Considerations for Mass Timber in Defense Construction Projects

Moderator: Marc Jones, P.E. – VP Electrical Engineering, Professional Engineering Consultants (PEC)

Speakers:

- Zach Bowden, P.E. – Structural Team Lead, PEC
- Karen Gesa, P.E. - Technical Director, WoodWorks
- Pete Stynoski, Ph.D., Research Civil Engineer, US Army ERDC

May 14, 2024, 1:30 p.m.

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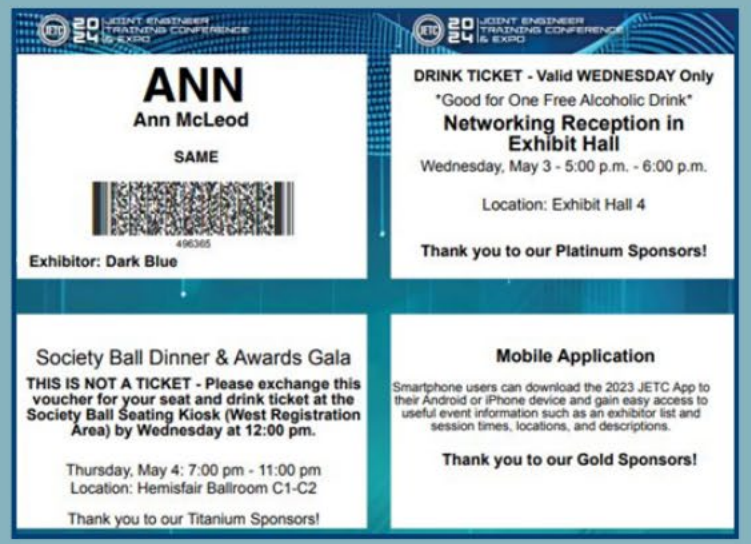

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MODERATOR

Marc Jones, P.E.

PEC

VP Electrical Engineering

Fun Facts

- I'm a Kansas State Wildcat and Kansas City Chiefs fan.
- I love to vacation anywhere in the mountains.
- My hobbies include woodworking, gardening and A/V systems.

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SPEAKER

Zach Bowden, P.E.

PEC

Structural Team Lead

Fun Facts

- Host of Structural Engineering podcast.
- Currently training for a 50k run.

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SPEAKER

Karen Gesa, P.E.

WoodWorks

Technical Director

Fun Facts

- I have a flower farm in northern Virginia
- I'm a horse person and used to enjoy hunter/jumper before I got all old
- I have had many different foster and rescue animals including a mammoth mule

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SPEAKER

Pete Stynoski, Ph.D.

US Army ERDC

Research Civil Engineer

Fun Facts

- Racecar designer, mechanic, and driver
- Rode four of the seven Giga Coasters
- Visited North Korea
- Superpower: Learning

Live Content Slide

Poll: Have you been involved with the design of a mass timber structure?

What is Mass Timber?

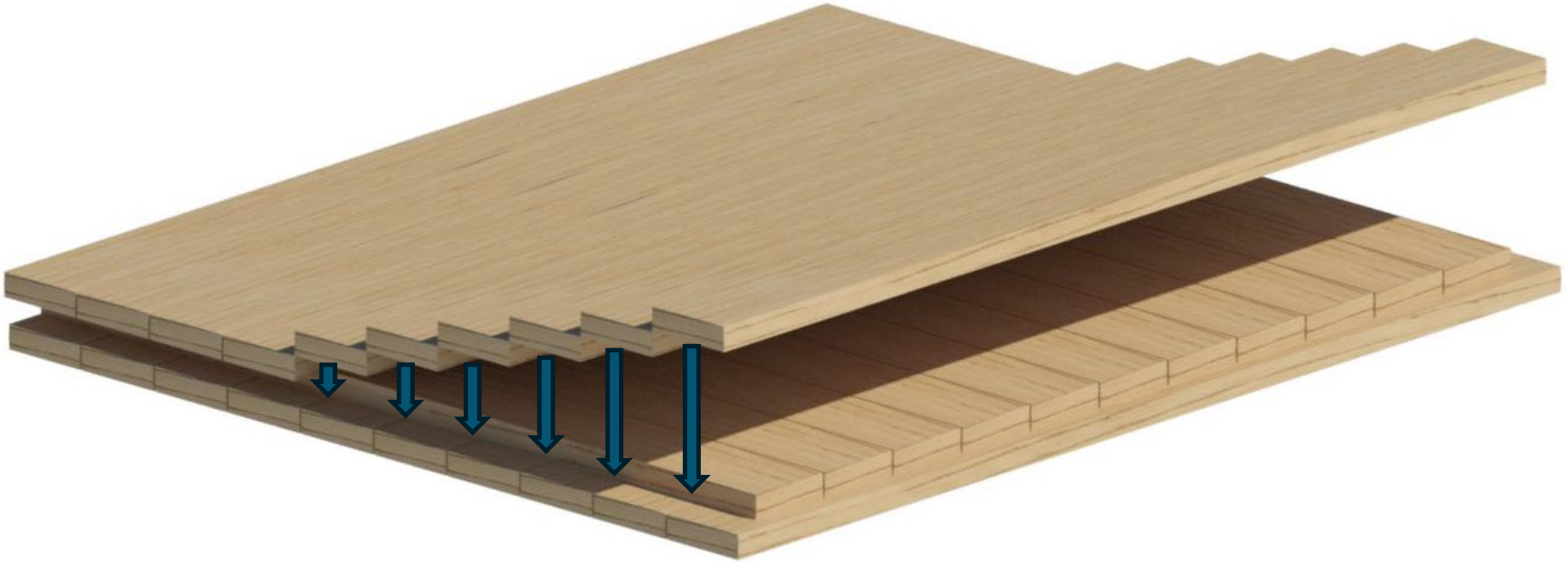
CLT

GLT

NLT

DLT

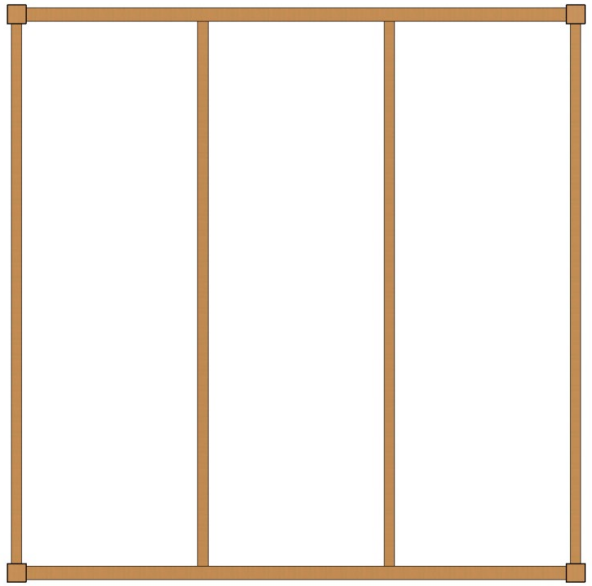
Source: StructureCraft

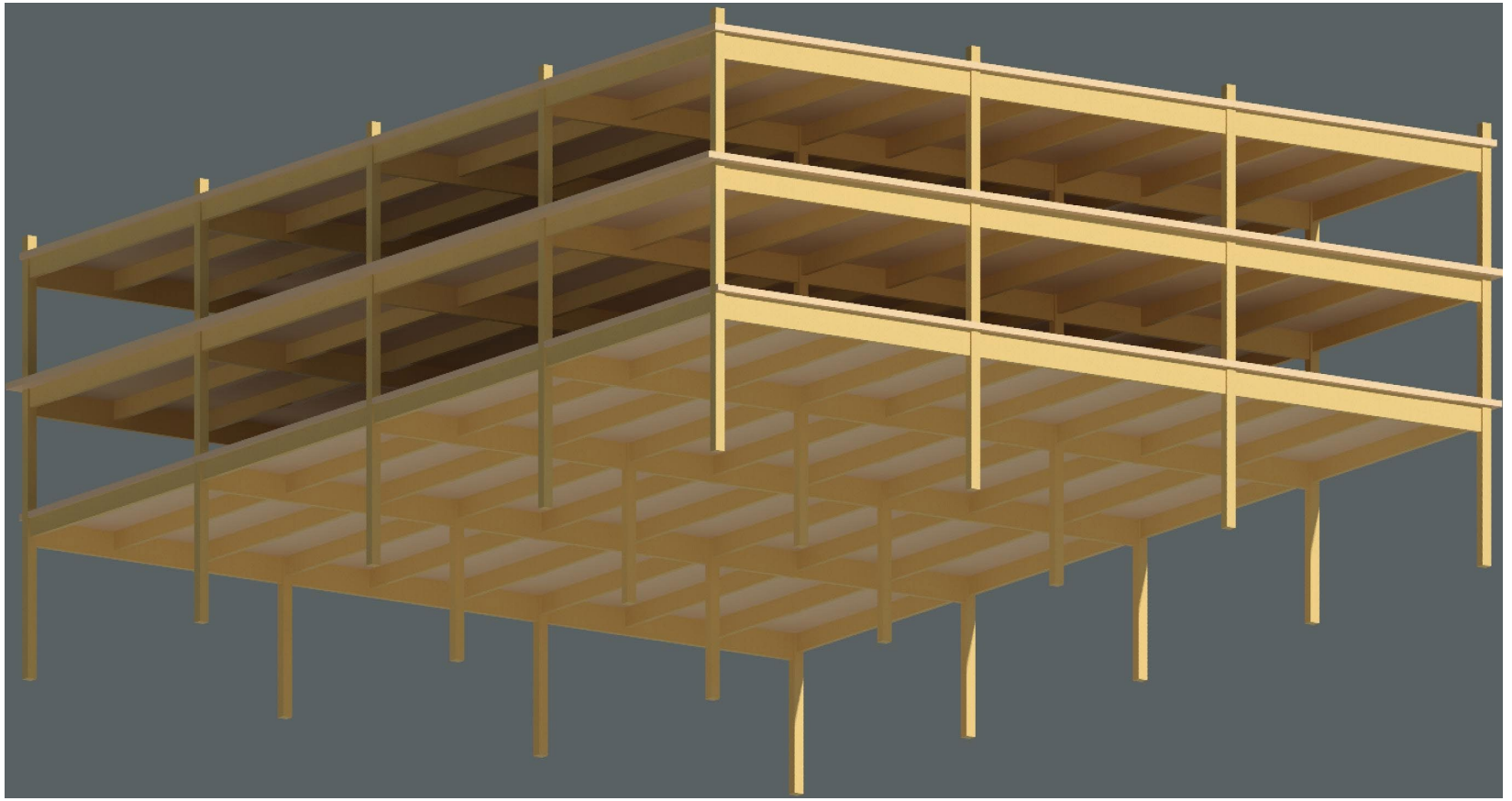


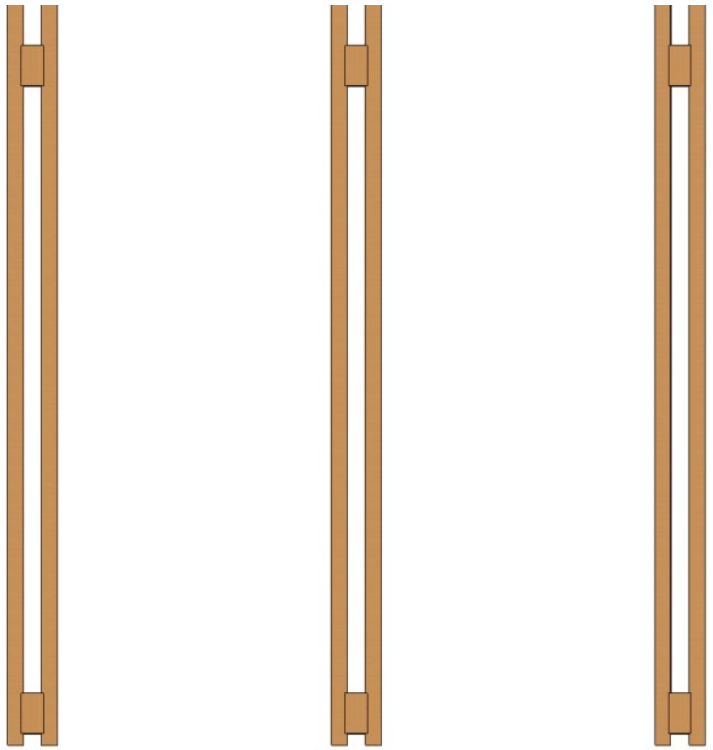
Design of Mass Timber?

