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

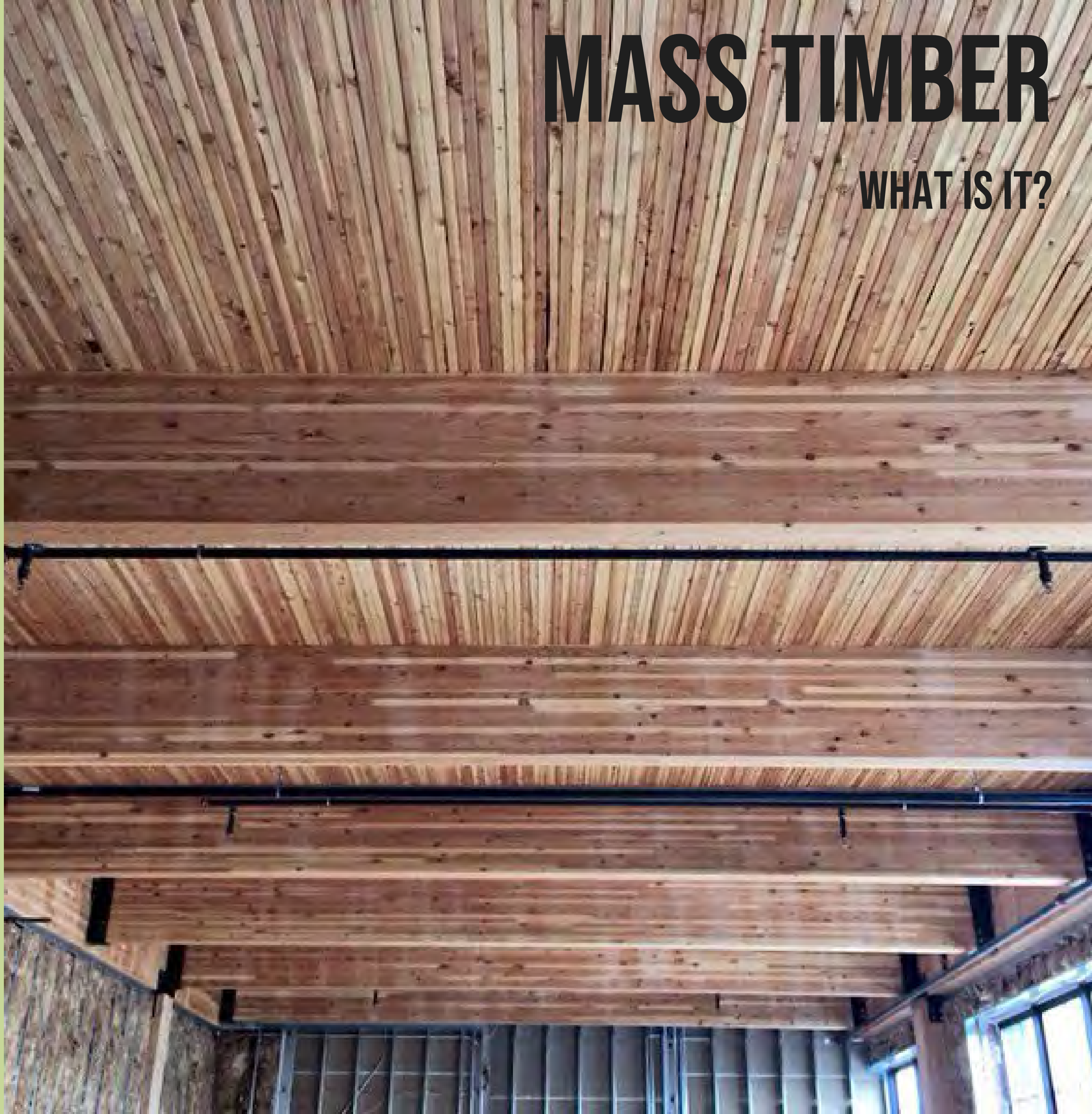
TODAY'S AGENDA

MASS TIMBER CONSTRUCTION

MASS TIMBER

- SYSTEMS
- PRODUCTS
- APPEAL
- DESIGN TOPICS
- CONSTRUCTION, SOURCING & COST
- CASE STUDIES
- WHAT'S NEXT?

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



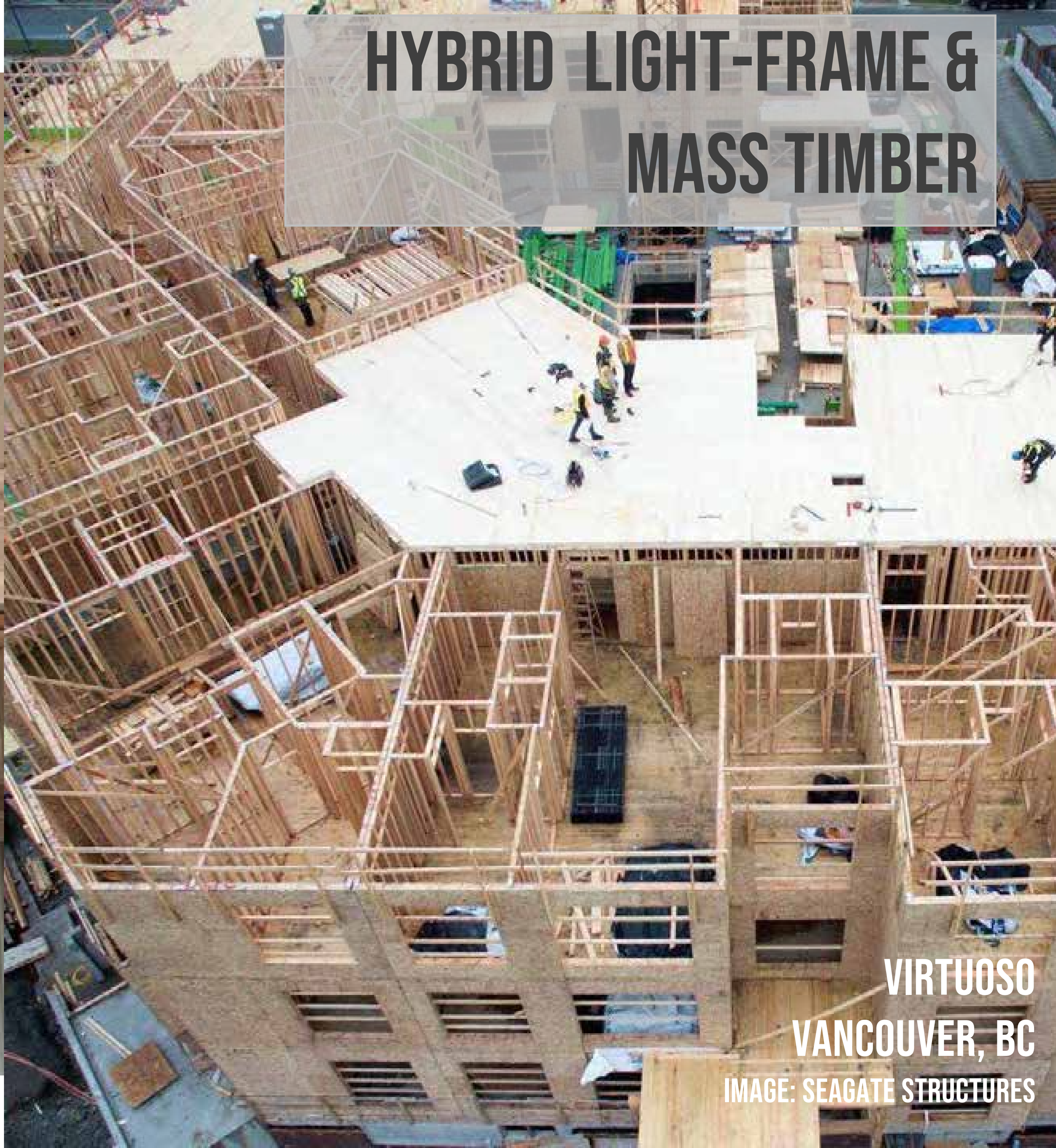

POST & BEAM
T3 MINNEAPOLIS
MINNEAPOLIS, MN
IMAGE CREDIT: BLAINE BROWNELL

TWO-WAY PANELS

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

BROCK COMMONS
VANCOUVER, BC
IMAGES: ACTON OSTRY ARCHITECTS


CARBON 12
PORTLAND, OR
IMAGE: WOODWORKS


HYBRID LIGHT-FRAME &
MASS TIMBER
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

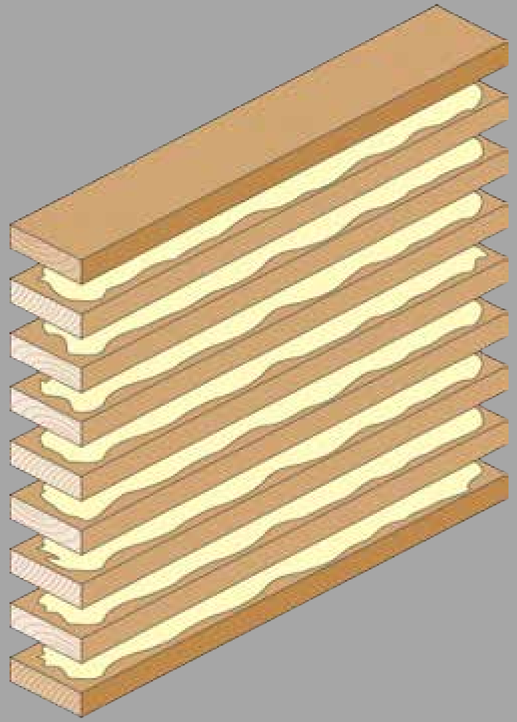
PHOTO CREDIT: ALEX SCHREYER

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 SPECS:

TYPICAL WIDTHS:
3-1/8”, 3-1/2”, 5-1/8”, 5-1/2”, 6-3/4”, 8-3/4”, 10-3/4”, 12-1/4”

TYPICAL DEPTHS:
INCREMENTS PER # OF LAMS FROM 6” TO 60”+
WESTERN SPECIES LAMS ARE TYPICALLY 1-1/2” THICK
SOUTHERN PINE LAMS ARE TYPICALLY 1-3/8” THICK

TYPICAL SPECIES:
DOUGLAS-FIR, SOUTHERN PINE, SPRUCE
ALSO AVAILABLE IN CEDAR & OTHERS

FIGURE 1
BEAM CROSS SECTION

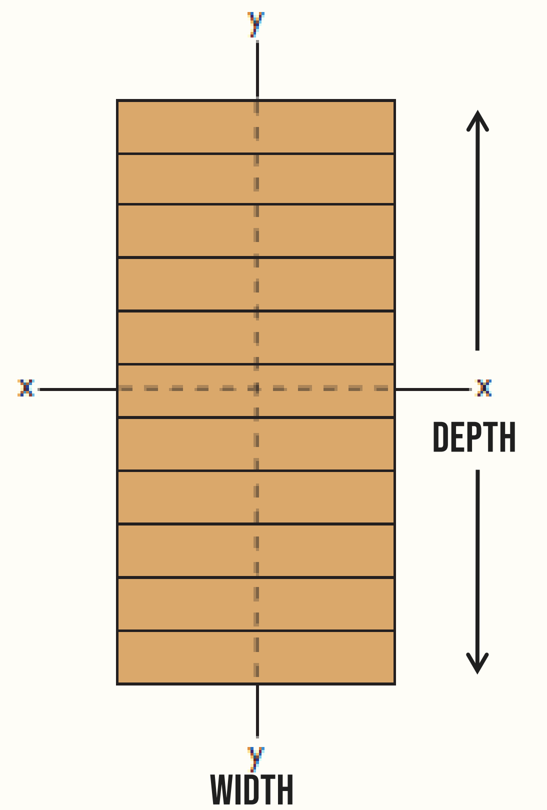
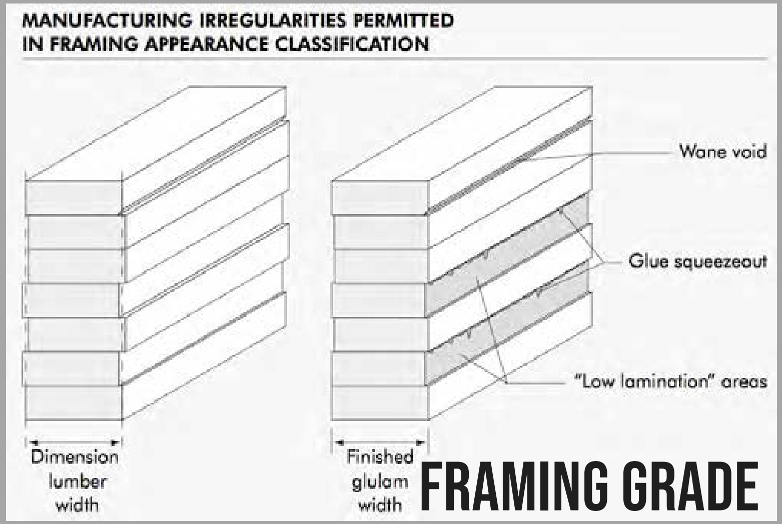


IMAGE: APA GLULAM PRODUCT GUIDE

PHOTO: EMA PETER PHOTOGRAPHY

MASS TIMBER PRODUCTS

GLULAM



GLULAM APPEARANCE GRADES

IMAGES: AMERICAN LAMINATORS

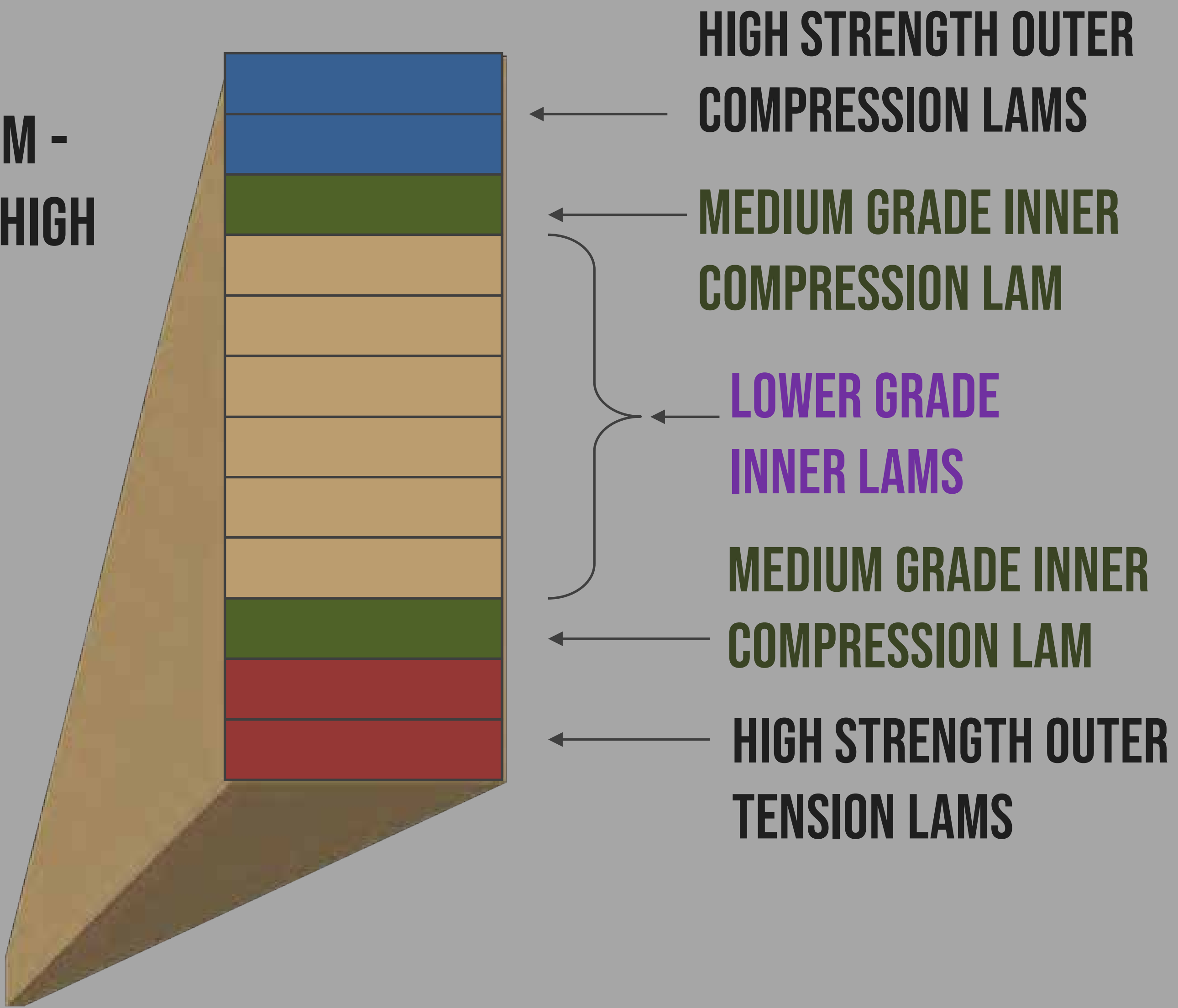
MASS TIMBER PRODUCTS

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



GLULAM CAMBER

- GLULAM CAN BE MANUFACTURED WITH CAMBER TO OFFSET DEAD LOAD DEFLECTION
- VERY IMPORTANT FOR LONG SPAN MEMBERS
- GLULAM INDUSTRY RECOMMENDS CAMBER = 1.5 TIMES CALCULATED DEAD LOAD DEFLECTION

FIGURE 2

BEAM CAMBER PARAMETERS

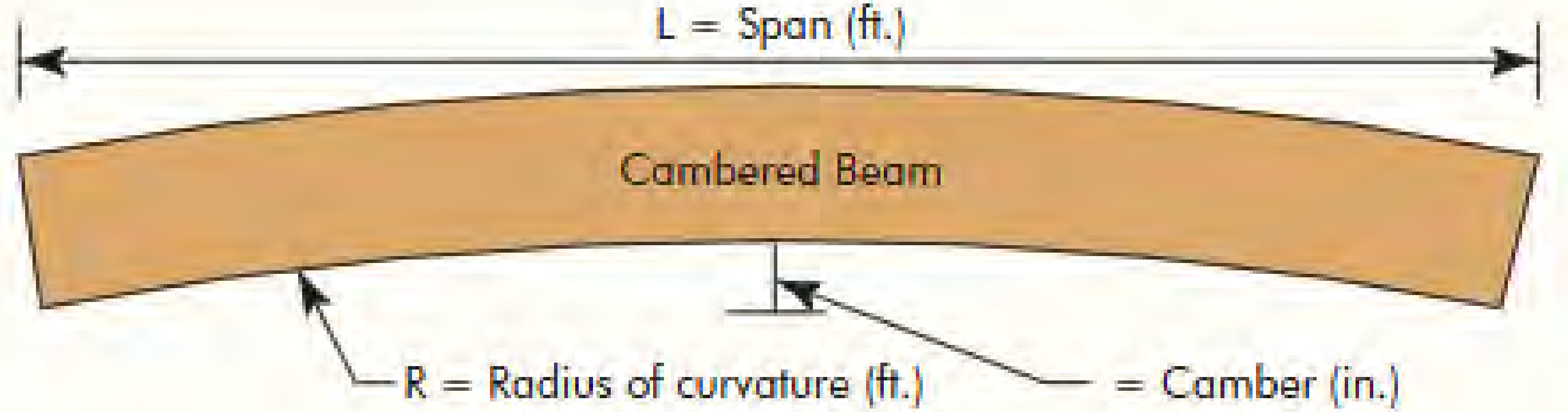
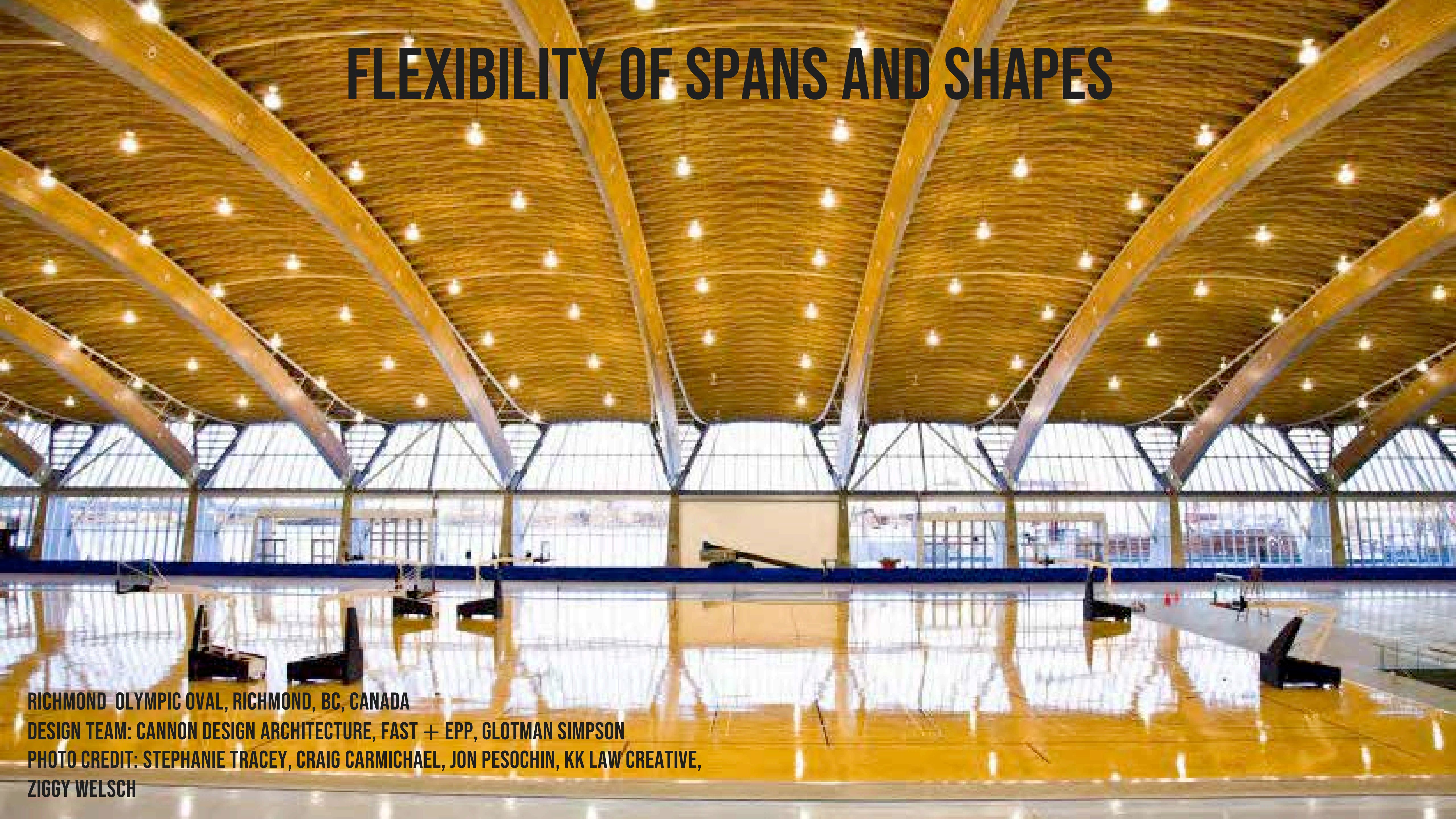


