Mass Timber Construction: Products, Performance and Design

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WoodWorks

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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.

Today's agenda

Mass timber construction

Mass timber

- Why use it – appeal
- What is it – products
- How does it work – design topics
- Where is it used – case studies
- What's next?

Mass timber appeal

Primary drivers

Construction speed & efficiency

Construction site constraints – urban infill

Innovation/aesthetic

Secondary drivers

Carbon reductions

Structural performance – lightweight

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

Mass timber appeal

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)

Less time on site = less $$

Franklin Elementary School, Franklin, WV

45,200 ft2 2 story elementary school

8 weeks to construct

Mass timber appeal

Material mass

75% lighter weight than concrete

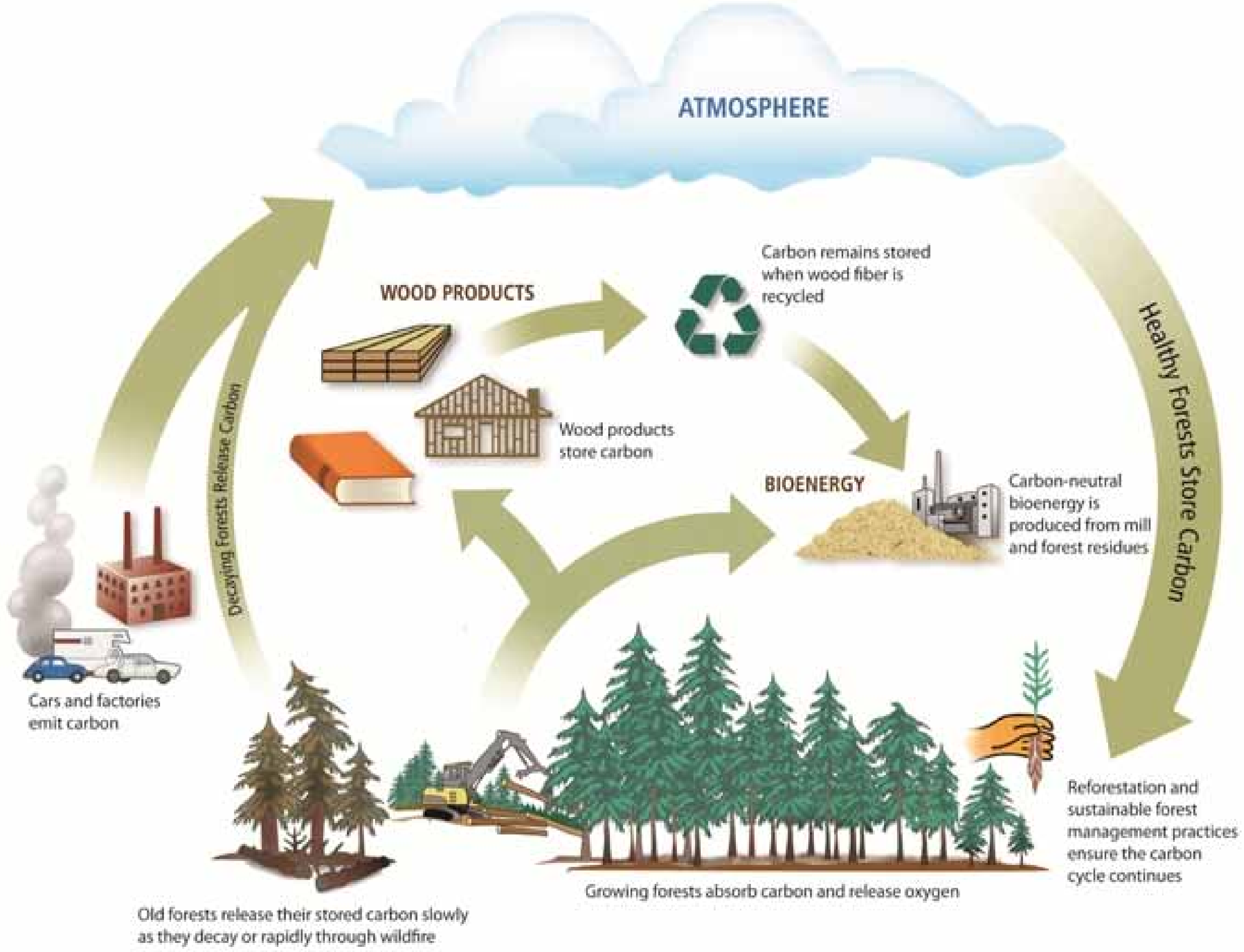
Mass timber appeal

Material mass

Completed in 2012
10 stories
~105 ft. tall, > 18.6 K sq ft.
3 million in R&D
Poor soils required a much lighter
BUILDING

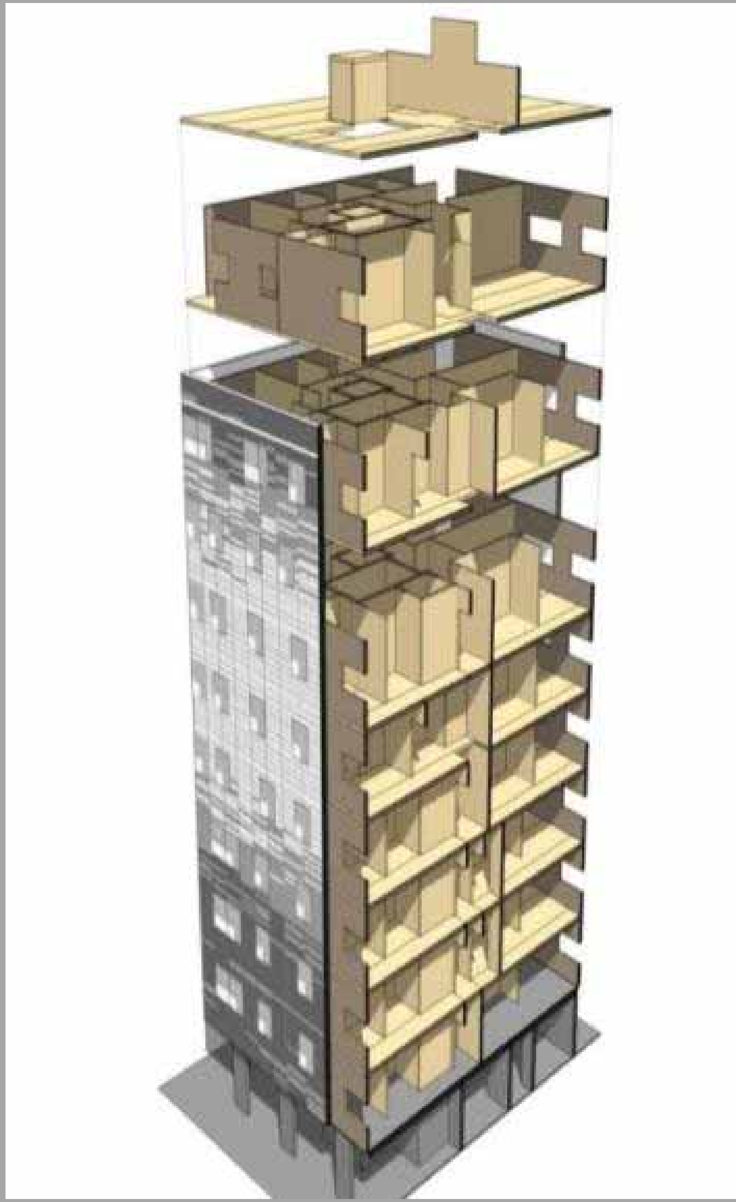
Forte', Victoria Harbor, Melbourne, Australia
Architect: Lend Lease