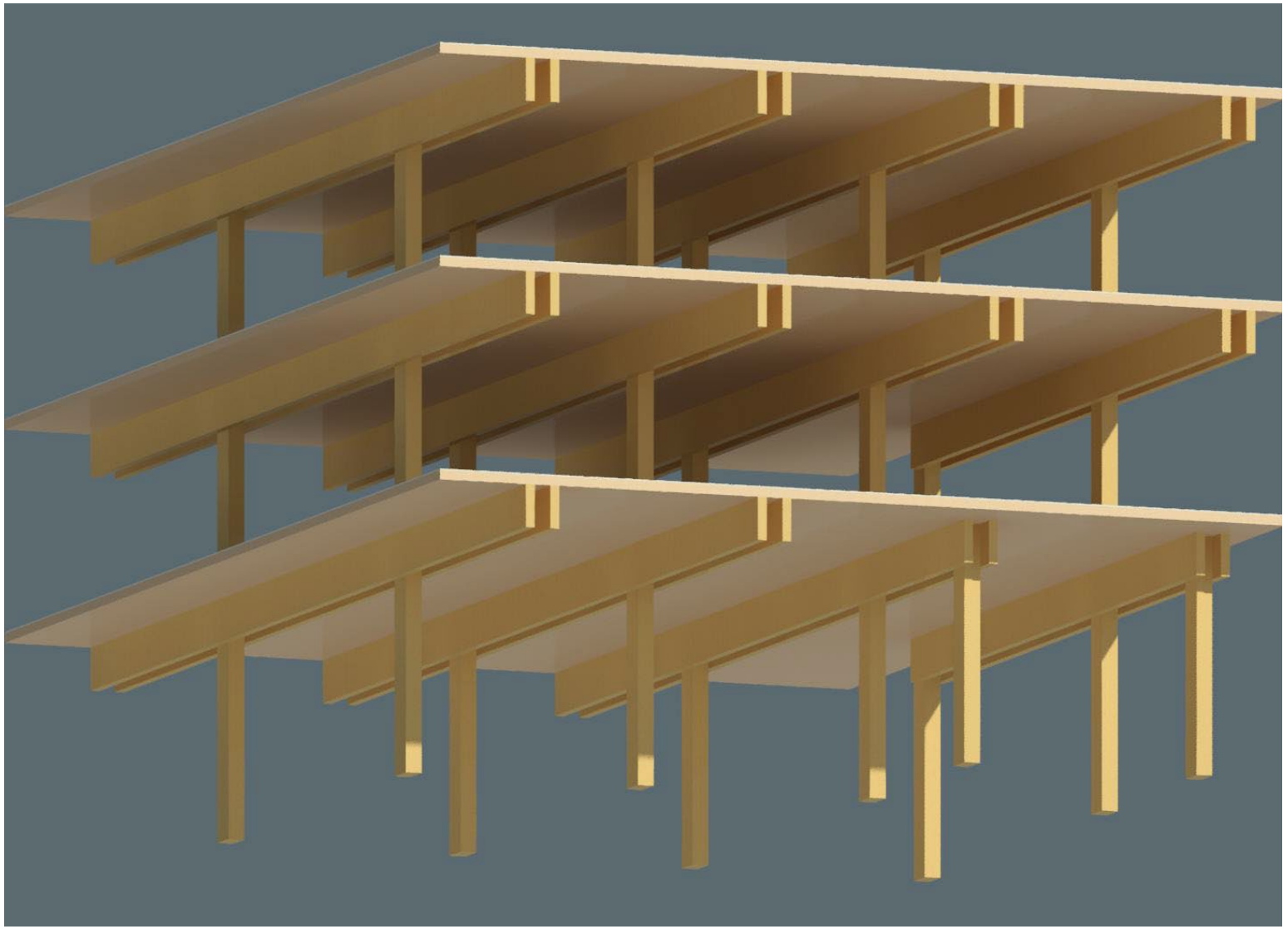
Panel Size and Efficiencies

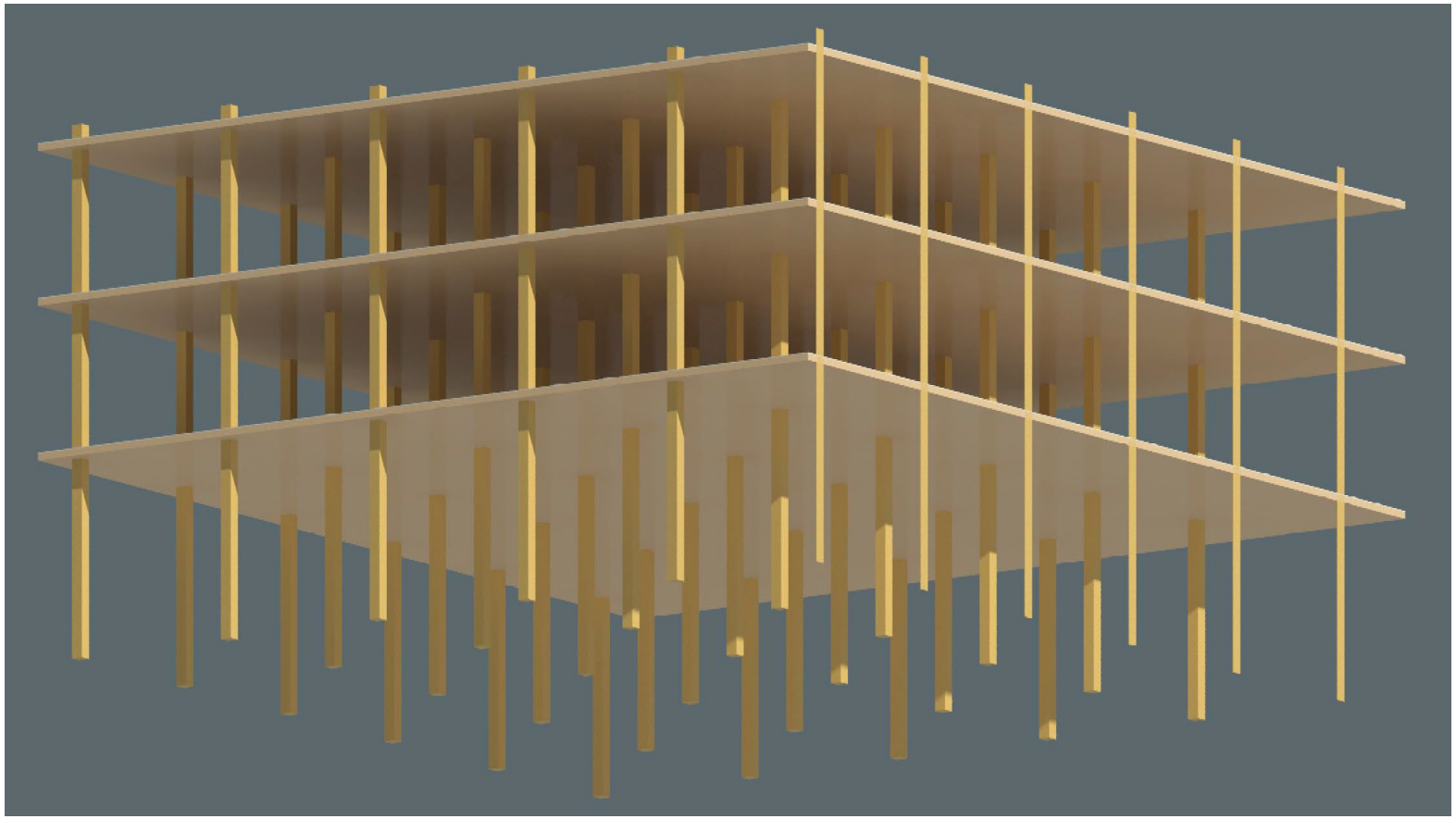
- 8 - 12 ft wide X 40 - 60 ft long
- Grid spacing
- Limit waste
- Framing types

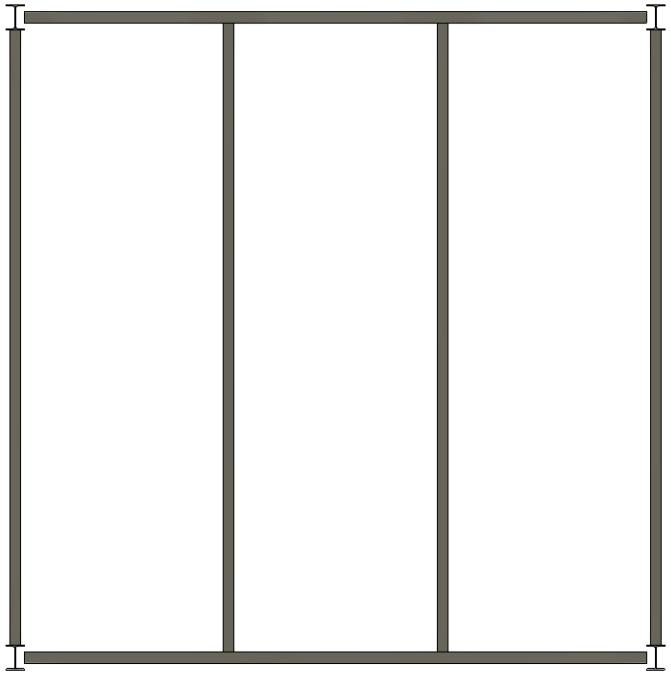


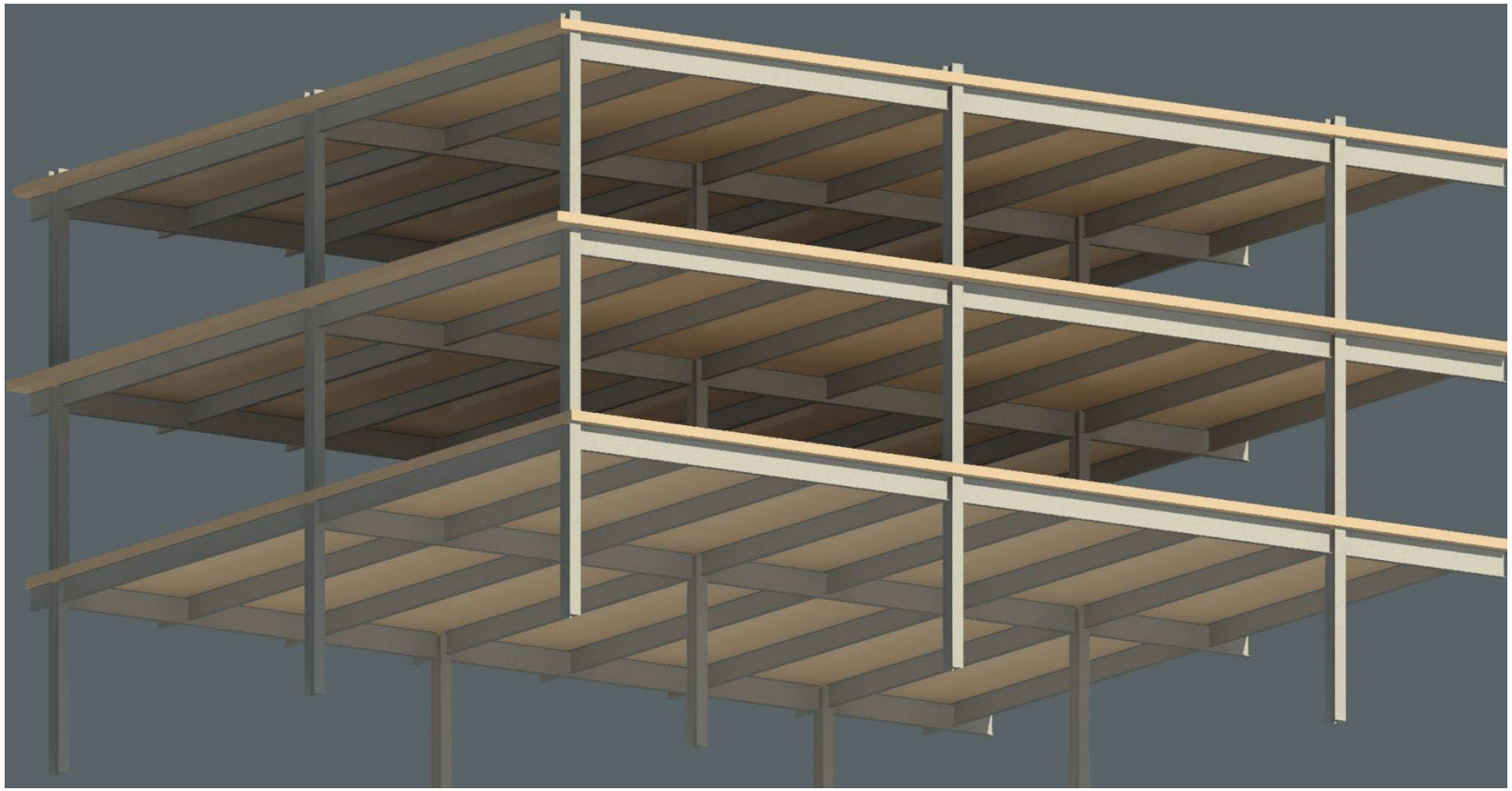




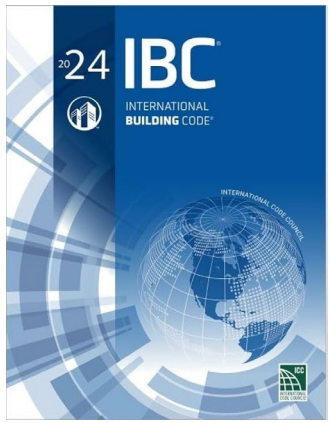


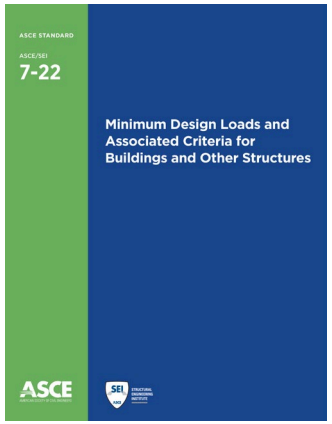


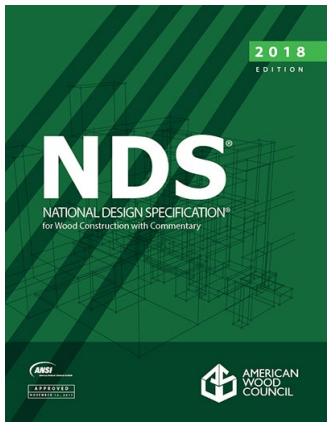


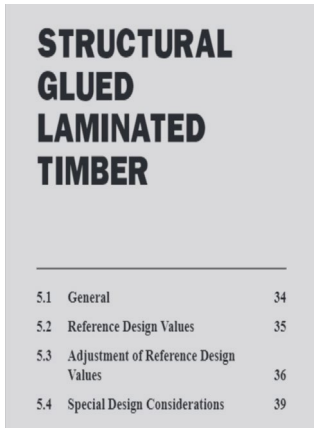


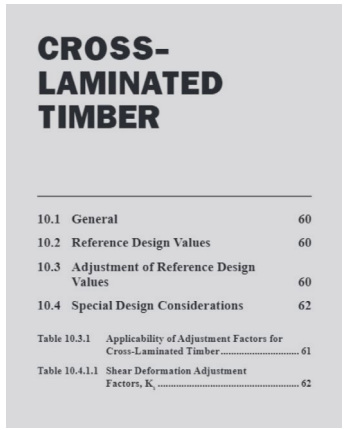
Where to start?