IMAGE: APA GLULAM PRODUCT GUIDE

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

FIRST TECH CREDIT UNION

HILLSBORO, OR

5 STORIES

156,000 SF

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

FIRST TECH CREDIT UNION

HILLSBORO, OR

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

Mass Timber Framing Systems

Framing Styles

- Post & Beam
- Two-Way Panel Deck
- Hybrid Light-Frame & Mass Timber
- “Honeycomb”

Horizontal panels – & vertical panels in “honeycomb” - many options

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

NAIL-LAMINATED TIMBER (NLT) PANELS

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.

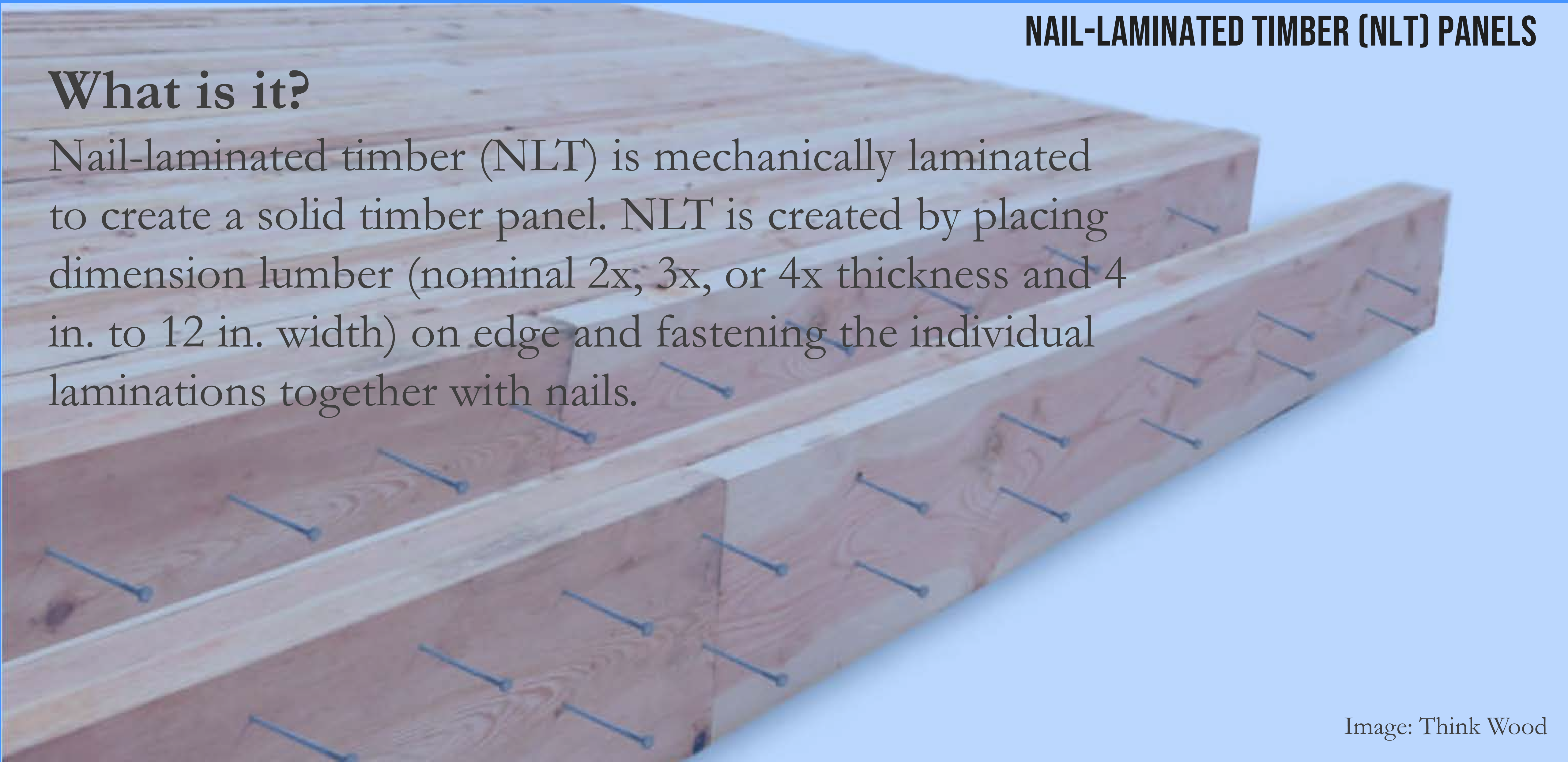


Image: Think Wood

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

When 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

NLT PANELS CAN BE BUILT ON-SITE/IN-PLACE OR PRE-FABRICATED OFFSITE

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

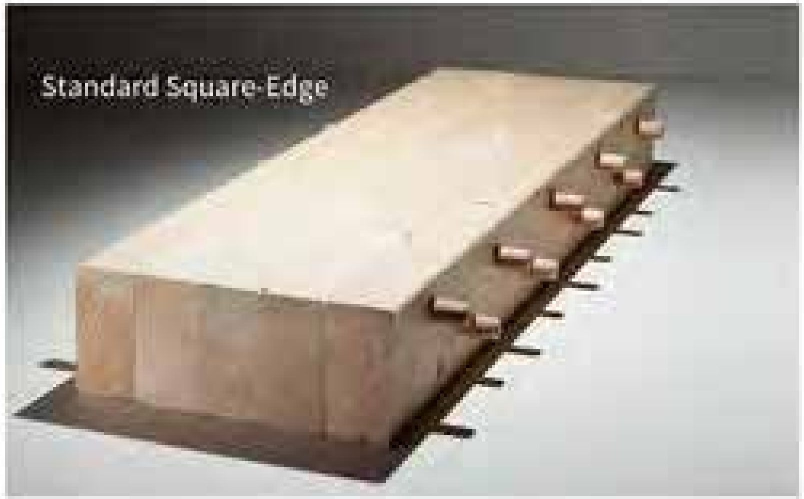
DOWEL-LAMINATED TIMBER (DLT)

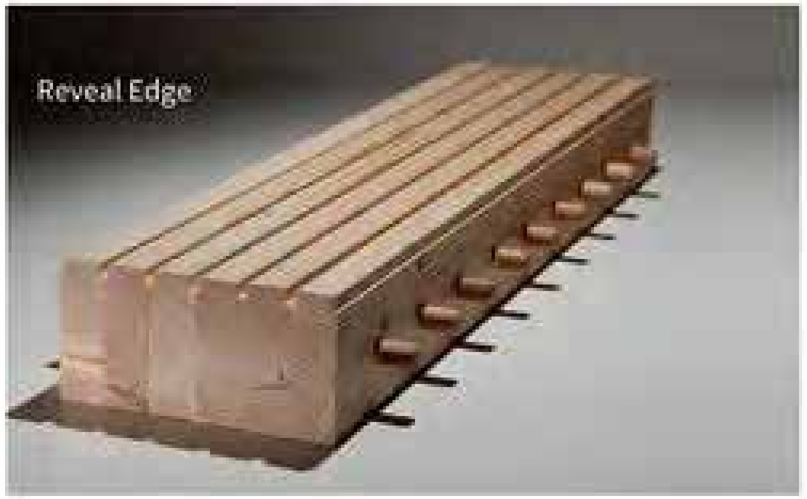
PHOTO CREDIT: STRUCTURECRAFT BUILDERS

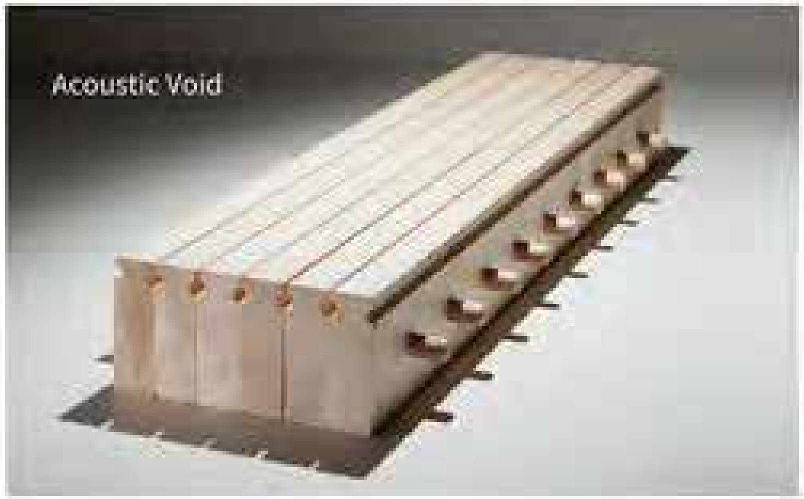
MASS TIMBER PRODUCTS

VARIOUS PROFILE OPTIONS

DOWEL-LAMINATED TIMBER (DLT) PANELS







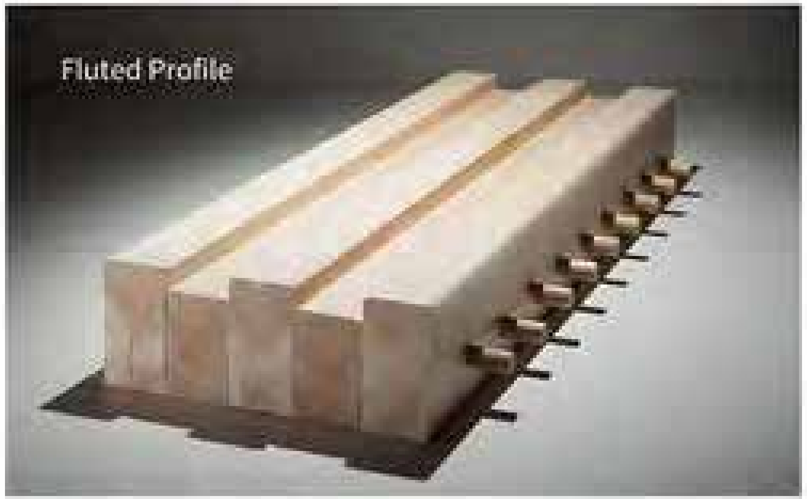


PHOTO CREDIT: STRUCTURECRAFT BUILDERS

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

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT) PANELS

PHOTO CREDIT: STRUCTURE FUSION

PHOTO CREDIT: UNALAM

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT) PANELS

IMAGE SOURCE: STRUCTURECRAFT BUILDERS

Use with Table 5A Adjustment Factors

	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)							Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations)				
	ending		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 Bea Stressed in Tension (Positive Bending)	Top of Beam Stressed in Tension (Negative Bending)	Tension Face	Compression Face		For Deflection Calculations	For Stabilit Calculations				For Deflection Calculations	For Stability Calculations
ecies r/ Core	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

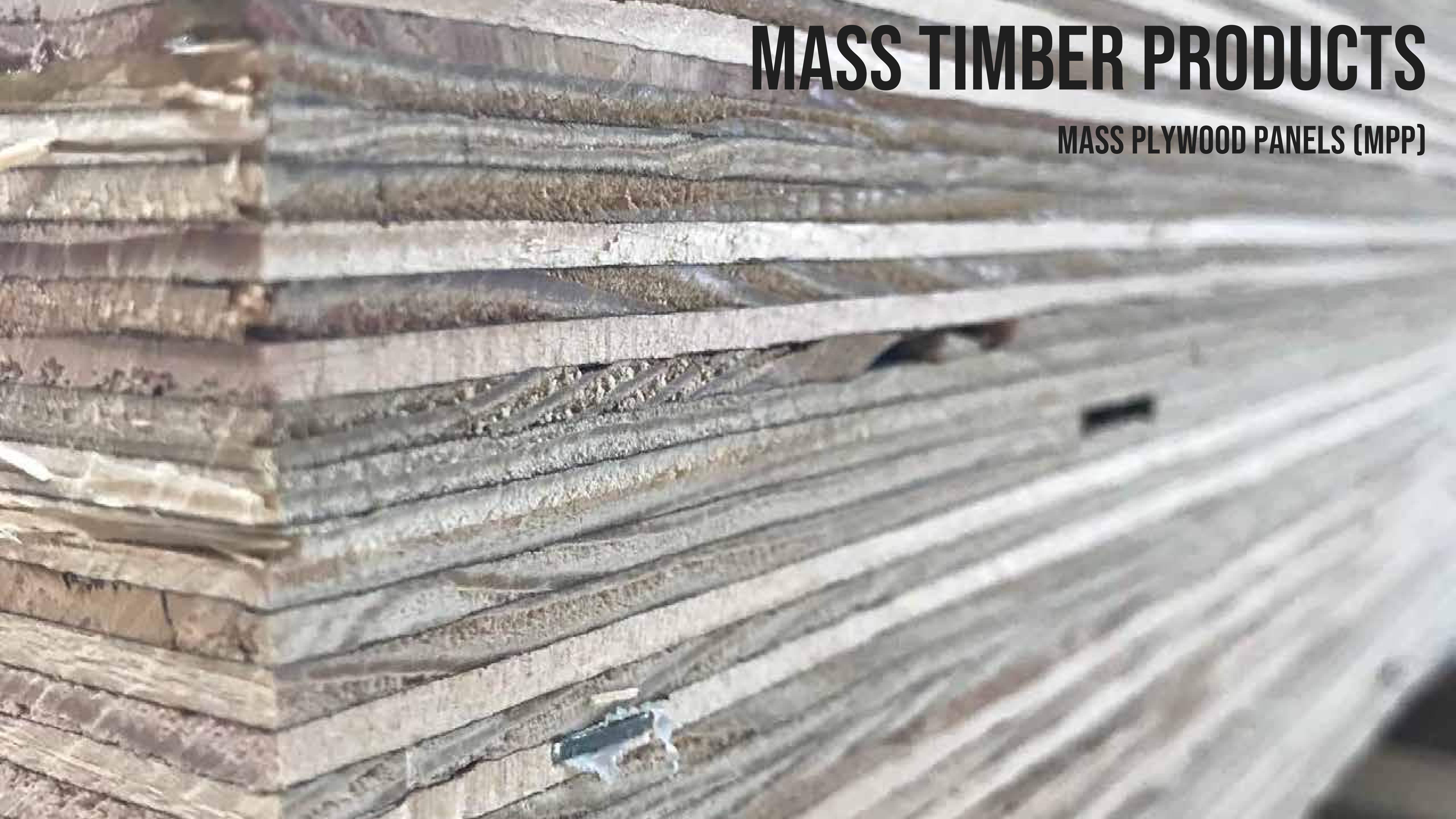
NDS SUPPLEMENT LISTS DIFFERENT DESIGN VALUES FOR BENDING.

LAYUP COMBINATIONS TYPICALLY OPTIMIZED FOR BEAM APPLICATIONS.

LAYUP COMBINATIONS AREN'T EFFECTIVE IN GLT DECKING APPLICATIONS

MASS TIMBER PRODUCTS

MASS PLYWOOD PANELS (MPP)



MASS TIMBER PRODUCTS

MASS PLYWOOD PANELS (MPP)

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

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

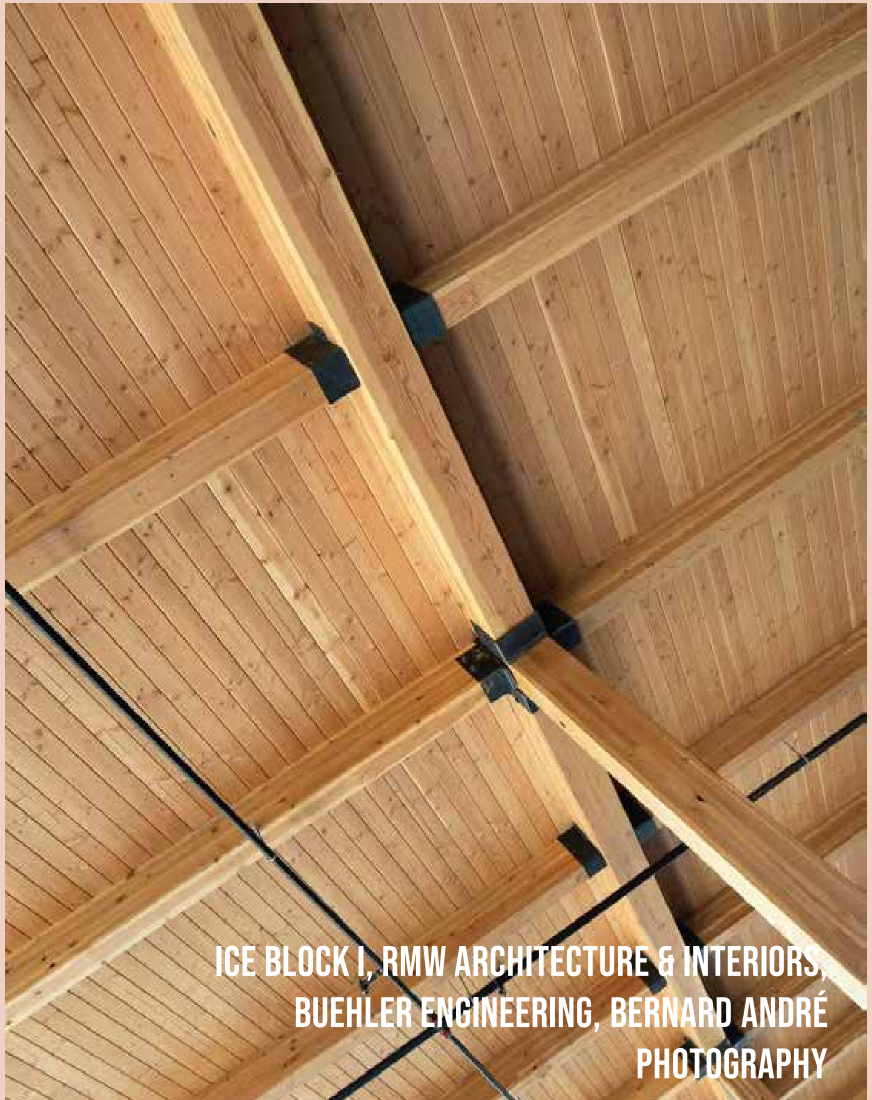
MASS TIMBER PRODUCTS

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



MASS TIMBER PRODUCTS

TONGUE AND GROOVE DECKING

T&G DIAPHRAGM DESIGN

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

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)

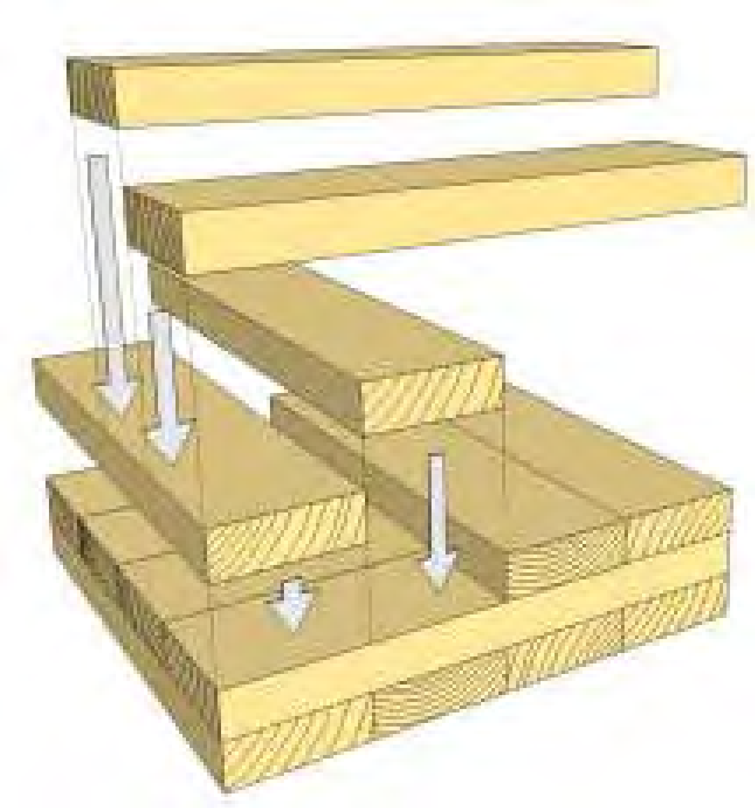
WHAT IS CLT?

