WoodWorks™
WOOD PRODUCTS COUNCIL

Mass Timber Construction: Products, Performance and Design

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Photo: Corey Gaffer courtesy Perkins + Will

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

Course Description

Due to their high strength, dimensional stability and positive environmental performance, mass timber building products are quickly becoming materials of choice for sustainably-minded designers. This presentation will provide a detailed look at the variety of mass timber products available, including glue-laminated timber (glulam), cross laminated timber (CLT), nail laminated timber (NLT), heavy timber decking, and other engineered and composite systems. Applications for the use of these products under modern building codes will be discussed, and examples of their use in U.S. projects reviewed. Mass timber's ability to act as both structure and exposed finish will also be highlighted, as will its performance as part of an assembly, considering design objectives related to structural performance, fire resistance, acoustics, and energy efficiency. Other topics will include detailing and construction best practices, lessons learned from completed projects and trends for the increased use of mass timber products in the future.

Learning Objectives

1. Identify mass timber products available in North America and consider how they can be used under current building codes and standards.
2. Review completed mass timber projects that demonstrate a range of applications and system configurations.
3. Discuss benefits of using mass timber products, including structural versatility, prefabrication, lighter carbon footprint, and reduced labor costs.
4. Highlight possibilities for the expanded use and application of mass timber in larger and taller buildings.

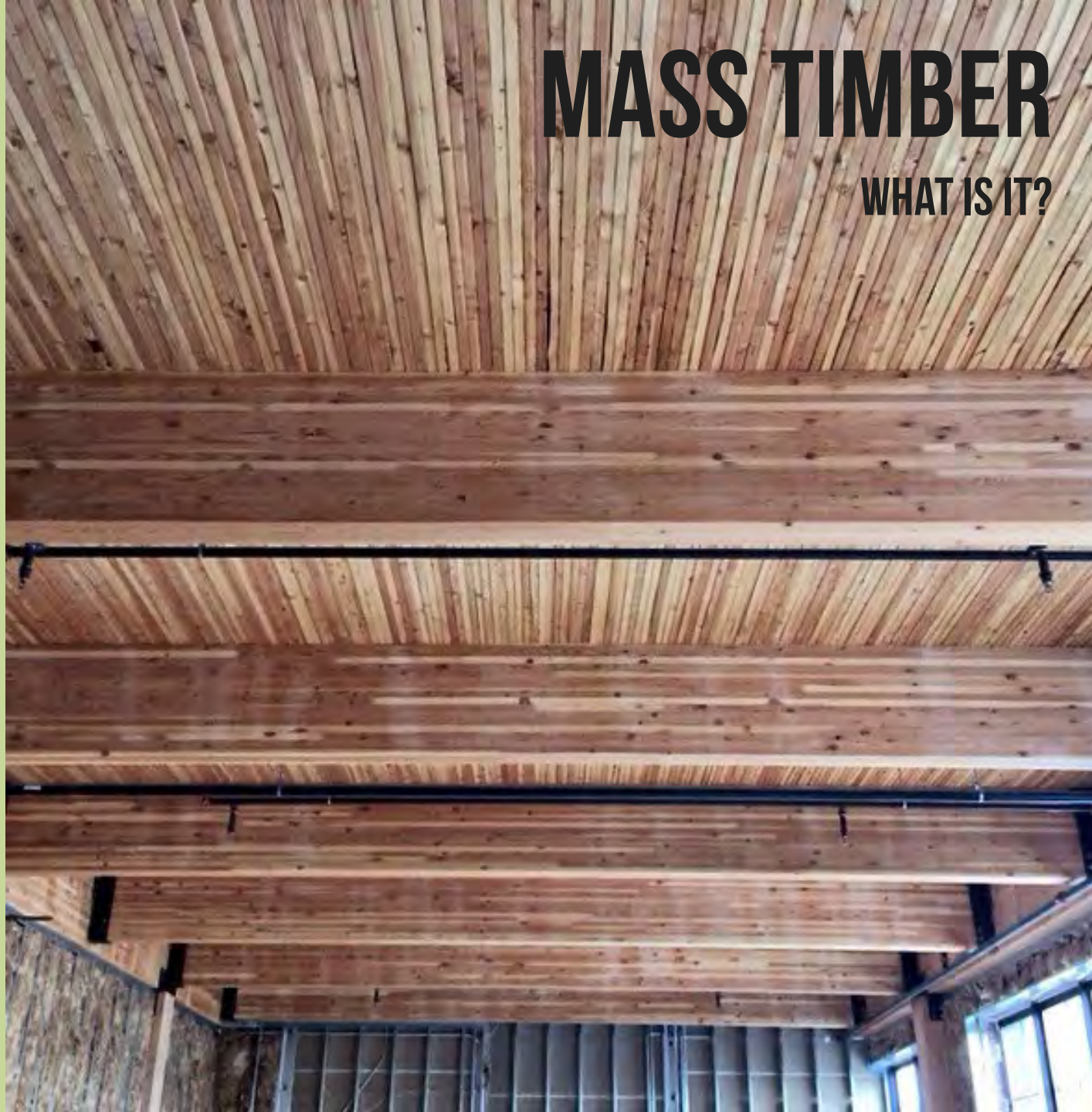
MASS

TIMBER

MASS TIMBER

WHAT IS IT?

MASS TIMBER IS A CATEGORY OF FRAMING STYLES OFTEN USING SMALL WOOD MEMBERS FORMED INTO LARGE PANELIZED SOLID WOOD CONSTRUCTION INCLUDING CLT, NLT OR GLULAM PANELS FOR FLOOR, ROOF AND WALL FRAMING



BUILDING FRAME SYSTEMS

POST & BEAM

T3 MINNEAPOLIS
MINNEAPOLIS, MN
IMAGE CREDIT: BLAINE BROWNELL

TWO-WAY PANELS

5 PLY CLT PANELS, 2-WAY SPAN
~9’X13’ GRID OF COLUMNS

BROCK COMMONS
VANCOUVER, BC
IMAGES: ACTON OSTRY ARCHITECTS

HYBRID LIGHT-FRAME & MASS TIMBER

CARBON 12
PORTLAND, OR
IMAGE: WOODWORKS

VIRTUOSO
VANCOUVER, BC
IMAGE: SEAGATE STRUCTURES

HONEYCOMB

CANDLEWOOD SUITES
REDSTONE ARESENAL, AL
IMAGE CREDIT: LENDLEASE

What's in a mass timber building?
Products used

MASS TIMBER PRODUCTS

GLULAM

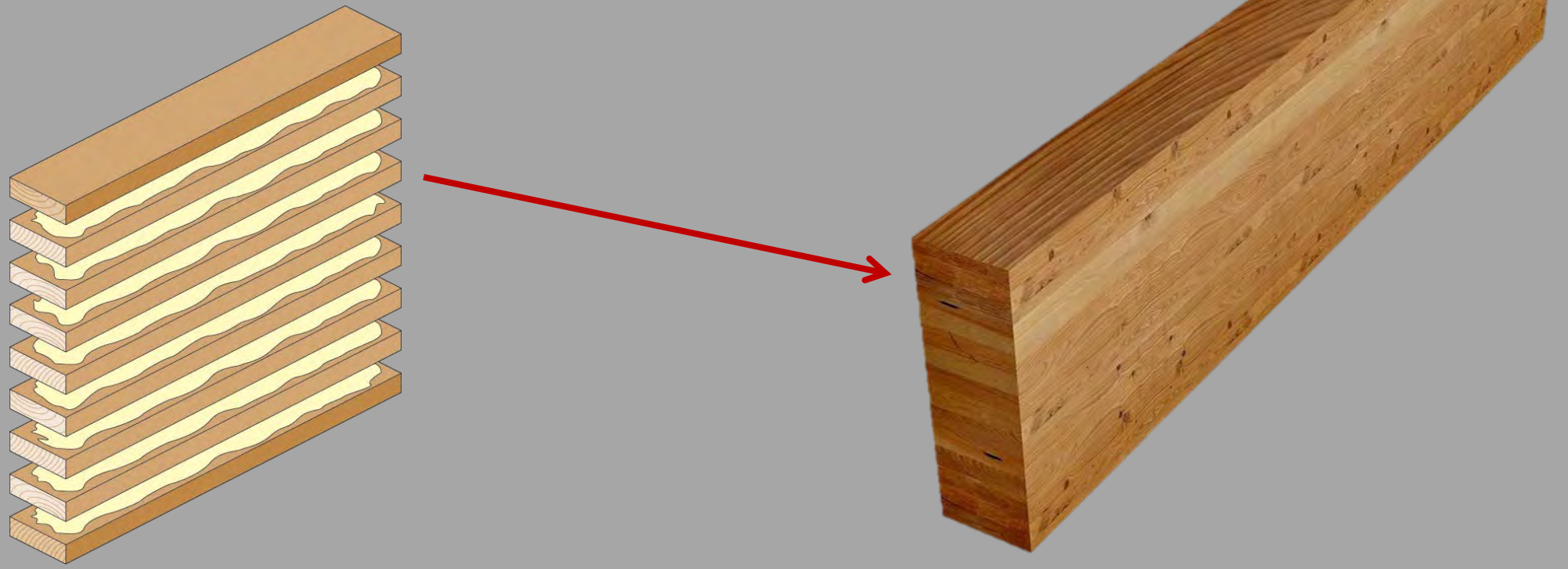
PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

GLULAM

GLULAM = A STRUCTURAL COMPOSITE OF LUMBER AND ADHESIVES

- RECOGNIZED IN IBC 2303.1.3 USING ANSI/AITC A 190.1 AND ASTM D 3737
- CAN BE USED FOR FLOOR, ROOF PURLINS, BEAMS, ARCHES, COLUMNS



MASS TIMBER PRODUCTS

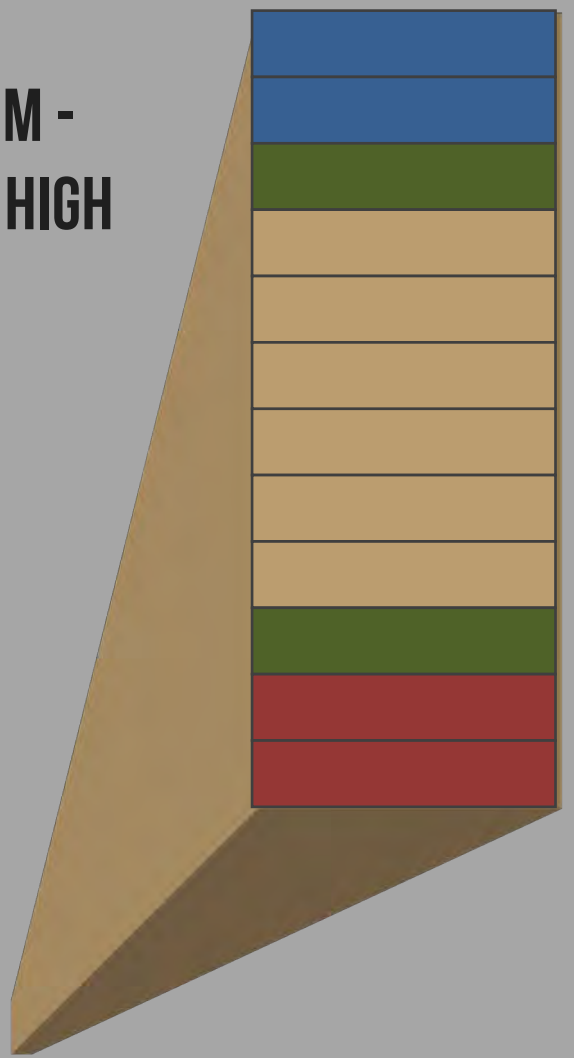
GLULAM

GLULAM LAYUP:

VARY STRENGTH OF LAMINATIONS

- HIGHER STRENGTH LAMS AT TOP AND BOTTOM - TENSION AND COMPRESSION STRESSES ARE HIGH
- LOWER STRENGTH LAMS IN CENTER PLIES

IMAGE: APA



HIGH STRENGTH OUTER COMPRESSION LAMS

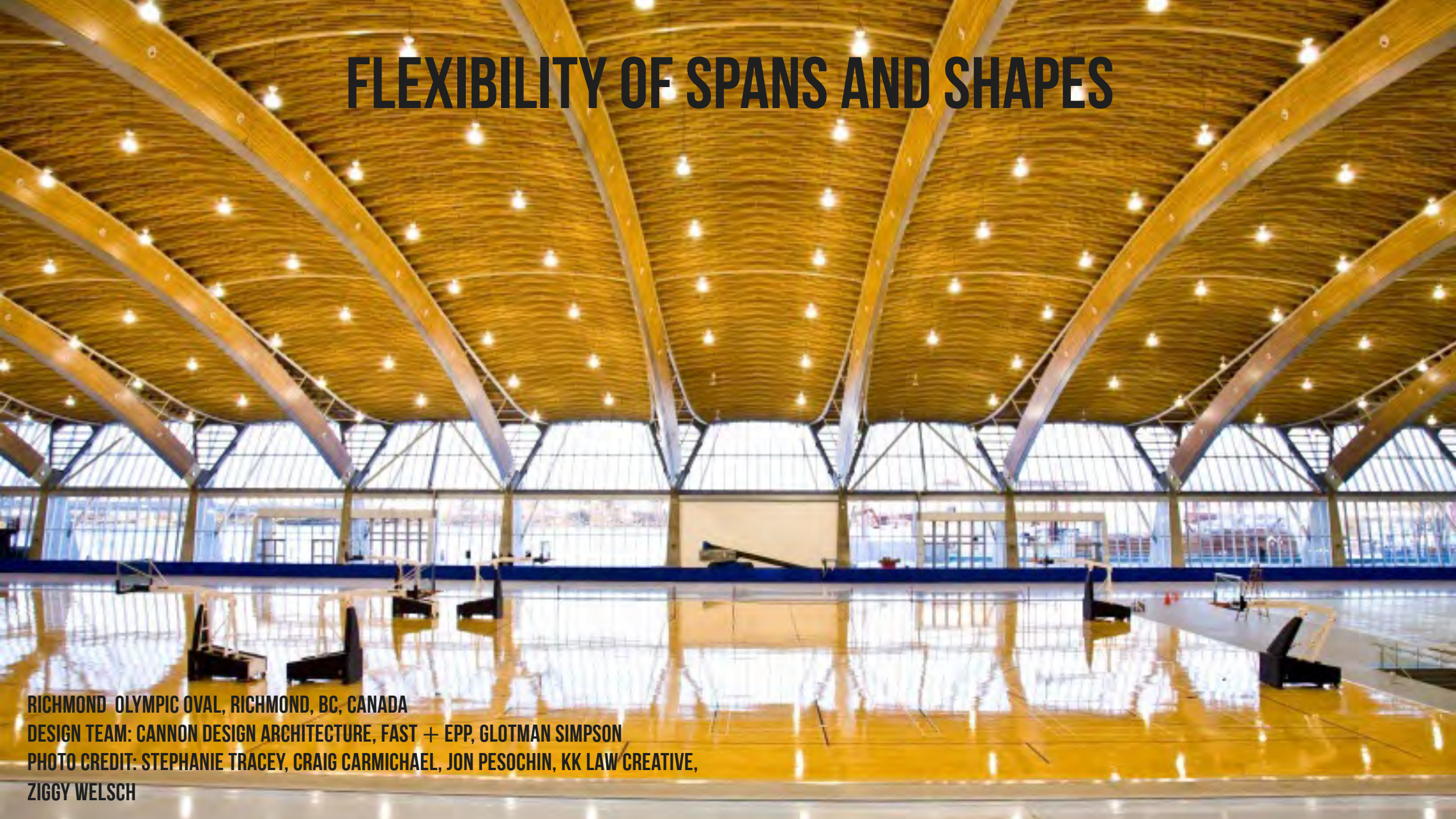
MEDIUM GRADE INNER COMPRESSION LAM

LOWER GRADE INNER LAMS

MEDIUM GRADE INNER COMPRESSION LAM

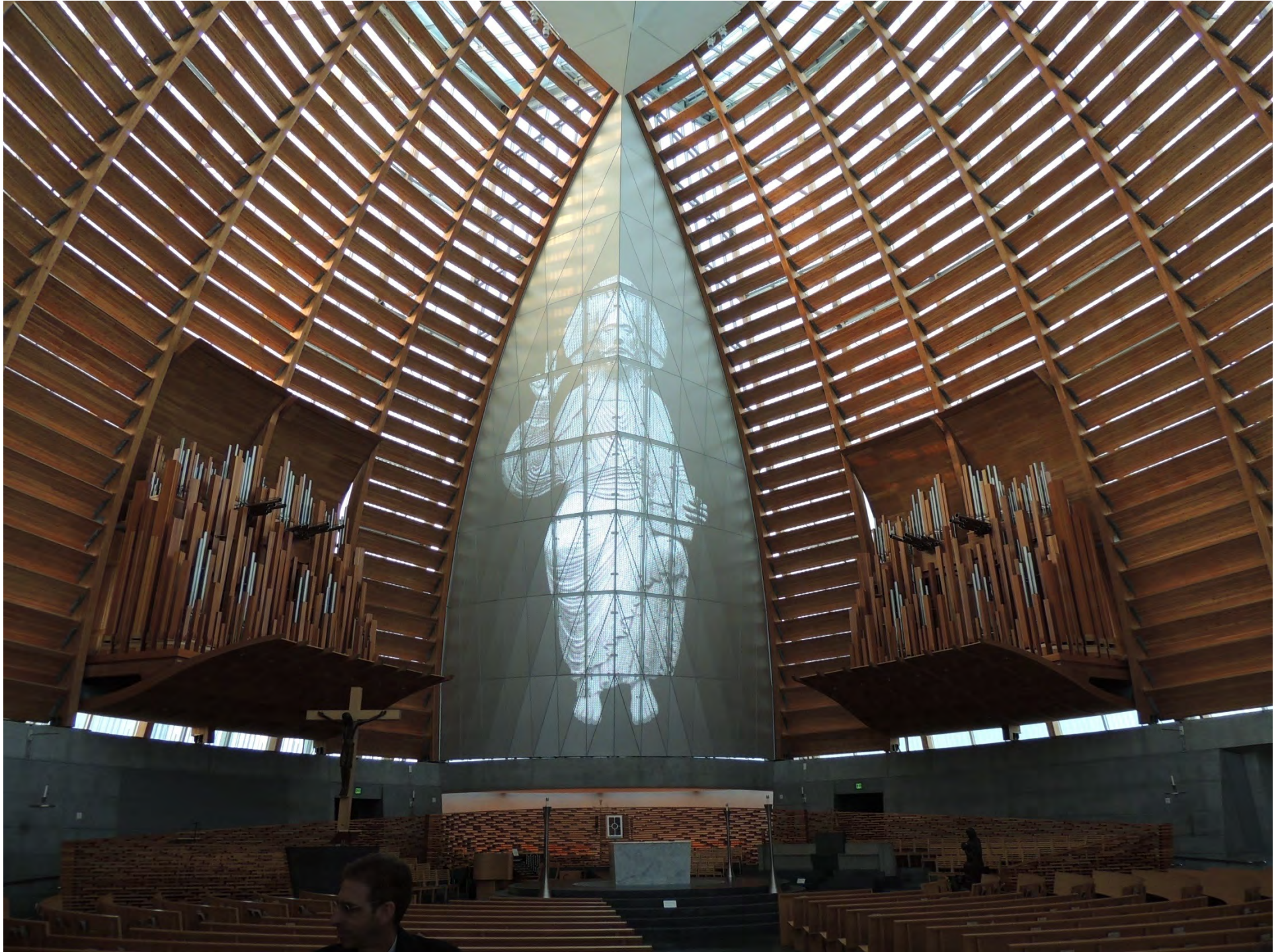
HIGH STRENGTH OUTER TENSION LAMS

FLEXIBILITY OF SPANS AND SHAPES



RICHMOND OLYMPIC OVAL, RICHMOND, BC, CANADA
DESIGN TEAM: CANNON DESIGN ARCHITECTURE, FAST + EPP, GLOTMAN SIMPSON
PHOTO CREDIT: STEPHANIE TRACEY, CRAIG CARMICHAEL, JON PESOCHIN, KK LAW CREATIVE, ZIGGY WELSCH

