Mass Timber Construction: Products, Performance and Design

Speaker Name

WoodWorks

T3 Minneapolis
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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

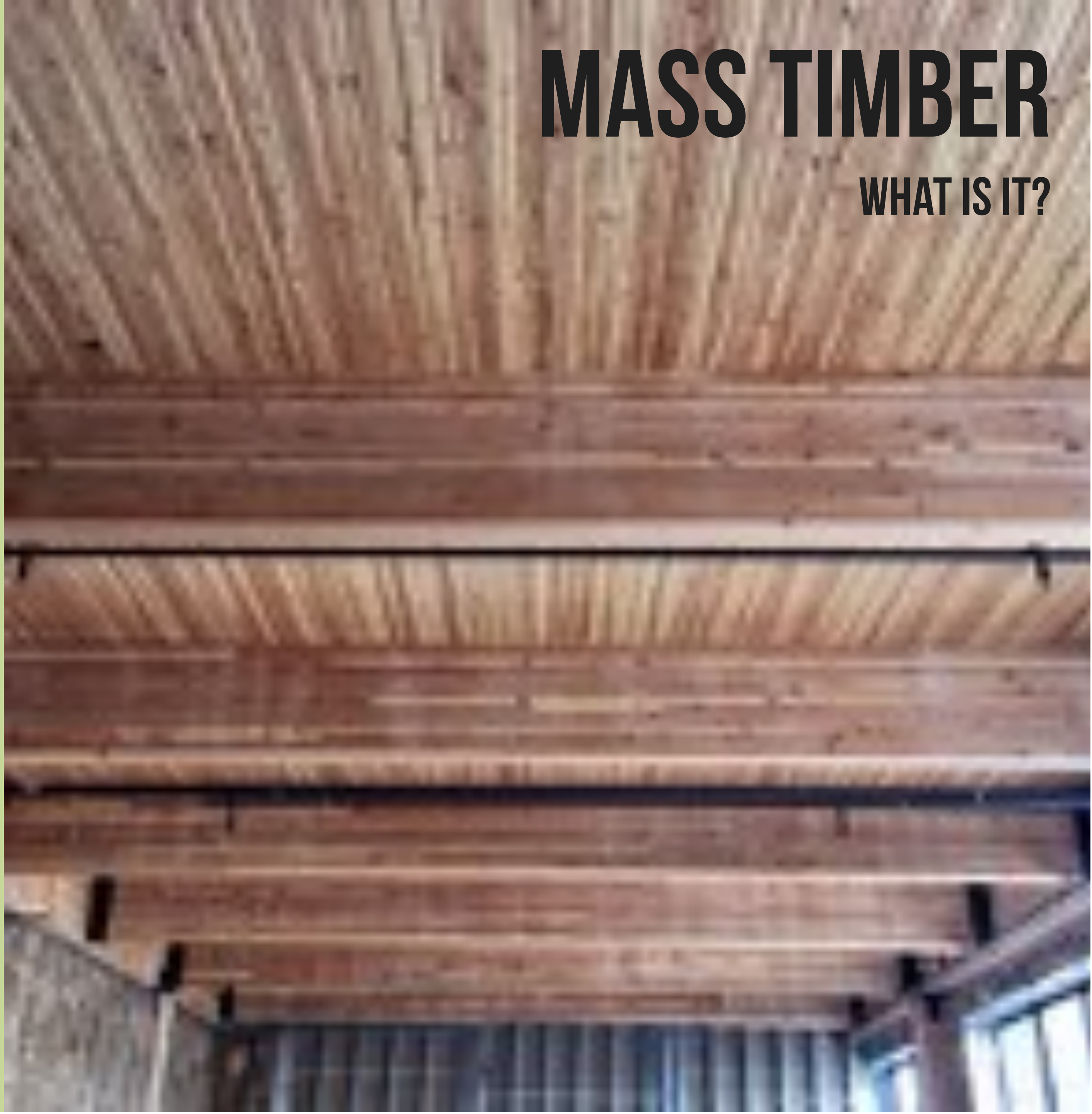
MASS TIMBER

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

MASS TIMBER

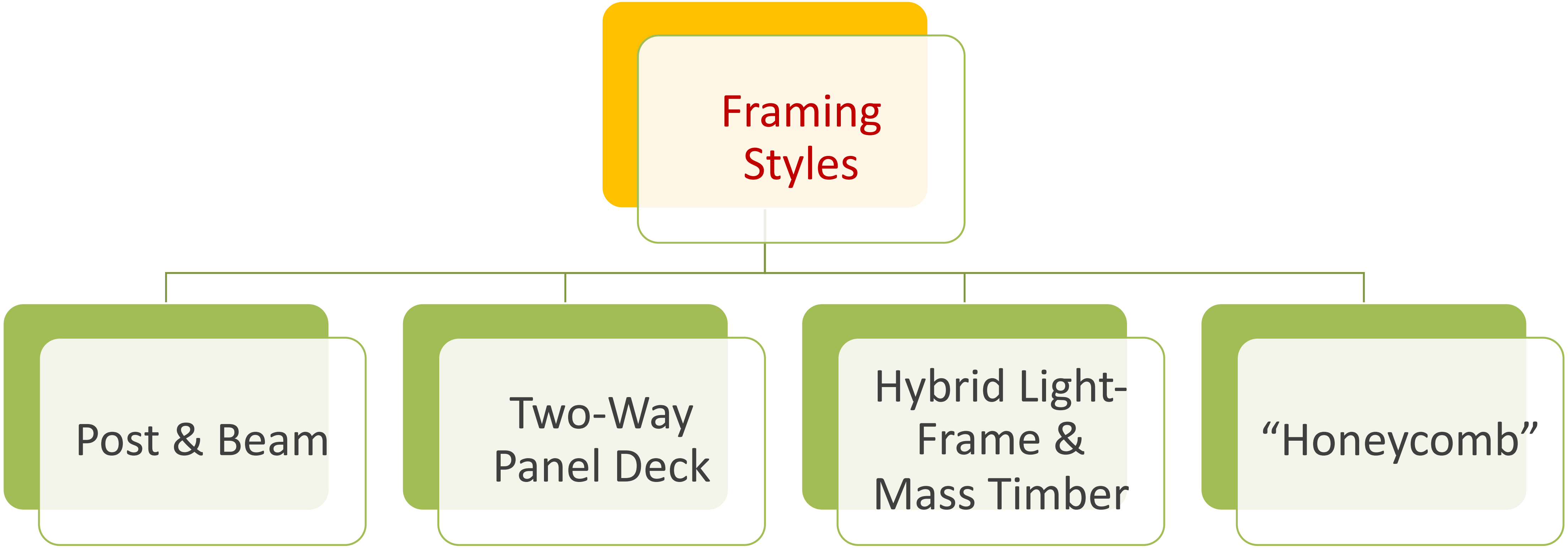
WHAT IS IT?

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

Mass Timber Framing 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

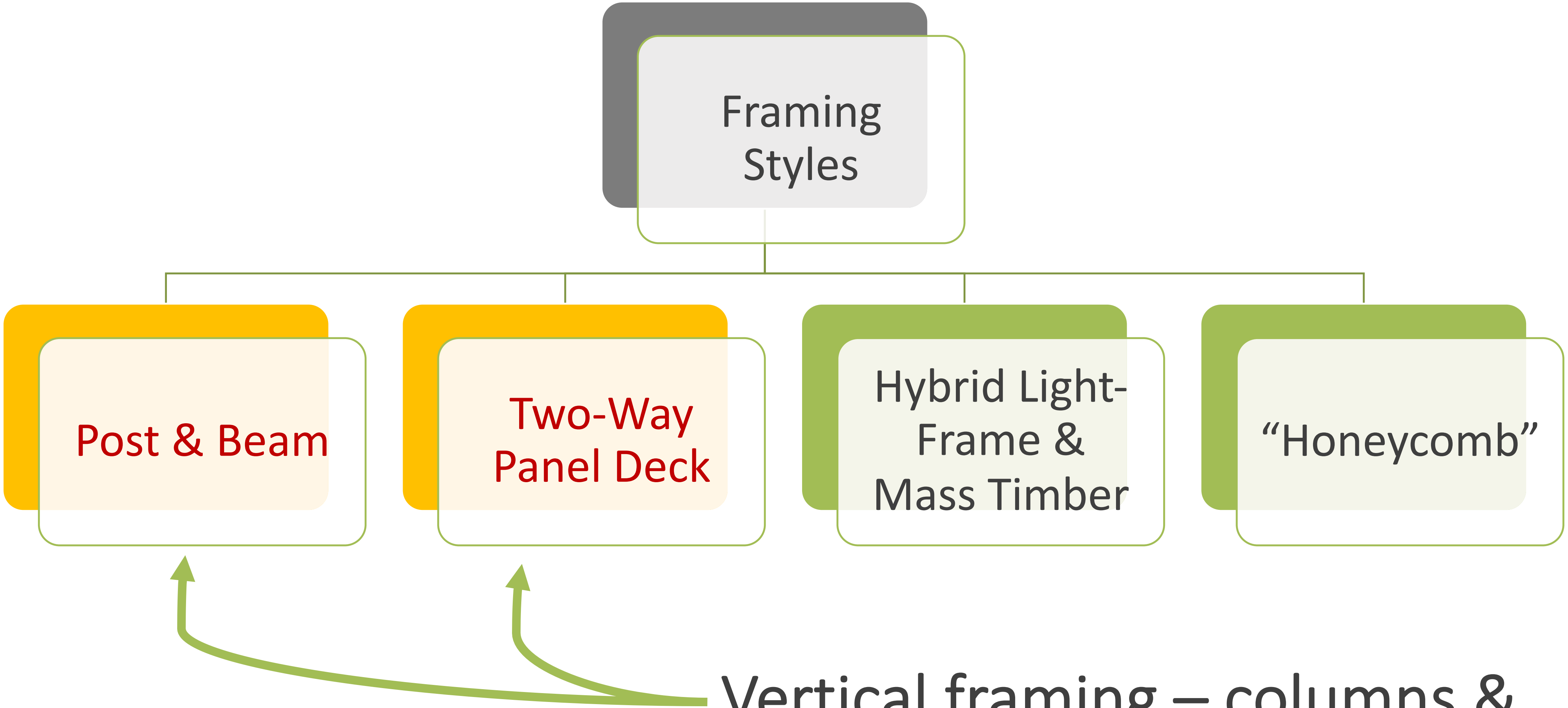
VIRTUOSO
VANCOUVER, BC
IMAGE: SEAGATE STRUCTURES

HONEYCOMB

CANDLEWOOD SUITES
REDSTONE ARESENAL, AL
IMAGE CREDIT: LENDLEASE

What’s in a mass timber building?
Products used

Mass Timber Framing Systems



Vertical framing – columns & beams - is commonly glulam

MASS TIMBER PRODUCTS

GLULAM

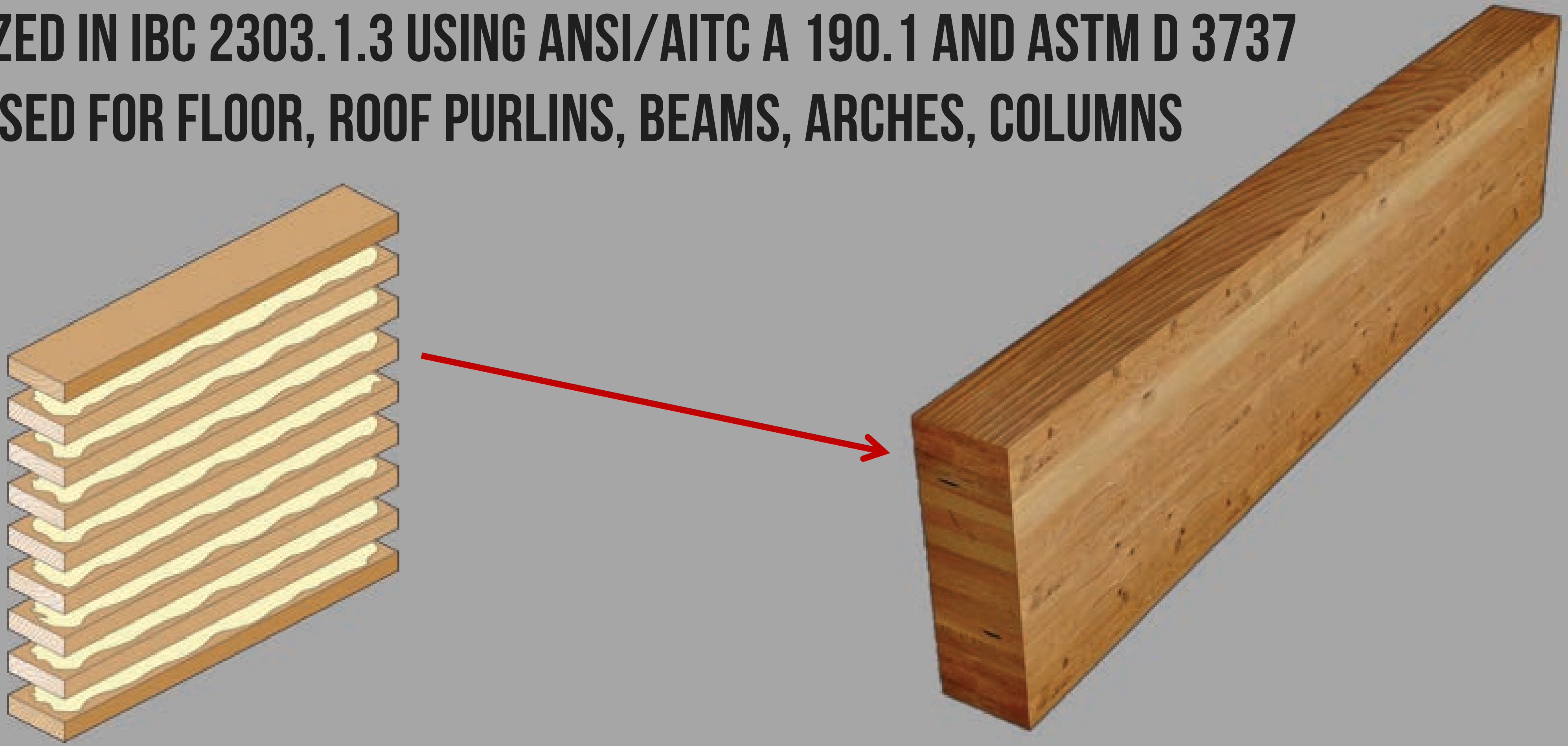
PHOTO CREDIT: ALEX SCHREYER

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

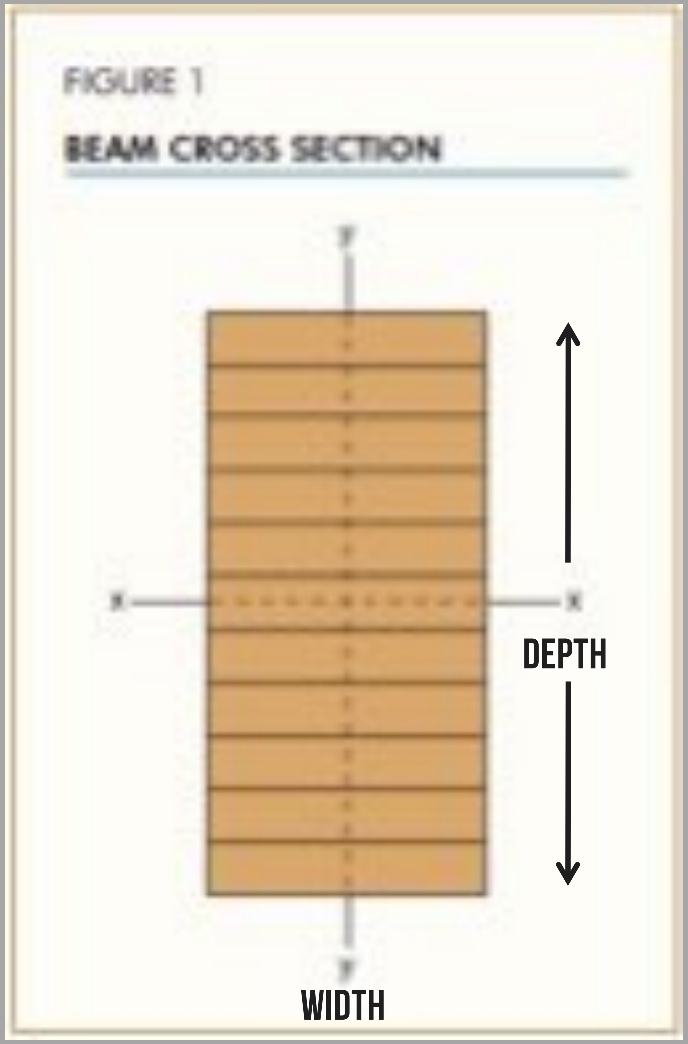
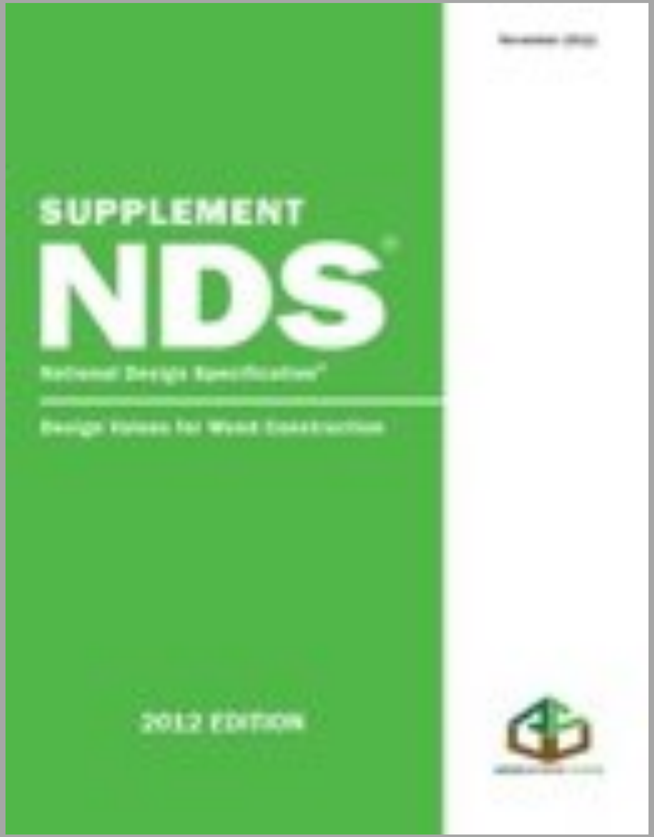


IMAGE: APA GLULAM PRODUCT GUIDE

GLULAM DESIGN VALUES

		Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)						
		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
Combination Symbol	Species Outer/ 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)
24F-1.8E		**2400**	**1450**	**650**		**265**	**1.8**	**0.95**
24F-V4	DF/DF	2400	1850	650	650	265	1.8	0.95
24F-V8	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-E4	DF/DF	2400	1450	650	650	265	1.8	0.95
24F-E13	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-E18	DF/DF	2400	2400	650	650	265	1.8	0.95
24F-V3	SP/SP	2400	2000	740	740	300	1.8	0.95
24F-V8	SP/SP	2400	2400	740	740	300	1.8	0.95
24F-E1	SP/SP	2400	1450	805	650	300	1.8	0.95
24F-E4	SP/SP	2400	2400	805	805	300	1.9	1.00



SOURCE: NDS SUPPLEMENT TABLE 5A

MASS TIMBER PRODUCTS

GLULAM

GLULAM BEAM CAPACITIES

TABLE DF-27

DOUGLAS FIR - LARCH — **THE AMERICAN INSTITUTE OF TIMBER CONSTRUCTION**

Structural Glued Laminated Timber

FLOOR BEAMS

FLOOR LIVE LOAD

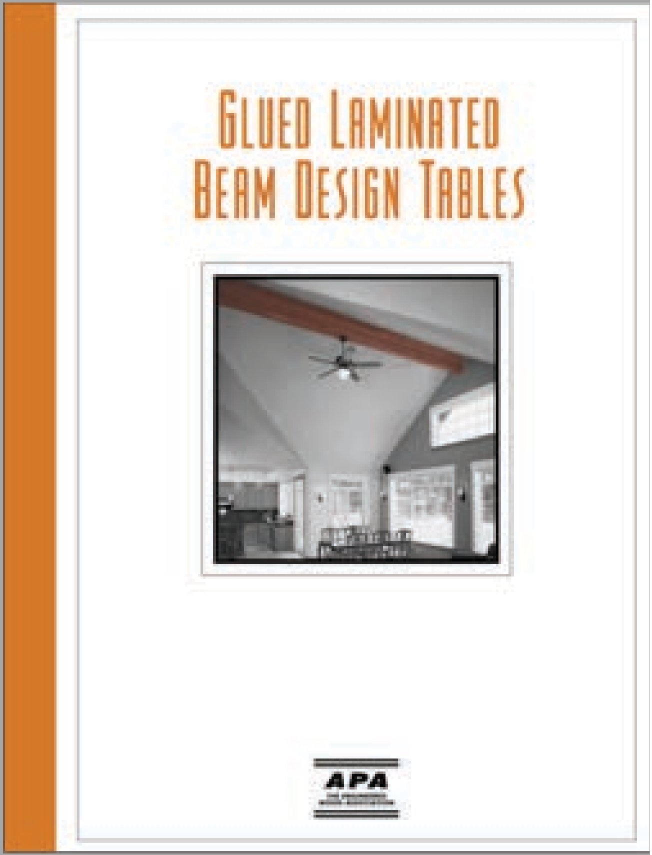
F_b	F_v	E	C_D	Deflection limit
2400 psi	240 psi	1.8 million psi	1.00	Span / 360 for LIVE LOAD

Simple Span Beams
For Preliminary Design Purposes
Lamination thickness: 1.500 in.

FLOOR LOAD FACTOR = 0.80

BEAM CAPACITY, UNIFORM LOAD w, plf

BEAM SIZE Width b, in.	Depth d, in.	BEAM WEIGHT plf	SPAN, ft 8	9	10	11	12	13	14	15	16	17	18	19	20	21
5 1/8	6	7.5	601 D	422 D	307 D	231 D	178 D	140 D	112 D	91 D	—	—	—	—	—	—
5 1/8	7 1/2	9.3	1173 D	824 D	601 D	451 D	348 D	273 D	219 D	178 D	147 D	122 D	103 D	—	—	—
5 1/8	9	11.2	1730 B	1367 B	1038 D	780 D	601 D	472 D	378 D	307 D	253 D	211 D	178 D	151 D	130 D	112 D
5 1/8	10 1/2	13.1	2354 B	1860 B	1507 B	1238 D	954 D	750 D	601 D	488 D	402 D	335 D	283 D	240 D	206 D	178 D
5 1/8	12	14.9	3075 B	2430 B	1968 B	1626 B	1367 B	1120 D	896 D	729 D	601 D	501 D	422 D	359 D	307 D	266 D
5 1/8	13 1/2	16.8	3850 S	3075 B	2491 B	2058 B	1730 B	1474 B	1271 B	1038 D	855 D	713 D	601 D	511 D	438 D	378 D
5 1/8	15	18.7	4473 S	3785 S	3075 B	2541 B	2135 B	1820 B	1569 B	1367 B	1173 D	978 D	824 D	700 D	601 D	519 D
5 1/8	16 1/2	20.6	5154 S	4330 S	3721 B	3075 B	2584 B	2202 B	1898 B	1654 B	1447 B	1274 B	1097 D	932 D	799 D	691 D
5 1/8	18	22.4	5904 S	4920 S	4217 S	3660 B	3075 B	2620 B	2259 B	1964 B	1707 B	1503 B	1333 B	1190 B	1038 D	896 D
5 1/8	19 1/2	24.3	6000 *	5562 S	4738 S	4126 S	3609 B	3073 B	2630 B	2275 B	1987 B	1750 B	1552 B	1385 B	1244 B	1123 B
5 1/8	21	26.2	6000 *	6000 *	5298 S	4592 S	4052 S	3538 B	3028 B	2620 B	2288 B	2014 B	1786 B	1595 B	1432 B	1292 B
5 1/8	22 1/2	28.0	6000 *	6000 *	5904 S	5090 S	4473 S	3989 S	3452 B	2986 B	2608 B	2296 B	2036 B	1818 B	1632 B	1473 B
5 1/8	24	29.9	6000 *	6000 *	6000 *	5623 S	4920 S	4373 S	3902 B	3376 B	2948 B	2596 B	2302 B	2055 B	1845 B	1665 B
5 1/8	25 1/2	31.8	6000 *	6000 *	6000 *	6000 *	5396 S	4779 S	4289 S	3788 B	3308 B	2913 B	2583 B	2306 B	2070 B	1869 B



SOURCE: APA

AITC BEAM CAPACITY TABLES HTTP://WWW.AITC-GLULAM.ORG/CAPACITY.ASP

S = CONTROLLED BY SHEAR, D = CONTROLLED BY DEFLECTION, B = CONTROLLED BY BENDING

MASS TIMBER PRODUCTS

GLULAM COLUMN CAPACITIES

GLULAM

American Institute of Timber Construction

Glued Laminated Timber Columns with Eccentric End Loads*

Combination 47 (SP N2M)** — **Duration of Load (C_D) = 1.00**

Lamination Thickness = 1- 3/8 in. — **Dry Conditions of Use**

Width (in) / Depth (in)	3 / 4 1/8	3 / 5 1/2	5 / 4 1/8	5 / 5 1/2	5 / 6 7/8	6 3/4 / 5 1/2	6 3/4 / 6 7/8	6 3/4 / 8 1/4	8 1/2 / 8 1/4	Width (in) / Depth (in)
Length (ft)	Column Capacity (lb)									Length (ft)
4	8350	13900	14270	24690	32110	33690	43720	53390	67420	4
5	7410	11260	13370	23420	30710	31780	42120	51920	65700	5
6	6240	9020	12300	21700	28950	29600	40230	50160	63660	6
7	5180	7300	11100	19780	26820	27200	38100	48090	61320	7
8	4310	6000	9860	17780	24000	24700	35770	45730	58730	8
9	3620	5000	8680	15860	21050	22230	33300	43090	55930	9
10	3080	4230	7630	14110	18470	19930	30760	40210	52950	10
11	2640	3610	6720	12580	16270	17870	28250	37230	49840	11
12	2290	3120	5940	11240	14400	16050	25870	34210	46680	12
13	--	--	5280	10090	12810	14460	23680	31060	43550	13
14	--	--	4720	9090	11460	13080	21690	28250	40520	14
15	--	--	4240	8220	10300	11860	19890	25750	37670	15
16	--	--	3830	7440	9300	10800	18290	23530	35020	16
17	--	--	3470	6750	8440	9870	16850	21570	32580	17
18	--	--	--	6150	7690	9050	15560	19820	30340	18
19	--	--	--	5620	7030	8320	14400	18270	28290	19
20	--	--	--	5160	6450	7680	13360	16890	26420	20

AITC COLUMN CAPACITY TABLES HTTP://WWW.AITC-GLULAM.ORG/COLUMN.ASP

MASS TIMBER PRODUCTS

GLULAM

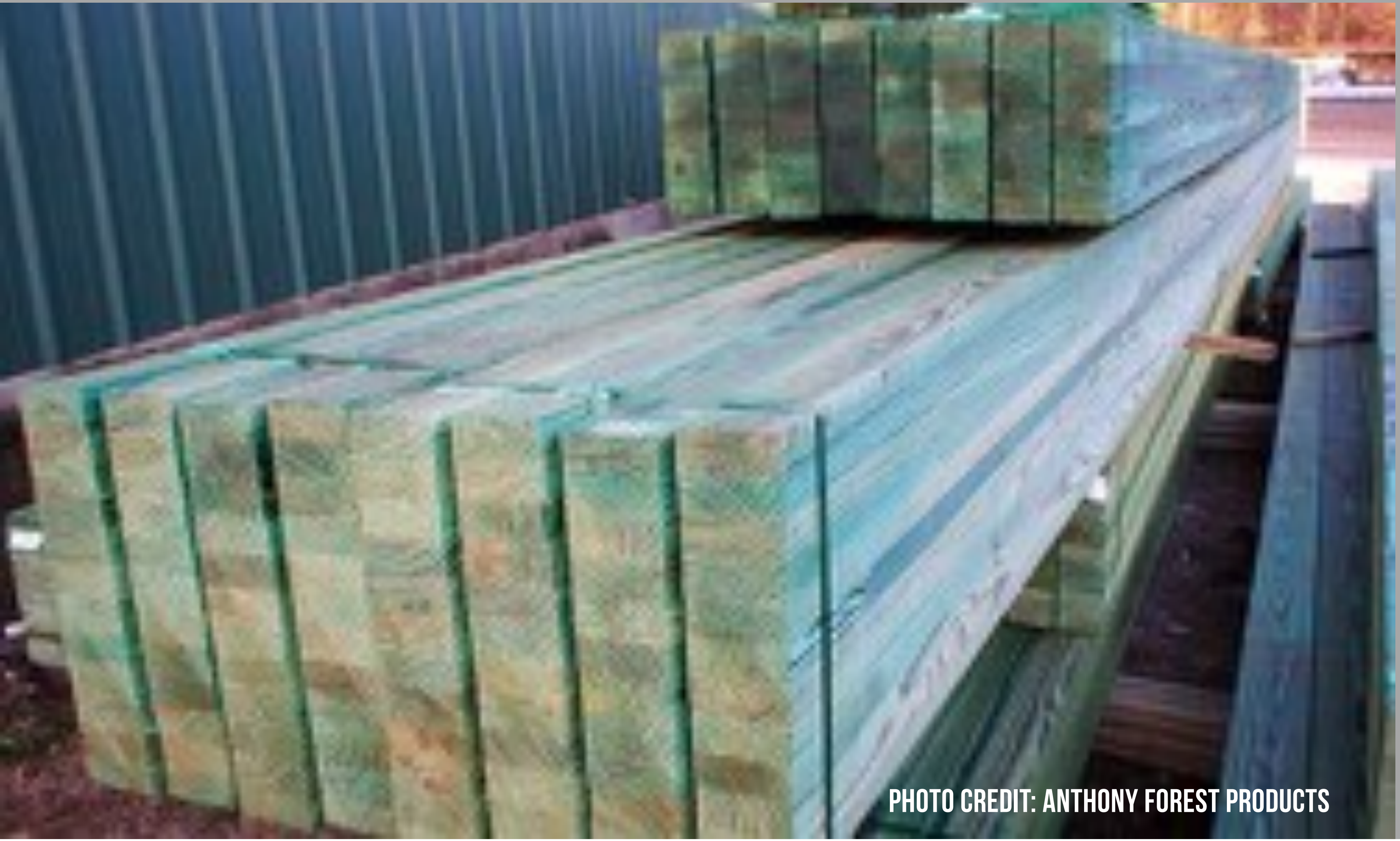


PHOTO CREDIT: ANTHONY FOREST PRODUCTS

GLULAM SPECS:

PT READILY AVAILABLE
FRT MAY BE AVAILABLE, VARIES BY MANUFACTURER & TREATER

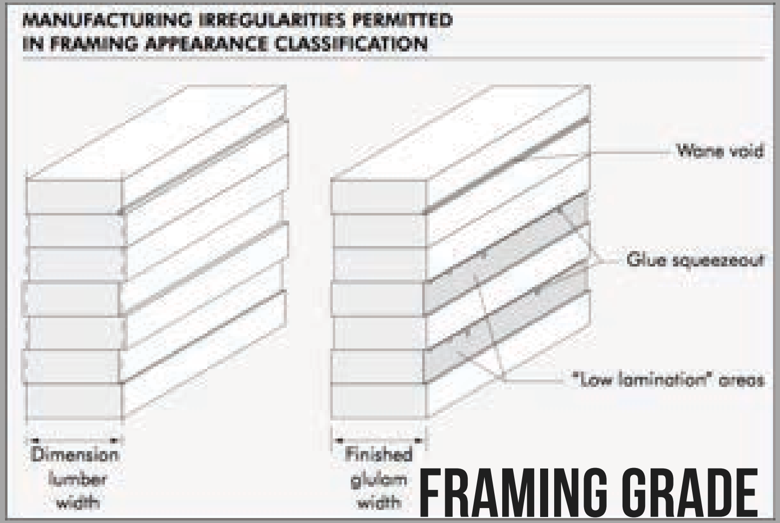
CAN BE CAMBERED, CURVED & TAPERED

DIFFERENT APPEARANCE GRADES AVAILABLE

PHOTO: EMA PETER PHOTOGRAPHY

MASS TIMBER PRODUCTS

GLULAM



GLULAM APPEARANCE GRADES

IMAGES: AMERICAN LAMINATORS

MASS TIMBER PRODUCTS

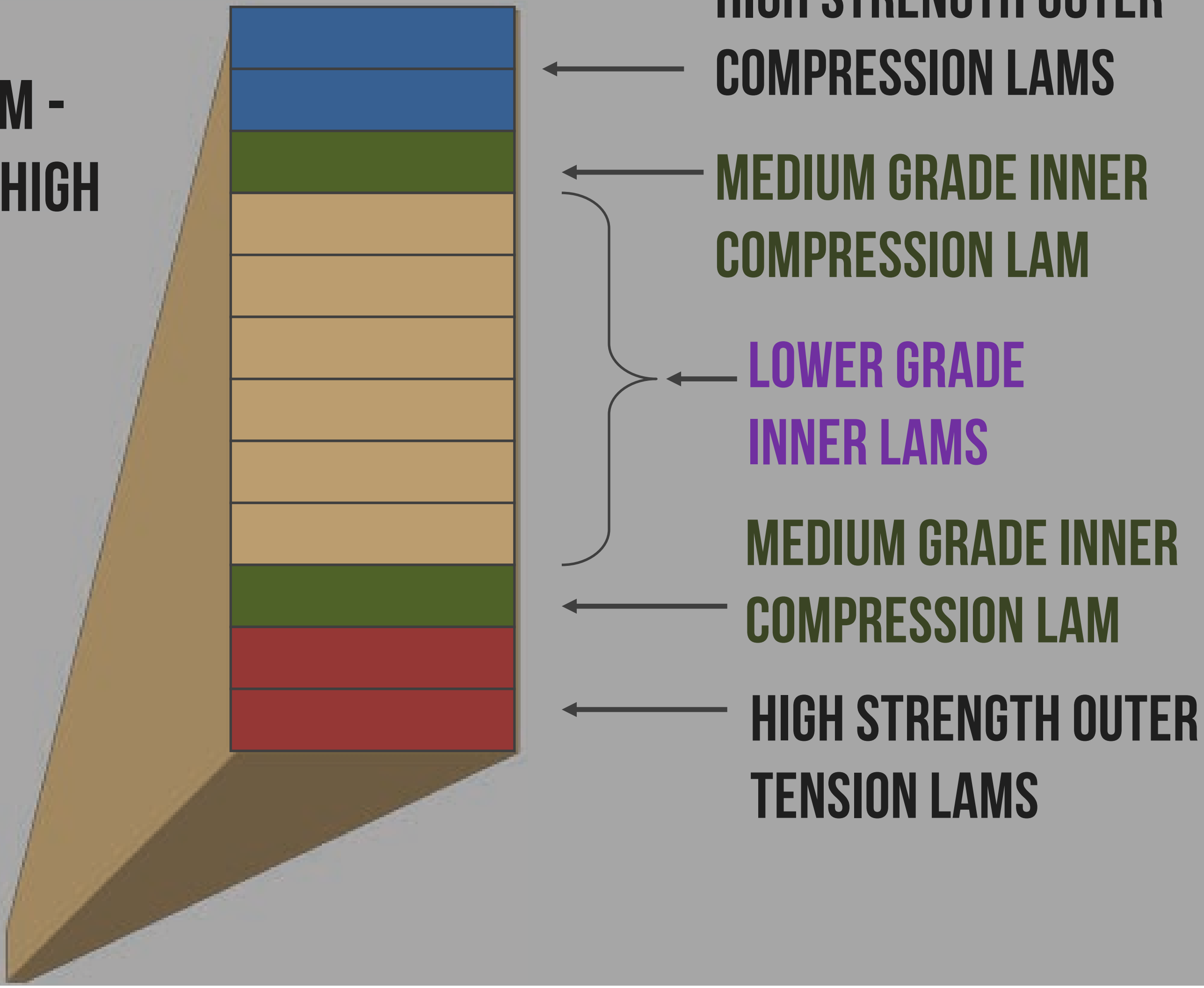
GLULAM

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



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

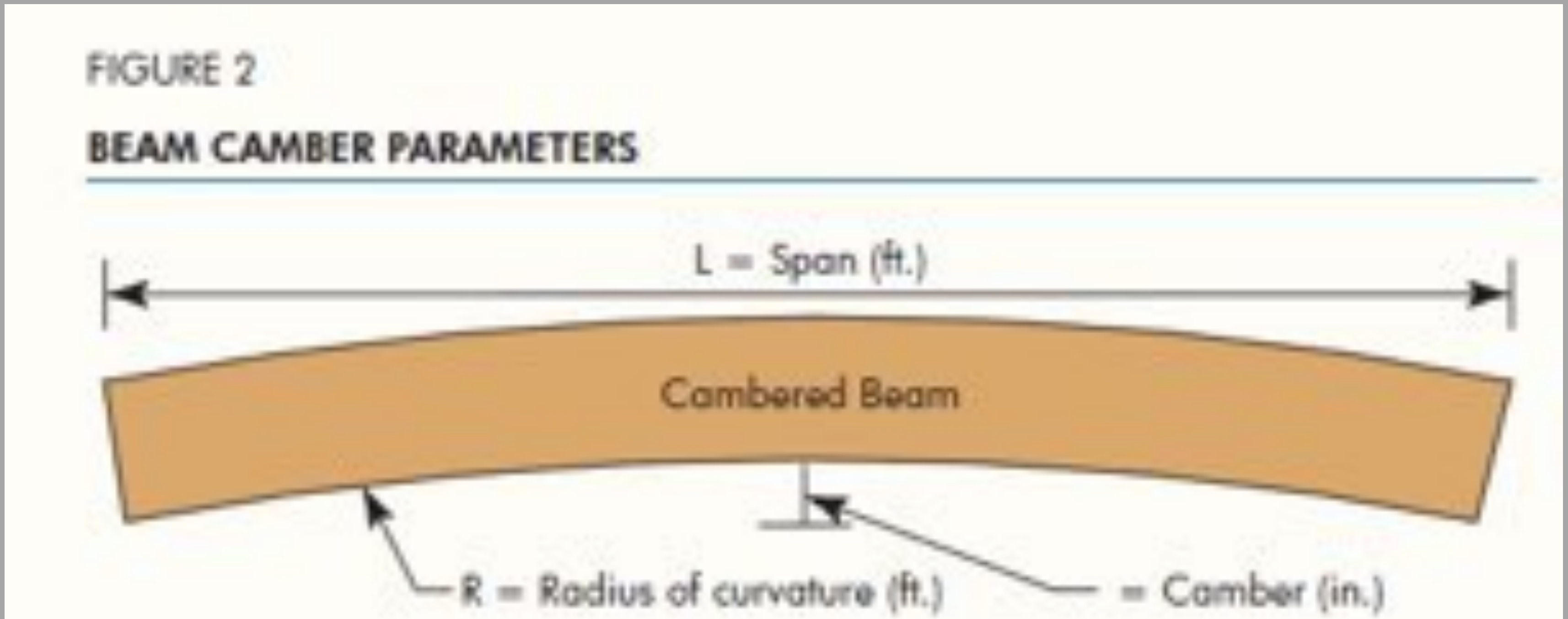


IMAGE: APA GLULAM PRODUCT GUIDE

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


104’ SPAN GLULAM ARCHES
GLULAM PURLINS @ 4’ O.C
LEMAY AMERICA AUTO MUSUEM
PHOTO CREDIT: WESTERN WOOD STRUCTURES


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

BUFFALO HARBOR CENTER RINK 1, BUFFALO, NY
PHOTO: HARBORCENTER.COM

LONG SPAN GLULAMS


PHOTO: AMERICAN WOOD COUNCIL

MASS TIMBER PRODUCTS

GLULAM

BUILT UP SECTIONS:

AVAILABLE FROM SOME MANUFACTURERS FOR WIDE BEAMS, LARGE COLUMNS. WIDTHS OF 24”± AVAILABLE

PHOTO: UNALAM

FIRST TECH CREDIT UNION

HILLSBORO, OR

5 STORIES

156,000 SF

ARCHITECT: HACKER

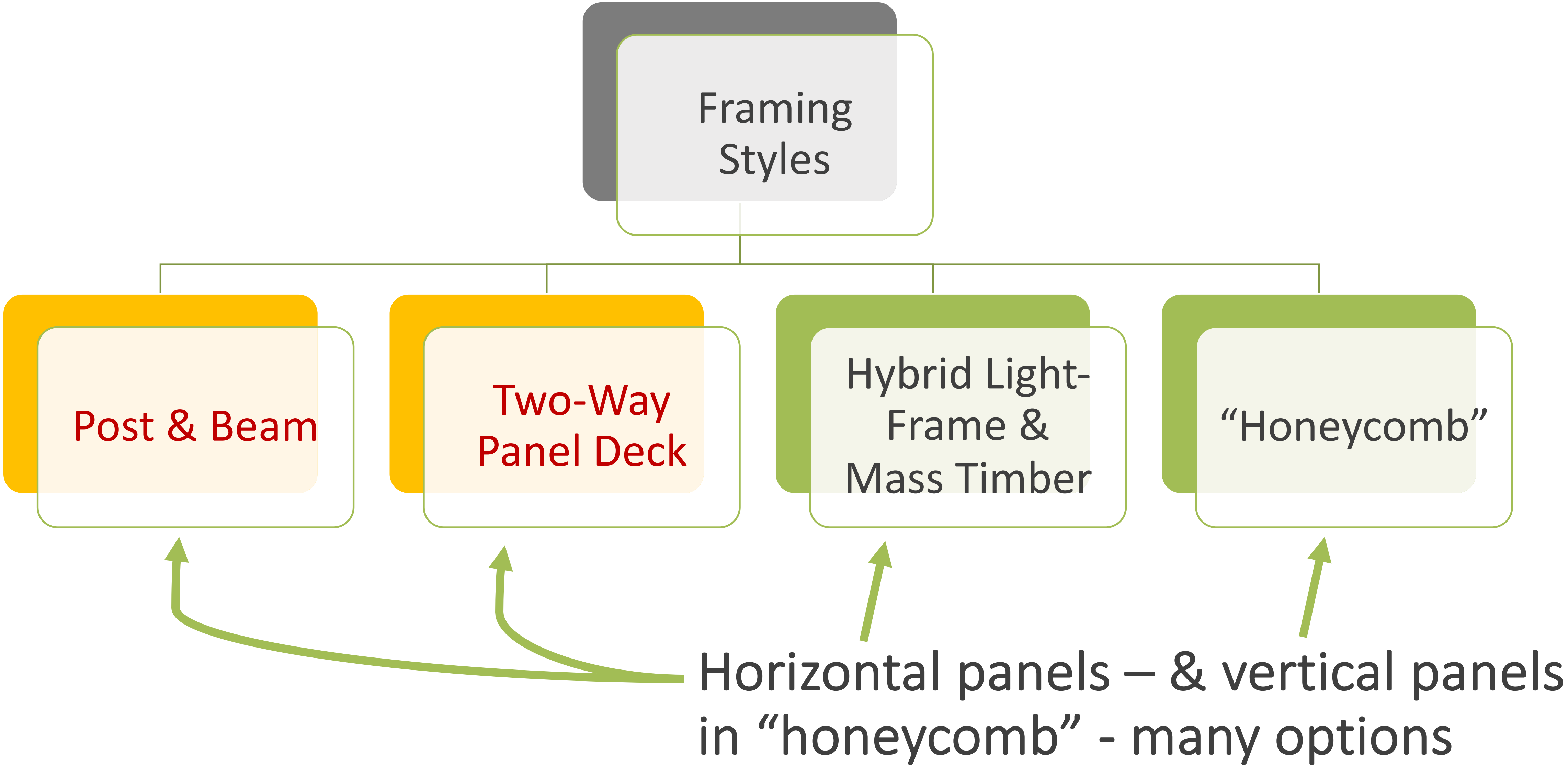
IMAGE CREDIT: STRUCTURLAM

FIRST TECH CREDIT UNION

HILLSBORO, OR

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

Mass Timber Framing Systems



Mass Timber Products

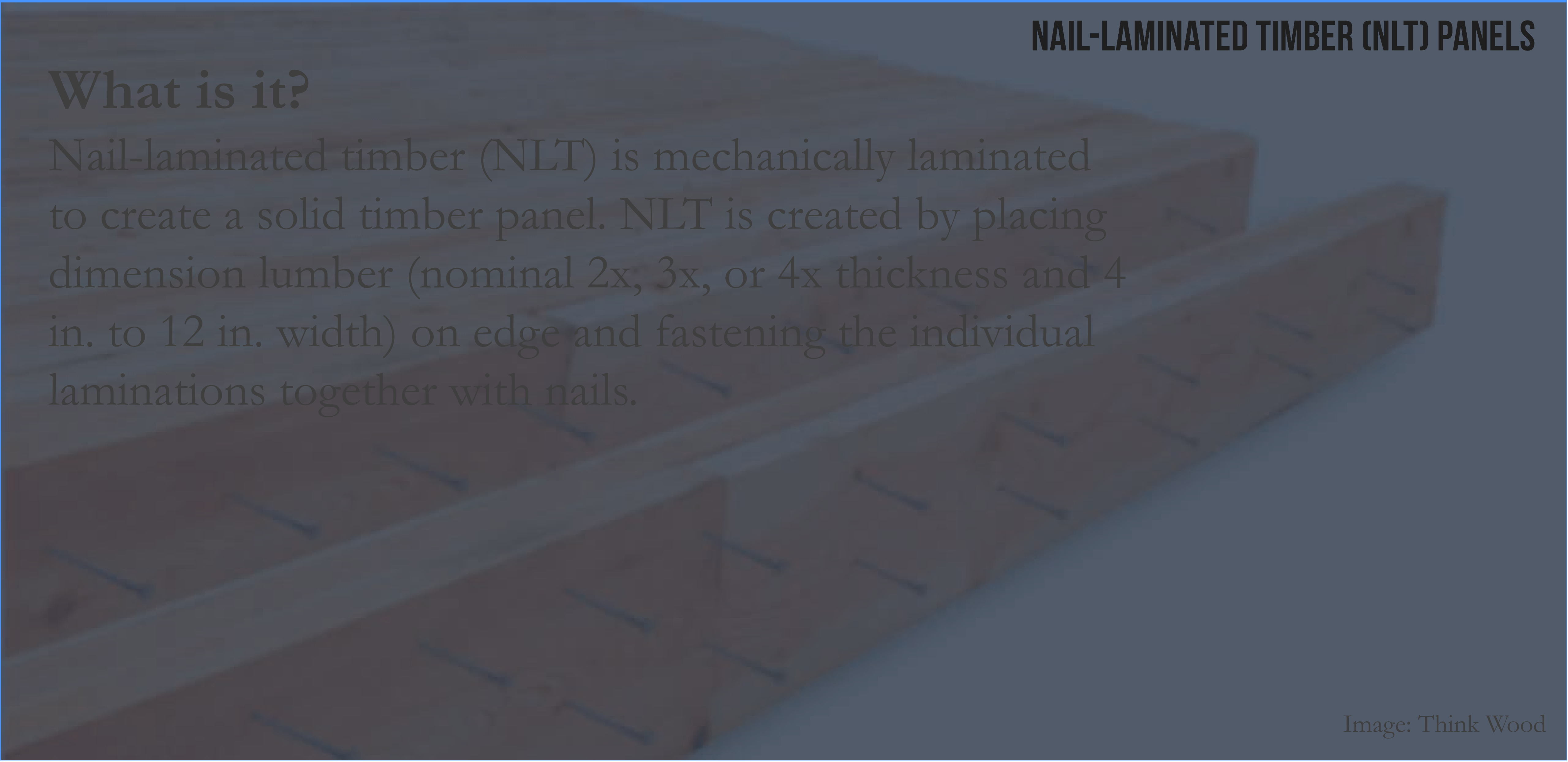
Photo credit: StructureCraft Builders/Freres Lumber

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

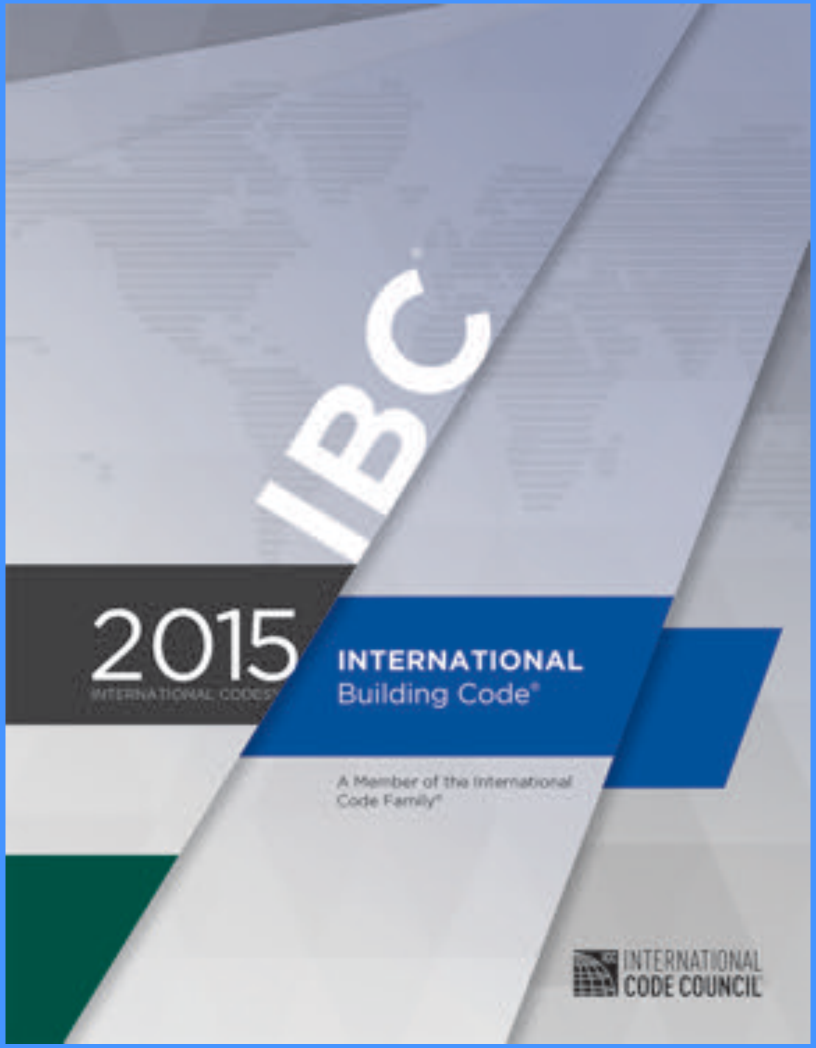
MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

When 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

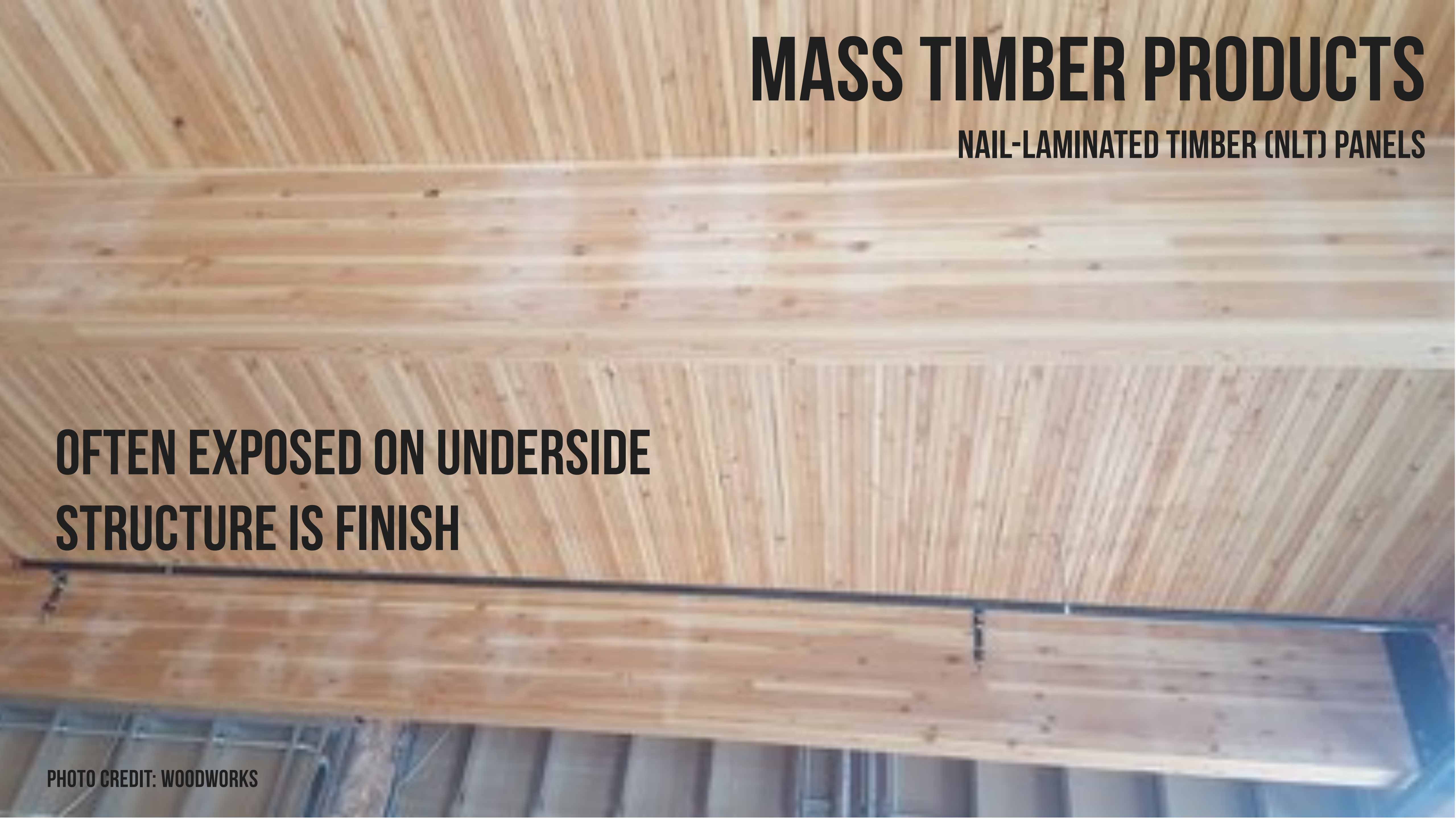
When is it used?

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

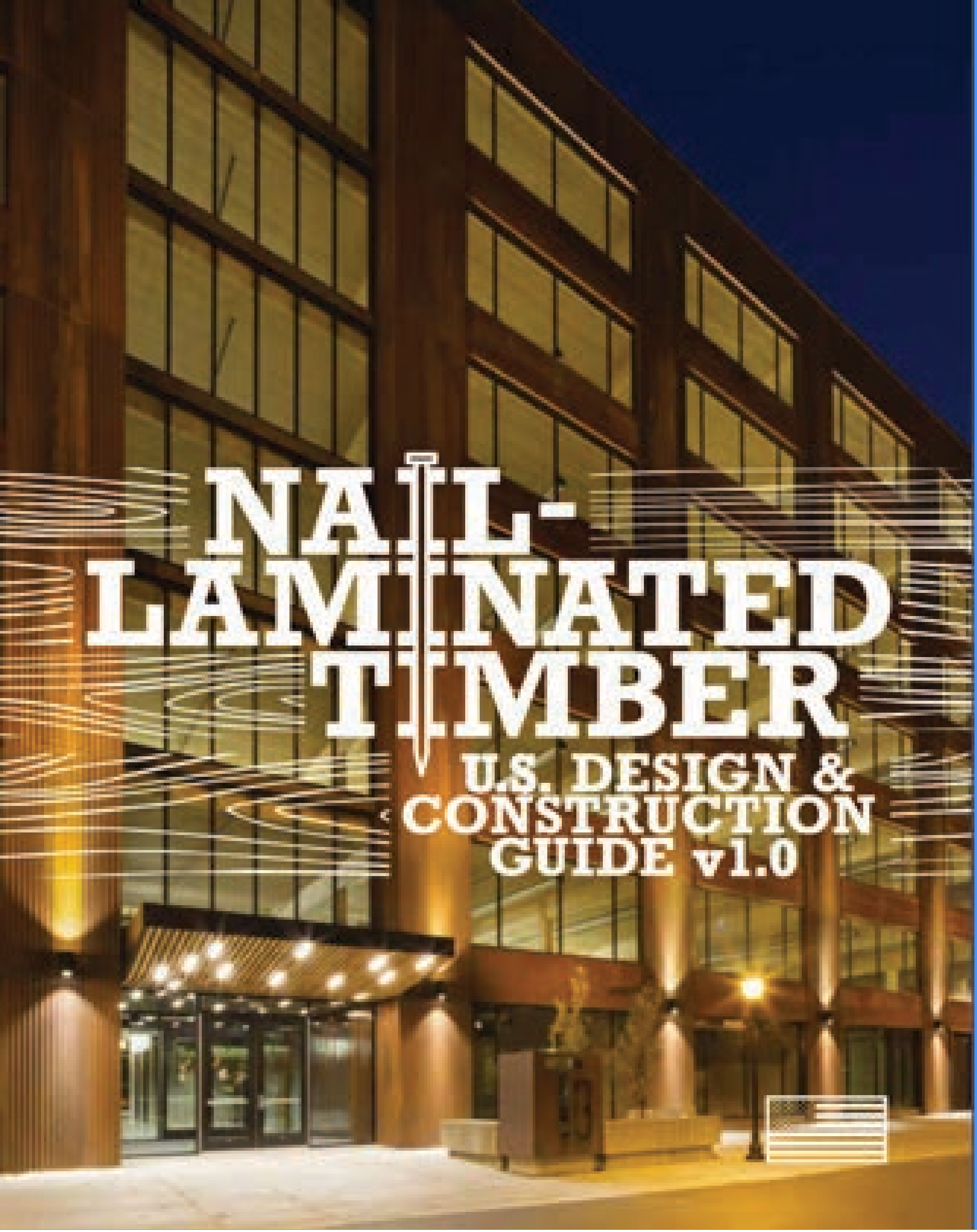
NAIL-LAMINATED TIMBER (NLT) PANELS



OFTEN EXPOSED ON UNDERSIDE

STRUCTURE IS FINISH

PHOTO CREDIT: WOODWORKS



MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

CONTENT INCLUDES:

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

FREE DOWNLOAD AT
WWW.THINKWOOD.COM/NLTGUIDE

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

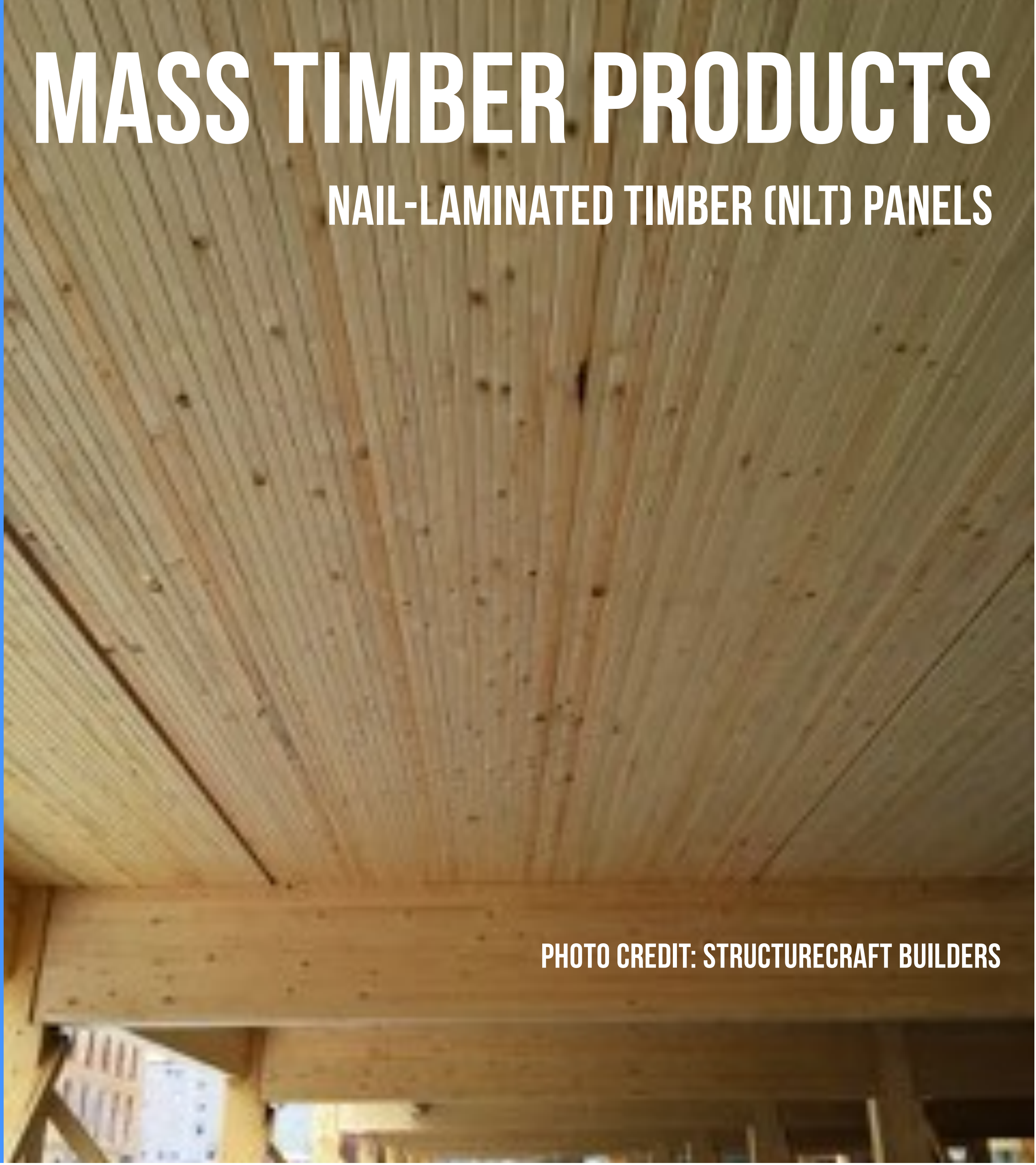


PHOTO CREDIT: STRUCTURECRAFT BUILDERS

NLT DIAPHRAGM DESIGN:

LACK OF TESTED, PUBLISHED DIAPHRAGM VALUES FOR BARE NLT LEAD MANY ENGINEERS TO COVERING WITH WOOD STRUCTURAL PANELS. DESIGN AS A BLOCKED, SHEATHED DIAPHRAGM. USE SDPWS TABLE 4.2A/4.2B

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

NLT SHRINKAGE/EXPANSION DESIGN:

RULE OF THUMB: LEAVE ONE PLY OUT PER 8'-10' WIDE PANEL

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

FLUTED PANEL OPTIONS
VARY LAMINATION DEPTHS

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS

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

MASS TIMBER PRODUCTS

NAIL-LAMINATED TIMBER (NLT) PANELS


PHOTO CREDIT: STRUCTURECRAFT BUILDERS

PRE-FABRICATED PANELS

OFTEN PRE-SHEATHED

ONCE INSTALLED, ADD STITCHING STRIPS, TAPE JOINT IF APPLICABLE

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

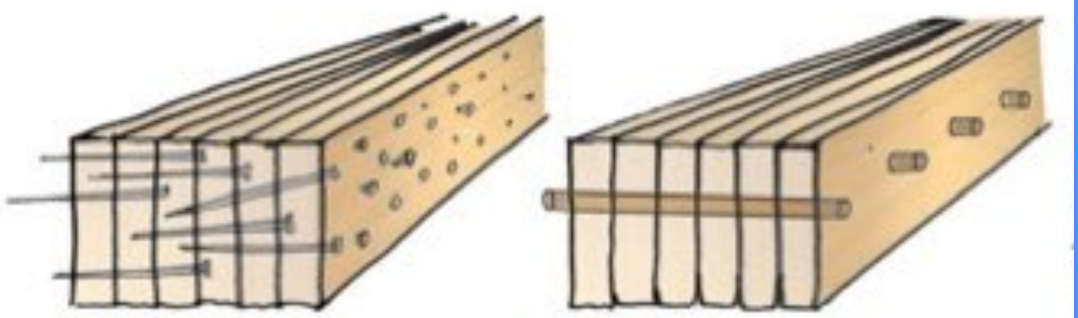
Image Credit: StructureCraft Builders


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 (DLT) PANELS

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

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: MANASC ISAAC ARCHITECTS/FAST ± EPP

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

	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
...ecies ...t 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	1750	650	260	1.8	0.85

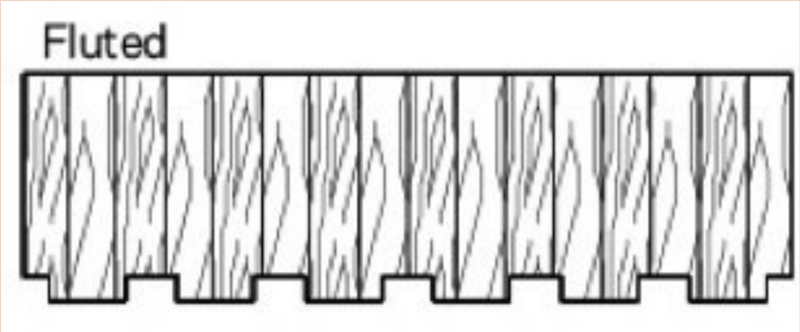
- NDS SUPPLEMENT LISTS DIFFERENT DESIGN VALUES FOR BENDING.
- LAYUP COMBINATIONS TYPICALLY OPTIMIZED FOR BEAM APPLICATIONS.
- LAYUP COMBINATIONS AREN'T EFFECTIVE IN GLT DECKING APPLICATIONS

MASS TIMBER PRODUCTS

GLUE-LAMINATED TIMBER (GLT)

SAME SHRINKAGE AND DIAPHRAGM CONSIDERATIONS AS NLT:

- GAP PANELS TO ALLOW MOVEMENT
- COVER WITH WOOD STRUCTURAL PANEL FOR DIAPHRAGM
- AVAILABLE IN VARIETY OF LAMINATION OPTIONS



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: $(F_bS)_{eff,f,0}$ (lbf-ft/ft)	Major: $(EI)_{eff,f,0}$ (10^6 lbf-in.^{2}/ft)	Major: $(GA)_{eff,f,0}$ (10^6 lbf/ft)	Major: $V_{s,0}$ (lbf/ft)	Minor Strength Direction: $(F_bS)_{eff,f,90}$ (lbf-ft/ft)	Minor: $(EI)_{eff,f,90}$ (10^6 lbf-in.^{2}/ft)	Minor: $(GA)_{eff,f,90}$ (10^6 lbf/ft)	Minor: $V_{s,90}$ (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 eff 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

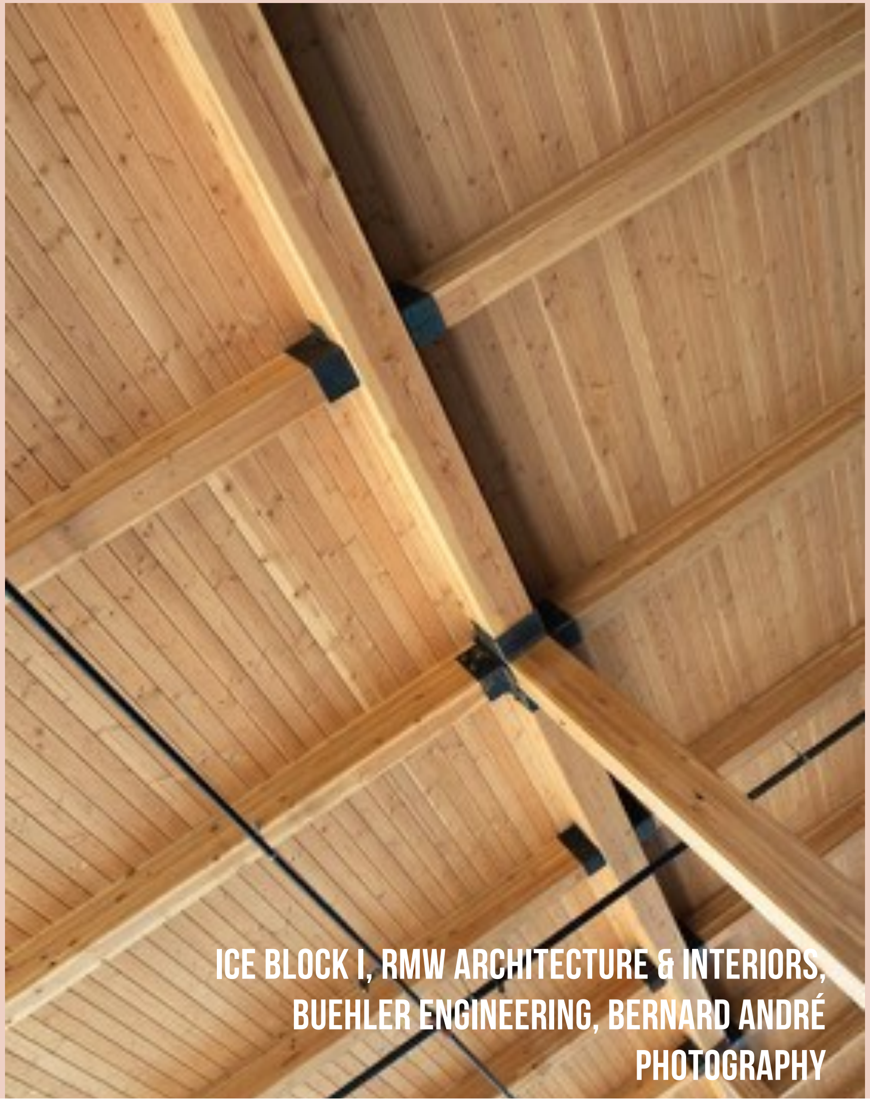
MASS TIMBER PRODUCTS

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

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

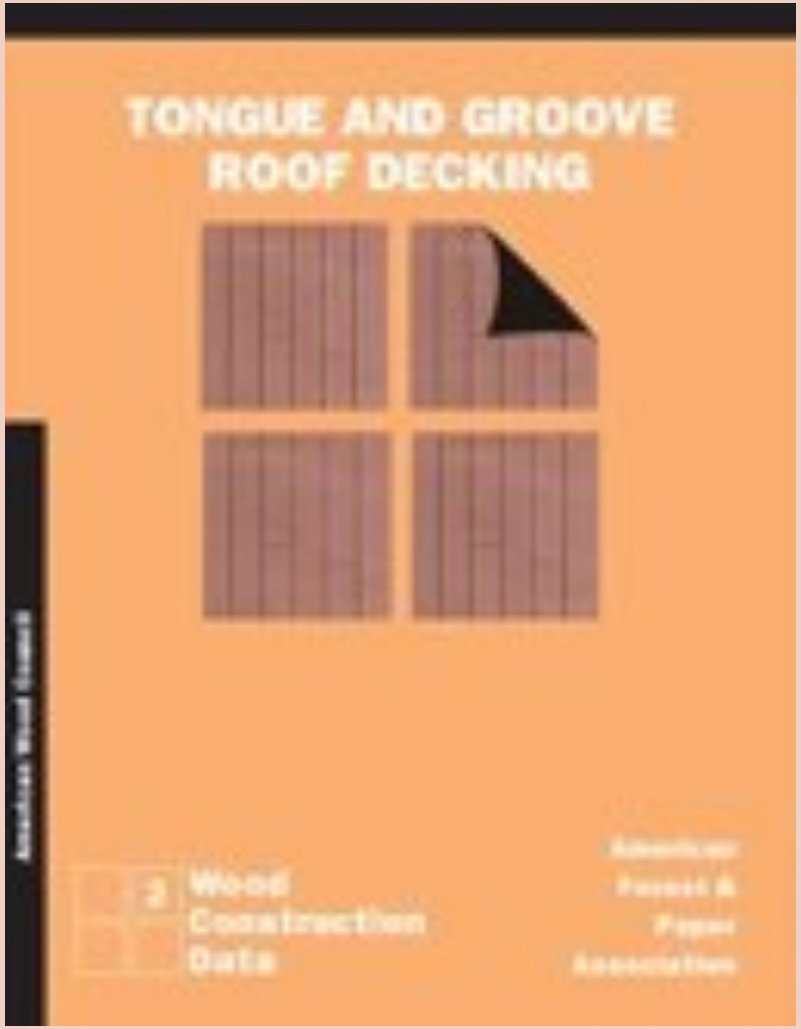
T&G DECKING DESIGN

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[7]	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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		



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)

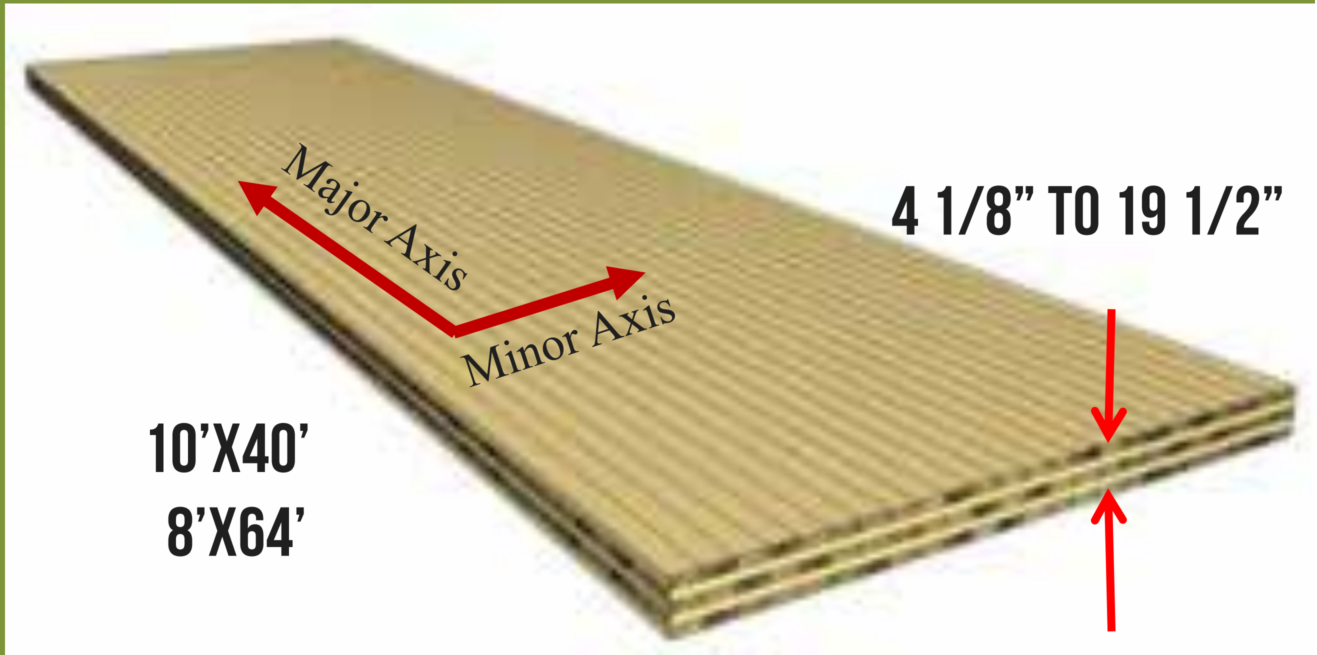
WHAT IS CLT?