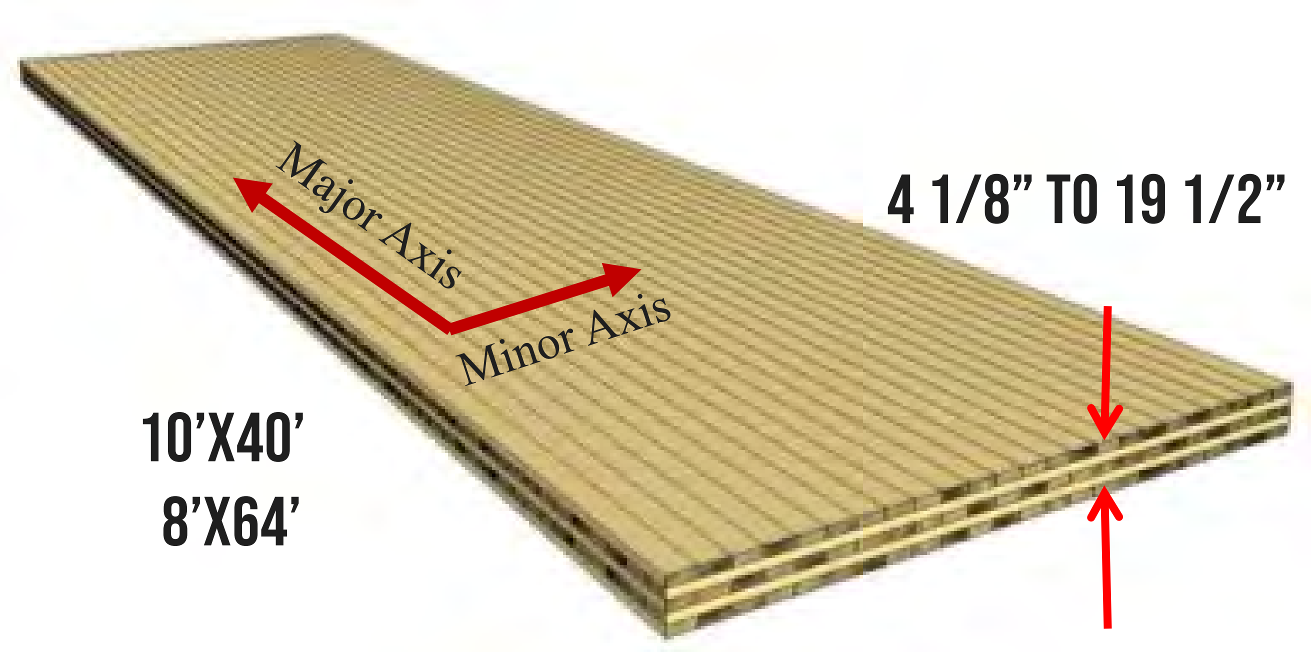
SOLID WOOD PANEL

3 LAYERS MIN. OF SOLID SAWN LAMS

90 DEG. CROSS-LAMS

SIMILAR TO PLYWOOD SHEATHING





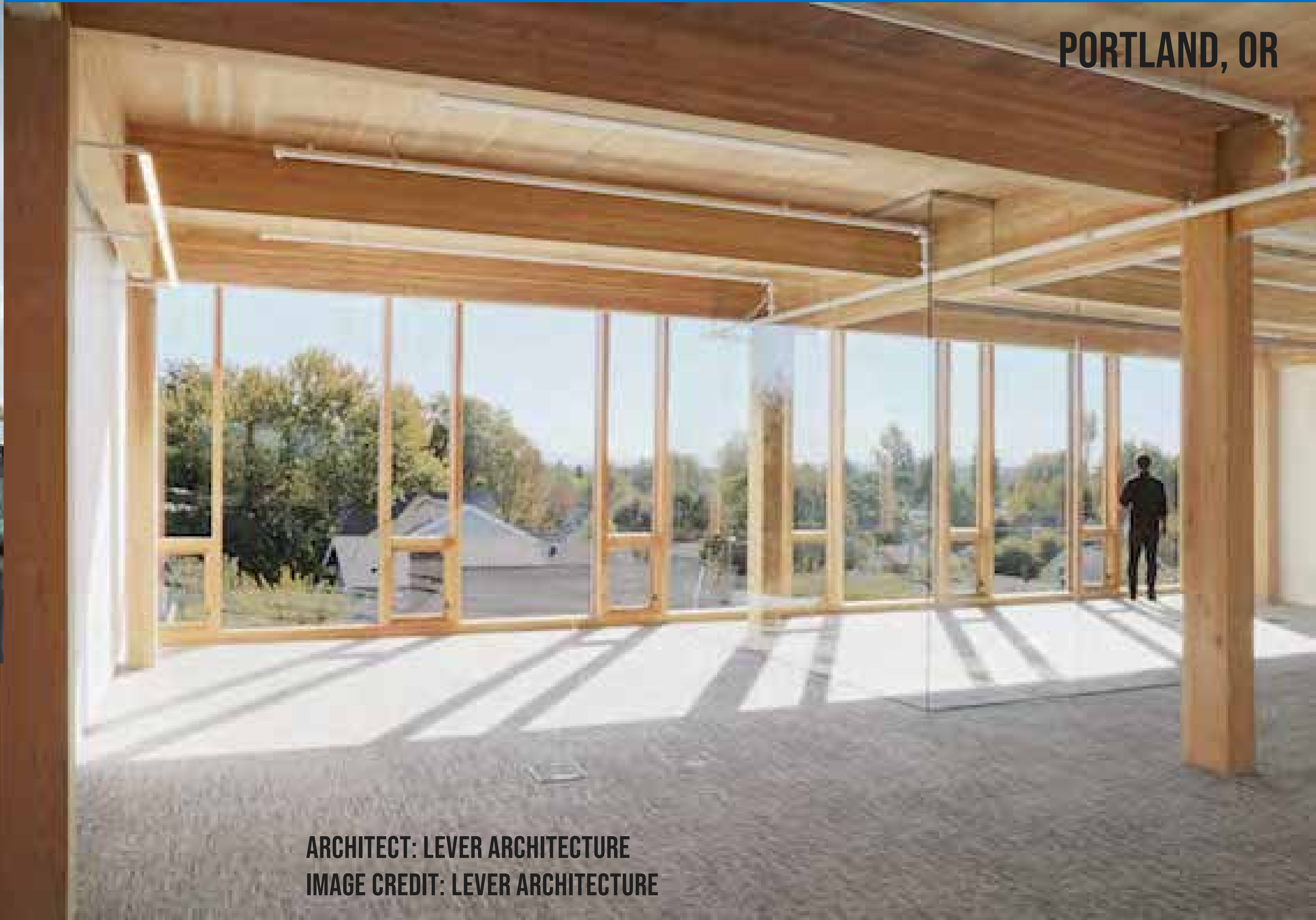
MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

PHOTO CREDIT: DR JOHNSON

ALBINA YARD

PORTLAND, OR



4 STORIES

16,000 SF

GREEN ROOF

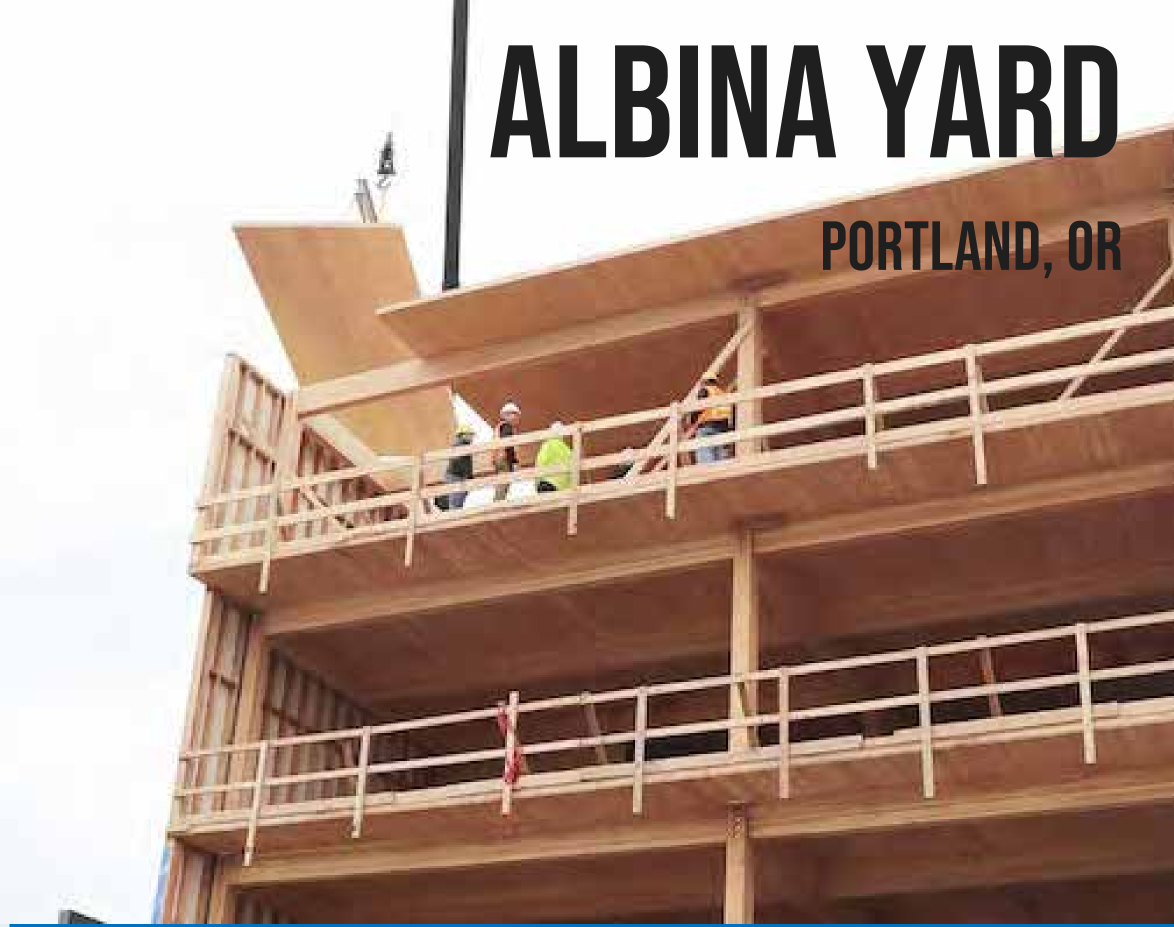
ARCHITECT: LEVER ARCHITECTURE

IMAGE CREDIT: LEVER ARCHITECTURE

ALBINA YARD

PORTLAND, OR

- 20'X20' GRID, 12' FLOOR TO FLOOR
- 3-PLY CLT FLOOR PANELS WITH ELECTRICAL CONDUIT POURED INTO 1" LIGHT WEIGH GYPSUM TOPPING
- WOOD SHEARWALL CORE WITH OPEN FRONT DESIGN FOR GLAZING WALL



CLT PANELS FOR AN ENTIRE FLOOR INSTALLED IN LESS THAN 4 HOURS

SOURCE: LEVER ARCHITECTURE[1]

ARCHITECT: LEVER ARCHITECTURE
IMAGE CREDIT: LEVER ARCHITECTURE

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: IHG® Army Hotels, Lendlease

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: LEND LEASE & SCHAEFER

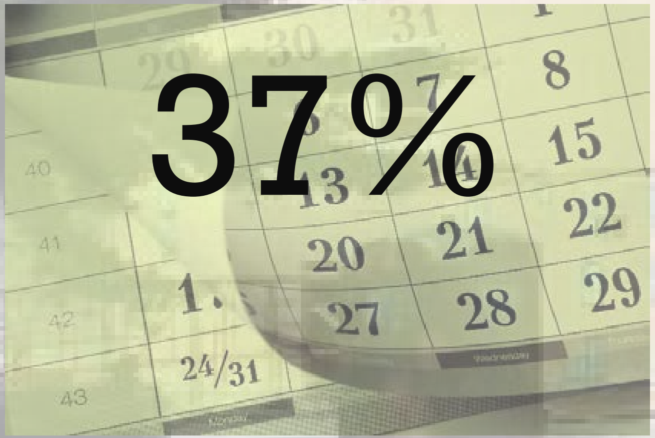
PAL Portfolio	Typical New PAL Hotel (Actual*)	Redstone Arsenal (Actual)	Difference
Gross square feet (sf)	54,891	62,688	+14%
Average # of employees	18 (peak 26)	10 (peak 11)	-43%
Structural duration (days)	123	78	-37%
Structural person hours	14,735	8,203	-44%
Structural production rate/day	460 sf	803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

* PAL New Build Hotel Historical Average

Source: Lendlease

43%

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



37%

Candlewood Suites at Redstone Arsenal, AL

4 Stories, 62k SF

Image: Lendlease | Source: Lendlease[2]