THE CATHEDRAL OF CHRIST THE LIGHT, OAKLAND, CA
PHOTO: TIMOTHY HURSLEY, CESAR RUBIO, AND JOHN BLAUSTEIN



FIRST TECH CREDIT UNION

HILLSBORO, OR

5 STORIES

156,000 SF

ARCHITECT: HACKER

IMAGE CREDIT: STRUCTURLAM

FIRST TECH CREDIT UNIO

HILLSBORO

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

Glue Laminated Timber
GLT

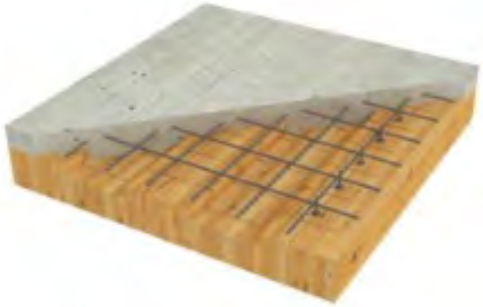
Laminated Veneer Lumber
LVL

Parallel Strand Lumber
PSL

Laminated Strand Lumber
LSL

Cross Laminated Timber
CLT

Nail Laminated Timber
NLT



Timber-Concrete Composite
TCC

DLT Dowel Laminated Timber

MPP Mass Plywood Panel

Mass Timber Products

Photo credit: StructureCraft Builders/Freres Lumber

NAIL LAMINATED TIMBER

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

MASS TIMBER PRODUCTS

What is it?

Nail-laminated timber (NLT) is mechanically laminated to create a solid timber panel. NLT is created by placing dimension lumber (nominal 2x, 3x, or 4x thickness and 4 in. to 12 in. width) on edge and fastening the individual laminations together with nails.

Image: Think Wood

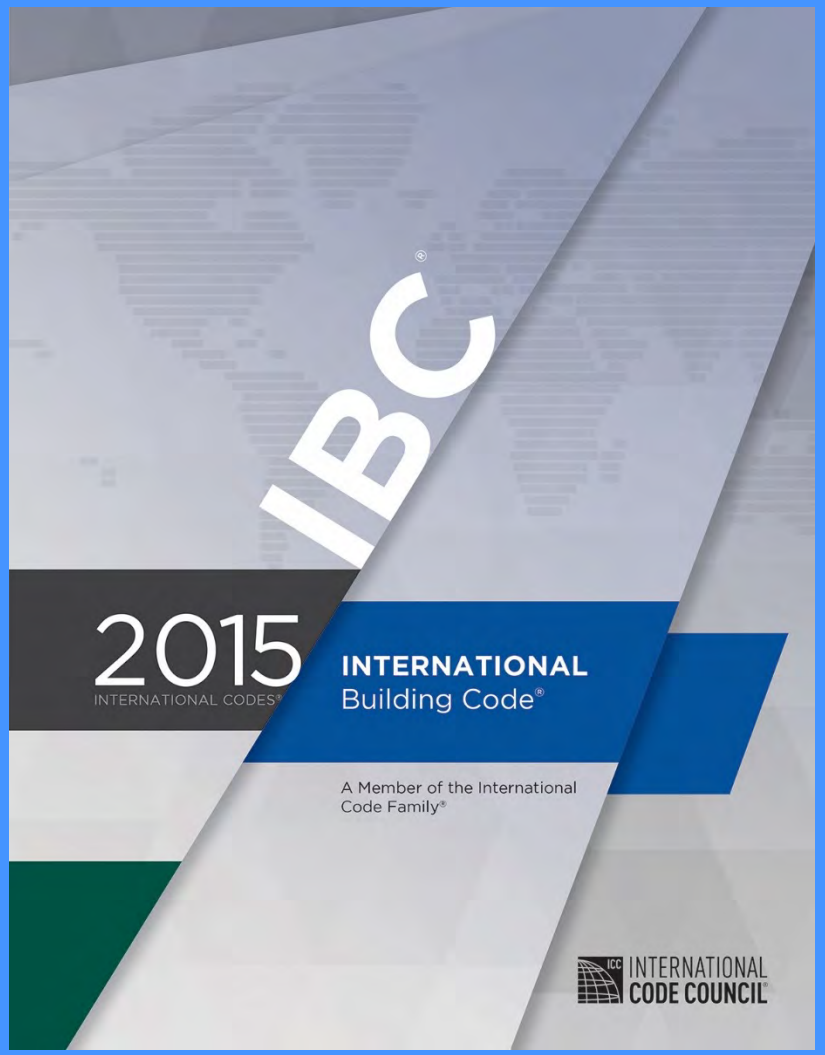
MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

When does the code allow it to be used?

IBC defines NLT as mechanically laminated decking per IBC 2304.9.3

Permitted anywhere that combustible materials and heavy timber are allowed, plus more



MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

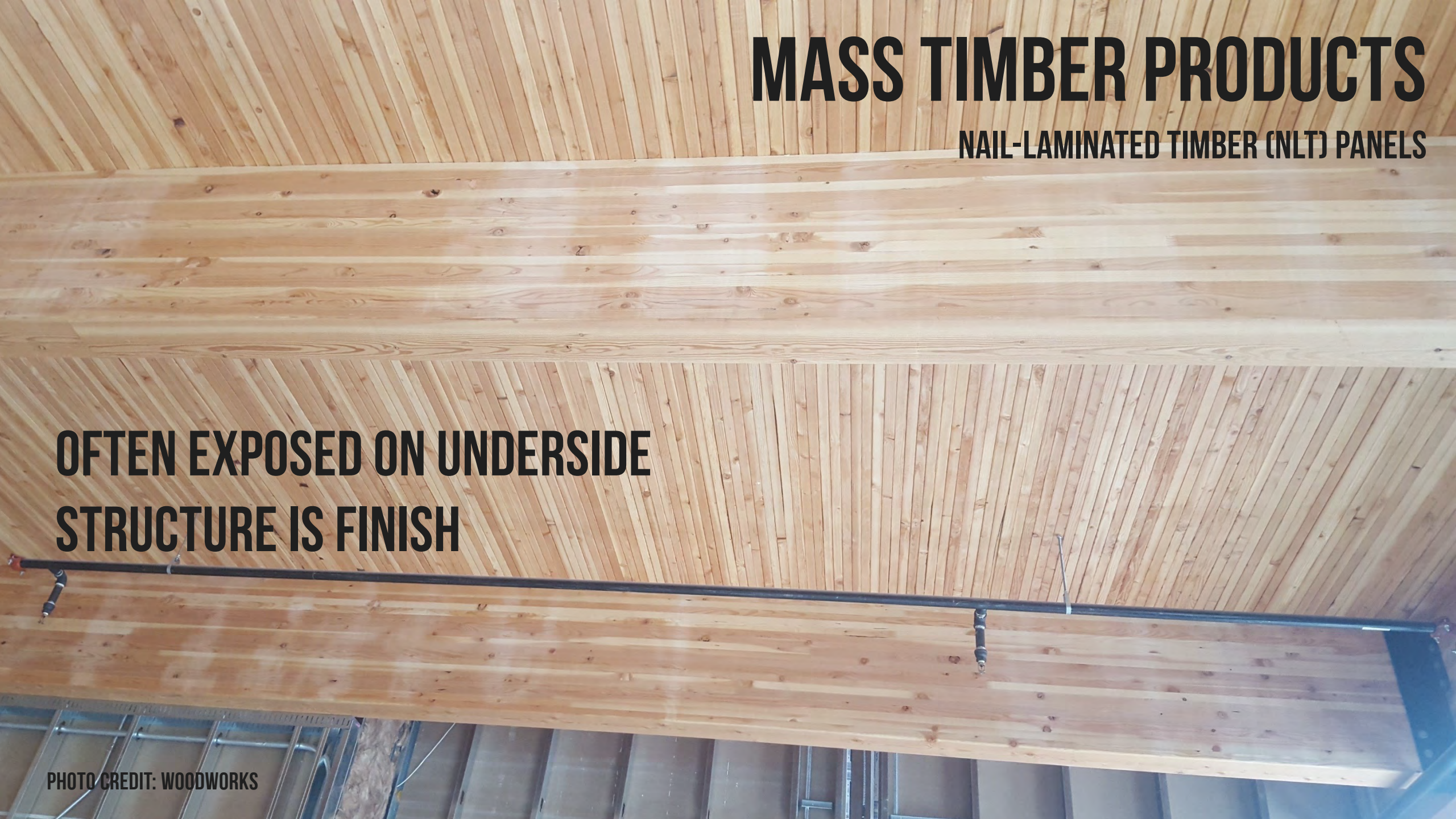
When is it used?

NLT is typically used for floor and roof panels. Plywood/OSB added to one face can provide in-plane shear capacity, allowing the product to be used as a diaphragm. Can also be used for walls, shafts.

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

MASS TIMBER PRODUCTS

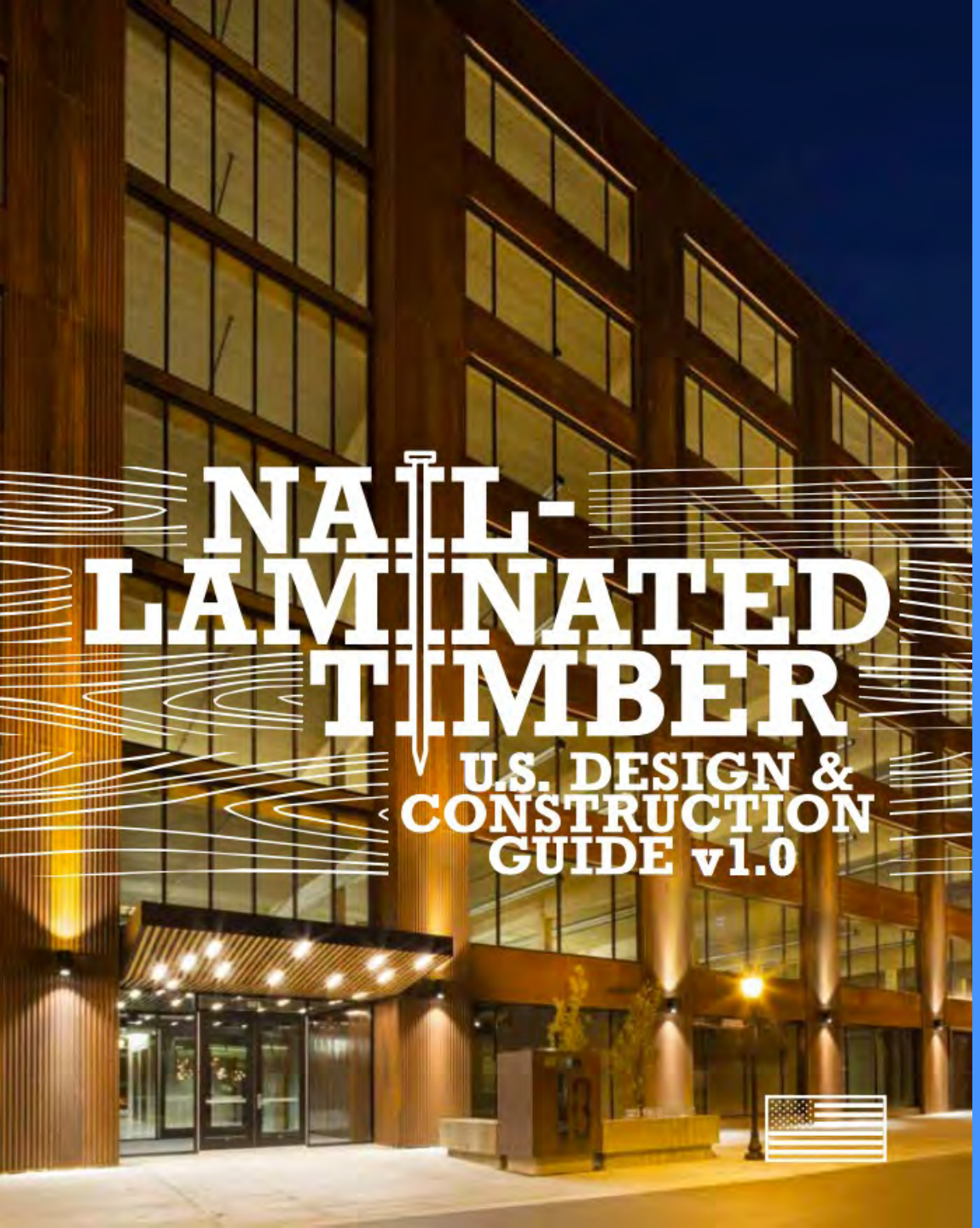
NAIL-LAMINATED TIMBER (NLT) PANELS



OFTEN EXPOSED ON UNDERSIDE

STRUCTURE IS FINISH

PHOTO CREDIT: WOODWORKS



MASS TIMBER PRODUCTS

CONTENT INCLUDES:

- ARCHITECTURE
- FIRE
- STRUCTURE
- ENCLOSURE
- SUPPLY AND FABRICATION
- CONSTRUCTION AND INSTALLATION
- ERECTION ENGINEERING

FREE DOWNLOAD AT

WWW.THINKWOOD.COM/NLTGUIDE

T3 MINNEAPOLIS

MINNEAPOLIS, MN

Photo Credit: Blaine Brownell

T3 MINNEAPOLIS

MINNEAPOLIS, MN

Type IV Construction
7 stories (6 Timber on 1 Concrete)
234,000 sf
2x8 NLT Floor Panels w/3” Concrete Topping
Glulam Beam and Column Frame
20’x25’ Grid

Image Credit: StructureCraft Builders

T3 MINNEAPOLIS

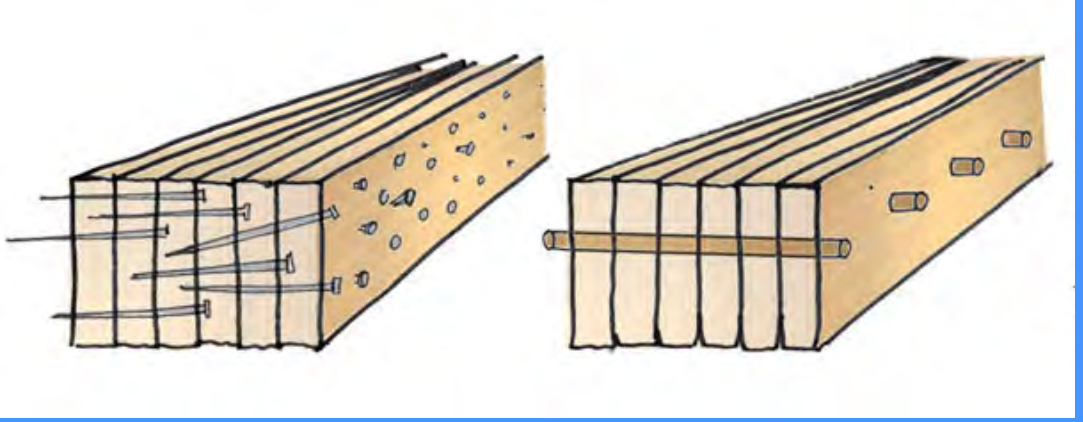
MINNEAPOLIS, MN

IMAGE CREDIT: EMA PETER

MASS TIMBER PRODUCTS

DOWEL-LAMINATED TIMBER (DLT)

PHOTO CREDIT: STRUCTURECRAFT BUILDERS



MASS TIMBER PRODUCTS

DOWEL-LAMINATED TIMBER (DLT) PANELS

DLT:

- SIMILAR TO NLT – NAILS CONNECTING LAMS REPLACED WITH HARDWOOD DOWELS
- COMMON IN EUROPE – OFTEN REFERRED TO AS BRETTSTAPEL
- NOT CURRENTLY RECOGNIZED AS PRESCRIPTIVELY PERMITTED MATERIAL IN IBC
- TIMBER FRAMERS GUILD – RESOURCES ON DOWEL DESIGN