SOLID WOOD PANEL

3 LAYERS MIN. OF SOLID SAWN LAMS

90 DEG. CROSS-LAMS

SIMILAR TO PLYWOOD SHEATHING



MASS TIMBER PRODUCTS

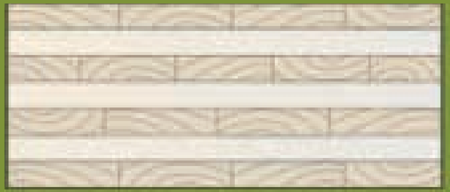
CROSS-LAMINATED TIMBER (CLT)

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

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

PHOTO CREDIT: DR JOHNSON

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

CLT PANEL FABRICATION

SPRINGER

SPRINGER®

THE WOOD-MECHANISING COMPANY

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

CLT PREFABRICATION

- FINISHED PANELS ARE PLANED, SANDED, CUT TO SIZE. THEN OPENINGS ARE CUT WITH PRECISE CNC ROUTERS.
- THIRD PARTY INSPECTION AT FACTORY
- CUSTOM ENGINEERED FOR MATERIAL EFFICIENCY
- CUSTOM DESIGNED FOR PROJECT
- EACH PANEL NUMBERED, DELIVERED & INSTALLED IN PREDETERMINED SEQUENCE

ALBINA YARD

PORTLAND, OR

ARCHITECT: LEVER ARCHITECTURE
IMAGE CREDIT: LEVER ARCHITECTURE

4 STORIES
16,000 SF
GREEN ROOF

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

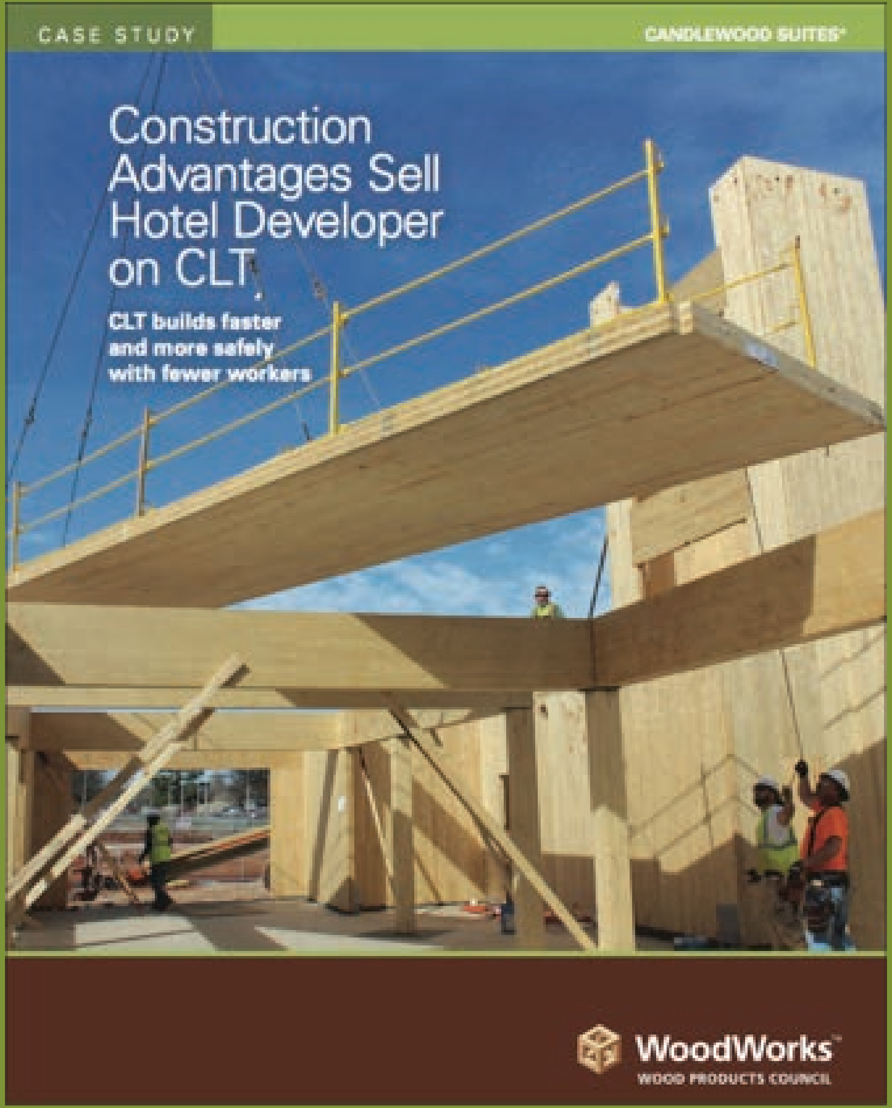
IMAGE CREDIT: LEND LEASE & SCHAEFER

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

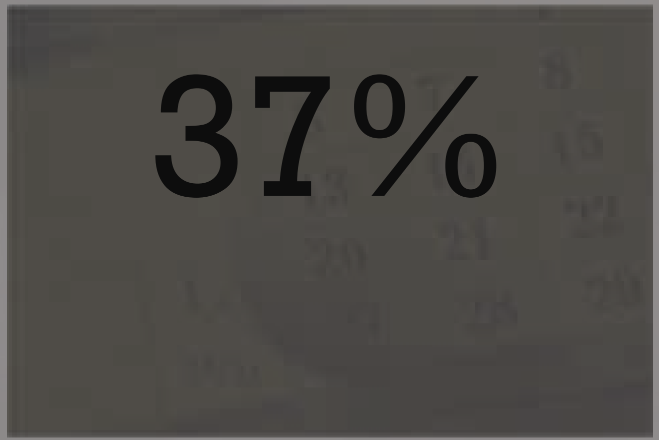


PAL Portfolio	Typical New PAL Hotel (Actual*)	Redstone Arsenal (Actual)	Difference
Gross square feet (sf)	54,891	62,688	+14%
Average # of employees	18 (peak 26)	10 (peak 11)	-43%
Structural duration (days)	123	78	-37%
Structural person hours	14,735	8,203	-44%
Structural production rate/day	460 sf	803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

* PAL New Build Hotel Historical Average

Source: Lendlease

43%



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

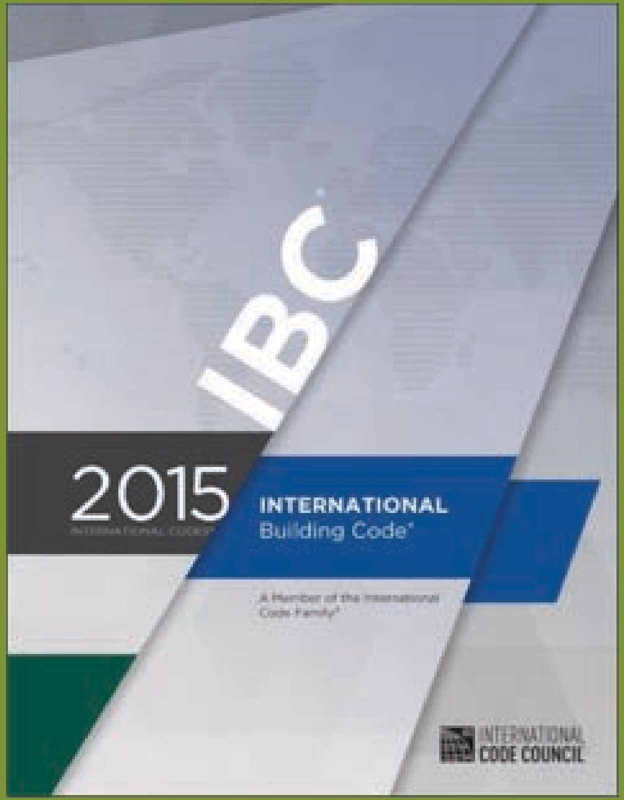
CROSS-LAMINATED TIMBER (CLT)

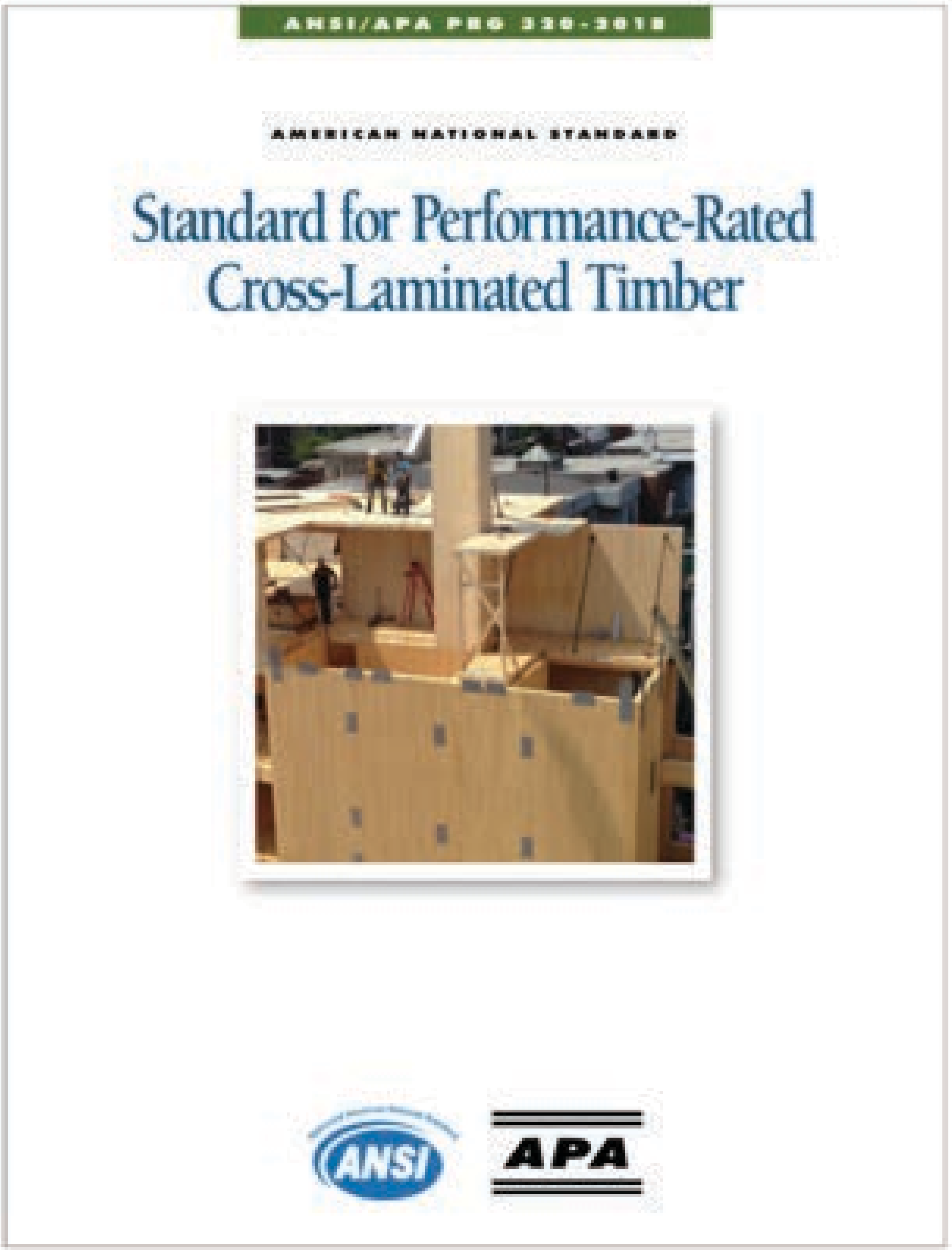
IN 2015 IBC, CLT IS NOW DEFINED IN CHAPTER 2 DEFINITIONS:

[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.

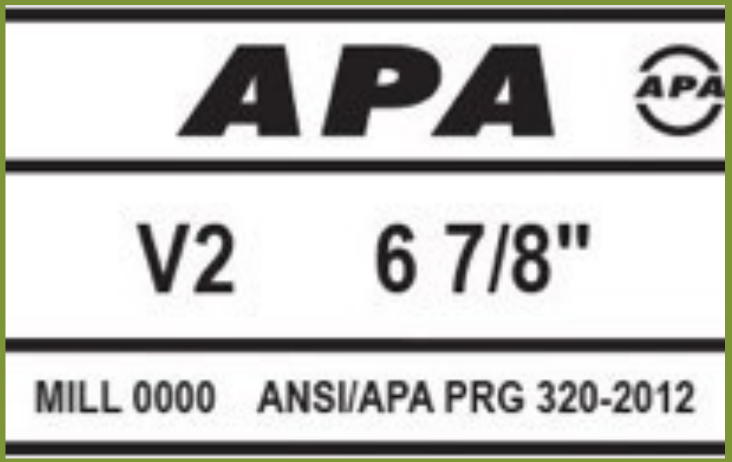




MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

CLT PRODUCT STANDARD



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

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

CLT PRODUCT REPORTS

INTERTEK DIRECTORY OF BUILDING PRODUCTS

KLH Massivholz GmbH - Massivholzplatten (solid wood slabs)
CLT

APA PRODUCT REPORT

Structurlam CrossLam
Structurlam Products LP
PR-L314
Revised May 9, 2016

APA PRODUCT REPORT

Nordic X-Lam
Nordic Structures
PR-L306
Revised March 26, 2016

Products: Nordic X-Lam
Nordic Structures
1100 Avenue des Canadiens-de-Montréal, Suite 504
Montreal, Québec, Canada H3B 2S2
(514) 871-8526
www.nordic.ca

1. Basis of the product report:
   - 2015 International Building Code (IBC): Section 2303.1.4 Structural Glued Cross-Laminated Timber
   - 2012 and 2009 IBC: Section 104.11 Alternative materials
   - 2015 International Residential Code (IRC): Sections R502.1.6, R602.1.6, and R802.1.6 Cross-Laminated Timber
   - 2012 and 2009 IRC: Section R104.11 Alternative materials
   - ANSI/APA PRG 320-2012 and PRG 320-2011 Performance Rated Cross-Laminated Timber
   - FPInnovations Reports 201002775, 201004981, and 301010401, HPVA Report T-14054R, and other qualification data
2. Product description:
   Nordic X-Lam cross-laminated timber (CLT) is manufactured with spruce-pine-fir in accordance with the E1 or custom grades of ANSI/APA PRG 320 through product

APA PRODUCT REPORT

SmartLam Cross-Laminated Timber
SmartLam, LLC
PR-L319
Issued August 15, 2016

APA PRODUCT REPORT

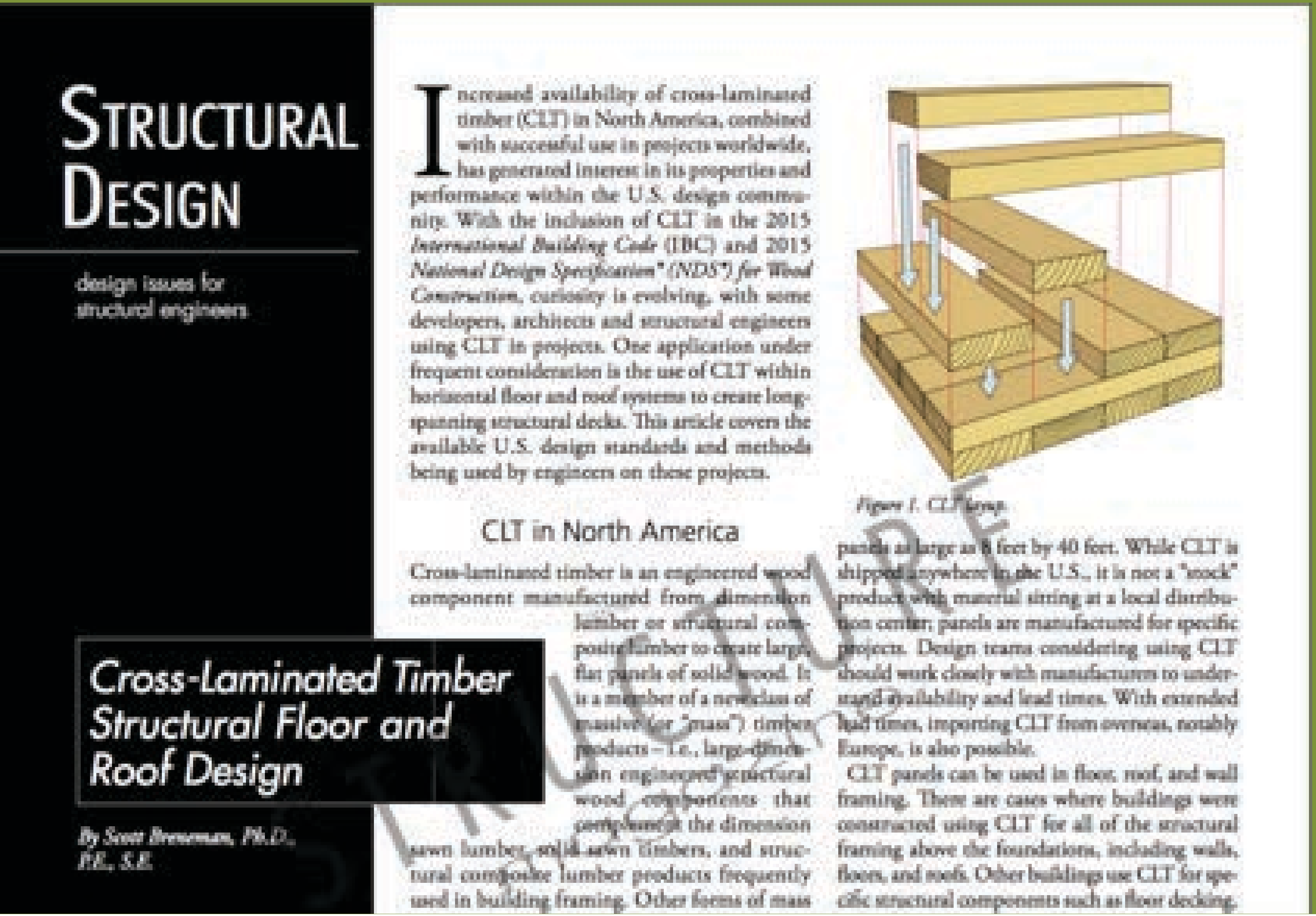
DRJ Cross-Laminated Timber
Riddle Laminators, Inc.
PR-L320
Issued January 25, 2017

APA PRODUCT REPORT

FRERES Mass Panel Products
Freres Lumber Co., Inc.
PR-L325
Issued July 3, 2018

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)



STRUCTURAL DESIGN

design issues for structural engineers

Cross-Laminated Timber Structural Floor and Roof Design

By Scott Breneman, Ph.D., P.E., S.E.

Increased availability of cross-laminated timber (CLT) in North America, combined with successful use in projects worldwide, has generated interest in its properties and performance within the U.S. design community. With the inclusion of CLT in the 2015 *International Building Code* (IBC) and 2015 *National Design Specification® (NDS®) for Wood Construction*, curiosity is evolving, with some developers, architects and structural engineers using CLT in projects. One application under frequent consideration is the use of CLT within horizontal floor and roof systems to create long-spanning structural decks. This article covers the available U.S. design standards and methods being used by engineers on these projects.

Figure 1. CLT layup.

CLT in North America

Cross-laminated timber is an engineered wood component manufactured from dimension lumber or structural composite lumber to create large, flat panels of solid wood. It is a member of a new class of massive (or "mass") timber products – i.e., large-dimension engineered structural wood components that complement the dimension sawn lumber, solid-sawn timbers, and structural composite lumber products frequently used in building framing. Other forms of mass

panels as large as 8 feet by 40 feet. While CLT is shipped anywhere in the U.S., it is not a "stock" product with material sitting at a local distribution center; panels are manufactured for specific projects. Design teams considering using CLT should work closely with manufacturers to understand availability and lead times. With extended lead times, importing CLT from overseas, notably Europe, is also possible.

CLT panels can be used in floor, roof, and wall framing. There are cases where buildings were constructed using CLT for all of the structural framing above the foundations, including walls, floors, and roofs. Other buildings use CLT for specific structural components such as floor decking.

JUNE, 2016 STRUCTURE MAGAZINE

[HTTP://WWW.STRUCTUREMAG.ORG/WP-CONTENT/UPLOADS/2016/05/C-STRUCDESIGN-BRENEMAN-JUN161.PDF](http://www.structuremag.org/wp-content/uploads/2016/05/C-StrucDesign-Breneman-Jun161.pdf)

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

1. INTRODUCTION
2. MANUFACTURING
3. STRUCTURAL
4. LATERAL
5. CONNECTIONS
6. DOL AND CREEP
7. VIBRATION
8. FIRE
9. SOUND
10. ENCLOSURE
11. ENVIRONMENTAL
12. LIFTING

THINKWOOD.COM/CLTHANDBOOK

PHOTO CREDIT: DAVID SUNDBERG AND GRAY ORGANSCHI ARCHITECTURE

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

MASS TIMBER PRODUCTS

WOOD CONCRETE COMPOSITE

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

STRUCTURAL COMPOSITE LUMBER (SCL)

LVL PANEL

LSL PANEL

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

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

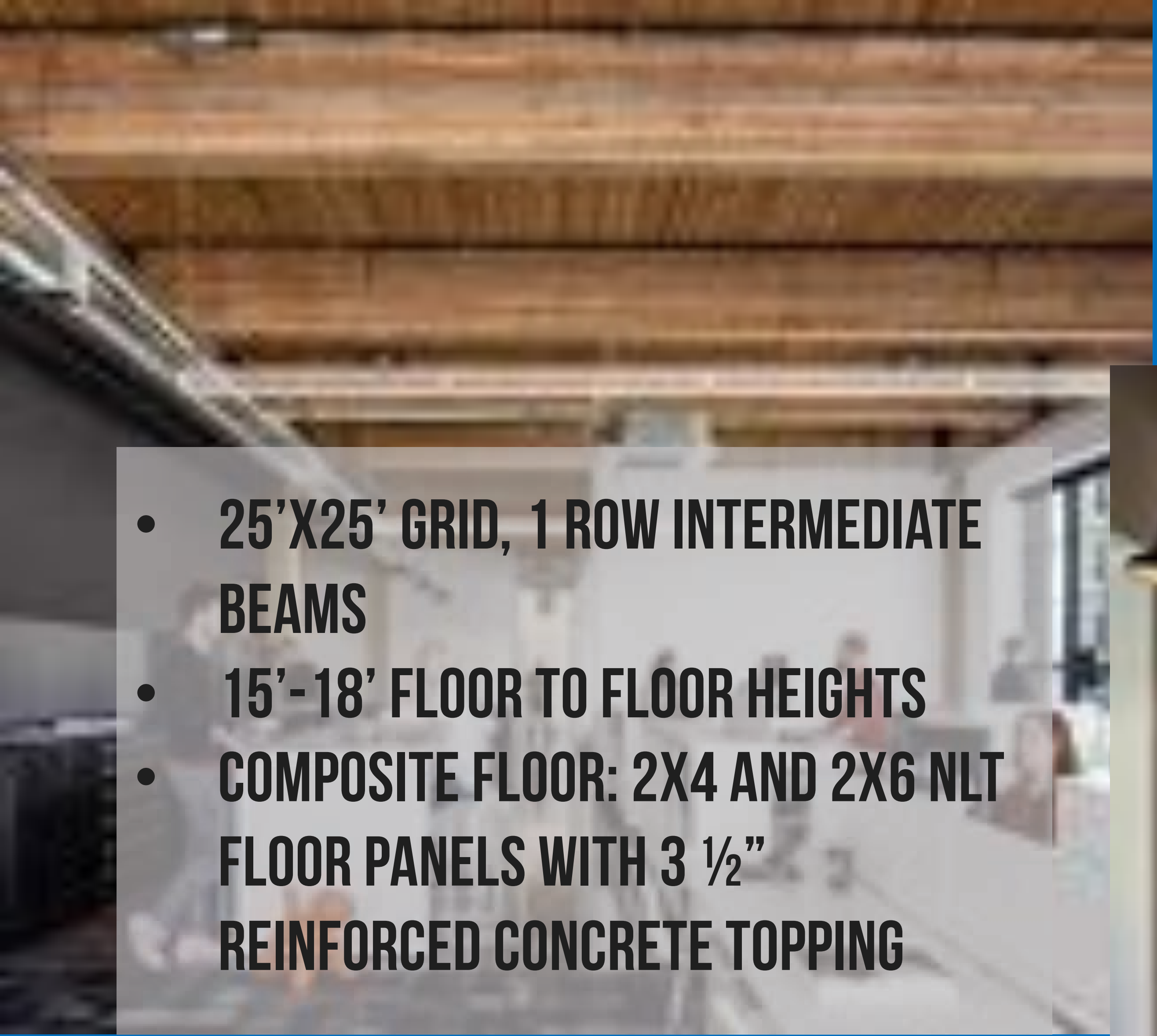
CLAY CREATIVE

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

HUDSON BUILDING

VANCOUVER, WA



- 25'X25' GRID, 1 ROW INTERMEDIATE BEAMS
- 15'-18' FLOOR TO FLOOR HEIGHTS
- COMPOSITE FLOOR: 2X4 AND 2X6 NLT FLOOR PANELS WITH 3 ½" REINFORCED CONCRETE TOPPING

IMAGE CREDIT: CHRISTIAN COLUMBRES


T3 MINNEAPOLIS
MINNEAPOLIS, MN
20'X25' GRID
2X8 NLT FLOOR PANELS SPAN 20' W/3" CONCRETE TOPPING
IMAGE CREDIT: EMA PETER

ALBINA YARD

PORTLAND, OR

20'X20' GRID
BEAMS AT 10' O.C.
3-PLY CLT

ARCHITECT: LEVER ARCHITECTURE
IMAGE CREDIT: LEVER ARCHITECTURE

FIRST TECH CREDIT UNION

HILLSBORO, OR

IMAGE CREDIT: SWINERTON BUILDERS

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

15'X32' & 15'X26' GRIDS
5-PLY CLT SPANS 15'

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

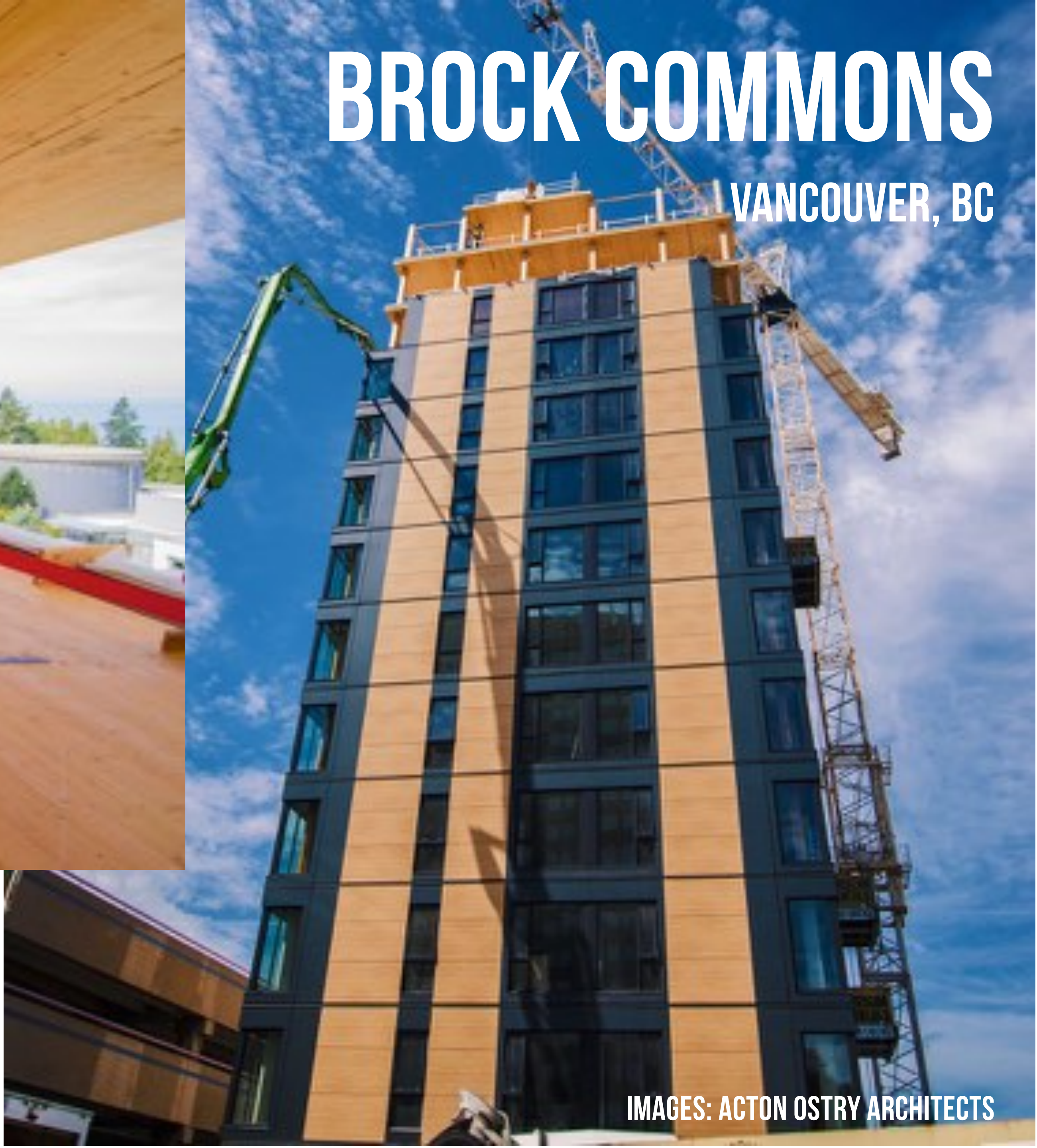
UMASS, AMHERST, MA

- 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

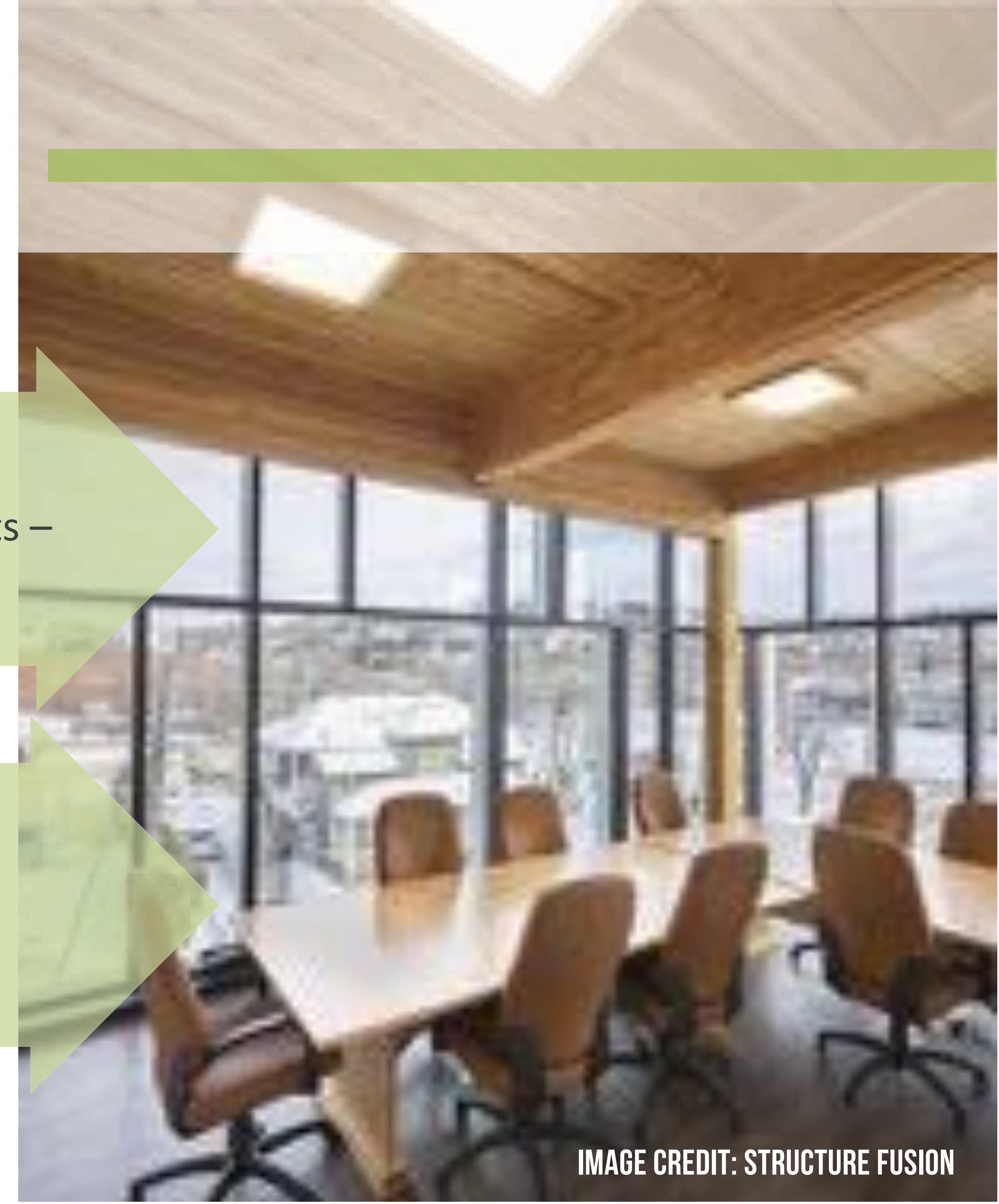


IMAGE CREDIT: STRUCTURE FUSION

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

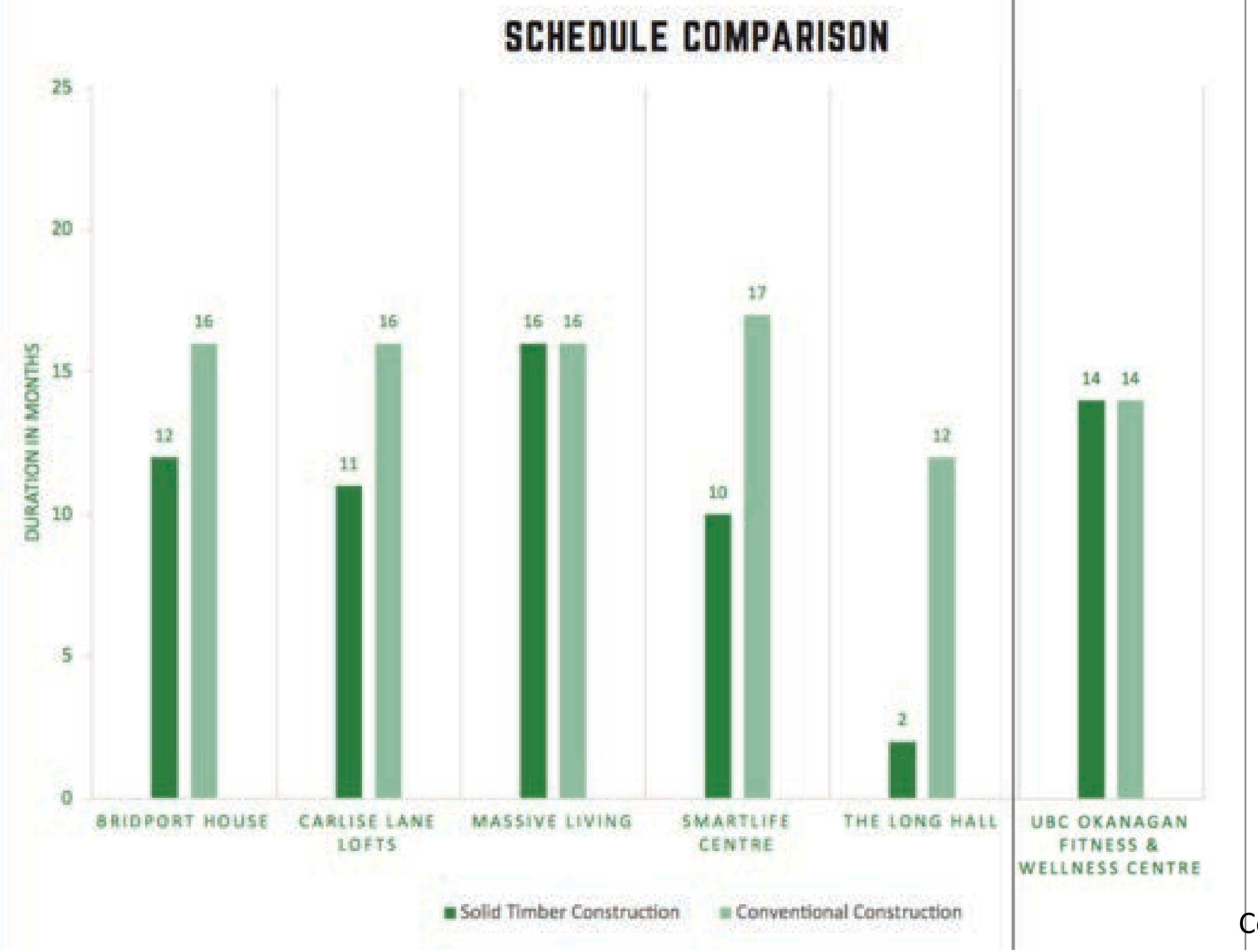
MASS TIMBER APPEAL

REDUCED CONSTRUCTION TIME

1 Floor = 3 Days

17 Floors Erected in 9.5 Weeks

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



Source: Solid Timber Construction[6], Ryan Smith

MASS TIMBER APPEAL

REDUCED CONSTRUCTION TIME

FORTE TIME LAPSE VIDEO

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

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

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

MASS TIMBER APPEAL

REDUCED EMBODIED CARBON

ESTIMATED ENVIRONMENTAL IMPACT OF WOOD USE

V	Volume of wood products used: 2,233 cubic meters of CLT and Glulam
(tree)	U.S. and Canadian forests grow this much wood in: 6 minutes
C	Carbon stored in the wood: 1,753 metric tons of CO_2
(C)	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