Mechanical / Electrical / Plumbing

Source: Charles Judd

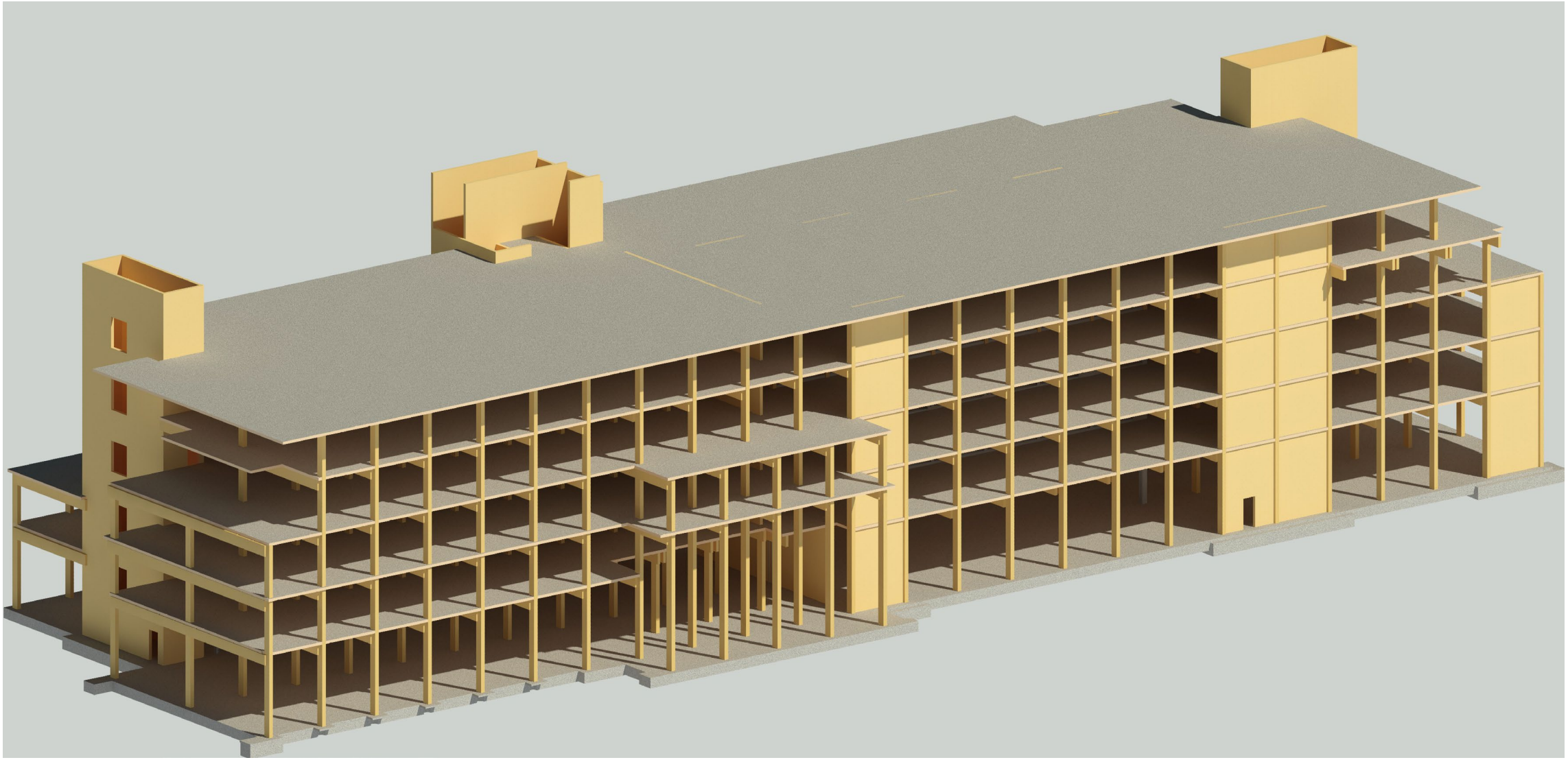
Source: Alex Schreyer

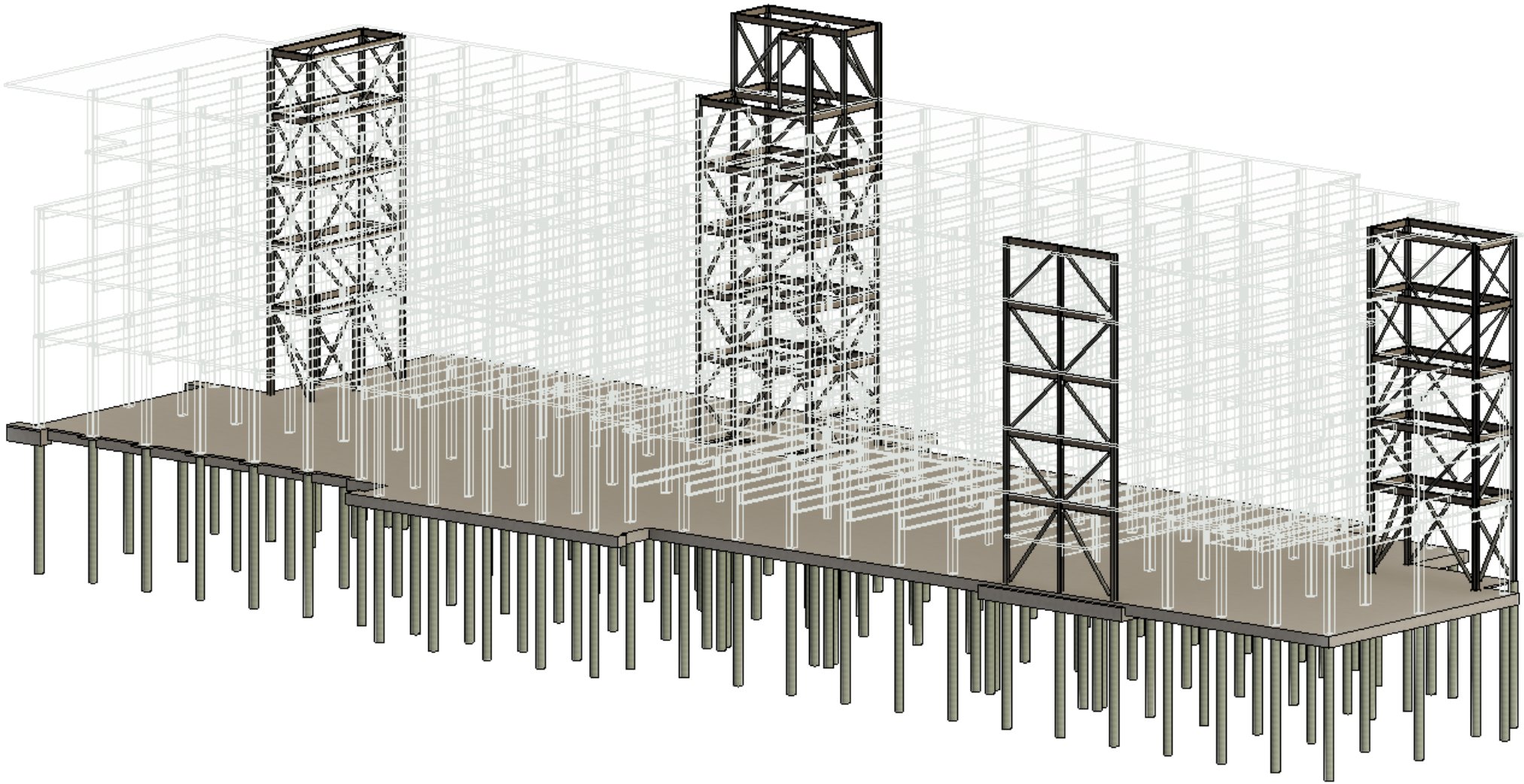

EXIT

Seismic Considerations

Codified Systems

- Concrete shearwalls (R = 2 - 8)
- Steel braced frame (R = 3 - 8)
- Light framed wood shear walls (R= 6.5 - 7)
- Steel moment frames (R = 3 - 8)
- Mass timber shearwalls (R = 1.5 - 4)



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80 M Street SE, Washington, DC | Photo: Hickok Cole | Architect: Hickok Cole

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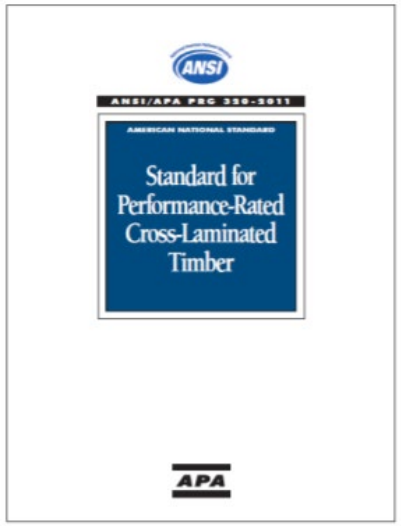
Poll: What is the main barrier keeping you from designing a mass timber project?

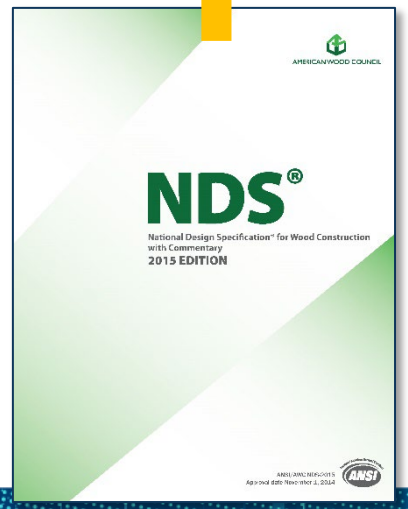
Code & Mass Timber

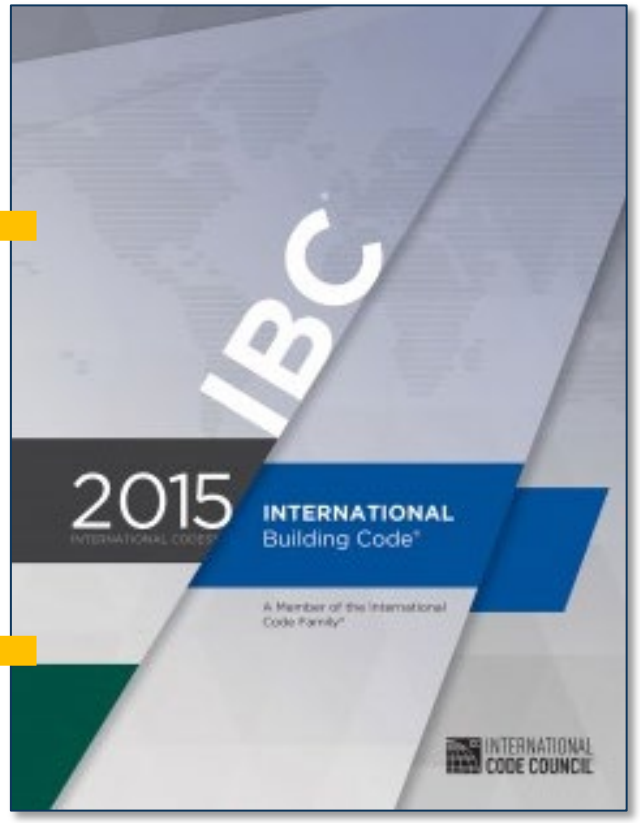
Model Building Code Acceptance

PRG-320

NDS







2015 International Building Code

TALL MASS TIMBER

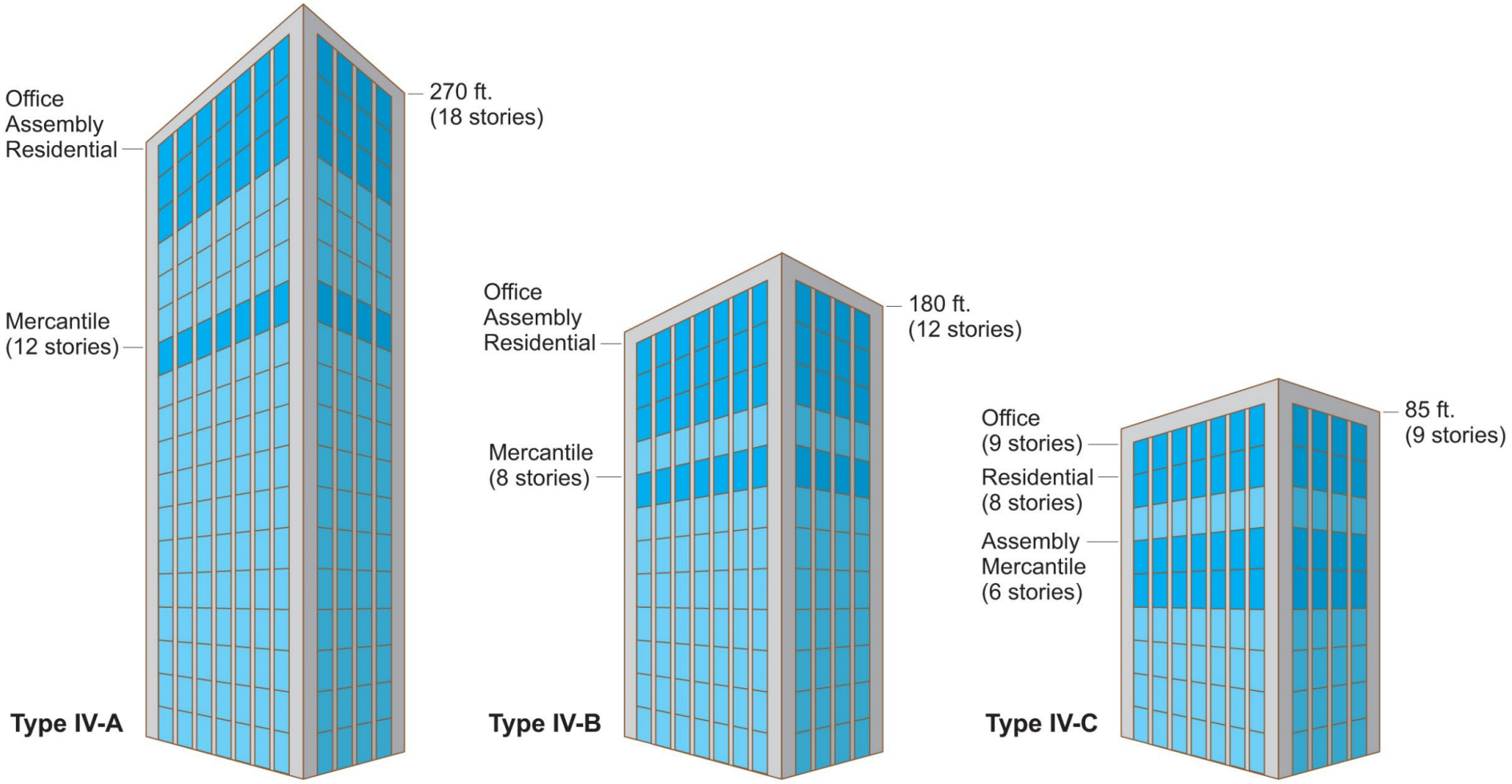
2021 IBC Introduces 3 new tall wood construction types:

IV-A, IV-B, IV-C

Previous type IV renamed type IV-HT

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B

Tall Mass Timber: Up to 18 Stories in Construction Types IV-A, IV-B or IV-C



Fire Resistance

Mass Timber's Fire-Resistive Performance is Well-Tested, Documented and Recognized via Code Acceptance

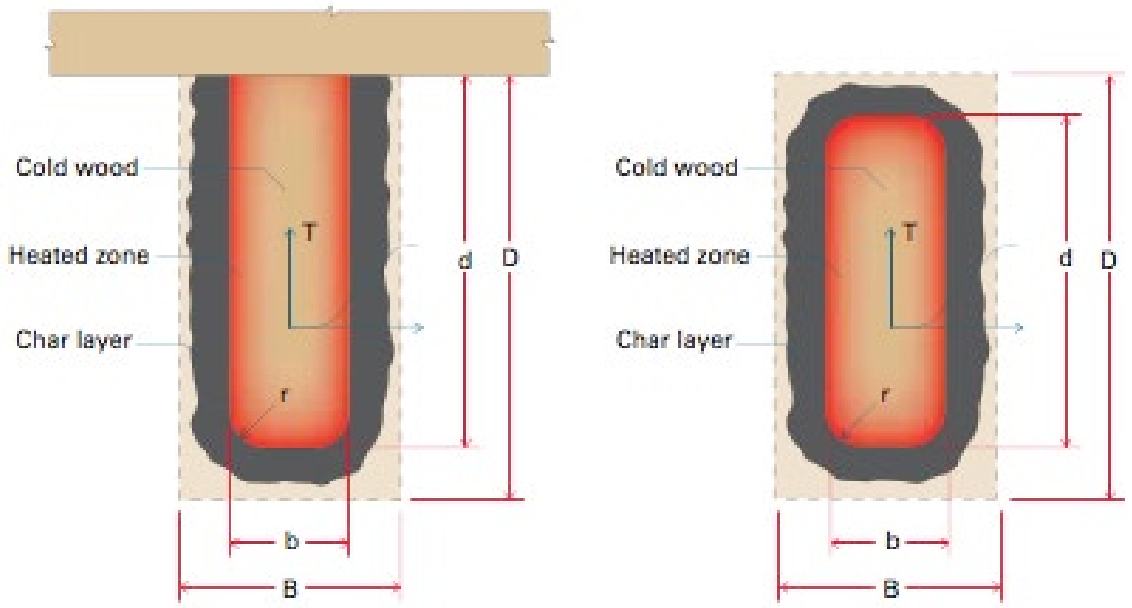


Table 16.2.1A Char Depth and Effective Char Depth (for β_n = 1.5 in./hr.)

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

Source: AWC's NDS

Credit: David Barber, ARUP

Source: AWC's NDS

Inventory of Fire Tested MT Assemblies

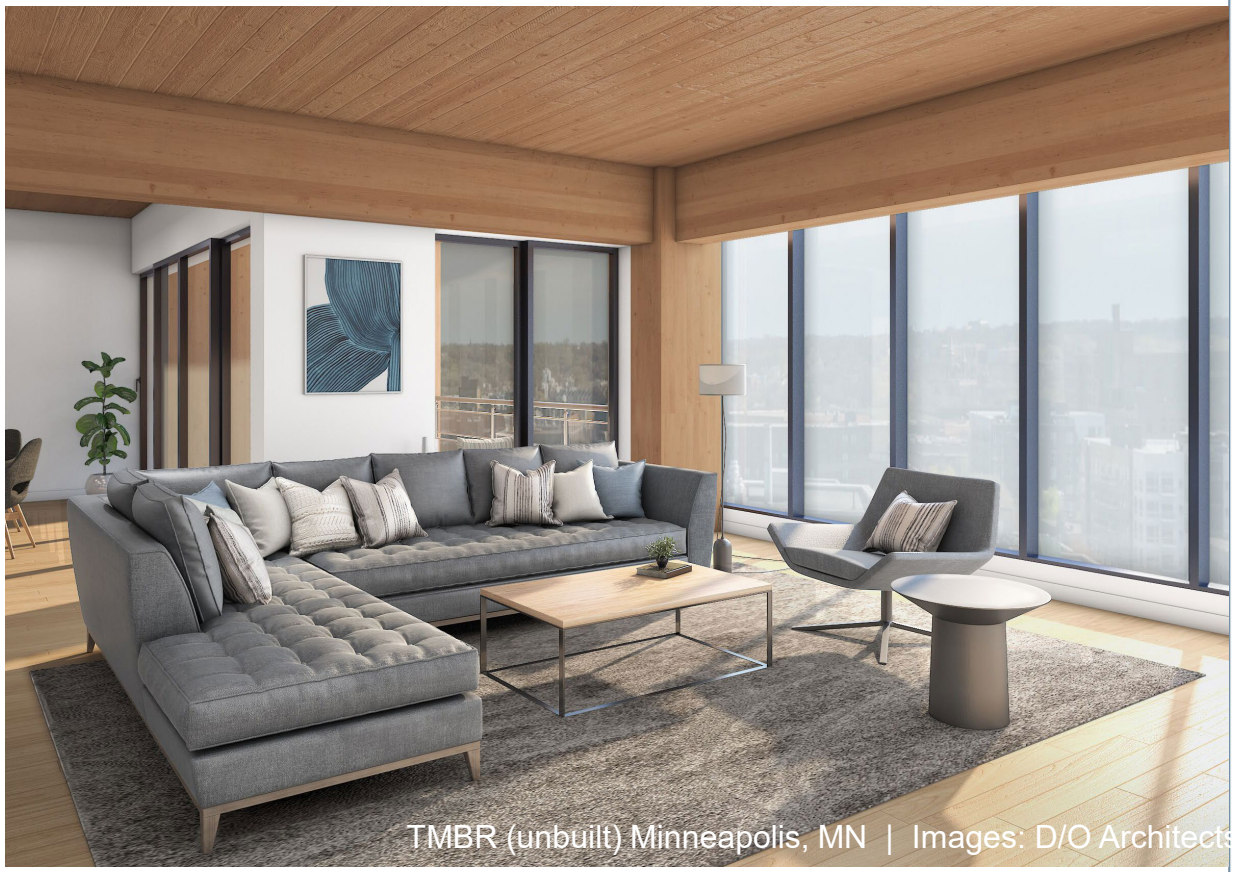
Table 1: North American Fire Resistance Tests of Mass Timber Floor / Roof Assemblies