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

MASS TIMBER PRODUCTS

Dowel Laminated Timber

The All Wood Panel

Mass Timber Design Guide

DLT: SIMILAR TO NLT – BUT LAMS ARE USUALLY FINGER JOINTED IN DLT SO JOINT LAYUPS NOT A CONCERN

CREDIT: STRUCTURECRAFT BUILDERS

MASS TIMBER PRODUCTS

DOWEL-LAMINATED TIMBER (DLT) PANELS

VARIOUS PROFILE OPTIONS

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

111 EAST GRAND

DES MOINES, IA

CREDIT: NUEMANN MONSON ARCHITECTS
COURTESY: RYAN COMPANIES

111 EAST GRAND

DES MOINES, IA

CREDIT: STRUCTURECRAFT BUILDERS

4 STORY, 66,800 SF SPEC OFFICE BUILDING

DLT PANELS, GLULAM FRAME

PHOTO CREDIT: STRUCTURE FUSION

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT) PANELS

PHOTO CREDIT: UNALAM

IMAGE SOURCE: MANASC ISAAC ARCHITECTS/FAST ± EPP

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT) PANELS

GLULAM DECKING:

- SIMILAR TO DEEP GLULAM BEAMS LAID ON THEIR SIDE
- SAME CODE REFERENCES AND MANUFACTURING STANDARDS AS GLULAM BEAMS AND COLUMNS
- BE CAREFUL OF DESIGN STRESSES AND LAYUPS USED – SPEC UNIFORM LAYUP (ALL LAMS SAME SPECIES & GRADE)

IMAGE SOURCE: STRUCTURECRAFT BUILDERS

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT) PANELS

IMAGE SOURCE: STRUCTURECRAFT BUILDERS

Use with Table 5A Adjustment Factors

ecies / r/ Core	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)							Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations)				
	Bending		Compression Perpendicular to Grain		Shear Parallel to Grain	Modulus of Elasticity		Bending	Compression Perpendicular to Grain	Shear Parallel to Grain	Modulus of Elasticity	
	Bottom of Beam Stressed in Tension (Positive Bending)	Top of Beam Stressed in Tension (Negative Bending)	Tension Face	Compression Face		For Deflection Calculations	For Stability Calculations				For Deflection Calculations	For Stability Calculations
	F_{bx}^{+} (psi)	F_{bx}^{-} (psi)	$F_{c\perp x}$ (psi)		$F_{vx}^{(2)}$ (psi)	E_x (10^6 psi)	$E_{x\,min}$ (10^6 psi)	F_{by} (psi)	$F_{c\perp y}$ (psi)	$F_{vy}^{(2)(3)}$ (psi)	E_y (10^6 psi)	$E_{y\,min}$ (10^6 psi)
	2400	**1450**	**650**		**265**	**1.8**	**0.95**	**1450**	**560**	**230**	**1.6**	**0.85**
F/DF	2400	1850	650	650	265	1.8	0.95	1450	560	230	1.6	0.85
F/DF	2400	2400	650	650	265	1.8	0.95	1550	560	230	1.6	0.85
F/DF	2400	1450	650	650	265	1.8	0.95	1400	560	230	1.7	0.90
F/DF	2400	2400	650	650	265	1.8	0.95	1750	560	230	1.7	0.90
F/DF	2400	2400	650	650	265	1.8	0.95	1550	560	230	1.7	0.90
P/SP	2400	2000	740	740	300	1.8	0.95	1700	650	260	1.6	0.85

NDS SUPPLEMENT LISTS DIFFERENT DESIGN VALUES FOR BENDING. LAYUP COMBINATIONS TYPICALLY OPTIMIZED FOR BEAM APPLICATIONS. LAYUP COMBINATIONS AREN'T EFFECTIVE IN GLT DECKING APPLICATIONS

MASS TIMBER PRODUCTS

MASS PLYWOOD PANELS (MPP)

THICKNESSES IN 1” INCREMENTS
STRUCTURAL PROPERTIES IN APA PRODUCT REPORT PR-L325

MASS TIMBER PRODUCTS

MASS PLYWOOD PANELS (MPP)

Table 1. ASD Reference Design Values[a,b,c] for Freres MPP (For Use in the U.S.)

MPP Layup	Layup ID	Thickness, t_p (in.)	Major Strength Direction				Minor Strength Direction			
			$(F_bS)_{eff,f,0}$ (lbf-ft/ft)	$(EI)_{eff,f,0}$ (10^6 lbf-in.^{2}/ft)	$(GA)_{eff,f,0}$ (10^6 lbf/ft)	$V_{s,0}$ (lbf/ft)	$(F_bS)_{eff,f,90}$ (lbf-ft/ft)	$(EI)_{eff,f,90}$ (10^6 lbf-in.^{2}/ft)	$(GA)_{eff,f,90}$ (10^6 lbf/ft)	$V_{s,90}$ (lbf/ft)
F16	F16-2	2	1,110	16	0.82	2,190	210	2.8	0.17	695
	F16-3	3	1,870	51	1.23	2,190	355	9.0	0.26	695
	F16-4	4	3,325	122	1.64	2,925	630	21	0.34	930
	F16-5	5	5,200	238	2.05	3,650	985	42	0.43	1,160
	F16-6	6	7,500	410	2.46	4,375	1,420	72	0.69	1,390
	F16-7	7	10,200	652	2.66	5,100	1,930	114	0.81	1,630
	F16-8	8	13,325	973	3.04	5,825	2,525	170	0.91	1,860
	F16-9	9	16,850	1,385	3.42	6,575	3,200	242	1.04	2,090
	F16-10	10	20,825	1,900	3.80	7,300	3,950	333	1.15	2,320
	F16-11	11	25,175	2,529	4.18	8,025	4,775	443	1.27	2,550
	F16-12	12	29,975	3,283	4.56	8,750	5,675	575	1.38	2,775

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448N

(a) Tabulated values are allowable design values.

(b) Tabulated values are limited to MPP manufactured with 1-inch-thick Freres 1.6E Douglas-fir LVL.

(c) Deflection under a specified uniformly distributed load, w, acting perpendicular to the face of a single deflections due to moment and shear effects using the effective bending stiffness, $(EI)_{eff}$, and the effe follows:

$$\delta = \frac{22.5wL^4}{(EI)_{eff}} + \frac{3wL^2}{2(GA)_{eff}}$$

where: δ = Estimated deflection, inches; w = uniform load, plf;
L = span, feet; $(EI)_{eff}$ = tabulated effective bending stiffness, 10^6
$(GA)_{eff}$ = tabulated effective in-plane (planar) shear rigidity, 10^6 lbf/ft

MPP

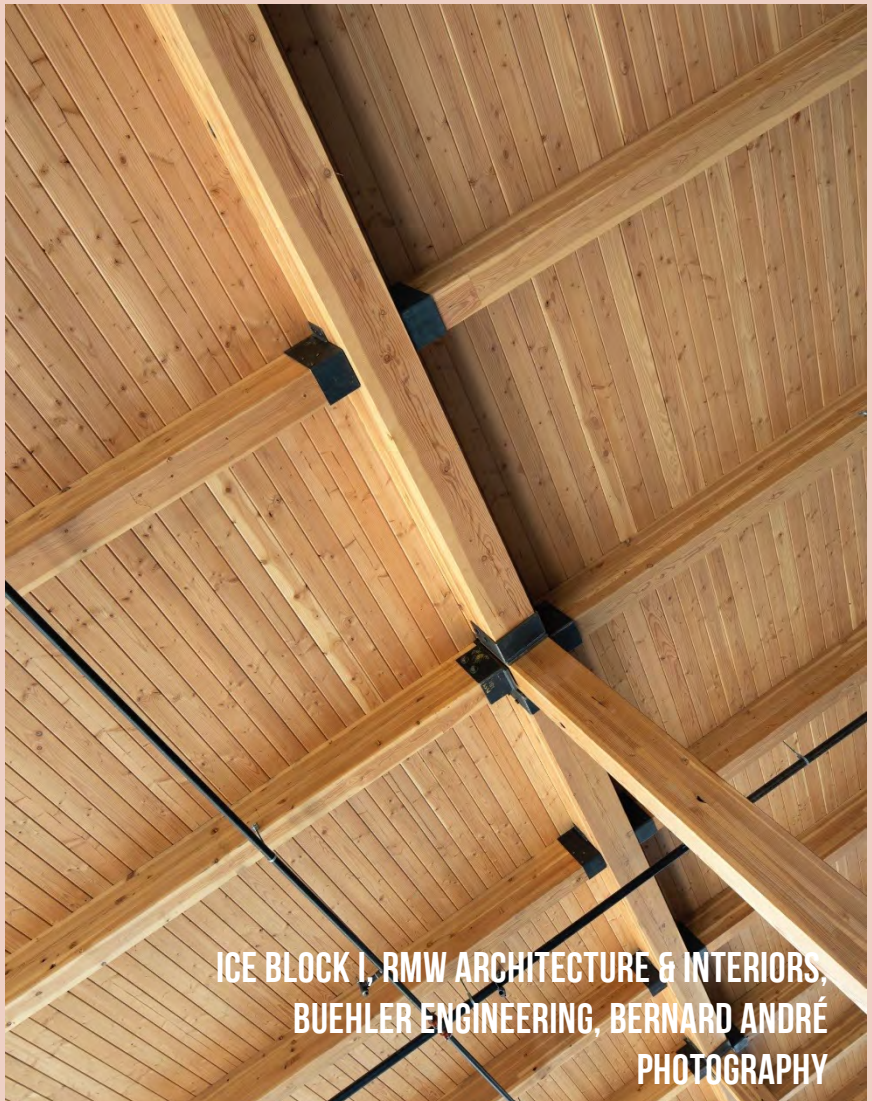
MASS TIMBER PRODUCTS

TONGUE AND GROOVE DECKING

TONGUE AND GROOVE DECKING:

2X, 3X OR 4X SOLID OR LAMINATED WOOD DECKING LAID FLAT WITH INTERLOCKING TONGUE AND GROOVE ON NARROW (SIDE) FACE

- RECOGNIZED IN IBC 2304.8 (LUMBER DECKING)
- 2X USUALLY HAS A SINGLE T&G; 3X AND 4X USUALLY HAVE A DOUBLE T&G
- 6” AND 8” ARE COMMON WIDTHS
- CAN BE USED FOR FLOOR, ROOF DECKING



ICE BLOCK I, RMW ARCHITECTURE & INTERIORS, BUEHLER ENGINEERING, BERNARD ANDRÉ PHOTOGRAPHY

MASS TIMBER PRODUCTS

TONGUE AND GROOVE DECKING

CAN BE USED BY ITSELF AS A DIAPHRAGM: SDPWS TABLE 4.2D
OR ADD LAYER OF WSP ON TOP, TREAT AS BLOCKED DIAPHRAGM

T&G DIAPHRAGM DESIGN

MASS TIMBER PRODUCTS

T&G DECKING DESIGN

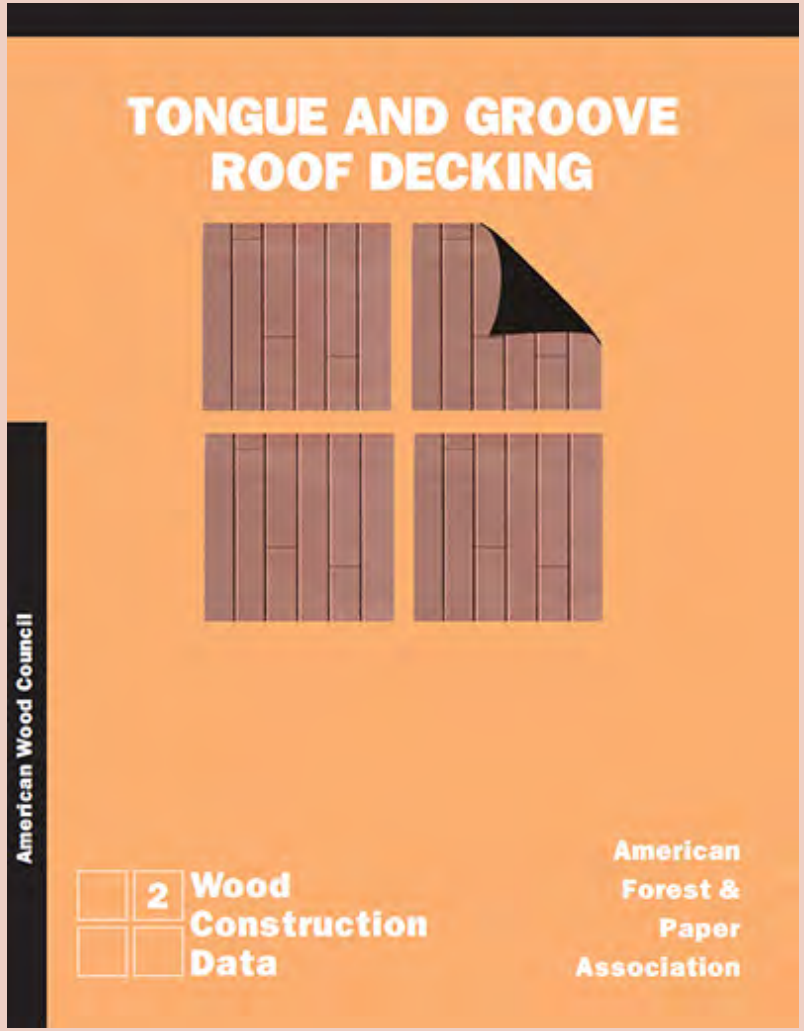
TONGUE AND GROOVE DECKING

Table 4E Reference Design Values for Visually Graded Decking[1,2]

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4E ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)					Specific Gravity[3]	Grading Rules Agency
		Bending		Compression perpendicular to grain	Modulus of Elasticity			
		Single Member F_b	Repetitive Member $(F_b)(C_r)$	$F_{c\perp}$	E	E_{min}	G	
BALSAM FIR								
Select	2"-4" thick	—	1,650	—	1,500,000	550,000	0.36	NELMA
Commercial	4"-12"wide	—	1,400	—	1,300,000	470,000		
COAST SITKA SPRUCE								
Select	2"-4" thick	1,250	1,450	455	1,700,000	620,000	0.43	NLGA
Commercial	4"& wider	1,050	1,200	455	1,500,000	550,000		
COAST SPECIES								
Select	2"-4" thick	1,250	1,450	370	1,500,000	550,000	0.43	NLGA
Commercial	4"& wider	1,050	1,200	370	1,400,000	510,000		
DOUGLAS FIR-LARCH								
Select Dex	2"-4" thick	1,750	2,000	625	1,800,000	660,000	0.50	WCLIB
Commercial Dex	6"-8"wide	1,450	1,650	625	1,700,000	620,000		



NDS SUPPLEMENT CONTAINS ALLOWABLE DESIGN VALUES

AWC'S WCD-2 CONTAINS SPAN TABLES

ICE BLOCK I

SACRAMENTO, CA

ICE BLOCK I, RMW ARCHITECTURE & INTERIORS, BUEHLER ENGINEERING, BERNARD ANDRÉ PHOTOGRAPHY

ICE BLOCK I

SACRAMENTO, CA

PHOTO CREDIT: RMW ARCHITECTURE

135,000 SF OF RETAIL AND RESTAURANT SPACE

GLULAM FRAME, 3X T&G DECKING

ICE BLOCK I, RMW ARCHITECTURE & INTERIORS, BUEHLER ENGINEERING, BERNARD ANDRÉ PHOTOGRAPHY

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

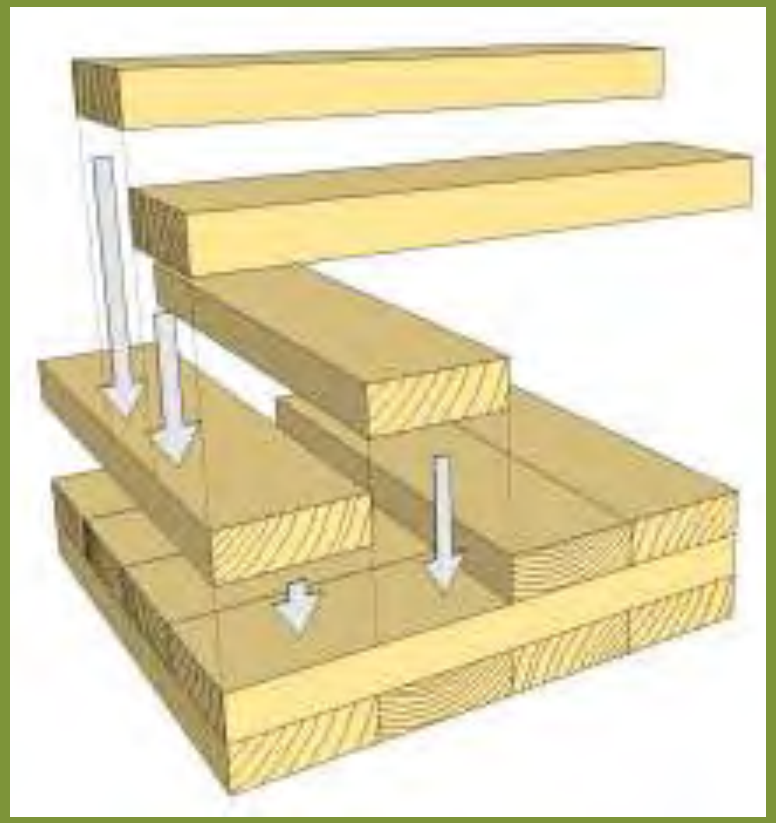
WHAT IS CLT?