MASS TIMBER PRODUCTS

WOOD CONCRETE COMPOSITE

PHOTO CREDIT: ALEX SCHREYER

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

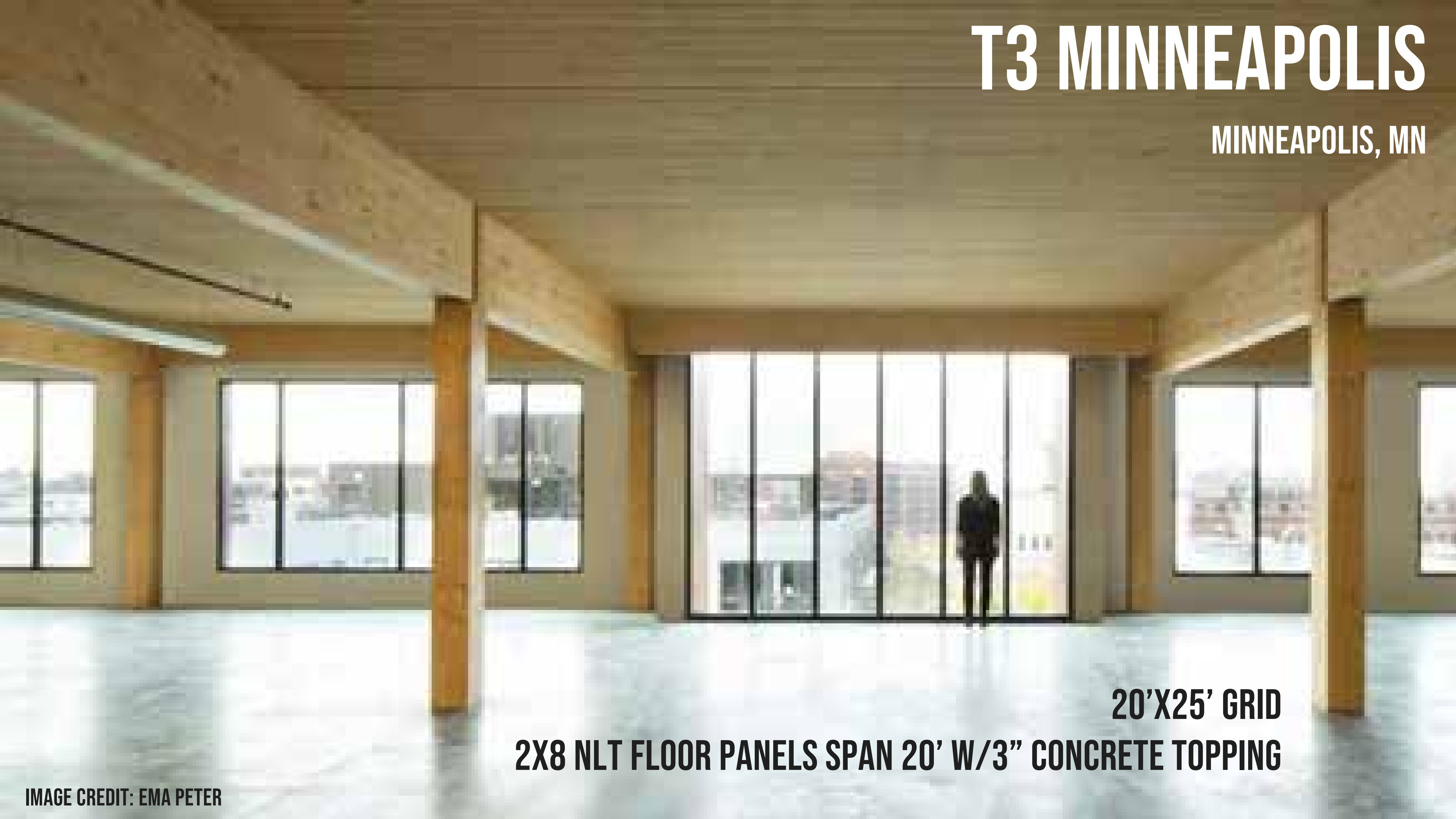
CLAY CREATIVE

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

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

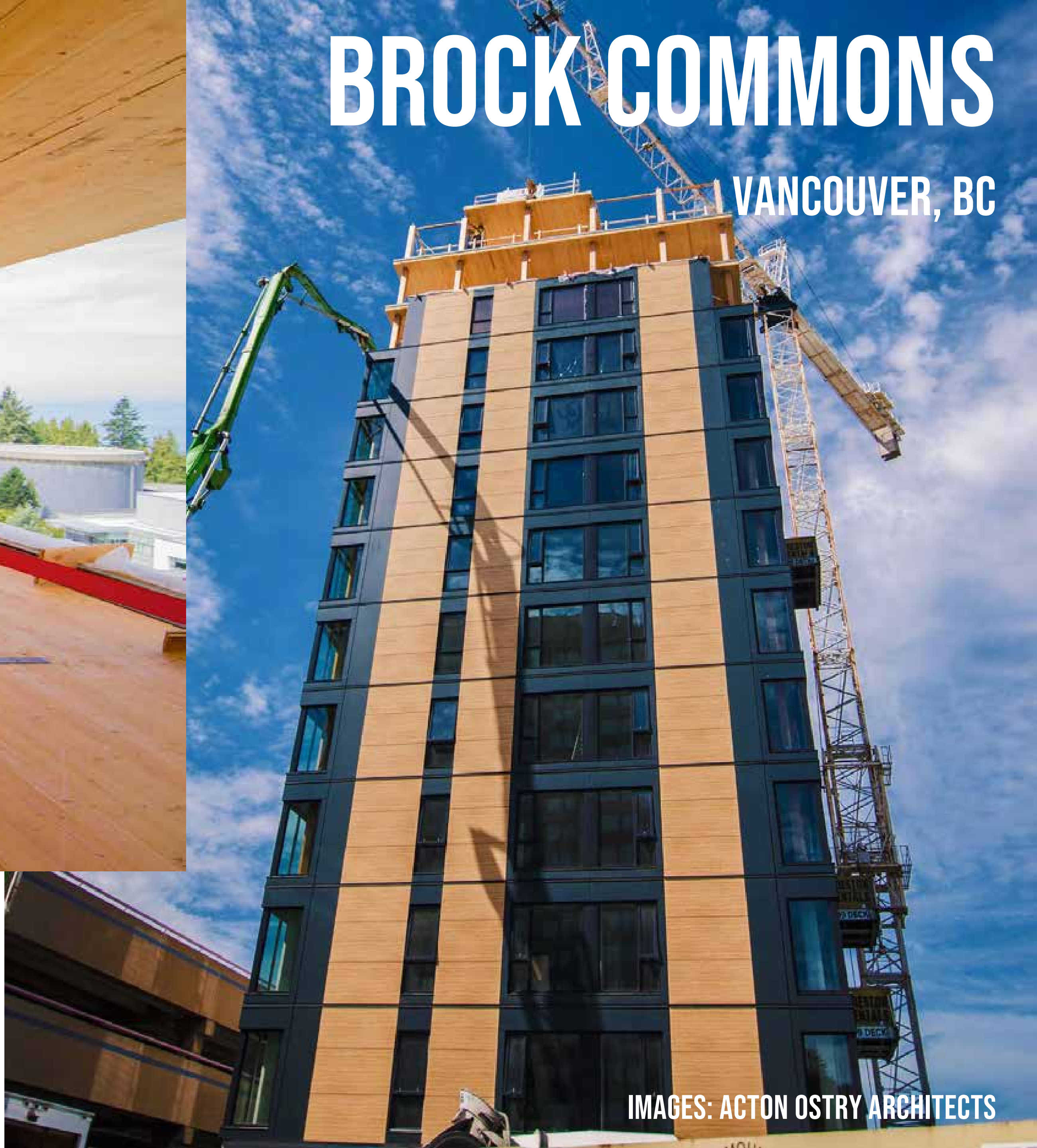
UMASS, AMHERST, MA

- 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

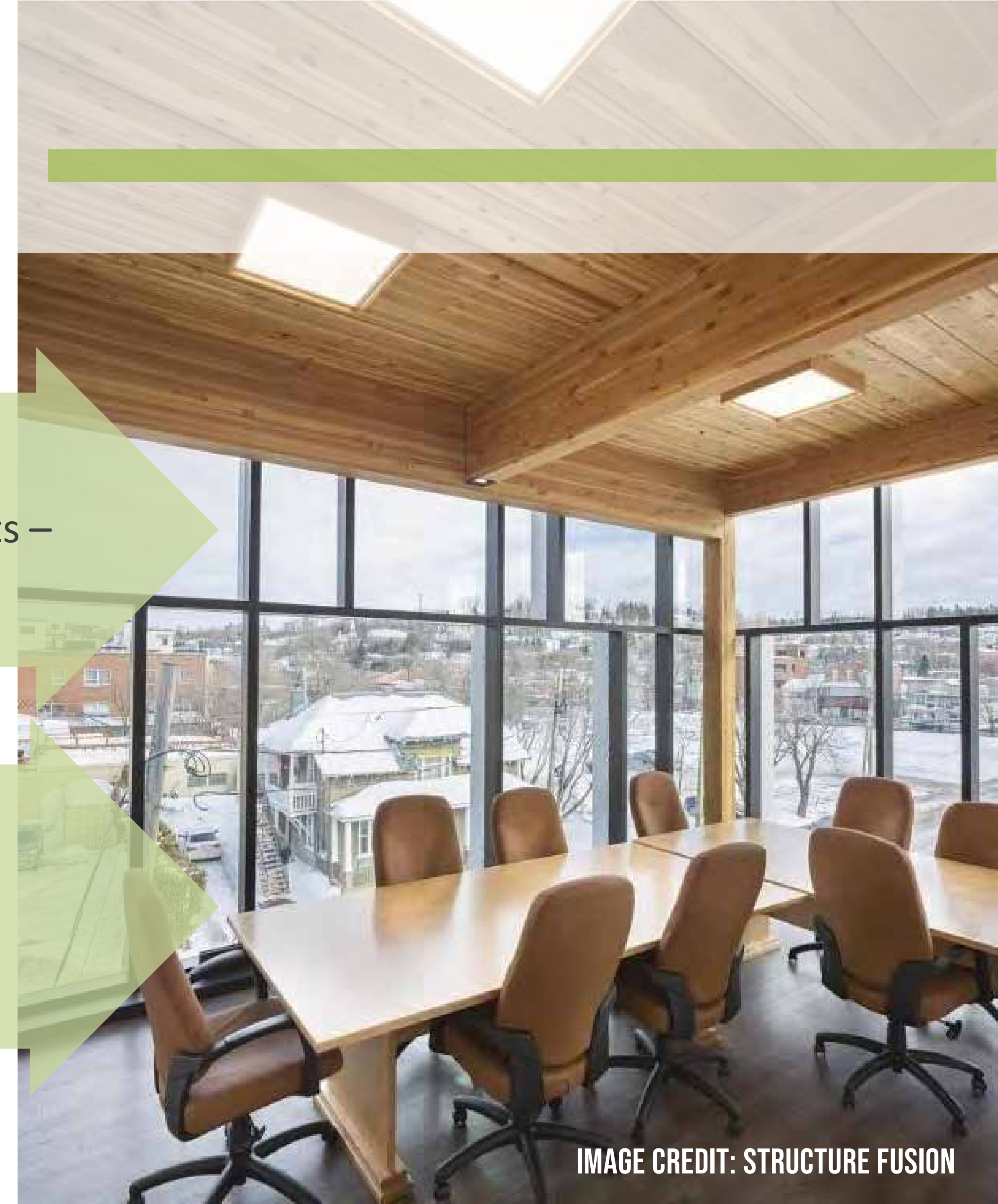


IMAGE CREDIT: STRUCTURE FUSION

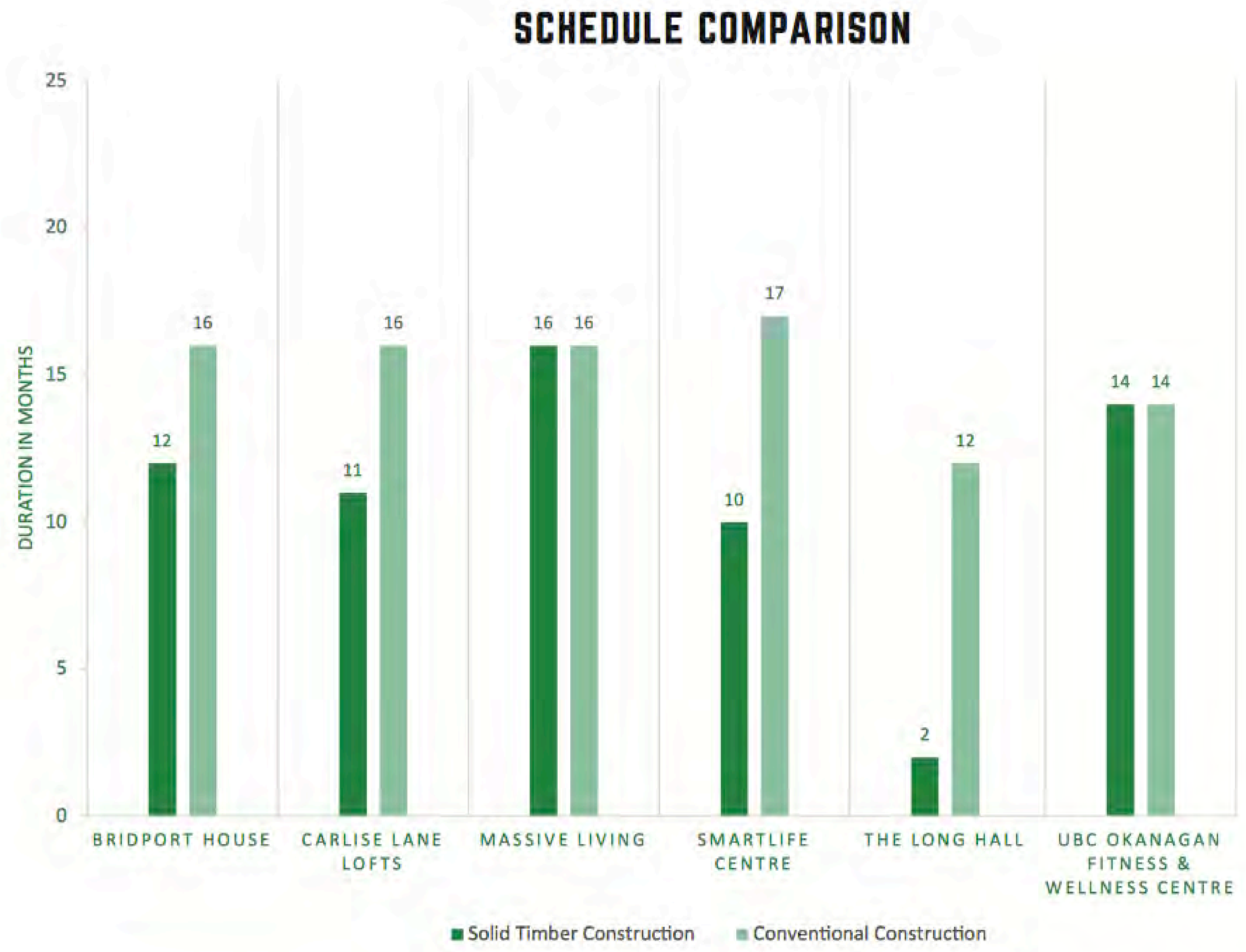
MASS TIMBER APPEAL

REDUCED CONSTRUCTION TIME

1 Floor = 3 Days

17 Floors Erected in 9.5 Weeks

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



Source: Solid Timber Construction[6], Ryan Smith

MASS TIMBER APPEAL

ALTERNATE TO CONCRETE & MASONRY

PHOTO CREDIT: CHARLES JUDD

MASS TIMBER APPEAL

MATERIAL MASS

75% LIGHTER WEIGHT THAN CONCRETE

SOURCE: STRUCTURLAM[7]

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

MINIMAL WASTE

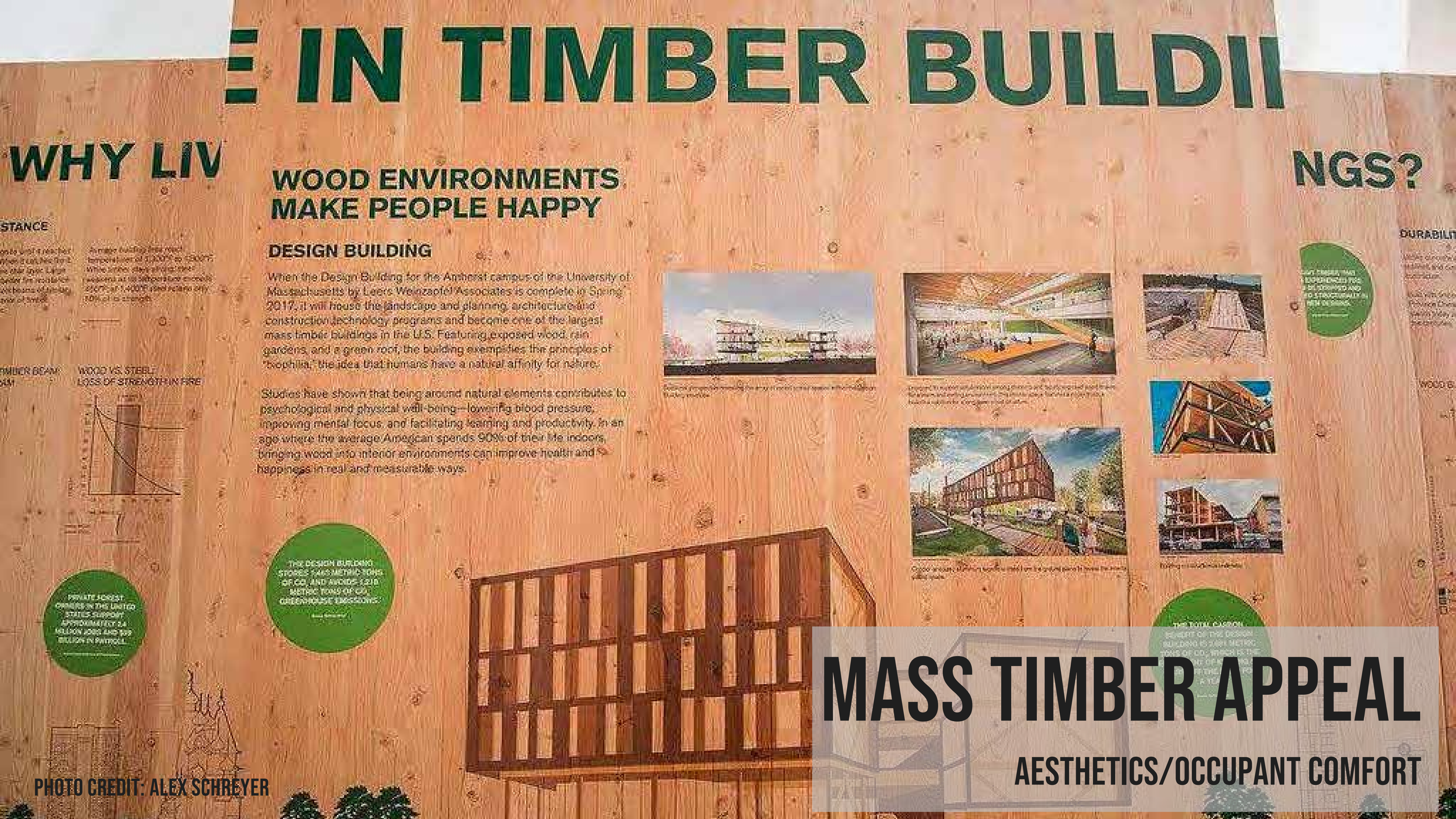
MASS TIMBER APPEAL

PREFABRICATED AND PRECISE

MASS TIMBER ELEMENTS FABRICATED TO TIGHT TOLERANCES

COMPUTER NUMERICALLY CONTROLLED (CNC) CONNECTIONS

PHOTO CREDIT: NATURALLY:WOOD



MASS TIMBER APPEAL

AESTHETICS/OCCUPANT COMFORT

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

DESIGN TOPICS

- CONSTRUCTION TYPES
- FIRE RESISTANCE
- ACOUSTICS
- SHAFTS
- MEP DETAILING
- BUILDING ENCLOSURE
- LATERAL FRAMING
- CONNECTIONS
- CONSTRUCTION PROCESS

MASS TIMBER DESIGN

CONSTRUCTION TYPES

Q: OF THE 5 CONSTRUCTION TYPES, WHICH ONES CAN MASS TIMBER BE USED IN?

A: ALL 5!

CONSTRUCTION TYPES

Image: StructureCraft Builders

Chapter 6:
Types of Construction

Where does the code allow MT to be used?

- Type IB & II: Roof Decking

Construction Type IB
Exposed Timber Roof Decking and Framing

Portland International Jetport

- LEED Gold
- Completed 2012

Design Team: Gensler, Oest Associates
Photo Credit: DeStafano & Chamberlain, Inc, Robert Benson Photography

CONSTRUCTION TYPES

ICE Block I, RMW Architecture & Interiors, Buehler Engineering, Bernard André Photography

Chapter 6: Types of Construction

Where does the code allow NLT to be used?

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

CONSTRUCTION TYPES

Where does the code allow mass timber to be used?

- Type IV: Any interior elements & roofs if meets min. size; exterior walls if FRT. No concealed spaces permitted

Chapter 6:
Types of Construction

Image: Perkins + Will

CONSTRUCTION TYPES

Chapter 6: Types of Construction


Image: Christian Columbres Photography

Where does the code allow MT to be used?

- <u>Type V</u>: Interior elements, roofs & exterior walls

CONSTRUCTION TYPES

Type III: 6 stories

Allowable mass timber building size for group B occupancy with NFPA 13 Sprinkler

Image credit: Ema Peter

Type IV: 6 stories

Image: Christian Columbres Photography

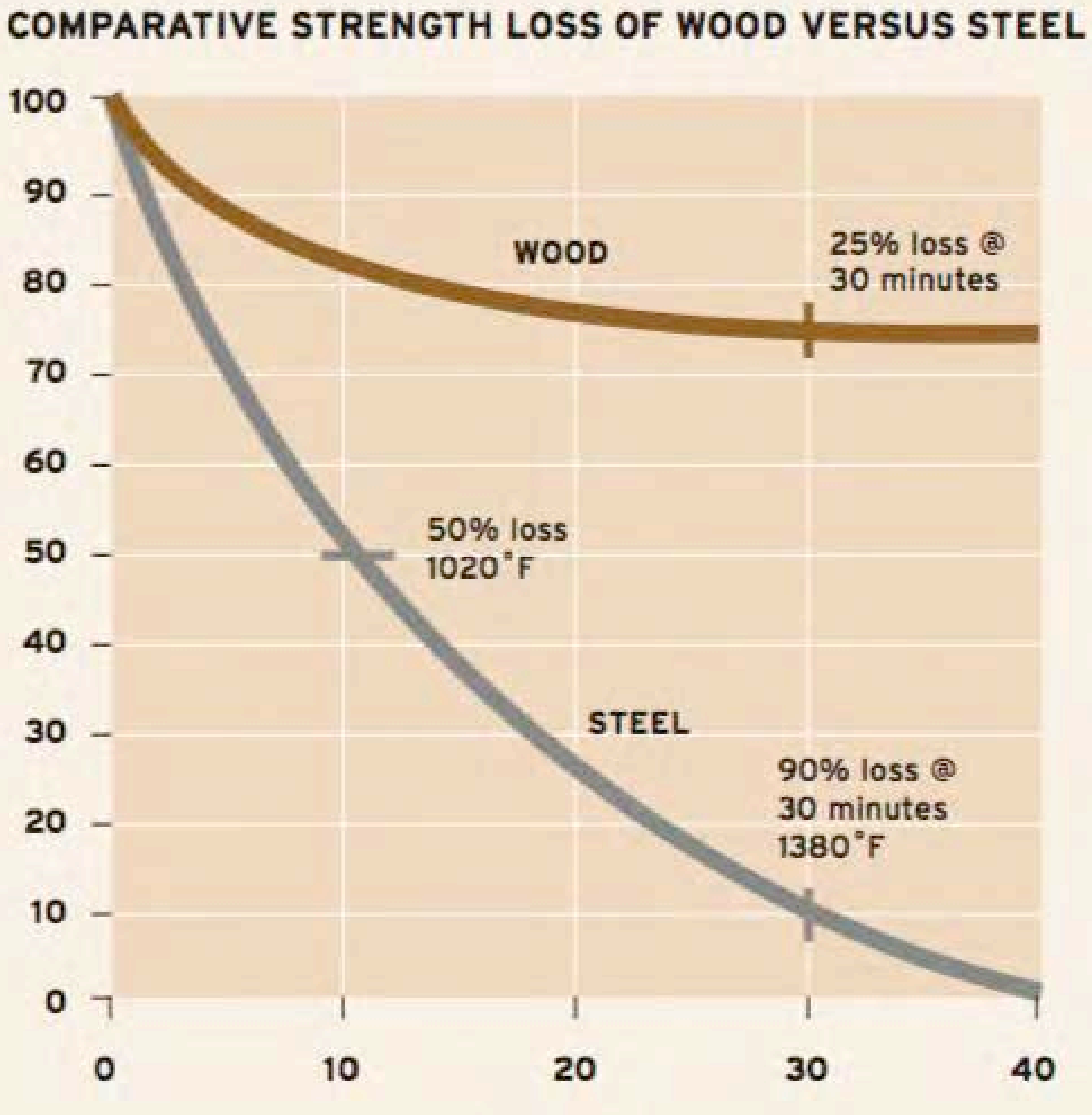
Type V: 4 stories

FIRE RESISTANCE

PHOTO CREDIT: FPINNOVATIONS

MASS TIMBER DESIGN

FIRE RESISTANCE

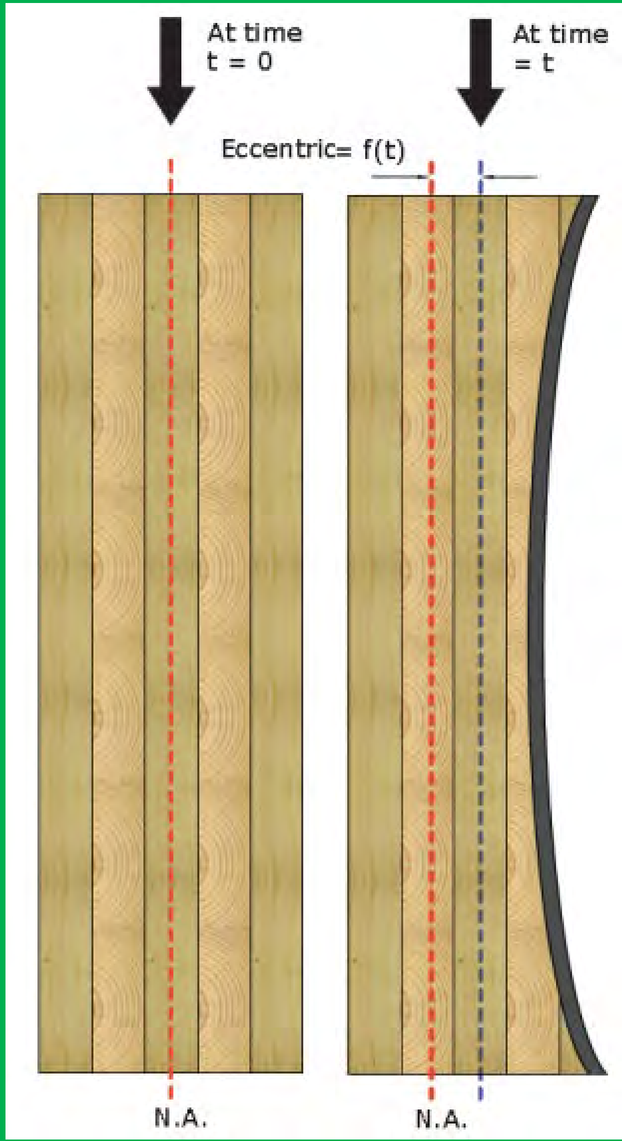


Results from test sponsored by National Forest Products Association at the Southwest Research Institute