(car)	511 cars off the road for a year
(house)	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

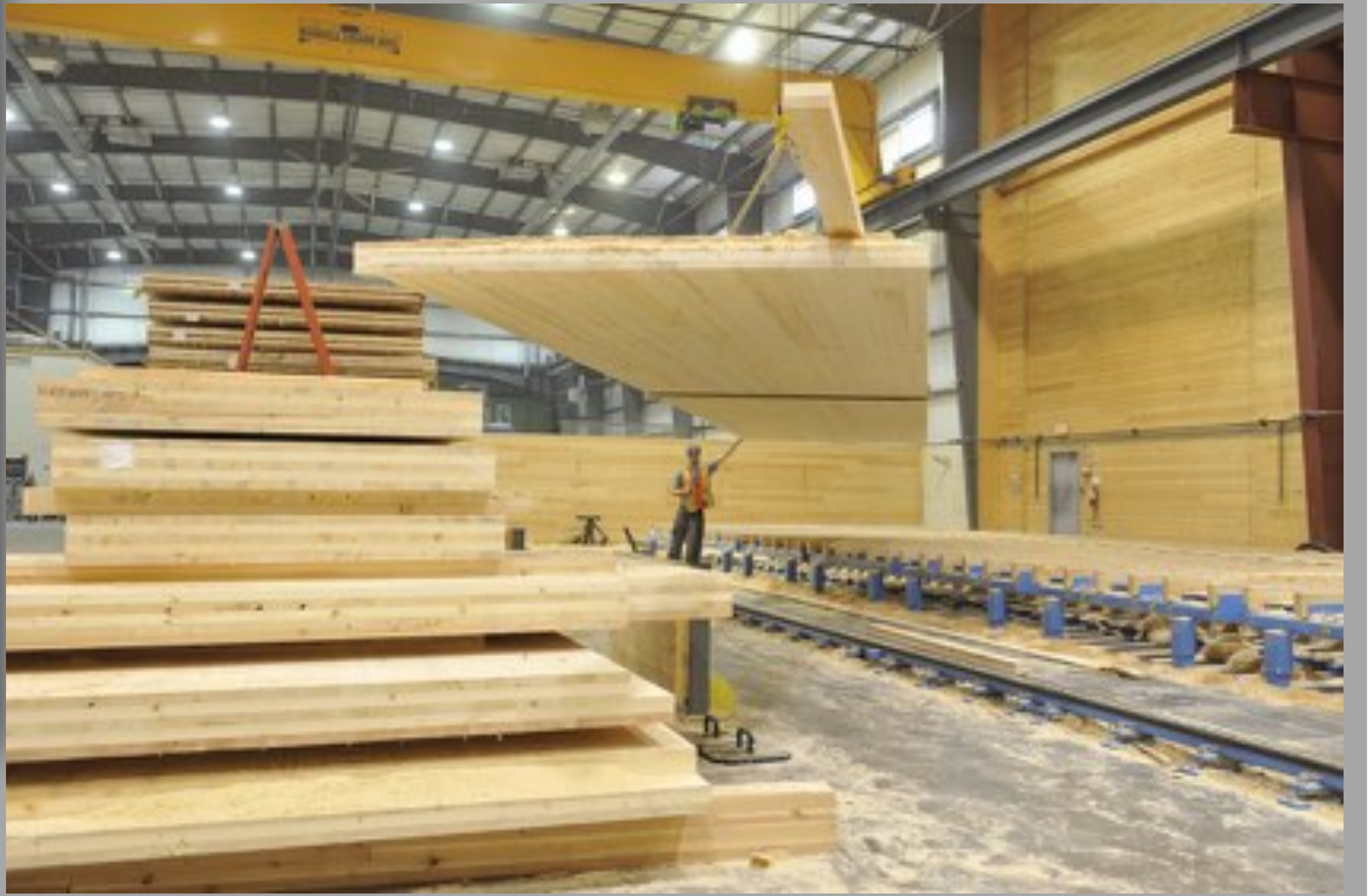


PHOTO CREDIT: NATURALLY:WOOD

MASS TIMBER APPEAL

ENERGY EFFICIENT

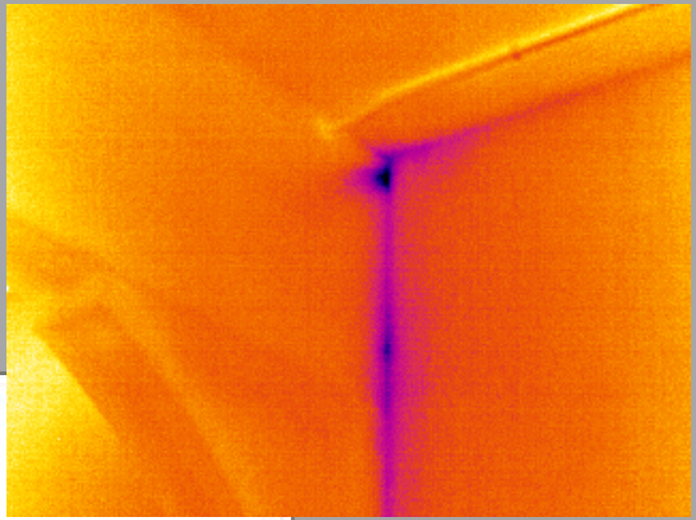


Table 2

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 ($h \cdot ft.^2 \cdot {}^\circ F \cdot Btu^{-1}$)	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

DISASTER RESILIENT

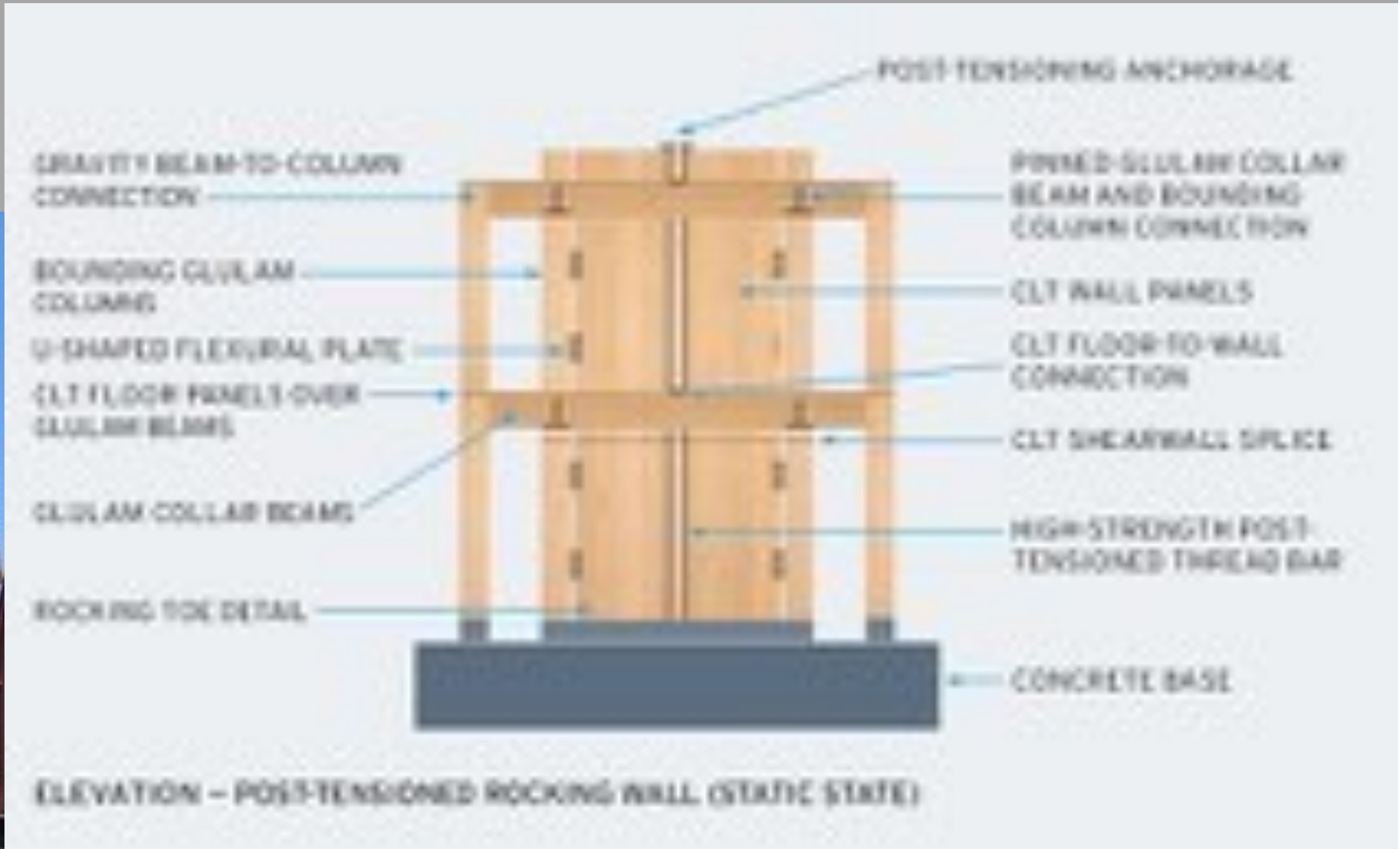
USFPL WOOD TORNADO SHELTER

MASS TIMBER APPEAL

DISASTER RESILIENT

INNOVATIVE MASS TIMBER LATERAL FORCE RESISTING SYSTEMS

MASS TIMBER SHAKE TABLE TEST AT UCSD



CLT ROCKING SHEAR WALL CONCEPT

SOURCE: KPFF

MASS TIMBER APPEAL

DISASTER RESILIENT

LIVE BLAST PERFORMANCE OF MASS TIMBER TESTING PROJECT ON-GOING

INITIAL RESULTS PROMISING

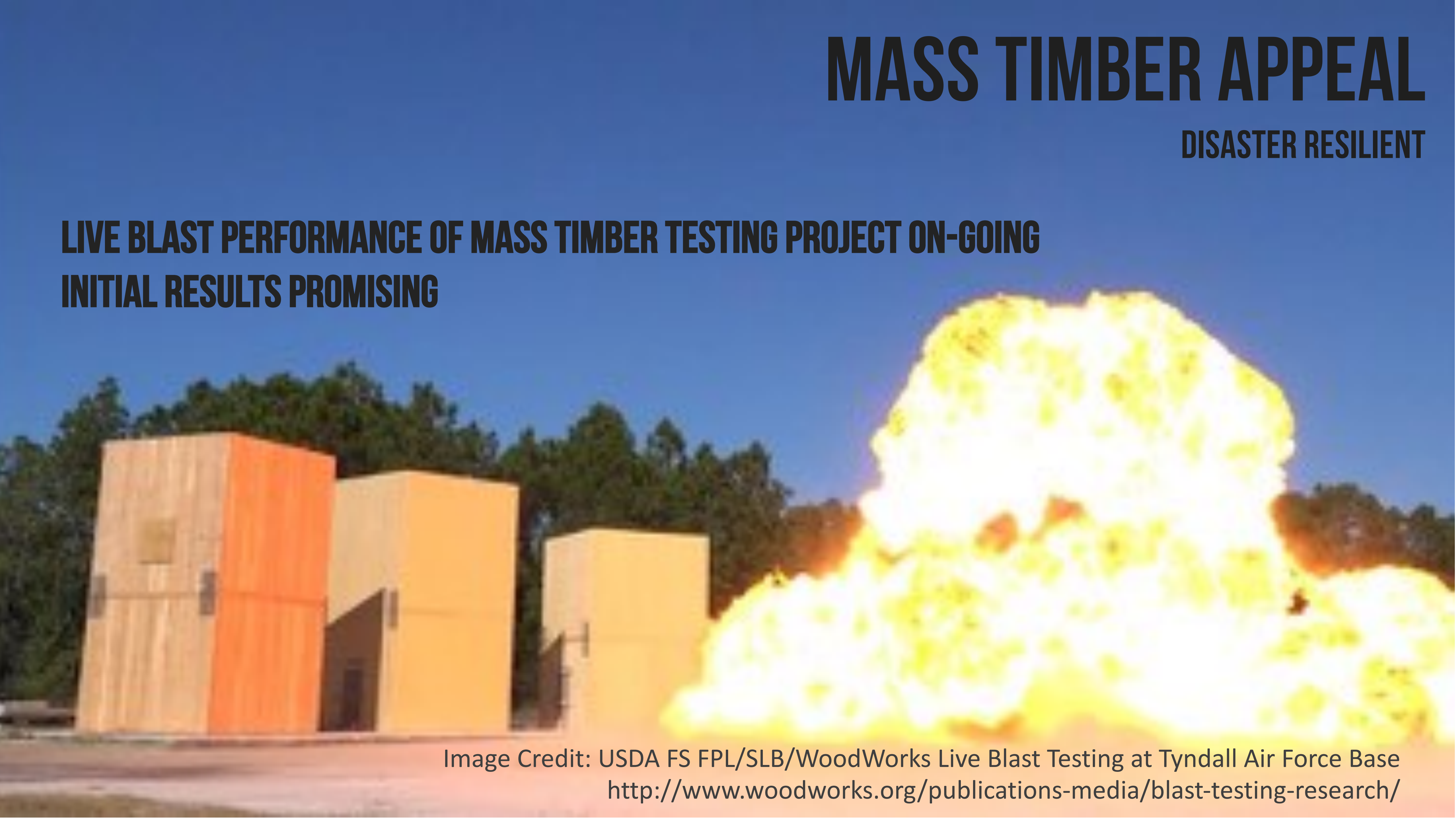


Image Credit: USDA FS FPL/SLB/WoodWorks Live Blast Testing at Tyndall Air Force Base
http://www.woodworks.org/publications-media/blast-testing-research/


MASS TIMBER APPEAL

STRUCTURAL FLEXIBILITY

PHOTO CREDIT: APA

MASS TIMBER APPEAL

AESTHETICS/OCCUPANT COMFORT

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER SUCCESS

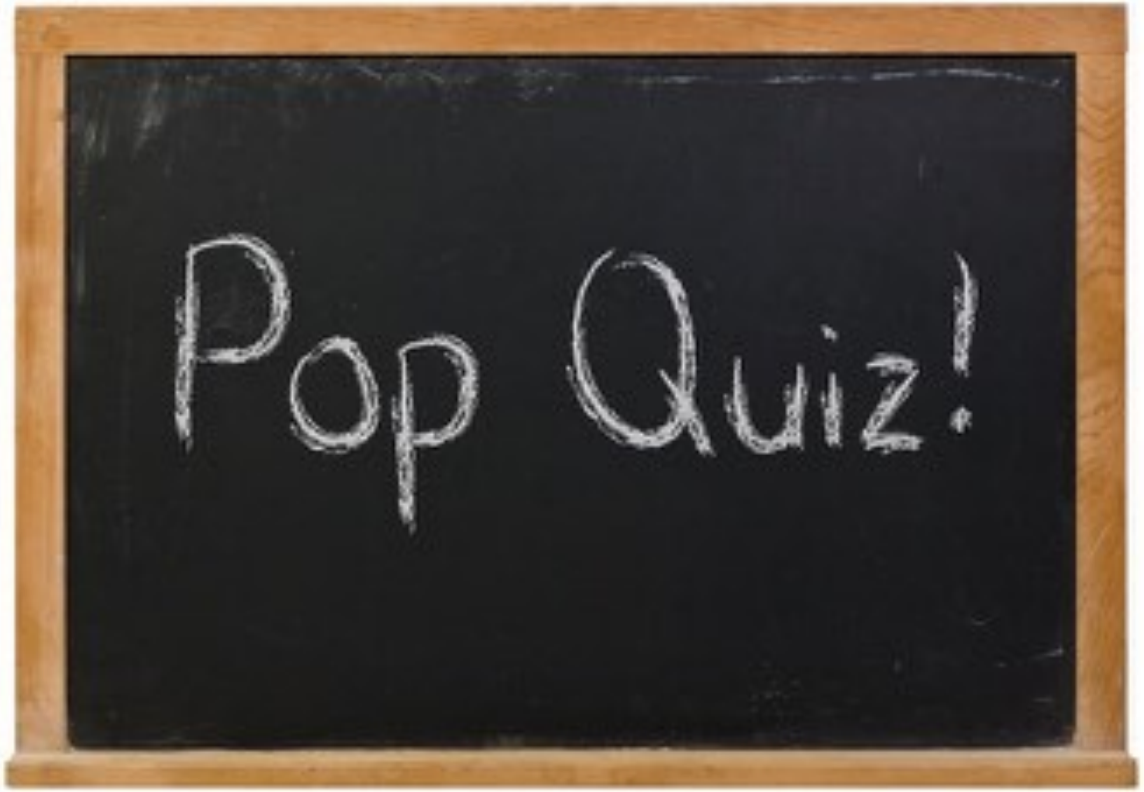
AS A DEVELOPER IS IMPROVED BY …

- HAVING A RANGE OF SCALE IN YOUR PORTFOLIO
- OPERATING REPETITIVELY IN THE SAME JURISDICTIONS
- STARTING WITH HORIZONTAL APPLICATIONS (ROOFS AND FLOORS)
- BEING FLEXIBLE WITH REGARDS TO LEVEL OF MASS TIMBER EXPOSURE
- COMMITTING EARLY AND HAVE TIME FOR NEGOTIATION

MASS TIMBER DESIGN

DESIGN TOPICS

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



MASS TIMBER DESIGN

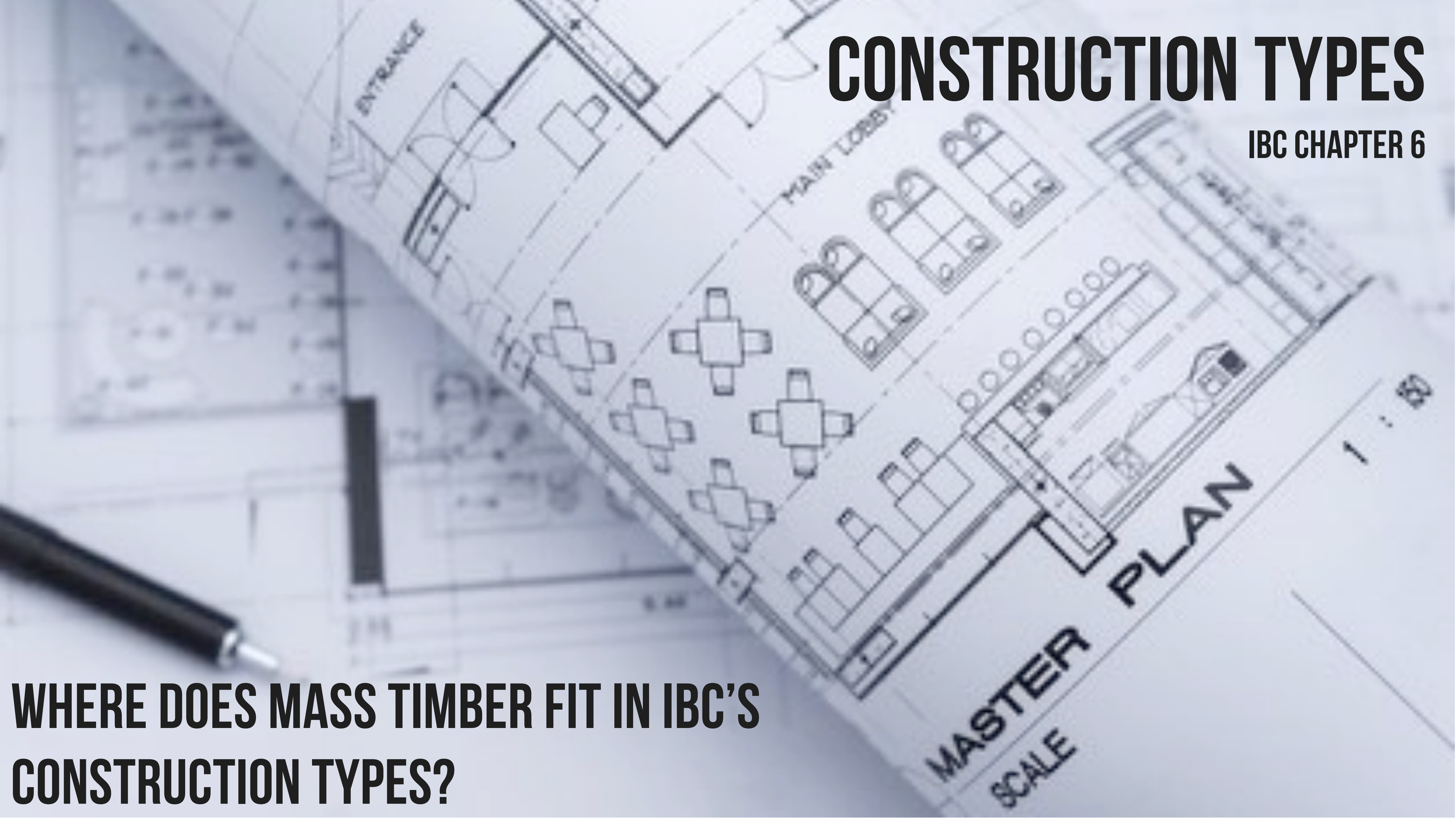
CONSTRUCTION TYPES

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

A: ALL 5!

CONSTRUCTION TYPES

IBC CHAPTER 6



WHERE DOES MASS TIMBER FIT IN IBC'S CONSTRUCTION TYPES?

CONSTRUCTION TYPES

IBC 602

IBC DEFINES 5 CONSTRUCTION TYPES: I, II, III, IV AND V

A BUILDING MUST BE CLASSIFIED AS ONE OF THESE

CONSTRUCTION TYPES I & II:

ALL ELEMENTS REQUIRED TO BE NON-COMBUSTIBLE MATERIALS

HOWEVER, THERE ARE EXCEPTIONS INLCUDING SEVERAL FOR MASS TIMBER

CONSTRUCTION TYPES

IBC 602

ALL WOOD FRAMED BUILDING OPTIONS:

TYPE III

EXTERIOR WALLS NON-COMBUSTIBLE (MAY BE FRTW)

INTERIOR ELEMENTS ANY ALLOWED BY CODE, INCLUDING MASS TIMBER

TYPE V

ALL BUILDING ELEMENTS ARE ANY ALLOWED BY CODE, INCLUDING MASS TIMBER

TYPES III AND V ARE SUBDIVIDED TO A (PROTECTED) AND B (UNPROTECTED)

TYPE IV (HEAVY TIMBER)

EXTERIOR WALLS NON-COMBUSTIBLE (MAY BE FRTW OR CLT)

INTERIOR ELEMENTS QUALIFY AS HEAVY TIMBER (MIN. SIZES, NO CONCEALED SPACES)

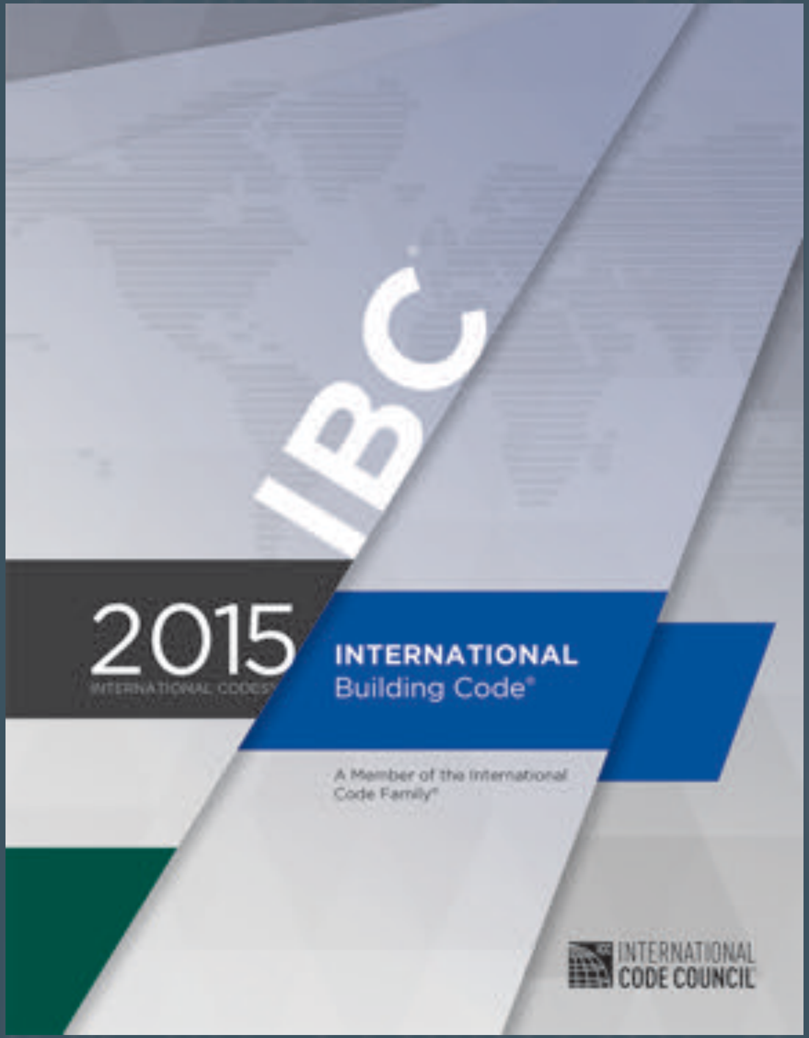
CONSTRUCTION TYPES

IBC 602

When does the code allow mass timber to be used?

IBC defines mass timber systems in IBC Chapter 2 and notes their acceptance and manufacturing/testing standards in IBC Chapter 23

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



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

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

CONSTRUCTION TYPES

Chapter 6:
Types of Construction

Where does the code allow NLT to be used?

- Type III: 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

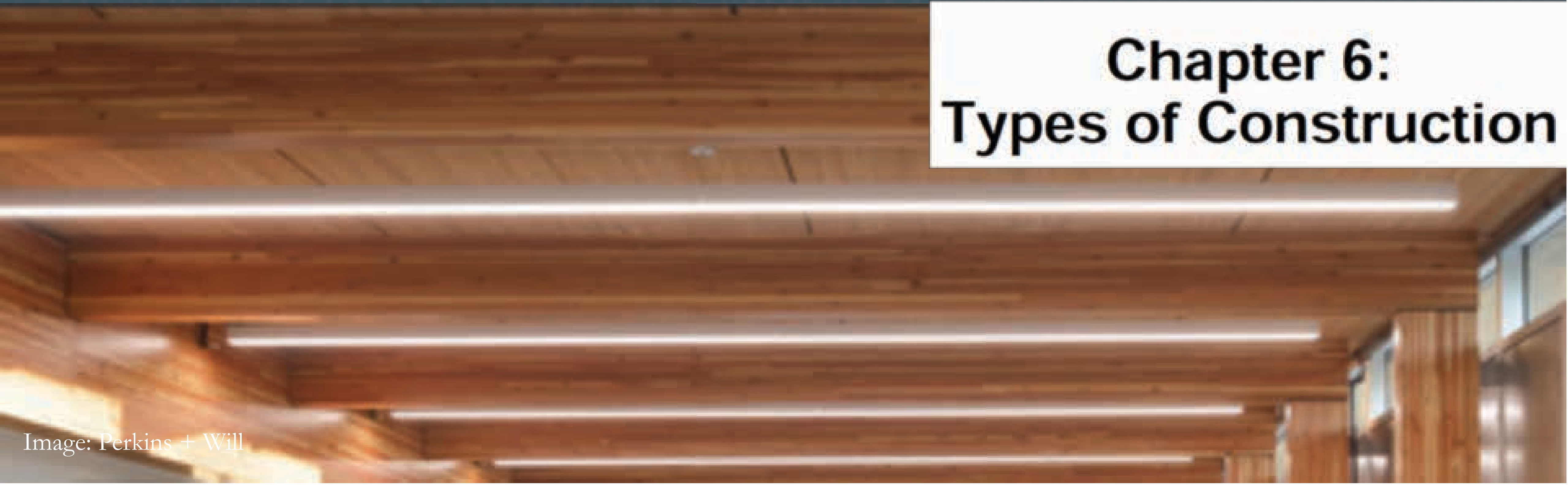


Image: Perkins + Will

CONSTRUCTION TYPES

IBC 602

TYPE IV CONSTRUCTION PERMITS EXPOSED HEAVY/MASS TIMBER ELEMENTS OF MINIMUM SIZES. EXAMPLES INLCUDE:

- ROOF DECKING: 3” CLT, 2X T&G
- COLUMN SUPPORTING ROOF: 6X8
- BEAM SUPPORTING FLOOR: 6X10

TABLE 602.4
WOOD MEMBER SIZE EQUIVALENCIES

MINIMUM NOMINAL SOLID SAWN SIZE		MINIMUM GLUED-LAMINATED NET SIZE		MINIMUM STRUCTURAL COMPOSITE LUMBER NET SIZE	
Width, inch	Depth, inch	Width, inch	Depth, inch	Width, inch	Depth, inch
8	8	$6^3/_4$	$8^1/_4$	7	$7^1/_2$
6	10	5	$10^1/_2$	$5^1/_4$	$9^1/_2$
6	8	5	$8^1/_4$	$5^1/_4$	$7^1/_2$
6	6	5	6	$5^1/_4$	$5^1/_2$
4	6	3	$6^7/_8$	$3^1/_2$	$5^1/_2$

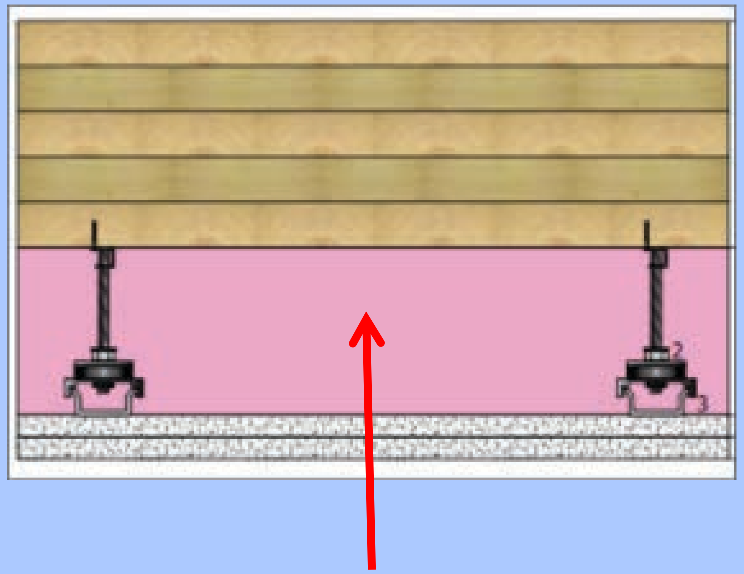
CONSTRUCTION TYPES

IBC 602

CONCEALED SPACES

TYPE IV CONSTRUCTION REQUIRES THAT INTERIOR ELEMENTS BE WITHOUT CONCEALED SPACES:

- CONCEALED SPACES INCLUDE DROPPED CEILINGS, ATTICS, CHASES, OTHERS
- CONCEALED SPACE RESTRICTION DOES NOT APPLY TO ANY OTHER CONSTRUCTION TYPE. IF USING MASS TIMBER ELEMENTS IN NON TYPE IV CONSTRUCTION, CONCEALED SPACES ARE PERMITTED BUT MAY BE REQUIRED TO BE SPRINKLERED
- IBC 602.4.6 PERMITS 1 HOUR FIRE RESISTANCE RATED CONSTRUCTION FOR PARTITIONS



EXAMPLE OF CONCEALED SPACE CREATED BY DROPPED CEILING

CONSTRUCTION TYPES

Chapter 6:
Types of Construction

Image: Christian Columbres Photography

Where does the code allow MT to be used?