Mass Timber Panel	Manufacturer	CLT Grade or Timber Grade	Ceiling Protection	Panel Connection	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	E1M5 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	SmartLam	SL-V4	None	Half-Lap	1/2" plywood with 8d nails	Loaded,	2	12	Western Fire Center

https://www.woodworks.org/resources/inventory-of-fire-resistance-tested-mass-timber-assemblies-penetrations/

Market Drivers

Tall Mass Timber: Structural Warmth is a Value-Add

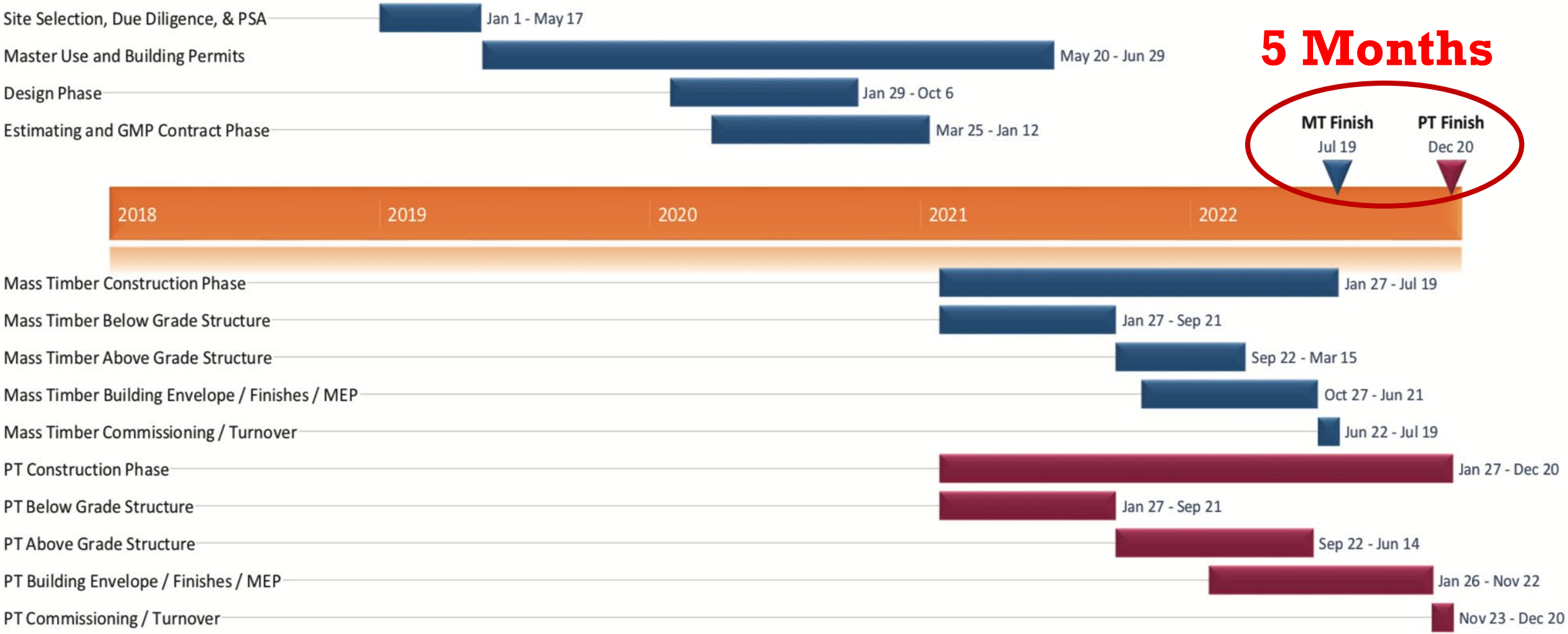


TMBR (unbuilt) Minneapolis, MN | Images: D/O Architects

Construction Impacts: Labor Availability

Photo: Lendlease

Construction Impacts: Schedule



Seattle Mass Timber Tower Study, Source: DLR Group | Fast + Epoxy | Swinerton Builders

Mass timber appeal

Reduced embodied carbon

ESTIMATED ENVIRONMENTAL IMPACT OF WOOD USE

- Volume of wood products used: 2,233 cubic meters of CLT and Glulam
- U.S. and Canadian forests grow this much wood in: 6 minutes
- Carbon stored in the wood: 1,753 metric tons of CO_2
- Avoided greenhouse gas emissions: 679 metric tons of CO_2
- Total potential carbon benefit: 2,432 metric tons of CO_2

THE ABOVE GHG EMISSIONS ARE EQUIVALENT

- 511 cars off the road for a year
- Energy to operate a home for 222 years

**Estimated by the Wood Carbon Calculator for Buildings, based on research by Sathre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations (this relates to carbon stored and avoided GHG).*

**CO2 in this case study refers to CO2 equivalent*

Source: Naturally:wood[9]

Brock Commons, Vancouver, BC

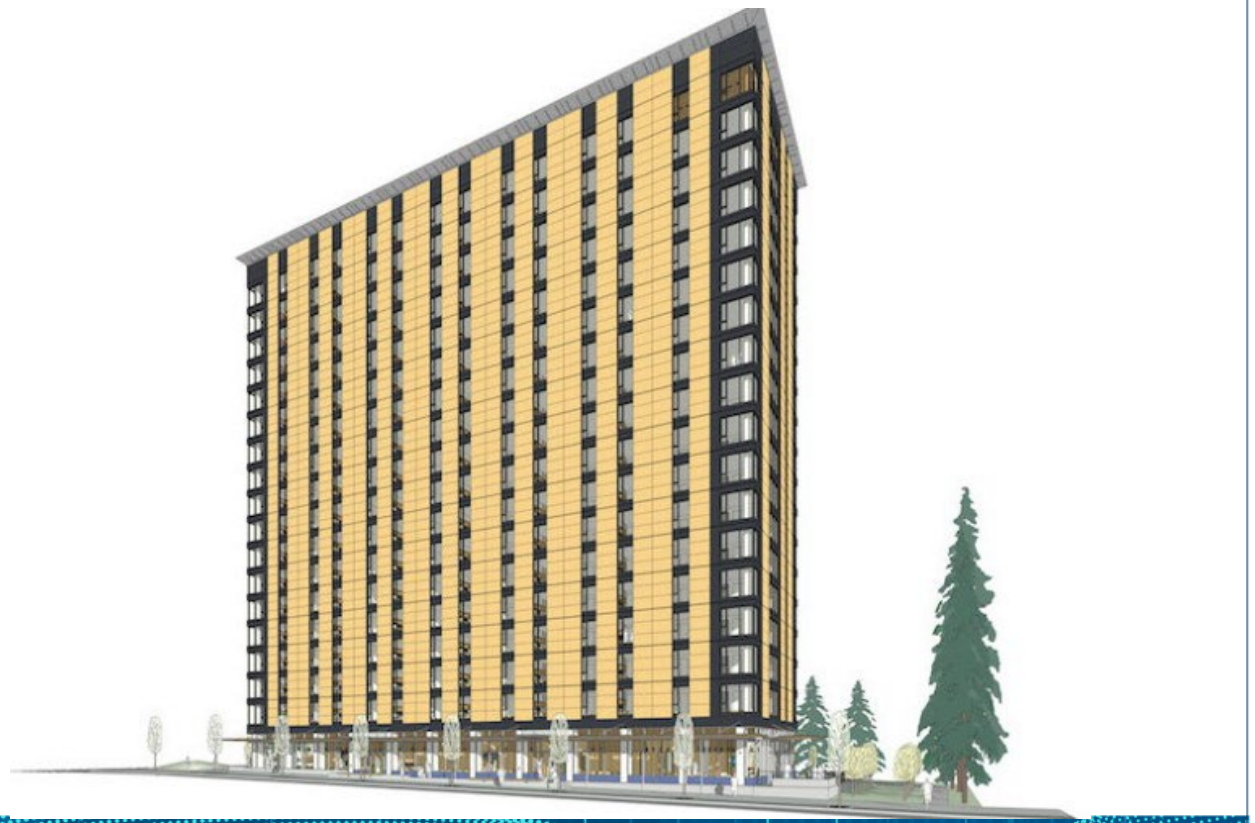


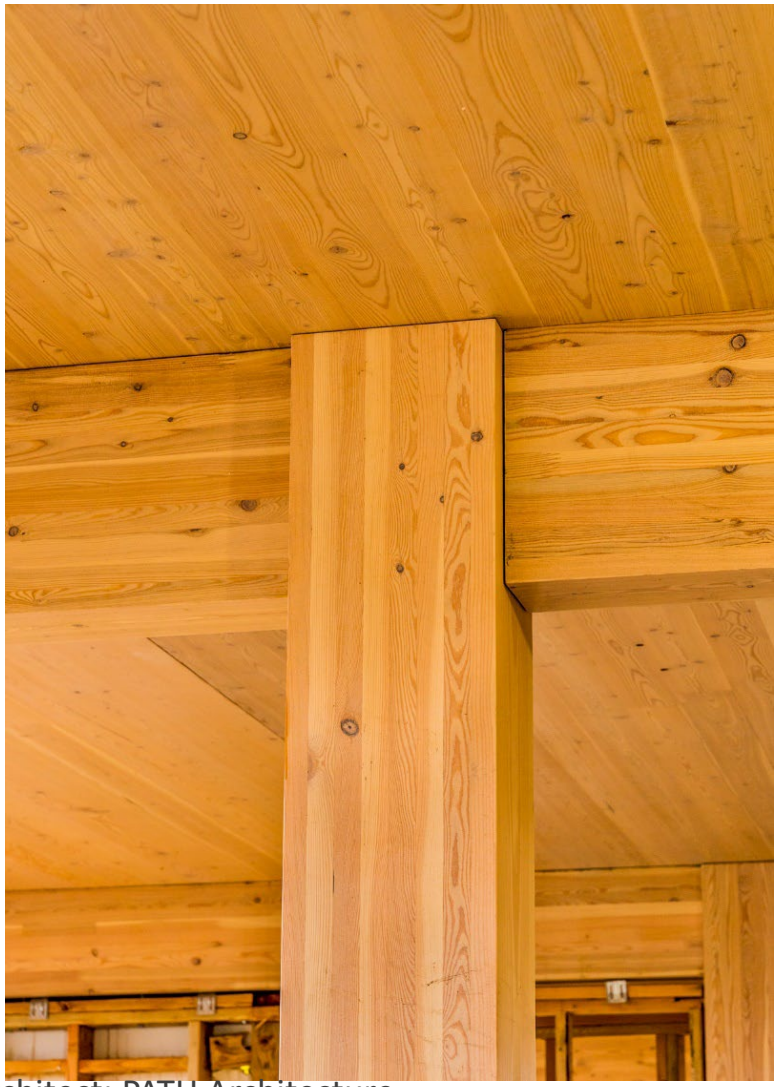
Photo credit: acton ostry architects

Mass Timber Appeal

MATERIAL MASS

75% lighter weight than concrete

Mass Timber: Structure Often is Finish



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

PUBLIC REPORT

New York City Public Schools
Mass Timber Design Feasibility Study

Submitted to:

SCA
School Construction Authority

NYC School Construction Authority
30-30 Thomson Avenue
Long Island City, NY 11101

Prepared by:

EME GROUP
Engineers & Architects

EME Group
550 7th Avenue, 10th Floor
New York, NY 10018

December 20, 2023

SPACE SAVINGS DUE TO USE OF MT	TYPE III-A*	TYPE IV-HT
GLT Columns	457.21	457.21
Exterior CLT Walls (Type IV-HT only)		325.50
Typical Classroom CLT Partitions	168.04	168.04
SPACE PENALTY DUE TO USE OF MT		
2-Hr and/or Acoustical CLT Partitions	-829.32	-674.27
TOTAL CHANGE IN USABLE GSF	**-204.06**	**276.49**
Percentage Change (from 40,510 GSF)	**-0.5%**	**0.7%**

*See notes under *Code Clarifications* section above

Table 3. *Space Savings of Mass Timber Construction at Addition*

http://www.nycsca.org/Design/NYC-Green-Schools-Guide#GSG-Reference-Materials-154

PUBLIC REPORT

New York City Public Schools
Mass Timber Design Feasibility Study

Submitted to:

NYC School Construction Authority
30-30 Thomson Avenue
Long Island City, NY 11101

Prepared by:

EME GROUP
Engineers & Architects

EME Group
550 7th Avenue, 10th Floor
New York, NY 10018

December 20, 2023

The following MT elements take up less space than their baseline counterparts:

- Exposed GLT columns vs. baseline reinforced concrete columns with GWB furring
- Classroom-to-classroom CLT partitions vs. baseline GWB stud walls
- Exterior CLT walls vs. baseline exterior stud walls (Type IV-HT construction only)

The following MT elements take up more space than on baseline counterpart:

- 2-hour rated and/or acoustical CLT partitions vs. baseline GWB rated stud walls
- This is one of the reasons why EME recommends the use of the baseline GWB stud wall design for 2-hr FRR and/or acoustical partitions instead of their CLT versions, in both the Type III and Type IV construction scenarios.

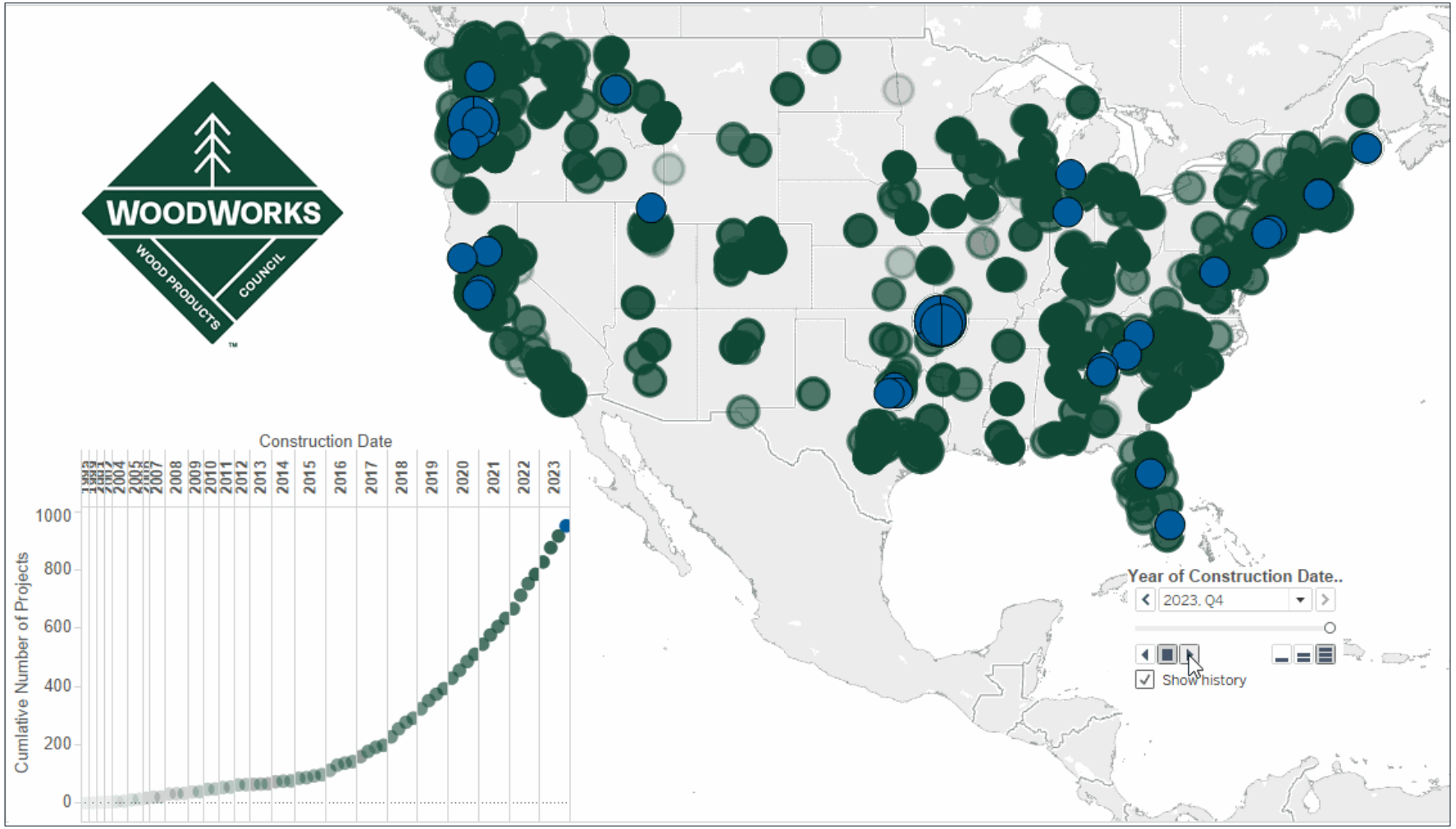
Candlewood Suites, AL

- Built by Lendlease
- 4-story hotel built on a military base pre-2018 using CLT floors, walls and roof
- CLT not considered conventional construction – so needed to meet blast and progressive collapse requirements
- Completed 37 percent faster than similar hotels
- Built with 44 percent fewer person-hours than similar hotels

https://www.woodworks.org/resources/construction-advantages-sell-hotel-developer-on-mass-timber/