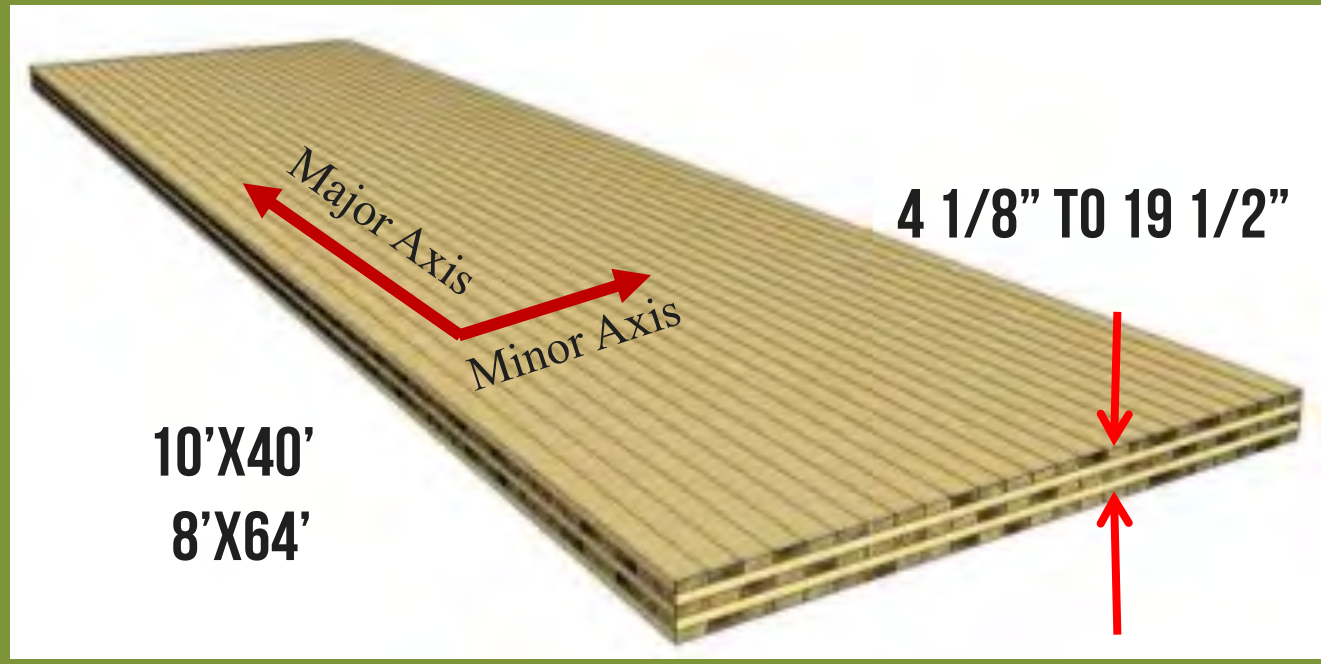
SOLID WOOD PANEL

3 LAYERS MIN. OF SOLID SAWN LAMS

90 DEG. CROSS-LAMS

SIMILAR TO PLYWOOD SHEATHING





MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

COMMON CLT LAYUPS

3-PLY 3-LAYER

5-PLY 5-LAYER

7-PLY 7-LAYER

9-PLY 9-LAYER

7-PLY 5-LAYER

9-PLY 7-LAYER

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: IHG® ARMY HOTELS, LENDLEASE

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

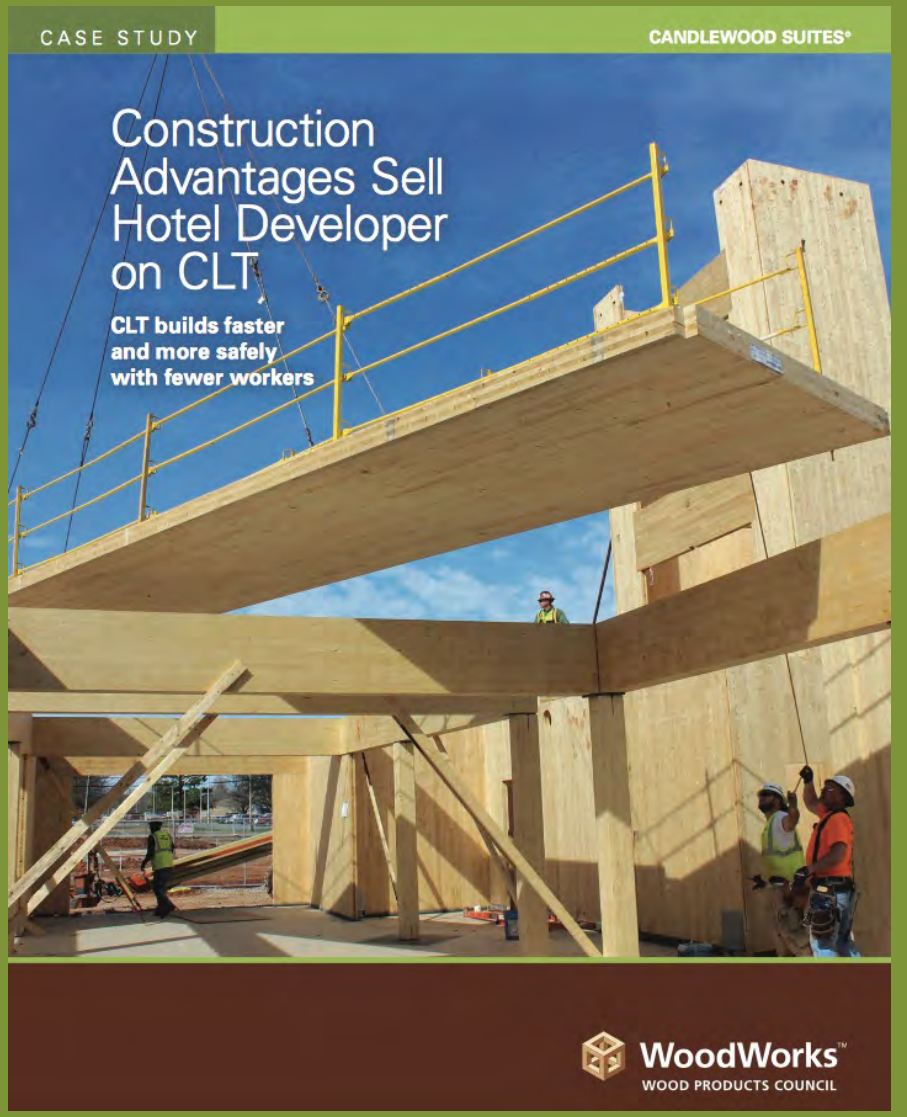
IMAGE CREDIT: LEND LEASE & SCHAEFER

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: LEND LEASE & SCHAEFER

- 62,600 SF, 4 STORY HOTEL, 92 PRIVATE ROOMS
- CLT UTILIZED FOR WALLS, ROOF PANELS, AND FLOOR PANELS
- 1,557 CLT PANELS; TYPICAL FLOOR PANEL IS 8'X50' & WEIGHS 8,000 LBS
- COMPLETED LATE 2015

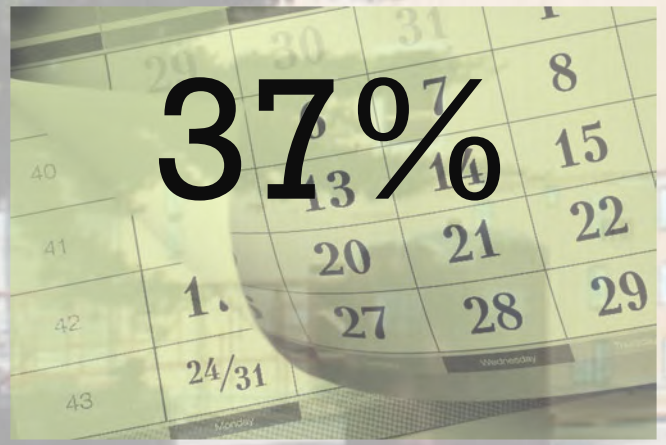


PAL Portfolio	Typical New PAL Hotel (Actual*)	Redstone Arsenal (Actual)	Difference
Gross square feet (sf)	54,891	62,688	+14%
Average # of employees	18 (peak 26)	10 (peak 11)	-43%
Structural duration (days)	123	78	-37%
Structural person hours	14,735	8,203	-44%
Structural production rate/day	460 sf	803 sf	+75%
Overall schedule	15 months	12 months	-20%

* PAL New Build Hotel Historical Average
Source: Lendlease

43%

37%



Savings on this CLT project compared to typical light gauge steel construction

Candlewood Suites at Redstone Arsenal, AL
4 Stories, 62k SF

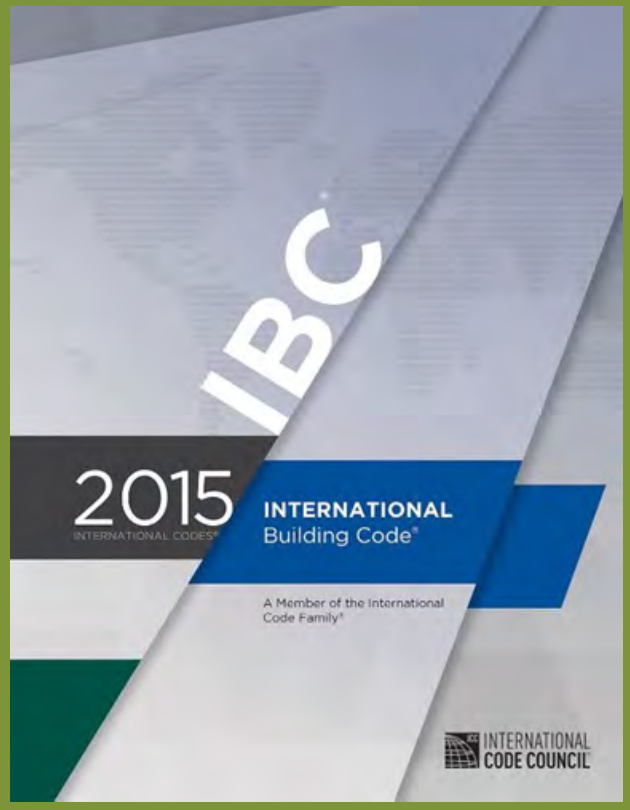
Image: Lendlease | Source: Lendlease[2]

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

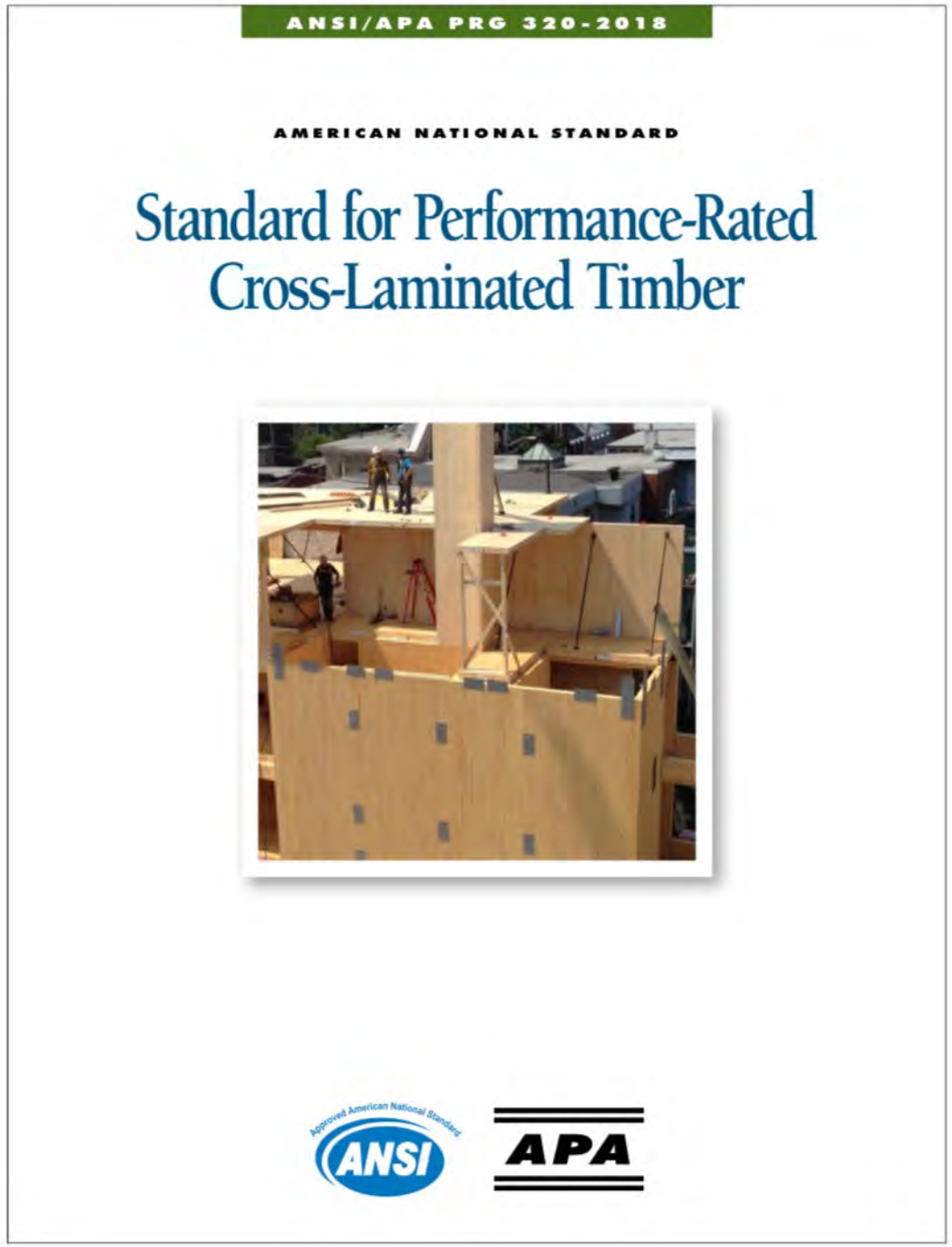
IN 2015 IBC, CLT IS NOW DEFINED IN CHAPTER 2 DEFINITIONS:

[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.



AND IS REFERENCED IN CHAPTER 23:

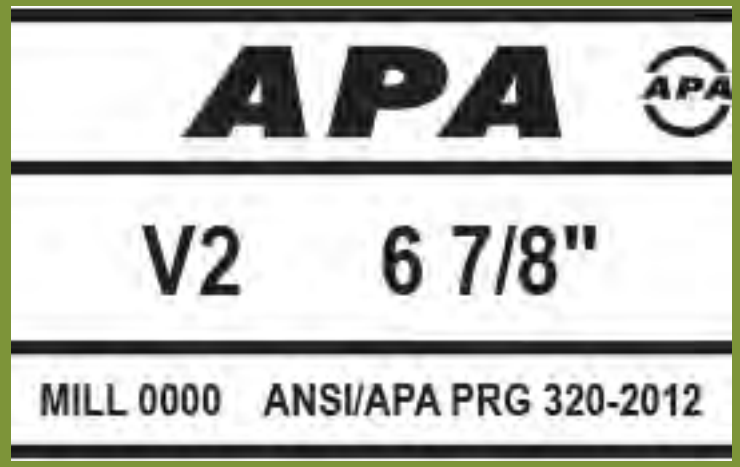
2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.



MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

CLT PRODUCT STANDARD



ANSI / APA PRG 320 STANDARD FOR PERFORMANCE RATED CROSS-LAMINATED TIMBER

Timber Concrete Composite

Timber Concrete Composites

Design Considerations:

- Unique composite connection options
- Not standardized in code – requires unique analysis and project approval

Graphic Credit: StructureCraft Builders

TIMBER COMPOSITE TECHNOLOGY

www.TiComTec.de

UBC Earth Science Building, Vancouver, Canada
ARCHITECT: Perkins + Will
ENGINEER: Equilibrium
Photo Credit: Structurlam

GRID OPTIONS AND MEMBER SIZES: WHAT'S BEEN DONE

PHOTO CREDIT: JOHN STAMETS

BULLITT CENTER

SEATTLE, WA

11’-6” BEAM SPACING
11’-6” COLUMN SPACING AT EXTERIOR
23’-0” COLUMN SPACING AT INTERIOR
2X6 NLT FLOOR DECK

PHOTO CREDIT: JOHN STAMETS

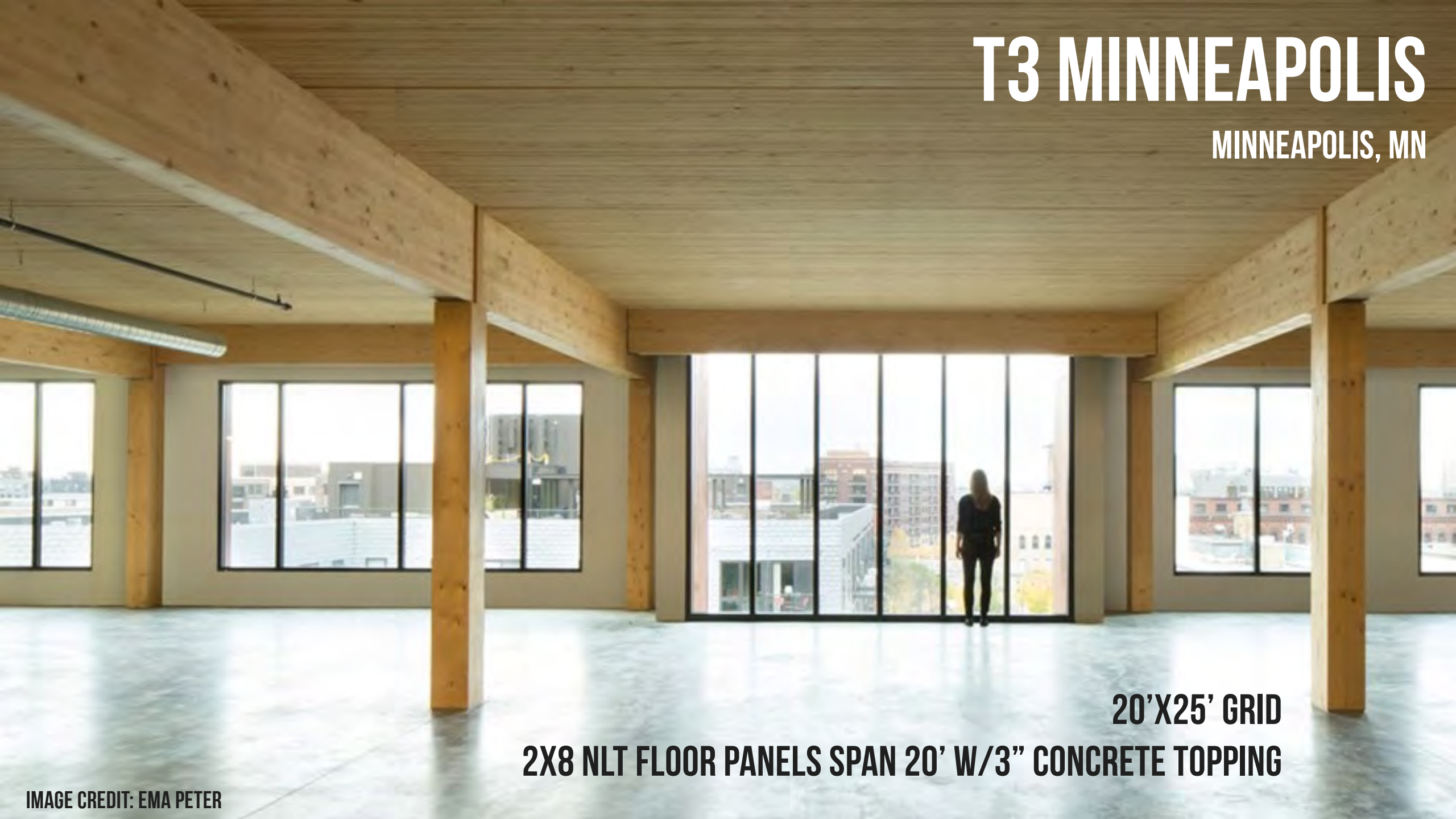
CLAY CREATIVE

PORTLAND, OR

- ~8’ FINISHED FLOOR TO BOTTOM OF BEAM
- 25’X30’ AT PERIMETER
- 30’X30’ BAYS AT CENTER
- 2X6 NLT SPANS 15’
- EXTERIOR STEEL MOMENT FRAME KEEPS CORE AREA MORE VERSATILE