- Type V: 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

ALLOWABLE BUILDING SIZE

IBC 503

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
	STORIES (S) AREA (A)									
A-1	S A	UL UL	5 UL	3 15,500	2 8,500	3 14,000	2 8,500	3 15,000	2 11,500	1 5,500
A-2	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-3	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-4	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-5	S A	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL
B	S A	UL UL	11 UL	5 37,500	3 23,000	5 28,500	3 19,000	5 36,000	3 18,000	2 9,000
E	S A	UL UL	5 UL	3 26,500	2 14,500	3 23,500	2 14,500	3 25,500	1 18,500	1 9,500

ALLOWABLE BUILDING SIZE

IBC 503

MULTI STORY BUSINESS OCCUPANCY (B)

BASED ON IBC 2012 TABLE 503 W/ ALLOWABLE INCREASES

HEIGHT AND AREA (WITH ALLOWABLE INCREASES)	IIB	IIIB	VA	VB
STORIES[1]	4	4	4	3
HEIGHT[1] (FT)	75	75	70	60
MAX STORY AREA[2] (FT^2)	69K	57K	54K	27K
TOTAL BUILDING AREA[3] (FT^2)	207K	171K	162K	81K

[1] ASSUMES NFPA 13 SPRINKLERS THROUGHOUT (IBC 504.2)

[2] ASSUMES NFPA 13 SPRINKLERS THROUGHOUT (IBC 506.3)

[3] ASSUMES 3 OR MORE NUMBER OF STORIES (IBC 506.4)

ALLOWABLE BUILDING SIZE

IBC 503

MULTI STORY BUSINESS OCCUPANCY (B)

BASED ON IBC 2012 TABLE 503 W/ ALLOWABLE INCREASES

CONSTRUCTION TYPE	IIA	IIIA	IV
STORIES[1]	6	6	6
HEIGHT[1] (FT)	85	85	85
STORY AREA[2] (FT^2)	112.5K	85.5K	108K
TOTAL BUILDING AREA[3] (FT^2)	337.5K	256.5K	324K

[1] ASSUMES NFPA 13 SPRINKLERS THROUGHOUT (IBC 504.2)

[2] ASSUMES NFPA 13 SPRINKLERS THROUGHOUT (IBC 506.3)

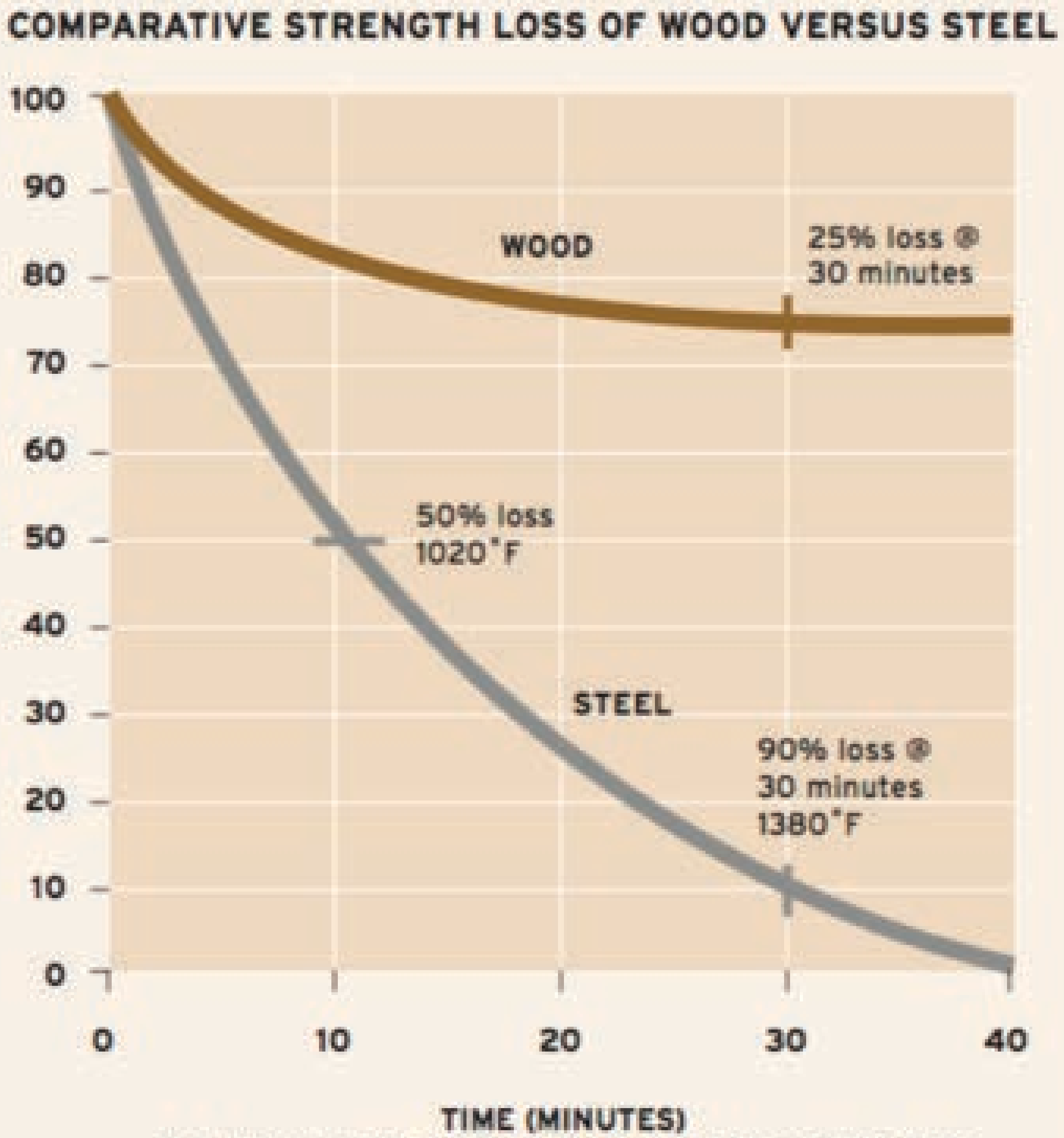
[3] ASSUMES 3 OR MORE NUMBER OF STORIES (IBC 506.4)

FIRE RESISTANCE

PHOTO CREDIT: FPINNOVATIONS

MASS TIMBER DESIGN

FIRE RESISTANCE

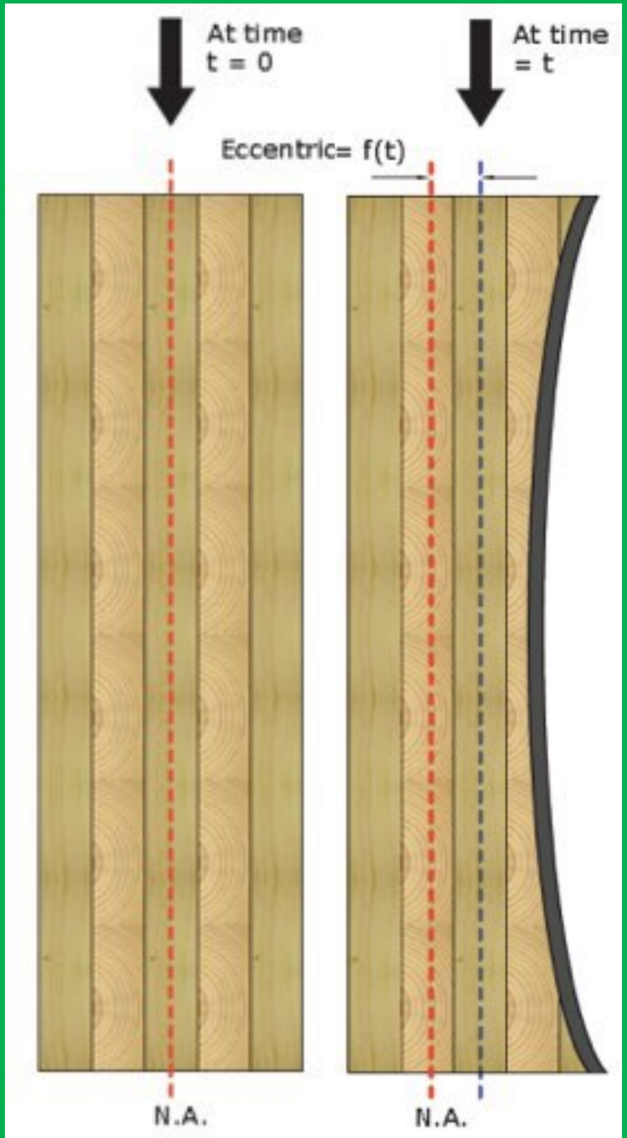


Results from test sponsored by National Forest Products Association at the Southwest Research Institute

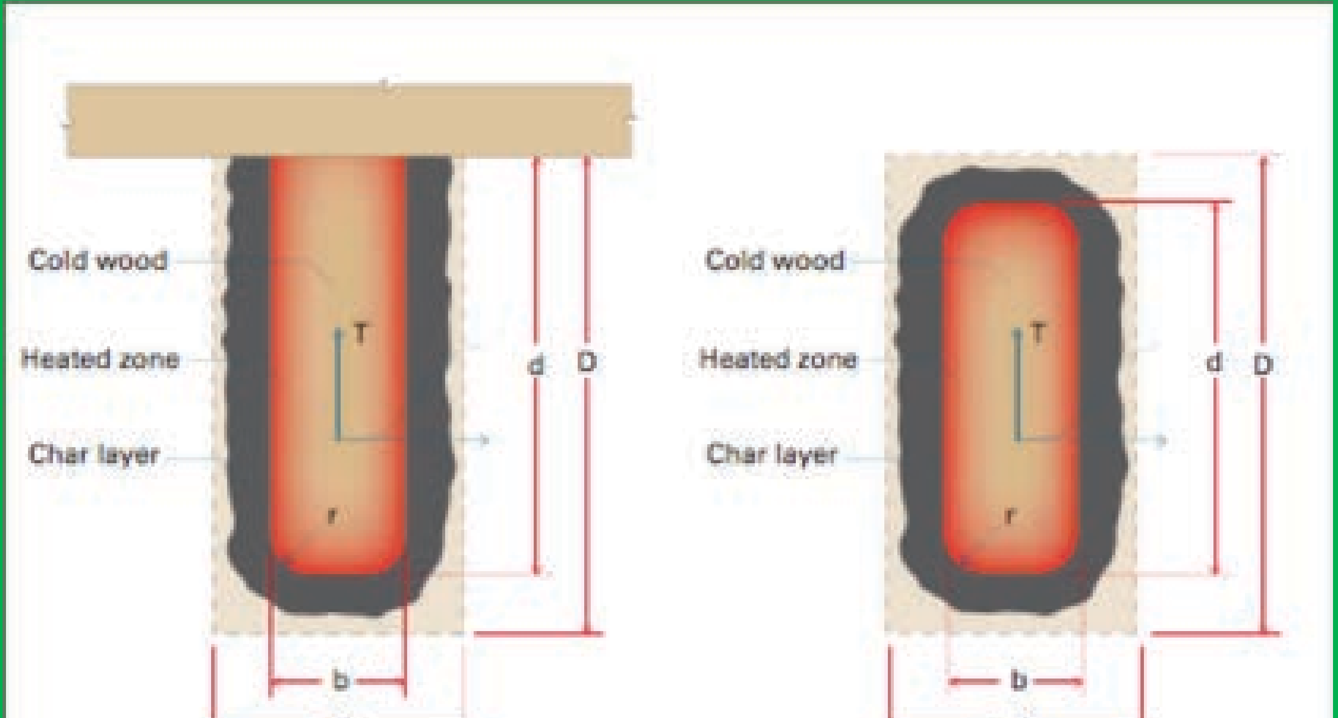
SOURCE: AITC

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

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

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

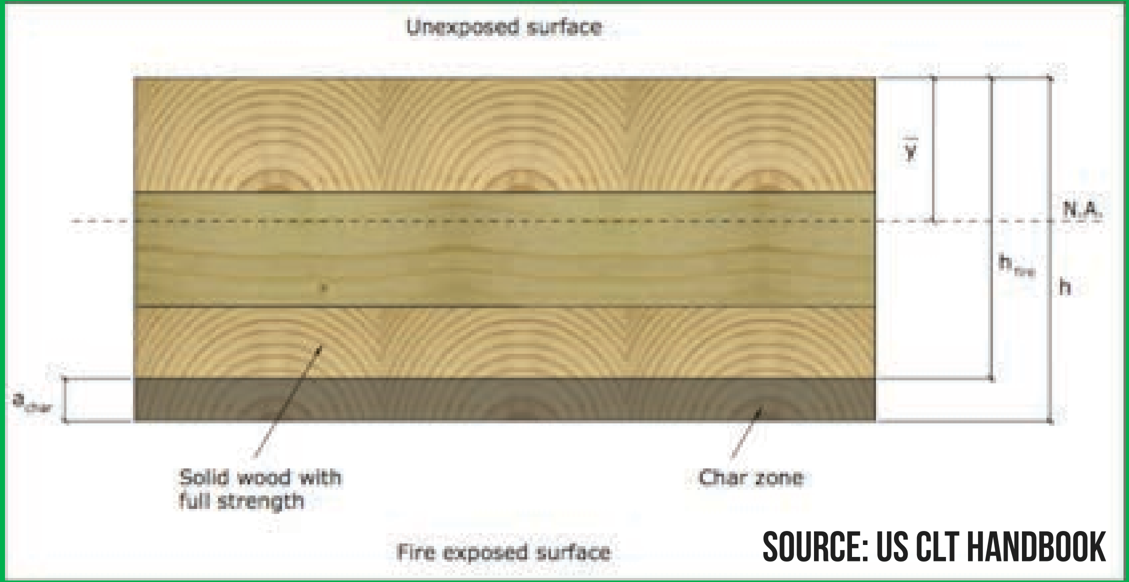
c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. Not less than the fire-resistance rating required by other sections of this code.

e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

f. Not less than the fire-resistance rating as referenced in Section 704.10.

SOURCE: IBC 2015 TABLE 601



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

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:

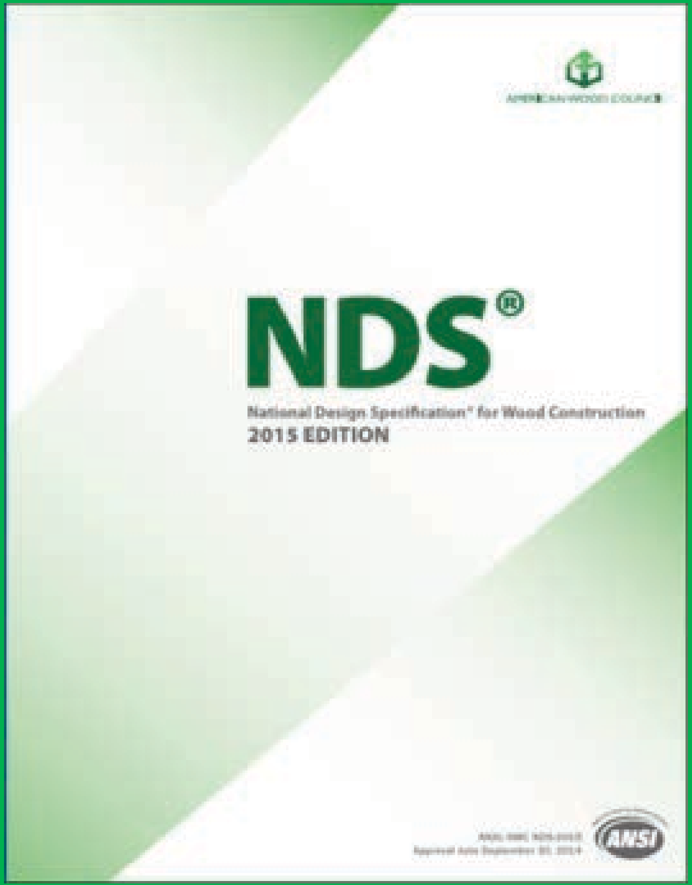
3. Calculations in accordance with Section 722.

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)

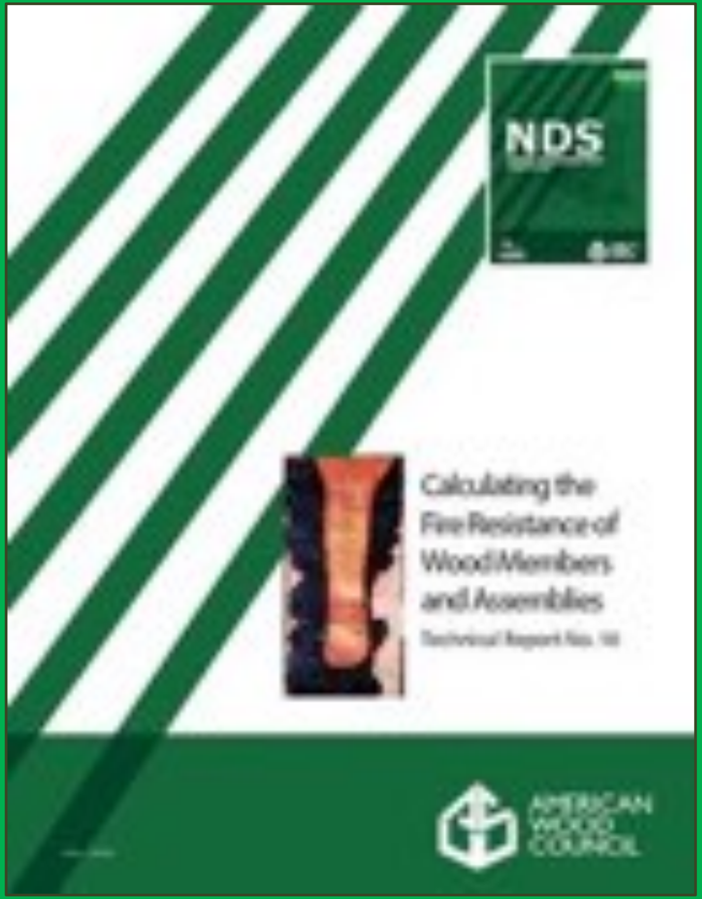



NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION 149

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	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 DESIGN

FIRE RESISTANCE

NDS Table 16.2.2 Design stress adjustment factors applied to adjust to average ultimate strength under fire design conditions

Table 16.2.2 Adjustment Factors for Fire Design[1]

			ASD					
			Design Stress to Member Strength Factor	Size Factor[2]	Volume Factor[3]	Flat Use Factor[2]	Beam Stability Factor[3]	Column Stability Factor[3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-	-	-

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.

SOURCE: AWC'S NDS

woodworks.org/ask-an-expert

MASS TIMBER DESIGN

FIRE RESISTANCE

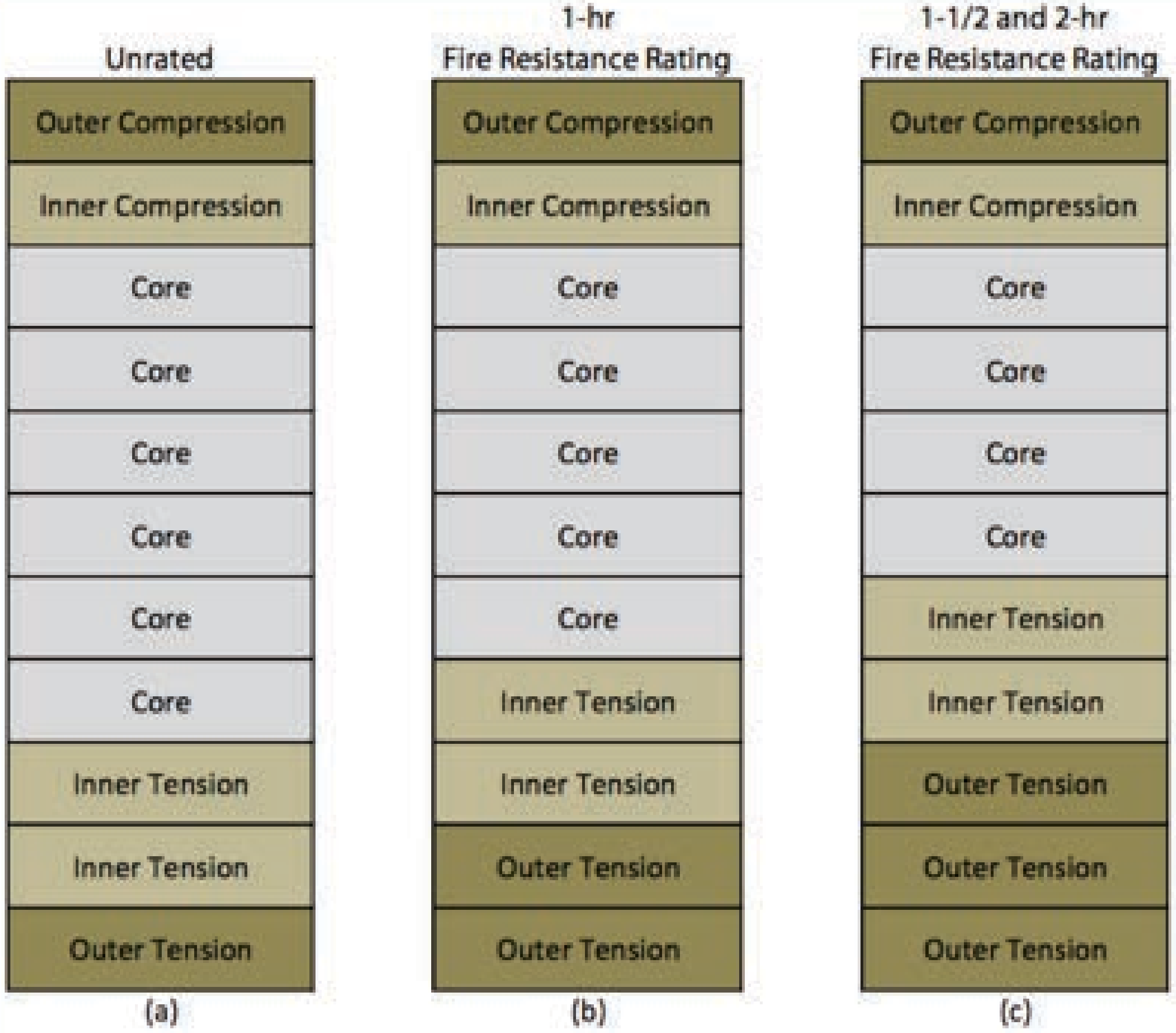


Figure 3-1 Typical glulam unbalanced beam layups

SOURCE: AWC'S TR 10

<u>GLULAM BEAM FIRE DESIGN:</u>

- FOR UNBALANCED BEAMS, SUBSTITUTE 1 CORE LAM FOR 1 TENSION LAM FOR 1 HOUR RATING, 2 CORE LAMS FOR 2 TENSION LAMS FOR 1.5 & 2 HOUR RATING
- FOR BALANCED BEAMS, MATCH ON COMPRESSION SIDE

MASS TIMBER DESIGN

FIRE RESISTANCE

GLULAM BEAM FIRE DESIGN EXAMPLE:

SPAN = 18', TRIB WIDTH = 6'

LL = 100 PSF, DL = 25 PSF

$$w_{load} = s\,(q_{dead} + q_{live}) = (6)(25 + 100) = 750 \text{ plf}$$

$$M_{max} = w_{load}\,L^2 / 8 = (750)(18^2)/8 = 30{,}375 \text{ ft-lb}$$

TRY 6-3/4"X13-1/2" DF 24F GLULAM

$$S_s = bd^2/6 = (6.75)(13.5)^2/6 = 205 \text{ in}^3$$

$$F'_b = F_b\,(C_D)(C_M)(C_t)(\text{lesser of } C_L \text{ or } C_V)$$

$$= 2400\,(1.0)(1.0)(1.0)(0.98) = 2343 \text{ psi (NDS 5.3.1)}$$

SOURCE: AWC'S TR 10

SOURCE: WOODWORKS

GLULAM BEAM FIRE DESIGN EXAMPLE:

$M'_s = F'_b S_s = (2343)(205.0)/12 = 40{,}032$ ft-lb

SOURCE: AWC'S TR 10

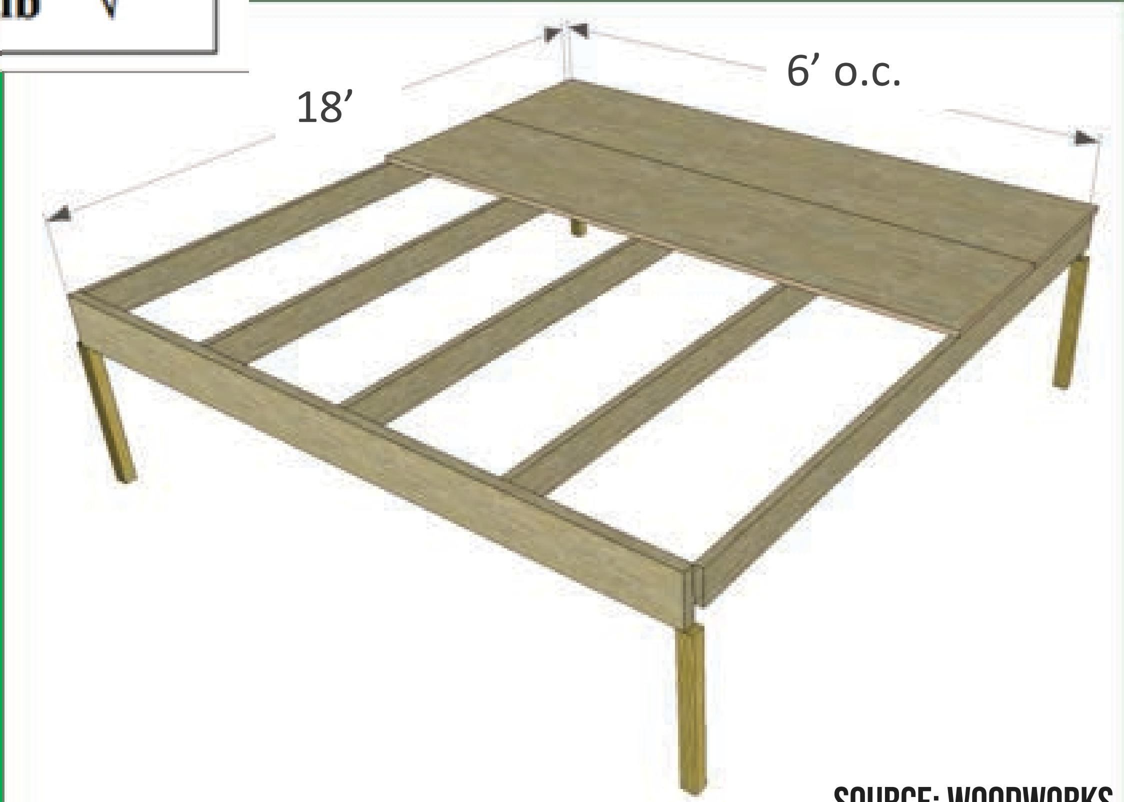
Structural Check: $M'_s \geq M_{max}$ **40,032 ft-lb > 30,375 ft-lb** √

CHECK FOR 1 HOUR FIRE RATING – EXPOSED 3 SIDES

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

Required Fire Endurance (hr.)	Effective Char Rate, β_{eff} (in./hr.)	Effective Char Depth, a_{char} (in.)
1-Hour	1.8	1.8
1½-Hour	1.67	2.5
2-Hour	1.58	3.2

SOURCE: AWC'S NDS



SOURCE: WOODWORKS

MASS TIMBER DESIGN

FIRE RESISTANCE

GLULAM BEAM FIRE DESIGN EXAMPLE:

SOURCE: AWC'S TR 10

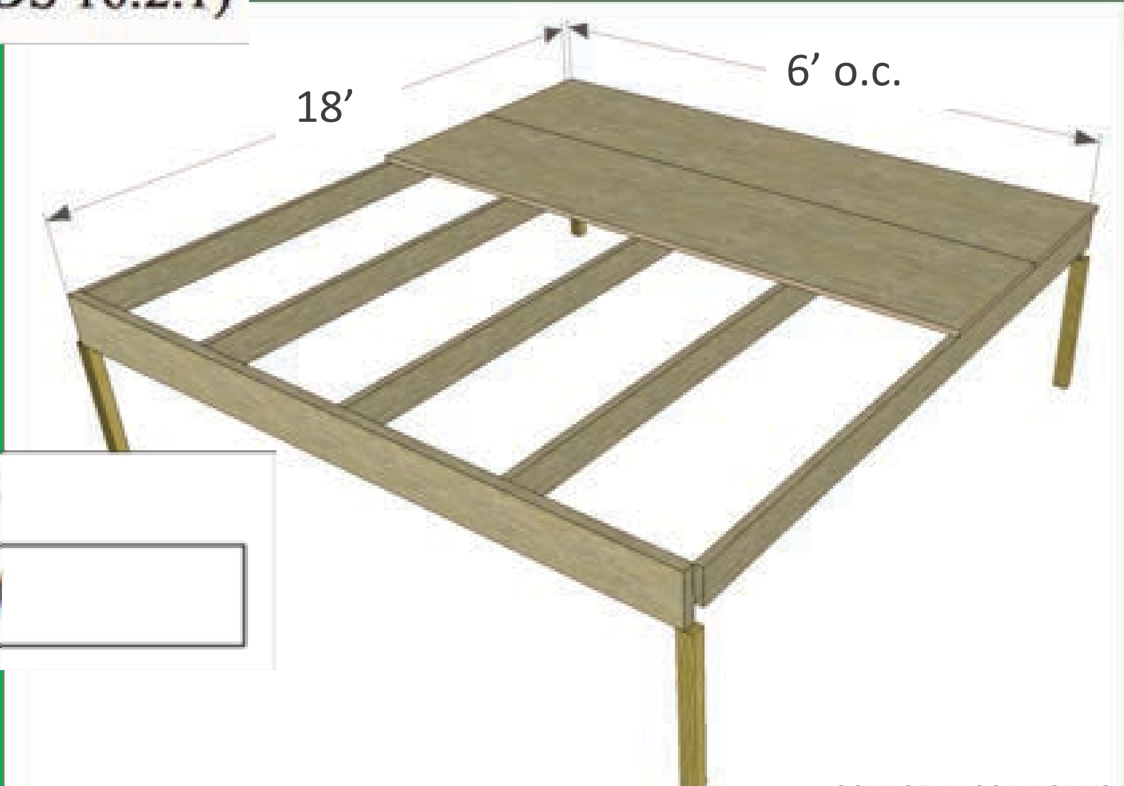
$S_f = (b\text{-}2a)(d\text{-}a)^2/6 = (6.75\text{-}3.6)(13.5\text{-}1.8)^2/6 = 71.9\ in^3$ (NDS 16.2.1)

$F'_{b,f} = (2.85)\ F_{b,f}$ (lesser of C_L or C_V)

$= 2.85(2400)(0.98) = 6703$ psi (NDS 16.2.2)

$M'_f = F'_{b,f}\ S_f = (6703)(71.9)/12 = 40{,}145$ ft-lb (NDS 16.2.2)

Fire Check: $M'_f \geq M_{max}$ **40,145 ft-lb > 30,375 ft-lb** √

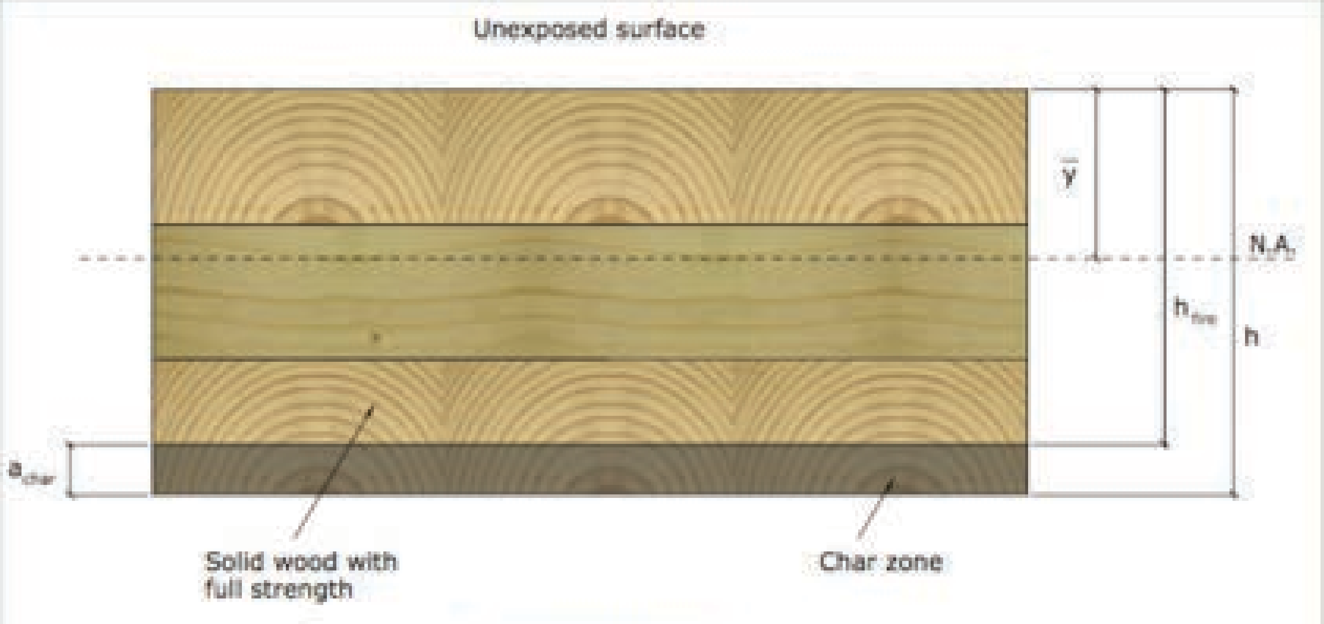


SOURCE: WOODWORKS

6-3/4"X13-1/2" DF 24F GLULAM ADEQUATE FOR 1 HOUR RATING, EXPOSED 3 SIDES

MASS TIMBER DESIGN

FIRE RESISTANCE



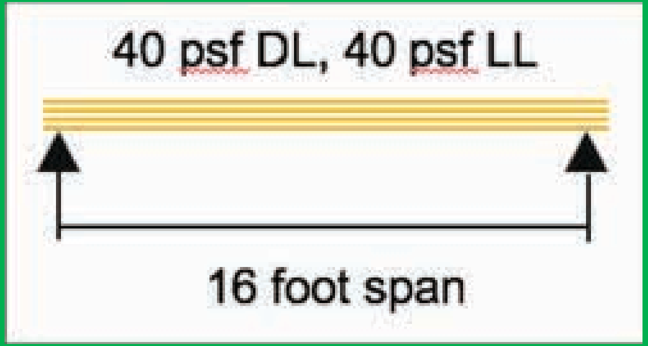
SOURCE: US CLT HANDBOOK

CLT FIRE DESIGN:

- LAM THICKNESS AFFECTS CHAR DEPTH
- PARTIALLY CHARRED CROSS LAYERS ARE TYPICALLY NEGLECTED FOR STRUCTURAL CHECKS

CLT FIRE DESIGN EXAMPLE:

SPAN = 16', LL = 40 PSF, DL = 40 PSF

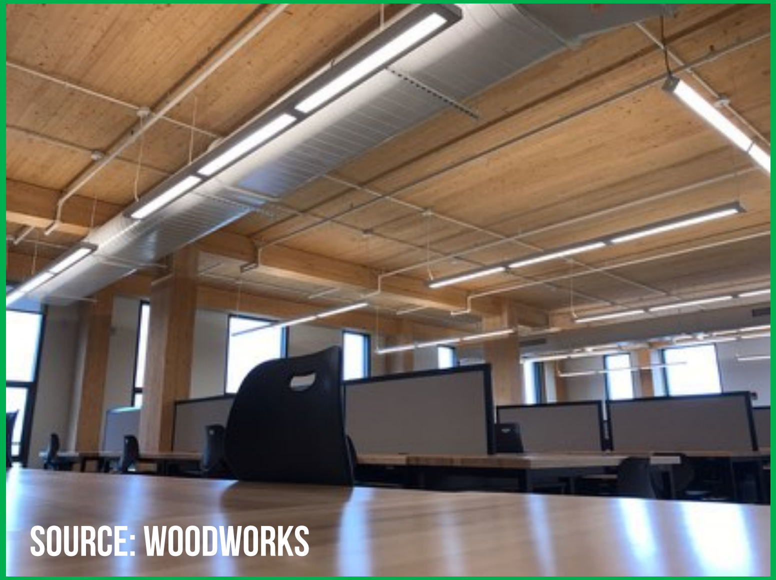


SOURCE: WOODWORKS

TRY 5-PLY, V1 CLT W/1-3/8" THICK LAMS
CHECK FOR 1 HOUR FIRE EXPOSURE

$M_b = w\,L^2 / 8 = (40+40psf)\,(16ft)^2 / 8 = 2560$ lb-ft/ft

$(F_bS_{eff})' = C_D\,(1.0)\,(F_bS_{eff}) = 4800$ lb-ft/ft PER PRG 320

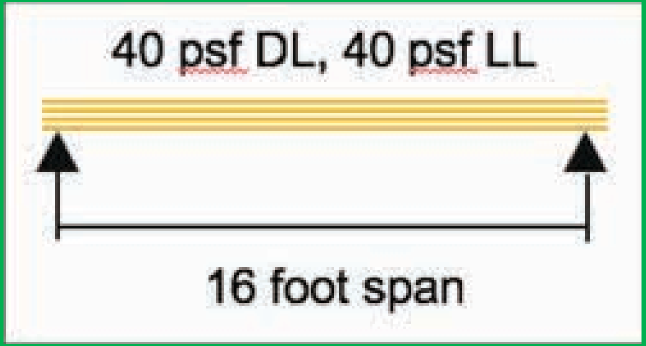


CLT FIRE DESIGN EXAMPLE:

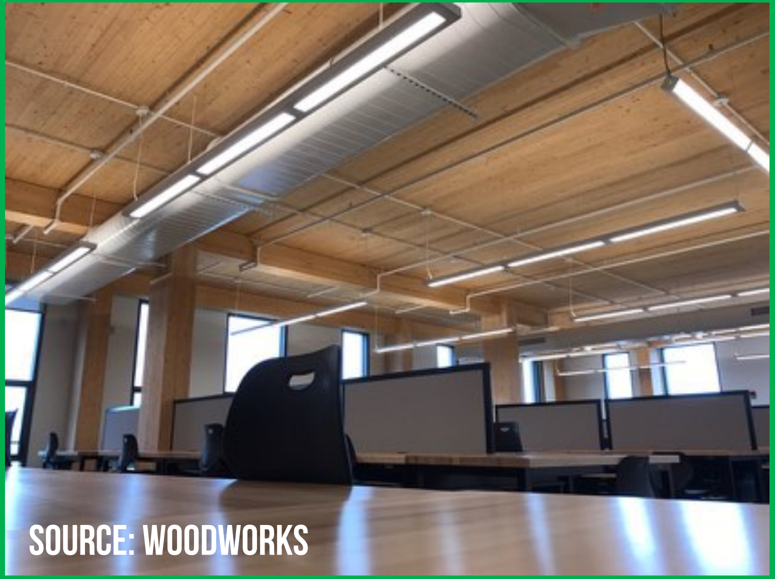
Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

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



SOURCE: WOODWORKS



SOURCE: WOODWORKS

MASS TIMBER DESIGN

FIRE RESISTANCE

CLT FIRE DESIGN EXAMPLE:

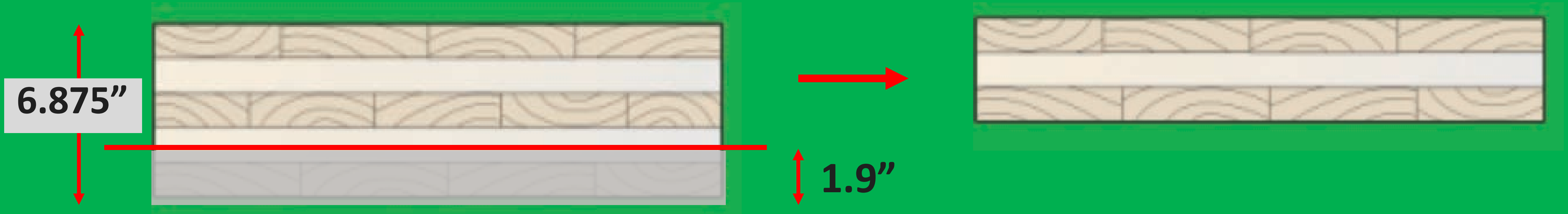


TABLE A2.
THE ALLOWABLE BENDING CAPACITIES[a,b,c] FOR CLT LISTED IN TABLE A1 (FOR USE IN THE U.S.)

