S13R

Max Area =
24,000 sf total

R-2
S1

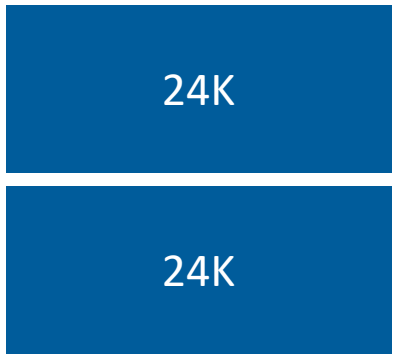
Max Area =
96,000 sf total

Total Building Area – IBC 506.2

2 story building (Type III-A)

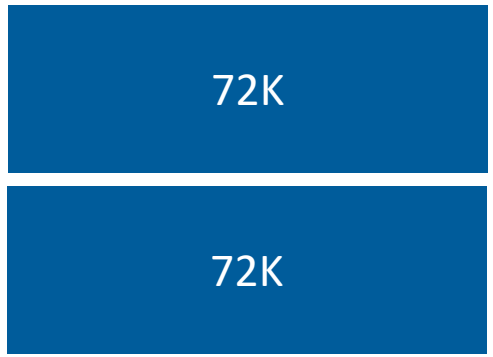
- Total Area is 2 x A_a
- No frontage increase shown

R-2
S13R



Max Area =
48,000 sf total

R-2
SM



Max Area =
144,000 sf total

Total Building Area – IBC 506.2

3 story building (Type III-A)

- Total Area is 3 x A_a
- Includes maximum frontage increase

R-2
S13R + I_f (NS)

24K +	.75(24K)
24K +	.75(24K)
24K +	.75(24K)

Max Area =
126,000 sf total

R-2
SM + I_f (NS)

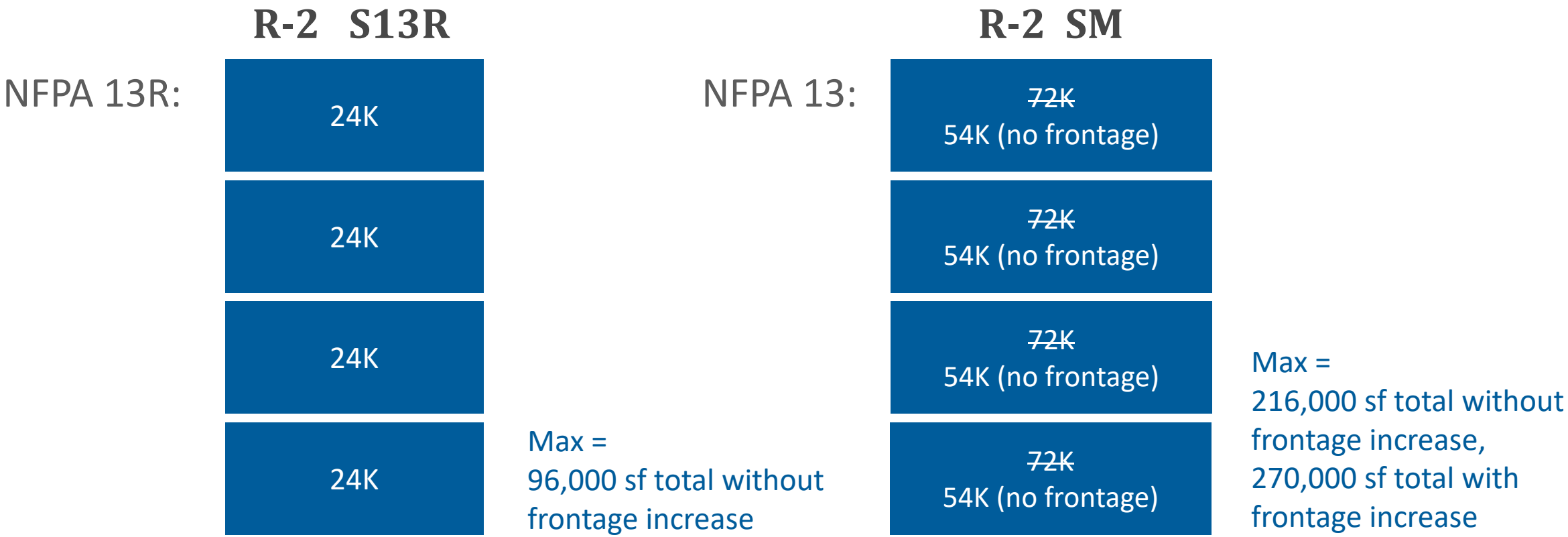
72K +	.75(24K)
72K +	.75(24K)
72K +	.75(24K)

Max Area =
270,000 sf total

Total Building Area – IBC 506.2

4 story building (Type III-A)

- Total Area is 3 x A_a for NFPA 13 sprinkler system (no frontage increase)
- Total area is 4 x A_a for NFPA 13R sprinkler system (no frontage increase)



Mixed Occupancy, Multi-story

Story Area: $\Sigma\ (A_i / A_{a,i}) \leq 1$

(Described in 2021/2024 IBC 508.4.2)

Total Building Area: $\Sigma\ (A_i / A_{a,i}) \leq S_a$

(Described in 2021/2024 IBC 506.2.2)

$\mathbf{A_i}$ = Actual area of occupancy *i* at a given story (sq. ft)

$\mathbf{A_{a,i}}$ = Allowable area per story for occupancy *i* (sq. ft) = $[A_{t,i} + (NS_i \times I_f)]$

$\mathbf{A_{t,i}}$ = Tabular allowable area per story for occupancy *i* per Table 506.2 (sq. ft.)

$\mathbf{NS_i}$ = Tabular allowable area per story for occupancy *i* per Table 506.2 for non-sprinklered building (sprinklered or not)

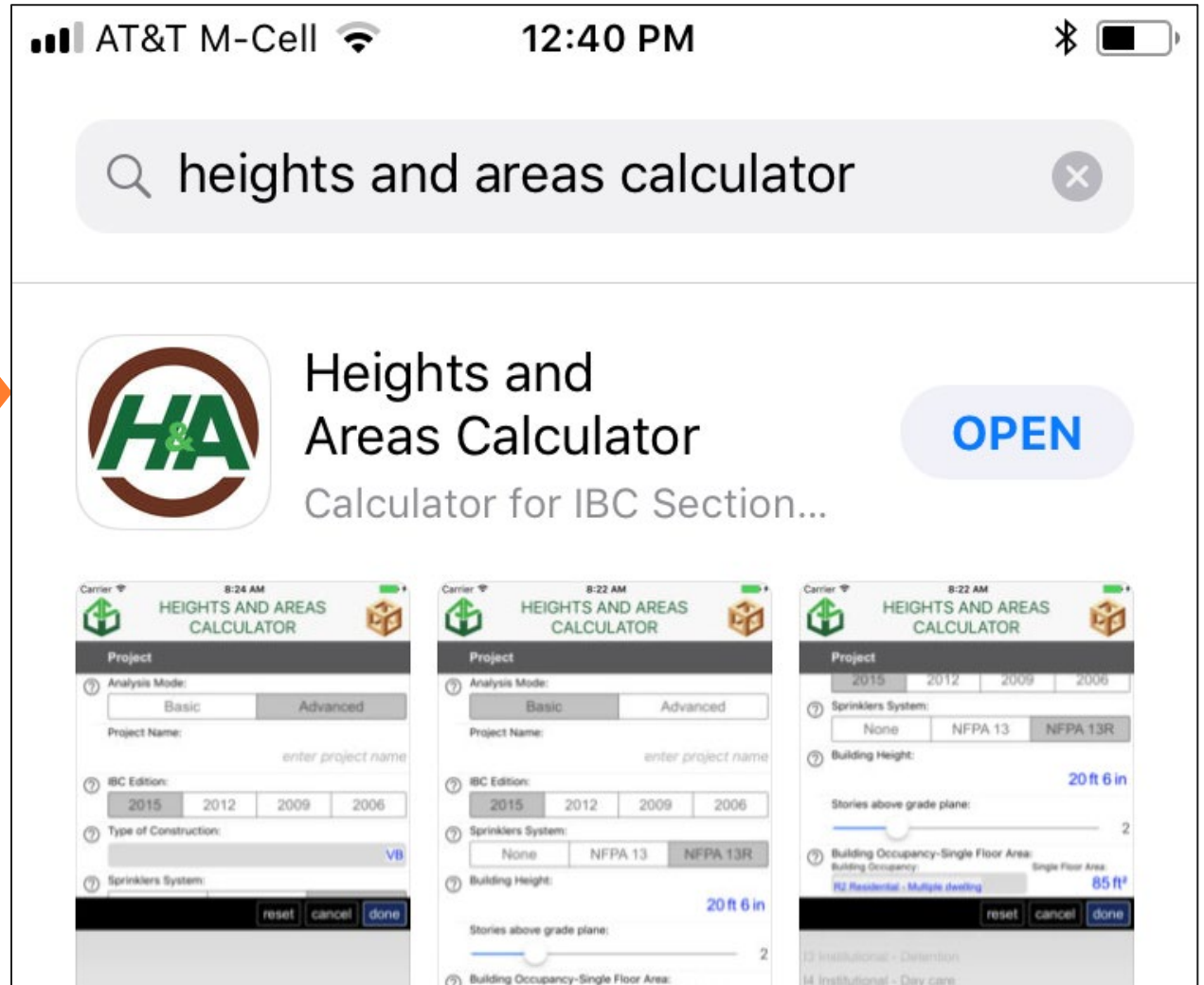
$\mathbf{I_f}$ = Area increase factor due to frontage per 506.3
I_f, max = 0.75

$\mathbf{S_a}$ = Actual number of building stories above grade not to exceed 3 for non-sprinklered buildings and those w/ NFPA13. **OR** 4 for buildings w/ NFPA 13R

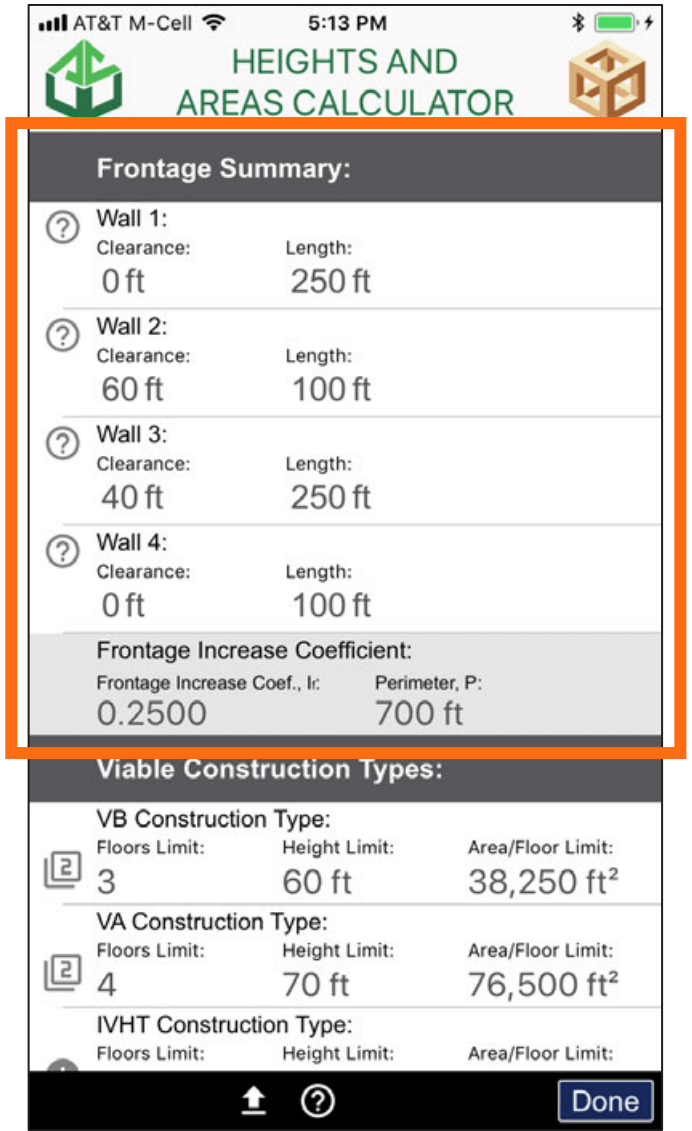
Mixed Use Occupancy – Design Aid

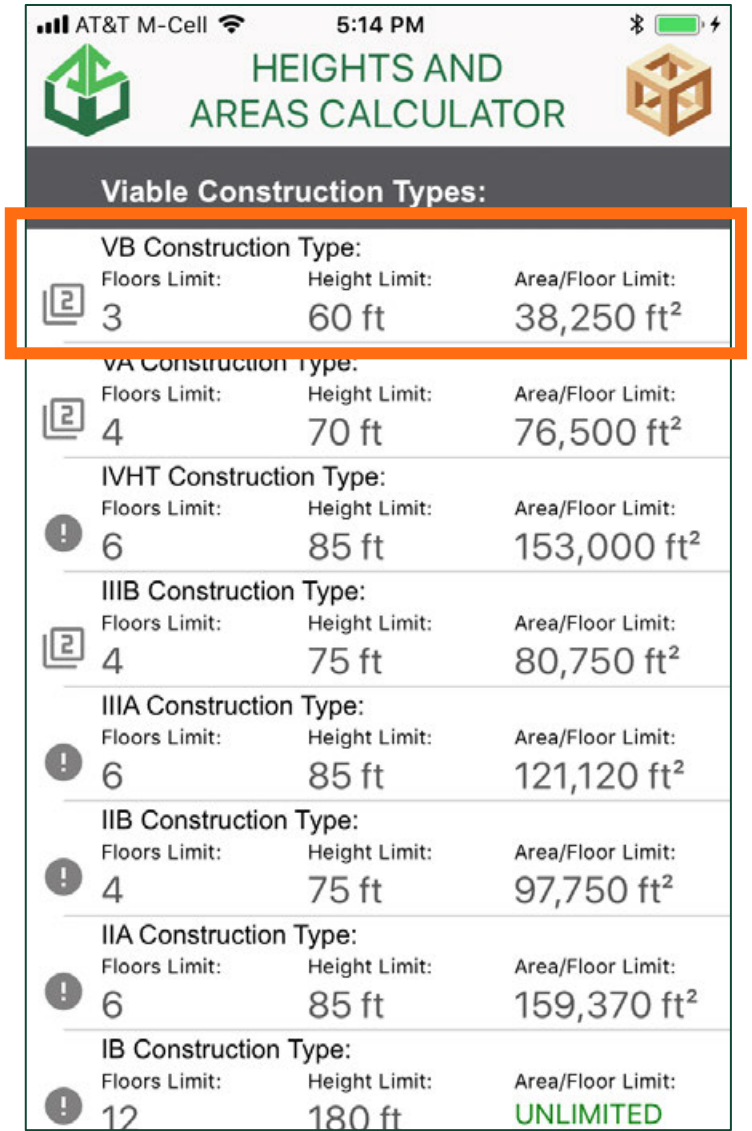
WoodWorks/AWC Heights & Areas Calculator App

Available for FREE at woodworks.org



Frontage Calculation – Design Aid





Case Study Innovations in Wood

Emory Point Atlanta, GA

- 3 buildings complete – Luxury Apt., retail, restaurants
- (1) 5 story Type III wood frame over slab on grade
- (2) 4 stories of wood over 1 story concrete podium

35% Structure Savings

- $14/sf (wood concept)
- $22/sf (PT conc. Slab and frame)

Architect: Cooper Carry, The Preston Partnership

Engineer: Ellinwood + Machado, Pruitt Eberly Stone

Contractor: Fortune-John

Photo credit: Gables Residential

Mezzanines – IBC 505.2

Not counted toward building area* or number of stories if:

- Maximum 1/3 floor area of *room* or *space* where located
- Special egress provisions apply
- Must be open and unobstructed to room in which it's located (walls ≤ 42" allowed)
  - Several exceptions
- Slightly different for equipment platforms

*Does count toward fire area with regard to fire protection in Chapter 9

Case Study Maximizing View and Value With Wood

Marselle Condominiums

Seattle, WA

- Type III-A condo complex
- 5-1/2 stories of wood over 2 stories of concrete
- Mezzanine added $250K cost but $1M in value
- 30% cost saving over concrete
- Time savings over steel

Architect: PB Architects

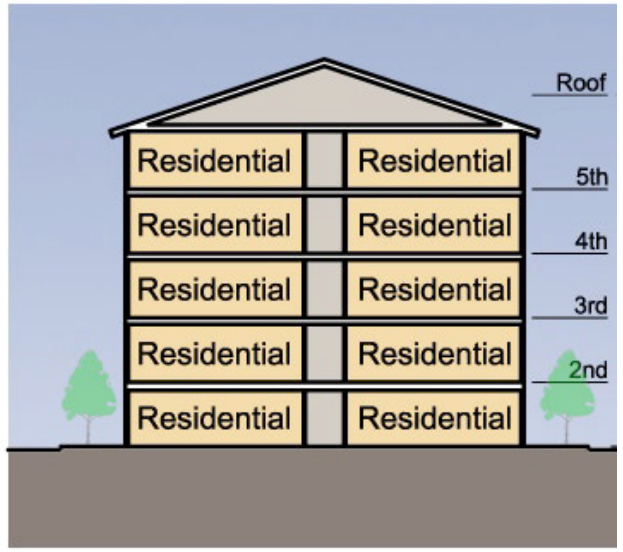
Engineer: Yu & Trochalakis

Contractor: Norcon, NW

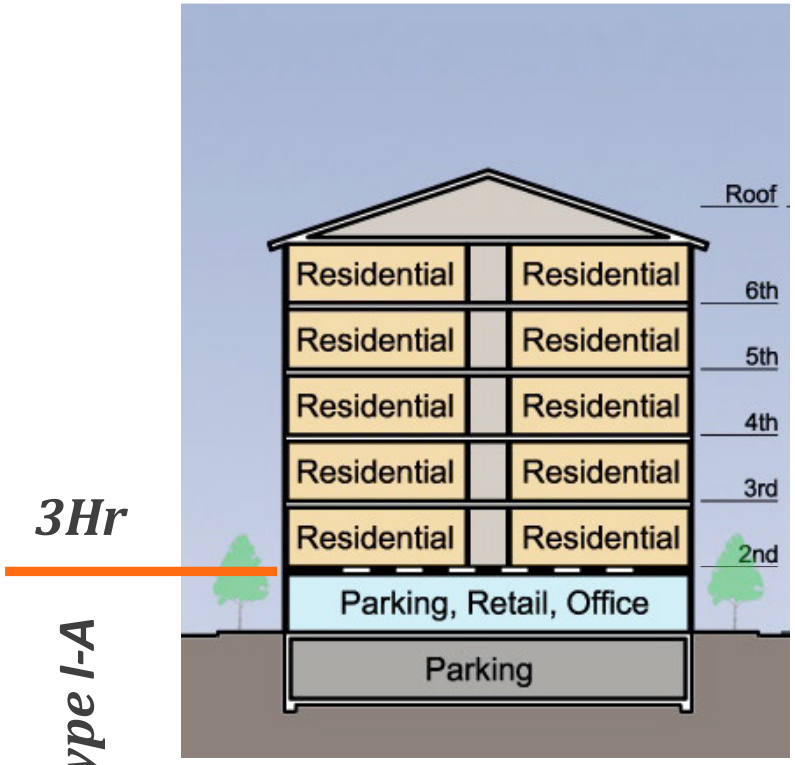
Completed: 2009

Photo Credit: Matt Todd Photography

IBC Podium Provisions



5 story Type III Building



5 story Type III Building
On Top of a Type I-A Podium

Special Provisions for Podiums in IBC 510.2
Increases allowable stories… not allowable building height