T3 MINNEAPOLIS

MINNEAPOLIS, MN



20’X25’ GRID

2X8 NLT FLOOR PANELS SPAN 20’ W/3” CONCRETE TOPPING

IMAGE CREDIT: EMA PETER

FIRST TECH CREDIT UNION

HILLSBORO, OR

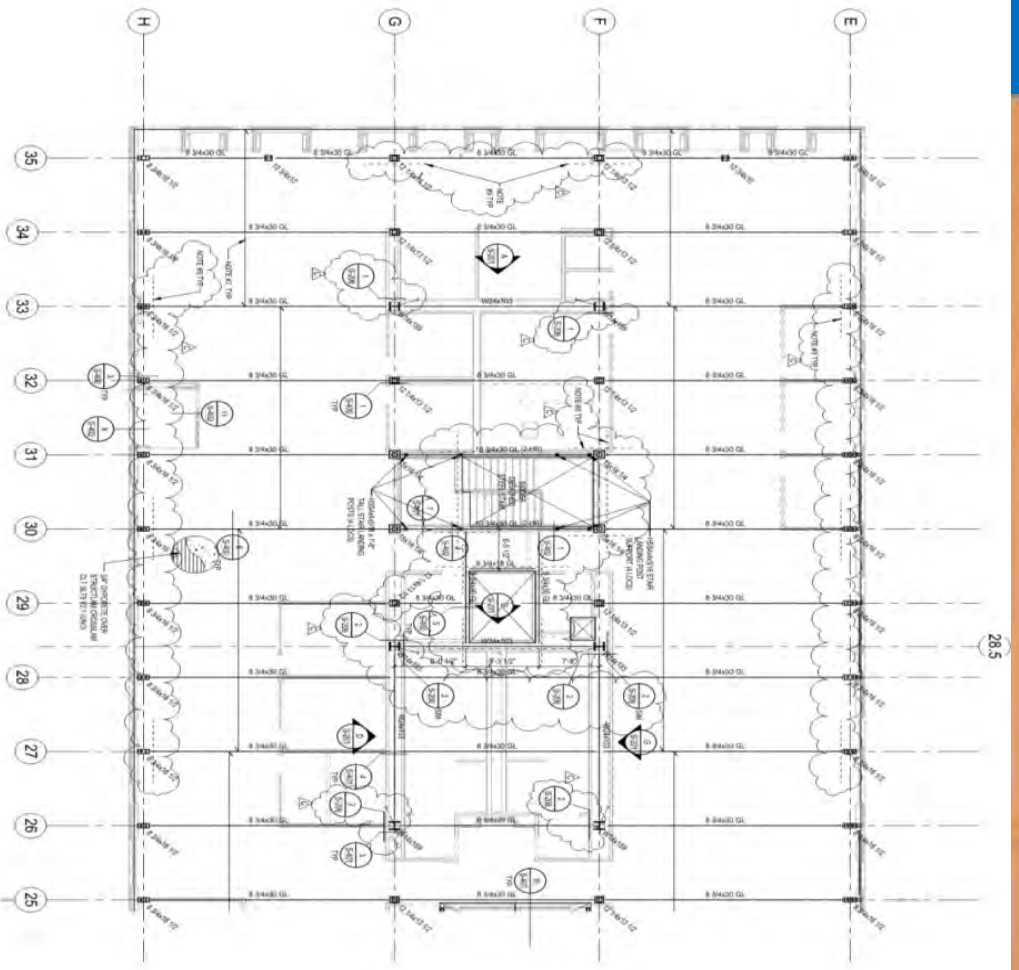


IMAGE CREDIT: SWINERTON BUILDERS

5-1/2”, 5-PLY CLT SPANS 12’

ARCHITECT: HACKER

IMAGE CREDIT: STRUCTURLAM

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

- 5-PLY CLT FLOOR PANELS, 3-PLY ROOF PANELS SPAN 16.5 FT

IMAGE CREDIT: LENDLEASE

JOHN W. OLVER DESIGN BUILDING

UMASS, AMHERST, MA

- 5-PLY CLT FLOOR PANELS, COMPOSITE WITH HBV SYSTEM
- GRIDS 20’X24’ TO 26’

PHOTO CREDIT: ALEX SCHREYER

BROCK COMMONS

VANCOUVER, BC

5 PLY CLT PANELS, 2-WAY SPAN

~9’X13’ GRID OF COLUMNS

IMAGES: ACTON OSTRY ARCHITECTS


MASS TIMBER APPEAL

MARKET DRIVERS FOR MASS TIMBER

PRIMARY DRIVERS

- Construction Efficiency & Speed
- Construction site constraints – Urban Infill
- Innovation/Aesthetic

SECONDARY DRIVERS

- Carbon Reductions
- Structural Performance – lightweight

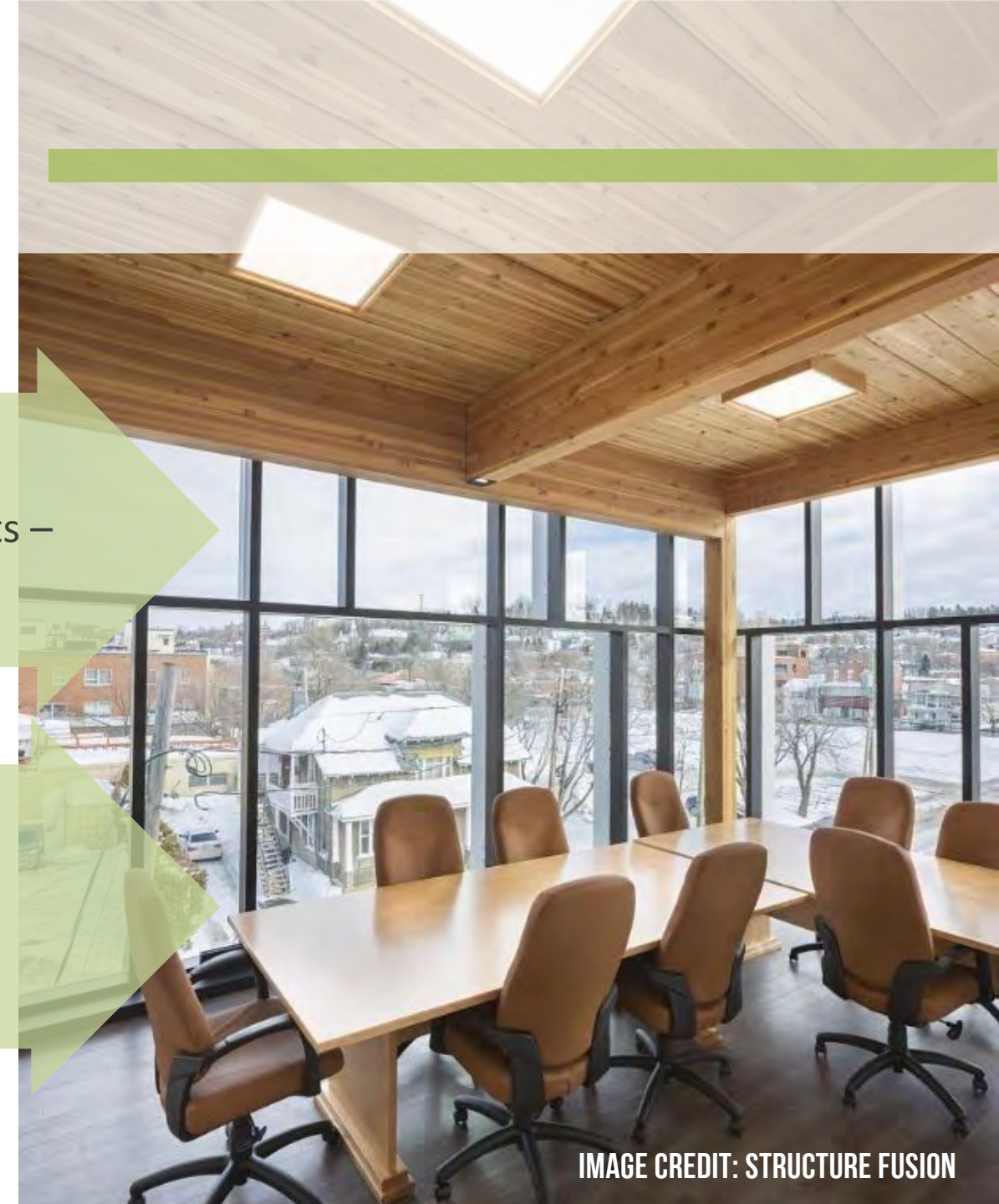


IMAGE CREDIT: STRUCTURE FUSION

MASS TIMBER APPEAL

WHAT IS THE ULTIMATE APPEAL AND DRIVER FOR ANY BUILDING AND MATERIAL TYPE?

MASS TIMBER APPEAL

REDUCED CONSTRUCTION TIME

MURRAY GROVE,
LONDON UK
8 STORIES OF CLT OVER 1 STORY CONCRETE PODIUM

8 STORIES BUILT IN 27 DAYS (~1/2 THE TIME OF PRECAST CONCRETE)

SOURCE: ARCHITECT MAGAZINE[3]

LESS TIME ON SITE = LESS $$

SOURCE: CITY CONSTRUCTION[4]

FRANKLIN ELEMENTARY SCHOOL, FRANKLIN, WV

45,200 FT2 2 STORY ELEMENTARY SCHOOL

2.5 MONTHS TO ERECT CLT

MASS TIMBER APPEAL

REDUCED CONSTRUCTION TIME

1 Floor = 3 Days

17 Floors Erected in 9.5 Weeks

Brock Commons, Vancouver, BC
Source: naturally:wood[5]

MASS TIMBER APPEAL

ALTERNATE TO CONCRETE & MASONRY

PHOTO CREDIT: CHARLES JUDD

MASS TIMBER APPEAL

MATERIAL MASS

MASS TIMBER APPEAL

MATERIAL MASS

75% LIGHTER WEIGHT THAN CONCRETE

SOURCE: STRUCTURLAM[7]

MASS TIMBER APPEAL

MATERIAL MASS

FORTE', VICTORIA HARBOR, MELBOURNE, AUSTRALIA
ARCHITECT: LENDLEASE | SOURCE: LENDLEASE[8]

COMPLETED IN 2012
10 STORIES
~ 105 FT. TALL, > 18.6 K SQFT.
3 YEAR INVESTMENT IN R&D
POOR SOILS REQUIRED A MUCH LIGHTER BUILDING

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]

MASS TIMBER APPEAL

REDUCED EMBODIED CARBON

BROCK COMMONS, VANCOUVER, BC

PHOTO CREDIT: ACTON OSTRY ARCHITECTS

MASS TIMBER APPEAL

MINIMAL WASTE

MASS TIMBER APPEAL

PREFABRICATED AND PRECISE

MASS TIMBER ELEMENTS FABRICATED TO TIGHT TOLERANCES

COMPUTER NUMERICALLY CONTROLLED (CNC) CONNECTIONS

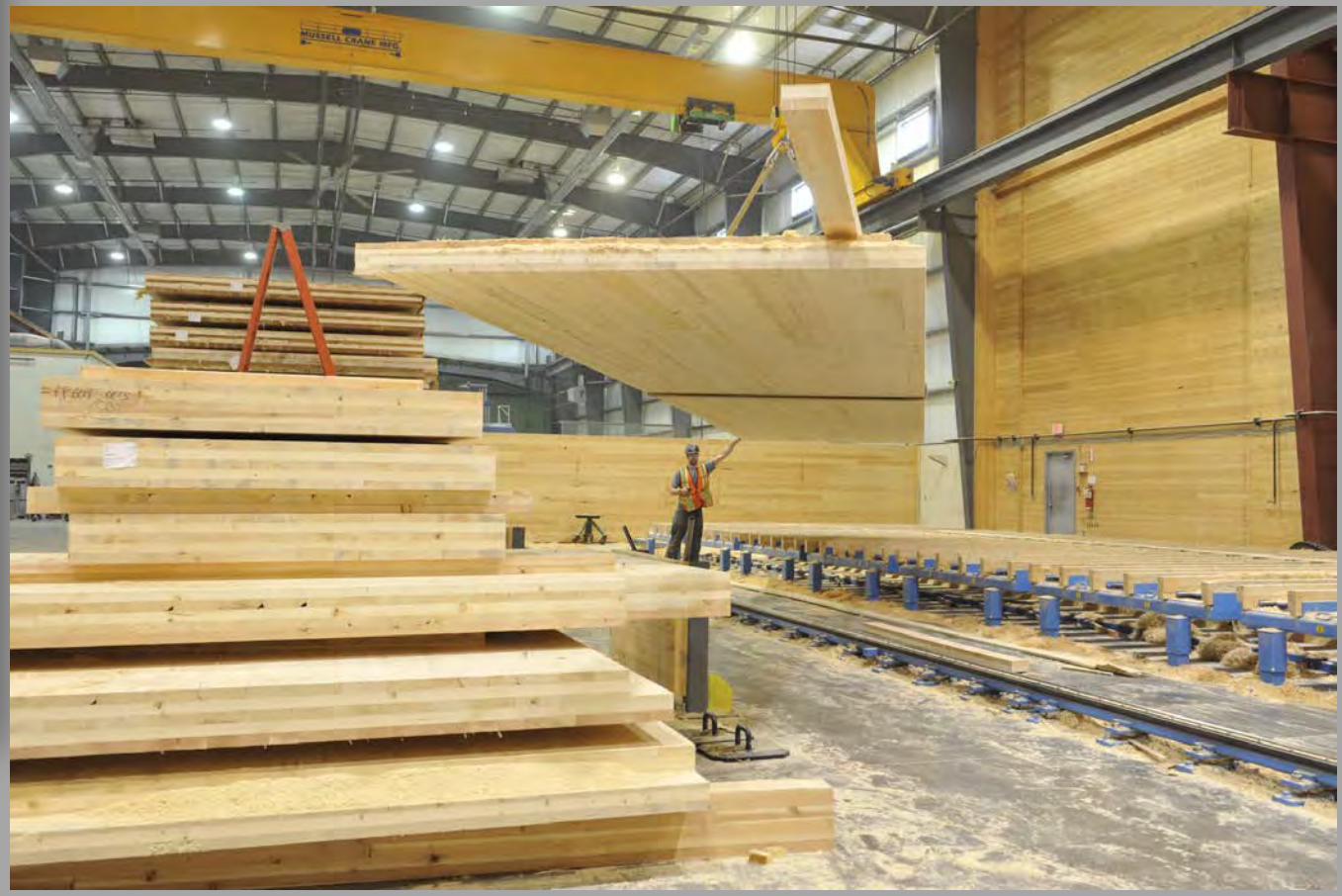


PHOTO CREDIT: NATURALLY:WOOD

MASS TIMBER APPEAL

ENERGY EFFICIENT

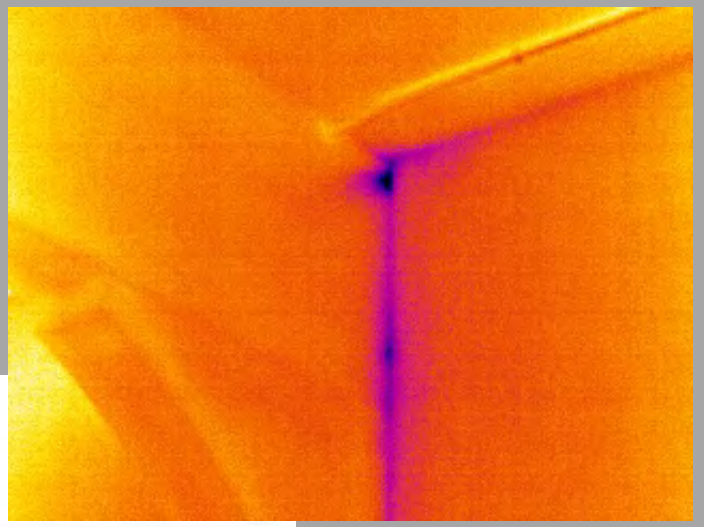


Table 2

Thermal resistance of typical softwood at various thicknesses and 12% moisture content

Thickness	1 in. (25 mm)	4 in. (100 mm)	6 in. (150 mm)	8 in. (200 mm)
R-value ($h \cdot ft.^2 \cdot °F \cdot Btu^{-1}$)	1.25	5.00	7.50	10.00
RSI ($m^2 \cdot K \cdot W^{-1}$)	0.22	0.88	1.30	1.80

CLT HAS AN R-VALUE OF APPROXIMATELY 1.25 PER INCH OF THICKNESS.