Current State of Mass Timber Projects

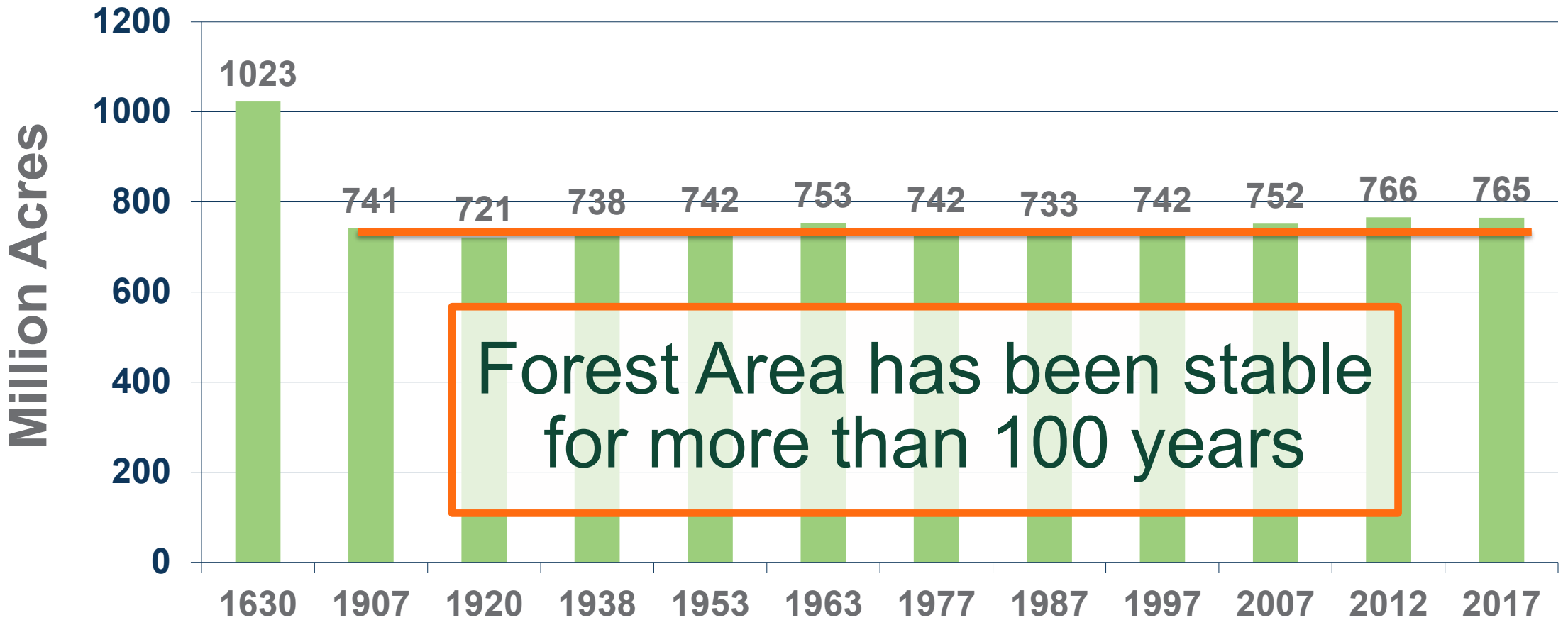
Through 2023 2,035 mass timber projects in design or have been constructed in the US



Sustainability

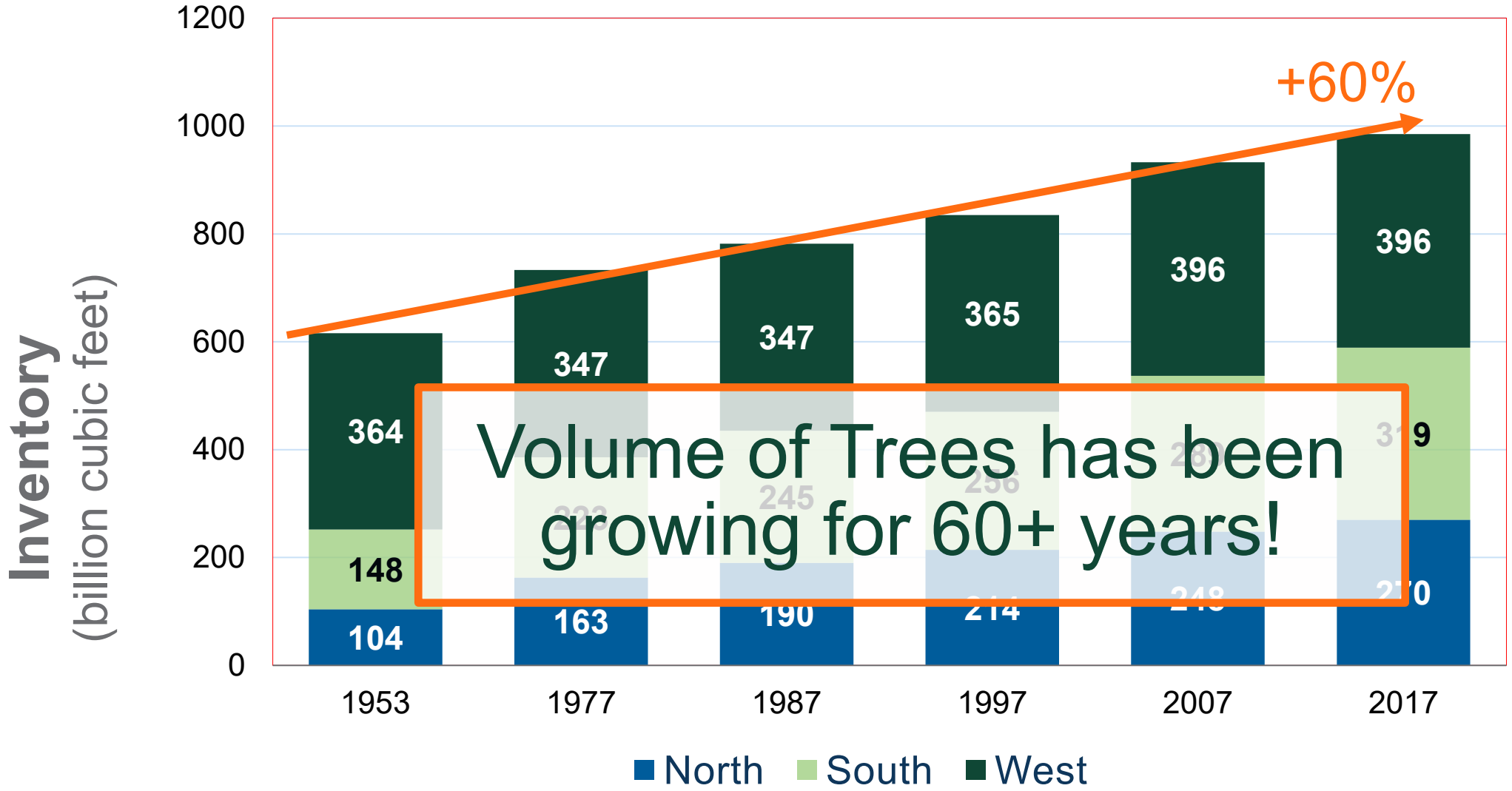
U.S. Forest Land:

Forest **Area** in the United States 1630 – 2017



Source: USDA Forest Service, Forest Resources of the United States, 2017 (2018)

State of our Forests: US Timber Volume on Timberland

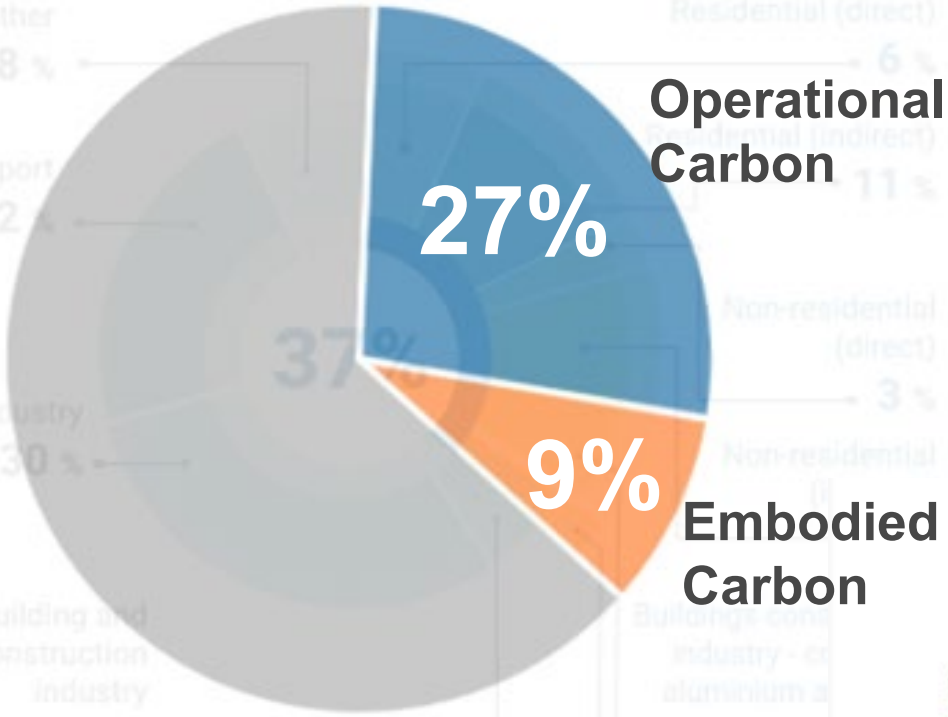


Not including national parks and preserves – only timberland

Source: USDA Forest Service. Forest Resources of the United States, 2017 (2018)

New Buildings & Carbon Dioxide Emissions

Global CO_2 Emissions by Sector



Adapted from: UN environment programme
Global Alliance for Buildings and Construction

Buildings generate **36%** of annual carbon dioxide emissions

Operational carbon: **27%**
Embodied carbon: **9%**

Carbon Benefits of Wood

- **Lower embodied carbon** compared to other common building materials
- **Less fossil fuel consumed** during manufacture
- **Avoid process emissions**
- Extended carbon **storage in products**
- **Carbon sequestration** in forests
- Promotes **forest health**

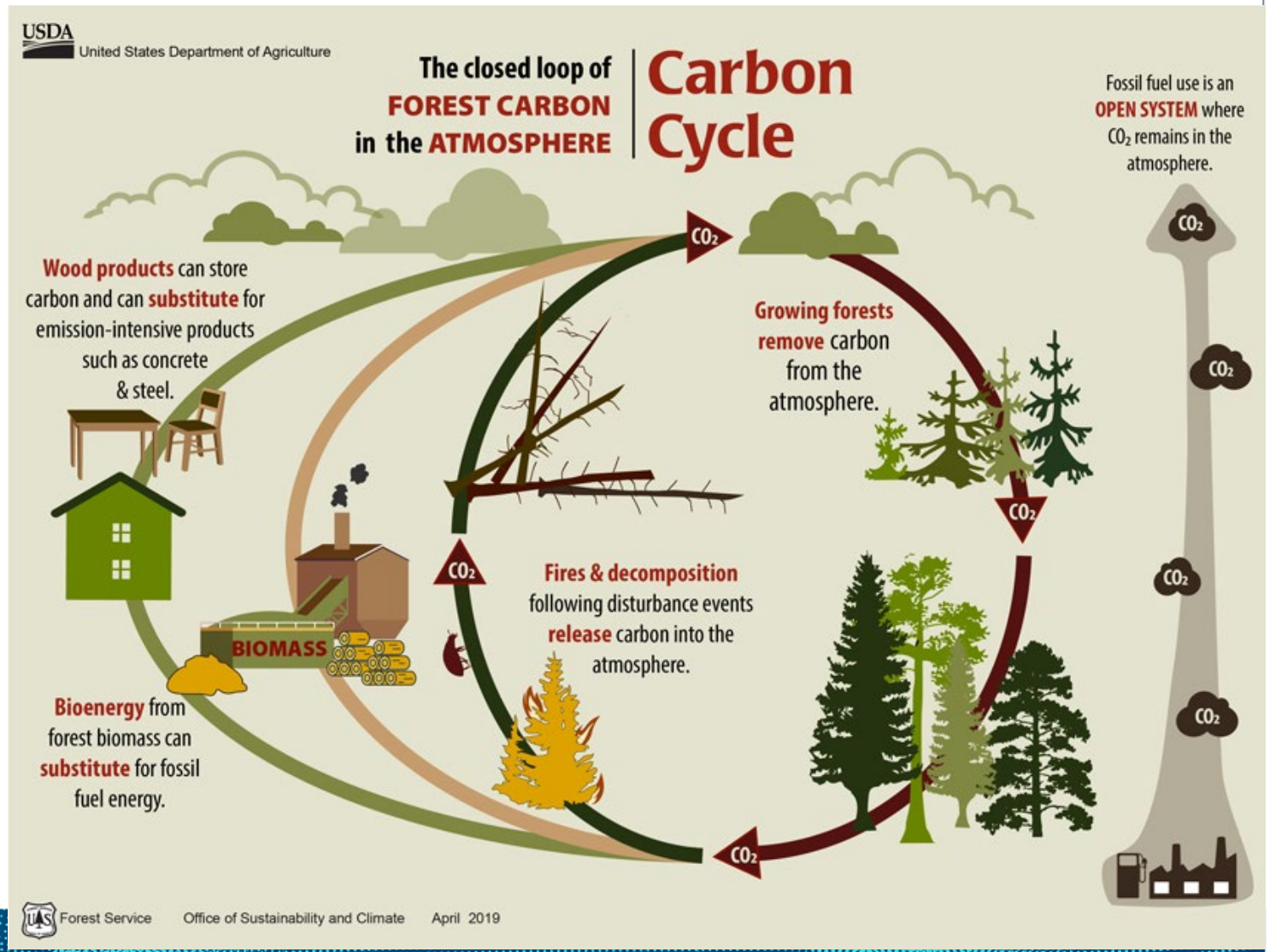
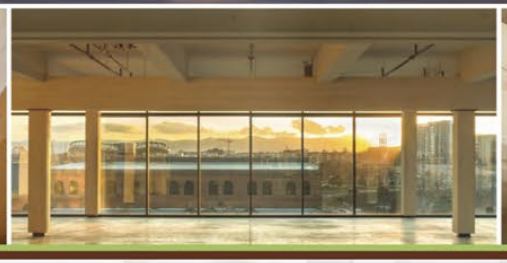


Image: USDA US Forest Service

Platte Fifteen

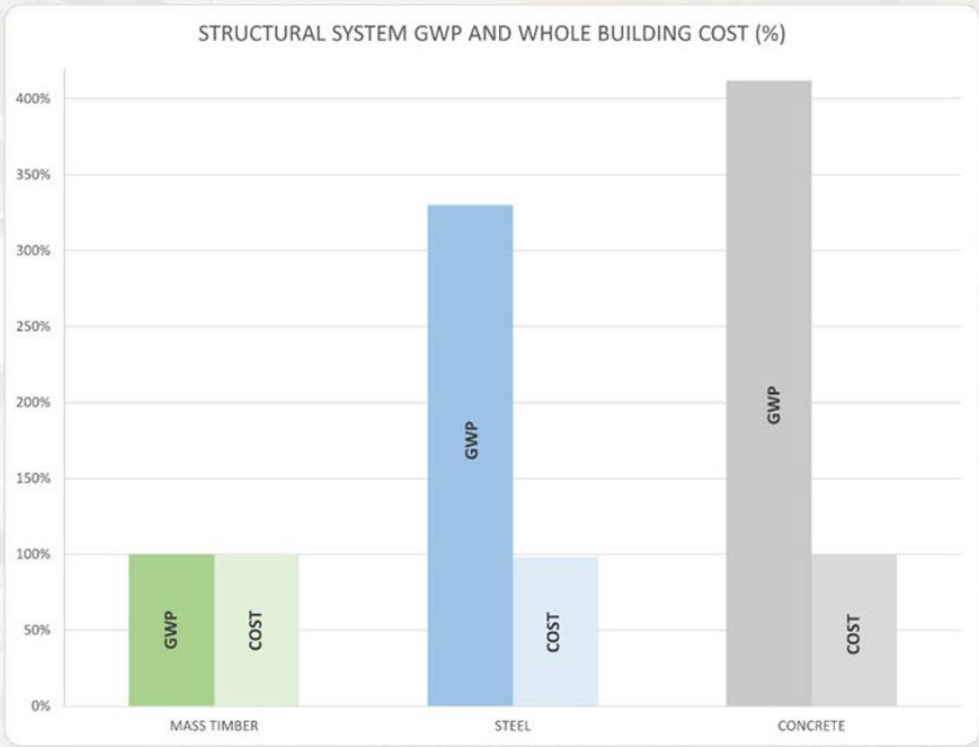
Denver's First CLT Commercial Office Building Puts Sustainability to Work