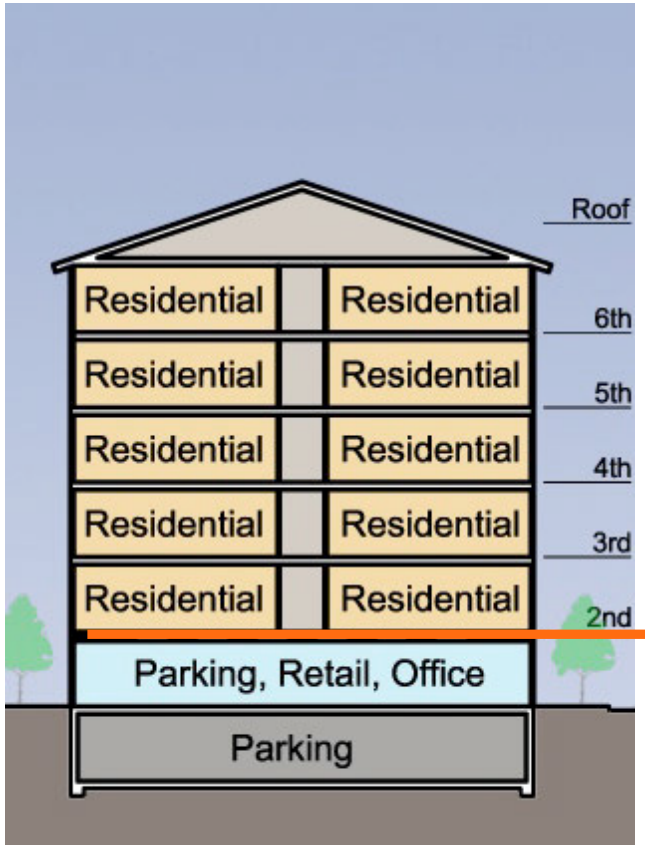
Horizontal Building Separation – 510.2

Considered separate buildings above and below for purposes of area calculations if:

- Overall height is still limited to min of either building
- 3-hr rated horizontal assembly
- Building below is Type 1-A with sprinklers
- Enclosures penetrating horizontal assembly are 2-hr rated
- Occupancy above is A (occupant load <300), B, M, R or S
- Occupancy below is any except H

The Flats at ISU, Normal, IL
OKW Architects
Precision Builders & Associates

Evolution of IBC Mixed-Use Podium



IBC	2006	2009	2012	2015	2018	2021	2024
Section	509.2	509.2	510.2	510.2	510.2	510.2	510.2
Upper Occupancy	A, B, M, R or S						
3Hr							
Lower Occupancy	S-2 Parking	A, B, M, R or S-2 Parking		Any Except H			
Type IA							
Podium Height	1 Story			No Restriction			

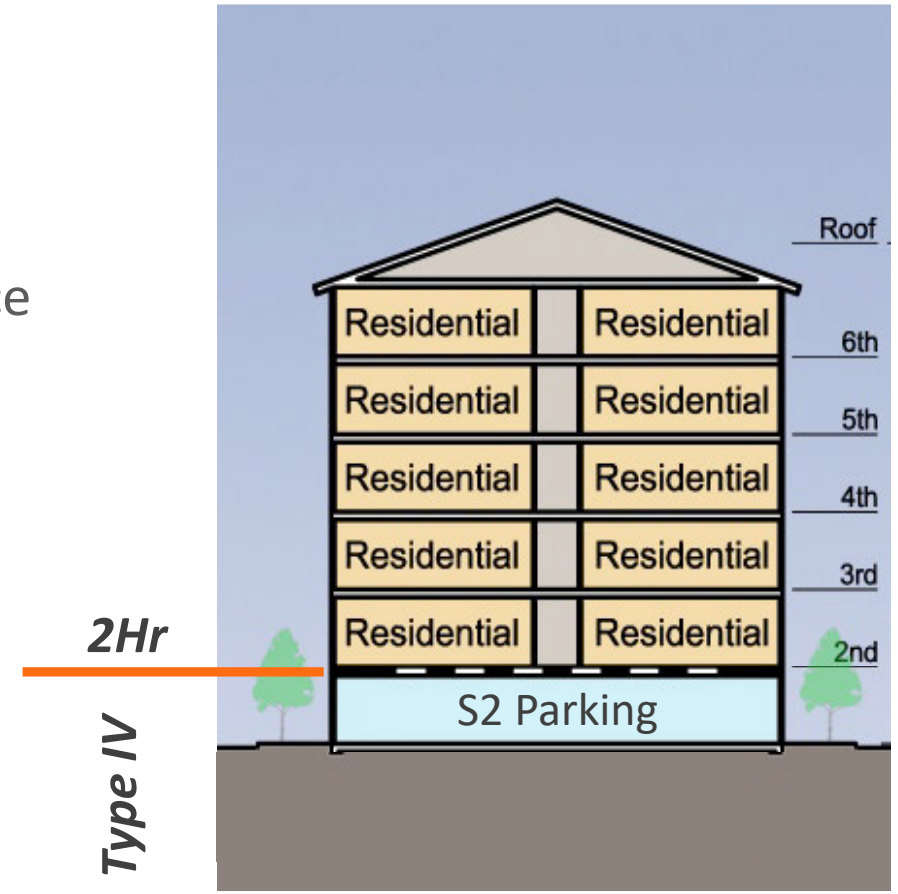
IBC Provisions for mixed-use podiums have been evolving.

Starting in 2015, IBC allows multiple podium stories above grade.

Parking Beneath Group R – IBC 510.4

Possibility of a Type IV podium where number of stories starts above parking when:

- Occupancy above is R and below is S-2
- Lower floor is Type IV (open) parking with grade entrance
- Horizontal assembly between 1st and 2nd floor shall be:
  - Same construction type as lower floor (Type IV)
  - 1-hr fire resistance rating when sprinklered
  - Overall height is still limited to occupancy



5 story Type III Building On Top of a Type IV

http://www.woodworks.org/experttip/can-parking-incorporated-mixed-use-wood-frame-buildings-construction-type-perspective/

2021 Code Conforming Wood

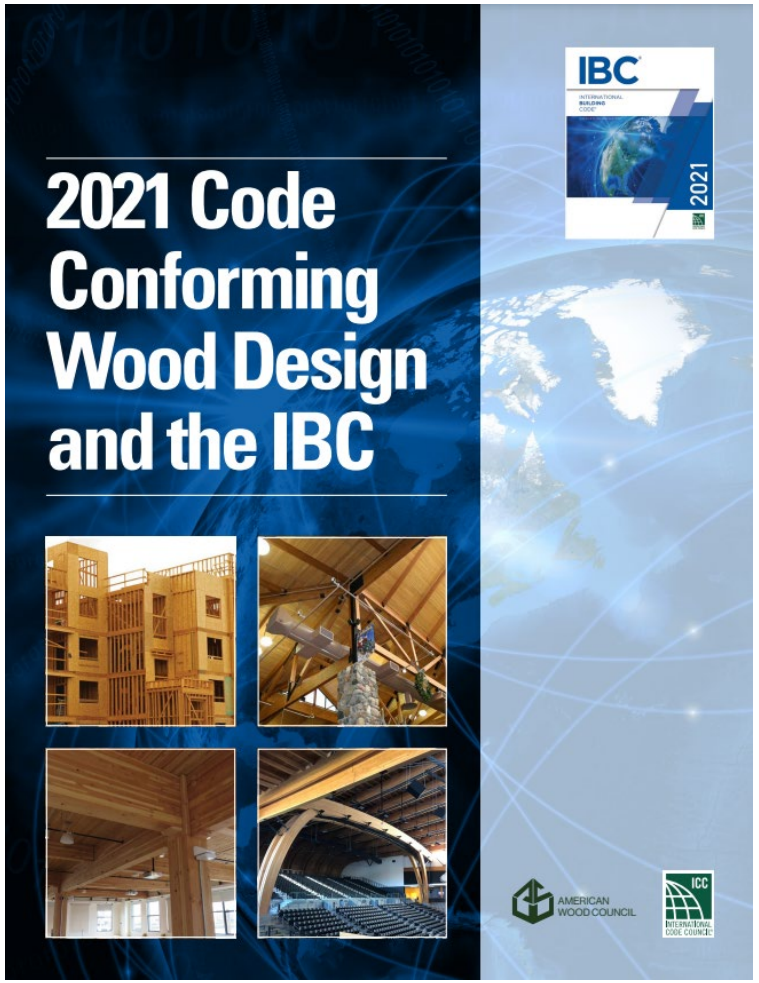


Table of Contents

Available for Free Download: www.awc.org

The Canyons, Kaiser+Path, Cantena Consulting Engineers, Photo Jeremy Bittermann

Mid-Rise Mass Timber

Navigating Construction Type Selection

Shannon A. Williams, PE | WoodWorks Regional Director – PA & NJ

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

AIA Approved Continuing Education

Course Description

Opportunities for using mass timber construction for new building projects have never been greater now that the International Building Code (IBC) allows up to 18 stories with these materials. However, with expanded code options, selecting the right construction type is crucial to making a project pencil. This course focuses on mid-rise mass timber construction, highlighting examples in the five- to eight-story range—including office, mixed-use, and multi-family projects. Discussion will help to inform decisions on how to incorporate mass timber based on a project's intended height, area, and occupancies. The presentation will also cover decisions that need to be made early in the design process, including grid layout, approach to achieving fire ratings, and lateral system selection.

Learning Objectives

1. Review mass timber products, framing options, and the potential benefits of utilizing mass timber in mid-rise construction.
2. Discuss the various building construction types identified in the International Building Code (IBC) and where opportunities exist for mass timber use.
3. Highlight key considerations during the design of mass timber buildings, including grid layout, fire ratings, acoustics, and lateral design.
4. Evaluate the impact of design decisions on providing cost-effective, code-compliant buildings and highlight methods of meeting project goals.

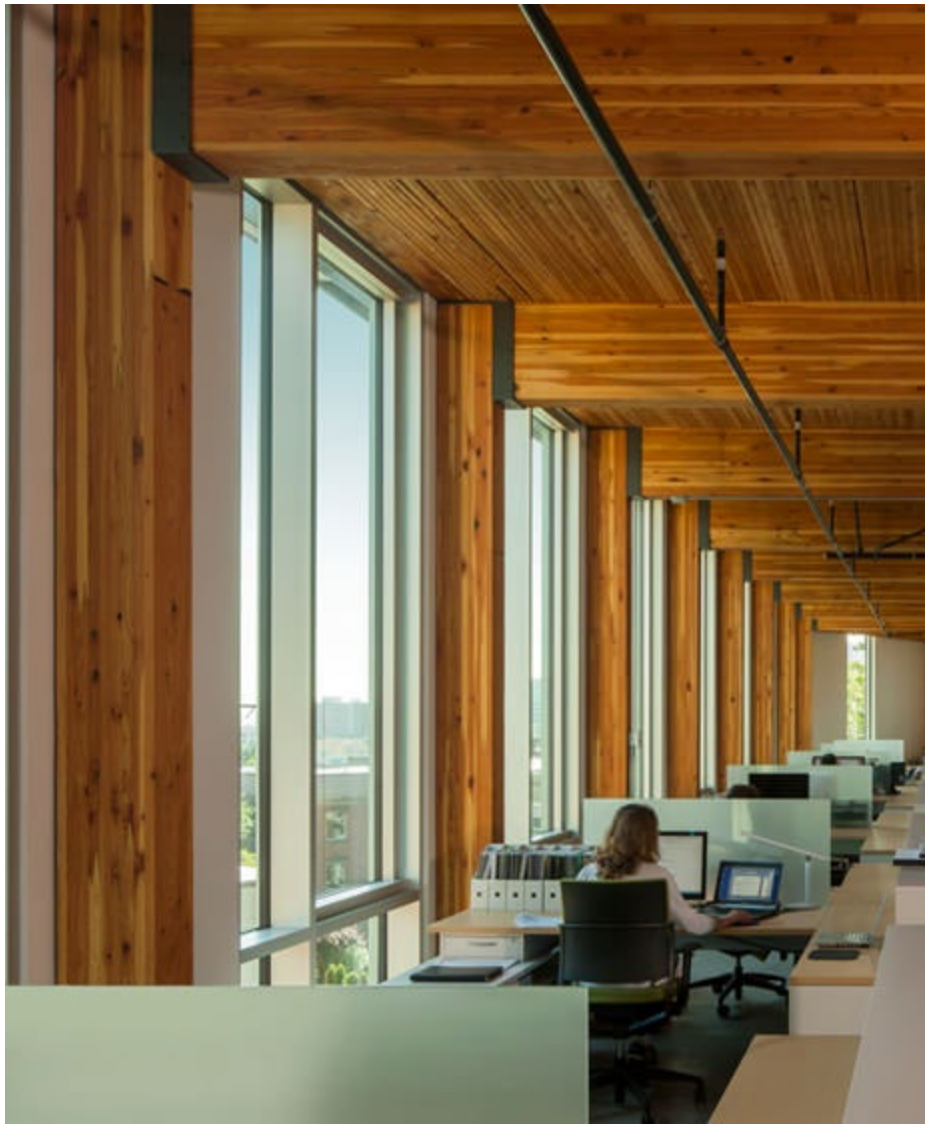
MASS TIMBER OVERVIEW

Ascent / New Land Enterprises / Korb + Associates Architects / Thorton Tomasetti / photo New Land Enterprises

Wood Construction Terminology

Light-Frame Wood
Photo: WoodWorks

Heavy Timber
Photo: Benjamin Benschneider



Mass Timber
Photo: John Stamets

Wood Construction Terminology

Glue Laminated Timber (Glulam)
Beams & columns

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo:
Freres Lumber

Wood Construction Terminology

Dowel-Laminated Timber (DLT)

Photo: StructureCraft

Nail-Laminated Timber (NLT)

Photo: Think Wood

Glue-Laminated Timber (GLT)

Plank orientation

Photo: StructureCraft

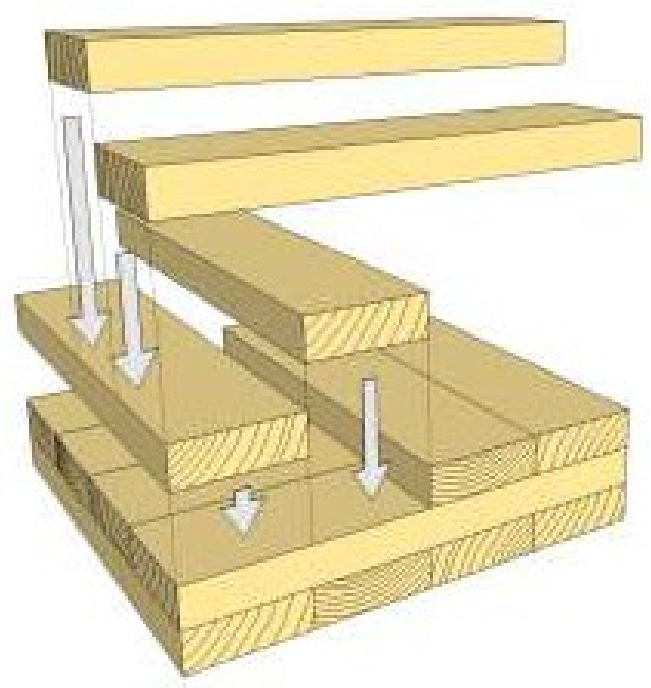
Photo: StructureCraft

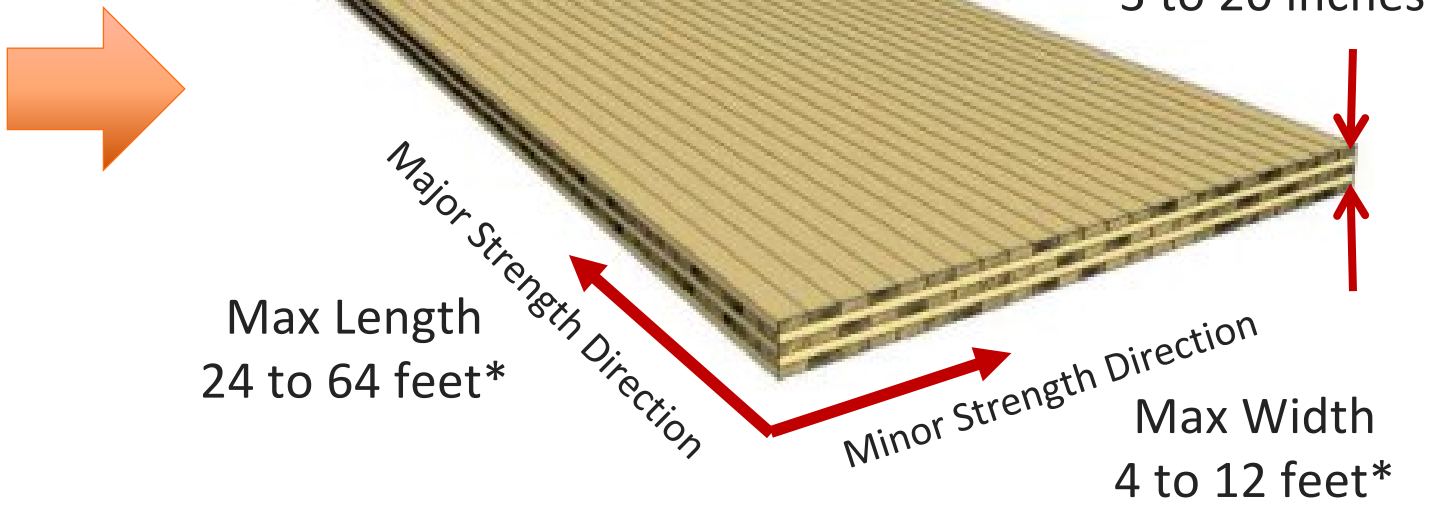
Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

What is CLT?

- 3+ layers of laminations
- Solid Sawn or Structural Composite Lumber Laminations
- Cross-Laminated Layup
- Glued with Structural Adhesives





*All dimensions are approximate.
Consult with manufacturers.

Mass Timber Building Options


Photo: Blaine Brownell


Photo: acton ostry architects


Photo: : LendLease

Post and Beam **Flat Plate** **Honeycomb**

Mass Timber Building Options

Hybrid: Light-frame

Hybrid: Steel framing

Potential Benefits	Project Goal ✓	Value Add ✓
Fast construction/shorter schedules; pre-fabricated and precise		
Exposed wood (structure is finish!) • Aesthetic value; potential for faster leasing and lease premiums; portfolio distinction • Biophilia; healthy indoor environment		
Lightweight structure, especially beneficial on sites with poor soils		
Labor shortage solutions • Small crews for timber frame erection • Utilize more entry-level laborers when MEP and fire protection systems are fully designed, coordinated and pre-planned		
Just-in-time delivery and small staging/lay-down areas; ideal for dense urban areas		
Natural, renewable material; environmentally friendly with a lighter carbon footprint		
Support healthy forests and rural economies • Mass timber can be made from relatively small-diameter trees and those affected by insects or disease; creates a market incentive for forest thinning and other landscape restoration efforts that reduce the risk of high-severity wildfires		

MASS TIMBER IN THE CODE

Central Lofts / Jones Architecture / Froelich Engineers / Photo Jones Architecture

Mass Timber in the IBC: Cross-Laminated Timber (CLT)

- CLT was first recognized in the 2015 IBC
- CLT in the 2021 IBC:
  - Chapter 2: Definitions

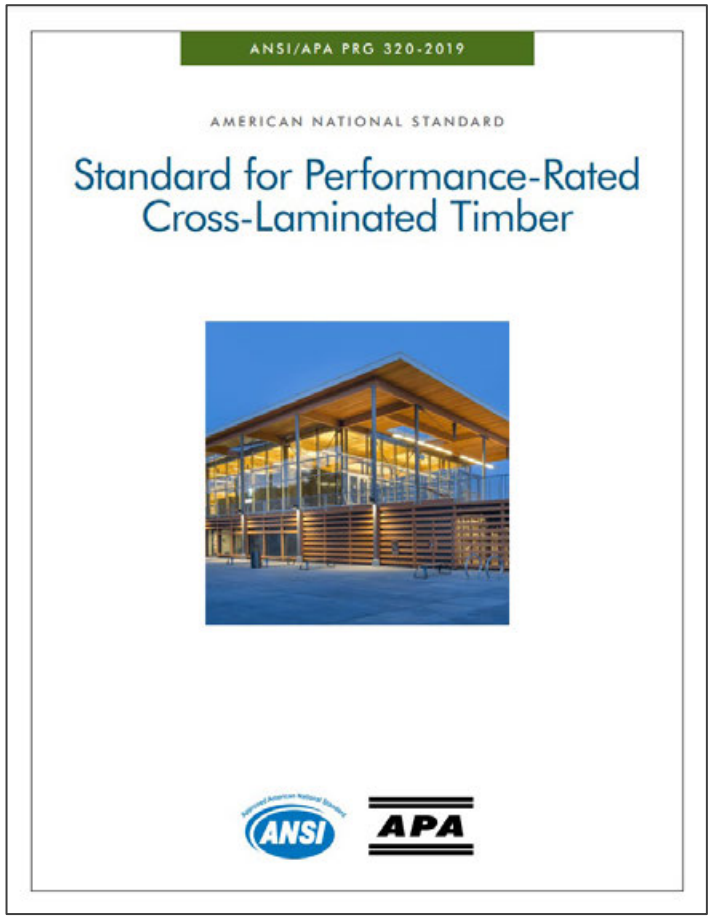
    [BS] CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or *structural composite lumber* where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.