SOURCE: US CLT HANDBOOK[10]

MASS TIMBER APPEAL

STRUCTURAL FLEXIBILITY

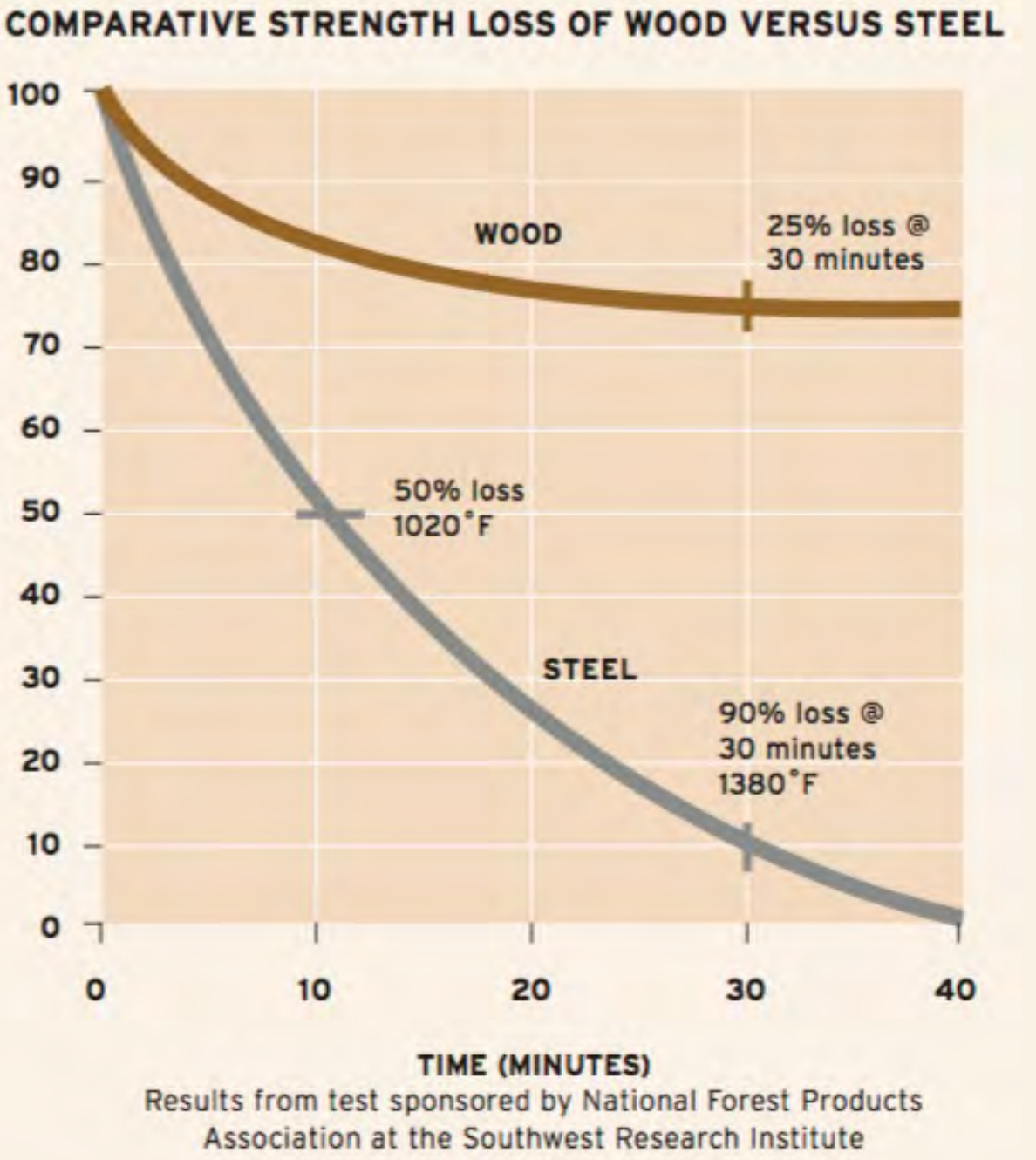
PHOTO CREDIT: APA

FIRE RESISTANCE

PHOTO CREDIT: FPINNOVATIONS

MASS TIMBER DESIGN

FIRE RESISTANCE

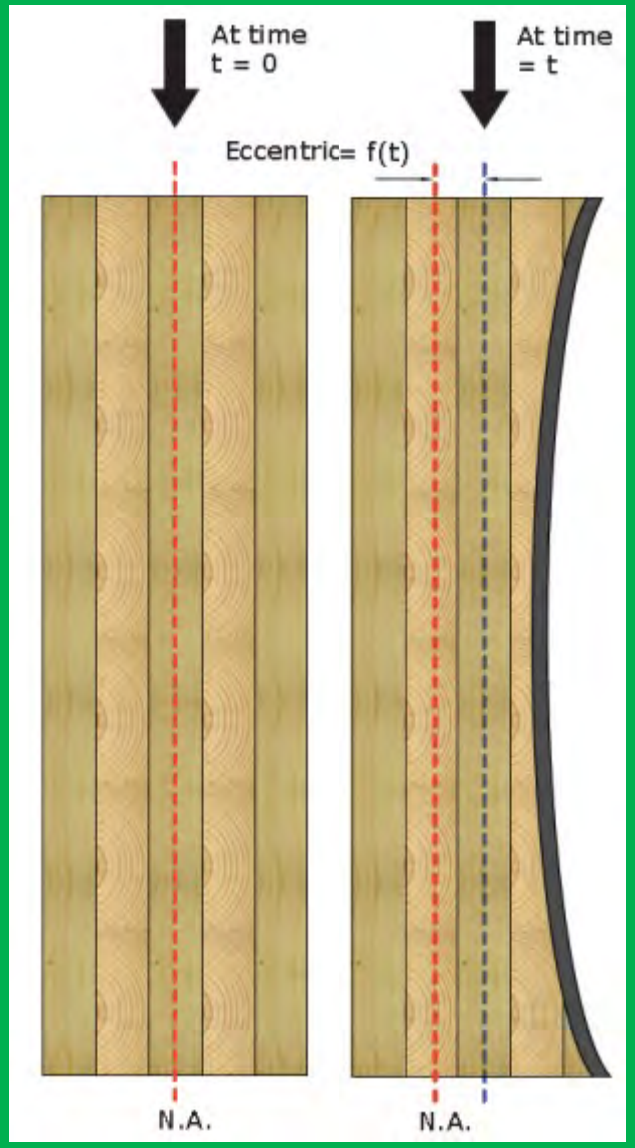


Results from test sponsored by National Forest Products Association at the Southwest Research Institute

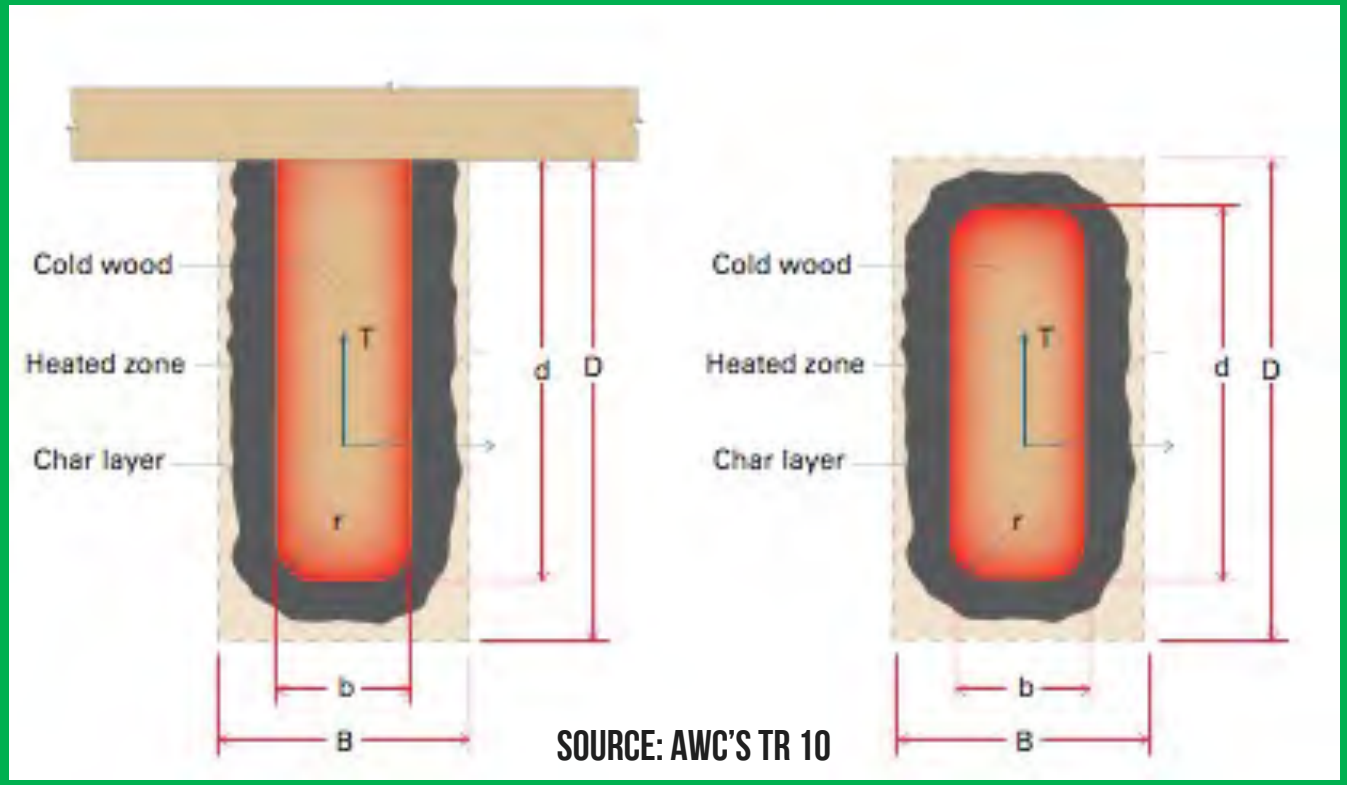
SOURCE: AITC

MASS TIMBER DESIGN

FIRE RESISTANCE



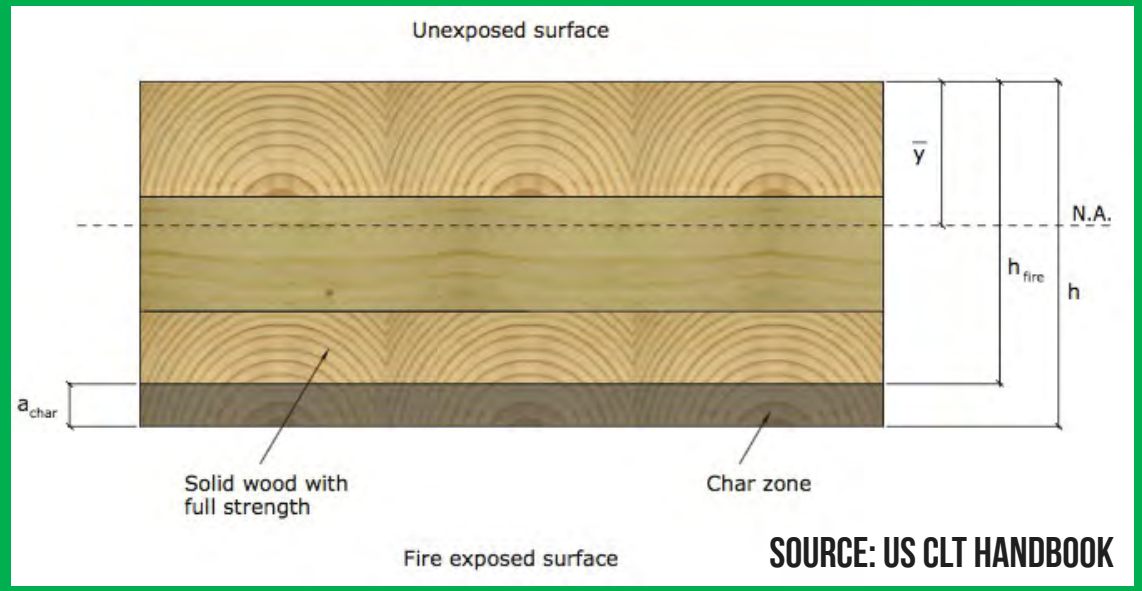
SIMILAR TO HEAVY TIMBER, MASS TIMBER PRODUCTS HAVE INHERENT FIRE RESISTANCE PROPERTIES



SOURCE: AWC'S TR 10

MASS TIMBER DESIGN

FIRE RESISTANCE



SOURCE: US CLT HANDBOOK

Construction type selection dictates prescriptive fire resistance requirements:

- Type IV Construction (minimum sizes)
- **Other than type IV**: Demonstrated fire resistance:
  - IBC 703.3 allows several options, including:
    - ASTM E119 assembly test
    - Calculations per IBC 722 → NDS Chapter 16

MASS TIMBER DESIGN

FIRE RESISTANCE

Mass timber in **other than** Type IV Construction:

- IBC 703.3 allows several options, including:
  - ASTM E119 assembly test (none currently exist for NLT)
  - Calculations per IBC 722 → NDS Chapter 16

703.3 Methods for determining fire resistance. The application of any of the methods listed in this section shall be based on the fire exposure and acceptance criteria specified in ASTM E119 or UL 263. The required *fire resistance* of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

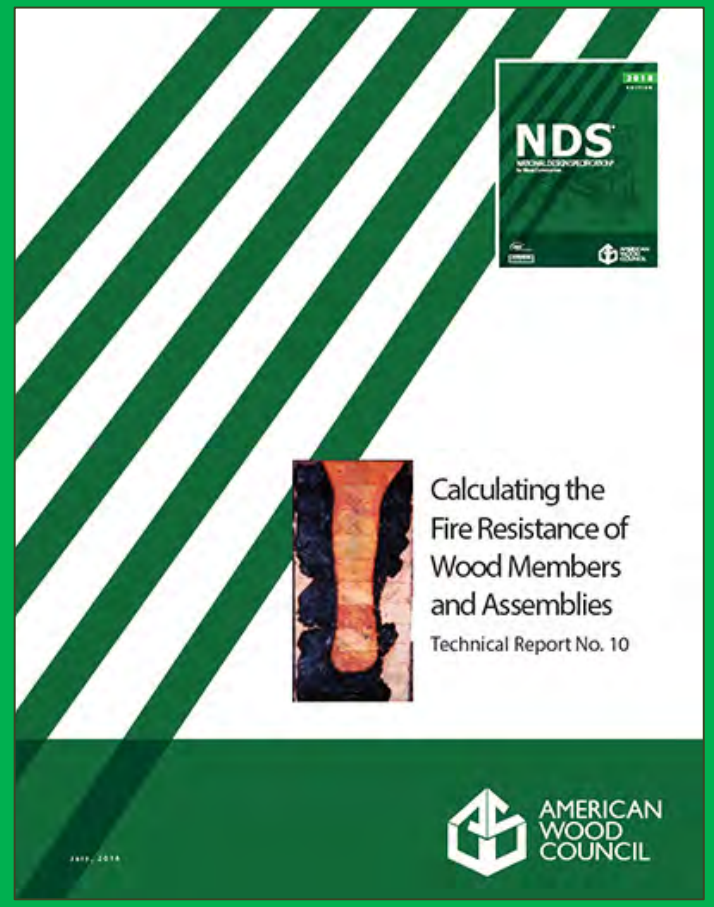
3. Calculations in accordance with Section 722.

722.1 General. The provisions of this section contain procedures by which the *fire resistance* of specific materials or combinations of materials is established by calculations. These procedures apply only to the information contained in this section and shall not be otherwise used. The calculated *fire resistance* of concrete, concrete masonry and clay masonry assemblies shall be permitted in accordance with ACI 216.1/TMS 0216. The calculated *fire resistance* of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 29. The calculated *fire resistance* of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA *National Design Specification for Wood Construction (NDS)*.

MASS TIMBER DESIGN

FIRE RESISTANCE

FOR EXPOSED WOOD MEMBERS: IBC 722.1 REFERENCES AWC'S NDS CHAPTER 16 (AWC'S TR 10 IS A DESIGN AID TO NDS CHAPTER 16)



MASS TIMBER DESIGN

FIRE RESISTANCE

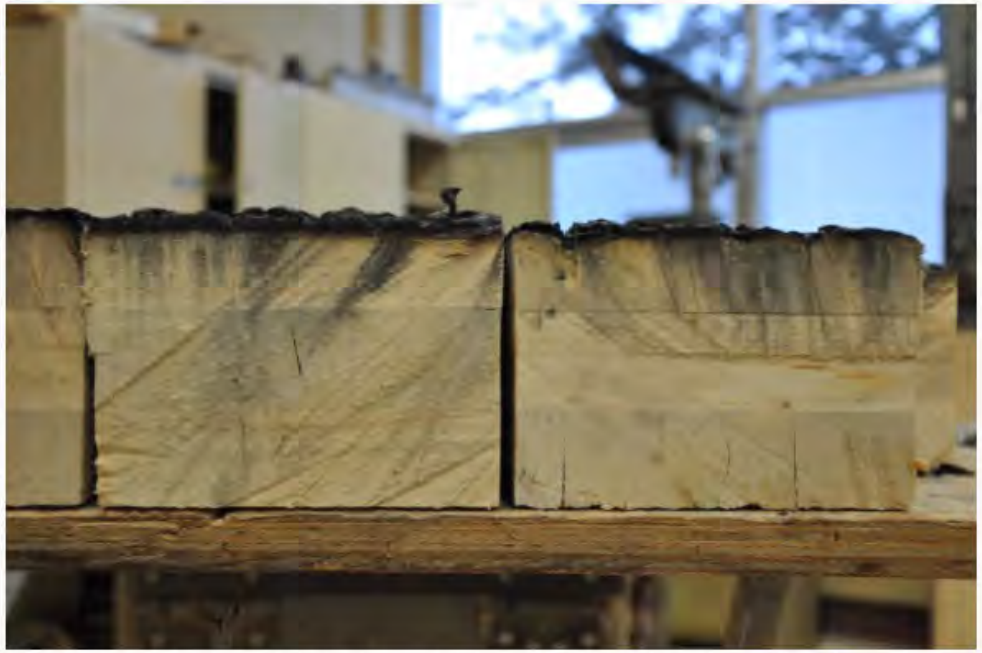
2015 NDS CHAPTER 16 INCLUDES CALCULATION OF FIRE RESISTANCE OF NLT, CLT, GLULAM, SOLID SAWN AND SCL WOOD PRODUCTS

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

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

SOURCE: AWC'S NDS

How do you demonstrate the fire resistance of exposed wood members using char methods in lieu of gypsum?



Per IBC Sections 703.2 and 703.3, there are multiple ways to demonstrate fire-resistance ratings of structural members and assemblies. One method noted in Section 703.3 is to calculate the rating in accordance with IBC Section 722.

For calculated fire resistance of exposed wood members and decking, IBC Section 722.1 references Chapter 16 of the American Wood Council's National Design Specification® (NDS®) for Wood Construction. This chapter gives a nominal char rate of 1.5 inches of wood thickness per hour of fire resistance. Using the calculations and information contained in NDS Chapter 16, a fire rating of up to 2 hours can be calculated.