PROJECT DETAILS

LOCATION:
Denver, Colorado

SIZE:
Five stories; 150,418 square feet



Source: Platte Fifteen Life Cycle Assessment https://www.woodworks.org/resources/platte-fifteen-life-cycle-assessment/

Rendering: Hickok Cole Architects

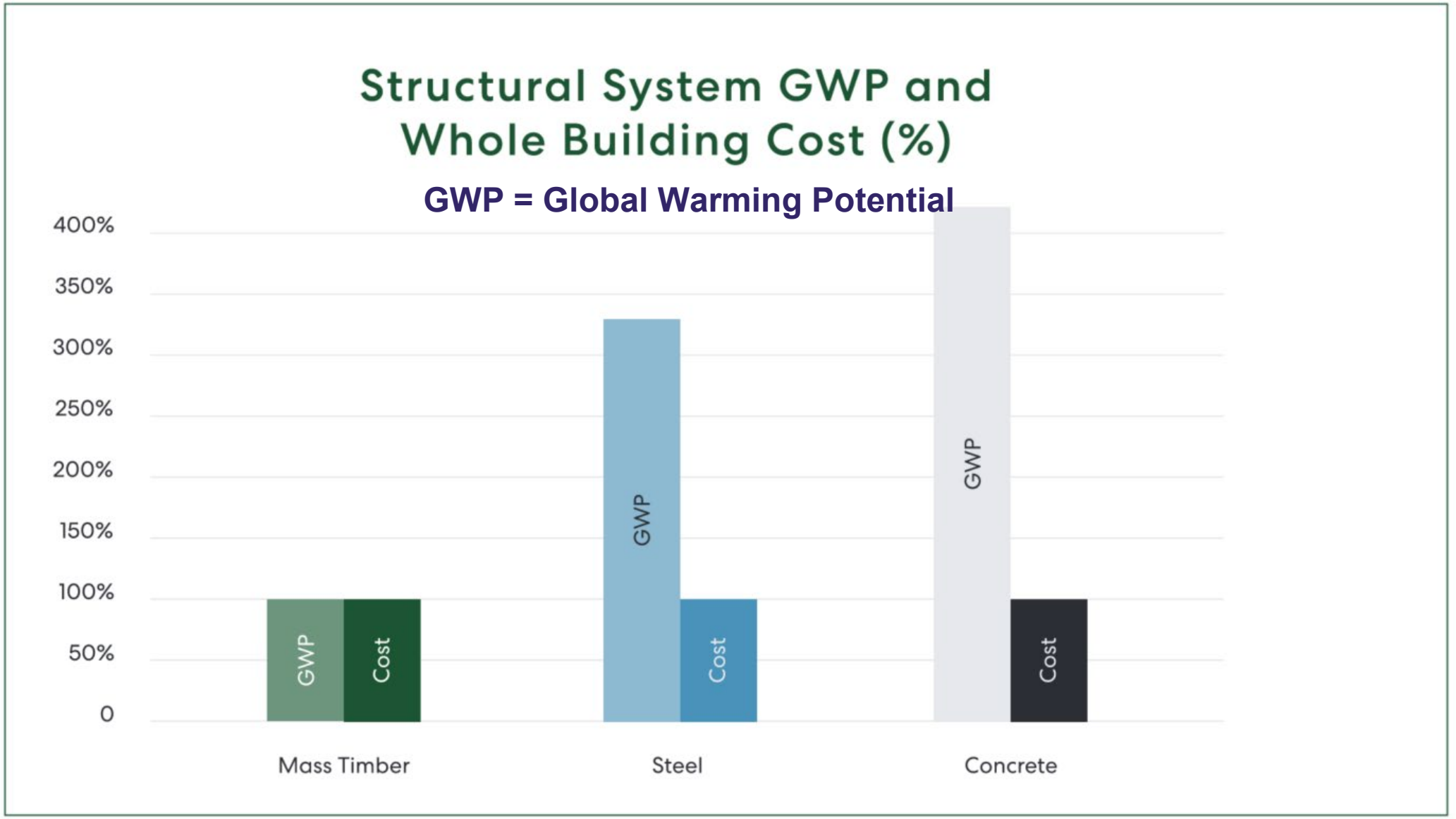


Figure 15. Comparison of the structural system GWP above the level two podium slab and the whole building cost of the three systems.

Source: Platte Fifteen Life Cycle Assessment https://www.woodworks.org/resources/platte-fifteen-life-cycle-assessment/

Protective Design

Protective Design Applied Research for Mass Timber

Blast

- WoodWorks Blast Testing
- ISIEMS Test on 7-Ply CLT Panel
- USACE PDC CLT Shock Tube Testing
- U of Ottawa CLT Shock Tube Testing
- WoodWorks NLT Shock Tube Testing

Ballistic

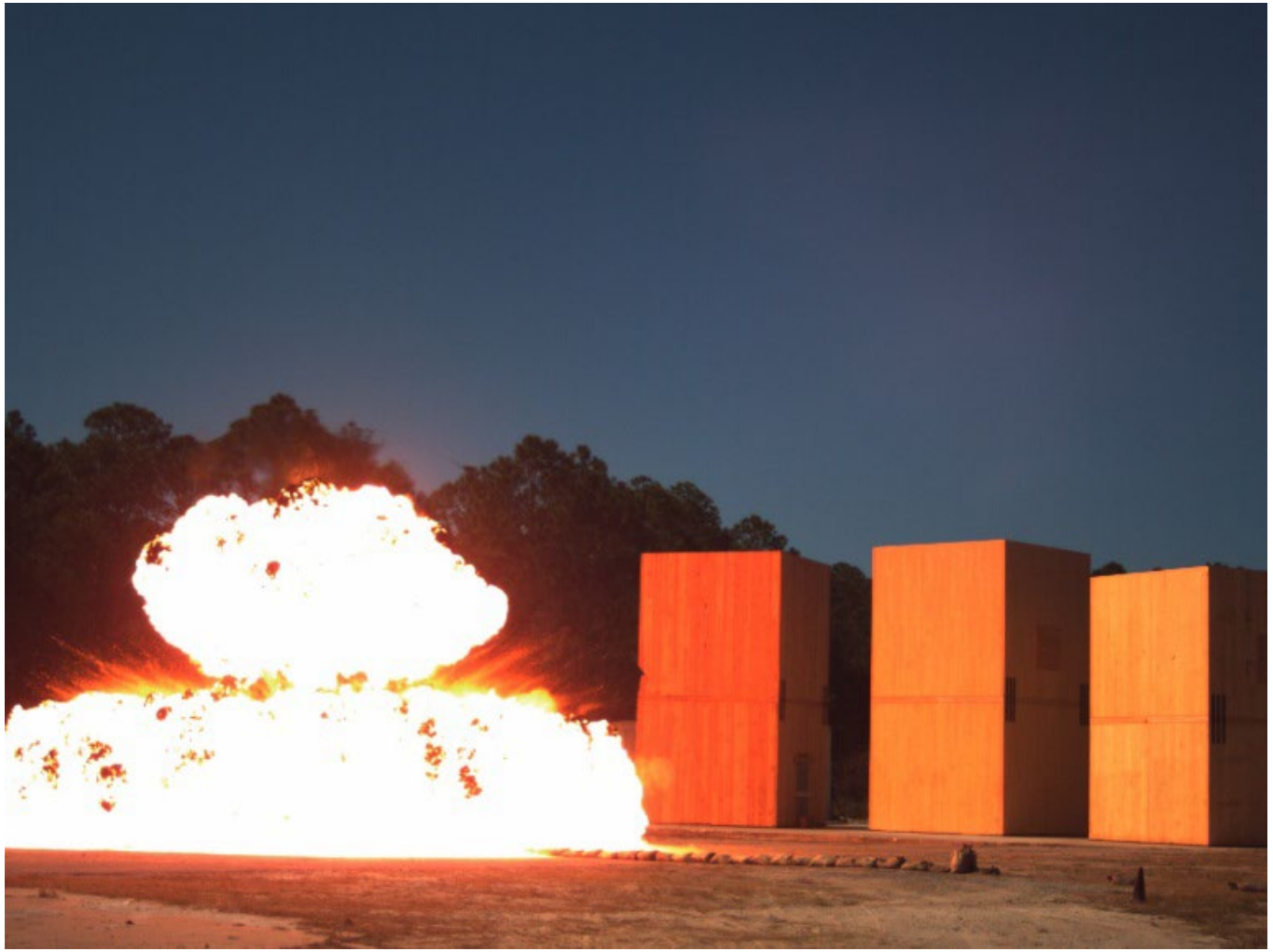
- Georgia Tech Ballistic Testing
- Reinforced CLT Development
- Ballistic Testing
- Quasi-Static Full-Size Panel Testing

Forced Entry

- DOS Forced Entry Test

Progressive Collapse

- Updates to the UFC 4-023-03 to include mass timber currently underway



Live Content Slide

Poll: How many Mass Timber DoD structures have you designed, built, operated from, or slept in?

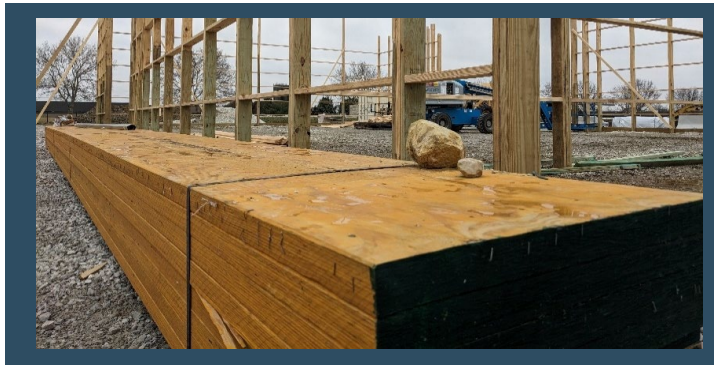
Drivers
(or Administrative Leadership Style)

- FY22 NDAA Sec. 2861 [*Sustainable Materials Pilot Projects*]
- EO 14008 [*Tackling the Climate Crisis*]
- EO 14057 [*Decarbonization of the Federal Economy*]
  - Buy Clean Task Force
- DODD 4715.21 [*Climate Change Adaptation and Resilience*]
- Joint Concept for Contested Logistics (JCL or JCCL)
  - Diversify Class IV (construction materials) supply chains
- Economic (LCCA) vs Environmental (LCI or LCA) factors
  - Proliferation of the Environmental Product Declaration (EPD)

Three Distinct Opportunities

Near-term and Mid-term goals:

- ✓ ECB directing consideration of Mass Timber
- Training and Guidance via Woodworks
- Criteria Change Request to update penetration equation (UFC 4-023-07)
- Progressive collapse experiments
- Custom reinforcement for signature reduction and max performance



‘Light Frame’ Designed for Disassembly

Anti-Terrorism / Force Protection

MILCON

5 CLT hotels operational via Privatization of Army Lodging (PAL) [Redstone, Drum, JBLM, Jackson]

US Army Corps of Engineers

ENGINEERING AND CONSTRUCTION BULLETIN

No. 2023-14 **Issuing Office:** CECW-EC **Issued:** 20 Sep 23 **Expires:** 20 Sep 25

SUBJECT: Mandatory Consideration of Mass Timber in Army Military Construction (MILCON) and Civil Works Vertical Construction Projects

CATEGORY: Directive and Policy

- "…consider at least one option where mass timber is a substantial structural component…"
- "For example, the high bay areas of fire stations, hangars, and tactical equipment maintenance facilities may not be practical … however, the administrative portions of these facilities may."
- "… justifications detailing why a mass timber structural system was or was not selected for the project must be included in the project Design Analysis…"
- "…if Mass Timber increases square footage beyond a Standard Design GSF limitation, the increase must be coordinated with the applicable COS…"

LendLease – CLT Privatized Army Lodging

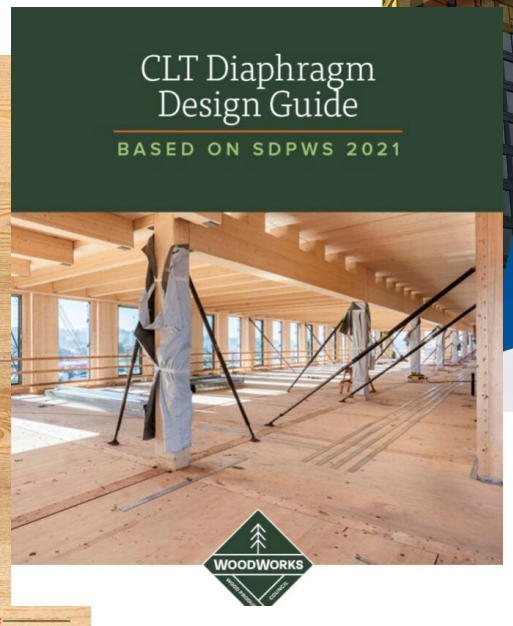
Redstone, Mar 2016

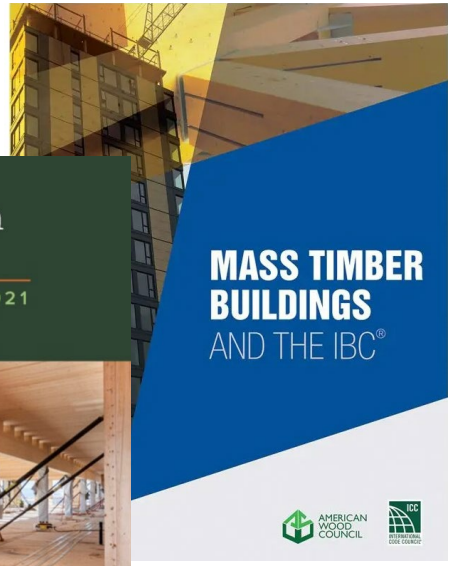
JBLM, Oct 2019

Drum, Nov 2018

Jackson, Oct 2020 & Jun 2021

Background





UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2024

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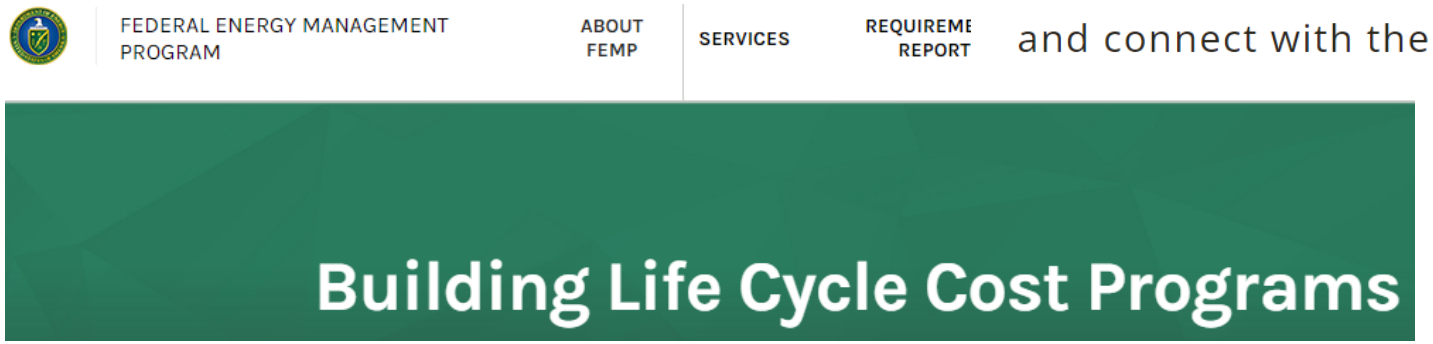
SECTION TABLE OF CONTENTS