Sustainable Forestry Carbon Cycle



Mass timber appeal

Reduced embodied carbon
Stadhaus, London, UK



Architect: Waugh Thistleton Architects
Photo credit: Waugh Thistleton Architects

Volume of wood used	950 m^3
Carbon sequestered and stored (CO_2e)	760 metric tons
Avoided greenhouse gases (CO_2e)	320 metric tons
Total potential carbon benefit (CO_2e)	1,080 metric tons

Carbon savings from the choice of wood in this one building are equivalent to:
1,615 passenger vehicles off the road for a year 
Enough energy to operate a home for 803 years

LCA of Materials: Carbon Emissions

	USEPA (2006)	USEPA (2006)
Material	**Process Emissions (kg CO_2e/ kg of product)**	**Process Emissions Including Carbon Storage within Material (kg CO_2e/ kg of product)**
Framing lumber	**0.12***	**-1.68**
Concrete	**0.12**	**0.12**
Concrete block	**0.14**	**0.14**
Brick	**0.32**	**0.32**
Medium density fiberboard (MDF)	**0.32**	**-1.47**
Recycled steel (avg recy content)	**0.81**	**0.81**
Glass (not including primary mfg.)	**0.57**	**0.57**
Cement (Portland, masonry)	**0.97**	**0.97**
Recycled aluminum (100% recycled content)	**1.13**	**1.13**
Vinyl	**--**	**1.00**
Steel (virgin)	**2.55**	**2.55**
Aluminum (virgin)	**16.60**	**16.60**

Carbon content of 49% assumed for wood. (measured values range from about 47-52%)

Source: 2006 US EPA Database

Mass timber appeal

Energy efficient

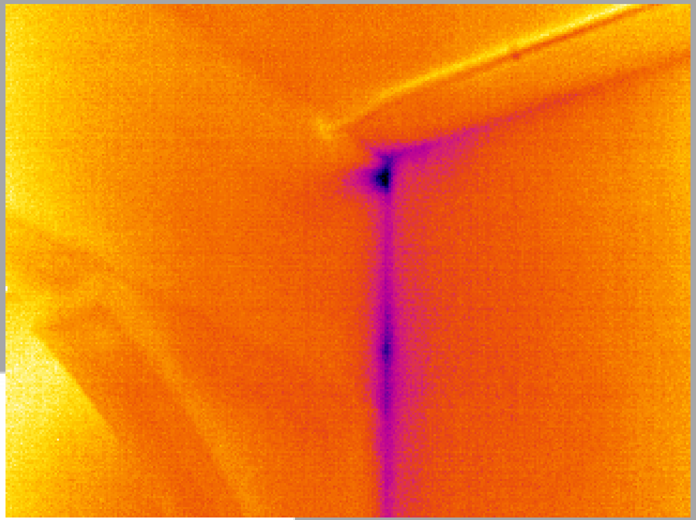


Table 2

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

Mass timber appeal

Disaster resilient

Usfpl wood tornado shelter

Mass timber appeal

Disaster resilient

Live blast performance of mass timber testing project on-going

Initial results very promising

Mass timber appeal

Structural flexibility

Photo Credit: APA

Mass timber systems

horizontal systems

- nlt panels
- Clt panels
- Glt panels
- T&g Decking
- Composite timber/concrete
- scl panels

Vertical systems

- Glulam frame
- Mass timber walls

Building frame systems

Mass timber products

horizontal framing

Nail-Laminated Timber (NLT)

Cross-Laminated Timber (CLT)

Glue-Laminated Timber (GLT)

Tongue & groove decking (T&G)

Timber concrete composite

Structural composite Lumber

Image source: structurecraft

Mass timber products

glulam

Photo Credit: alex schreyer

Richmond Olympic Oval, Richmond, BC, Canada
Design Team: Cannon Design Architecture, Fast + Epp,
Glotman Simpson