  - Chapter 23: Wood

    2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.

Cross Laminated Timber (CLT)

- ANSI / APA PRG 320 Standard



CLT Trademark Example:

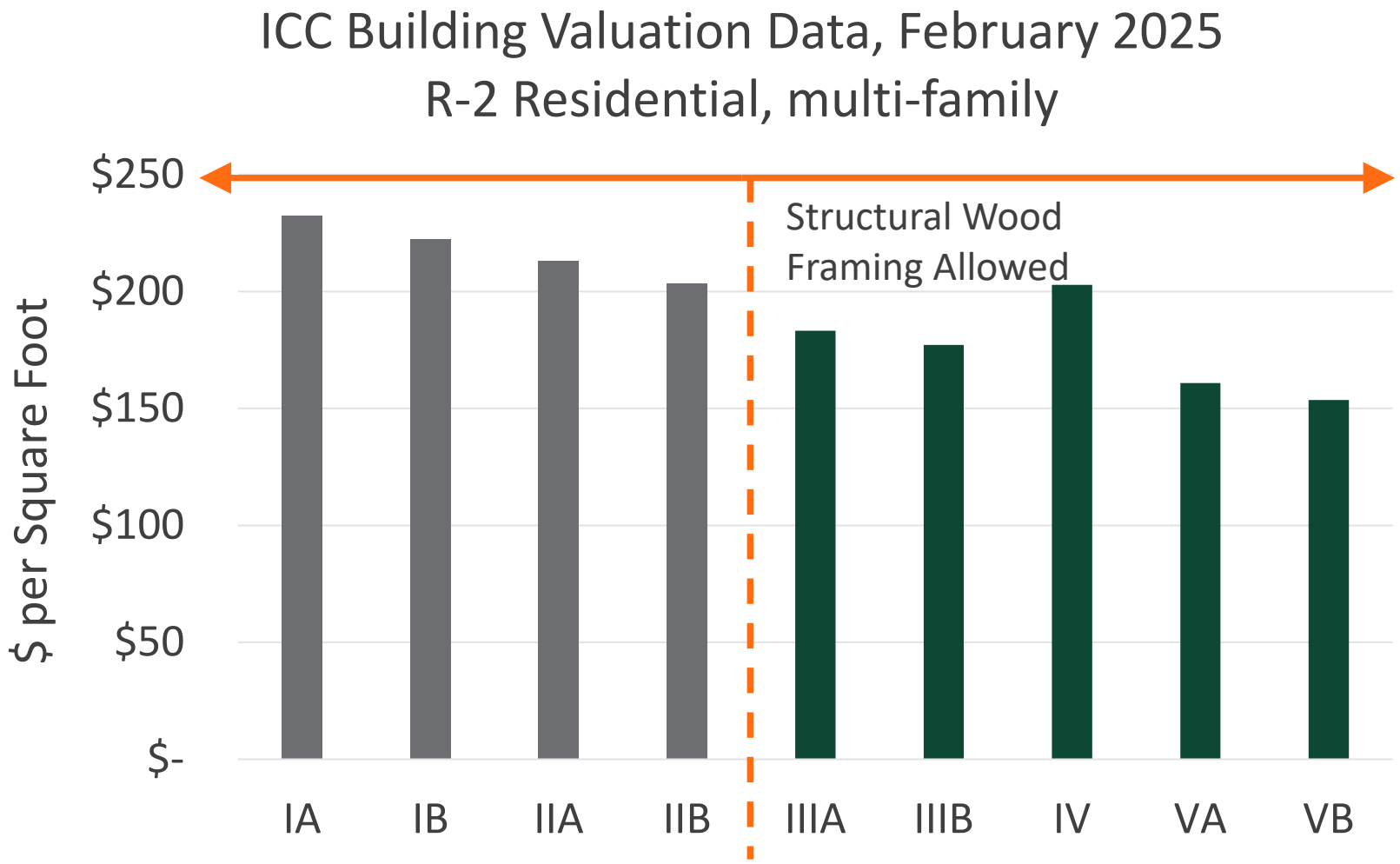
1. Grade qualified in accordance with ANSI/APA PRG 320.
2. Product thickness.
3. APA mill number.
4. Referenced product standard.

Source: Structure Magazine, April 2022

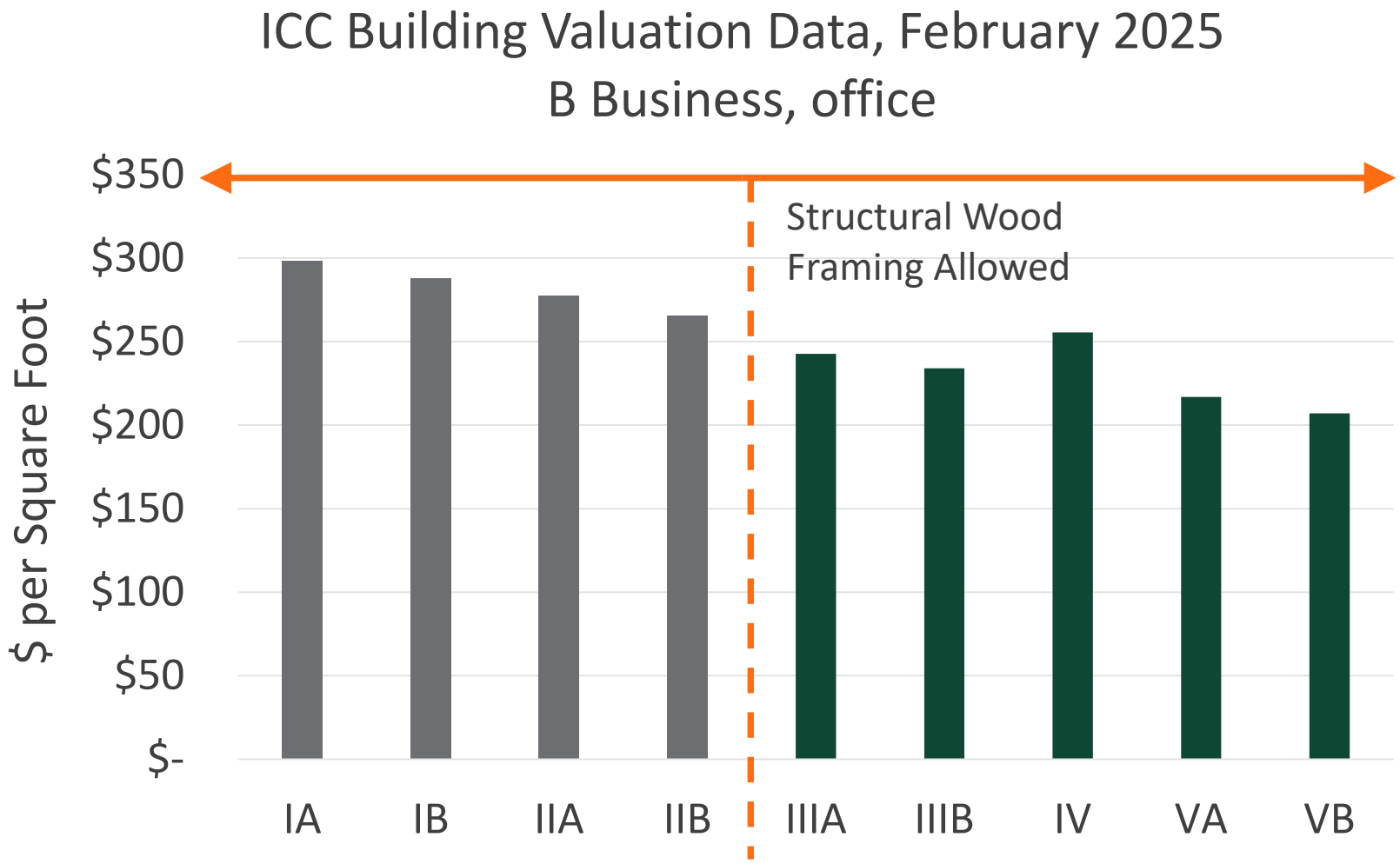
Which Construction Type?

- Many buildings use higher construction type than necessary
  - Traditional practice
  - Fire ratings
  - Materials
  - Cost!

ICC Building Valuation Data



ICC Building Valuation Data



Which Construction Type?

- Start with lowest common denominator and work up
- Don’t assume construction type, occupancy separation, etc. required simply because of materials or occupancies

Image: Neo Studio

Construction Types

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Mid-Rise Construction Types

Type III

- Exterior walls non-combustible (may be light frame FRTW)
- Interior elements any allowed by code

Type V

- All building elements any allowed by code

Types III and V can be subdivided:

- A (protected)
- B (unprotected)

Type IV (C & HT)

- All building elements mass timber (covered CLT) or non-combustible
  - For IV-HT, interior elements may also be 1-hour FRR light frame
  - For IV-HT, exterior walls may also be FRTW, including light frame walls)

Construction Types V-A, V-B

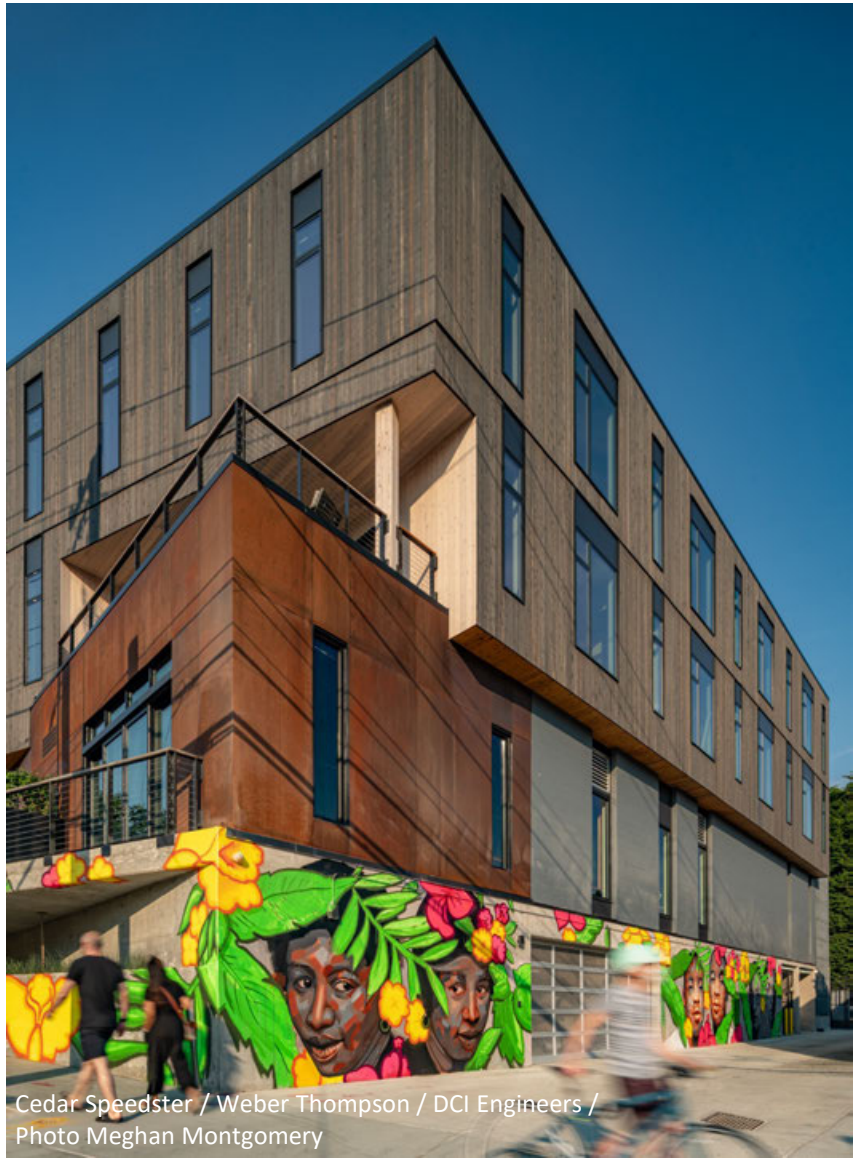
	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types V-A, V-B

IBC Section 602.5:

- Structural Elements, Exterior Walls, and Interior Walls
  - Any material permitted by code

Cedar Speedster, Seattle, WA



Cedar Speedster / Weber Thompson / DCI Engineers / Photo Meghan Montgomery

Construction Types V-A, V-B

Type V Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - Light-frame walls
  - Mass Timber

Star Lofts, Des Moines, IA

Image: Cutler Development

Construction Types V-A, V-B

Type V Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - Light-frame walls
  - Mass Timber

340+ Dixwell Ave, New Haven, CT

Image: GOA Architecture

Construction Types III-A, III-B

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types III-A, III-B

IBC Section 602.3:

- Interior elements
  - Any material permitted by code
- Exterior walls
  - Noncombustible materials
  - Fire-retardant-treated wood (FRTW) framing and sheathing shall be permitted within exterior wall assemblies
  - Note: CLT not allowed

Adidas Headquarters, Portland, OR

Adidas East Village Expansion / LEVER Architecture / KPFF Consulting Engineers / Photo Jeremy Bittermann

Construction Types III-A, III-B

Type III Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - FRTW light-frame walls
  - FRTW mass timber (NLT, DLT)
    - Note: CLT not allowed

MSU STEM Facility, East Lansing, MI

MSU STEM Teaching and Learning Facility / Integrated Design Solutions / SDI Structures / Photo Kevin Marshall/Integrated Design Solutions

Construction Types III-A, III-B

Type III Construction:

- Interior Elements (Floors, Roofs, Partitions/Shafts, Etc.)
  - Any material permitted by code, including light frame and mass timber
- Exterior Walls
  - Non-combustible walls: light-gauge steel, curtainwall systems
  - FRTW light-frame walls
  - FRTW mass timber (NLT, DLT)
    - Note: CLT not allowed

The Canyons, Portland, OR

The Canyons, Kaiser+Path, Cantena Consulting Engineers, Photo Jeremy Bittermann

Construction Types IV-HT and IV-A, B, and C

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Type IV-A, B, and C

U.S. Building Codes, Tall Wood Ad Hoc Committee (2016-2018)

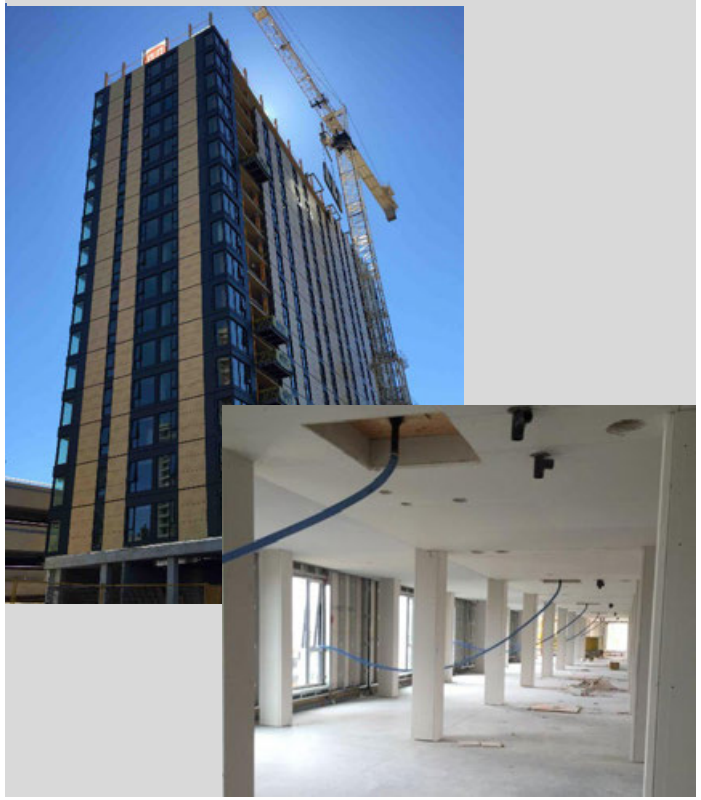
» Development of code change proposal for prescriptive code allowance of tall wood buildings.