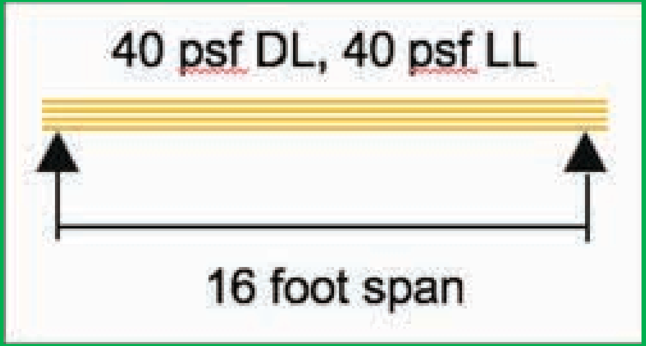
CLT Grade	CLT t (in.)	=	⊥	=	⊥	=	⊥	=	Major: $F_bS_{eff,0}$ (lbf-ft/ft)	Major: $EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	Major: $GA_{eff,0}$ (10^6 lbf/ft)	Minor: $F_bS_{eff,90}$ (lbf-ft/ft)	Minor: $EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	Minor: $GA_{eff,90}$ (10^6 lbf/ft)
V1	4 1/8	1 3/8	1 3/8	1 3/8					2,090	108	0.53	165	3.6	0.59
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,800	415	1.1	1,430	95	1.2
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,500	1,027	1.6	3,275	360	1.8
V2	4 1/8	1 3/8	1 3/8	1 3/8					2,030	95	0.46	160	3.1	0.52
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,675	363	0.91	1,370	81	1.0
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,275	898	1.4	3,125	309	1.6

(Columns = through =: Lamination Thickness (in.) in CLT Layup; Major Strength Direction; Minor Strength Direction)

SOURCE: ANSI/APA PRG 320

MASS TIMBER DESIGN

CLT FIRE DESIGN EXAMPLE:



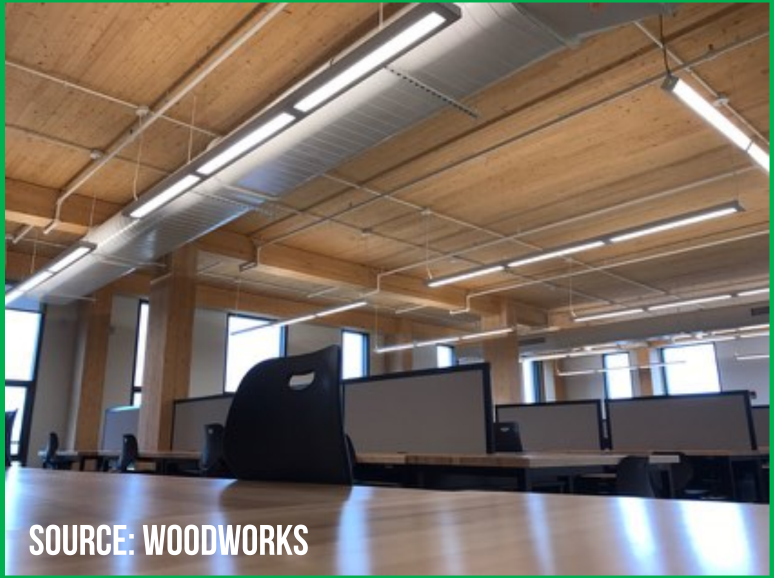
SOURCE: WOODWORKS

$M_f' = (2.85)(F_bS_{eff})(C_L) = (2.85)(2090)(1.0) = 5957$ lb-ft/ft

Fire Check: $M_f' > M_b$

$M_f' = 5957$ lb-ft/ft $> M_b = 2560$ lb-ft/ft

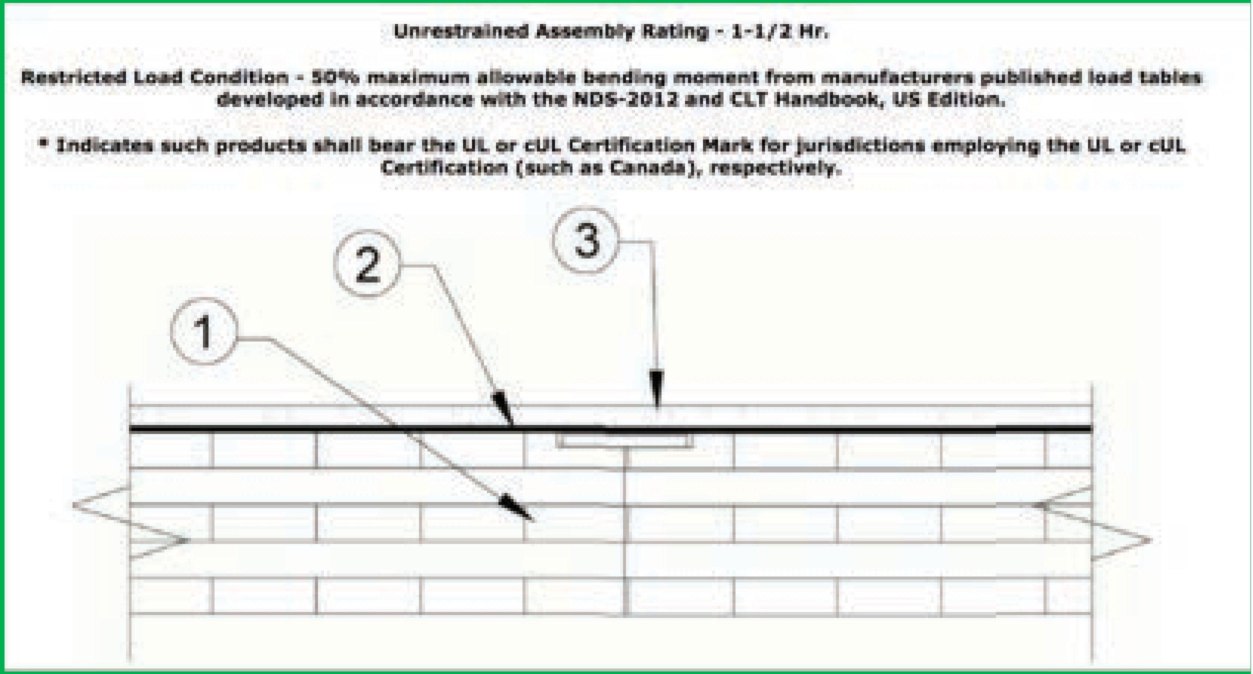
5-PLY V1 CLT adequate for 1 Hour Fire Exposure



MASS TIMBER FIRE DESIGN METHODS:

NDS Chapter 16 Char Calculations vs. ASTM E119 Tested Assembly

- **NDS Chpt 16 calcs check structural integrity**
- **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

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):

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

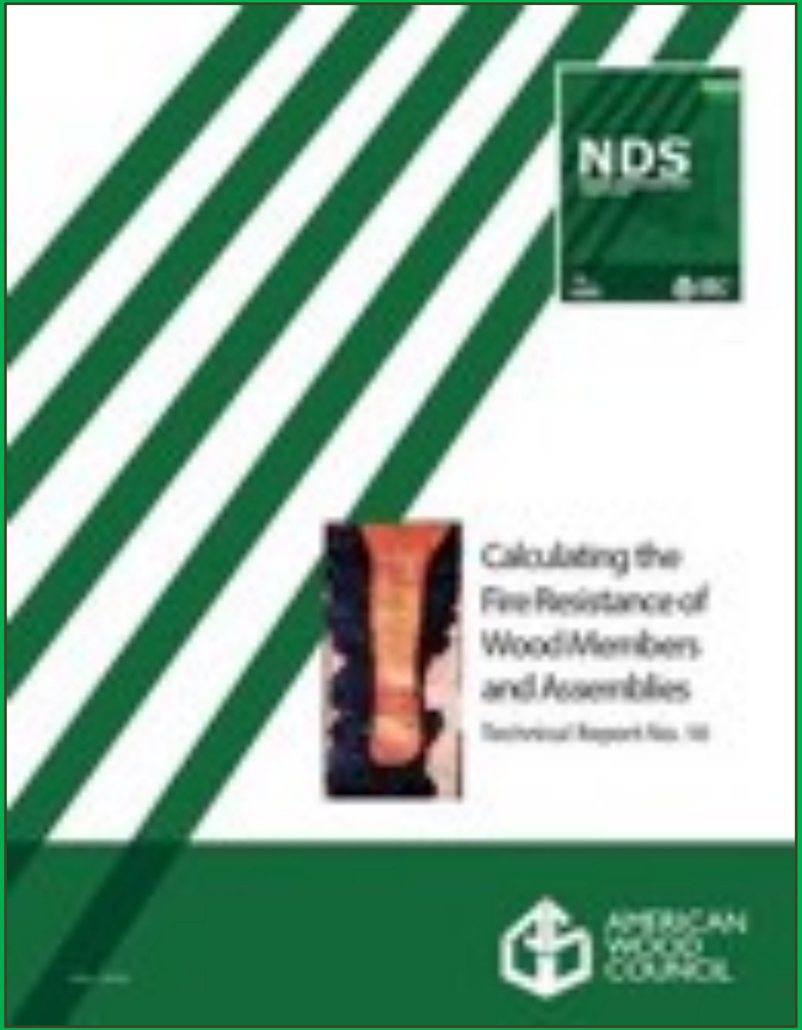
Calculate maximum induced moment (per foot of width):

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

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

SOURCE: AWC'S TR 10



FREE DOWNLOAD AT AWC.ORG

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

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

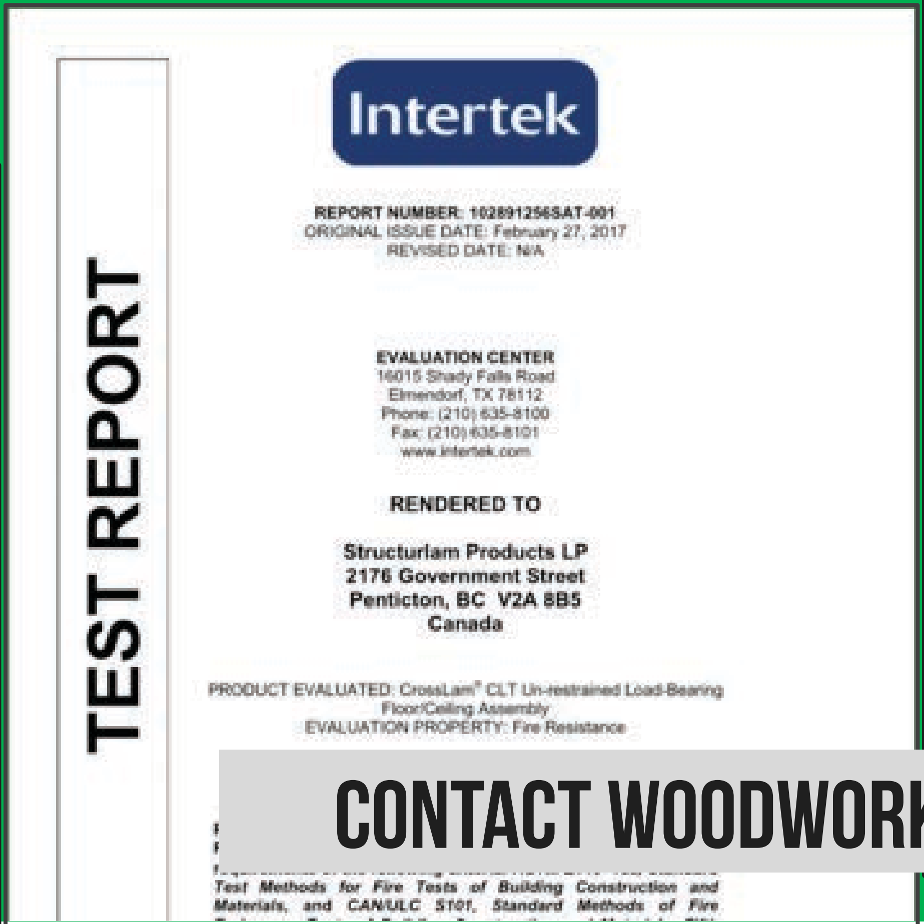
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)

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

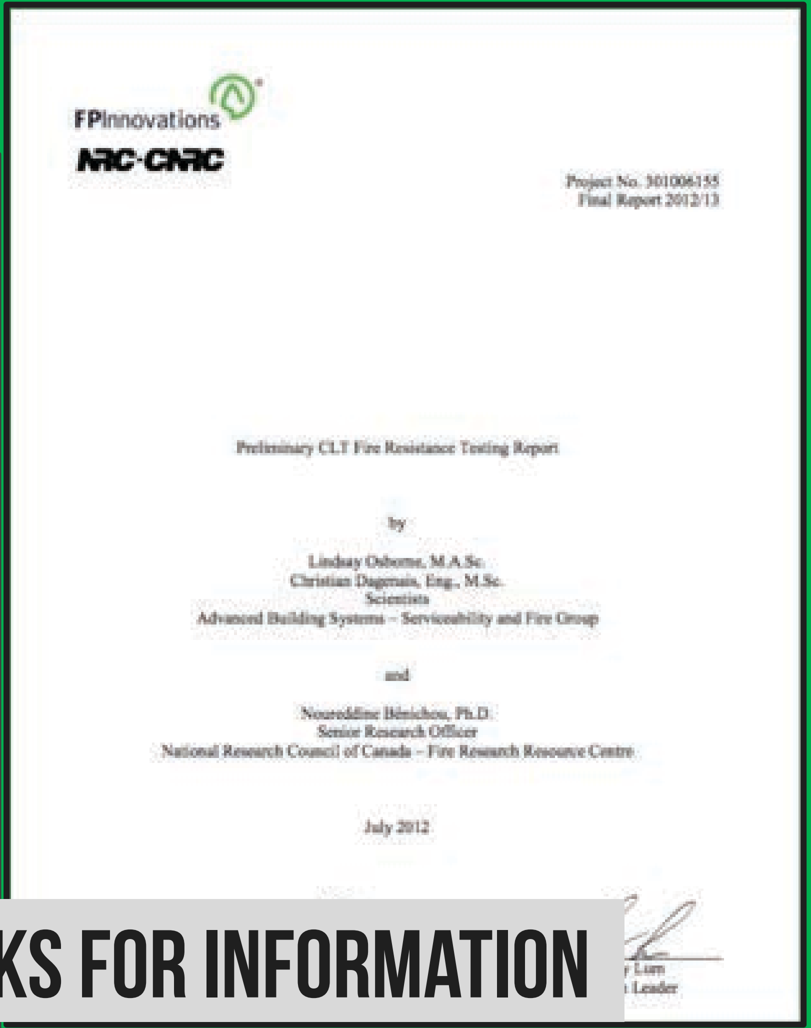
Penticton, BC V2A 8B5

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

CONTACT WOODWORKS FOR INFORMATION

MASS TIMBER PRODUCTS

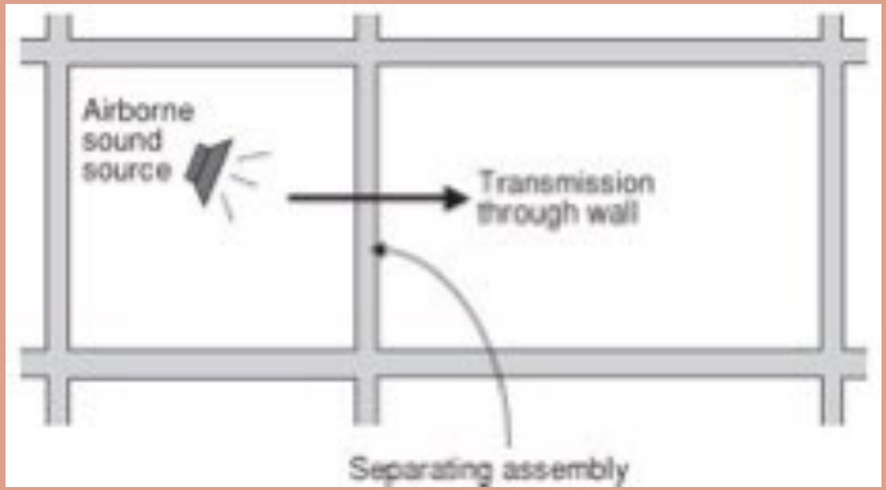
ACOUSTICS

MASS TIMBER DESIGN

AIR-BORNE SOUND:

- SOUND TRANSMISSION CLASS (STC)

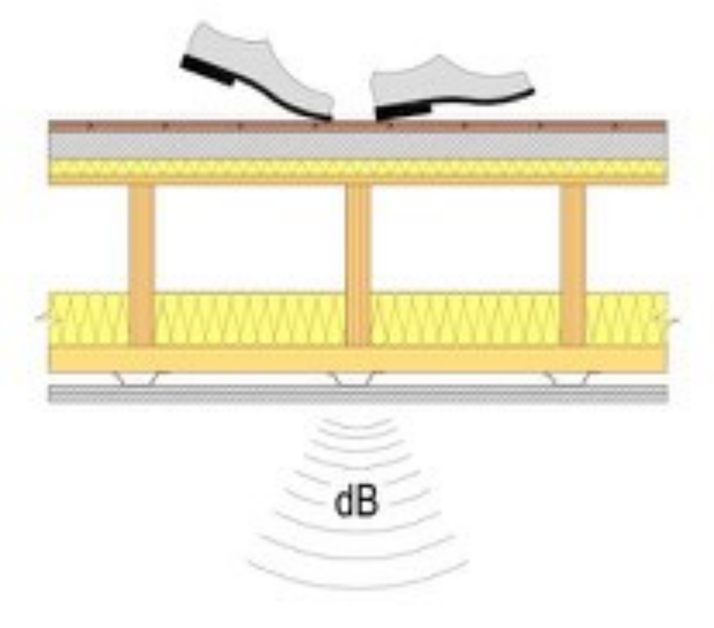
MEASURES HOW EFFECTIVELY AN ASSEMBLY ISOLATES AIR-BORNE SOUND AND REDUCES THE LEVEL THAT PASSES FROM ONE SIDE TO THE OTHER



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

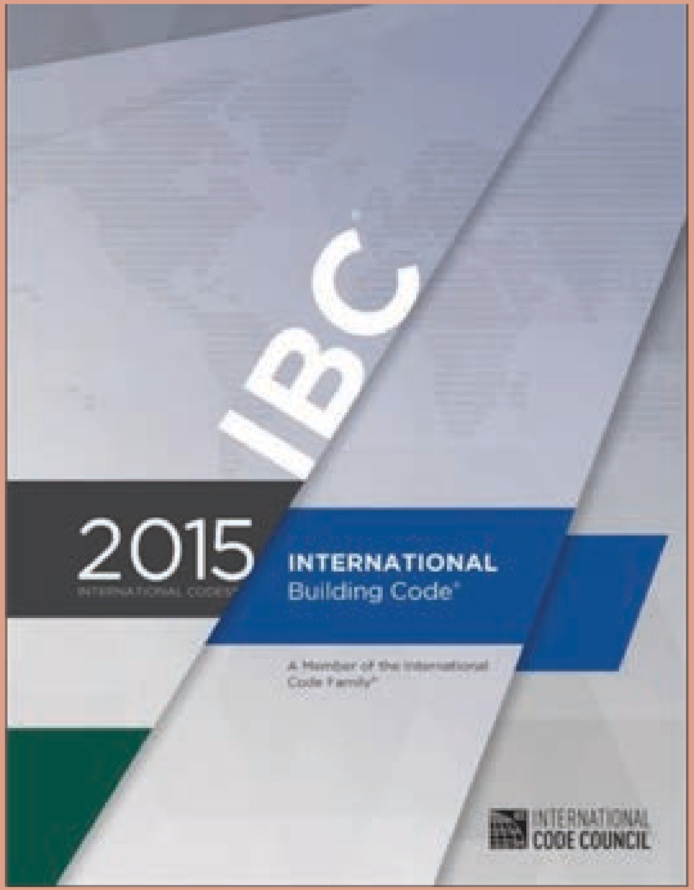
CODE REQUIREMENTS FOR RESIDENTIAL OCCUPANCIES:

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

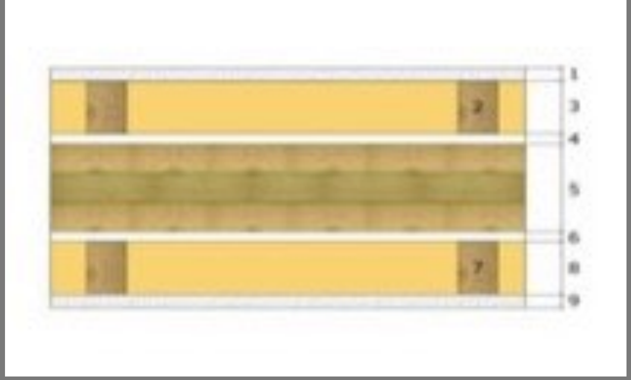


Sound Insulation of Bare CLT Floors and Walls

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

Design Examples for >45 FSTC Walls

Plan view of cross-section	Wall detail	FSTC
	1 = 3-layer CLT ~ 4-1/8” 2 = 1/2” air gap 3 = 2” by 3” wood studs at 16” o.c. 4 = 2-1/2” mineral wool 5 = 5/8” gypsum board	47
	1 & 9 = 5/8” gypsum board 2 & 7 = 2” by 3” wood studs at 16” o.c. 4 & 6 = 1/2” air gap 5 = 3-layer CLT of 4-1/8”	50

Credit: US CLT Handbook

MASS TIMBER DESIGN

ACOUSTICS

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

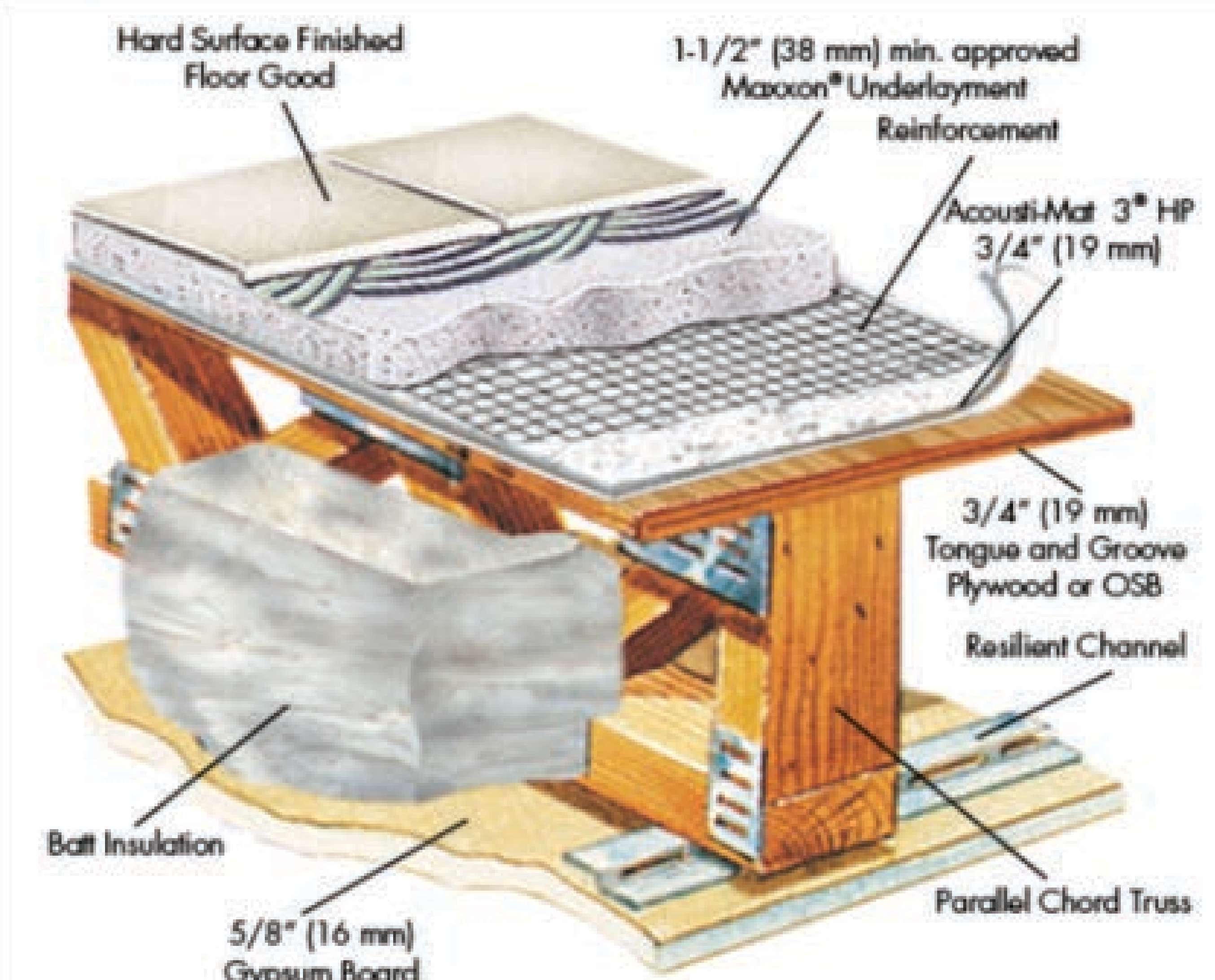


Image credit: Maxxon

MASS TIMBER DESIGN

ACOUSTICS

Acoustical mat - typically installed between subfloor and topping or flooring

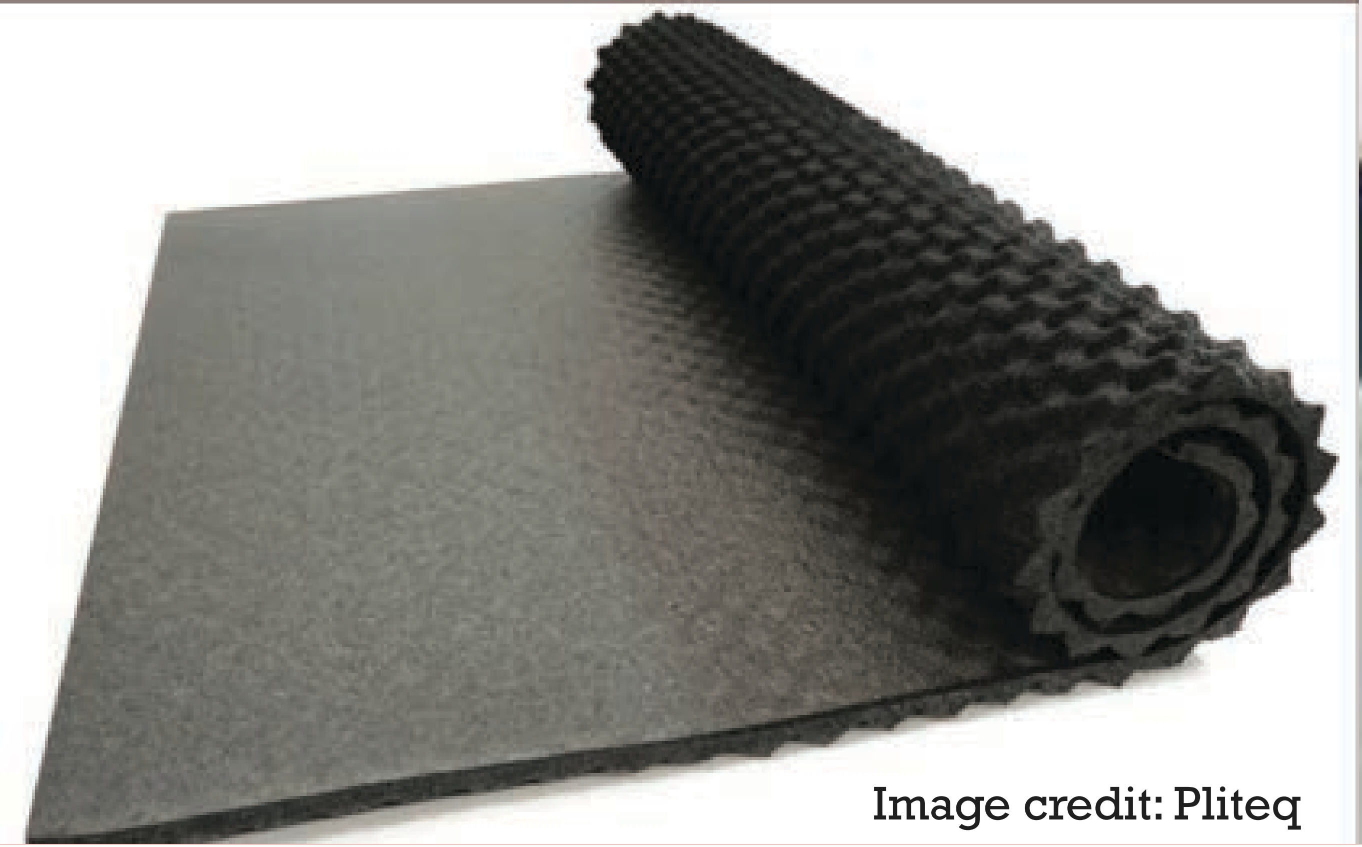


Image credit: Pliteq

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:

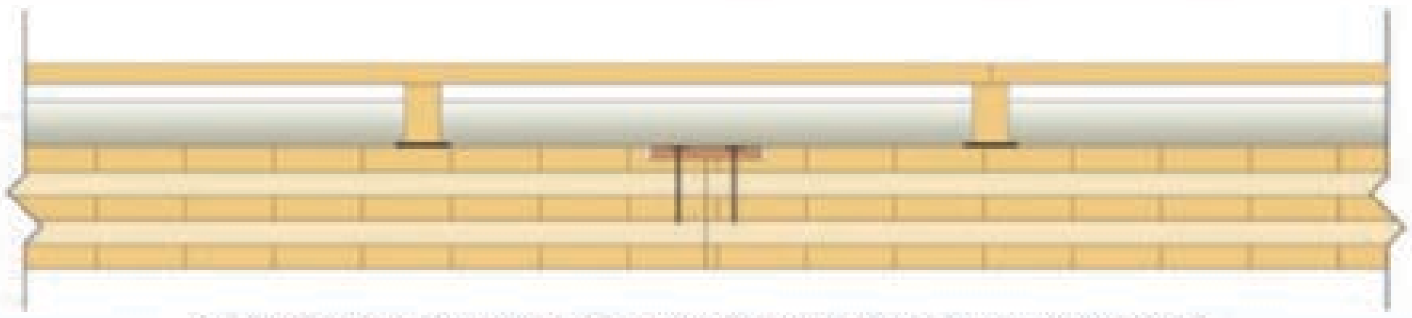
- Gypsum/cement board (Fermacell, Permabase, etc.)
- Proprietary products

Image credit: AcoustiTECH

MASS TIMBER DESIGN

ACOUSTICS

Image credit: Regupol



OSB wood raft with sand on top of a CLT 5 ply (131 mm)	52	47

Options without concrete topping:

- Wood sleepers
- Honeycombs
- Sand fill
- Mineral wool insulation

	Assembly Description from Top to Bottom (7.1)	STC	IIC
1	Gypsum fiberboard FERMACELL of 1.0 in. (25 mm)	62	59
2	Sub-floor ISOVER EP3 of 0.79 in. (20 mm)		
3	Honeycomb acoustic infill FERMACELL of 1.18 in. (30 mm)		
4	Honeycomb acoustic infill FERMACELL of 1.18 in. (30 mm)		
5	Kraft paper underlayment		
6	5-layer CLT panel of 5 5/16 in. (135 mm)		

Credit: US CLT Handbook

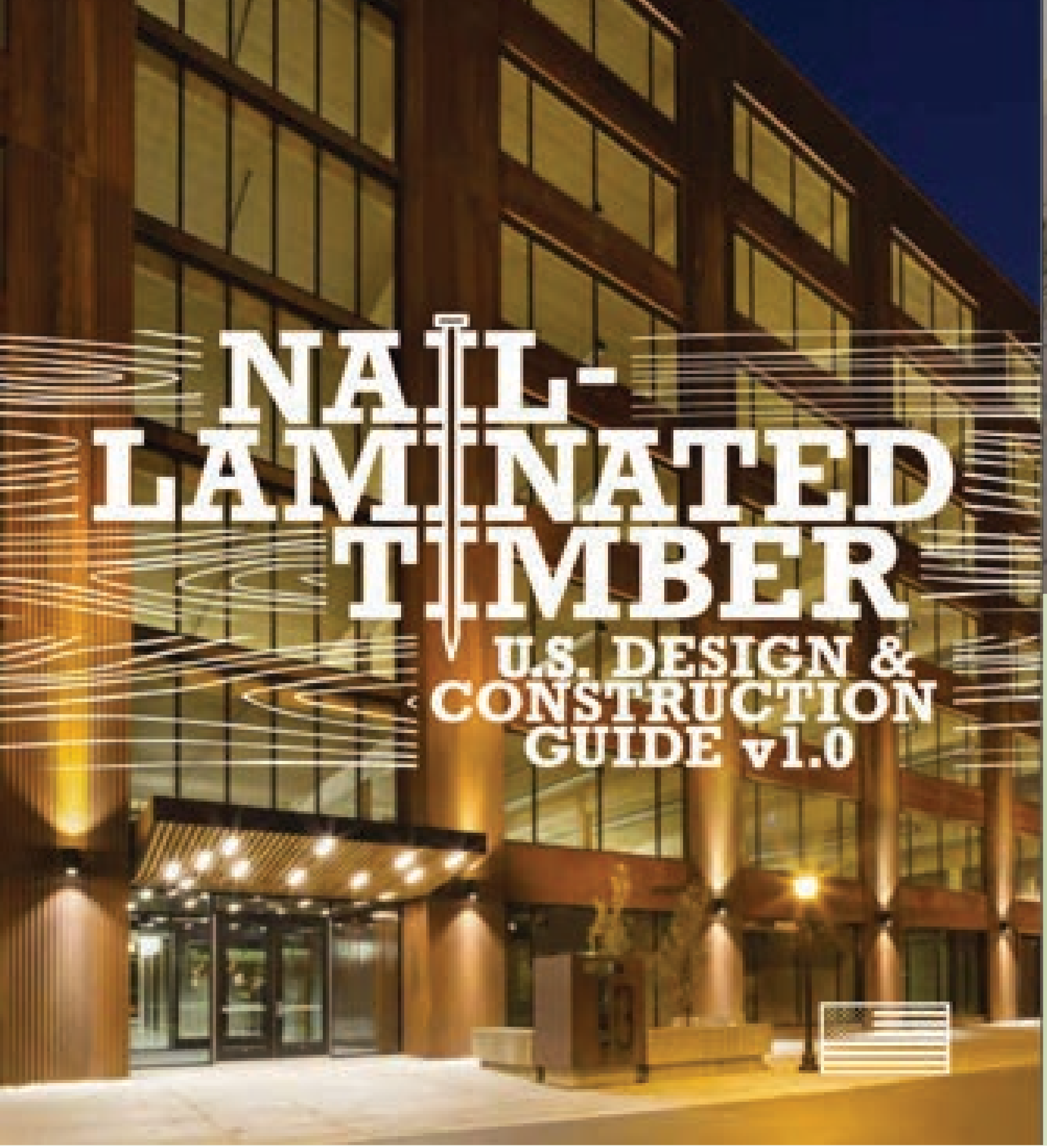
Table A.2 - 13: Tested 5-ply CLT floor specimens with descriptions and STC and IIC-ratings

CLT Acoustics Resources:

- US CLT Handbook
- Acoustics Manufacturers Literature:
  - Maxxon
  - Pliteq
  - AcoustiTECH
  - Kinetics
  - USG
  - Regupol
  - Rothoblaas
- Industry tests – FP Innovations, NRCAN

Contact WoodWorks for information

NLT Acoustics



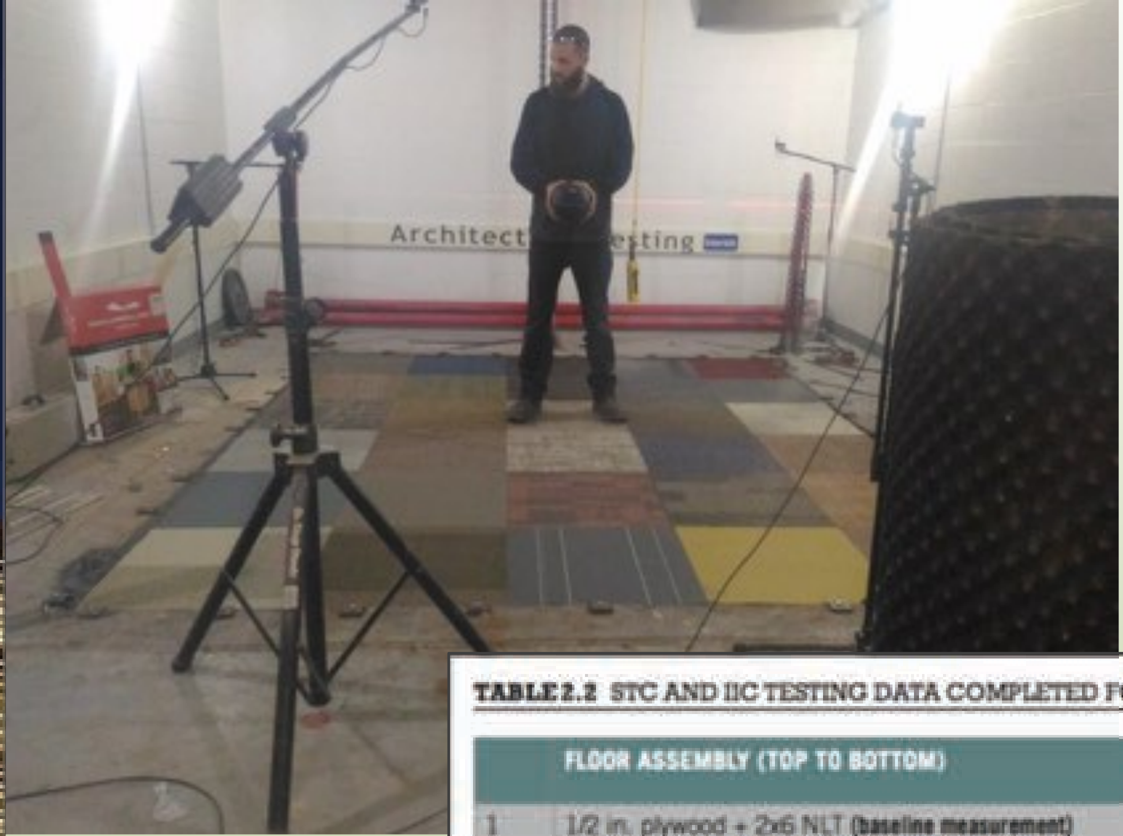


TABLE 2.2 STC AND IIC TESTING DATA COMPLETED FOR NLT FLOORS

	FLOOR ASSEMBLY (TOP TO BOTTOM)	STC	IIC
1	1/2 in. plywood + 2x6 NLT **(baseline measurement)**	34	32
2	Bare CLT (5-ply, 6-7/8 in. thick)	39	25
3	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT	51	44
4	Carpet + 4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT	51	58
5	4 in. normal weight concrete topping + Pliteq GenieMat FF25 acoustical mat + 1/2 in. plywood + 2x6 NLT	54	50
6	4 in. normal weight concrete topping + Pliteq GenieMat FF50 acoustical mat + 1/2 in. plywood + 2x6 NLT	56	52
7	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT + RC + 5/8 in. Type C Gypsum	55	49
8	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT + Pliteq GenieClip RST Clip + R8 Fiberglass batts + 5/8 in. Type C Gypsum	60	59

Credit: NLT Design & Construction Guide


MASS TIMBER SHAFTS
PHOTO CREDIT: ALEX SCHREYER


MASS TIMBER SHAFTS
PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER SHAFTS