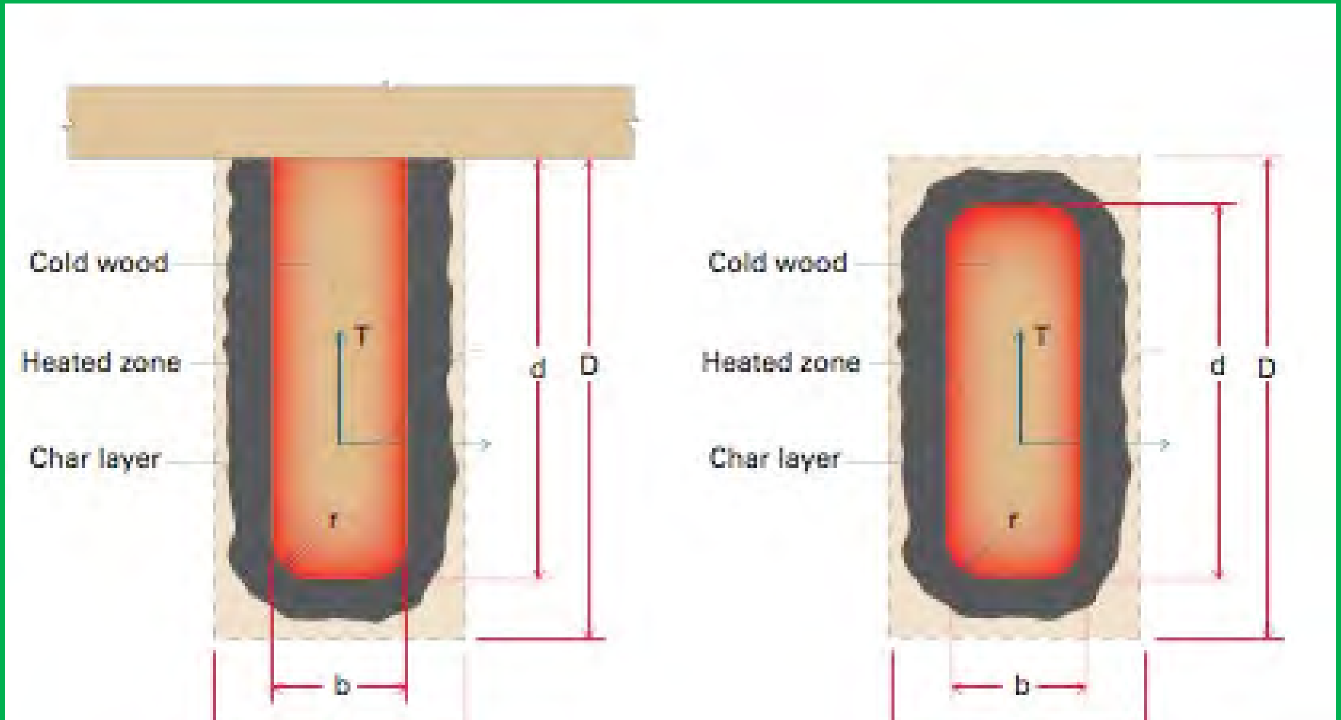
SOURCE: AITC

MASS TIMBER DESIGN

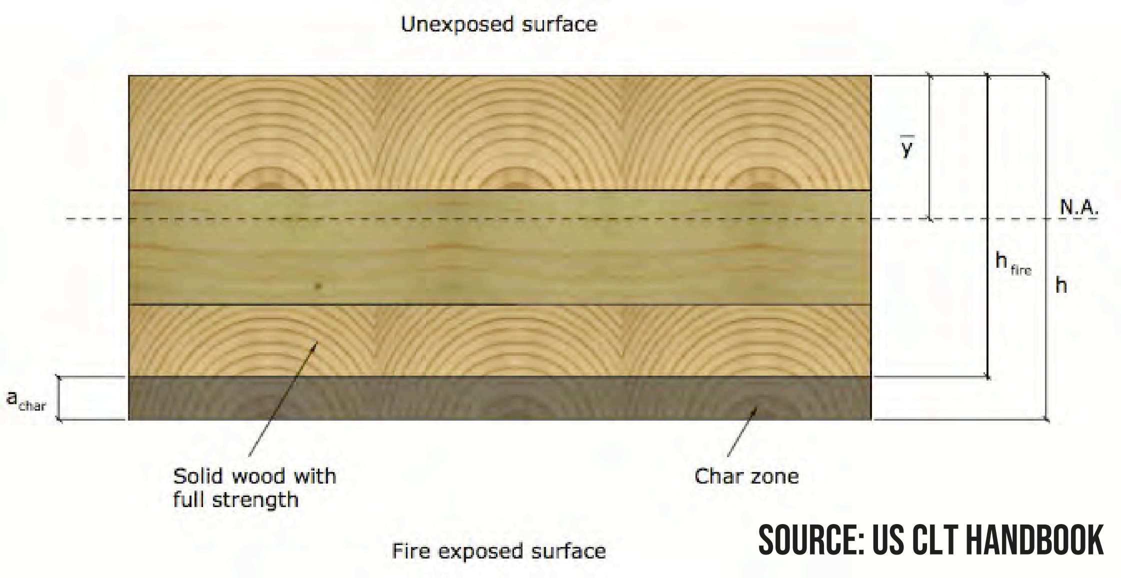
FIRE RESISTANCE



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



SOURCE: AWC'S TR 10



MASS TIMBER DESIGN

FIRE RESISTANCE

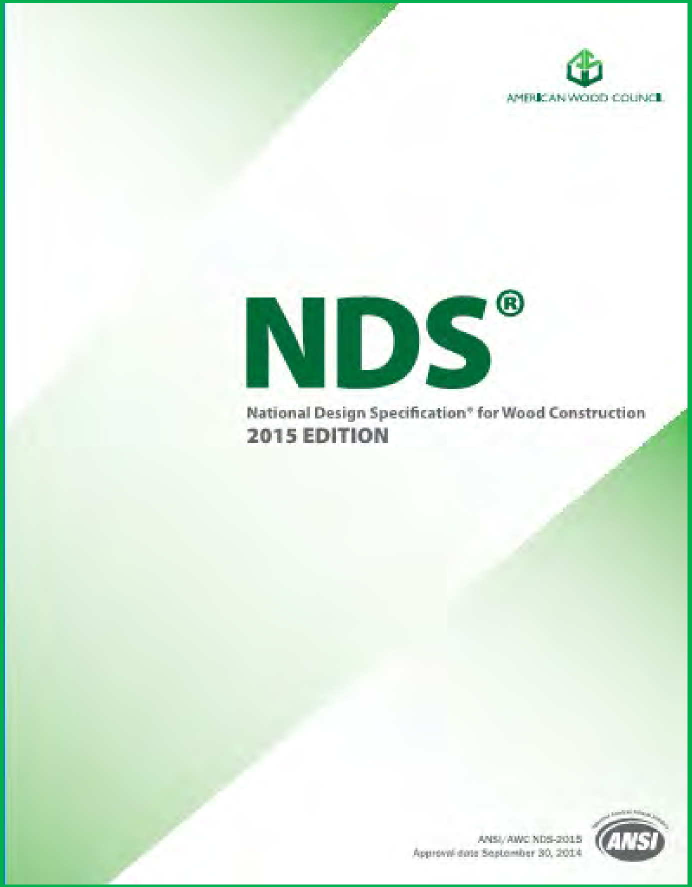
Construction type selection dictates prescriptive fire resistance requirements:

- 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

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)

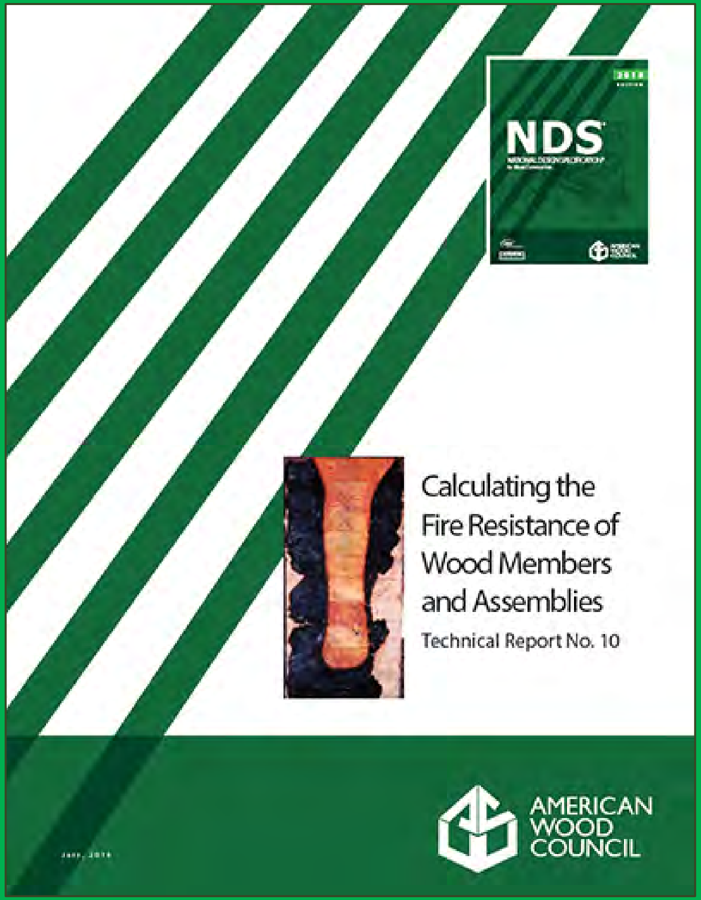


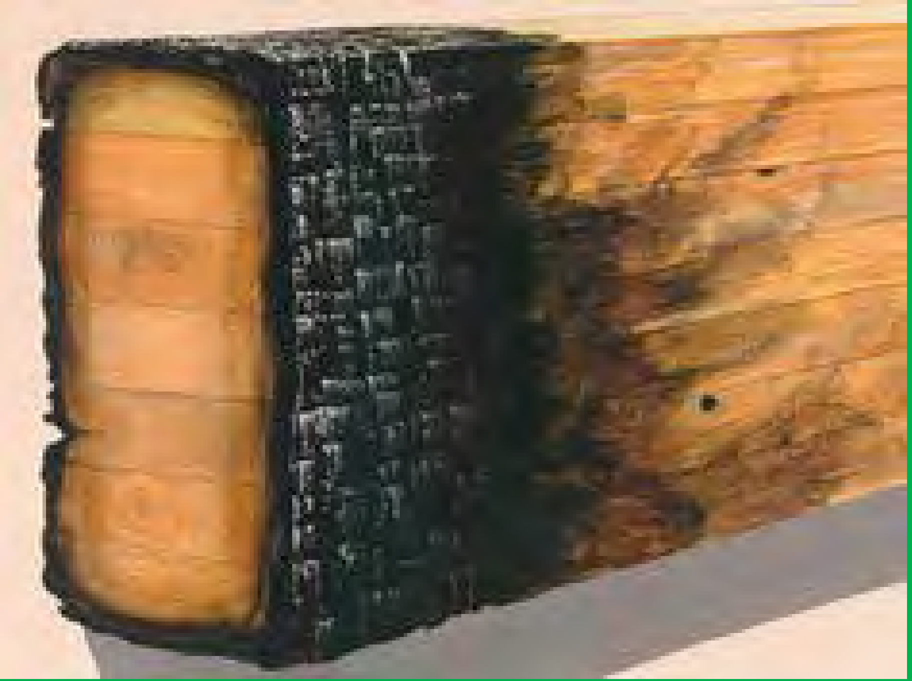

NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION 149

FIRE DESIGN OF WOOD MEMBERS

16.1	General	150
16.2	Design Procedures for Exposed Wood Members	150
16.3	Wood Connections	151
Table 16.2.1	Effective Char Rates and Char Layer Thicknesses (for β_n = 1.5 in./hr.)	150
Table 16.2.2	Adjustment Factors for Fire Design	151

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.)

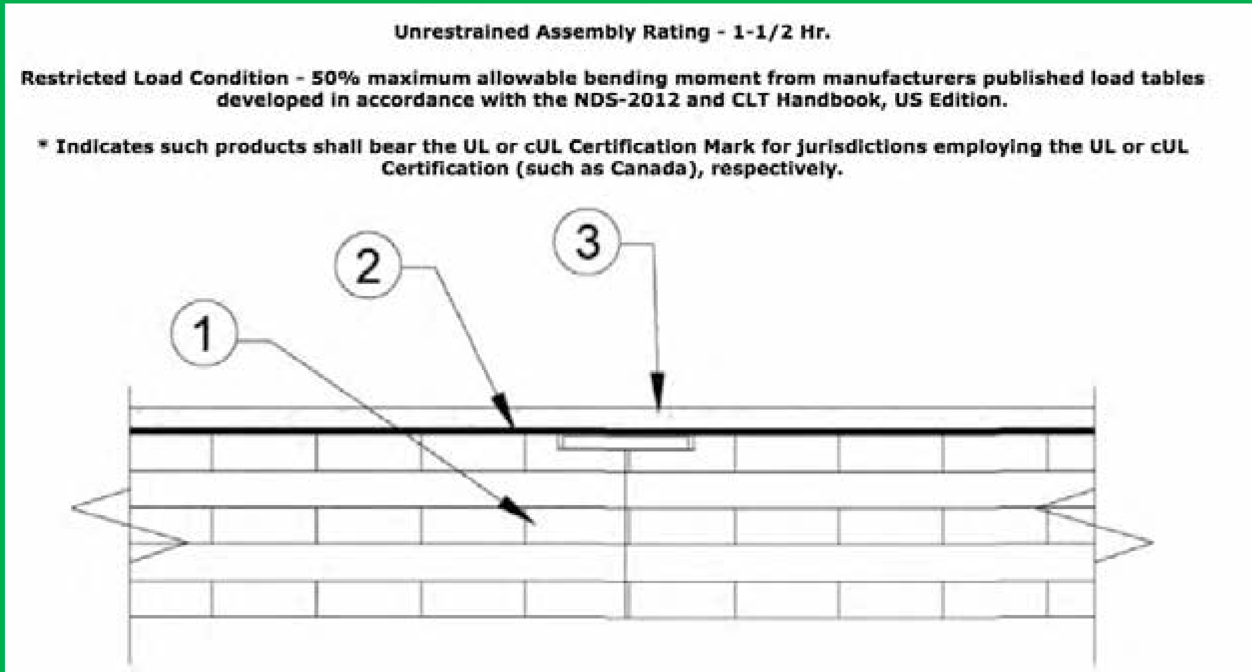
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

SOURCE: AWC'S NDS

MASS TIMBER FIRE DESIGN METHODS:

NDS Chapter 16 Char Calculations vs. ASTM E119 Tested Assembly

- **NDS Chpt 16 calcs check structural integrity**
- **ASTM E119 checks structural integrity, thermal separation (elevated temp. on unexposed side) and burn through (ignition of cotton waste at gaps)**
- **Reasonable to assume other assembly components such as concrete topping aid in other 2 criteria**



SOURCE: UL L901

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
IAS ACCREDITED Testing Laboratory TL-216

TEST REPORT
for
American Wood Council
222 Catoctin Circle SE, Suite 201
Leesburg, VA 20175

Page 1 of 53

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, 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

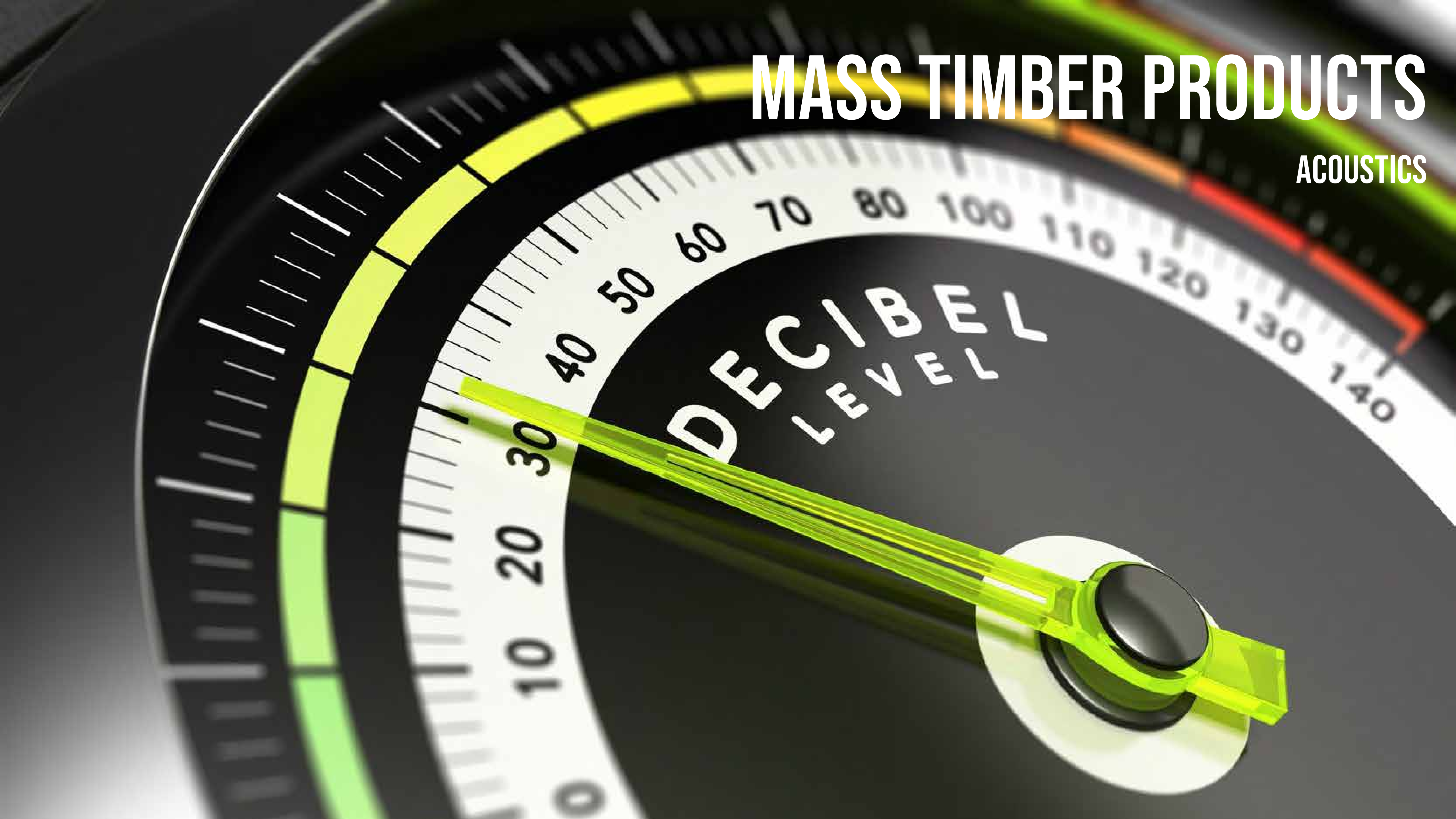
Noureddine Bénichou, Ph.D.
Senior Research Officer
National Research Council of Canada – Fire Research Resource Centre