Mass Timber Fire Testing at ATF Lab (2017)

Construction Types IV-A, B, and C

» Business Occupancy (Group B) Size Limits:

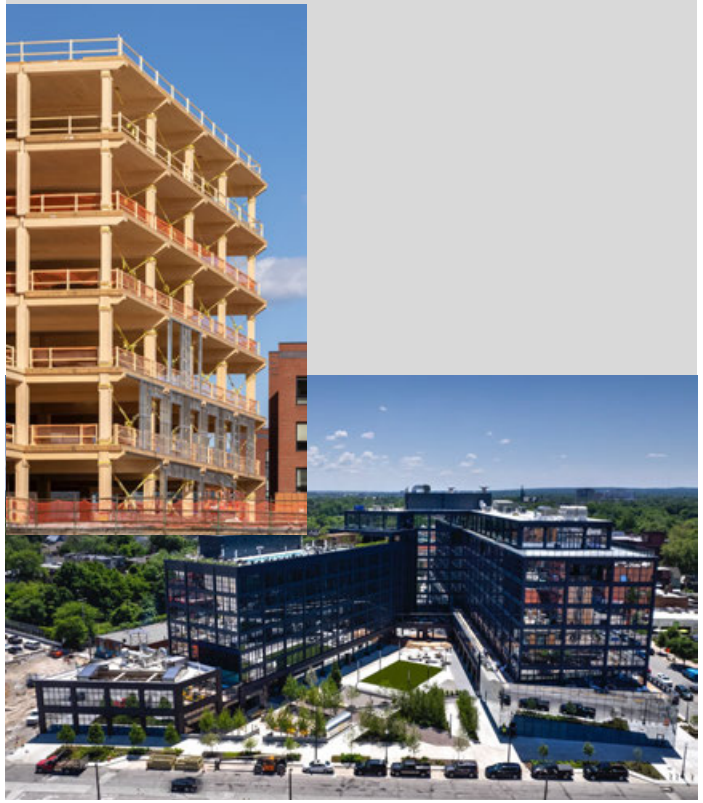
Type IV-A



Photos: Flor Projects

18 STORIES	
BUILDING HEIGHT	270’
PER STORY AREA	324,000 SF
BUILDING AREA	972,000 SF

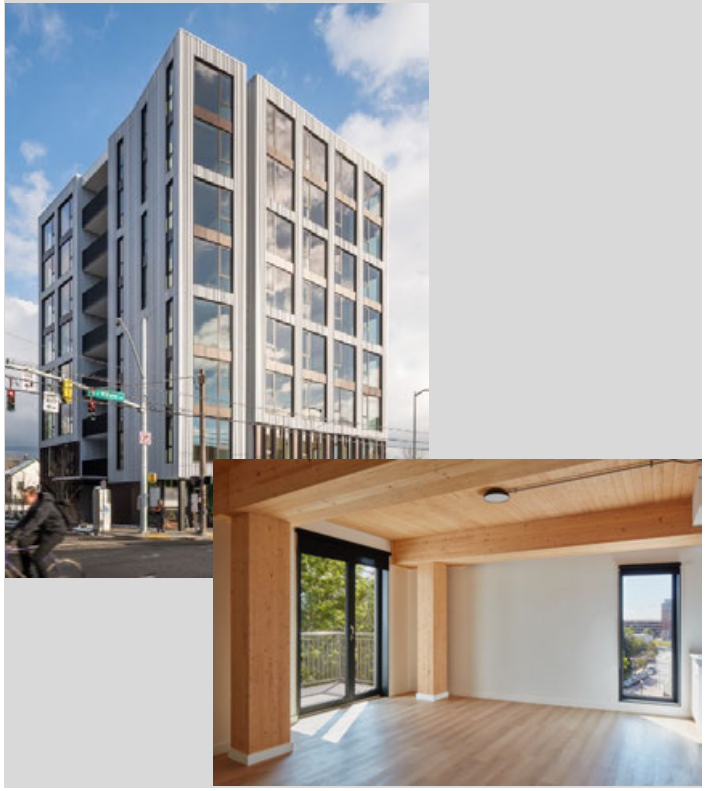
Type IV-B



Photos: ©Prakash Patel

12 STORIES	
BUILDING HEIGHT	180’
PER STORY AREA	216,000 SF
BUILDING AREA	648,000 SF

Type IV-C



Monte French Design Studio, Photos: Jane Messinger

9 STORIES	
BUILDING HEIGHT	85’
PER STORY AREA	135,000 SF
BUILDING AREA	405,000 SF

Construction Types IV-HT and IV-A, B, and C

IBC Section 602.4:

- Building elements are mass timber or noncombustible materials
  - No light frame walls in Types IV-A, B, or C
  - Light frame only allowed in Type IV-HT for FRTW exterior walls or 1-hour FRR interior walls
  - Allowable mass timber types at exterior walls vary
- Minimum mass timber dimensions per Section 2304.11

1030 Music Row, Nashville, TN

1030 Music Row / Anecdote Architectural Experiences / StructureCraft / Photo Andrew Keithly

Construction Types IV-HT and IV-A, B, and C

Type IV-HT Construction:

- Interior Elements
  - Mass timber, non-combustible, or 1-hour FRR light frame
- Exterior Walls
  - Non-combustible
  - CLT covered at exterior face with FRTW or noncombustible sheathing
  - FRTW (light frame or mass timber)

The Soto, San Antonio, TX

The Soto, Hixon Properties, Lake|Flato, BOKA Powell, StructureCraft, Photo Erika Brown Edwards

Construction Types IV-HT and IV-A, B, and C

Type IV-A, B, and C Construction:

- Interior Elements
  - Mass timber or non-combustible
  - No light frame
- Exterior Walls
  - Non-combustible
  - CLT covered at exterior face with noncombustible sheathing
  - No light frame

Heartwood, Seattle, WA

Heartwood, Atelier Jones, DCI Engineers, rendering Atelier Jones

Construction Types IV-HT and IV-A, B, and C

FRR Requirements

- Type IV-HT
  - Minimum Dimensions
- Type IV-A, B, and C
  - Minimum Dimensions
  - FRRs per IBC Table 601

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

BUILDING ELEMENT	TYPE IV			
	A	B	C	HT
Primary structural frame[f] (see Section 202)	3[a]	2[a]	2[a]	HT
Bearing walls				
Exterior[e, f]	3	2	2	2
Interior	3	2	2	1/HT[g]
Nonbearing walls and partitions Exterior	See Table 705.5			
Nonbearing walls and partitions Interior[d]	0	0	0	See Section 2304.11.2
Floor construction and associated secondary structural members (see Section 202)	2	2	2	HT
Roof construction and associated secondary structural members (see Section 202)	$1^1/_2$	1	1	HT

Construction Types IV-HT and IV-A, B, and C

Type IV Minimum Dimensions (IBC Section 2304.11):

TABLE 2304.11
MINIMUM DIMENSIONS OF HEAVY TIMBER STRUCTURAL MEMBERS

		MINIMUM NOMINAL SOLID SAWN SIZE		MINIMUM GLUED-LAMINATED NET SIZE		MINIMUM STRUCTURAL COMPOSITE LUMBER NET SIZE	
SUPPORTING	HEAVY TIMBER STRUCTURAL ELEMENTS	Width, inch	Depth, inch	Width, inch	Depth, inch	Width, inch	Depth, inch
Floor loads only or combined floor and roof loads	Columns; Framed sawn or glued-laminated timber arches that spring from the floor line; Framed timber trusses	8	8	$6\frac{3}{4}$	$8\frac{1}{4}$	7	$7\frac{1}{2}$
	Wood beams and girders	6	10	5	$10\frac{1}{2}$	$5\frac{1}{4}$	$9\frac{1}{2}$
Roof loads only	Columns (roof and ceiling loads); Lower half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	8	5	$8\frac{1}{4}$	$5\frac{1}{4}$	$7\frac{1}{2}$
	Upper half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	6	5	6	$5\frac{1}{4}$	$5\frac{1}{2}$
	Framed timber trusses and other roof framing;[a] Framed or glued-laminated arches that spring from the top of walls or wall abutments	4[b]	6	3[b]	$6\frac{7}{8}$	$3\frac{1}{2}$[b]	$5\frac{1}{2}$

Construction Types IV-HT and IV-A, B, and C

Type IV Minimum Dimensions (IBC Section 2304.11):

- Floor Panels / Decking
  - CLT: 4” thick (actual)
  - NLT/DLT/GLT: 4” thick (nominal) OR Decking: 3” thick (nominal), covered with:
    - 1” tongue-and-groove
    - OR 15/32” WSP
    - OR 1/2“ particleboard

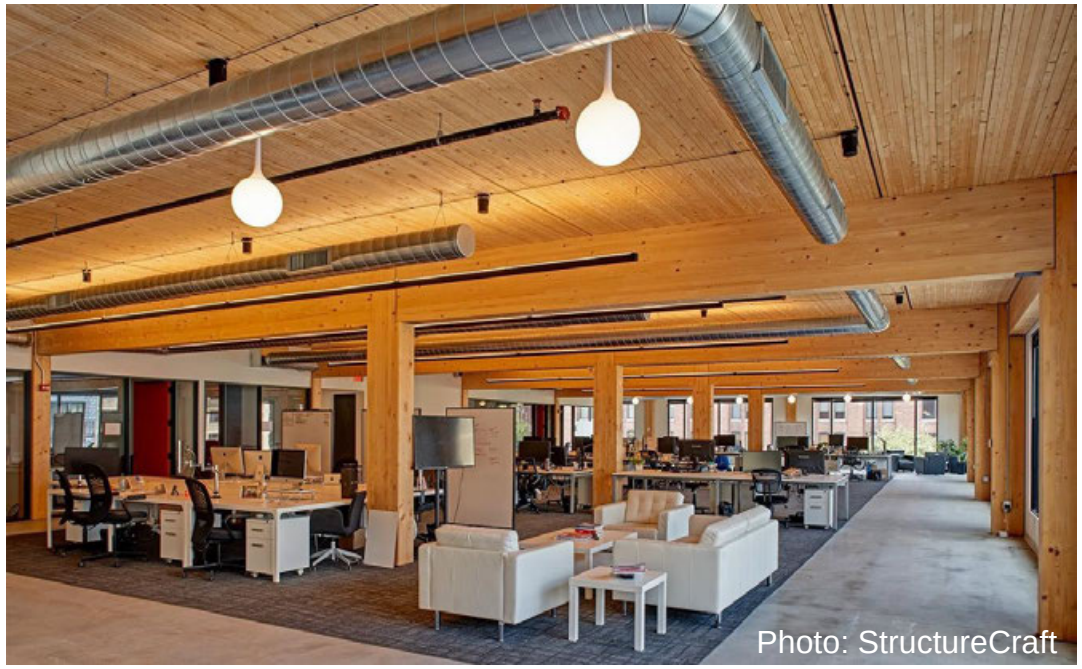


Photo: StructureCraft


Photo: Aitor Sanchez/ Ewing Cole


Photo: WoodWorks

Construction Types IV-HT and IV-A, B, and C

Type IV Minimum Dimensions
(IBC Section 2304.11)

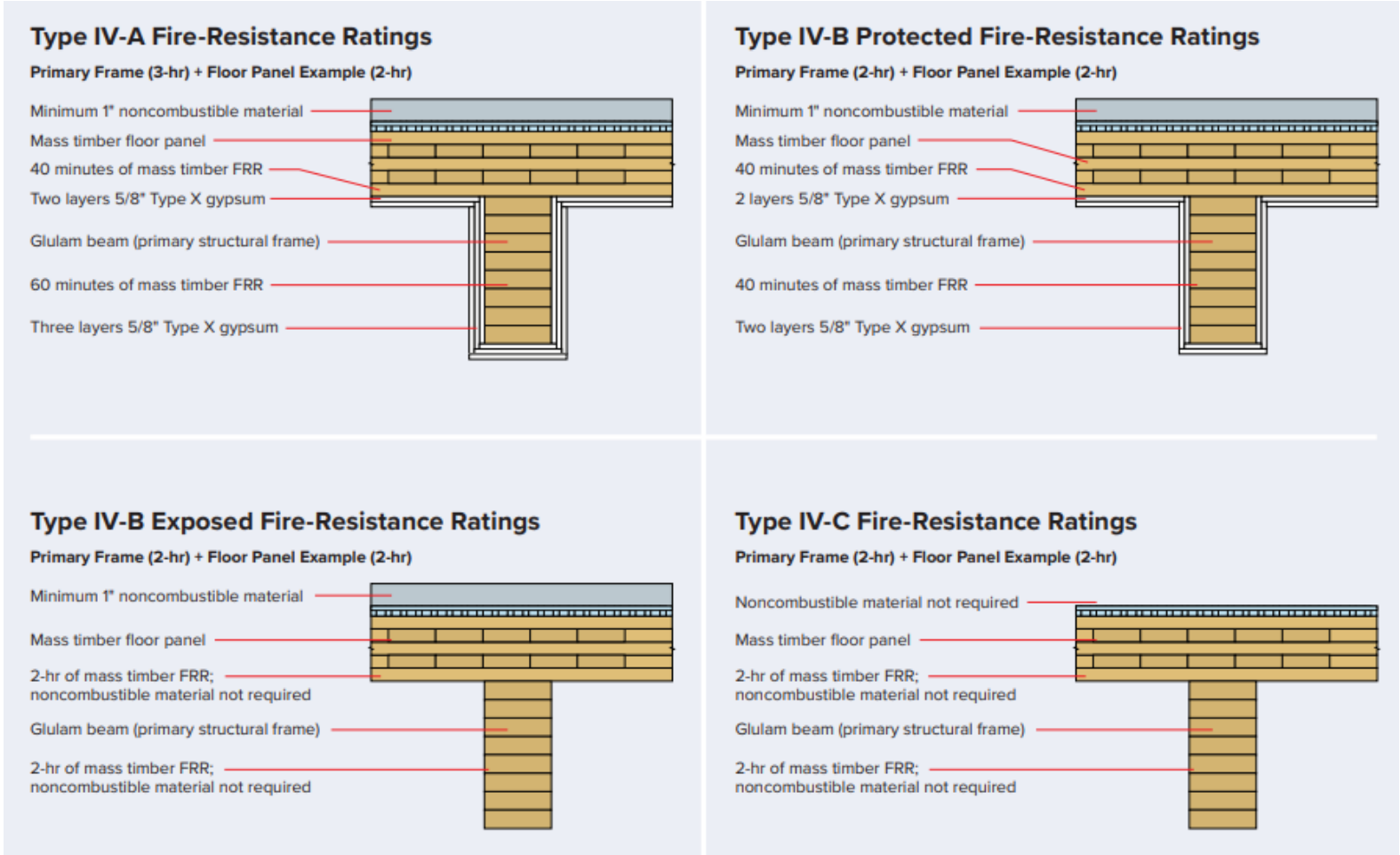
- Interior Walls
  - Laminated construction: 4” thick
  - Solid wood construction: Min (2) layers of 1” matched boards
  - Wood stud walls, 1-hour min (IV-HT only)
  - Non-combustible, 1-hour min

Verify other code requirements for FRR (e.g. interior bearing walls, occupancy separation, etc.)

Construction Types IV-HT and IV-A, B, and C

Type IV exposure

- Type IV-A: No exposed timber
- Type IV-B: Partial exposed timber
- Type IV-C: Fully exposed timber permitted
- Type IV-HT: Fully exposed timber permitted



https://www.woodworks.org/wp-content/uploads/wood_solution_paper-demonstrating-frrs-in-tall-wood-buildings-woodworks.pdf

Construction Types IV-HT and IV-A, B, and C

Type IV Noncombustible Protection (Types IV-A and B)

- 1/2” Type X gypsum = 25 minutes
- 5/8” Type X gypsum = 40 minutes

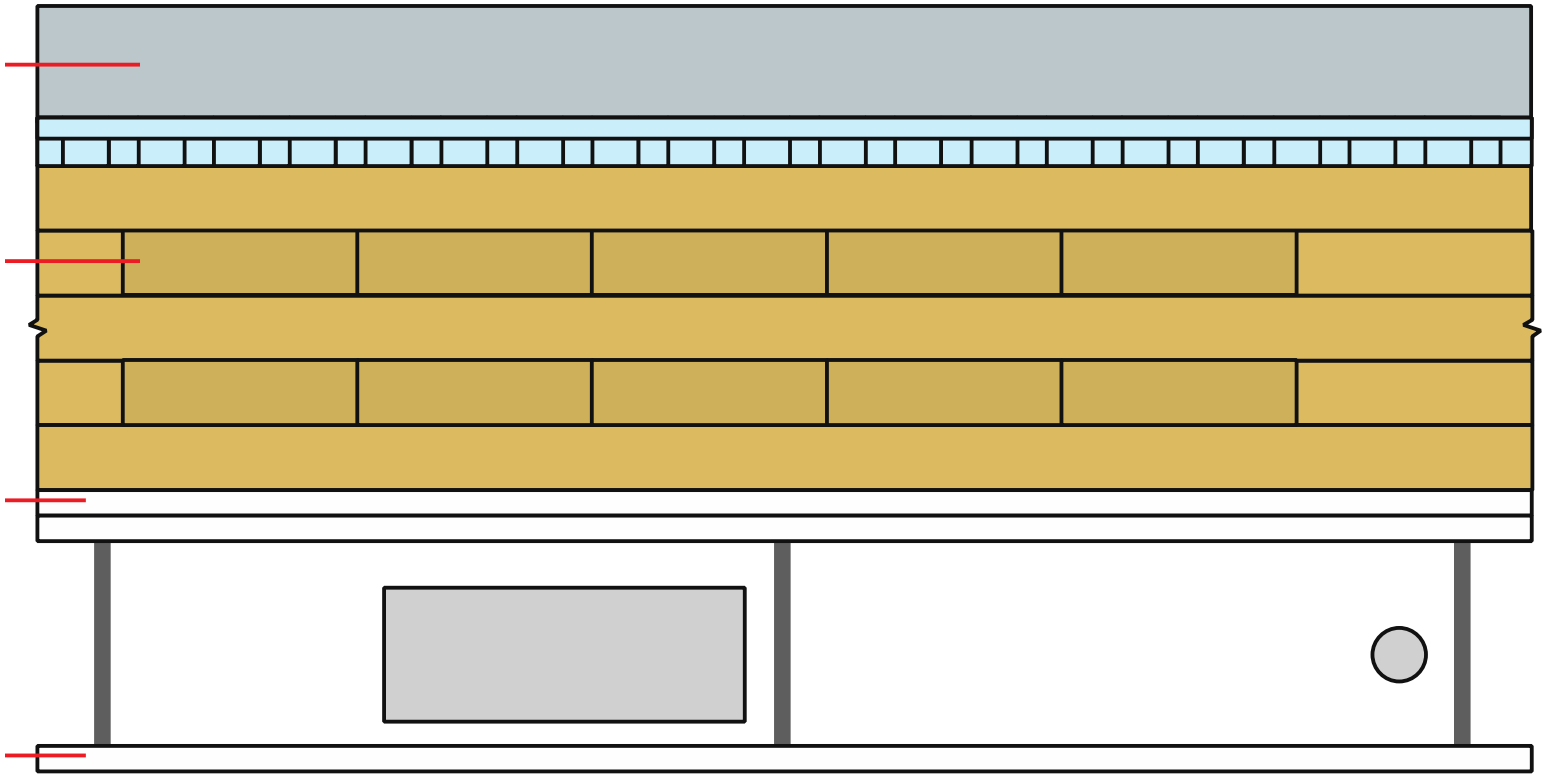
FRR of Building Element (Hours)	Min Protection from Noncombustible (Minutes)	Example Assembly	
		Mass Timber FRR	Type X gypsum
1	40	20 minutes	(1) Layer 5/8”
2	80	40 minutes	(2) Layers 5/8”
3 or more	120	60 minutes	(3) Layers 5/8”

https://www.woodworks.org/wp-content/uploads/wood_solution_paper-demonstrating-frrs-in-tall-wood-buildings-woodworks.pdf

Construction Types IV-HT and IV-A, B, and C

Type IV concealed spaces

- Can I have a dropped ceiling? Raised access floor?