PHOTO CREDIT: WILL PRYCE

MASS TIMBER SHAFTS


MASS TIMBER SHAFT WALL CONSIDERATIONS:

- COST
- CONSTRUCTION SCHEDULE
- MATERIAL COMPATIBILITY (MOVEMENT & LATERAL LOAD RESISTANCE)
- CAN DOUBLE AS ARCHITECTURAL FEATURE
- SIMILAR TO TILT UP OR CONTINUOUS WALL APPLICATIONS
- SUCCESSFUL FIRE TESTS FOR 2 HR MASS TIMBER SHAFT WALLS EXIST (EXPOSED AND PROTECTED)

PHOTO CREDIT: LENDLEASE

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

ACCOMMODATING MEP

PHOTO CREDIT: WOODWORKS

EXPOSED MEP

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

MASS TIMBER PRODUCTS

ACCOMMODATING MEP

Photo Credit: KK Law, Courtesy: naturally:wood

PHOTO CREDIT: WOODWORKS

RAISED ACCESS FLOOR

INSTALLED ON TOP OF FLOOR STRUCTURE

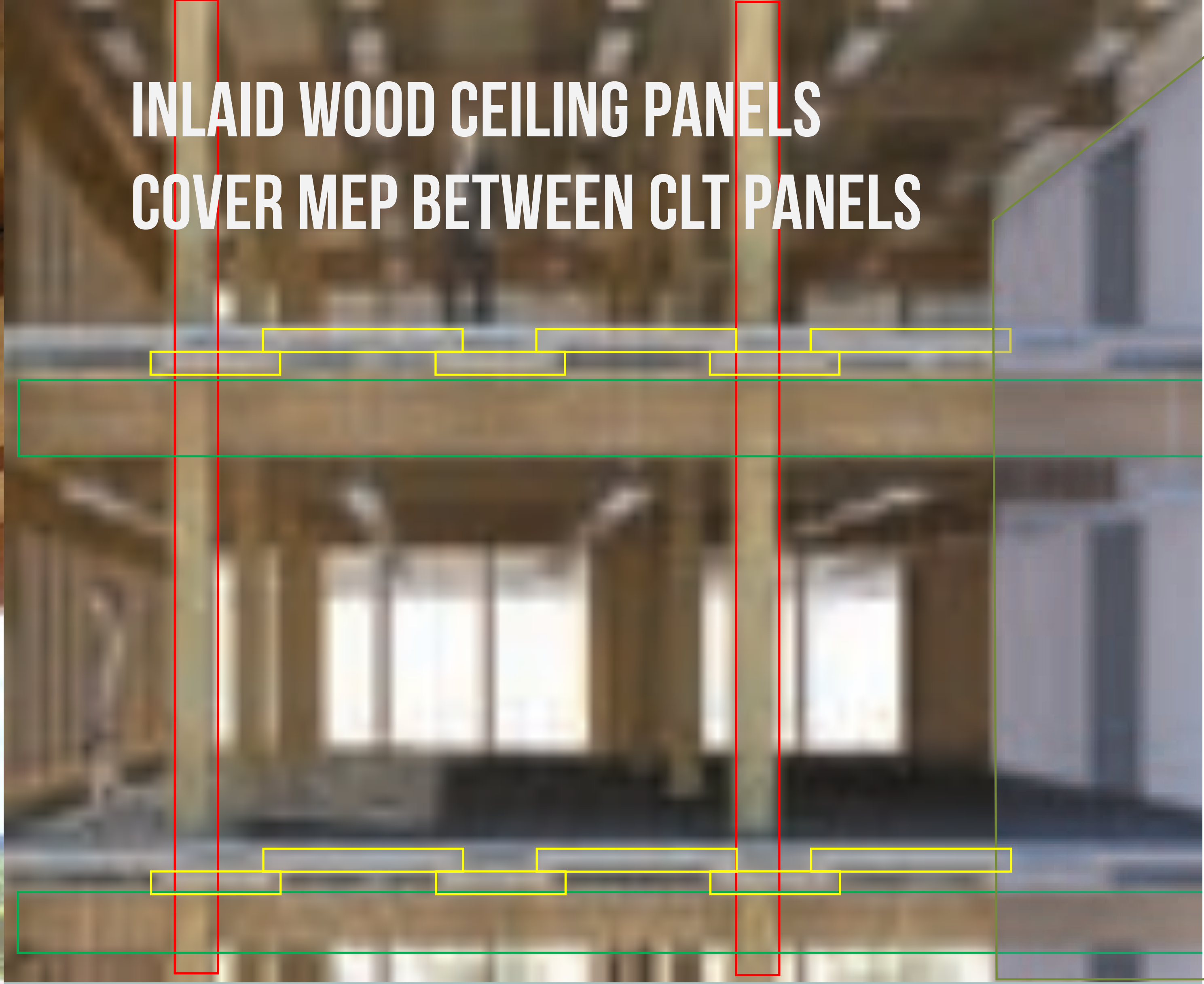
PROVIDES 2” TO 18” OF PLENUM SPACE FOR MEP

WOOD INNOVATION DESIGN CENTER

PRINCE GEORGE, BC

PHOTO CREDIT: ED WHITE

PHOTO CREDIT: MGA



WIDC MEP ACCOMMODATION

ROCKY MOUNTAIN INSTITUTE INNOVATION CENTER

BASALT, CO

PHOTO CREDIT: ROCKY MOUNTAIN INSTITUTE, TIM GRIFFITH

ROCKY MOUNTAIN INSTITUTE INNOVATION CENTER

BASALT, CO

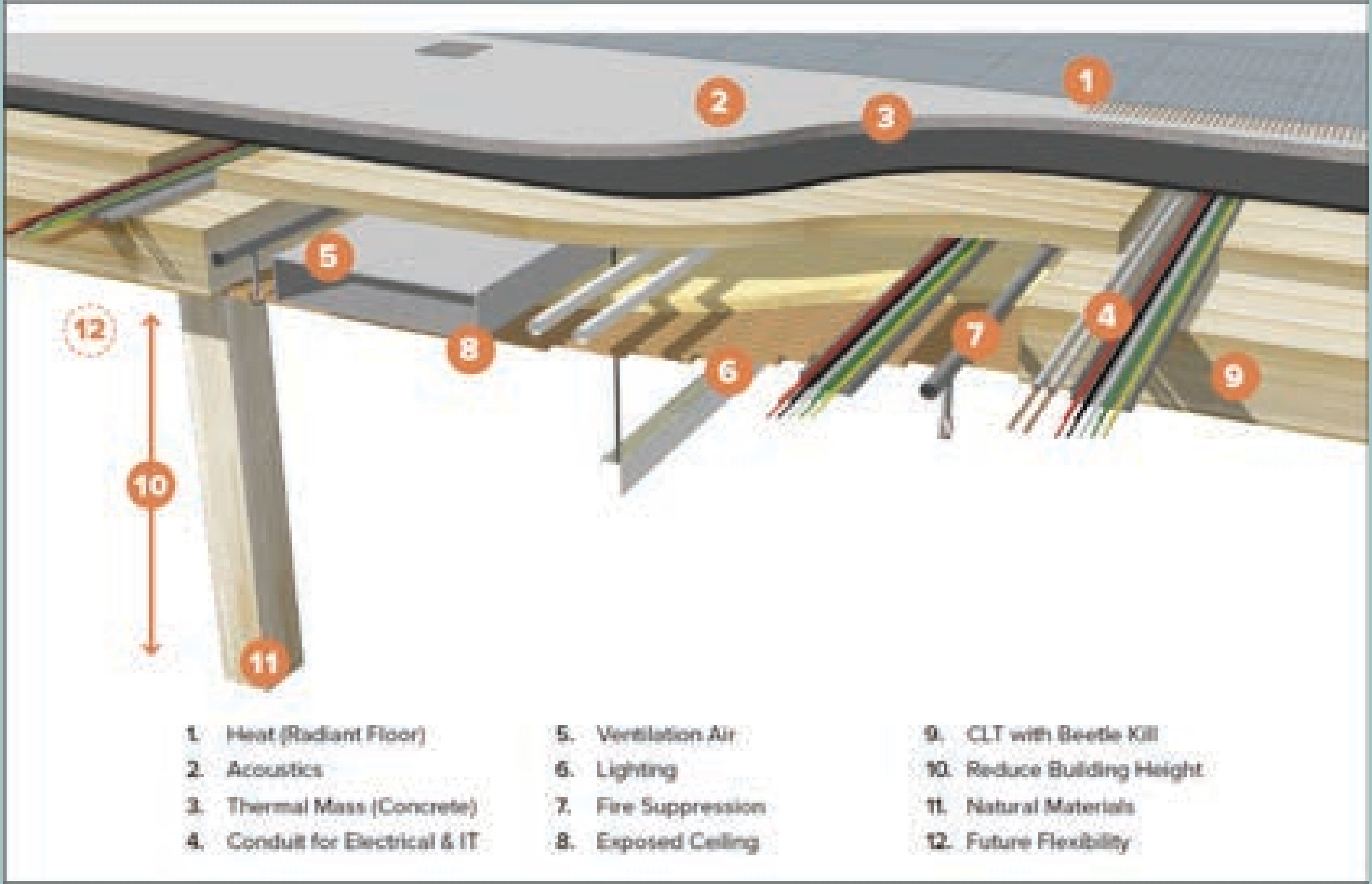


IMAGE CREDIT: ZGF ARCHITECTS


MASS TIMBER PRODUCTS
ACCOMMODATING MEP
EMBEDDED CONDUIT IN
CONCRETE TOPPING SLAB
PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

ACCOMMODATING MEP

EMBEDDED CONDUIT IN WALL PANELS

PHOTO CREDIT: CHARLES JUDD

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How is MEP accommodated in exposed mass timber buildings-e.g., CLT and NLT wall and floor/roof panels?

Mass timber panel products such as cross-laminated timber (CLT), nail-laminated timber (NLT) and dowel-laminated timber (DLT) are used in many applications in multi-family and commercial construction—e.g., floors, roofs, shaft walls, bearing walls and partition walls. In many instances, the panels are left exposed on one side to take advantage of the aesthetic appeal of the timber. For these buildings, accommodation of mechanical, electrical and plumbing (MEP) services is an important design consideration.

Options for Incorporating MEP in Exposed Mass Timber Structures

Accommodating MEP on mass timber walls:

- Fur out a wainscoting wall on the lower half of the mass timber wall to accommodate electrical outlets and plumbing pipes.
- Add light-frame partition walls on one or both sides of the mass timber wall panel to accommodate MEP items, completely covering the mass timber wall panels (note that this can also have acoustical advantages).
- Run the conduit, pipes, etc. on the face of the mass timber wall panels, leaving them exposed and using them as architectural elements.
- Rout and bore the panels to take the electrical conduit, plumbing pipes and mechanical chases. This can be done on site with traditional carpentry tools or in the factory using CNC technology. Structural effects related to panel cross-section reduction should be taken into account. *(See Figure 1.)*

Figure 1 – Credit: Charles Judd

Accommodating MEP on mass timber floor panels:

- Run the conduit, pipes, etc. on the face of the mass timber floor panels, leaving them exposed and using them as architectural elements. *(See Figure 2.)*
- Create a drop ceiling to conce...
- Gap the mass timber panels, running the MEP items between the panels and adding wood ceiling inlay panels between the ...

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.

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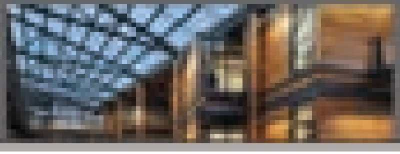
Have a question? Email Us »

Feature Project

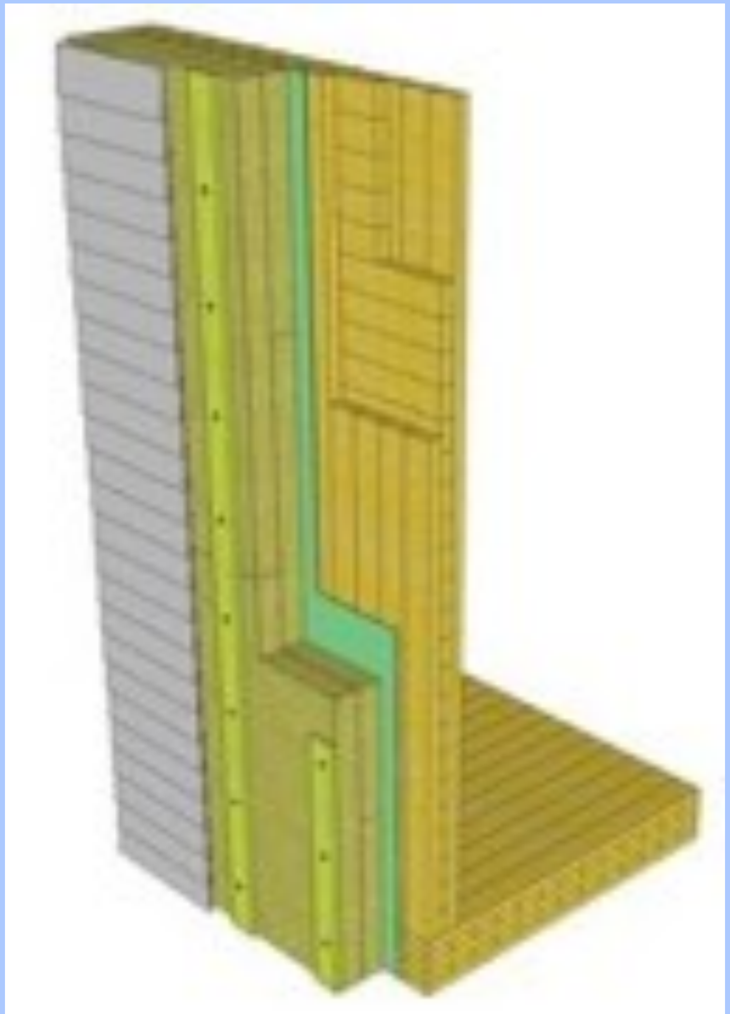


woodworks.org/ask-an-expert

MASS TIMBER DESIGN

BUILDING ENCLOSURE

MASS TIMBER BUILDING ENVELOPES



SIMILAR TO OTHER WALL ASSEMBLIES:

CONTINUOUS INSULATION AND OTHER CONTROL LAYERS

INSTALLED ON OUTSIDE OF WALL PANELS

PHOTO CREDIT: ALEX SCHREYER

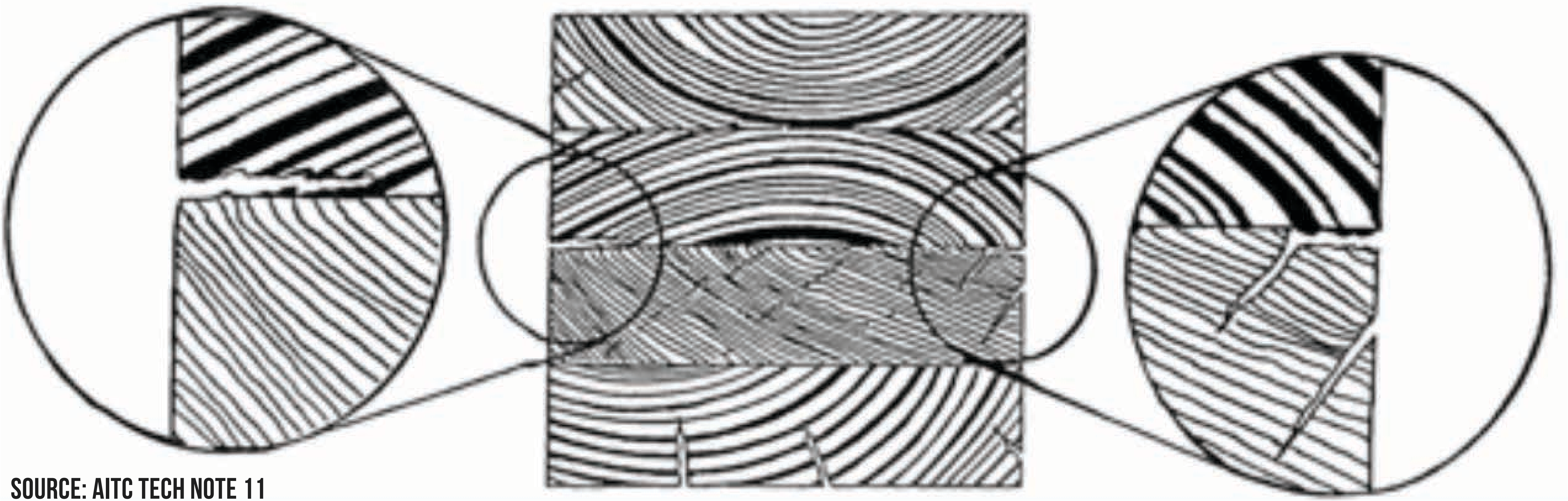
MASS TIMBER DESIGN

BUILDING ENCLOSURE

MASS TIMBER DESIGN

SPLITTING AND CHECKING

ARE SPLITS AND CHECKS IN MASS TIMBER ELEMENTS A STRUCTURAL CONCERN?



SOURCE: AITC TECH NOTE 11

MASS TIMBER DESIGN

SPLITTING AND CHECKING

WHAT CAUSES SPLITS AND CHECKS?

CHECKING AND SPLITTING IS A RESULT OF LOSS OF MOISTURE. AS OUT FIBERS IN WOOD MEMBER TRY TO SHRINK, THEY ARE RESTRAINED BY INNER PORTION OF MEMBER WHICH HAS A HIGHER MOISTURE CONTENT.

SOURCE: APA FORM F450

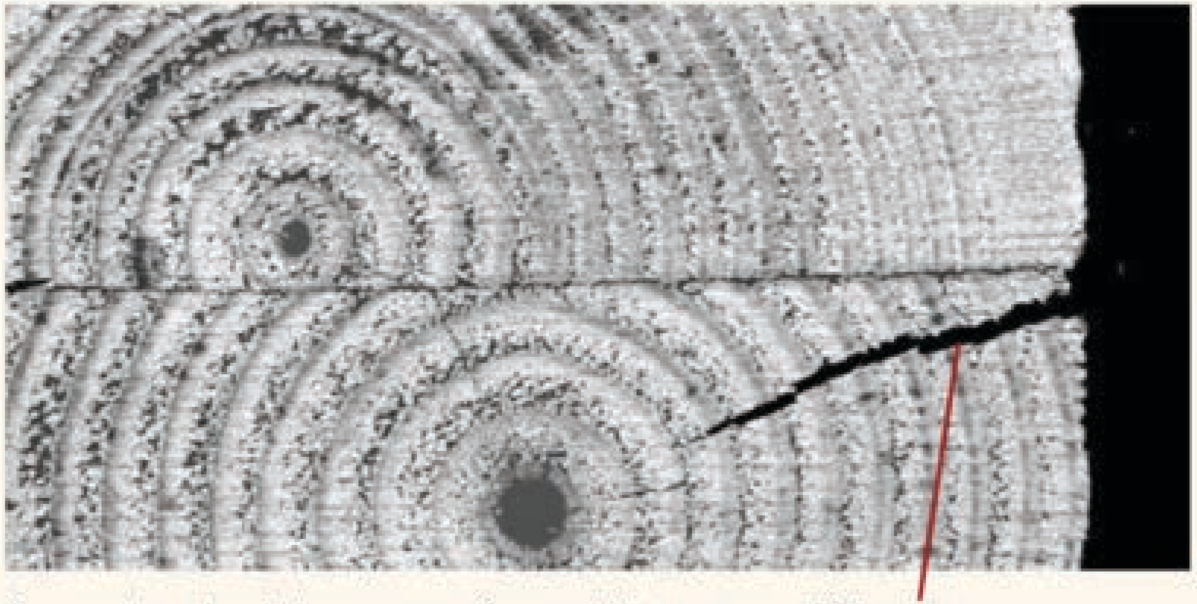
MASS TIMBER DESIGN

SPLITTING AND CHECKING

WHAT CAUSES SPLITS AND CHECKS?

THE MORE RAPID THE RATE OF DRYING, THE GREATER THE DIFFERENTIAL IN SHRINKAGE BETWEEN THE OUTER AND INNER FIBERS RESULTING IN HIGHER SHRINKAGE STRESSES. THESE RESULTANT STRESSES PERPENDICULAR TO GRAIN CAN CAUSE CHARACTERISTIC SEASONING CHECKS.

GLUED LAMINATED BEAM CROSS SECTION ILLUSTRATING CHECKING



Seasoning check (uneven surfaces with torn wood fiber)

SOURCE: APA TECH NOTE R475

MASS TIMBER DESIGN

SPLITTING AND CHECKING

WHEN DOES CHECKING OCCUR?

CHECKING IN MEMBERS IN ENCLOSED BUILDINGS IS USUALLY COMPLETED WITHIN THE FIRST FULL CYCLE OF ENVIRONMENTAL CONDITIONING OF THE SPACE. HOWEVER, CHANGES IN THE END USE OF THE STRUCTURE MAY EFFECT FUTURE CHECKING.

MASS TIMBER DESIGN

SPLITTING AND CHECKING

ARE SPLITS AND CHECKS IN MASS TIMBER ELEMENTS A STRUCTURAL CONCERN?

THE INFLUENCE OF CHECKS ON THE STRUCTURAL PERFORMANCE OF GLUED LAMINATED TIMBER MEMBERS IS GENERALLY MINOR. CHECKING CAN BE MINIMIZED BY CAREFUL INSTALLATION PRACTICES THAT AVOID PROLONGED EXPOSURE OF THE MEMBERS DURING CONSTRUCTION.

MASS TIMBER DESIGN

SPLITTING AND CHECKING

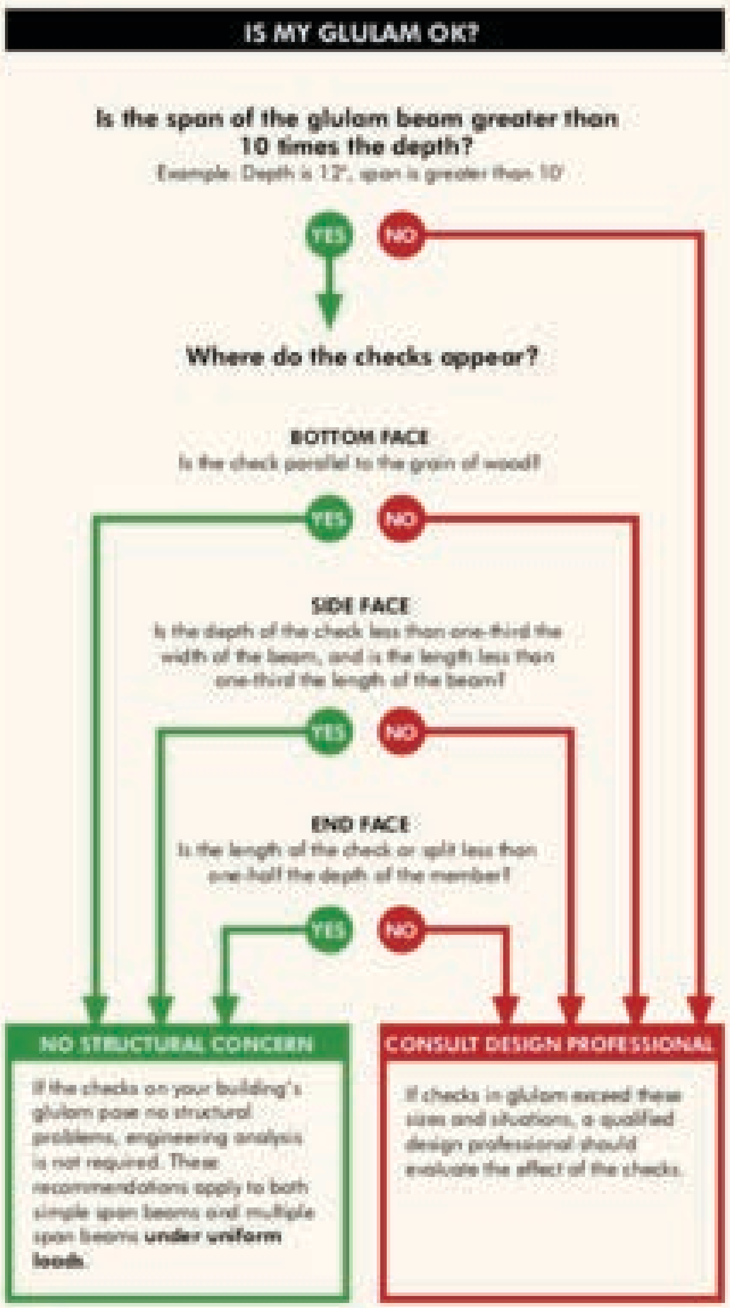
RESOURCES:

- AITC TECH NOTE 11
- APA TECH NOTE R475
- APA FORM F450

MASS TIMBER DESIGN

SPLITTING AND CHECKING

FIGURE 4



EVALUATING SPLITS AND CHECKS IN GLULAM

TABLE 2

ALLOWABLE CHECK SIZE OUTSIDE THE SHEAR-CRITICAL ZONE

Beam Width in Inches	Allowable Side Checks (Depth) in Inches				Allowable End Checks (Length) in Inches			
	y/h							
	0.30	0.35	0.40	0.45	0.30	0.35	0.40	0.45
2-1/2	3/4	1-1/4	1-5/8	2	2-3/8	3-5/8	5	6
3, 3-1/8	1	1-1/2	2	2-3/8	2-7/8	4-3/8	6	7-1/4
3-1/2	1-1/8	1-3/4	2-1/4	2-3/4	3-3/8	5-1/8	6-7/8	8-3/8
5, 5-1/8	1-5/8	2-1/2	3-1/4	4	4-3/4	7-3/8	9-7/8	12
5-1/2	1-3/4	2-3/4	3-5/8	4-3/8	5-1/4	8-1/8	10-7/8	13-1/4
6-3/4	2-1/8	3-1/4	4-1/2	5-3/8	6-1/2	9-7/8	13-3/8	16-1/4
8-1/2, 8-3/4	2-3/4	4-1/8	5-5/8	6-3/4	8-1/8	12-1/2	16-7/8	20-3/8
10-1/2, 10-3/4	3-3/8	5-1/8	6-7/8	8-3/8	10-1/8	15-3/8	20-3/4	25-1/4

SOURCE: APA TECH NOTE R475

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:

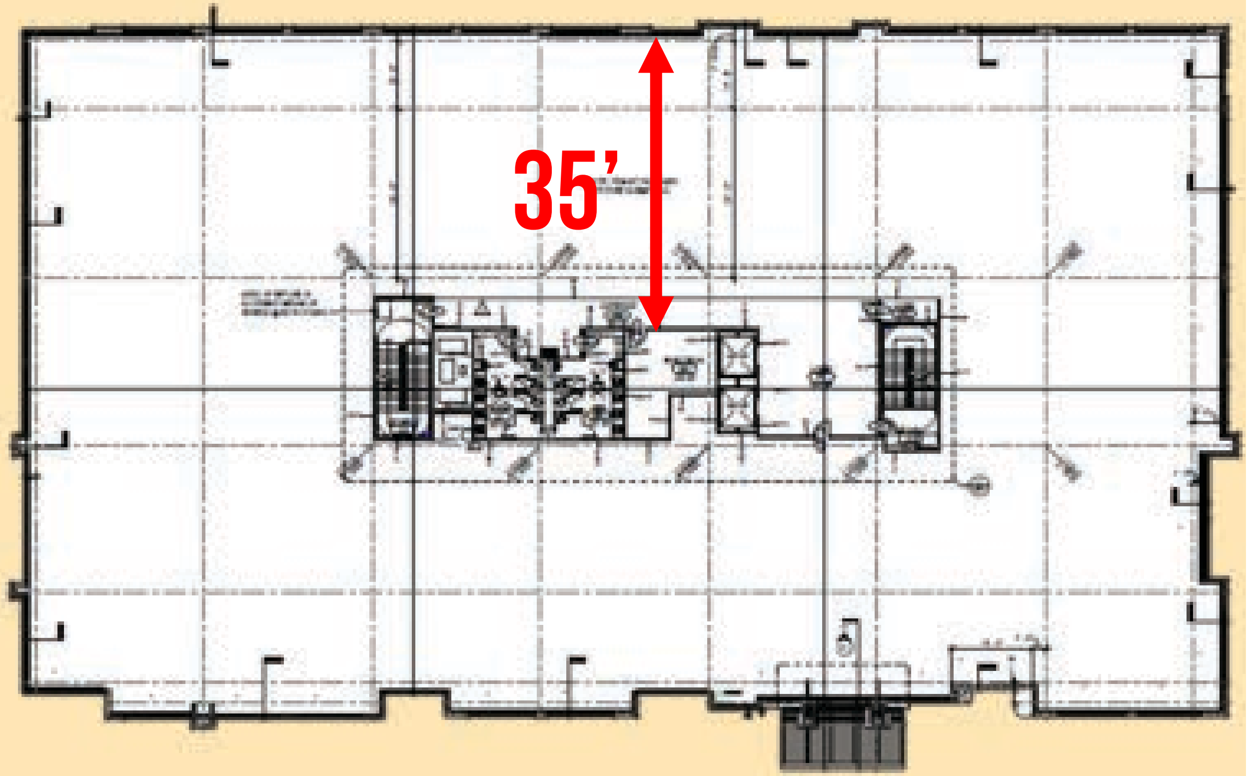
- TYPICAL FOR 1-5 STORIES
- TYPICALLY ASSUME FLEXIBLE DIAPHRAGM
- NEED AMPLE WALL AT PERIMETER

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

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

INTERIOR STEEL MOMENT FRAME

PHOTO CREDIT: WOODWORKS

MASS TIMBER DESIGN

LATERAL FRAMING SYSTEMS

STEEL BRACED FRAME

PHOTO CREDIT: JOHN STAMETS


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


PHOTO CREDIT: STRUCTURECRAFT BUILDERS


PHOTO CREDIT: STRUCTURECRAFT BUILDERS


PHOTO CREDIT: ALEX SCHREYER

BEAM TO COLUMN CONNECTIONS

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: JOHN STAMETS

BEAM TO COLUMN & COLUMN TO COLUMN CONNECTIONS

COLUMN TO FOUNDATION CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

BRACED FRAME CONNECTIONS

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER DESIGN

CONNECTIONS

PANEL TO FOUNDATION CONNECTIONS

PHOTO CREDIT: STRUCTURECRAFT BUILDERS

PHOTO CREDIT: CHARLES JUDD

MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: CHARLES JUDD

PHOTO CREDIT: ALEX SCHREYER

PANEL TO PANEL CONNECTIONS – SURFACE SPLINE

PANEL TO PANEL CONNECTIONS

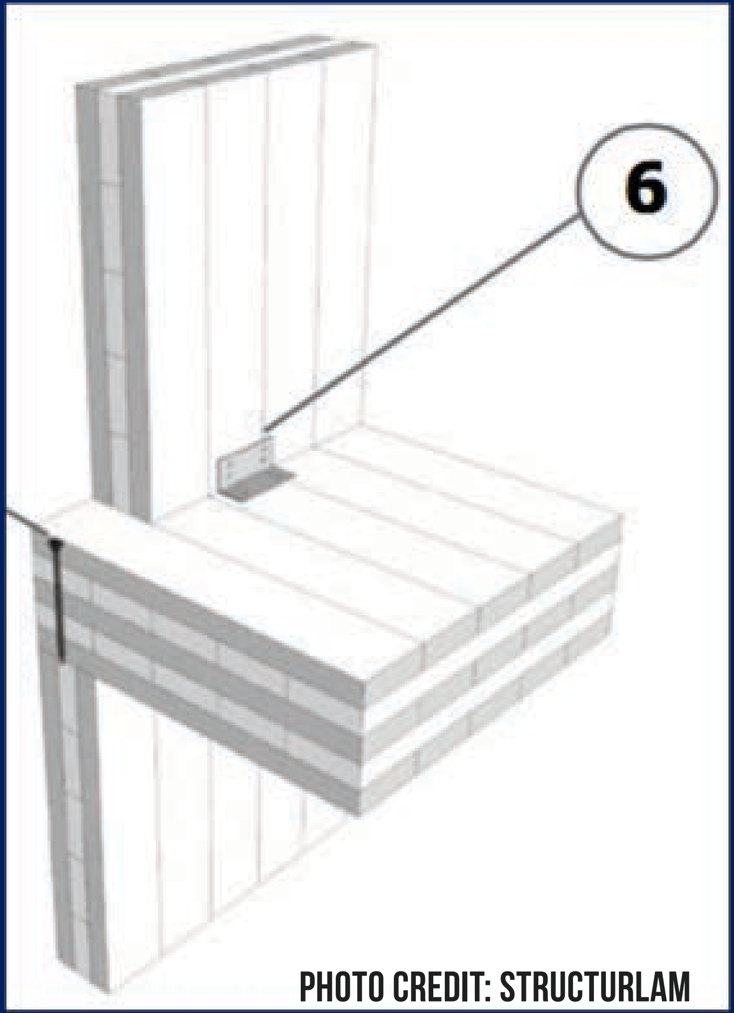
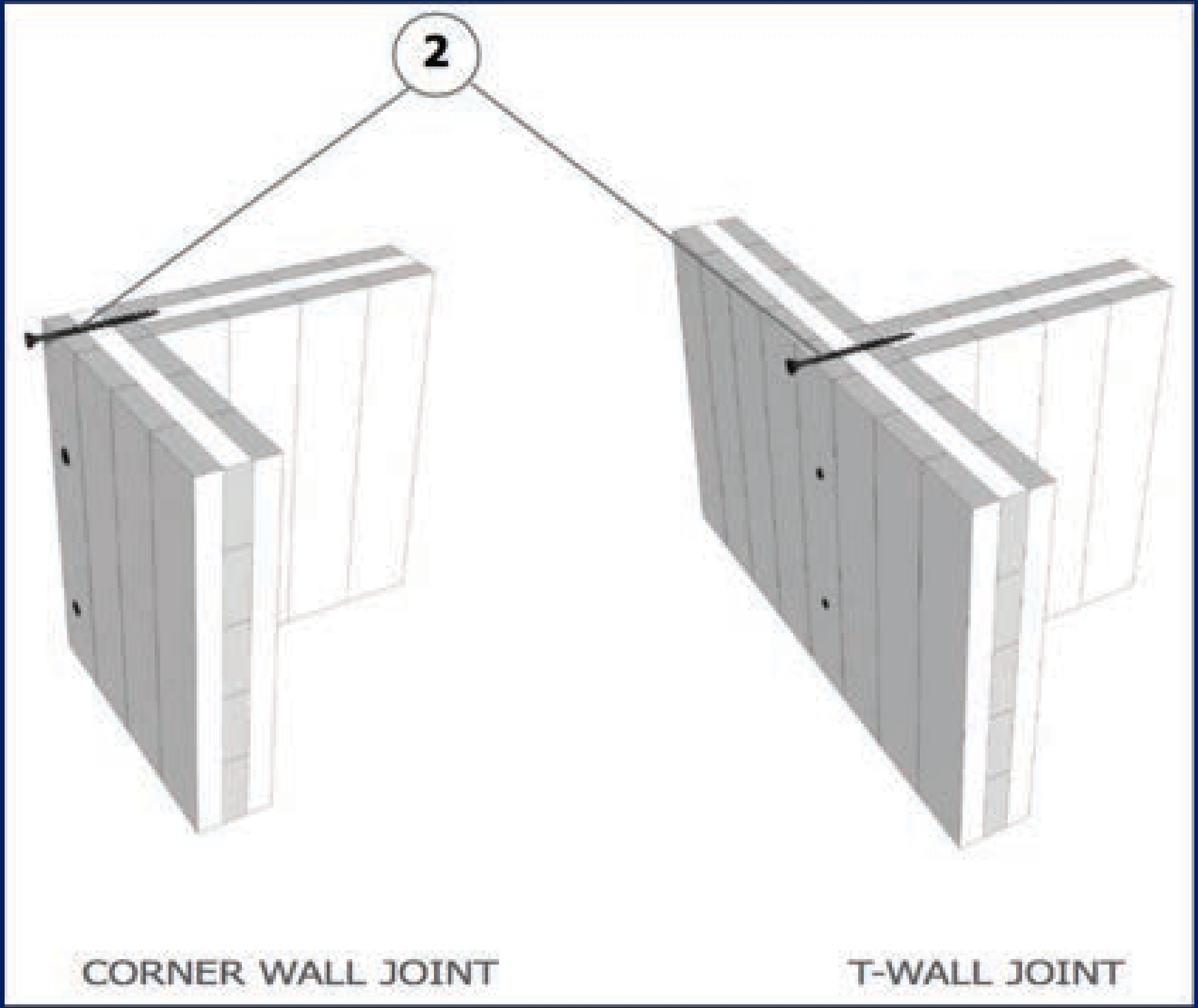


PHOTO CREDIT: STRUCTURLAM



MASS TIMBER DESIGN

CONNECTIONS

PHOTO CREDIT: MYTICON

PANEL TO BEAM CONNECTIONS

MASS TIMBER DESIGN

CONNECTIONS

HYBRID WOOD/STEEL CONNECTIONS:
LOTS OF VARIATION POSSIBLE

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER

SOURCING, CONSTRUCTION & COST CONSIDERATIONS

CLT Manufactures for use in the US - PRG-320 Certified

- SmartLam, Columbia Fall, Montana
- DR Johnson Lumber, Oregon
- Nordic Structures, Quebec, Canada
- Structurlam, British Columbia, Canada
- KLH USA, Subsidiary of KLH Massivholz, Austria

Certified North American CLT Manufacturers

Certified CLT:

- **Nordic** (Chibougamau , QC, Canada)
- **SmartLam** (Whitefish, MT, US)
- **Structurlam** (Penticton, BC, Canada)
- **DR Johnson Lumber** (Riddle, OR, US)

Certified North American CLT Manufacturers

Certified CLT:

- **Nordic** (Chibougamau , QC, Canada)
- **SmartLam** (Whitefish, MT, US)
- **Structurlam** (Penticton, BC, Canada)
- **DR Johnson Lumber** (Riddle, OR, US)

Not Yet Certified:

- **Guardian Structures** (St. Marys, ON, Canada)
- **Element 5** (Ripon, QC, Canada)
- **LEAF EWP** (ON, Canada)

Certified North American CLT Manufacturers

Certified CLT:

- **Nordic** (Chibougamau , QC, Canada)
- **SmartLam** (Whitefish, MT, US)
- **Structurlam** (Penticton, BC, Canada)
- **DR Johnson Lumber** (Riddle, OR, US)

Not Yet Certified:

- **Guardian Structures** (St. Marys, ON, Canada)
- **Element 5** (Ripon, QC, Canada)
- **LEAF EWP** (ON, Canada)

Coming Soon:

- **International Beams** (Dothan, AL)
- **Katerra** (Spokane, WA)
- **Vaagen Timbers** (Colville, WA)
- **SmartLam** (TBD)
- **Texas CLT** (Magnolia, AR)

Certified North American CLT Manufacturers

CLT Distributer w/ US Certification:
- KLH US

CLT Distributer w/ European Certification:
- Stora Enso Wood Products
- Metsa Wood
- Merk
- BinderHolz
- Hasslacher Norica Timber

US Distribution (sourced from Various European Suppliers):
- Innovative Timber Systems/Smartwoods
- StructureCraft
- Structure Fusion
- Cross Lam Timber Solutions
- Holzpack
- Sauter Timber

* CLT imports may have more restrictions on panel sizes due to shipping, longer lead times and less access to design assist services.