DIVISION 06 - WOOD, PLASTICS, AND COMPOSITES

SECTION 06 18 00

GLUED-LAMINATED CONSTRUCTION



Discover mass timber & light-frame projects

and connect with their project teams

Department of Defense

Potential Usage in Military Construction of Cross-Laminated Timber (CLT) A Next Generation Mass Timber Construction System

National Standards, Local Codes

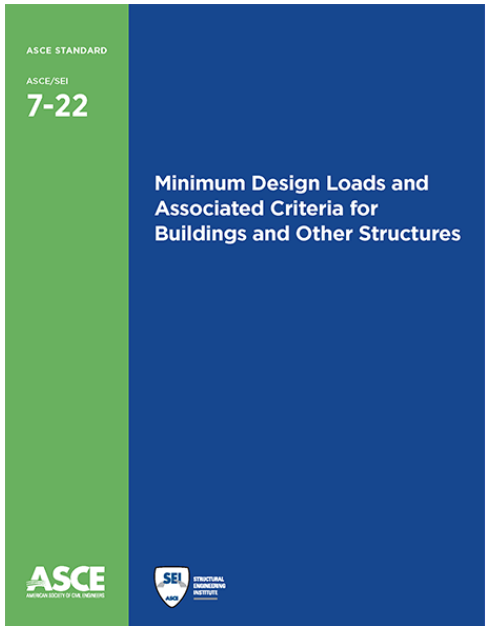
- ASCE 7-22 Chapter 12 Seismic Response
  - R Value modification
  - Higher Seismic Demand AND Less Efficient System
- IBC 2021 Revamped CLT Information in Chapter 6 Building Types
  - Unknown unknowns drive Type III-B
- NDS/AWC Special Design Provisions for Wind and Seismic
- Capacity Based Design for Shear Walls
  - Impact in Seismic Design Category C and D regions

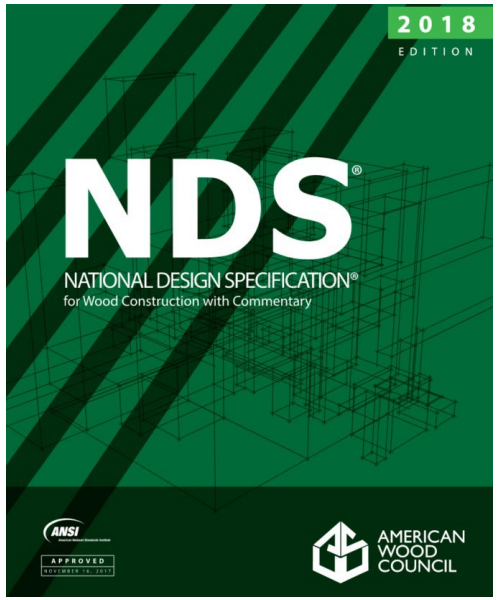
2020 NEHRP Recommended Seismic Provisions: Design Examples, Training Materials, and Design Flow Charts

FEMA P-2192-V1/November 2021

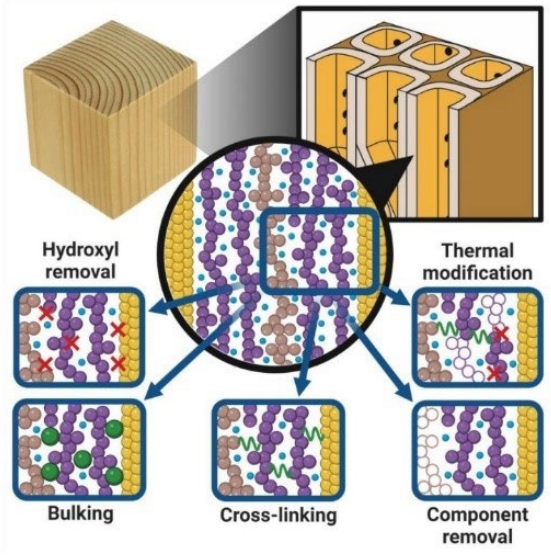
Volume I: Design Examples

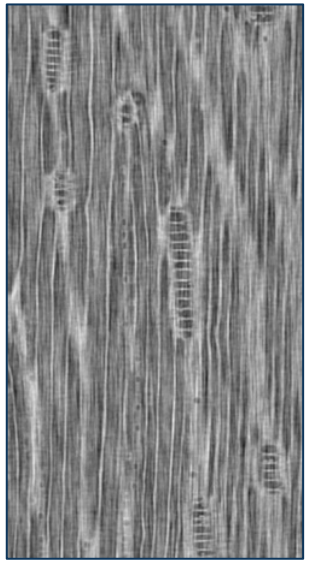
FEMA nehrp

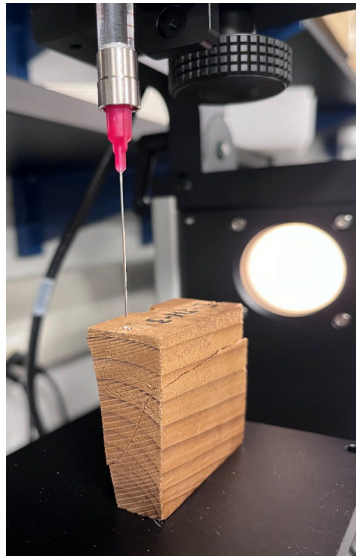




R&D – Environmental Resilience

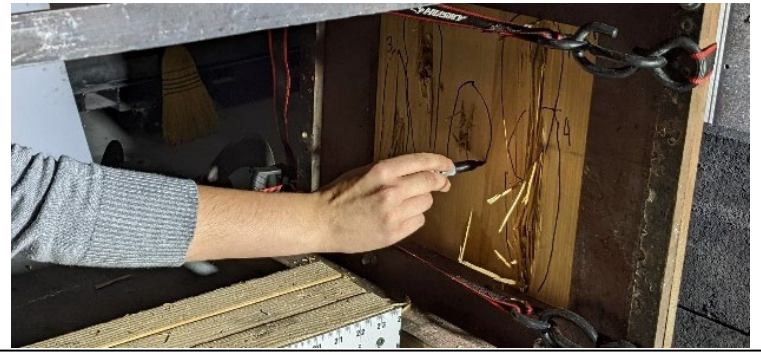


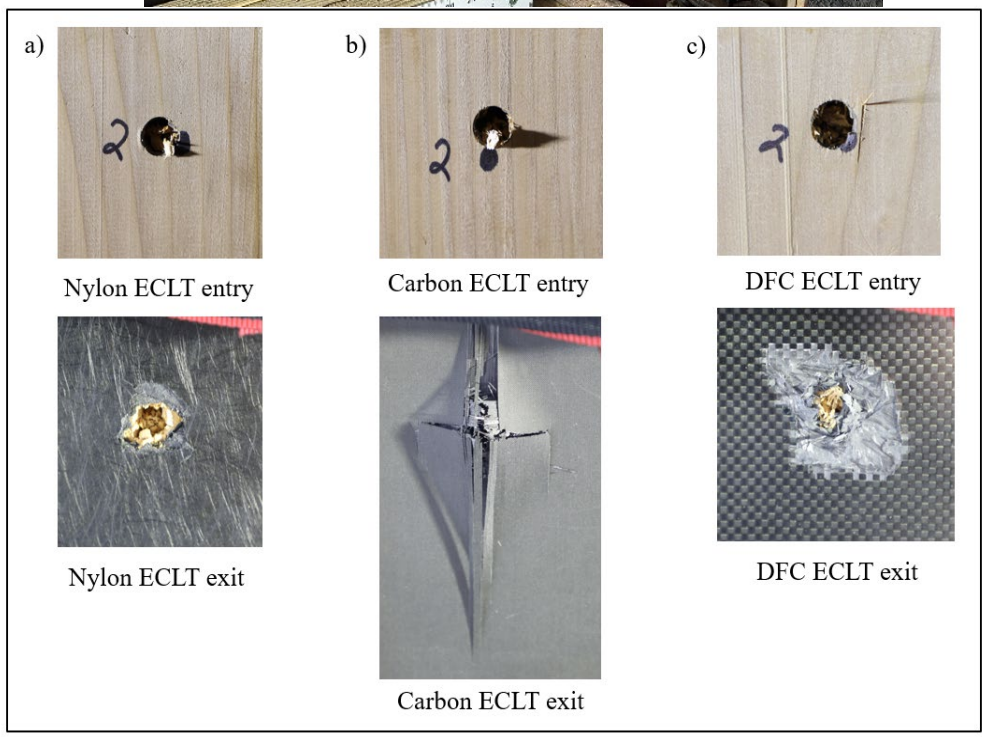


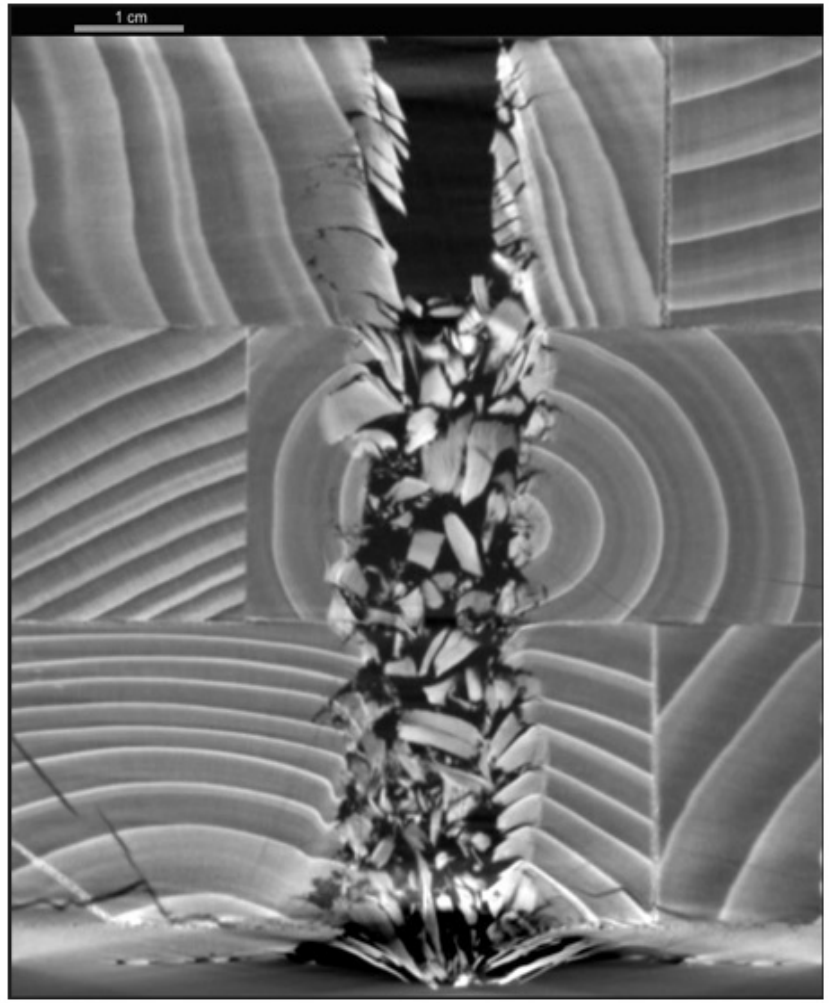


R&D – Penetration Resistance

$$T_W = 9837\left(\frac{v^{0.4113} w^{1.4897}}{\rho\left(\frac{\pi D^2}{4}\right)^{1.3596} H^{0.5414}}\right)$$