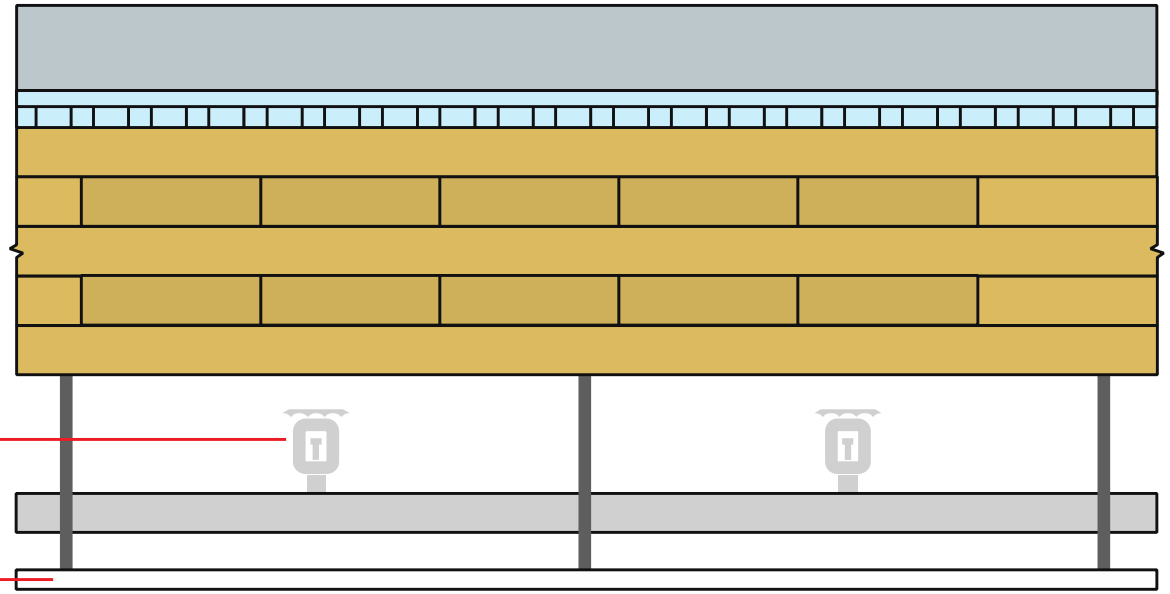


Construction Types IV-HT and IV-A, B, and C

Concealed Spaces in Type IV-HT

CONCEALED SPACES: TYPE IV-HT

Option 1:

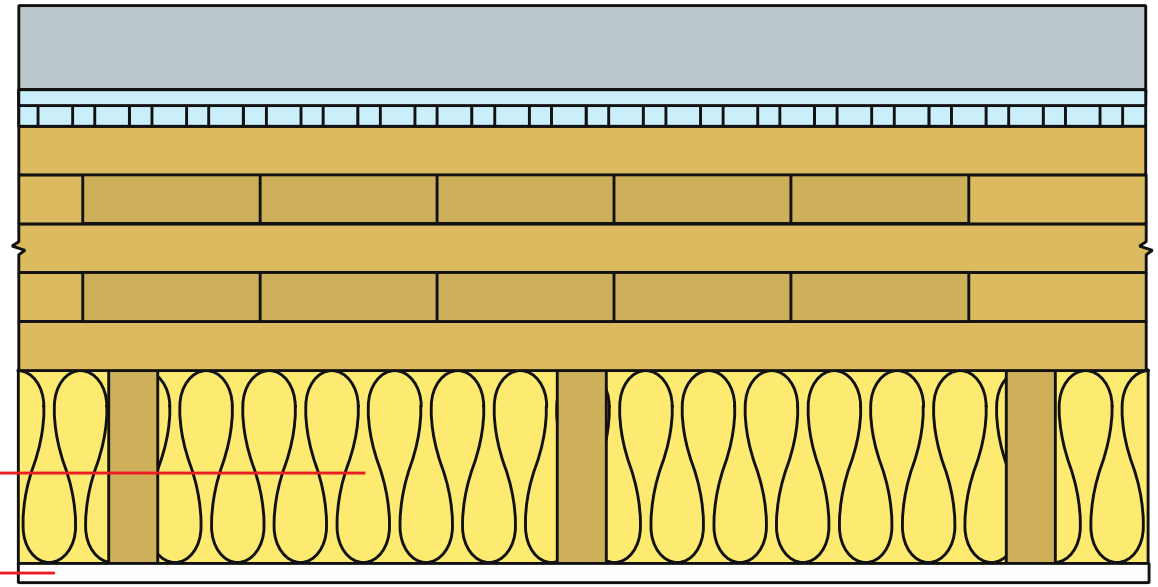


Construction Types IV-HT and IV-A, B, and C

Concealed Spaces in Type IV-HT

CONCEALED SPACES: TYPE IV-HT

Option 2:



Construction Types IV-HT and IV-A, B, and C

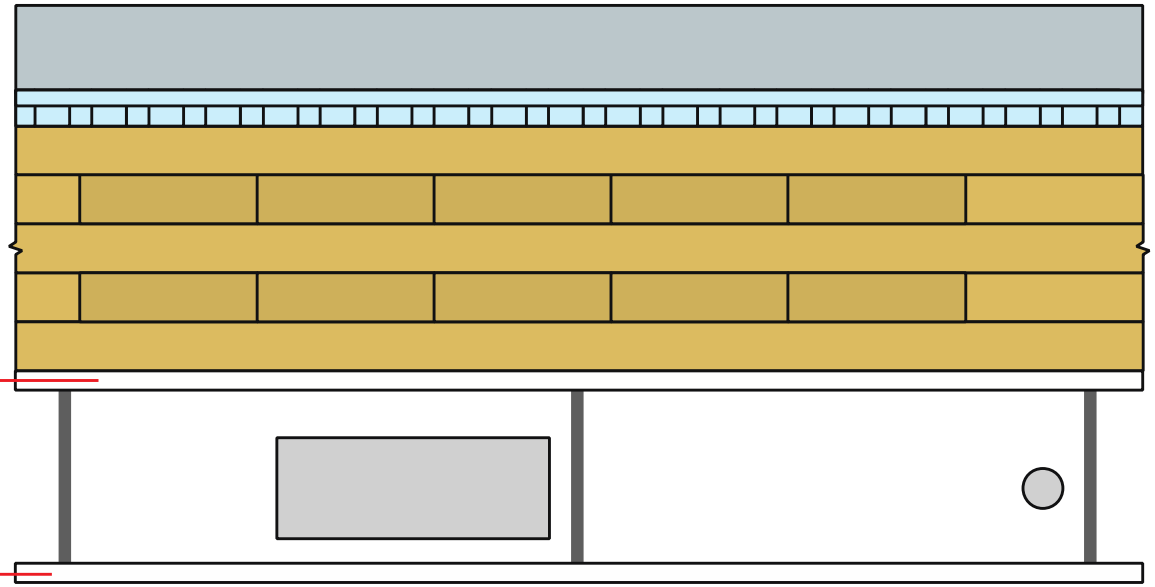
Concealed Spaces in Type IV-HT

CONCEALED SPACES: TYPE IV-HT

Option 3:

5/8" Type X gypsum on all mass timber surfaces within concealed space

Dropped ceiling



Construction Types IV-HT and IV-A, B, and C

Concealed spaces solutions paper

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

Richard McLain, PE, SE
Senior Technical Director – Tall Wood
WoodWorks – Wood Products Council

Concealed Spaces in Mass Timber and Heavy Timber Structures

Concealed spaces, such as those created by a dropped ceiling in a floor/ceiling assembly or by a stud wall assembly, have unique requirements in the International Building Code (IBC) to address the potential of fire spread in non-visible areas of a building. Section 718 of the 2018 IBC includes prescriptive requirements for protection and/or compartmentalization of concealed spaces through the use of draft stopping, fire blocking, sprinklers and other means. For information on these requirements, see the WoodWorks Q&A, *Are sprinklers required in concealed spaces such as floor and roof cavities in multi-family wood-frame buildings?*[1]

For mass timber building elements, the choice of construction type can have a significant impact on concealed space requirements. Because mass timber products such as cross-laminated timber (CLT) are prescriptively recognized for Type IV construction, there is a common misperception that exposed mass timber building elements cannot be used or exposed in other construction types. This is not the case.

In addition to Type IV buildings, structural mass timber elements—including CLT, glue-laminated timber (glulam), nail-laminated timber (NLT), structural composite lumber (SCL), and tongue-and-groove (T&G) decking—can be utilized and exposed in the following construction types, whether or not a fire-resistance rating is required:

- **Type III** – Floors, roofs and interior walls may be any material permitted by code, including mass timber; exterior walls are required to be noncombustible or fire retardant-treated wood.
- **Type V** – Floors, roofs, interior walls and exterior walls (i.e., the entire structure) may be constructed of mass timber.
- **Types I and II** – Mass timber may be used in select circumstances such as roof construction—including the primary frame in the 2021 IBC—in Types I-B, II-A or II-B; exterior columns and arches when 20 feet or more of horizontal separation is provided; and balconies, canopies and similar projections.

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

Construction Types I-A, II-A, II-B

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

Construction Types I-B, II-A, II-B

Where does the code allow wood to be used?

- Mass Timber Roof Construction

Wellesley College, Wellesley, MA

Wellesley College Science Complex / Skidmore, Owings & Merrill / Le Messurier / Photo Dave Burk © SOM

Construction Types I-B, II-A, II-B

- IBC Table 601, Footnote c:
  - In all occupancies, heavy timber complying with Section 2304.11 shall be allowed for roof construction, including primary structural frame members, where a 1-hour or less fire-resistance rating is required.

Wellesley College, Wellesley, MA

Wellesley College Science Complex / Skidmore, Owings & Merrill / Le Messurier / Photo Dave Burk © SOM

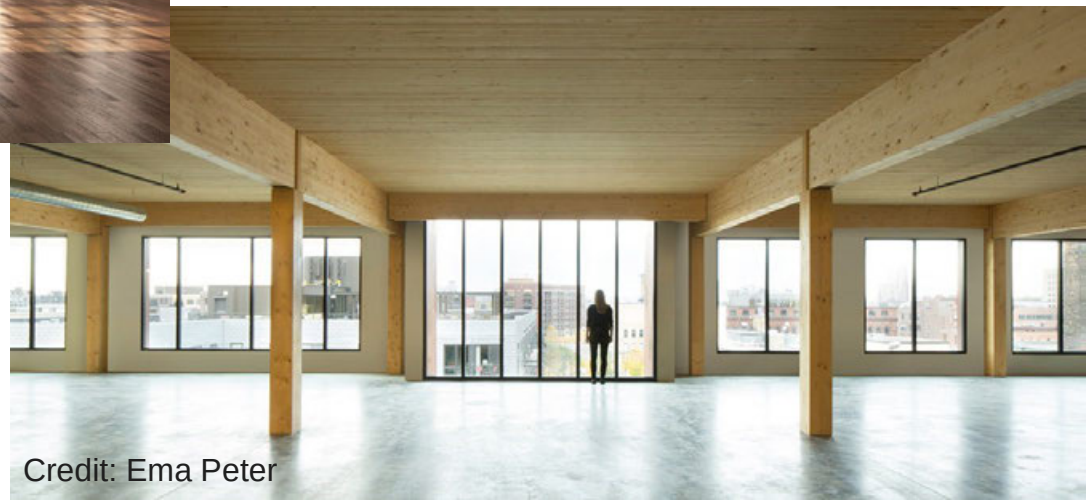
Which Construction Type?

	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Exterior Wall Material	Non-combustible		Non-combustible		FRTW		CLT (protected)			FRTW (LF, MT), CLT (protected)	Any wood	
Interior Elements	Non-combustible		Non-combustible		Any wood		Heavy Timber			Heavy Timber	Any wood	

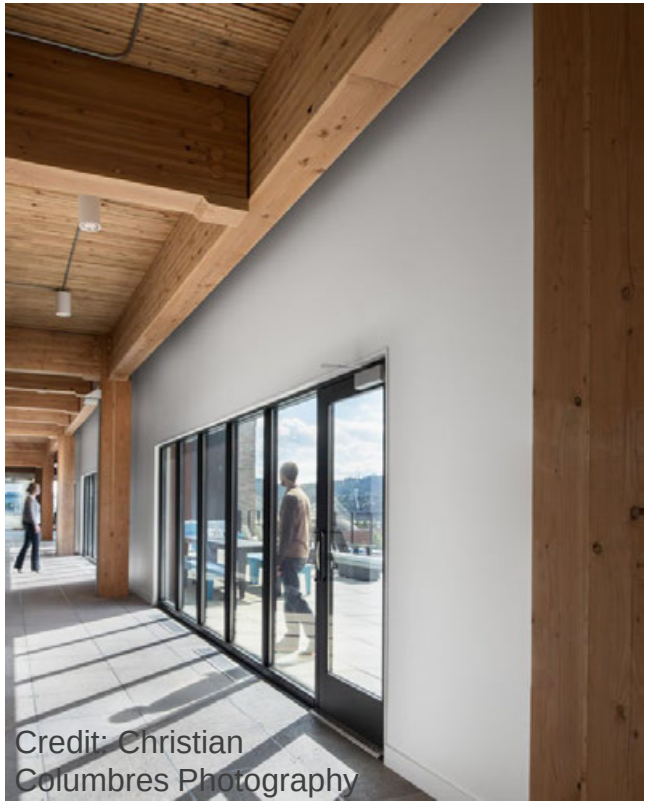
Which Construction Type?

Type III-A: 6 stories

Allowable mass timber building size:
Group B occupancy
with NFPA 13 Sprinkler



Type IV-HT: 6 stories



Type V-A: 4 stories

Which Construction Type? - Height Limits

- IBC Table 504.3 provides base and increased heights

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION												
	See Footnotes	Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S13D	60	60	60	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	270	180	85	85	70	60

NS = Buildings not equipped throughout with an automatic sprinkler system

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

S13D = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.3 (1 & 2-family dwellings)

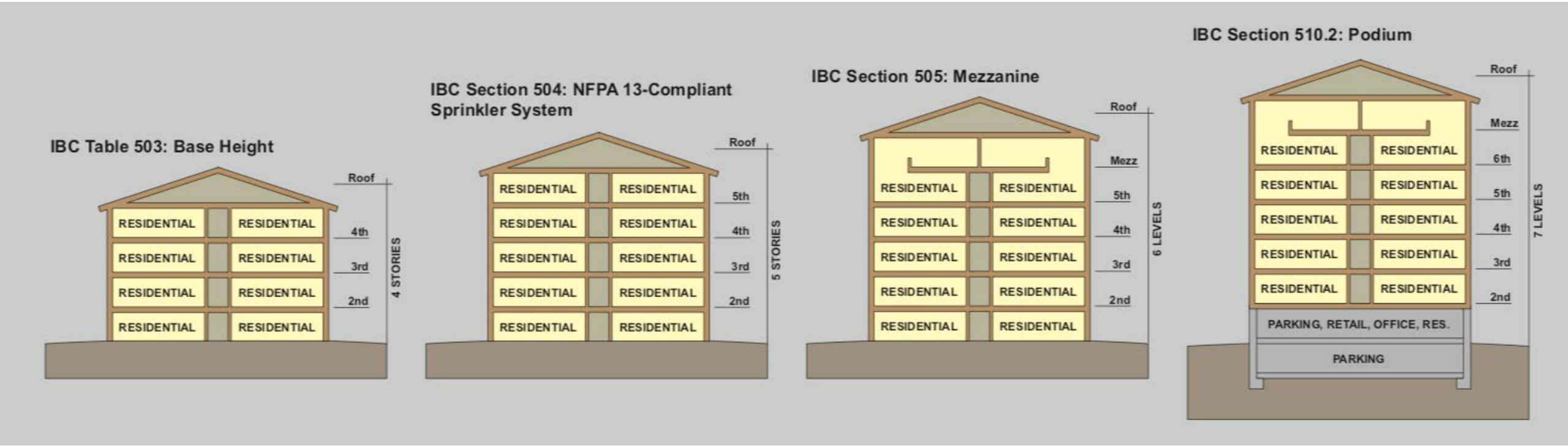
Which Construction Type? - Story Limits

- IBC Table 504.4 provides limits to number of stories

TABLE 504.4
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE[a, b]

OCCUPANCY CLASSIFICATION	See Footnotes	TYPE OF CONSTRUCTION											
		Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A-2	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2
A-3	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2
B	NS	UL	11	5	3	5	3	5	5	5	5	3	2
	S	UL	12	6	4	6	4	18	12	9	6	4	3
R-1[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4									4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
R-2[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4	4								4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
S-1	NS	UL	11	4	2	3	2	4	4	4	4	3	1
	S	UL	12	5	4	4	4	10	7	5	5	4	2

Which Construction Type? - Height & Story Limits



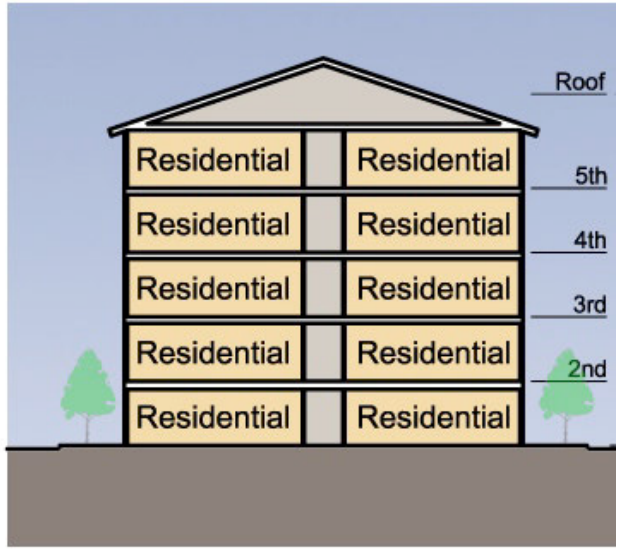
Source: WoodWorks

Type V → Type III
Type IV-HT → + Mezzanines → + Podiums

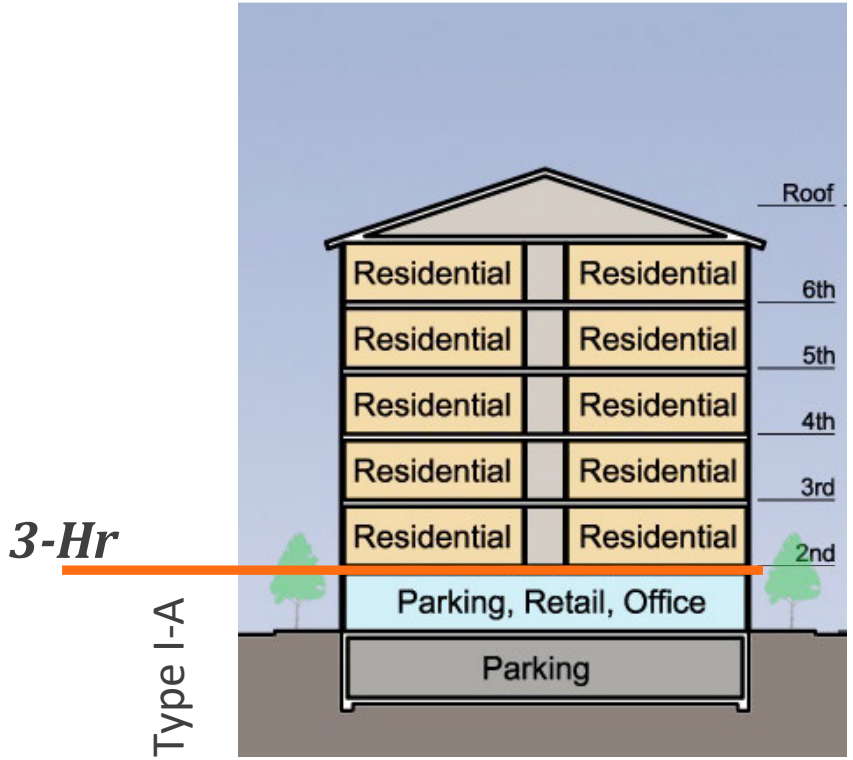
Which Construction Type? - Podium Provisions

Special provisions for podiums (IBC 510.2)

- Increases allowable stories…. not allowable building height



5 story Type III Building

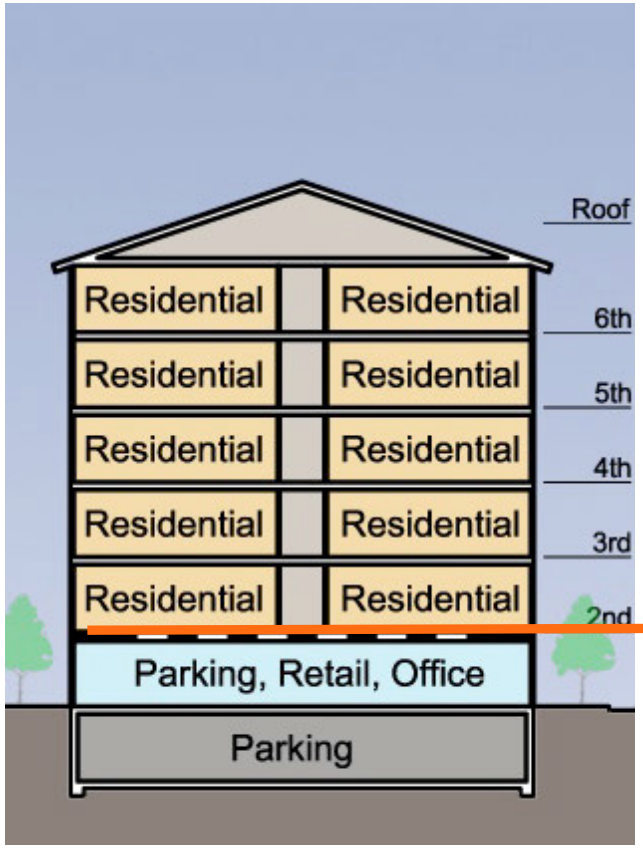


5 story Type III Building
on Top of a Type I-A Podium

Which Construction Type? – Podium Provisions

Evolution of IBC podium provisions

» Starting in 2015, IBC allows multiple podium stories above grade



3-Hr

Type I-A

IBC	2006	2009	2012	2015	2018	2021
Section	509.2	509.2	510.2	510.2	510.2	510.2
Upper Occupancy	A, B, M, R or S					
Lower Occupancy	S-2 Parking	A, B, M, R or S-2 Parking		Any Except H		
Podium Height	1 Story			No Restriction		

Which Construction Type? – Building Size & Occupancy

» Building size by construction type (sprinklered construction)

	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	**Allowable Height (IBC Table 504.3)**							
A, B, R	270	180	85	85	85	75	70	60
	Allowable Stories (IBC Table 505.4)							
A-2, A-3, A-4	18	12	6	4	4	3	3	2
B	18	12	9	6	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area per Story (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

Which Construction Type? – Building Size & Occupancy

» Building size by construction type (sprinklered construction)

	IV-A	IV-B	IV-C	IV-HT	III-A	III-B	V-A	V-B
Occupancies	**Allowable Height (IBC Table 504.3)**							
A, B, R	270	180	85	85	85	75	70	60
	Allowable Stories (IBC Table 505.4)							
A-2, A-3, A-4	18	12	6	4	4	3	3	2
B	18	12	9	6	6	4	4	3
R-2	18	12	8	5	5	5	4	3
	Allowable Area per Story (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

Which Construction Type?