July 2012

CONTACT WOODWORKS FOR INFORMATION

MASS TIMBER PRODUCTS

ACOUSTICS

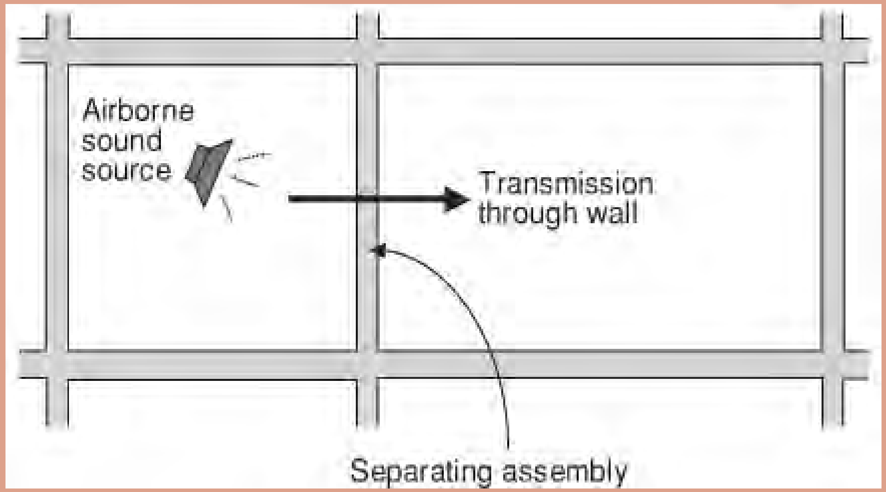


MASS TIMBER DESIGN

AIR-BORNE SOUND:

- SOUND TRANSMISSION CLASS (STC)

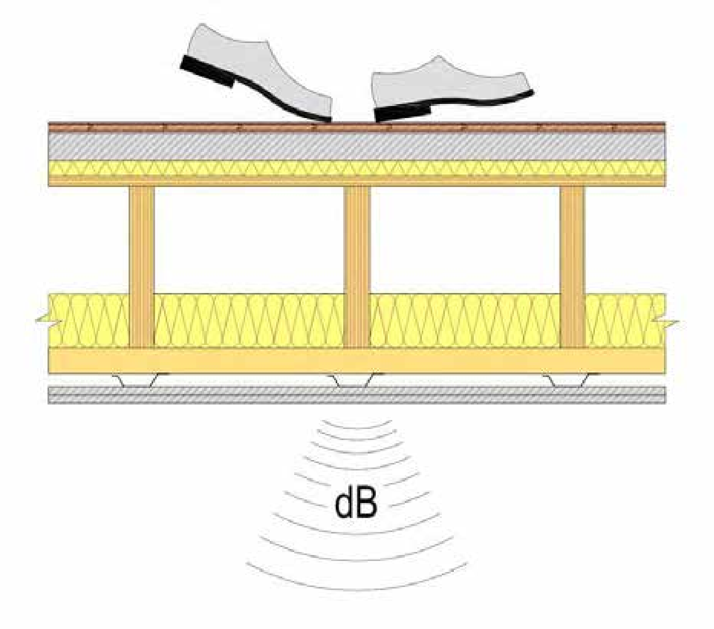
MEASURES HOW EFFECTIVELY AN ASSEMBLY ISOLATES AIR-BORNE SOUND AND REDUCES THE LEVEL THAT PASSES FROM ONE SIDE TO THE OTHER



STRUCTURE-BORNE SOUND:

- IMPACT INSULATION CLASS (IIC)

EVALUATES HOW EFFECTIVELY AN ASSEMBLY BLOCKS IMPACT SOUND FROM PASSING THROUGH IT



MASS TIMBER DESIGN

ACOUSTICS – IBC 1207

NO ACOUSTICAL CODE REQUIREMENTS FOR MANY MASS TIMBER BUILDING TYPES SUCH AS OFFICES AND ASSEMBLY. HOWEVER, MANY OWNERS REQUIRE A MINIMUM LEVEL OF PERFORMANCE

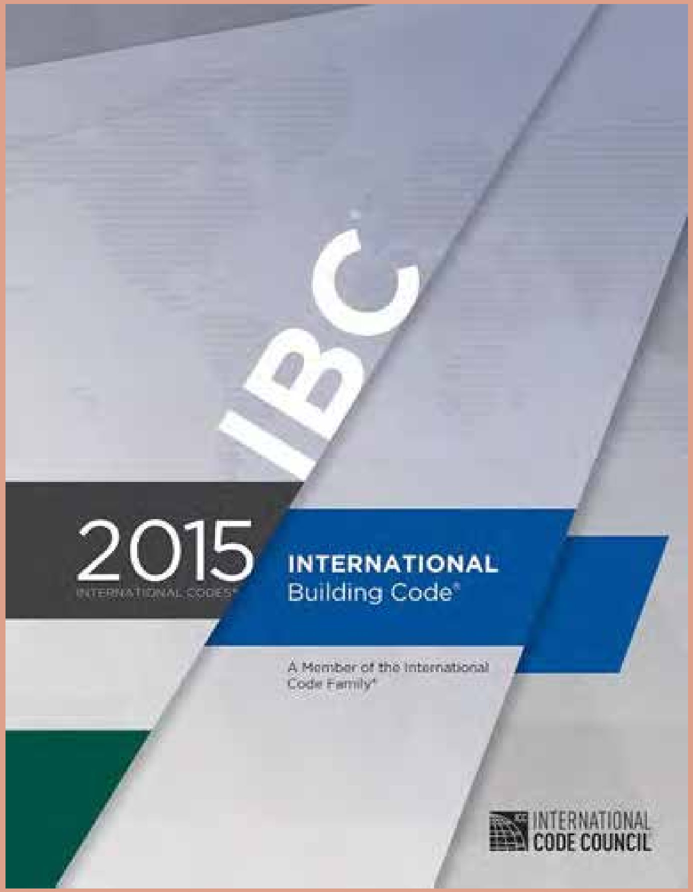
CODE REQUIREMENTS FOR RESIDENTIAL OCCUPANCIES:

MIN. STC OF 50 (45 IF FIELD TESTED):

- WALLS, PARTITIONS, AND FLOOR/CEILING ASSEMBLIES

MIN. IIC OF 50 (45 IF FIELD TESTED) FOR:

- FLOOR/CEILING ASSEMBLIES



Sound Insulation of Bare CLT Floors and Walls

Number of layers	Thickness (in.)	Wall or Floor	STC	IIC
3	3-3/4 to 4-1/2	Wall	32-34	N.A.
5	5-1/3	Floor	39	23
5	5-3/4	Floor	39	24
Measured on field bare CLT wall and floor				
Number of layers	Thickness in.	Assembly type	FSTC	FIIC
3	4-1/8	Wall	28	N.A.
7	8-1/5	Floor	N.A	25-30

Credit: US CLT Handbook

MASS TIMBER DESIGN

ACOUSTICS

Lightweight concrete topping or other similar materials can provide improved acoustical performance, increased durability

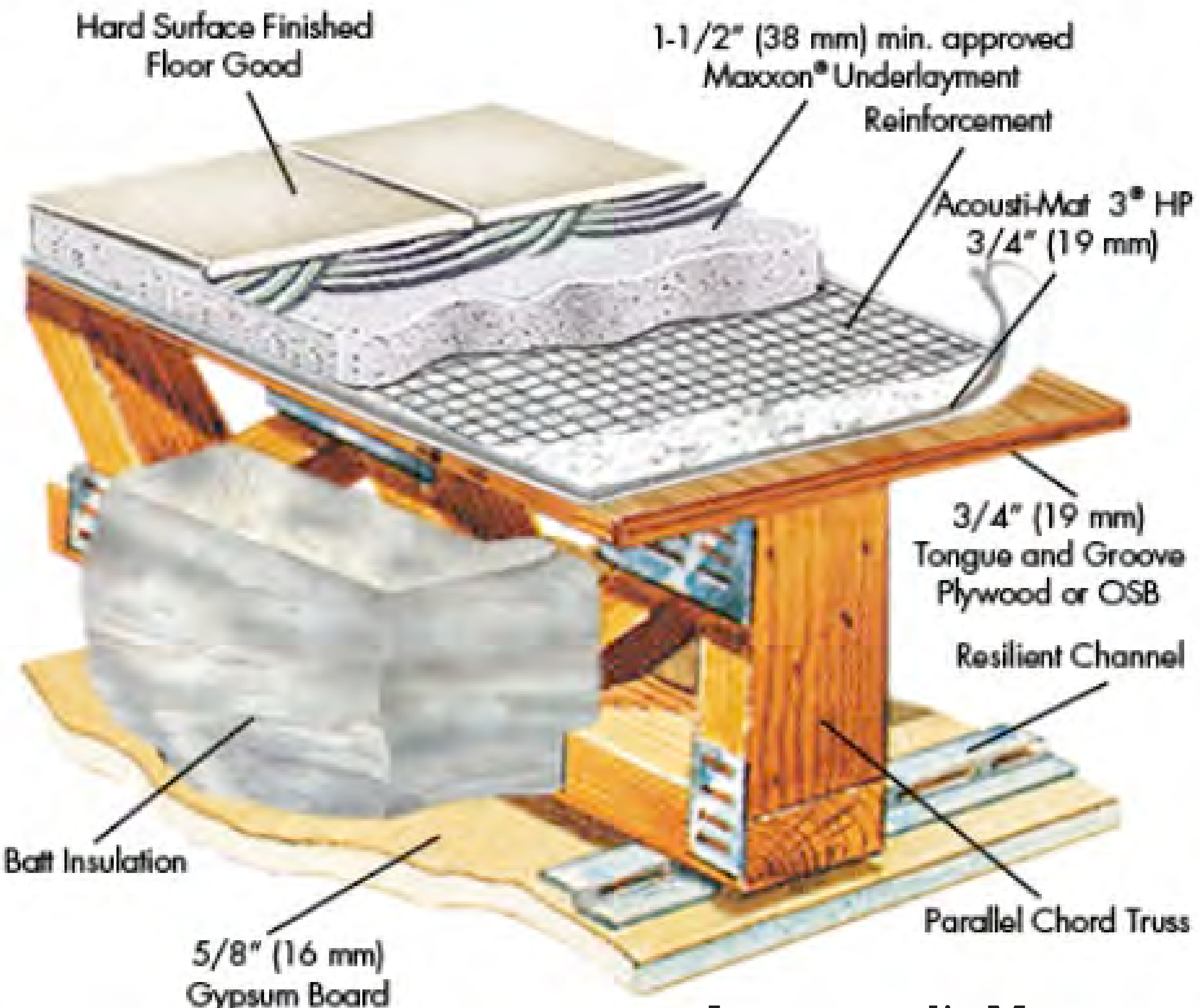


Image credit: Maxxon

MASS TIMBER DESIGN

ACOUSTICS

Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5” to 3” thick concrete/gypcrete topping
- Acoustical mat
- WSP (if applicable)
- Mass timber floor panels

Image credit: AcoustiTECH

MASS TIMBER DESIGN

ACOUSTICS

Options without concrete topping:

- Gypsum/cement board (Fermacell, Permabase, etc.)
- Proprietary products

Image credit: AcoustiTECH

MEP DETAILING

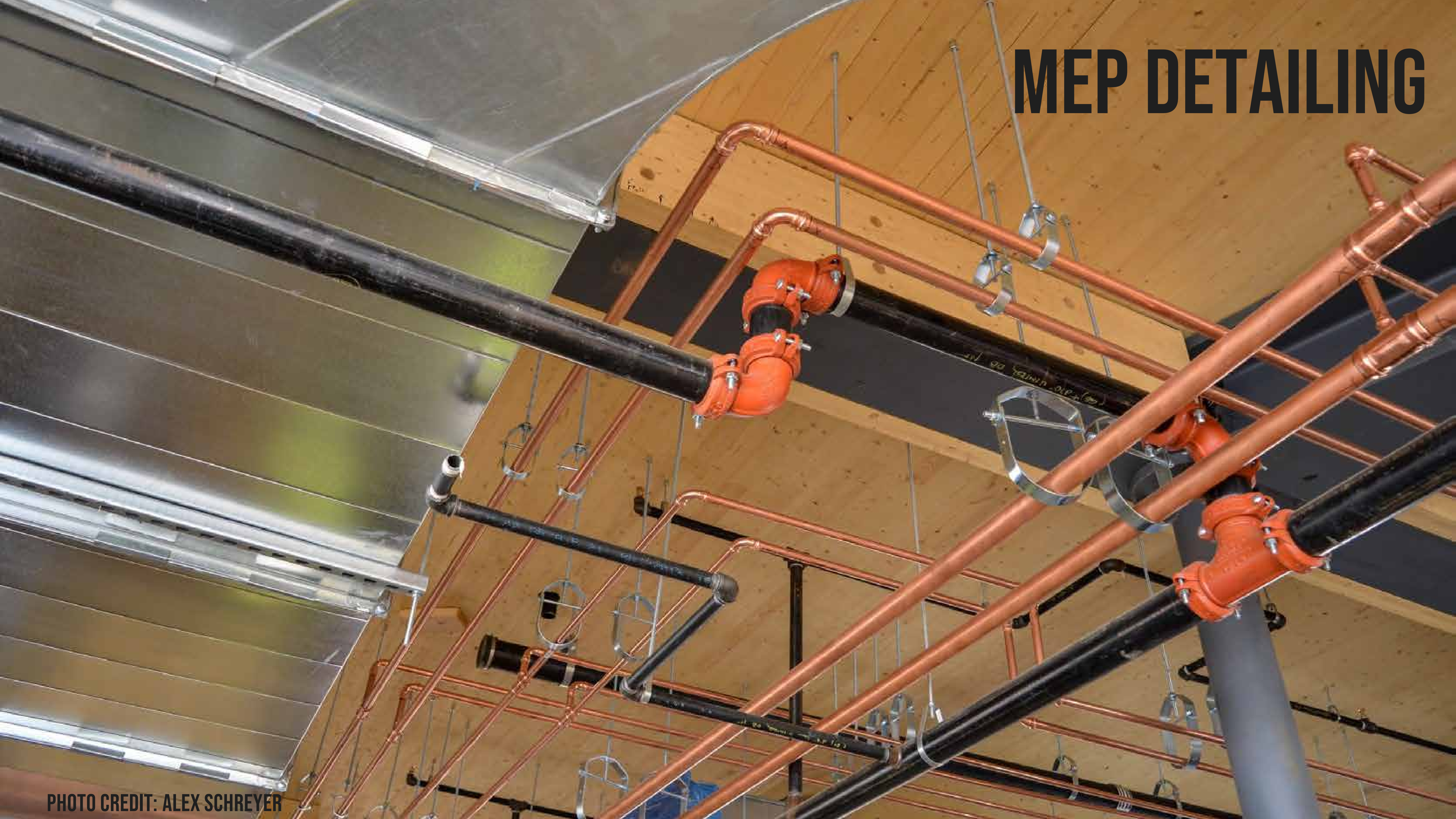


PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

ACCOMMODATING MEP

DUE TO EXPOSED MASS TIMBER STRUCTURE AND FINISH, UNIQUE MEP ACCOMMODATION SOLUTIONS ARE REQUIRED

IF USING TYPE IV CONSTRUCTION, NO CONCEALED SPACES ARE ALLOWED

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

PHOTO CREDIT: WOODWORKS

EXPOSED MEP

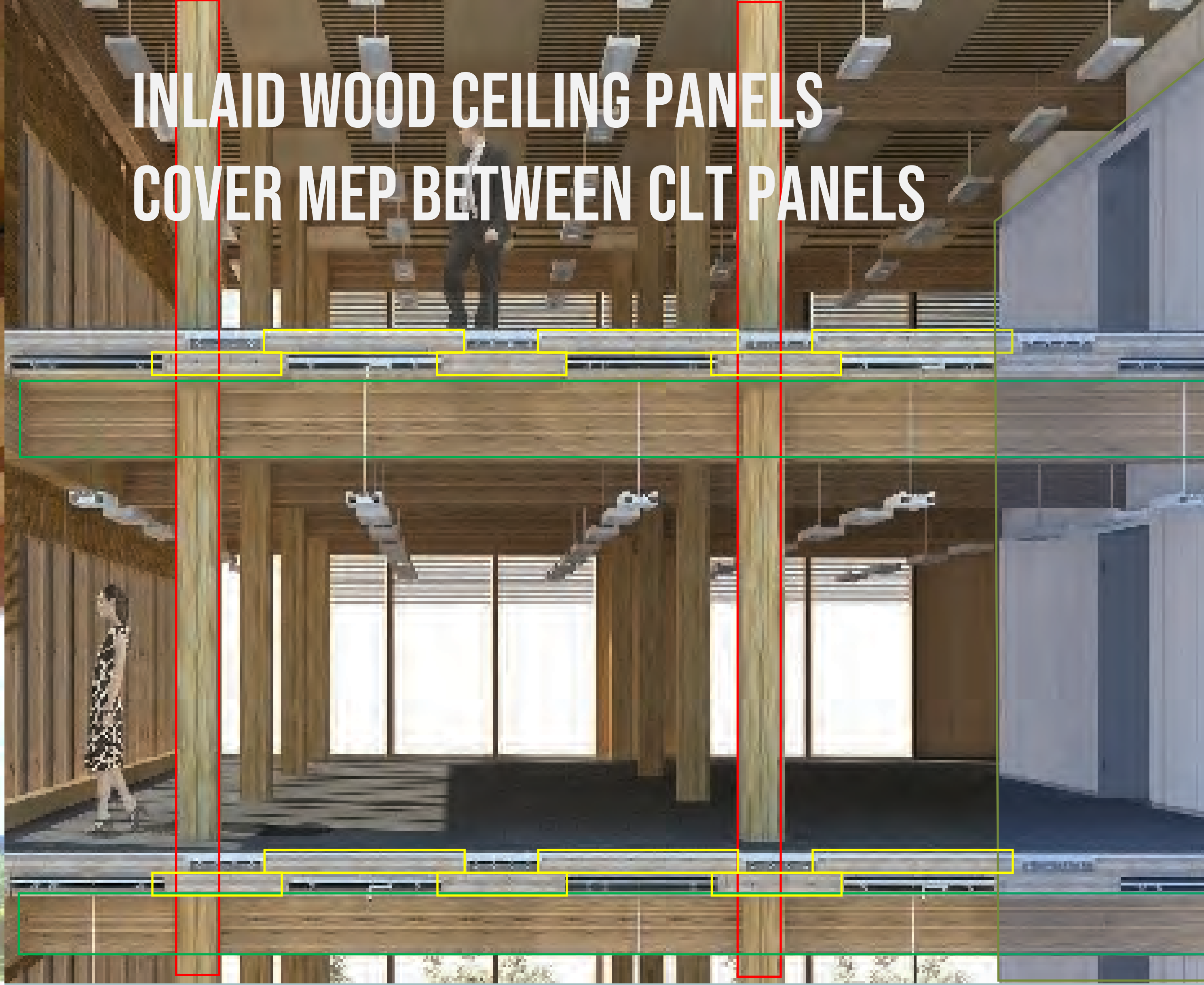
MEP ITEMS LEFT EXPOSED, USUALLY ON CEILING SIDE OF FLOOR ASSEMBLY

WOOD INNOVATION DESIGN CENTER

PRINCE GEORGE, BC

PHOTO CREDIT: ED WHITE

PHOTO CREDIT: MGA



WIDC MEP ACCOMMODATION

MASS TIMBER PRODUCTS

ACCOMMODATING MEP


Photo Credit: KK Law, Courtesy: naturally:wood


PHOTO CREDIT: WOODWORKS

RAISED ACCESS FLOOR

INSTALLED ON TOP OF FLOOR STRUCTURE

PROVIDES 2” TO 18” OF PLENUM SPACE FOR MEP

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

LATERAL CORE RESISTING SYSTEM:

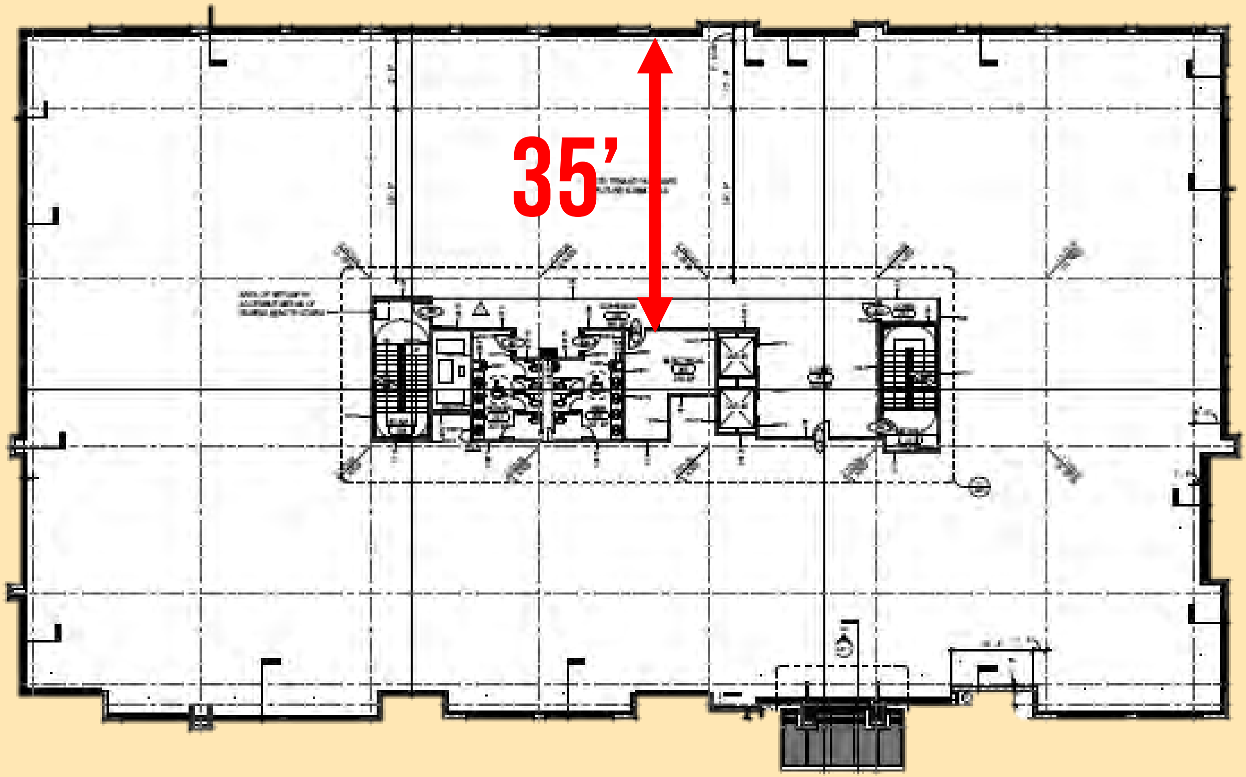
- COMMONLY USED WITH GLAZING/CURTAIN WALLS
- MAY USE RIGID OR SEMI-RIGID (IF USED WITH FRAMES AT EXTERIOR) ANALYSIS

LIGHT FRAME SHEARWALLS:

- TYPICAL FOR 1-5 STORIES
- TYPICALLY ASSUME FLEXIBLE DIAPHRAGM
- NEED AMPLE WALL AT PERIMETER

DIAPHRAGM DESIGN OPTIONS FOR CENTRAL CORE:

- AWC'S 2015 SPECIAL DESIGN PROVISIONS FOR WIND AND SEISMIC (SDPWS) 4.2.5.2 PERMITS A SEMI-RIGID OR RIGID, CANTILEVER DIAPHRAGM UP TO 35 FT
- IF MORE THAN 35FT, CONSIDER PERIMETER LATERAL RESISTANCE SUCH AS MOMENT FRAME



COURTESY OF ARCH NEXUS

MASS TIMBER DESIGN

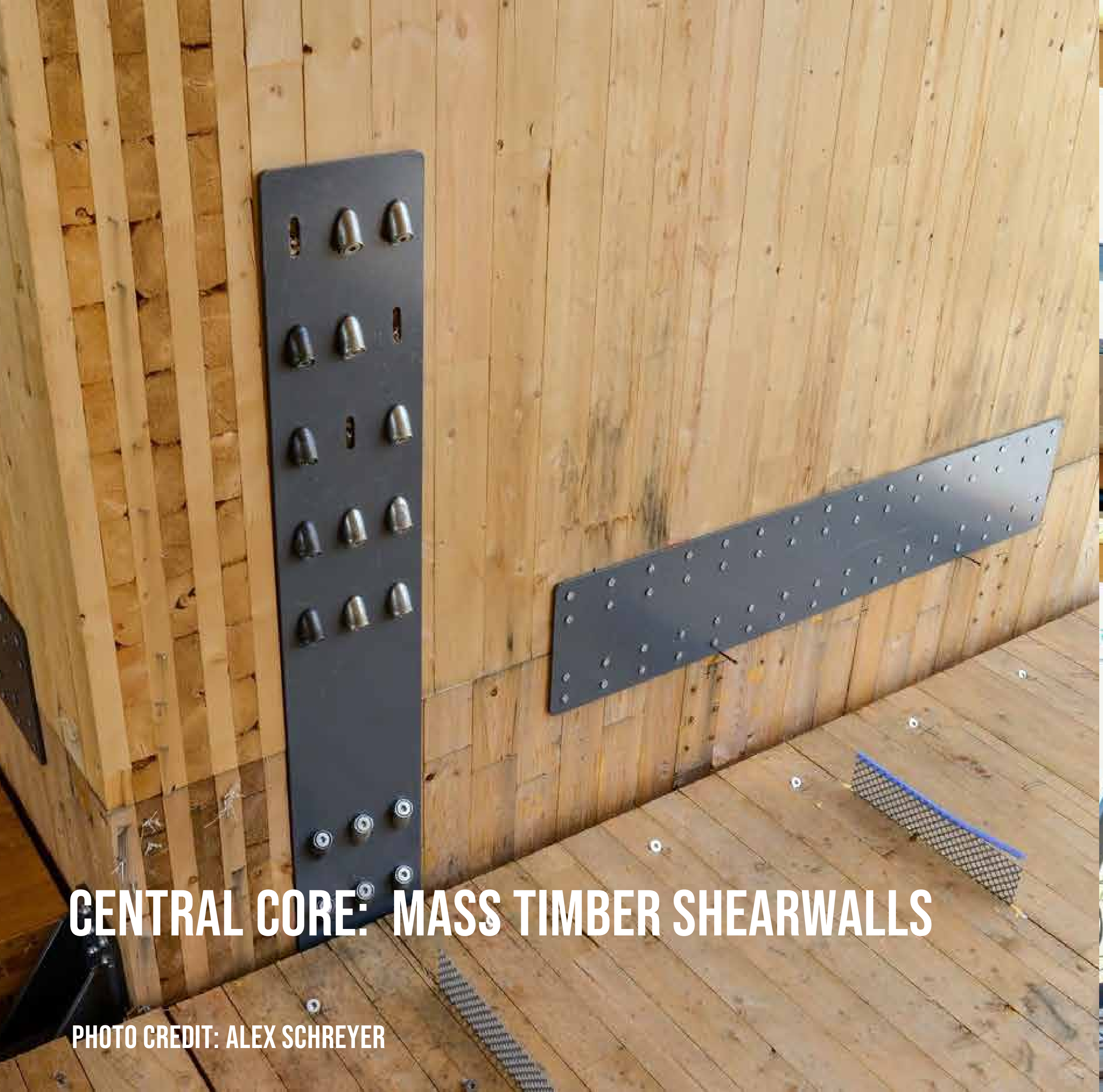
LATERAL FRAMING SYSTEMS

CENTRAL CORE: CONCRETE SHEARWALLS

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

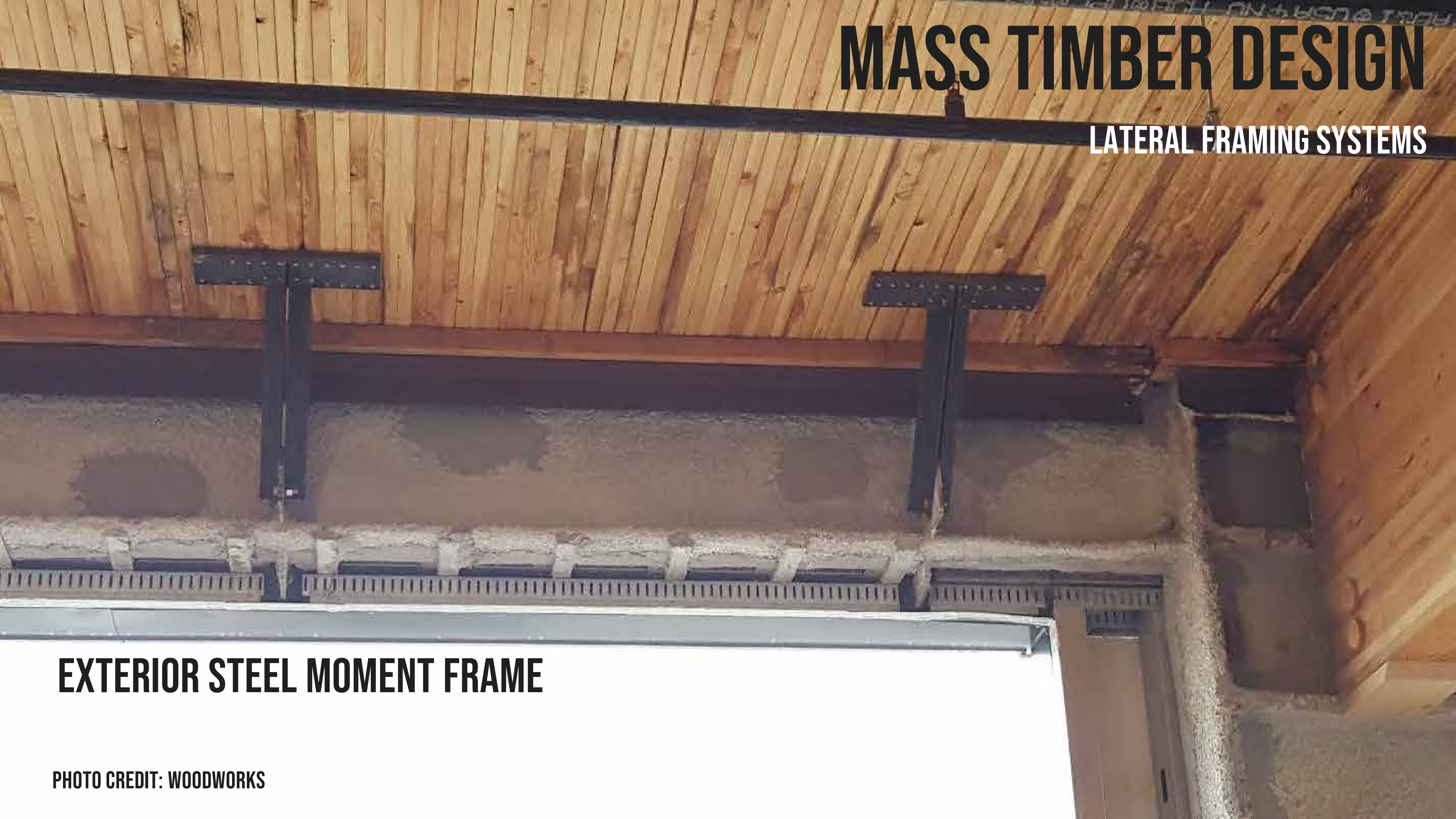


CENTRAL CORE: MASS TIMBER SHEARWALLS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS



EXTERIOR STEEL MOMENT FRAME

PHOTO CREDIT: WOODWORKS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

SHEATHED WOOD SHEARWALLS

PHOTO CREDIT: WOODWORKS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

PHOTO: ANDREAS SAUTER, TIM CLAY PHOTOGRAPHY

PHOTO CREDIT: KOMATSU/JAPAN

PROPRIETARY RIGID/SEMI-RIGID FRAMES

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

TIMBER BRACED FRAME

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

CONNECTION DESIGN CONSIDERATIONS:

- STRUCTURAL CAPACITY
- SHRINKAGE
- FIRE
- CONSTRUCTABILITY
- AESTHETICS
- COST

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

LONG SELF TAPPING SCREWS USED EXTENSIVELY THROUGHOUT MASS TIMBER CONSTRUCTION

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: MYTICON

BEAM TO BEAM CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

BEAM TO COLUMN CONNECTIONS

MASS TIMBER DESIGN

CONNECTIONS

COLUMN TO FOUNDATION CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: CHARLES JUDD

PANEL TO PANEL CONNECTIONS – SURFACE SPLINE

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

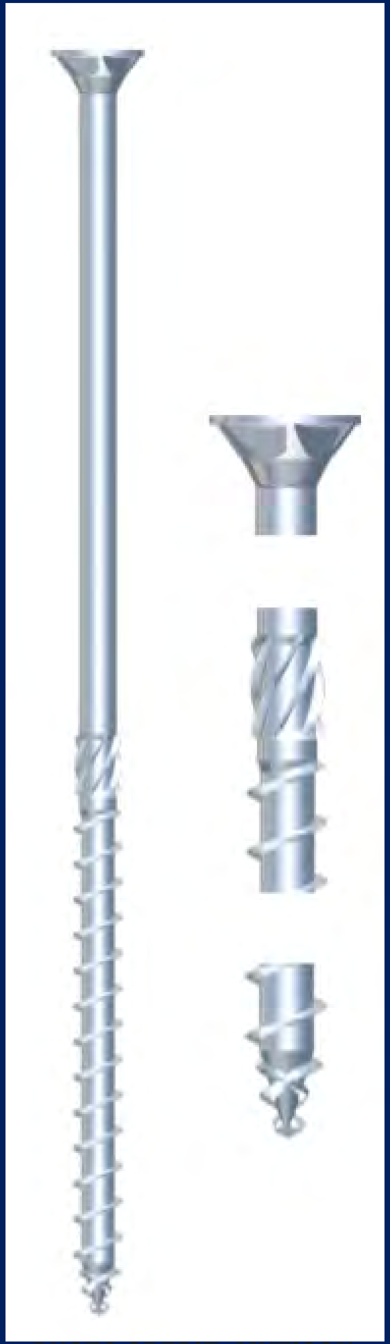


PHOTO CREDIT: MYTICON

PANEL TO BEAM CONNECTIONS

MASS TIMBER

SOURCING, CONSTRUCTION & COST CONSIDERATIONS

MASS TIMBER PRODUCTS

WORKING WITH MASS TIMBER: KNOW YOUR SUPPLY CHAIN

- MANUFACTURERS - DIFFERENT SPECIES, GRADES AND MAXIMUM PANEL/BEAM SIZES
- TRUCKING LOGISTICS AND COST
- MANUFACTURERS HAVE SPECIFIC CNC CAPABILITIES
- 3RD PARTY FABRICATORS CAN HAVE ADDITIONAL CNC CAPABILITIES

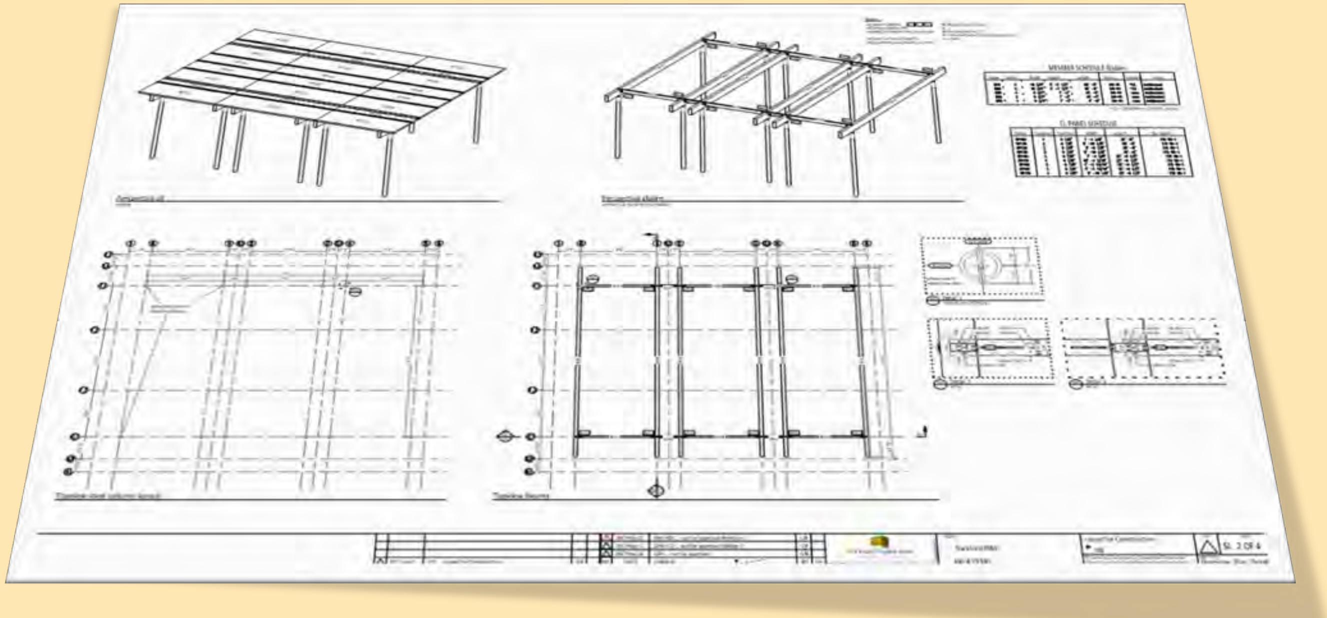
Photo: DR Johnson

Photo: Sauter Timber

MASS TIMBER PRODUCTS

DEFINE & COMMUNICATE THE DELIVERABLES YOU NEED FROM THE SUPPLIER:

- SHOP DRAWINGS
- SHOP DRAWINGS WITH ENGINEERING STAMP
- ENGINEERED DRAWINGS AND CALCULATIONS (E.G. AS A DEFERRED SUBMITTAL)

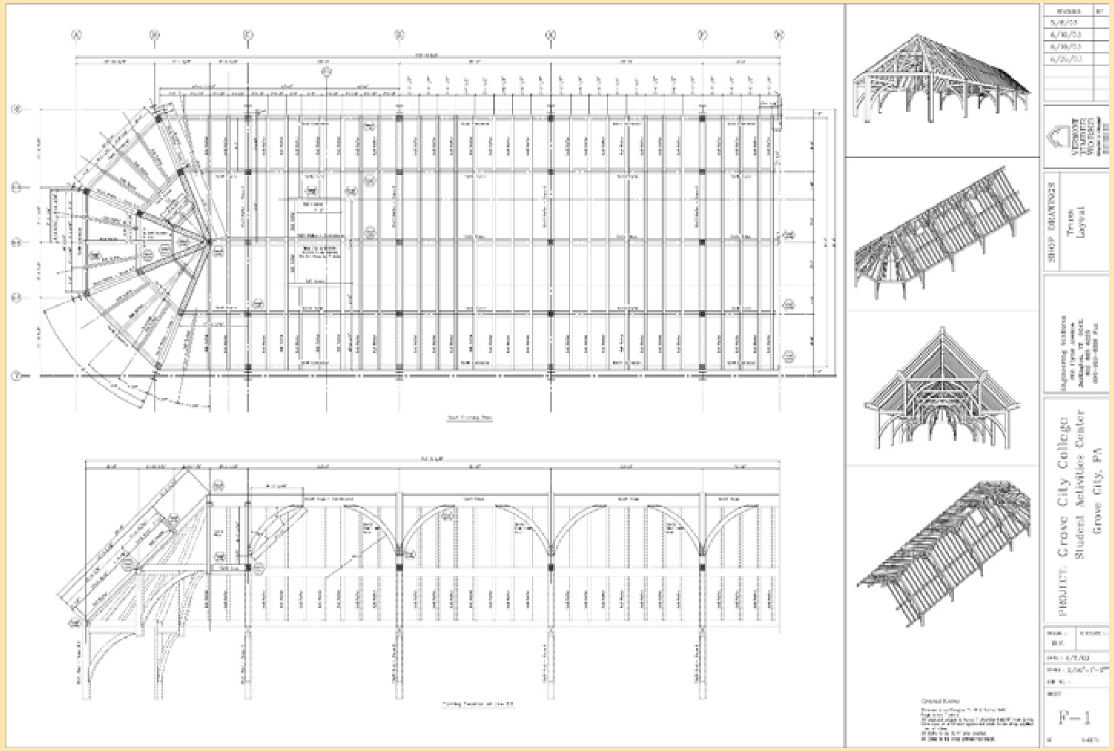


MASS TIMBER PRODUCTS

CONSTRUCTION

WHAT DOES A MASS TIMBER CONSTRUCTION PROCESS LOOK LIKE?