MASS TIMBER PRODUCTS

CONSTRUCTION

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

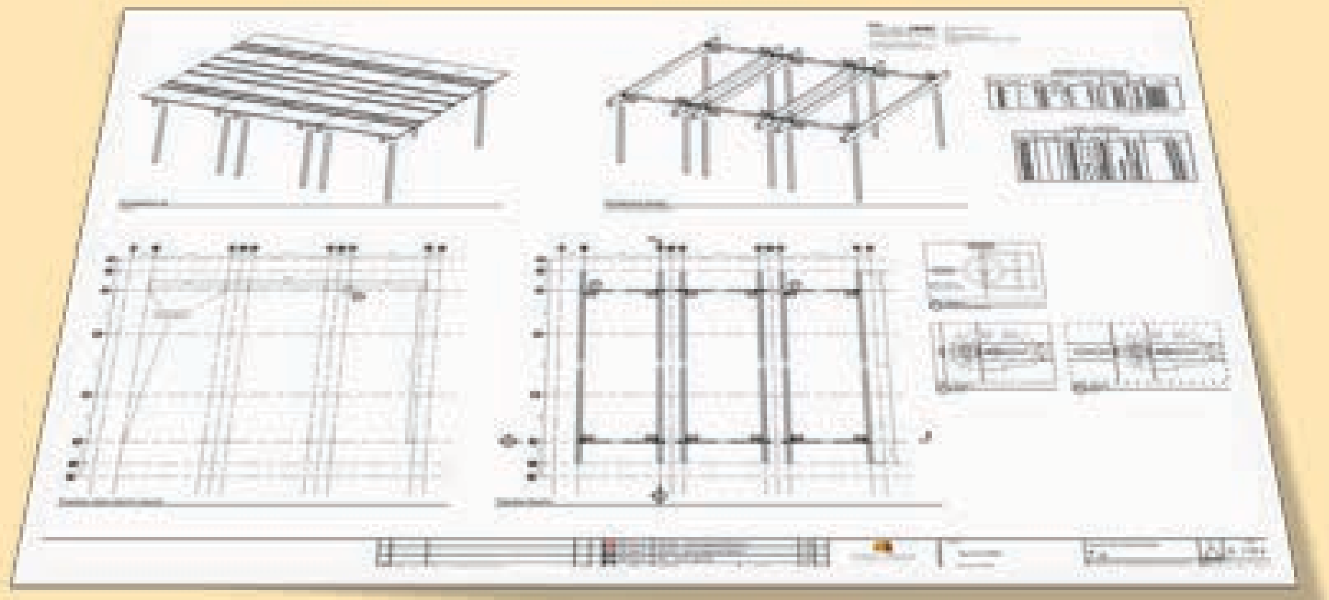
Photo: DR Johnson


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

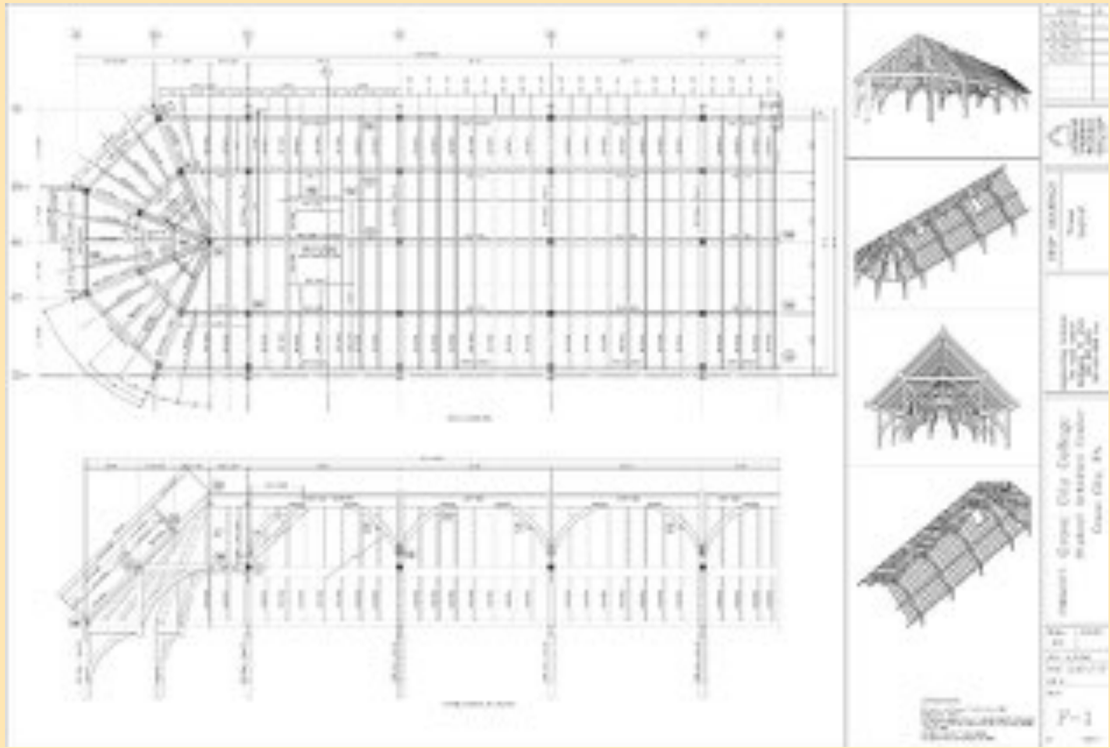


PHOTO CREDIT: ALEX SCHREYER

- SHOP DRAWINGS
- ERECTION DRAWINGS
- PREFABRICATED MEMBERS AND CONNECTIONS

MASS TIMBER PRODUCTS

CONSTRUCTION

- STAGING AREAS
- CRANES

PHOTO CREDIT: ALEX SCHREYER

MASS TIMBER PRODUCTS

CONSTRUCTION

RIGGING HOOKS ARE REMOVED AFTER PANEL PLACEMENT

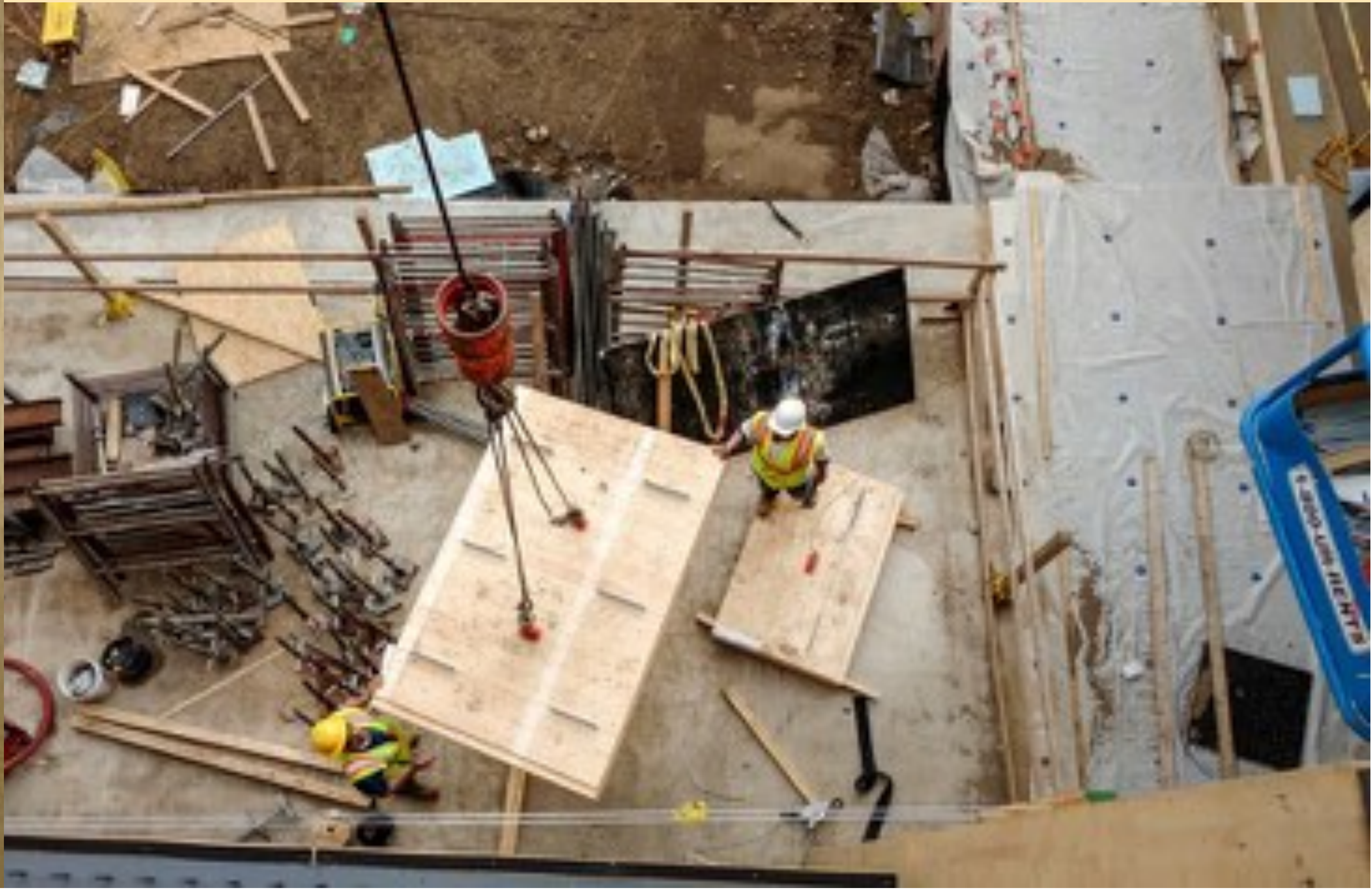


PHOTO CREDIT: ALEX SCHREYER

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

RADIATOR BUILDING

PORTLAND, OR

PHOTO CREDIT: JOSH PARTEE

RADIATOR BUILDING

PORTLAND, OR

PHOTO CREDIT: JOSH PARTEE

BUILDING INFO:

OFFICE BUILDING
5 STORIES
36,000 SF
COMPLETED 2015

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 DORMS

FAYETVILLE, AR

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

IMAGE CREDIT: MODUS STUDIO/LEERS WEINZAPFEL ARCHITECTS

COMMON GROUND HIGH SCHOOL

NEW HAVEN, CT

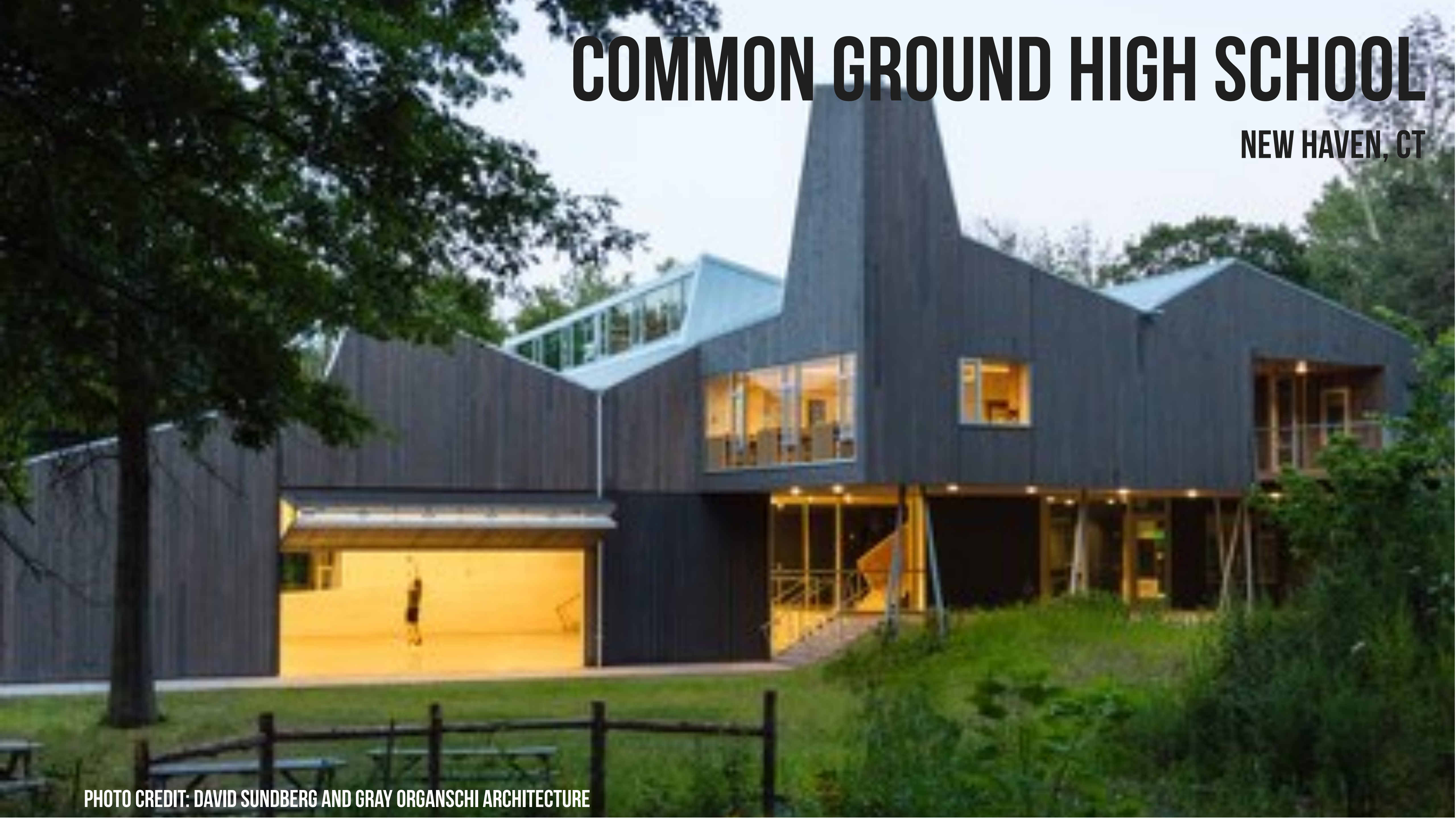


PHOTO CREDIT: DAVID SUNDBERG AND GRAY ORGANSCHI ARCHITECTURE

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

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

CLAY CREATIVE

PORTLAND, OR

IMAGE CREDIT: CHRISTIAN COLUMBRES

CLAY CREATIVE

PORTLAND, OR

5 STORIES

MOSTLY OFFICE, SOME RETAIL AND AMENITY

72,000 SF

IMAGE CREDIT: CHRISTIAN COLUMBRES

CLAY CREATIVE

PORTLAND, OR

- ~8' FINISHED FLOOR TO BOTTOM OF BEAM
- 25'X30' AT PERIMETER
- 30'X30' BAYS AT CENTER
- 1.5" GYPSUM, WSP, 2X6 NLT FLOOR PANELS
- RAISED FLOOR SYSTEM FOR MECHANICAL, DATA AND ACOUSTICS
- EXTERIOR STEEL MOMENT FRAME KEEPS CORE AREA MORE VERSATILE

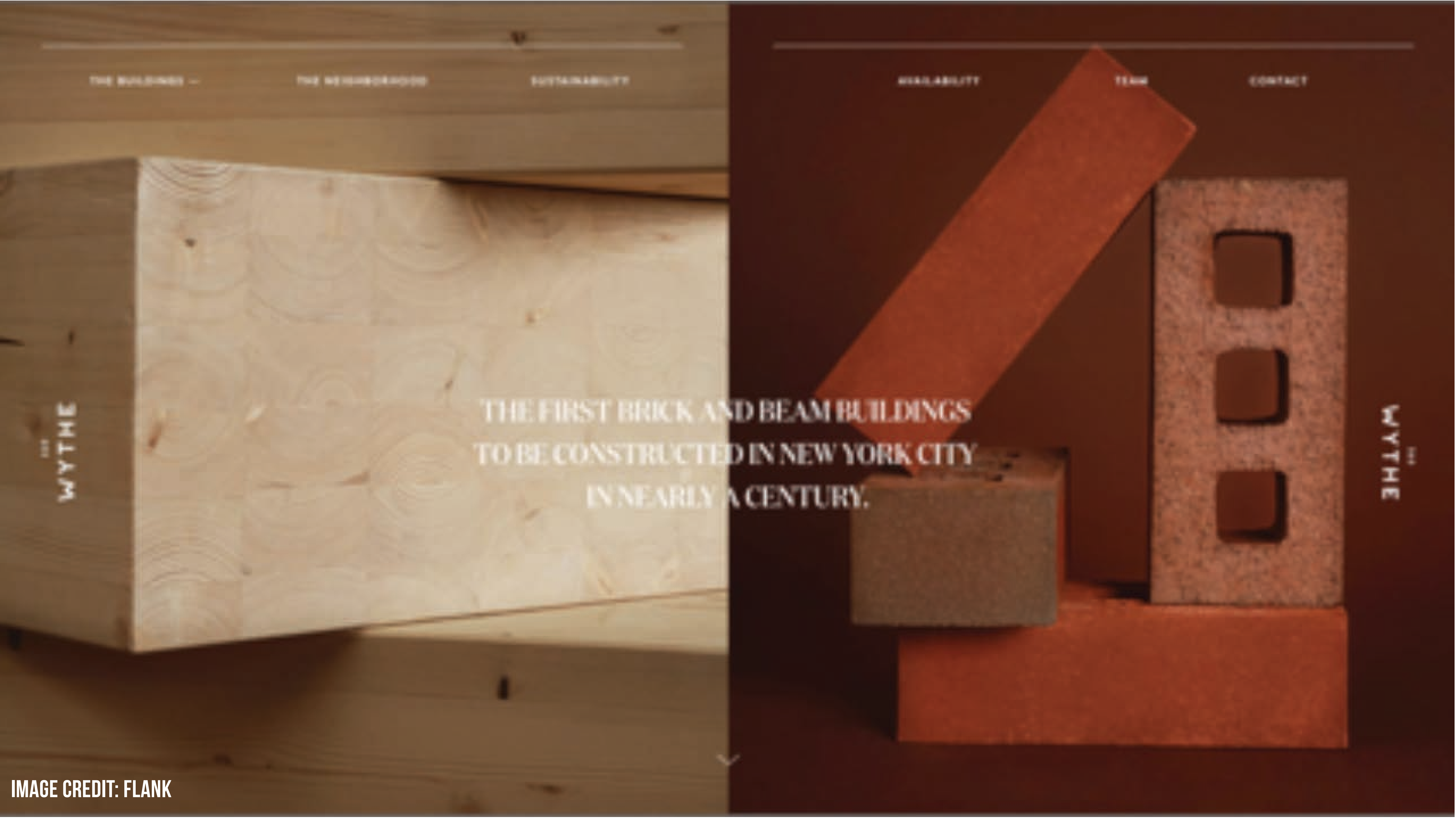


IMAGE CREDIT: FLANK

320 & 360 WYTHE AVE.

NEW YORK, NY

IMAGE CREDIT: FIELD CONDITION/FLANK

3 STORY & 5 STORY BUILDINGS

MOSTLY OFFICE, SOME APARTMENTS

NLT & GLULAM

320 & 360 WYTHE AVE.

NEW YORK, NY

IMAGE CREDIT: FLANK

FRANKLIN ELEMENTARY SCHOOL

FRANKLIN, WV

FRANKLIN ELEMENTARY SCHOOL

PHOTO CREDIT: PAM WEAN, MSES ARCHITECTS

FRANKLIN, WV

- 45,200 SF, 2 STORY SCHOOL
- CLT UTILIZED FOR WALLS, ROOF PANELS, AND FLOOR PANELS
- CLT CHOSEN FOR ITS CONSTRUCTION SCHEDULE BENEFITS
- COMPLETED JANUARY 2015


FRANKLIN ELEMENTARY SCHOOL
FRANKLIN, WV
Summit
PHOTO CREDIT: PAM WEAN, MSES 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

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

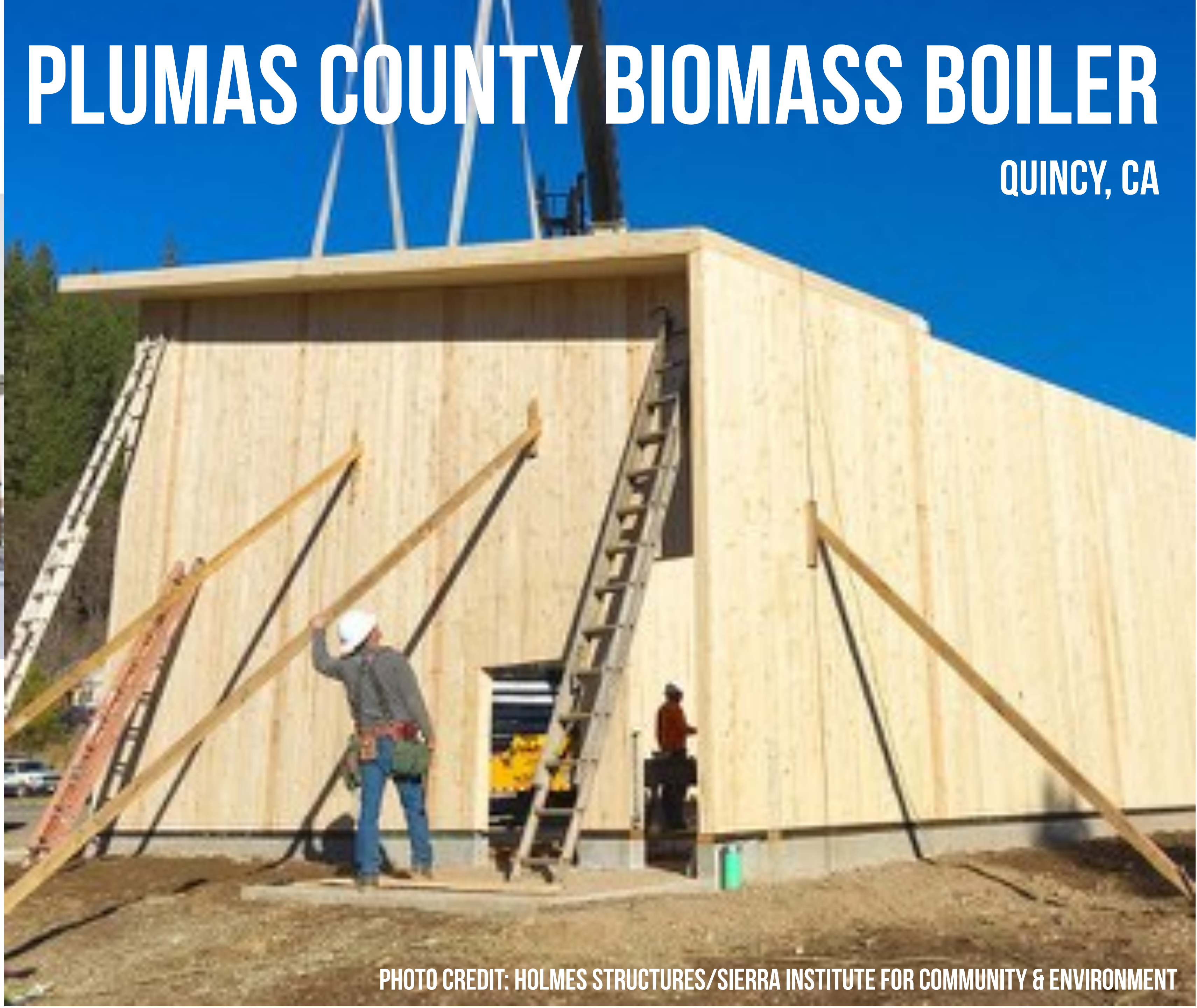
SEATTLE, WA

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

PHOTO CREDIT: JOHN STAMETS

PLUMAS COUNTY BIOMASS BOILER

QUINCY, CA



- 2,000 SF
- 1ST FULL CLT STRUCTURE IN CALIFORNIA
- COMPLETED 2018

PHOTO CREDIT: HOLMES STRUCTURES/SIERRA INSTITUTE FOR COMMUNITY & ENVIRONMENT

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

FRAMEWORK

PORTLAND, OR

PHOTO: JOSHUA JAY ELLIOT

FRAMEWORK

PORTLAND, OR

4 STORIES OF WOOD (OFFICE) OVER 1 STORY OF CONCRETE (RETAIL & PARKING)
6,800 SF
COMPLETED 2015

PHOTO: JOSHUA JAY ELLIOT


FRAMEWORK
PORTLAND, OR
PHOTO CREDIT: WOODWORKS

NEW ENERGY WORKS TOMORROWLAND

FARMINGTON, NY

PHOTO CREDIT: NESEA/NEW ENERGY WORKS

- 21,000 SF FACILITY
- 3-PLY CLT WALL AND ROOF PANELS
- FIRST CLT BUILDING IN NEW YORK STATE
- COMPLETED 2017

HUDSON BUILDING

VANCOUVER, WA

3 STORIES
45,000 SF
TYPE VA CONSTRUCTION

DEVELOPER: KILLIAN PACIFIC AND MACKENZIE
PHOTO CREDIT: CHRISTIAN COLUMBRES

HUDSON BUILDING

VANCOUVER, WA

- 25'X25' GRID
- 15'-18' FLOOR TO FLOOR HEIGHTS
- COMPOSITE FLOOR: 2X4 AND 2X6 NLT FLOOR PANELS WITH 3 ½" REINFORCED CONCRETE TOPPING
- ALL MEP EXPOSED

IMAGE CREDIT: CRHISTIAN COLUMBRES

WASHINGTON LATIN PUBLIC CHARTER SCHOOL GYM

WASHINGTON, DC

- 11,266 SF GYM ADDITION
- 3-PLY CLT WALL AND ROOF PANELS
- 75 FT SPAN GLULAM ROOF BEAMS
- COMPLETED 2016

IMAGE CREDIT: KLH USA

BOISE PUBLIC LIBRARY AT BROWN CROSSING

BOISE, ID

- CLT USED FOR ROOF PANELS IN LIBRARY ADDITION
- COMPLETED 2017

IMAGE CREDIT: BOISE PUBLIC LIBRARY & IDAHO STATESMAN

BRELSFORD WSU VISITOR CENTER

PULLMAN, WA

PHOTO CREDIT: WASHINGTON STATE UNIVERSITY

BRELSFORD WSU VISITOR CENTER

PULLMAN, WA

4,277 SF, 1 STORY VISITOR CENTER
CLT UTILIZED FOR ROOF PANELS WITH LARGE, EXPRESSED OVERHANGS
COMPLETED LATE 2013

PHOTOS: WSU & BENJAMIN BENSCHNEIDER


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


TALL WOOD IN THE U.S.

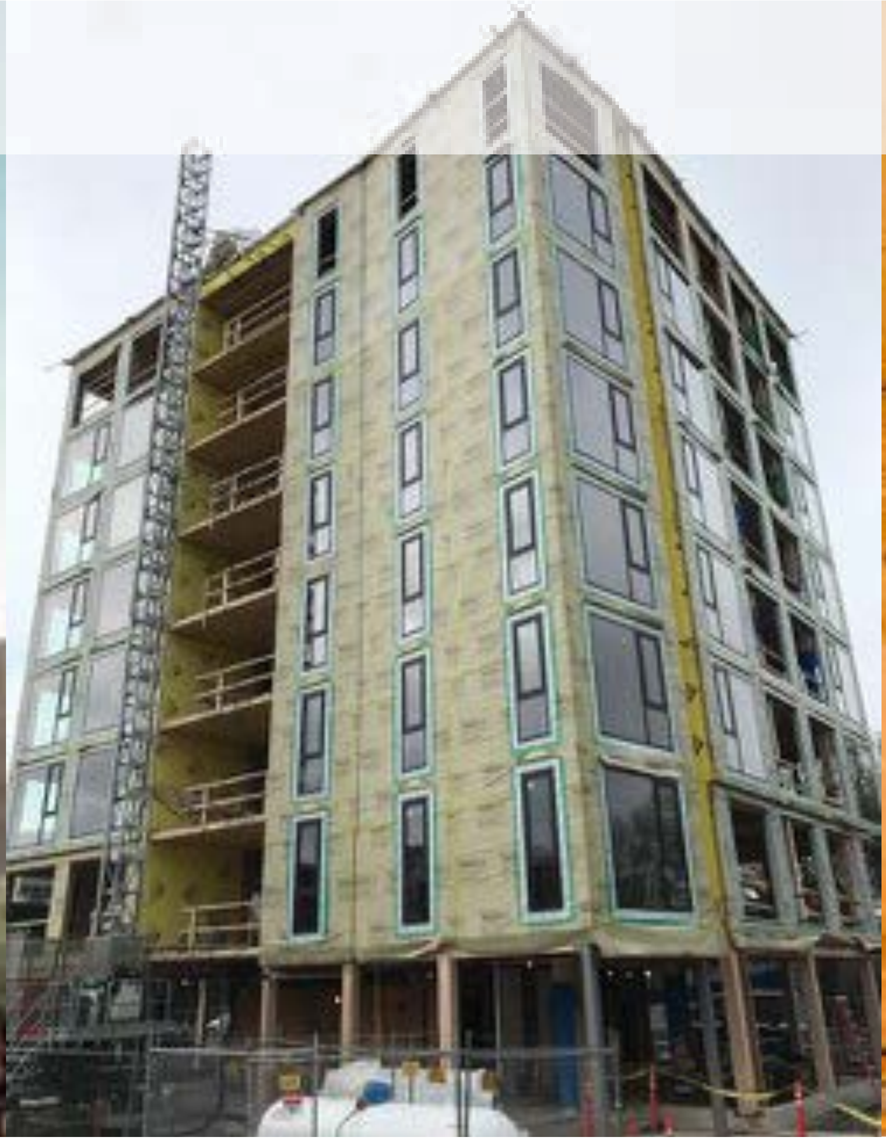
- Current Prescriptive Code Limit - 6 stories or 85 feet
- Over 6 Stories - Alternate Means and Methods Request (AMMR) through performance based design
- Based on the 1910 Heights and Areas Act

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

U.S. BUILDING CODE STATUS

U.S. BUILDING CODES

Tall Wood Ad Hoc Committee

Balanced Committee: 2016-2018

Development of code change proposals for prescriptive code allowances of tall wood buildings.

Mass Timber Fire Testing at ATF Lab

Mass Timber Shake Table Test at UCSD

Three Main Categories:

1. Noncombustible (Types I and II)
2. Light-Frame (Types III and V)
3. **Mass Timber (Type IV)**

IBC TABLE 601

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

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:	NC	Not Permitted	Not Permitted

*see IBC definition of highrise

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

Tall Mass Timber Building Code Changes Pass First Hurdle

The highly-anticipated International Code Council (ICC) Tall Mass Timber Building code changes passed a first hurdle in April with approval by the ICC code changes committee responsible for this part of the process. By wide margins a series of 14 proposals was each approved. The Hearings brought together code and fire officials, along with engineers, architects, builders, and other construction professionals as part of the first public step in approving code change proposals for the 2021 set of ICC codes. The proposals submitted by the ICC Ad Hoc Committee on Tall Wood Buildings (TWB), once officially approved by year-end, would allow mass timber buildings to be constructed up to 18 stories in height. AWC had a significant number of staff in attendance at the Hearings who spoke in support of the Ad Hoc Committee proposals. For more information see www.awc.org/tallmasstimber.

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BROCK COMMONS

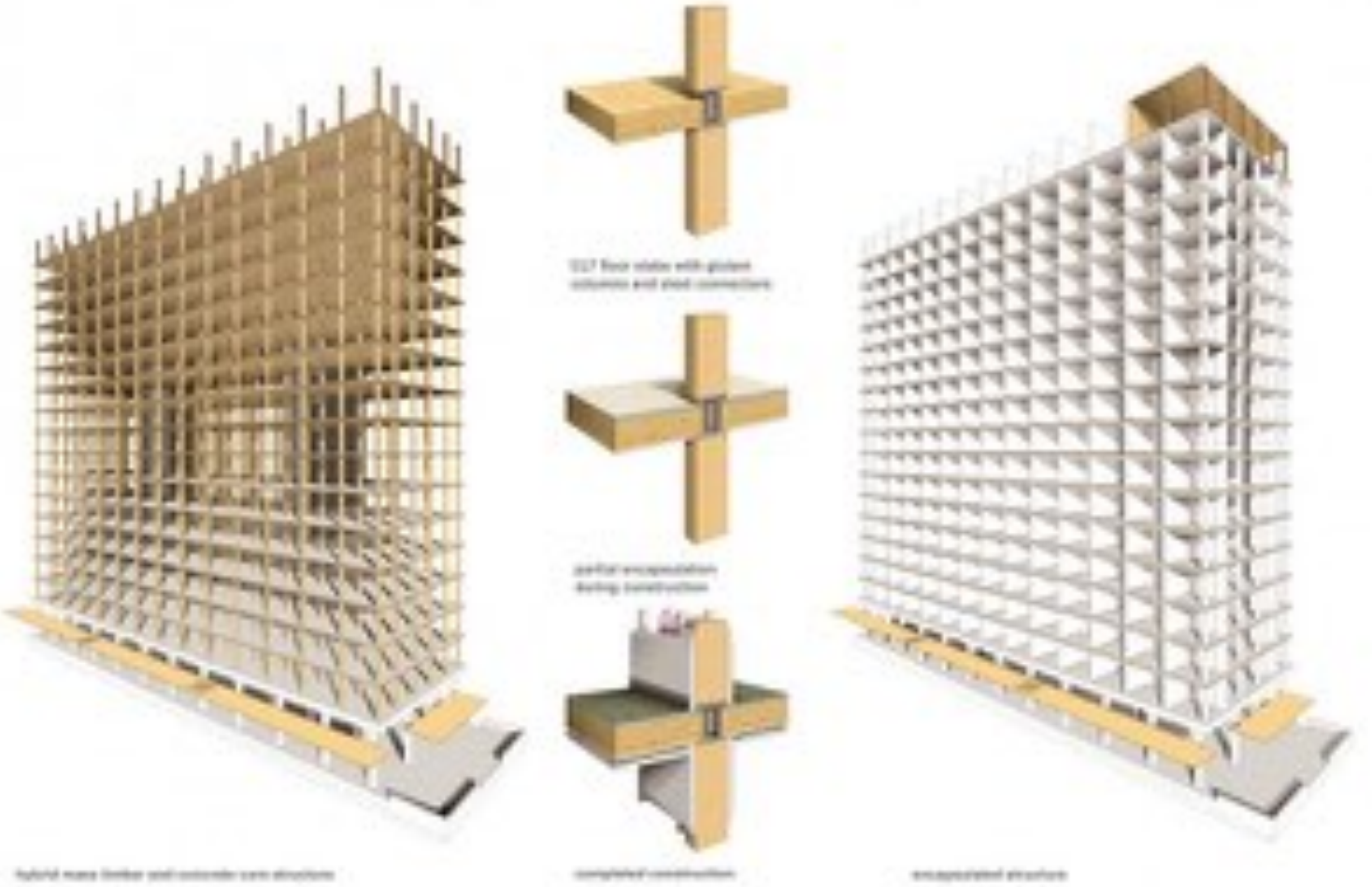
VANCOUVER, BC

COMPLETED FALL 2017
18 STORIES
174 FT
156K SF

PHOTO CREDIT: ACTON OSTRY ARCHITECTS

BROCK COMMONS

VANCOUVER, BC



5 PLY CLT PANELS, 2-WAY SPAN

~9'X13' GRID OF COLUMNS

PHOTO CREDIT: ACTON OSTRY ARCHITECTS

BROCK COMMONS

VANCOUVER, BC

BROCK COMMONS

VANCOUVER, BC

17 STORIES OF TIMBER INSTALLATION

STARTED JUNE 6, 2016

FINISHED AUGUST 10, 2016

SOURCE: CANADIAN DESIGN & CONSTRUCTION REPORT[12]

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Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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