Business (B) Occupancy with NFPA 13 sprinklers		**III-B**	**III-A**	**IV-HT**	**IV-C**
Heights & areas	Area per story (ft^2)	57,000	85,500	108,000	135,000
	Max stories	4	6	6	9
	Max height (ft)	75	85	85	85
Rating Requirements	Primary structural frame	0-hr	1-hr	HT-hr	2-hr
	Exterior bearing walls	2-hr	2-hr	2-hr	2-hr
	Interior bearing walls	0-hr	1-hr	1-hr / HT	2-hr
	Nonbearing exterior walls	Table 705.5			
	Nonbearing interior walls	0-hr	0-hr	1-hr or Section 602.4.8.1	0-hr
	Floor construction	0-hr	1-hr	HT	2-hr
	Roof construction	0-hr	1-hr	HT	1-hr

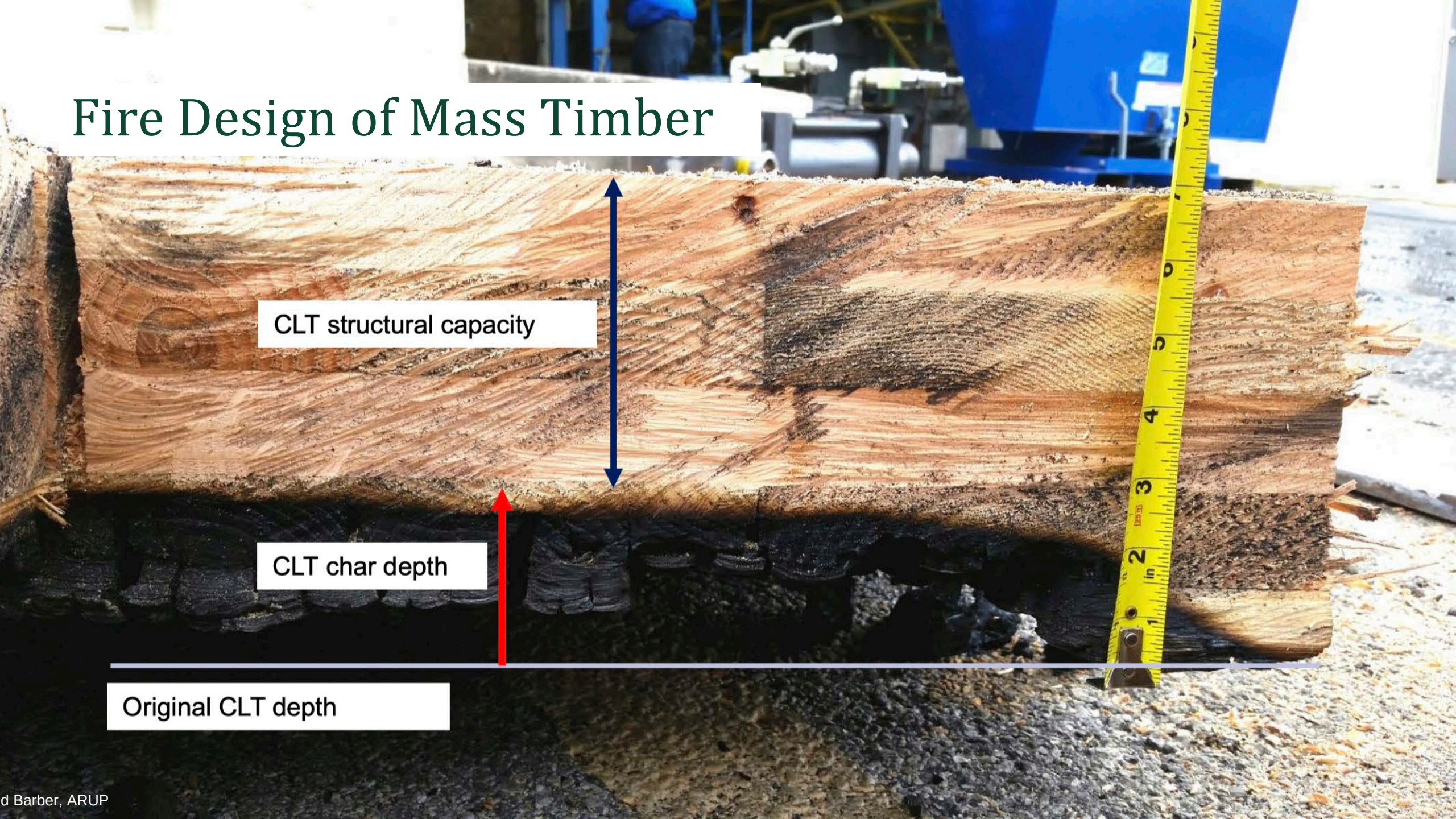
Which Construction Type?

Residential (R-2) Occupancy with NFPA 13 sprinklers		**III-B**	**III-A**	**IV-HT**	**IV-C**
Heights & areas	Area per story (ft^2)	48,000	72,000	61,500	76,875
	Max stories	5	5	5	8
	Max height (ft)	75	85	85	85
Rating Requirements	Primary structural frame	0-hr	1-hr	HT	2-hr
	Exterior bearing walls	2-hr	2-hr	2-hr	2-hr
	Interior bearing walls	0-hr	1-hr	1-hr / HT	2-hr
	Nonbearing exterior walls	Table 705.5			
	Nonbearing interior walls	0-hr	0-hr	1-hr or Section 602.4.8.1	0-hr
	Floor construction	0-hr	1-hr	HT	2-hr
	Roof construction	0-hr	1-hr	HT	1-hr

MASS TIMBER FIRE RESISTANCE

Chemeketa Community College Agricultural Complex / FFA Architecture and Interiors / KPFF Consulting Engineers / Photo Christian Columbres

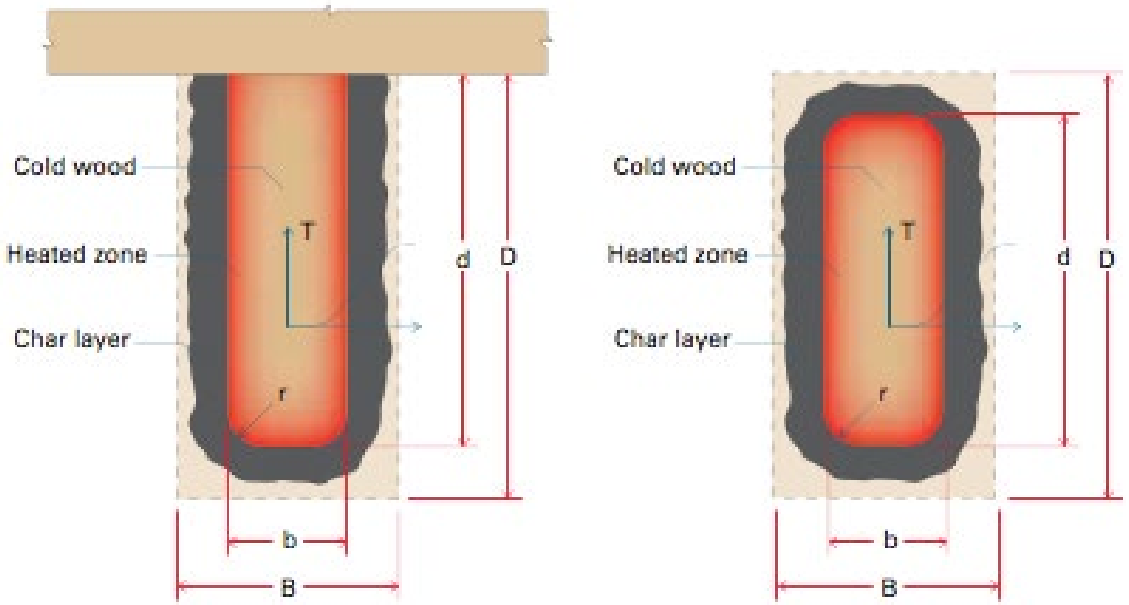
Fire Design of Mass Timber



d Barber, ARUP

Fire Design of Mass Timber

- Mass Timber's Fire-Resistive Performance is well-tested, documented and recognized



Source: AWC's TR 10

Fire Design of Mass Timber

Fire-Resistance Ratings

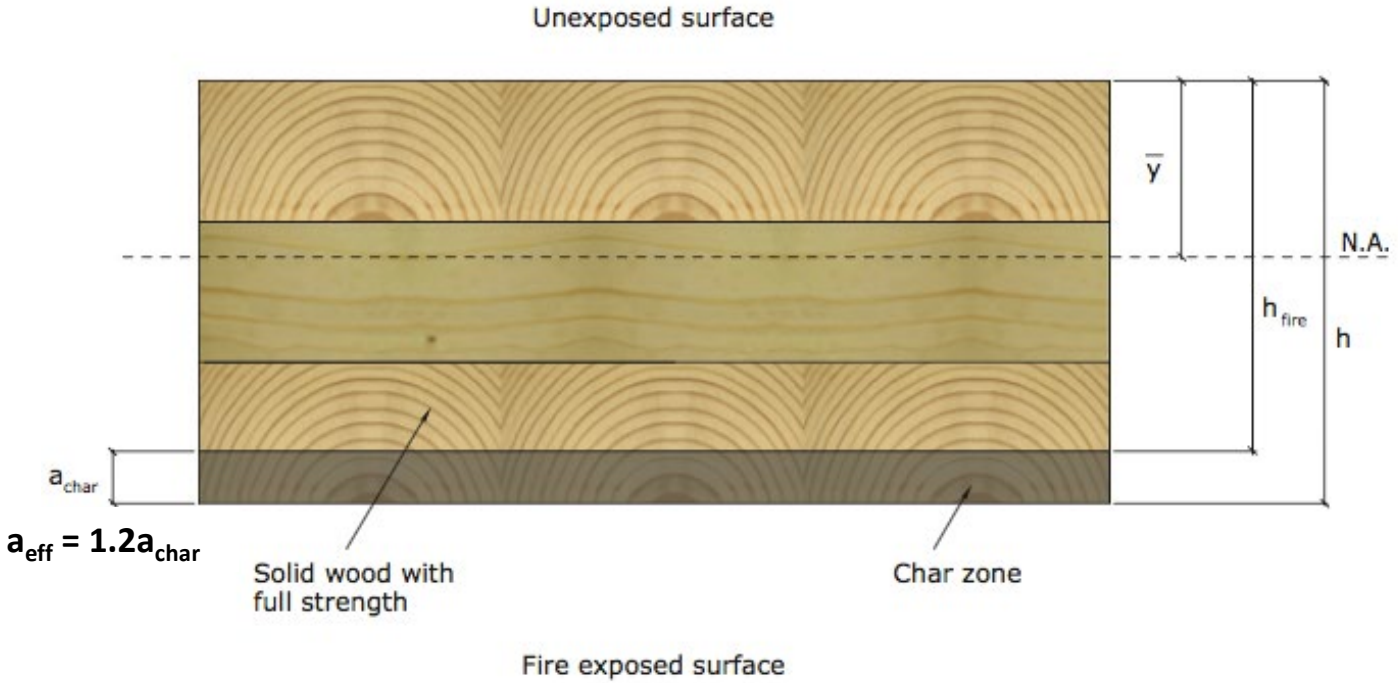
- **Driven primarily by construction type**
- **Rating achieved through timber alone or non-com protection required?**

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

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

Fire Design of Mass Timber

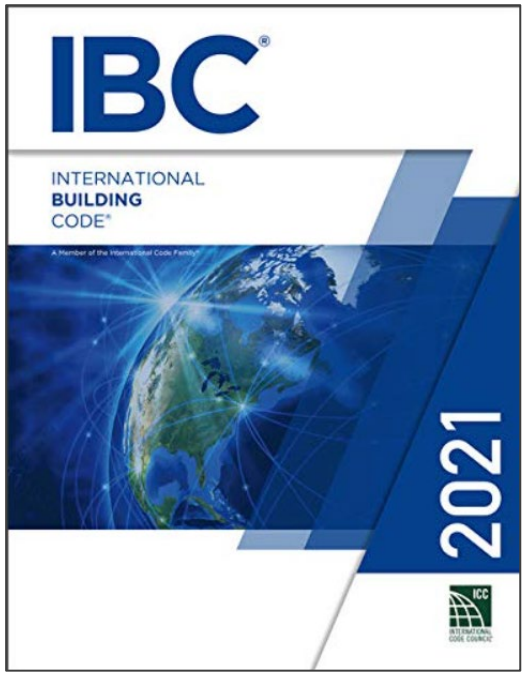
- Demonstrating FRR of mass timber:
  - 1. Calculations in accordance with IBC 722 (NDS Chapter 16)
  - 2. Tests in accordance with ASTM E119

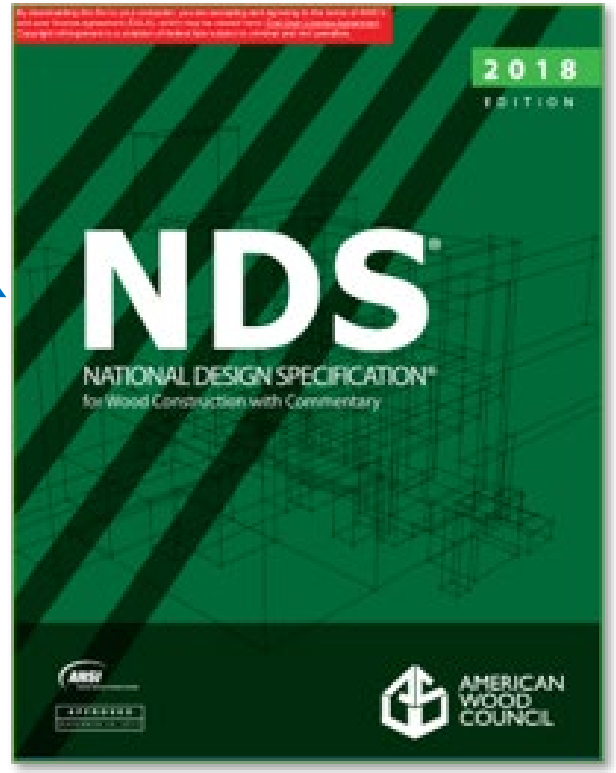


Fire Design of Mass Timber

Calculated FRR of Exposed MT:

» IBC to NDS code compliance path





Code Path for Exposed Wood Fire-Resistance Calculations

IBC 703.2.2
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.

Fire Design of Mass Timber

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 16.2.1A Char Depth and Effective Char Depth (for β_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
1½-Hour	2.1	2.5
2-Hour	2.6	3.2

Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

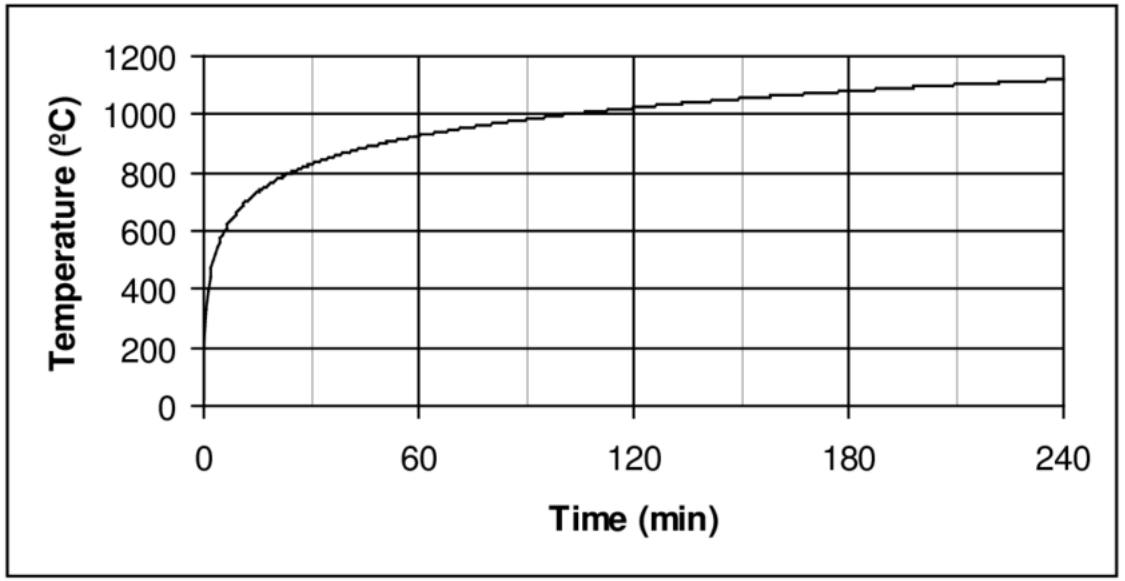
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Fire Design of Mass Timber

Tested FRR of Exposed MT:

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

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



Standard ASTM E119 test time-temperature curve

Fire Design of Mass Timber

WoodWorks Inventory of Fire Tested Mass Timber Assemblies

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

WoodWorks™ WOOD PRODUCTS COUNCIL

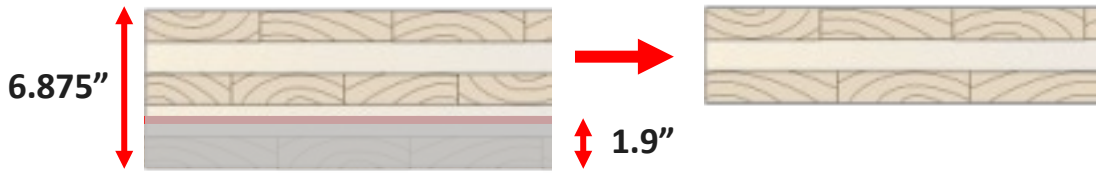
CLT Panel	Manufacturer	CLT Grade or Major x Minor Grade	Ceiling Protection	Panel Connection in Test	Floor Topping	Load Rating	Fire Resistance Achieved (Hours)	Source	Testing Lab
3-ply CLT (114mm 4.488 in)	Nordic	SPF 1650 Fb 1.5E MSR x SPF #3	2 layers 1/2" Type X gypsum	Half-Lap	None	Reduced 36% Moment Capacity	1	1 (Test 1)	NRC Fire Laboratory
3-ply CLT (105mm 4.133 in)	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Reduced 75% Moment Capacity	1	1 (Test 5)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	2	NRC Fire Laboratory March 2016
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer of 5/8" Type X gypsum under Z-channels and furring strips with 3 5/8" fiberglass batts	Topside Spline	2 staggered layers of 1/2" cement boards	Loaded, See Manufacturer	2	5	NRC Fire Laboratory Nov 2014
5-ply CLT (175mm 6.875")	Nordic	E1	None	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat	Reduced 50% Moment Capactiy	1.5	3	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" normal gypsum	Topside Spline	3/4 in. proprietary gypcrete over Maxxon acoustical mat or proprietary sound board	Reduced 50% Moment Capactiy	2	4	UL
5-ply CLT (175mm 6.875")	Nordic	E1	1 layer 5/8" Type X Gyp under Resilient Channel under 7 7/8" I-Joists with 3 1/2" Mineral Wool beween Joists	Half-Lap	None	Loaded, See Manufacturer	2	21	Intertek 8/24/2012
5-ply CLT (175mm 6.875")	Structurlam	E1 M5 MSR 2100 x SPF #2	None	Topside Spline	1-1/2" Maxxon Cyp-Grete 2000 over Maxxon Reinforcing Mesh	Loaded, See Manufacturer	2.5	6	Intertek, 2/22/2016
5-ply CLT (175mm 6.875")	DR Johnson	V1	None	Half-Lap & Topside Spline	2" gypsum topping	Loaded, See Manufacturer	2	7	SwRI (May 2016)
5-ply CLT (175mm 6.875")	Nordic	SPF 1950 Fb MSR x SPF #3	None	Half-Lap	None	Reduced 59% Moment Capacity	1.5	1 (Test 3)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	Structurlam	SPF #1/#2 x SPF #1/#2	1 layer 5/8" Type X gypsum	Half-Lap	None	Unreduced 101% Moment Capacity	2	1 (Test 6)	NRC Fire Laboratory
7-ply CLT (245mm 9.65")	Structurlam	SPF #1/#2 x SPF #1/#2	None	Half-Lap	None	Unreduced 101% Moment Capacity	2.5	1 (Test 7)	NRC Fire Laboratory
5-ply CLT (175mm 6.875")	SmartLam	SL-V4	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 4)	Western Fire Center 10/26/2016
5-ply CLT (175mm 6.875")	SmartLam	V1	None	Half-Lap	nominal 1/2" plywood with 8d nails.	Loaded, See Manufacturer	2	12 (Test 5)	Western Fire Center 10/28/2016

Fire Design of Mass Timber

- Fire Resistance Ratings (FRR)
  - Thinner panels (i.e. 3-ply) can be difficult to achieve 1+ hour FRR
  - 5-ply CLT panels can usually achieve 1- or 2-hour FRR
  - Construction Type -> FRR -> Member size -> Grid (order as needed)

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

3 ply (after 1-hour rating)



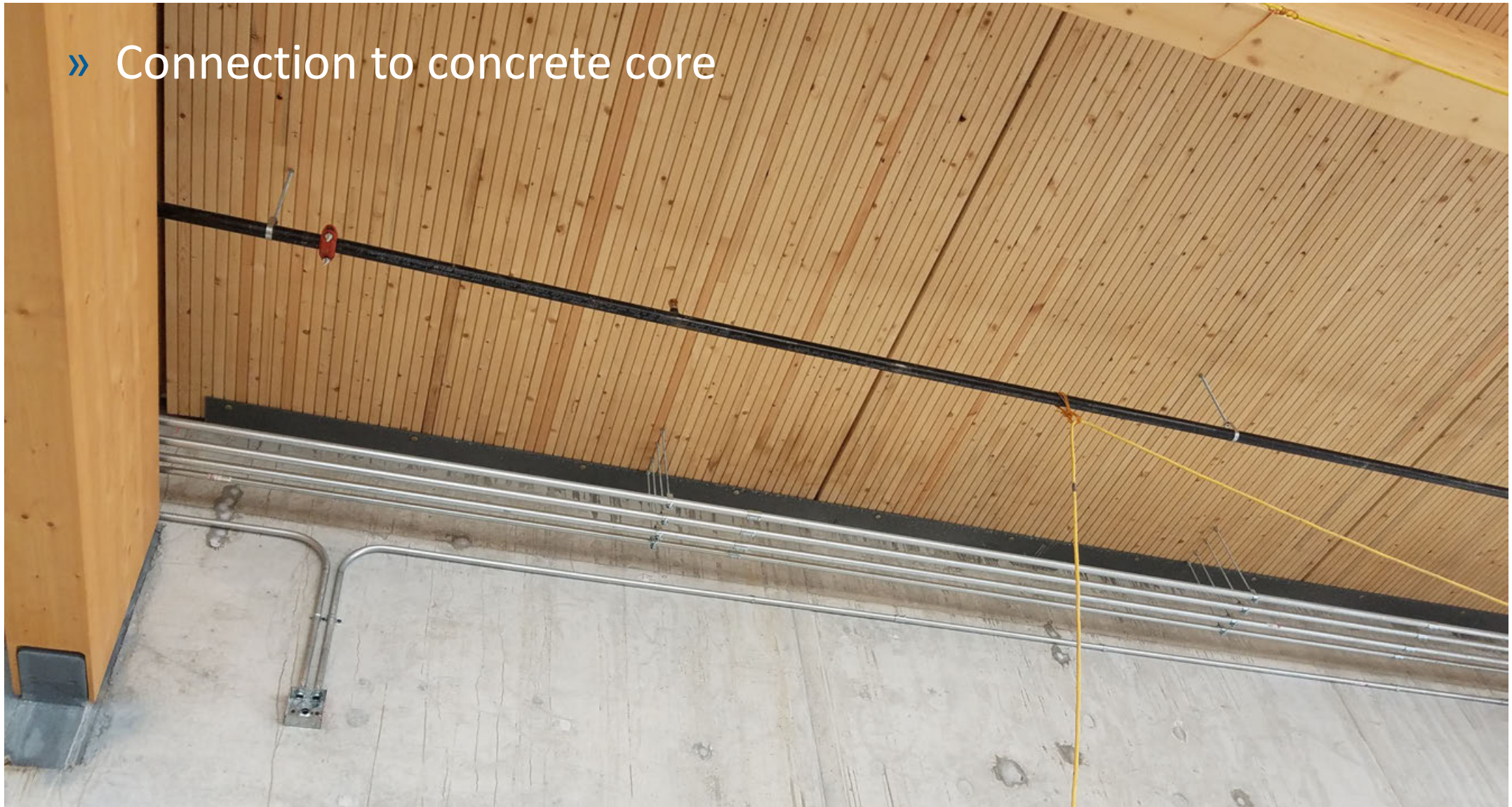
5 ply (after 1-hour rating)

LATERAL DESIGN OPTIONS

Mass Timber Lateral Systems

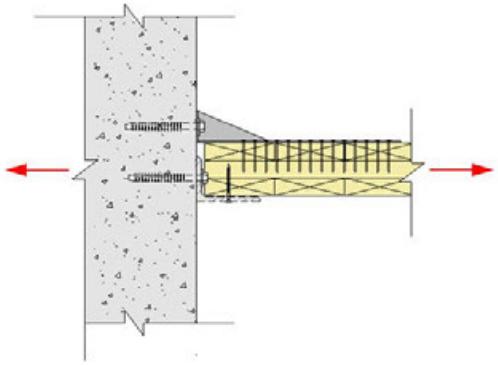
Mass Timber Lateral Systems

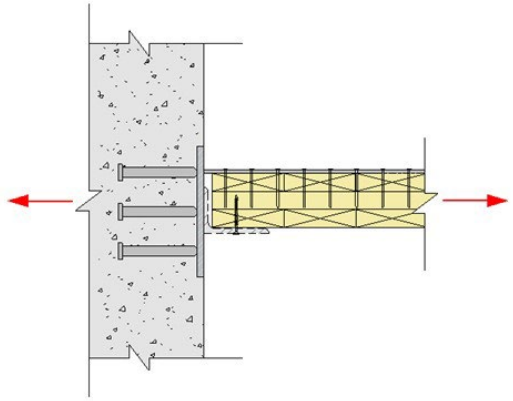
- Connection to concrete core

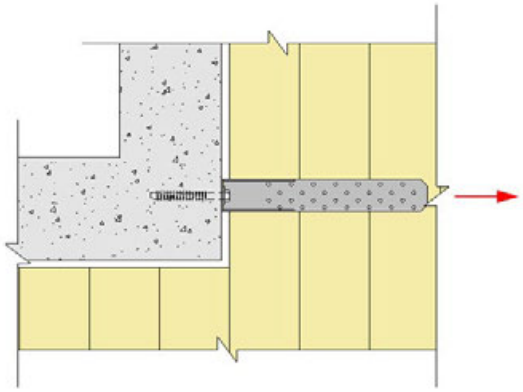


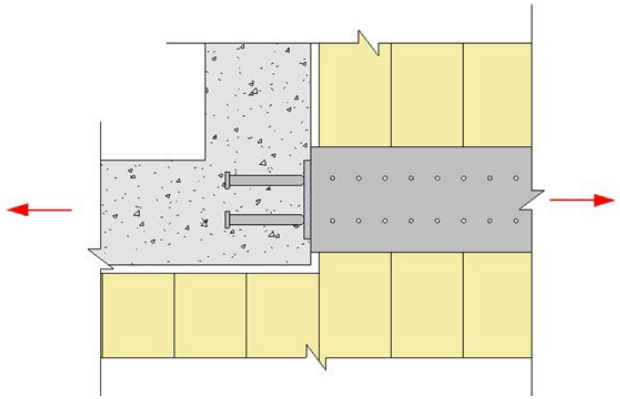
Mass Timber Lateral Systems

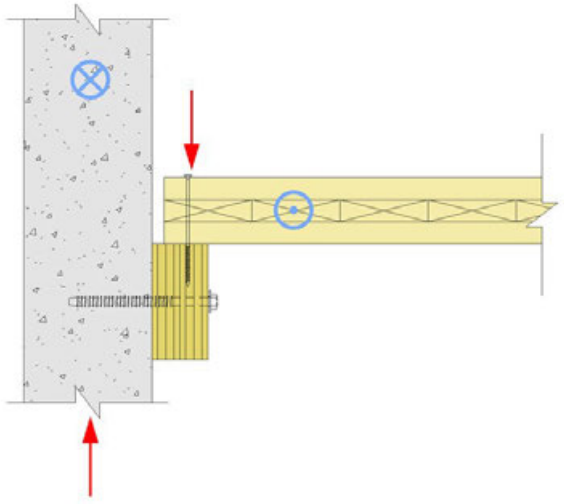
- Connections to concrete core
  - Tolerances & adjustability
  - Drag / collector forces











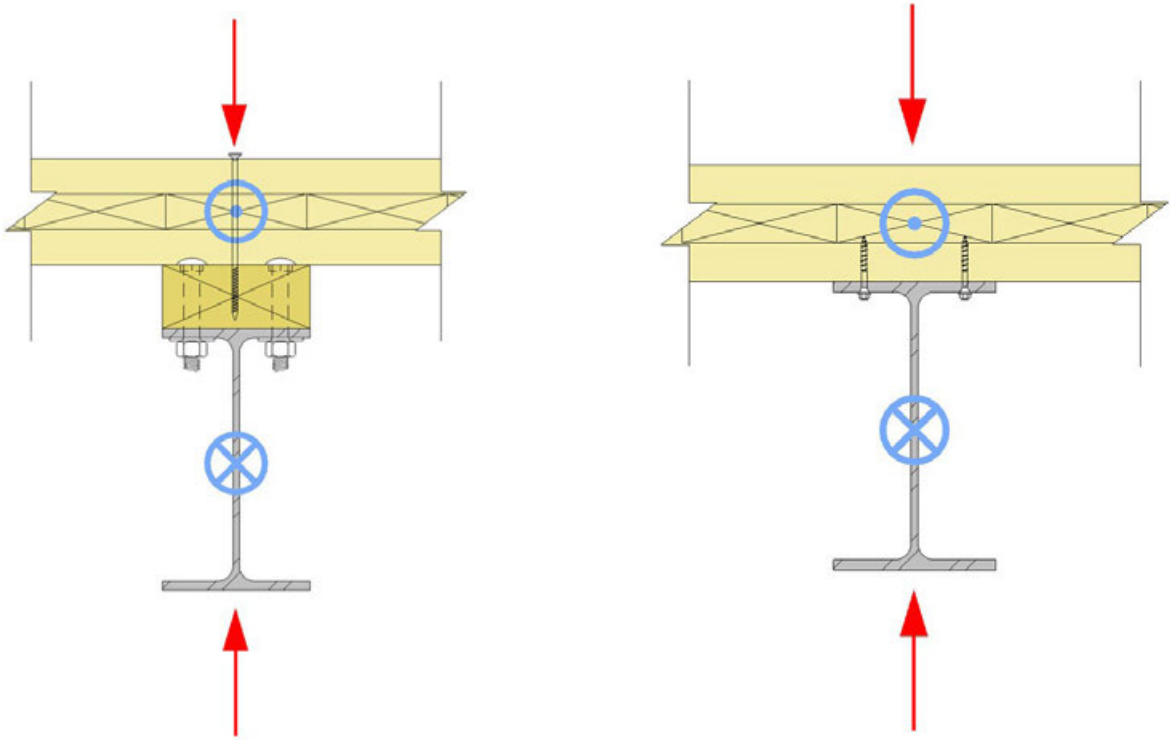
Mass Timber Lateral Systems

- Steel Braced Frame

Photos: Marcus Kauffmann, ODF

Mass Timber Lateral Systems

- Connections to steel frame
  - Tolerances & adjustability
  - Consider temperature fluctuations
  - East of installation



Photos: Marcus Kauffmann, ODF

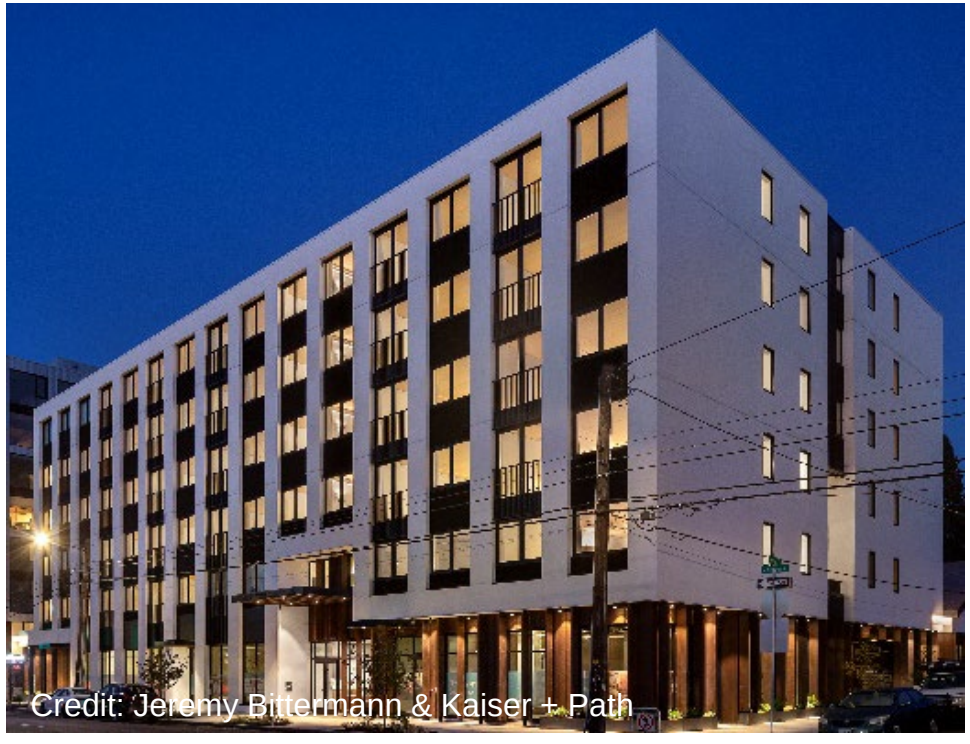
Mass Timber Lateral Systems

- Light Frame Wood Shear Walls

Credit: KL&A Engineers & Builders

Mass Timber Lateral Systems

- Light frame wood Shear Walls:
  - Code compliance
  - Standard of construction practice well know
  - Limited to 65’ shear wall height, 85’ overall building height (Type III-A)