The 2015 NDS allows calculated fire resistance of a number of wood products, including solid sawn lumber (this includes nail laminated timber), glue-laminated timber (glulam), laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL), and cross laminated timber (CLT). For structural members using this method of exposed fire-resistance calculations, the effective char rate, which is slightly higher than the nominal char rate and includes a heat-affected zone, is used. For non- e is used. Additional design considerations for certain structural m presented in NDS Chapter 16. Adjustment factors applied to the allowable design properties of exposed structural members rated for fire resistance are also presented in this chapter.

View All Expert Tips

Project Assistance

Our technical experts offer free project support from design through construction, on issues ranging from allowable heights and areas to structural design, lateral systems and fire- or acoustical-rated assemblies.

Get Assistance >

Ask an Expert

Q: Can exposed wood framing be used in buildings such as aquatic centers and pools? Are there durability concerns?

A: The main durability consideration associated with the use of wood in environments such as pools and aquatic centers is high moisture content in the wood. Buildings such as this may have high relative humidity and, as such, it is important to understand how relative humidity of a condition space affects exposed wood within that space

- Learn More
Have a question? Email Us >

Feature Project

PROJECT: Biomass Heating Plant, Hotchkiss School

MASS TIMBER DESIGN

FIRE RESISTANCE

AWC'S TECHNICAL REPORT 10 INCLUDES DISCUSSION OF FIRE TESTS AND DESIGN EXAMPLES

4.5 Exposed CLT Floor Example (*Allowable Stress Design*)

Simply-supported cross-laminated timber (CLT) floor spanning L=18 ft in the strong-axis direction. The design loads are q_{live} = 80 psf and q_{dead} = 30 psf including estimated self-weight of the CLT panel. Floor decking, nailed to the unexposed face of CLT panel, is spaced to restrict hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a one-hour fire resistance time.

For the structural design of the CLT panel, calculate the maximum induced moment. Calculate panel load (per foot of width):

$$W_{load} = (q_{dead} + q_{live}) = (30 \text{ psf} + 80 \text{ psf})(1\text{ft width}) = 110 \text{ plf/ft of width}$$

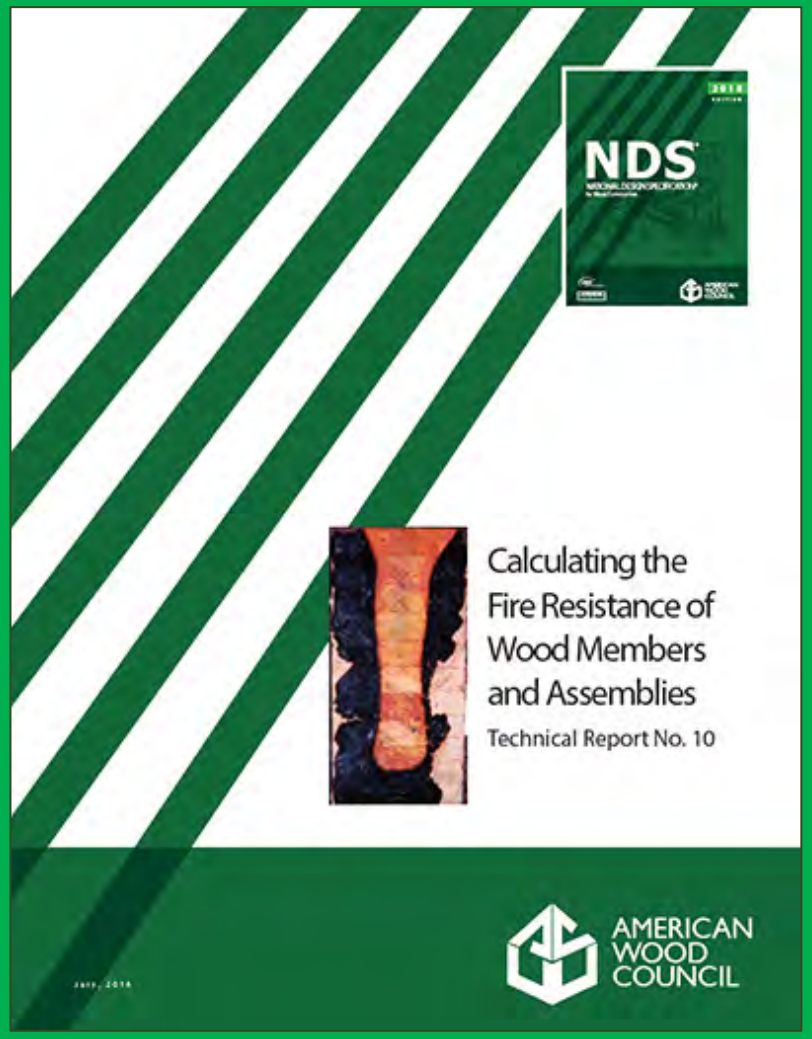
Calculate maximum induced moment (per foot of width):

$$M_{max} = w_{load} L^2 / 8 = (110)(18^2)/8 = 4{,}455 \text{ ft-lb/ft of width}$$

From PRG 320, select a 5-ply CLT floor panel made from $1^3/_8$ in x $3^1/_2$ inch lumber boards (CLT thickness of $6^7/_8$ inches). For CLT grade V2, tabulated properties are:

Bending moment, $F_b S_{eff,0}$ = 4,675 ft-lb/ft of width (PRG 320 Annex A, Table A2)

SOURCE: AWC'S TR 10



FREE DOWNLOAD AT AWC.ORG

MASS TIMBER DESIGN

FIRE RESISTANCE

MANY SUCCESSFUL CLT FIRE TESTS HAVE BEEN CONDUCTED, BOTH WITH AND WITHOUT GYPSUM BOARD PROTECTION

NGC Testing Services

Fire Testing Laboratory

ACCREDITED Testing Laboratory TL-216

TEST REPORT

Page 1 of 53

for

American Wood Council

222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

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

Test Report No: WP-1950

Assignment No: K-1089

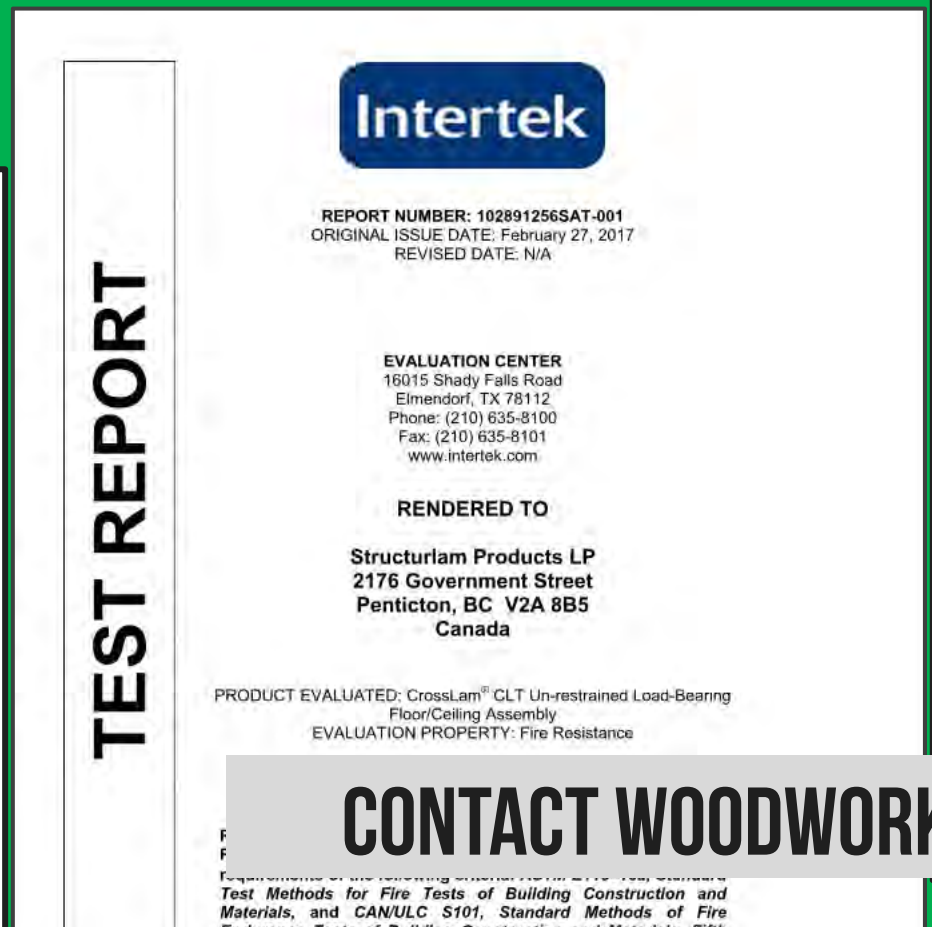
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)

Test Date: October 4, 2012

Report Date: October 15, 2012

Prepared by: Michael J. Rizzo
Test Engineer

Reviewed by: Robert J. Menchetti



TEST REPORT

Intertek

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

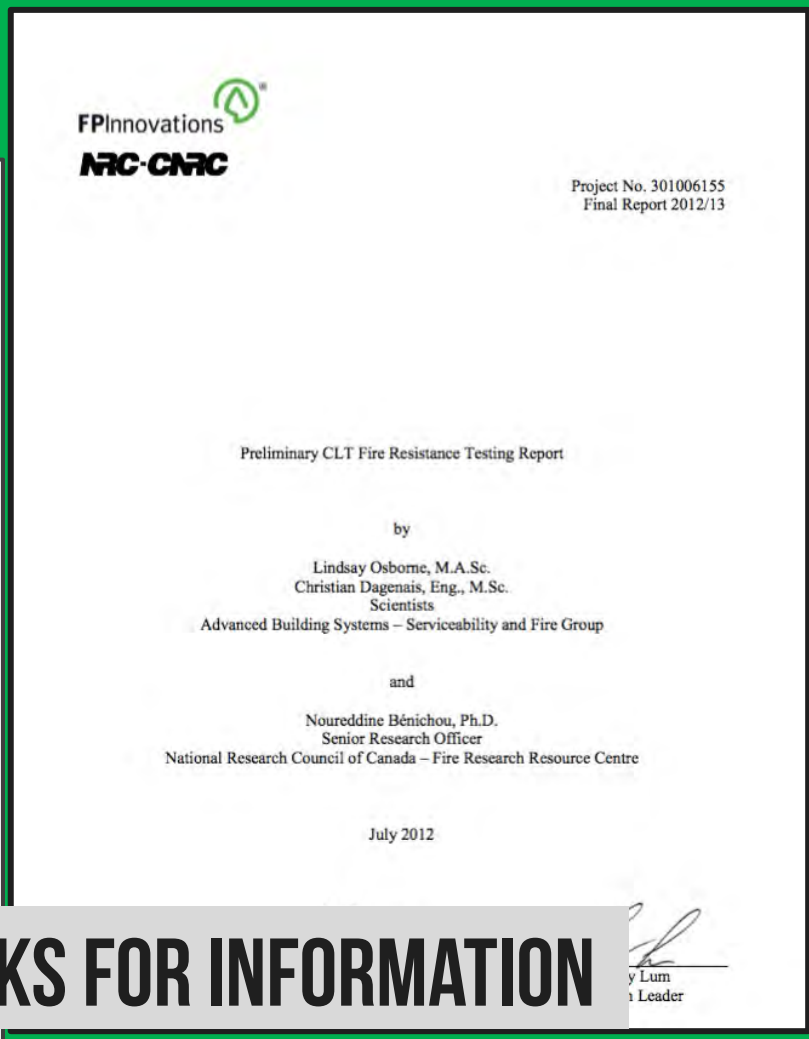
EVALUATION CENTER
16015 Shady Falls Road
Elmendorf, TX 78112
Phone: (210) 635-8100
Fax: (210) 635-8101
www.intertek.com

RENDERED TO

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

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

Test Methods for Fire Tests of Building Construction and Materials, and *CAN/ULC S101, Standard Methods of Fire*



FPInnovations
NRC·CNRC

Project No. 301006155
Final Report 2012/13

Preliminary CLT Fire Resistance Testing Report

by

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

and

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

July 2012

y Lum
n Leader

CONTACT WOODWORKS FOR INFORMATION

ONE NORTH

PORTLAND, OR

EXPOSED STEEL CONNECTIONS
GLULAM GIRDER & PURLIN FRAME

PHOTO CREDIT: JOSH PARTEE

U OF ARKANSAS STUDENT DORMS

FAYETVILLE, AR

IMAGE CREDIT: MODUS STUDIO

U OF ARKANSAS STUDENT DO

FAY

(2) – 5 STORY BUILDINGS
TOTAL OVER 200,000 SF
368 RESIDENTIAL ROOMS

IMAGE CREDIT: MODUS STUDIO

IMAGE CREDIT: MODUS STUDIO/LEERS WEINZAPFEL ARCHITECTS

MCDONALD'S

CHICAGO, IL

PHOTO CREDIT: WOODWORKING NETWORK AND ROSS BARNEY ARCHITECTS

MCDONALD'S

CHICAGO, IL

19,000 SF

CLT, GLULAM AND STEEL STRUCTURE

PHOTO CREDIT: WOODWORKING NETWORK AND ROSS BARNEY ARCHITECTS

BULLITT CENTER

SEATTLE, WA

PHOTO CREDIT: BULLITT CENTER

BULLITT CENTER

SEATTLE, WA

BUILDING INFO:

OFFICE BUILDING

4 STORIES MASS TIMBER OVER 2 STORIES CONCRETE

52,000 SF

NET ZERO

LIVING BUILDING CHALLENGE CERTIFIED

TYPE IV CONSTRUCTION

250 YR DESIGN LIFE

COMPLETED 2013

250 YEAR STRUCTURE

HEAVY TIMBER, CONCRETE & STEEL

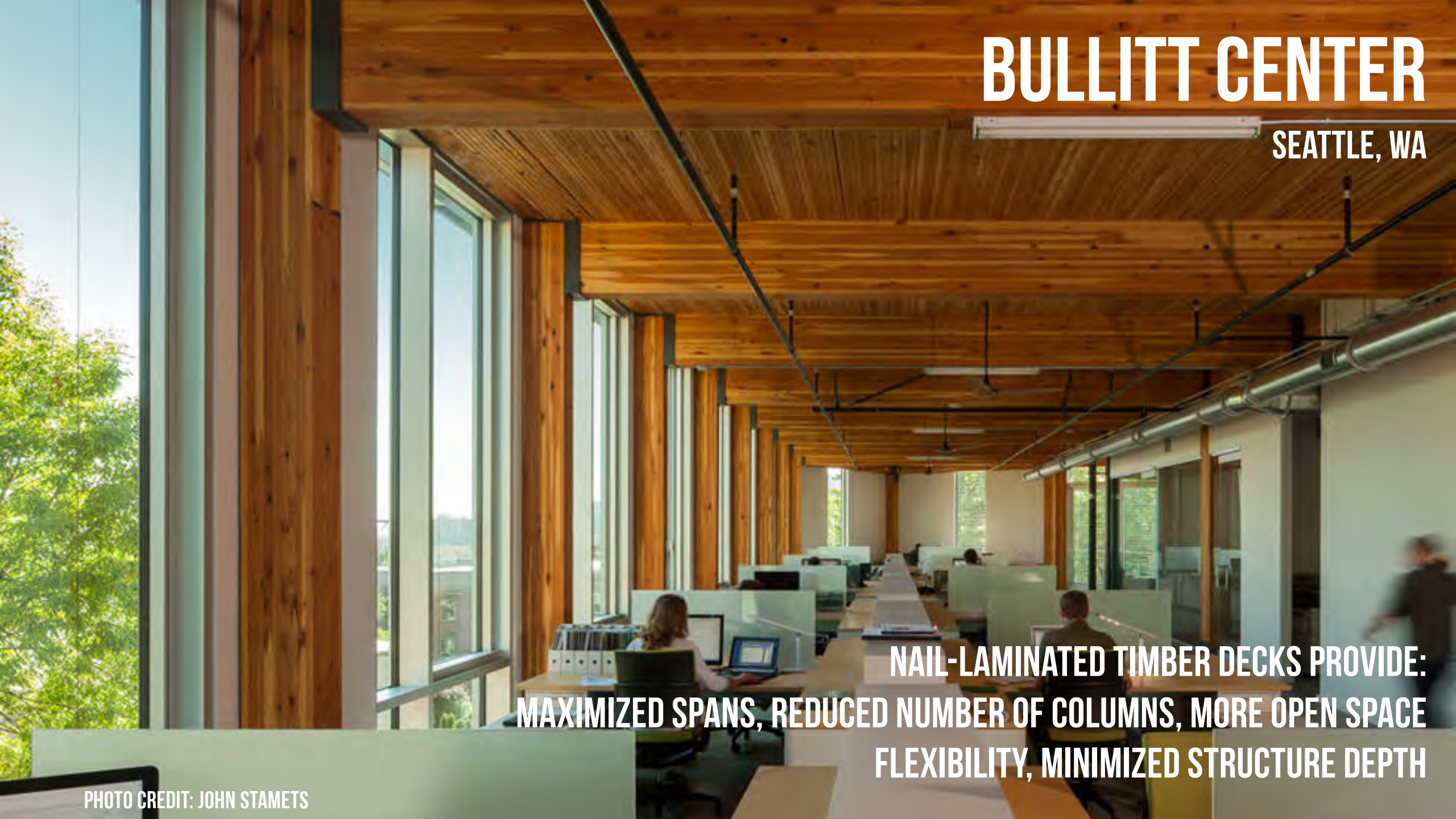
PHOTO CREDIT: MILLER HULL PARTNERSHIP

BULLITT CENTER

SEATTLE, WA

2X6 NLT FLOOR DECK
2X4 NLT ROOF DECK
FLOOR ASSEMBLY TOP TO BOTTOM:
3” CONCRETE TOPPING, ACOUSTICAL MAT, WSP, 2X6 NLT

PHOTO CREDIT: JOHN STAMETS



BULLITT CENTER

SEATTLE, WA

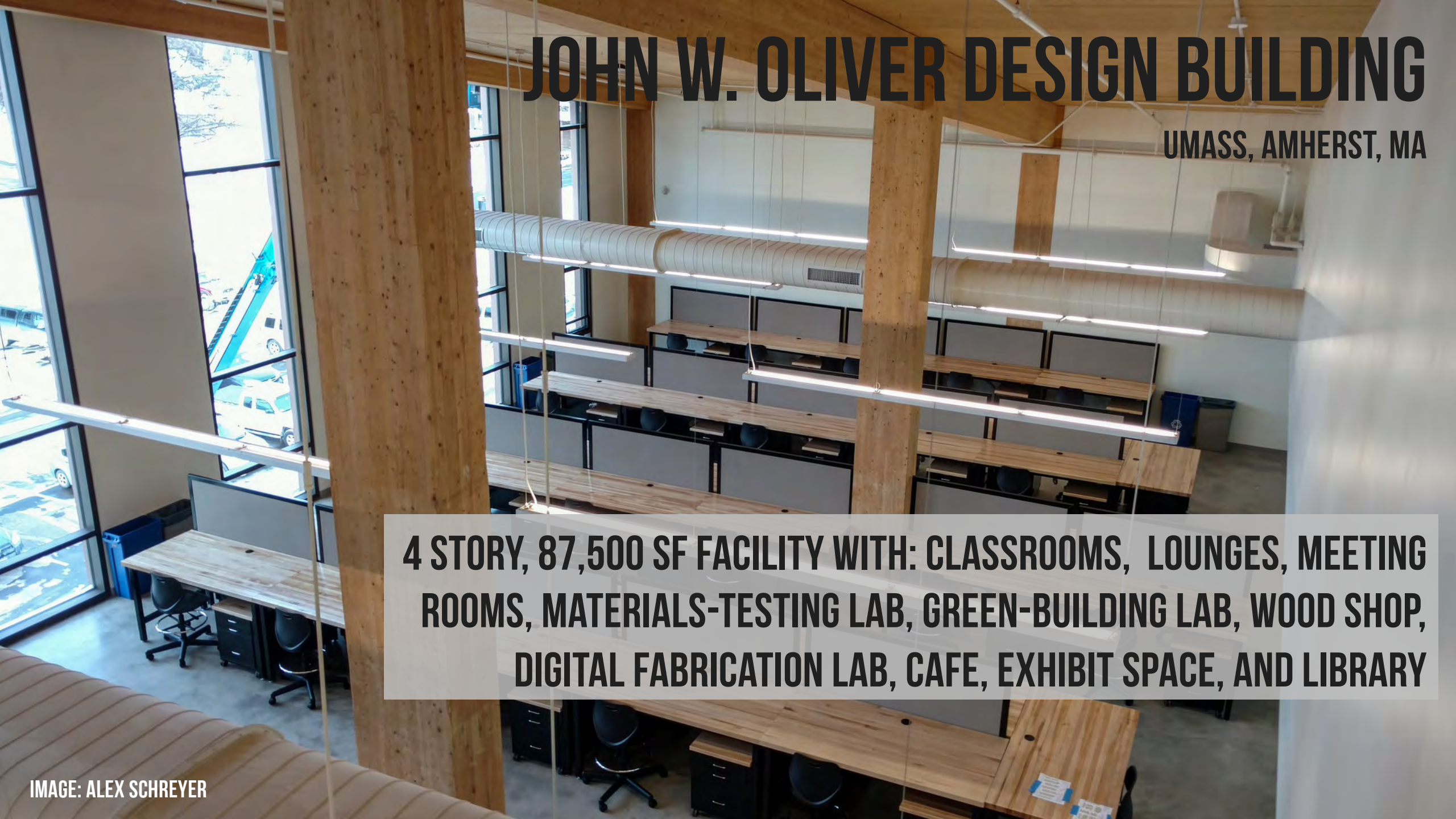
NAIL-LAMINATED TIMBER DECKS PROVIDE:
MAXIMIZED SPANS, REDUCED NUMBER OF COLUMNS, MORE OPEN SPACE
FLEXIBILITY, MINIMIZED STRUCTURE DEPTH

PHOTO CREDIT: JOHN STAMETS

UMASS DESIGN BUILDING

AMHERST, MA

IMAGE CREDIT: ALEX SCHREYER



JOHN W. OLIVER DESIGN BUILDING

UMASS, AMHERST, MA

4 STORY, 87,500 SF FACILITY WITH: CLASSROOMS, LOUNGES, MEETING ROOMS, MATERIALS-TESTING LAB, GREEN-BUILDING LAB, WOOD SHOP, DIGITAL FABRICATION LAB, CAFE, EXHIBIT SPACE, AND LIBRARY

IMAGE: ALEX SCHREYER

UMASS DESIGN BUILDING

AMHERST, MA

COMPLETED SPRING 2017

PHOTO CREDIT: ALEX SCHREYER

UMASS DESIGN BUILDING

AMHERST, MA

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER CONSTRUCTION

THE FUTURE'S LOOKING UP

PHOTO CREDIT: ALEX SCHREYER

TALL WOOD IN THE U.S.

- Current Prescriptive Code Limit - 6 stories or 85 feet
- Over 6 Stories - Alternate Means and Methods Request (AMMR) through performance based design
- Based on the 1910 Heights and Areas Act

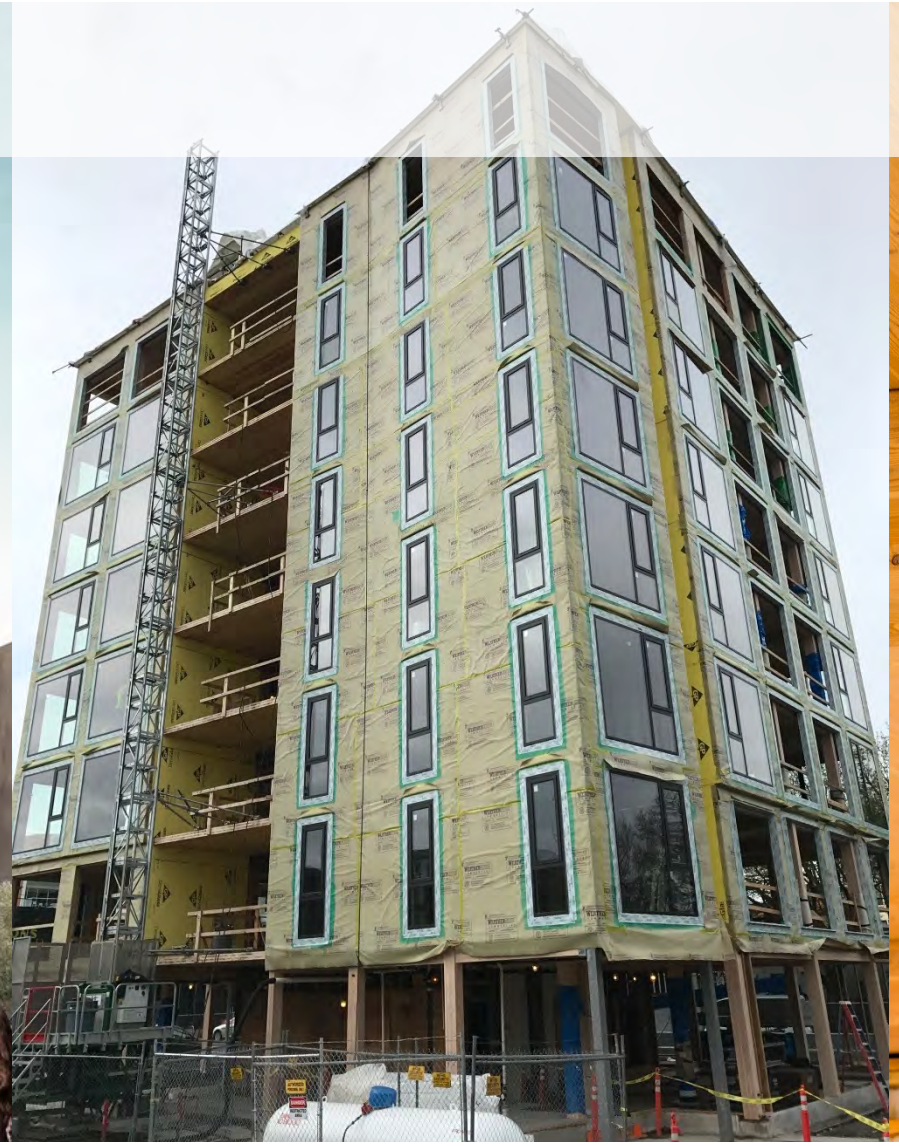
MODERN TALL WOOD
7 STORIES IN 2016

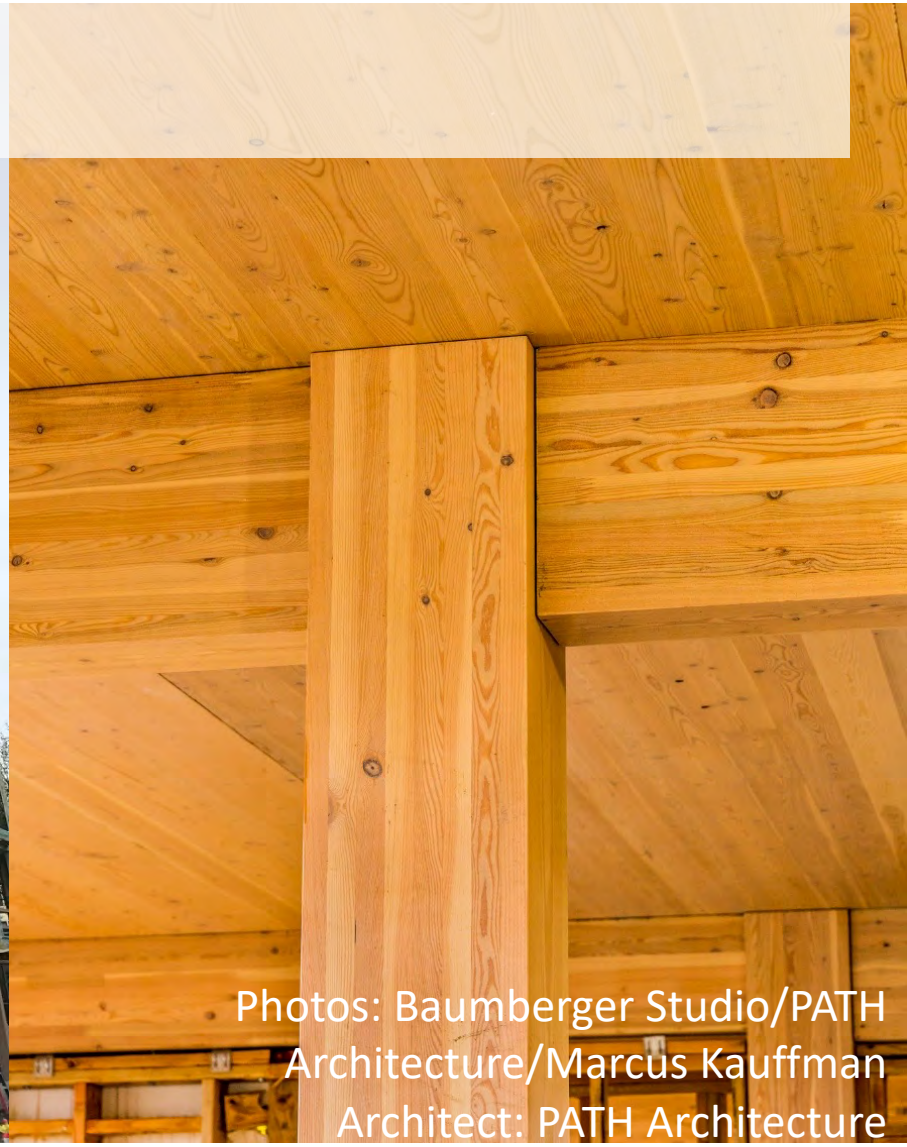
Image: Michael Green Architects/Hines Group
Architect: DLR Group

T3 Office Building – 230,000 sf – Minneapolis, MN

MODERN TALL WOOD

8 STORIES IN 2017





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

Carbon12 – 32,000 sf – Portland, OR

New Building Types

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

TYPE IV-A

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

TYPE IV-B

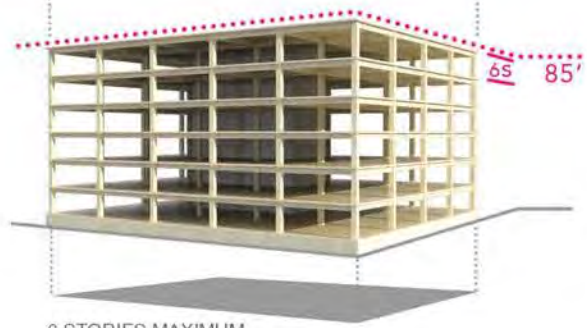
9 STORIES
BUILDING HEIGHT 85'
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

TYPE IV-C

IBC 2021

324,000 SF
ALLOWABLE BUILDING AREA

54,000 SF
AVERAGE AREA PER STORY



6 STORIES MAXIMUM
85'-0" MAXIMUM BUILDING HEIGHT
324,00 SF MAXIMUM AREA

TYPE IV- HT

IBC 2015

BUSINESS OCCUPANCY [GROUP B]

*BUILDING FLOOR-TO-FLOOR HEIGHTS ARE SHOWN AT 12'-0" FOR ALL EXAMPLES FOR CLARITY IN COMPARISON BETWEEN 2015 TO 2021 IBC CODES.

New Building Types

Tall Mass Timber Type of Construction Comparison			
Feature	**Type IVA**	**Type IVB**	**Type IVC**
Description of new Type IV Types	100 % Noncombustible (NC) protection on all surfaces of Mass Timber (MT).	NC protection on all surfaces of mass timber (MT) except for limited exposed areas.	Exposed mass timber (MT), except shafts, concealed spaces, and outside of exterior walls.
Permitted Materials			
Structural Building Elements	MT or NC	MT or NC	MT or NC
Nonloadbearing Ext Walls	MT or NC	MT or NC	MT or NC
Nonloadbearing Int Walls	MT or NC	MT or NC	MT or NC
Exit and Hoistway Enclosures			
Highrise* to 12 stories or 180 feet:	NC or MT protected with 2 (or 3 when 3 hr FRR) layers of 5/8" Type X.	NC or MT protected with 2 layers of 5/8" Type X gypsum or equiv each side of enclosure.	NC or MT protected with one layer of 5/8" Type X gypsum each side of shaft or enclosure.
Above 12 stories or 180 ft: *see IBC definition of highrise	NC	Not Permitted	Not Permitted

Source: AWC https://www.awc.org/tallmasstimber

Tall Mass Timber Type of Construction Comparison

Feature	Type IVA	Type IVB	Type IVC
Noncombustible Protection			
Interior Protection Req'd 3 hr FRR Req'd for 2 hr or less FRR	3 layers of 5/8" Type X gypsum 2 layers of 5/8" Type X gypsum	Same as Type IV-A for protected MT. Limited exposed MT elements must have same FRR, but may be calculated.	All MT is allowed to be exposed except for 1 layer of 5/8" Type X on outside surfaces of exterior walls, inside and outside of shafts and exit enclosures, and in concealed spaces.
Exterior Protection	Minimum of 1 layer of 5/8" Type X gypsum	Minimum of 1 layer of 5/8" Type X gypsum	Minimum of 1 layer of 5/8" Type X gypsum
Floor Surface	1 inch of NC protection	1 inch of NC protection	No protection required
Roof	No NC protection on exterior roof surface, 2 layers of 5/8" Type X gypsum on inside of roof deck.	No NC protection on exterior roof surface, 2 layers of 5/8" Type X gypsum on inside of roof deck.	No protection on roof surface or inside of roof deck is required (unless concealed space).
Concealed Spaces	No exposed MT in concealed spaces. NC protection in concealed spaces.	No exposed MT in concealed spaces. NC protection in concealed spaces.	No exposed MT in concealed spaces. One layer of 5/8" Type X gypsum NC protection in concealed spaces.
Table 601 Fire Resistance Rating (FRR)			
Primary Frame or Bearing Wall: Floors: Roof:	 3 hr FRR (2 hr at roof) 2 hr FRR 1.5 hr FRR	 2 hr FRR (1 hr at roof) 2 hr FRR 1 hr FRR	 2 hr FRR (1 hr at roof) 2 hr FRR 1 hr FRR
Fire Resistance Rating Trade-off	No FRR reduction for sprinkler in 403.2.1	No FRR reduction for sprinkler in 403.2.1	No FRR reduction for sprinkler in 403.2.1

Source: AWC https://www.awc.org/tallmasstimber

BROCK COMMONS

VANCOUVER, BC

COMPLETED FALL 2017

18 STORIES

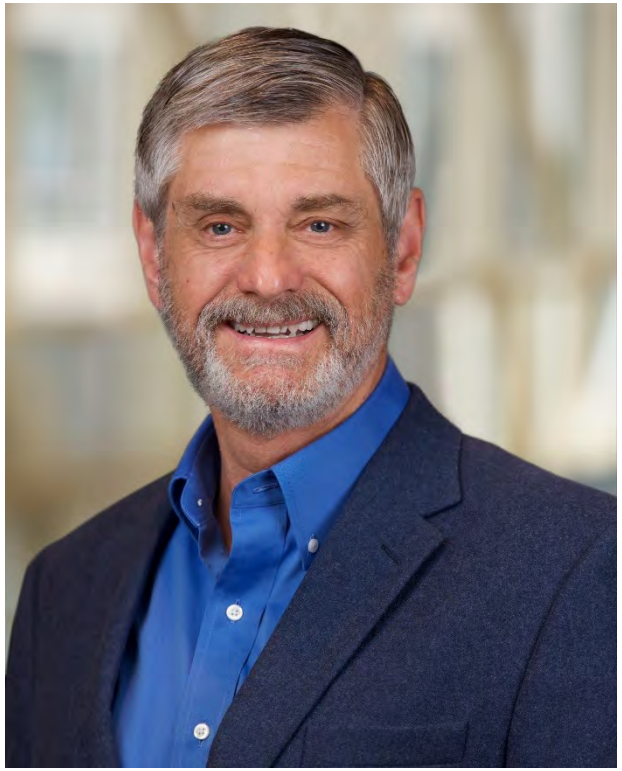
174 FT

156K SF

PHOTO CREDIT: ACTON OSTRY ARCHITECTS


This concludes The American Institute of Architects Continuing Education Systems Course
OTO CREDIT: TOM HARRIS

ANY QUESTIONS?



Keep your **regional staff member** in mind for questions and support:

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