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

Mass timber products

Nail-laminated timber (NLT) panels

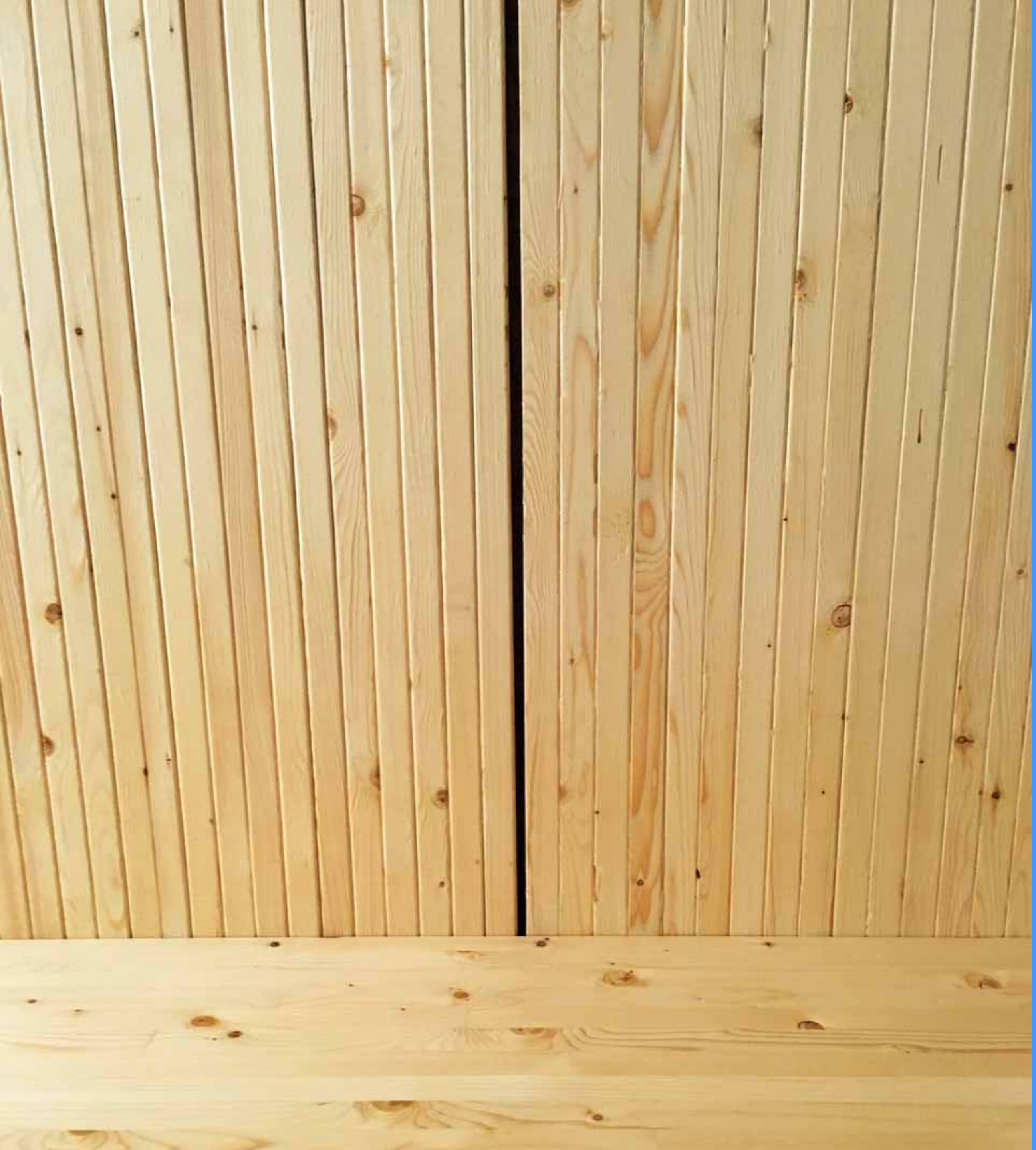
Mass timber products

Nail-laminated timber (NLT) panels

Nail-laminated timber (nlt)=

a structural panel of square-edged dimensional lumber laminations (usually 2x) set on edge and nailed wide face together