Credit: Jeremy Bittermann & Kaiser + Path

Mass Timber Lateral Systems

- Mass Timber Shear Walls

Photo: Alex Schreyer

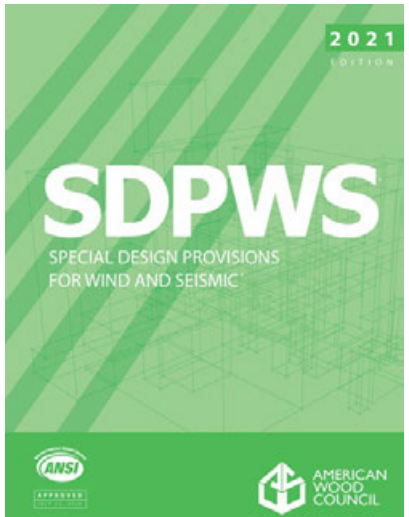
Mass Timber Lateral Systems

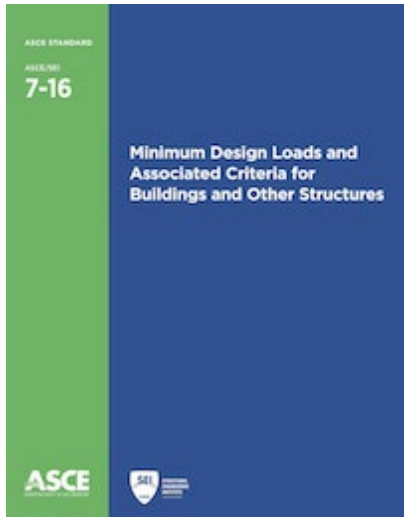
Lateral System Choices

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



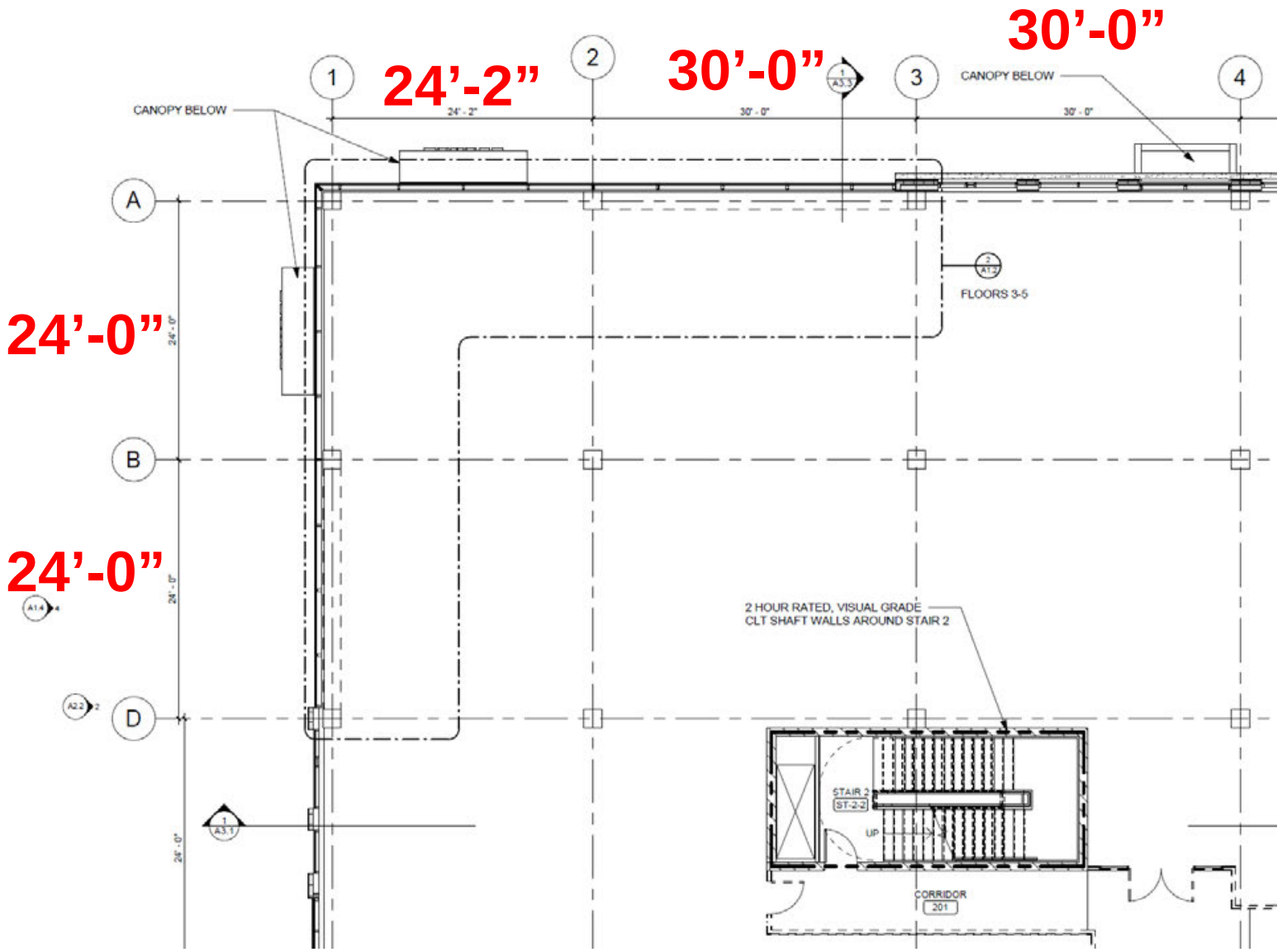


STRUCTURAL GRID

Structural Grid

Grids & Spans

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



Structural Grid

Grids & Spans

- Consider Efficient Layouts
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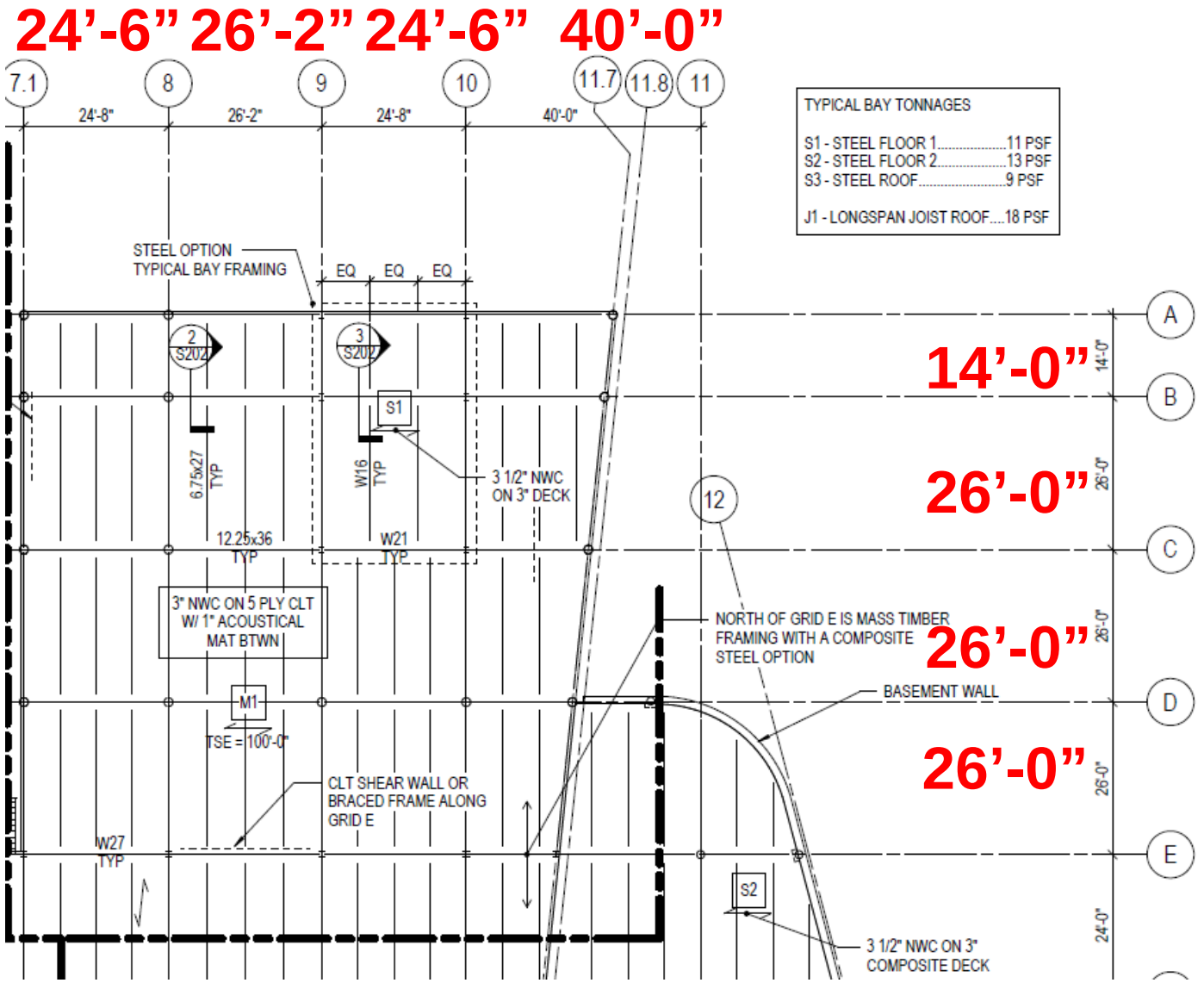


Structural Grid

Member Sizes

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

0 HR FRR: Consider 3-ply Panel

- Efficient Spans of 10-12 ft
- Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

Albina Yard, Portland, OR
20x20 Grid, 1 purlin per bay
3-ply CLT
Image: Lever Architecture

Structural Grid

Member Sizes

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

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**

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

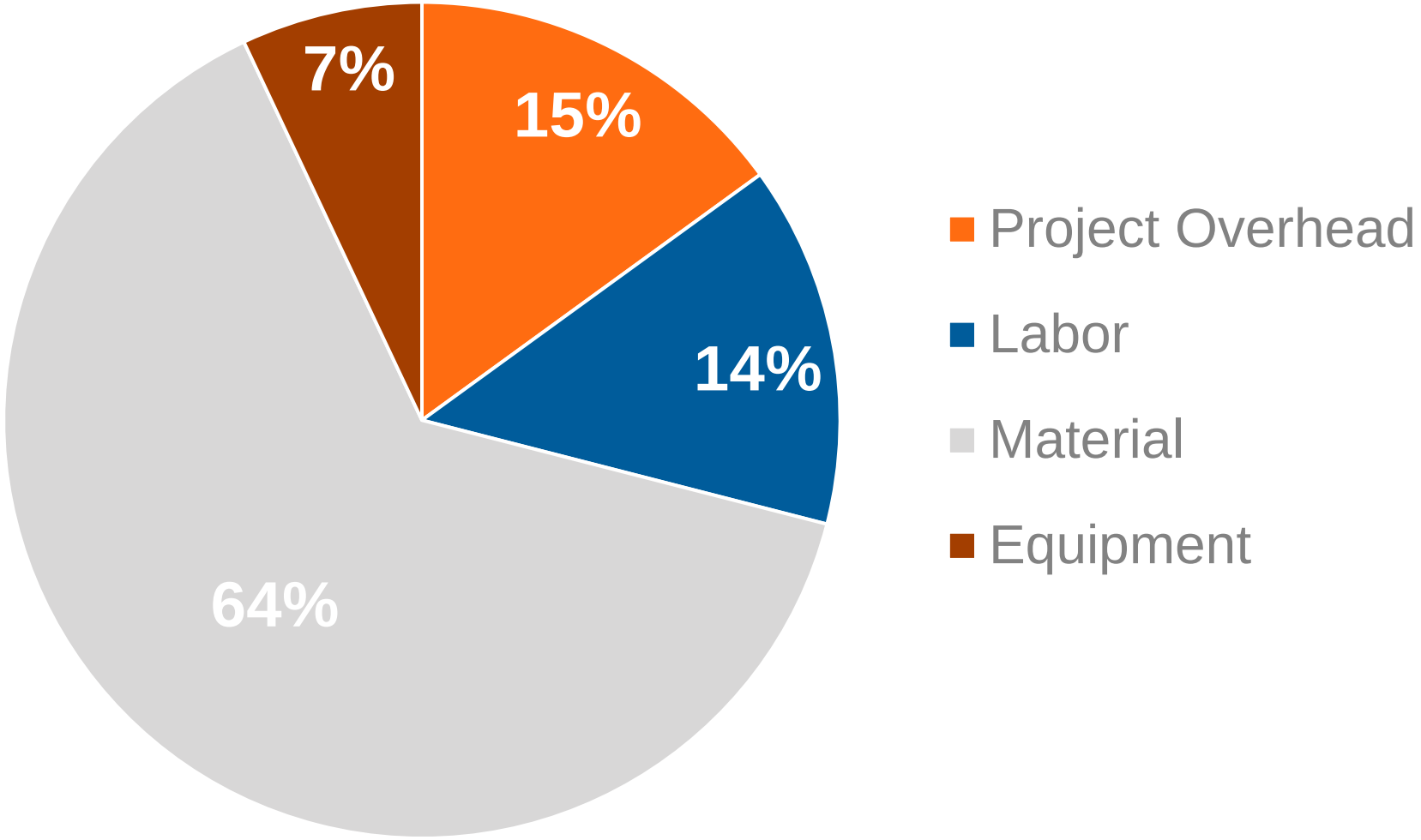
Clay Creative, Portland, OR
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie

Structural Grid - Panels

- Why so much focus on panel thickness?

Structural Grid - Panels

» Typical Mass Timber Package Costs

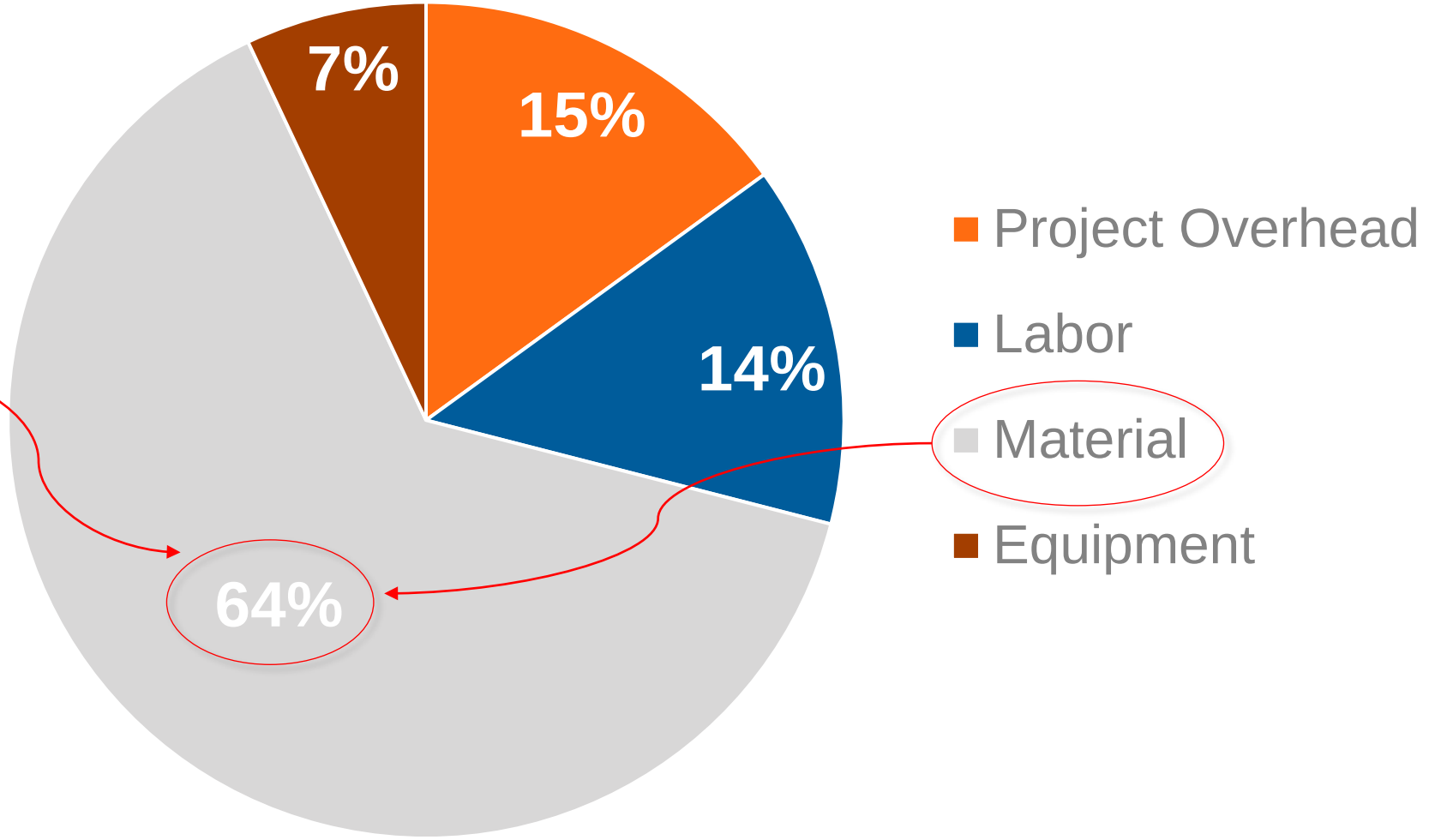


Source: Swinerton

Structural Grid - Panels

» Typical Mass Timber Package Costs

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



Source: Swinerton

Structural Grid - Panels

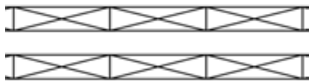
» Cost and Construction Type – Panel selection

TABLE 601

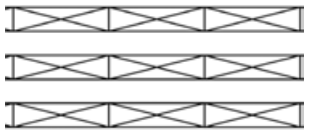
Fire Resistance Rating Requirements for Building Elements (Hours)

Building Element	I-A	I-B	III-A	III-B	IV-A	IV-B	IV-C	IV-HT	V-A	V-B
Primary Structural Frame	3*	2*	1	0	3*	2	2	HT	1	0
Ext. Bearing Walls	3*	2*	2	2	3*	2	2	2	1	0
Int. Bearing Walls	3*	2*	1	0	3*	2	2	1/HT	1	0
Floor Construction	2	2*	1	0	2	2	2	HT	1	0
Roof Construction	1.5*	1*	1	0	1.5	1	1	HT	1	0
Exposed Mass Timber Elements					None	20-40%	Most	All		

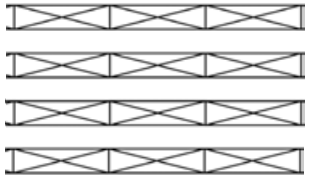
Baseline
0hr & HT



+$10/SF
1hr & maybe 2hr



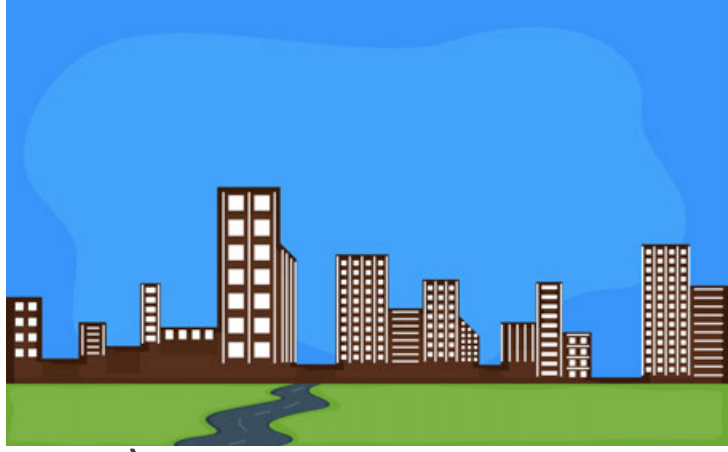
+$12-15/SF
2hr FRR



Cost Source: Swinerton

*These values can be reduced based on certain conditions in IBC 403.2.1, which do not apply to Type IV buildings.

Structural Grid - Panels



4-story building on college campus

- Mostly Group B occupancy (some assembly / events spaces)
- NFPA 13 sprinklers throughout
- Floor plate = 7,700 ft^2
- Total Building Area = 23,100 ft^2

Impact of Assembly Occupancy placement:

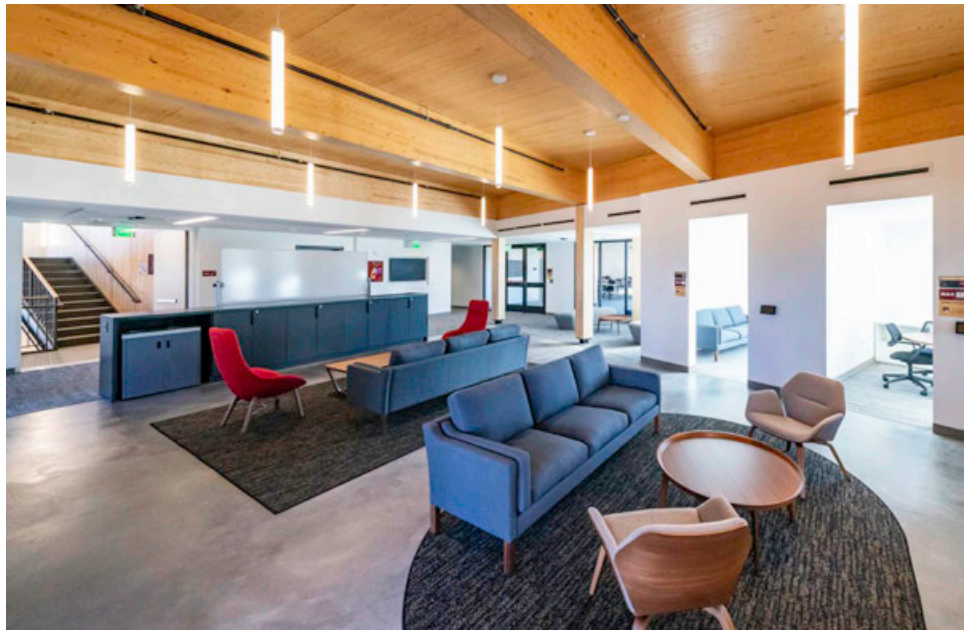
- Owner originally desires events space on top floor (4th floor)
  - Type III-A
- If owner permits moving events space to 1st, 2nd or 3rd floor
  - Type III-B

Structural Grid - Panels

4-story building on college campus

» Cost Impact of Assembly Occupancy placement

Location of Event Space	4th Floor	1st Floor
Construction Type	III-A	III-B
Assembly Group	A-3	A-3
Fire Resistive Rating	1-Hr	0-Hr
Connections	Concealed	Exposed
CLT Panel Thickness	5-Ply	3-Ply
Superstructure Cost/SF	**$65/SF**	**$53/SF**



Source: PCL Construction

Questions? Ask us anything.

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