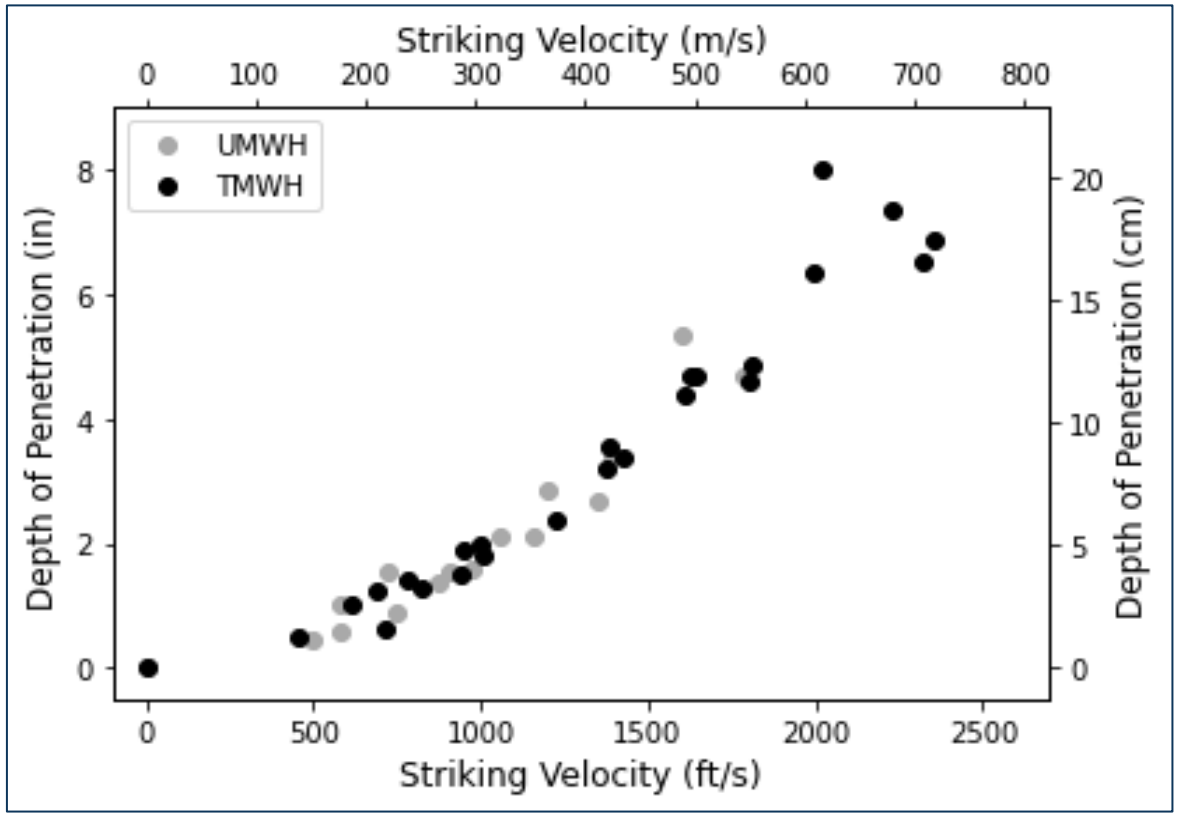




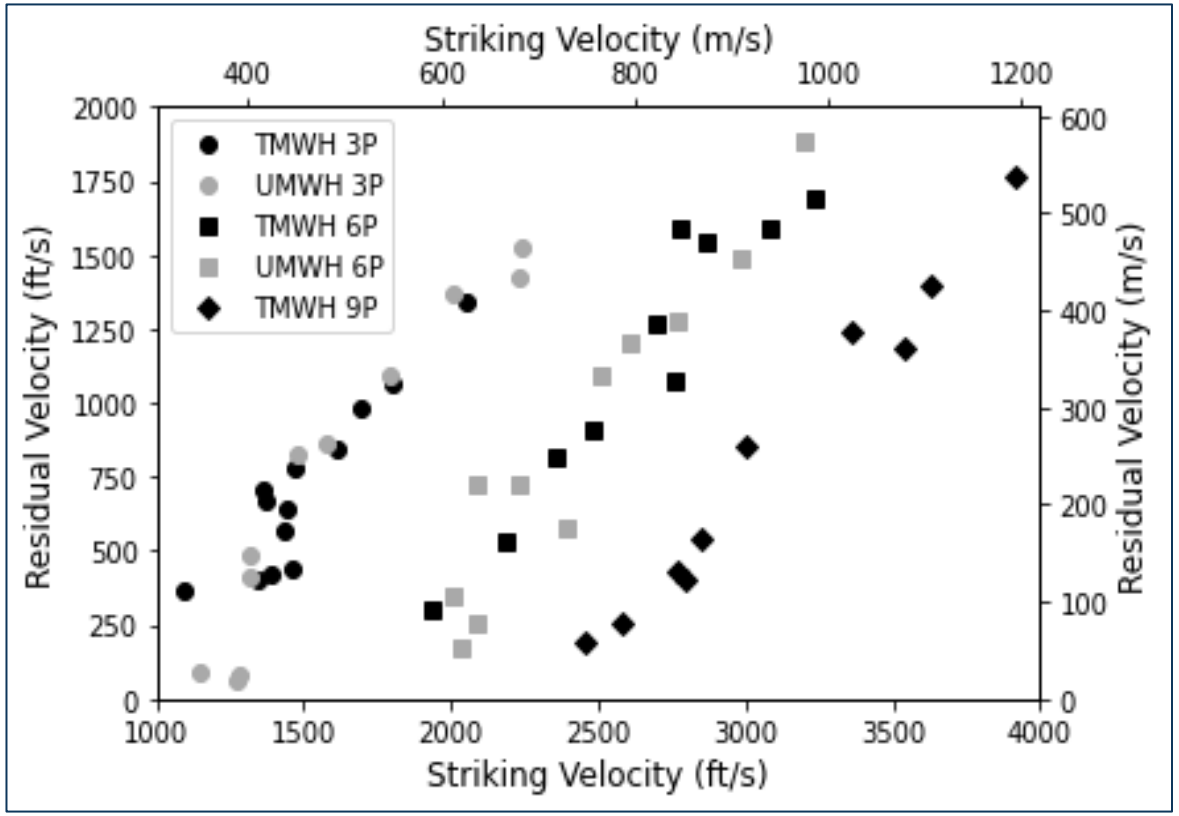


DFC ECLT fracture path

R&D – Penetration Resistance

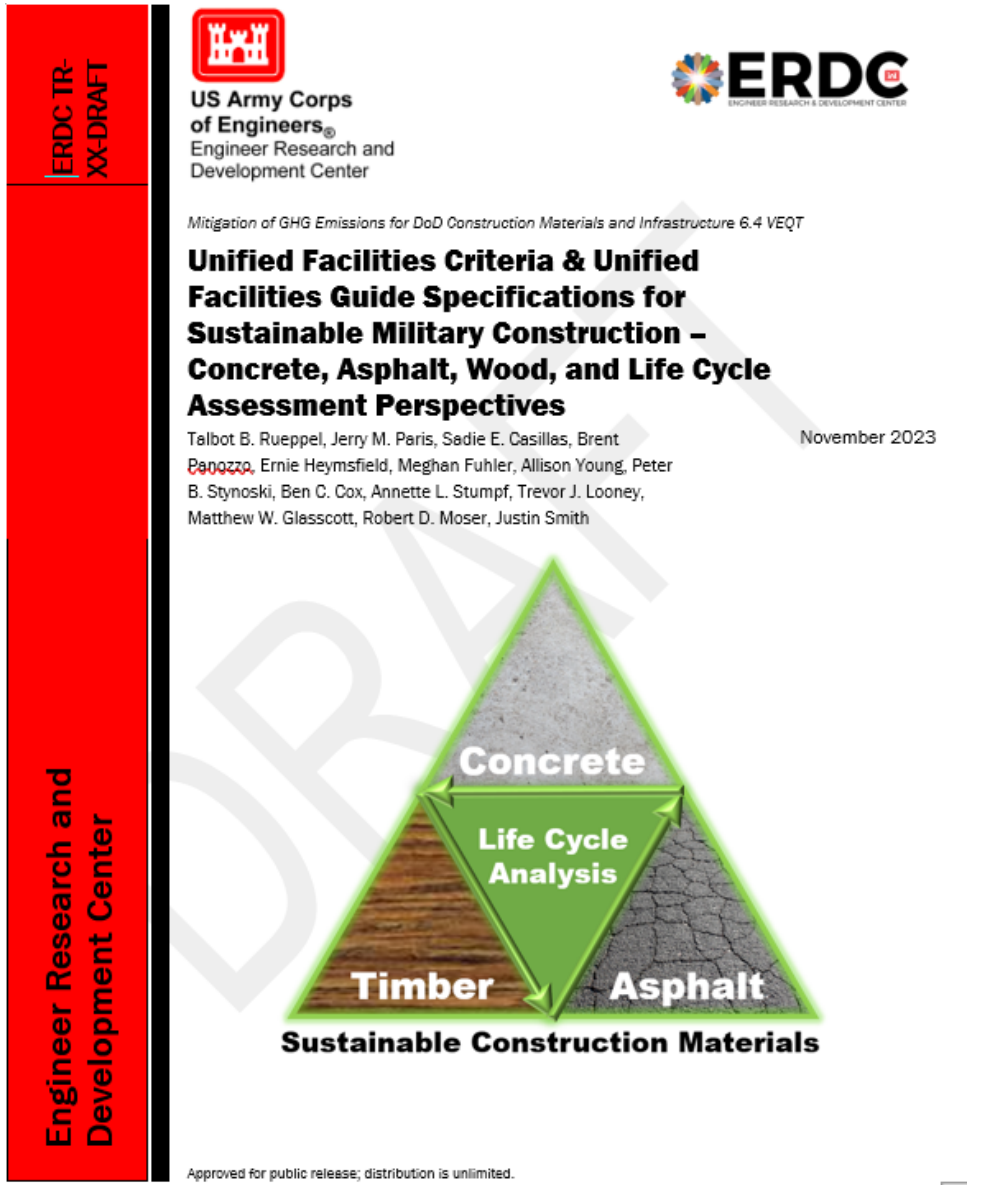


Partial penetration

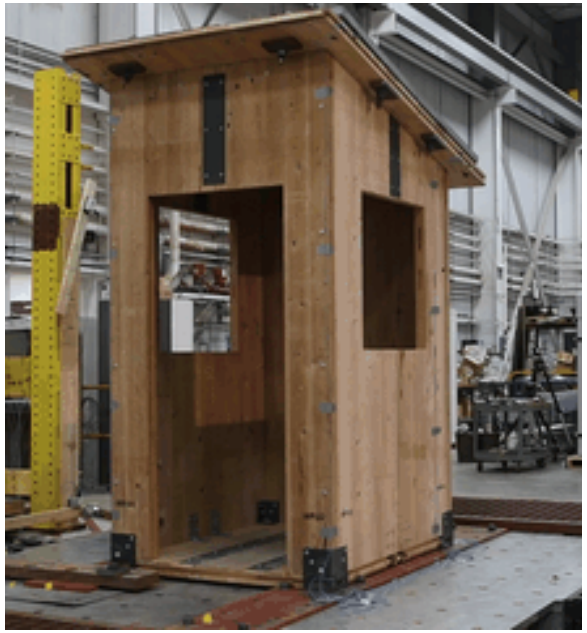


Full perforation

R&D – Spec Updates



Mitigation of Progressive Collapse

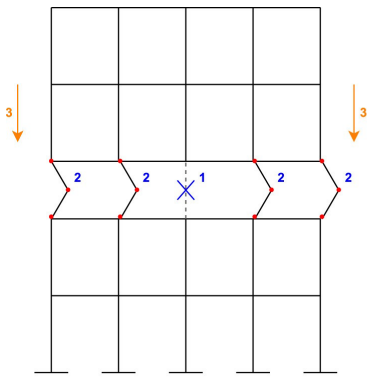


- UFC 4-023-03, ASCE/SEI 76-23
  - Govt-Private partnership for Criteria Change Request

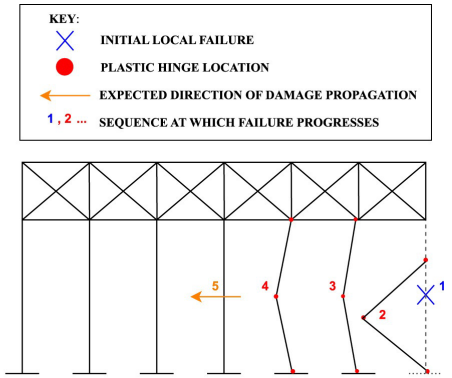
Common MT Pitfalls:

- Brittle material, yet ductile connections
  - Insufficient bracing
  - Ignoring moisture effects
- Glulam beams generally enable longer spans
  - Leads to deformation control
- Load-bearing exterior walls not always avoidable
  - Result: CLT acts as Deep Beam

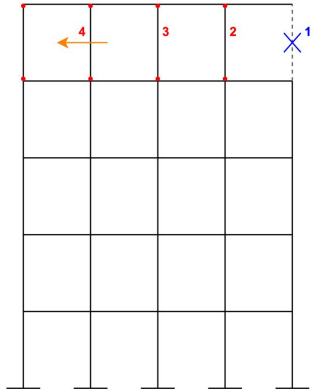
https://doi.org/10.1016/j.istruc.2024.106131



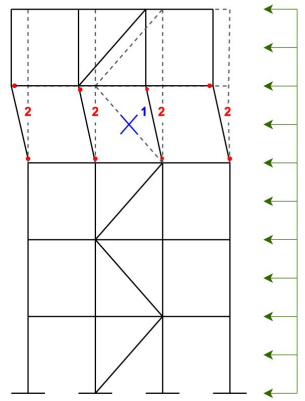
(a) Pancake type



(b) Domino type



(c) Zipper type



(d) Instability type

Mitigation of Progressive Collapse

Common strategies:

- Just make shorter MT buildings!
  - < 3 stories → FSL I or II
  - CLT Report to Congress, pg. 1
  - At odds with economic first cost
- Alternate Load Path method
  - Tie Force method poses connection challenges
- Proper detailing of fully-restrained, moment-carrying connections
- Glulam or CLT panel cantilevers

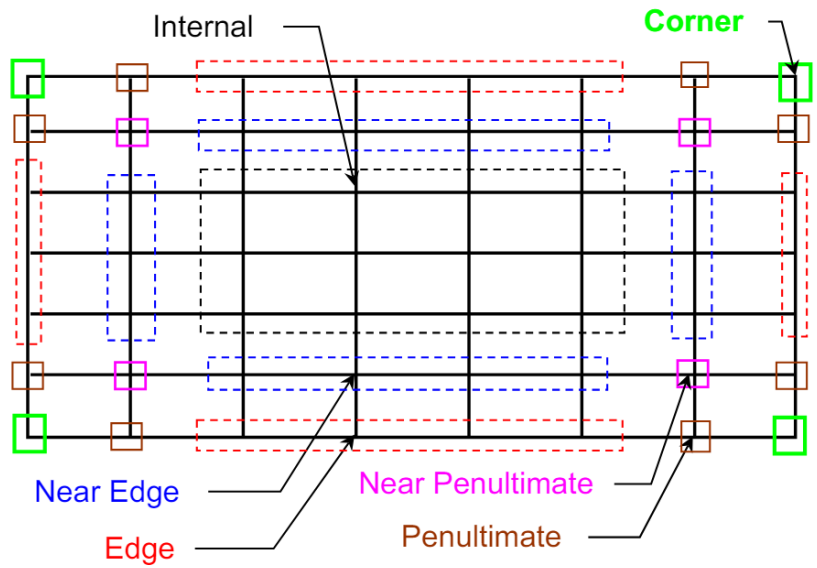
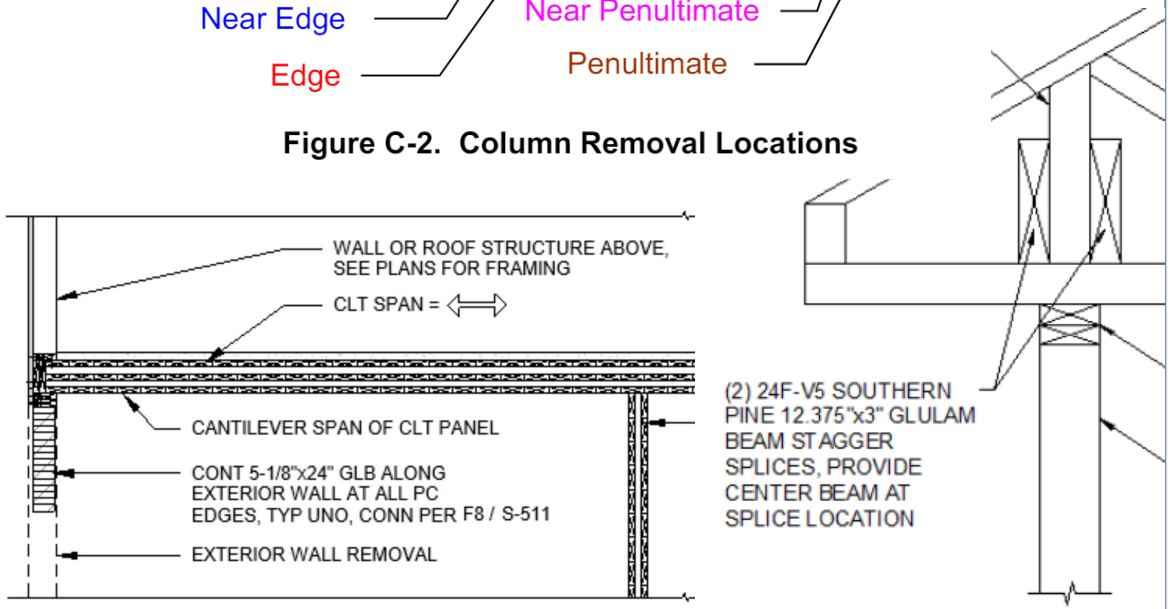
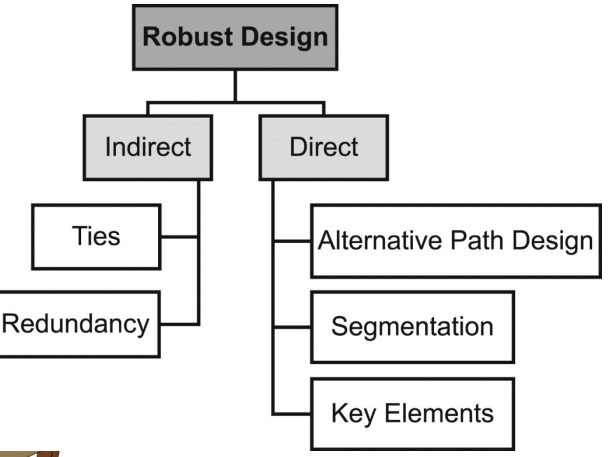


Figure C-2. Column Removal Locations

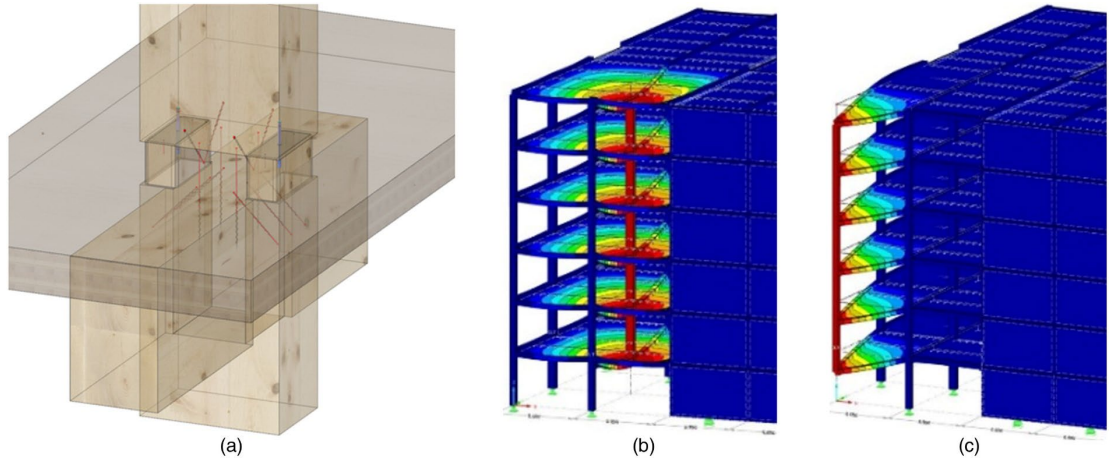


Mitigation of Progressive Collapse



Further reading:

- Structural Robustness and Timber Buildings
  - Wood Material Science & Engineering 14(2) 2019
  - https://doi.org/10.1080/17480272.2018.1446052
- Prevention of Disproportionate Collapse for Multistory Mass Timber Buildings: Review of Current Practices and Recent Research
  - Journal of Structural Engineering 148(7) 2022
  - https://doi.org/10.1061/(ASCE)ST.1943-541X.0003377



THANK YOU

Please take a few minutes to complete a short survey about this session. Your feedback will help us improve future programming for JETC.

conferences i/o

or browse to
jetc.cnf.io

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