VERY SIMILAR TO A PRECAST CONCRETE OR STRUCTURAL STEEL PROJECT



- SHOP DRAWINGS
- ERECTION DRAWINGS
- PREFABRICATED MEMBERS AND CONNECTIONS

MASS TIMBER COSTS

MASS TIMBER CONSTRUCTION COSTS VARY WITH PROJECT LOCATION, SIZE, SPANS, FINISH LEVEL AND MANY OTHER VARIABLES

PRODUCT MANUFACTURERS ARE THE BEST SOURCE OF PRICING INFORMATION

MASS TIMBER COSTS

FACTORS RELEVANT TO THE COST CONVERSATION:

- CURE TIME: MASS TIMBER HAS NONE. CAN BE WORKED ON IMMEDIATELY AFTER BEING PLACED
- LIGHT-WEIGHT:
- CRANE SIZE: MASS TIMBER IS LIGHTER THAN TRADITIONAL MATERIALS[7]. SMALLER CRANE = POTENTIAL SAVINGS
- SMALLER SEISMIC FORCES & FOUNDATIONS = POTENTIAL SAVINGS
- CONSTRUCTION SPEED: ESTIMATED TO BE 25% FASTER[11]. SOONER COMPLETION = SOONER OCCUPANCY = SOONER REVENUE
- OTHERS: LESS CONSTRUCTION TRAFFIC[11], PREFABRICATED & PRECISE – GOES TOGETHER SMOOTHLY
- OTHER ITEMS THAT AFFECT COST: SHIPPING DISTANCE, SEALERS/SANDING REQUIREMENTS, AMOUNT OF CUSTOM CNC WORK

SOURCE 7: STRUCTURLAM
SOURCE 11: FAST + EPP
PHOTO CREDIT: STRUCTURLAM


TIME FOR
CASE STUDY
12
9
3
6

COMMON GROUND HIGH SCHOOL

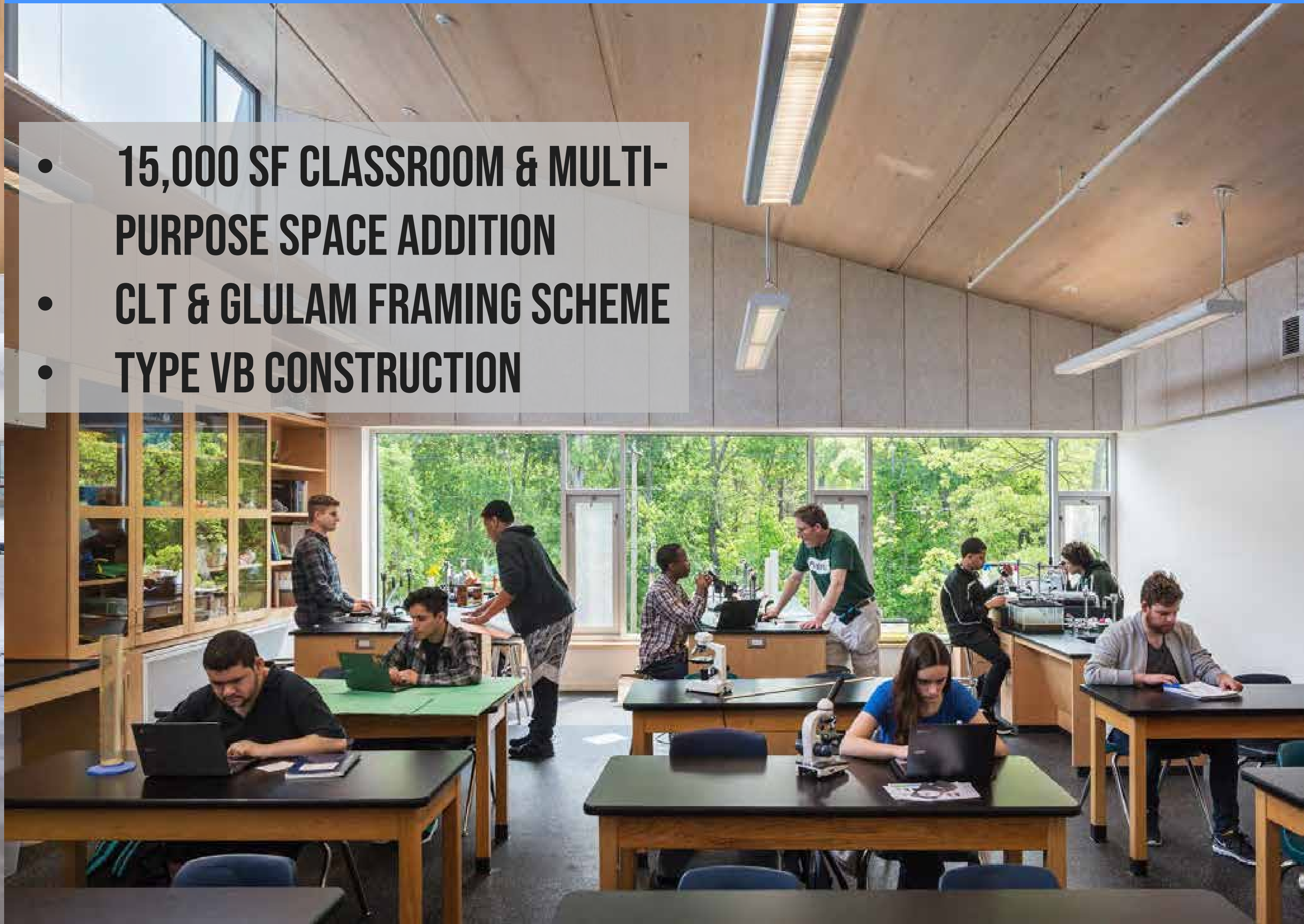
NEW HAVEN, CT

PHOTO CREDIT: DAVID SUNDBERG AND GRAY ORGANSCHI ARCHITECTURE

COMMON GROUND HIGH SCHOOL

NEW HAVEN, CT

PHOTO CREDIT: DAVID SUNDBERG AND GRAY ORGANSCHI ARCHITECTURE



- 15,000 SF CLASSROOM & MULTI-PURPOSE SPACE ADDITION
- CLT & GLULAM FRAMING SCHEME
- TYPE VB CONSTRUCTION

COMMON GROUND HIGH SCHOOL

NEW HAVEN, CT

PHOTO CREDIT: DAVID SUNDBERG AND GRAY ORGANSCHI ARCHITECTURE


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

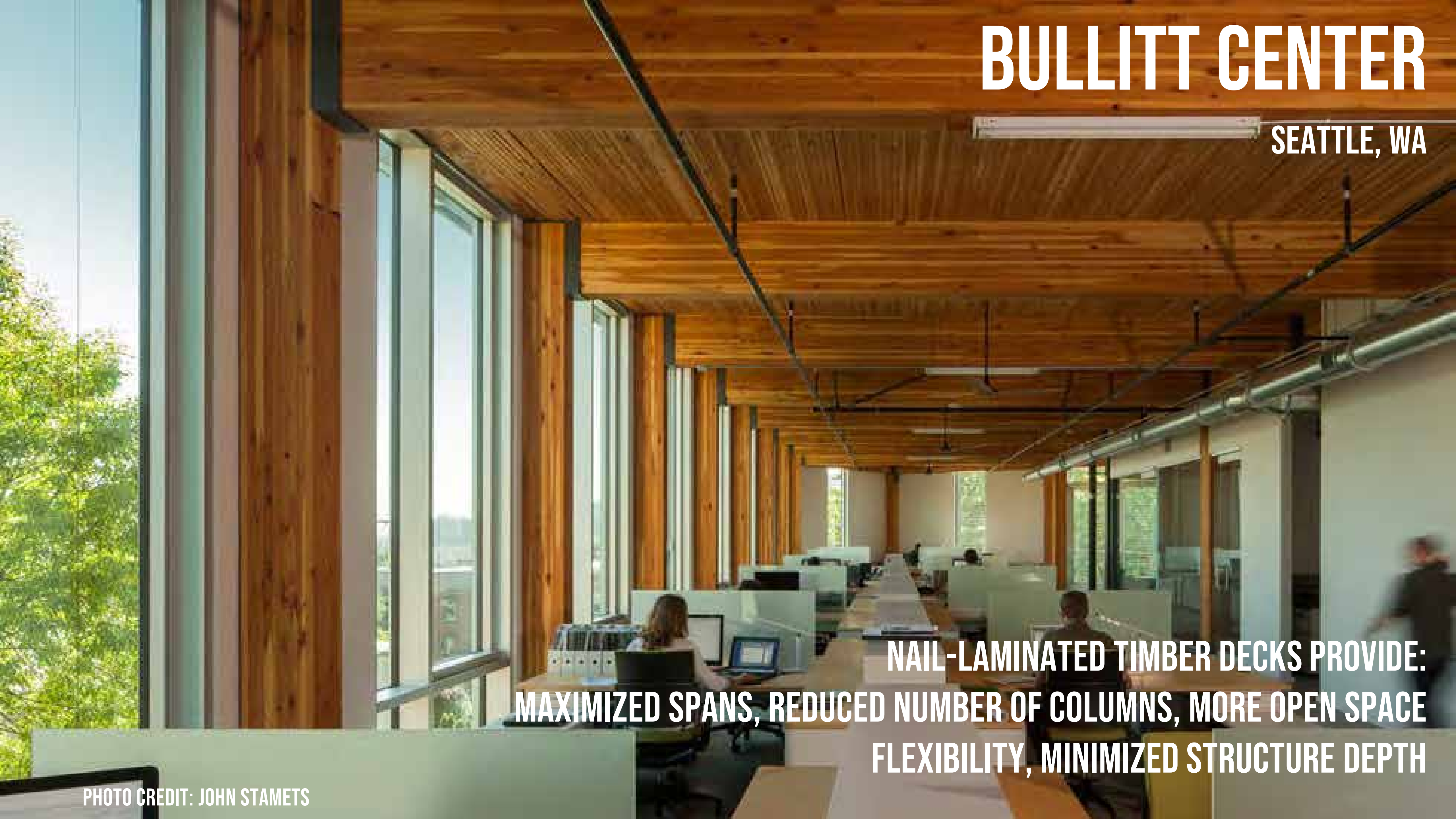
HEAVY TIMBER, CONCRETE & STEEL

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

CHICAGO HORIZON PAVILION

CHICAGO, IL

PHOTO CREDIT: TOM HARRIS

CHICAGO HORIZON PAVILION

CHICAGO, IL

56’ SQUARE KIOSK

2 LAYERS OF 3-PLY, 4-1/8” CLT ROOF PANELS IN OPPOSITE DIRECTIONS, EACH PANEL 8’ X 56’, CREATING 2 WAY SPANNING PLATE

PHOTO CREDIT: TOM HARRIS

CHICAGO HORIZON PAVILION

CHICAGO, IL

TOTAL ROOF STRUCTURE THICKNESS
8-1/4"
SPANS UP TO 30 FEET BETWEEN
COLUMNS AT ISOLATED POINTS

PHOTO CREDIT: AARON FORREST

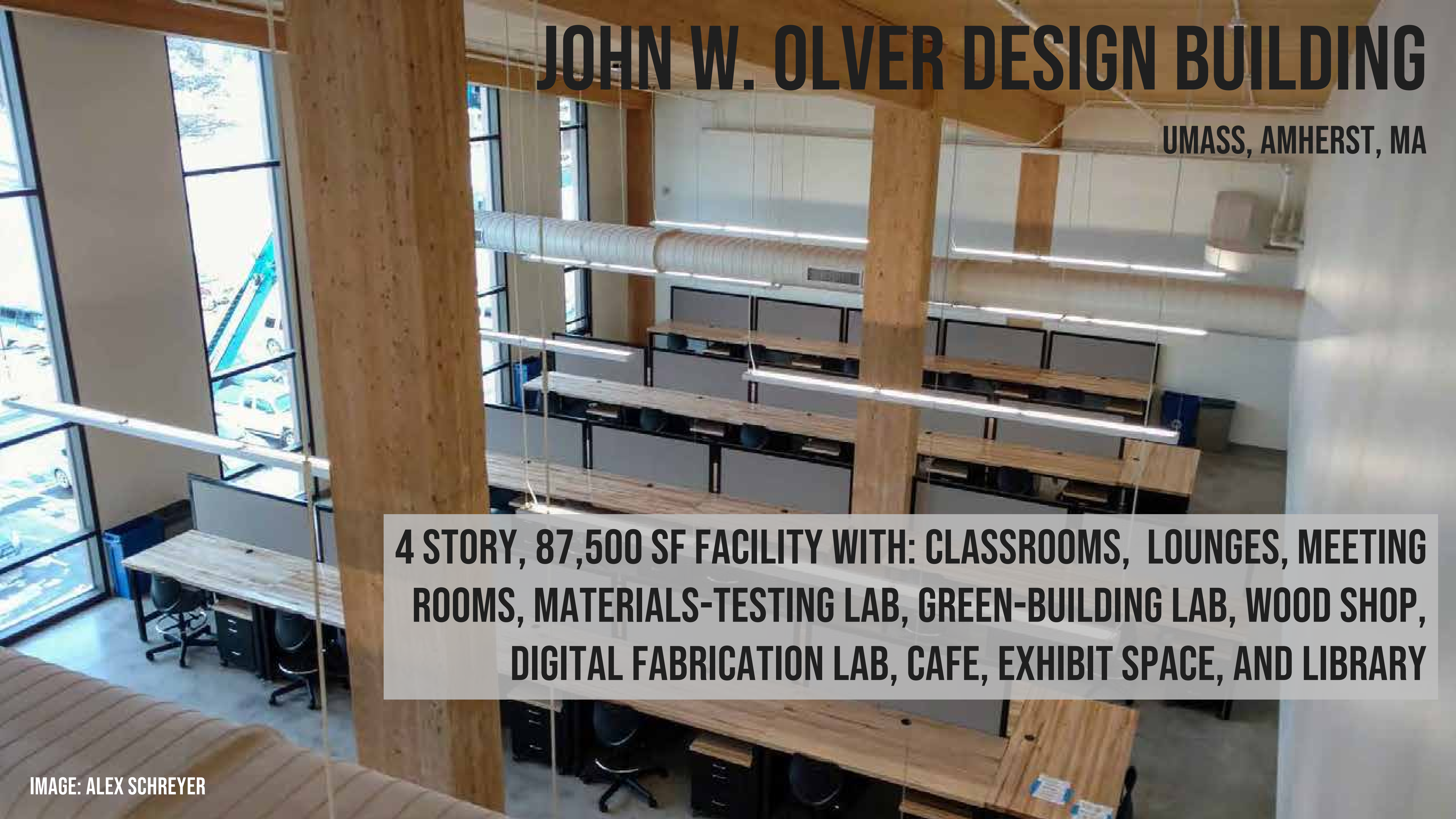
UMASS DESIGN BUILDING

AMHERST, MA

IMAGE CREDIT: ALEX SCHREYER

JOHN W. OLVER 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

» 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

U.S. BUILDING CODE STATUS

New Building Types

INTRO, CLEVELAND
9 Stories | 115 ft
8 Timber Over 1 Podium
512,000 SF
297 Apartments, Mixed-Use
Photo: Harbor Bay Real Estate Advisors, Purple Film | Architect: Hartshorne Plunkard Architecture

INTRO, CLEVELAND

9 Stories | 115 ft

8 Timber Over 1 Podium

Type IV-B

Variance to expose ~50% ceilings

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

ASCENT, MILWAUKEE

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

493,000 SF

259 APARTMENTS, MIXED-USE

ASCENT, MILWAUKEE
Tallest Mass Timber Building in the World

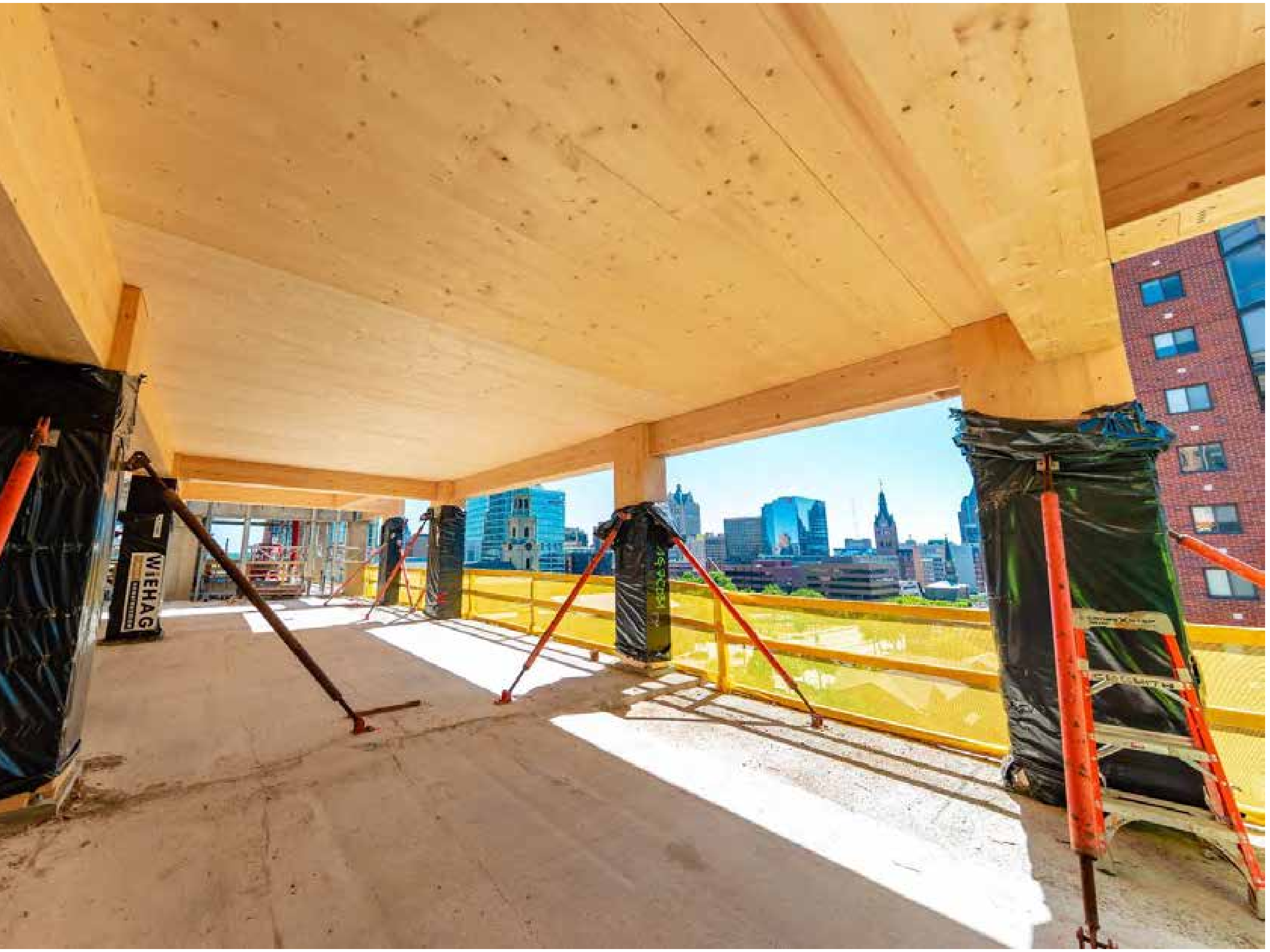


Photo: CD Smith Construction |
Architect: Korb & Associates Architects

ASCENT, MILWAUKEE

25 STORIES

19 TIMBER OVER 6 PODIUM, 284 FT

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

80 M ST, WASHINGTON, DC

Photo: Hickok Cole | Architect: Hickok Cole

80 M ST, WASHINGTON, DC

3 STORY VERTICAL ADDITION
7 STORY EXISTING BUILDING

Photo: WoodWorks | Architect: Hickok Cole

80 M ST, WASHINGTON, DC

100,000 SF

2 NEW LEVELS OF CLASS A OFFICE SPACE

OCCUPIED PENTHOUSE

17’-0” CEILING HEIGHTS

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Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Speaker Name

Contact info

PHOTO CREDIT: TOM HARRIS

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Thank You

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