- Recognized in IBC 2304.8.3 (mechanically laminated decking)
- Nds 15.1.1 provides distribution factors for concentrated loads
- Can be used for floor, roof decking. Occasionally used for shaft walls



Mass timber products

Nail-laminated timber (NLT) panels

Nlt shrinkage/expansion design:

Consider leaving one ply out per 8′-10′ wide panel

Bullitt center

Seattle, wa

Photo Credit: bullitt center

Bullitt center

Seattle, wa

Structural Frame:
Douglas-Fir Glulam Beams and Columns
5-1/8″x15″ to 12-1/4″x21″

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

Bullitt center

Seattle, wa

The Bullitt Center is considered a market-rate, class A commercial office building

Enhanced occupant experience

Photo Credit: John Stamets

Mass timber products

Glue-laminated timber (gLT) panels

Photo credit: unalam

Mass timber products

Glue-laminated timber (gLT) panels

Glulam decking:

- Similar to deep glulam beams laid on their side
- Same code references and manufacturing standards as glulam beams and columns
- Be careful of design stresses and layups used – spec uniform layup (all lams same species & grade)

IMAGE SOURCE: STRUCTURECRAFT

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

Photo credit: josh partee

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

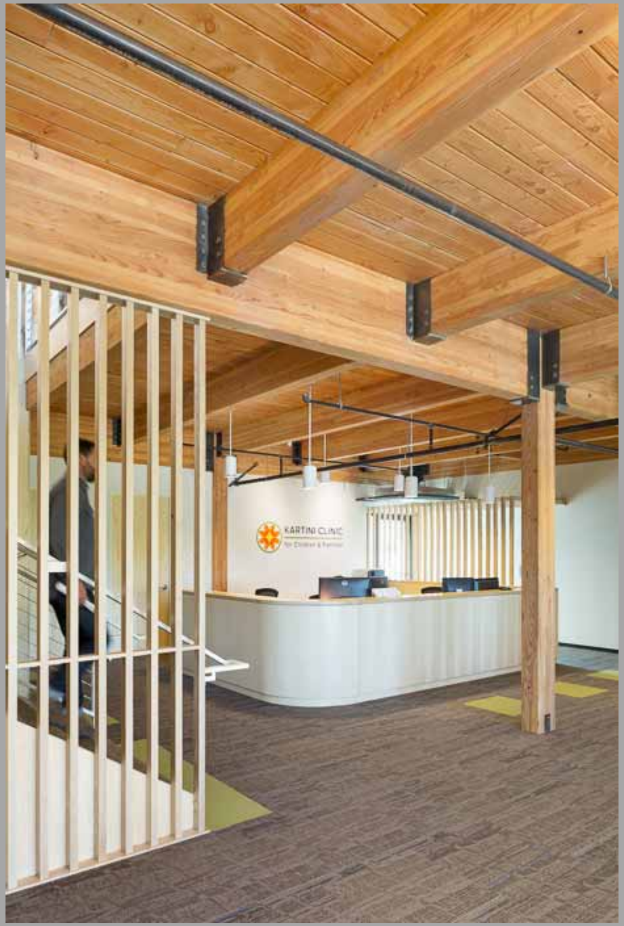
Radiator building

Portland,or

Photo Credit: Josh Partee

Radiator building

Portland, or



Building info:
Office building
5 stories
36,000 sf
Completed 2015

Photo Credit: Josh Partee

One north

Portland, or

Long term sustainability

Why a Timber Framed Office Building?

"Wood consumes and sequesters carbon. There's a lot of momentum for this. Timber framing is so much more sustainable."

Ben Kaiser of PATH Architecture, Project Architect, Developer, and General Contractor

Photo Credit: Josh Partee


Mass timber products
Cross-laminated timber (CLT)

Mass timber products

Cross-laminated timber (CLT)

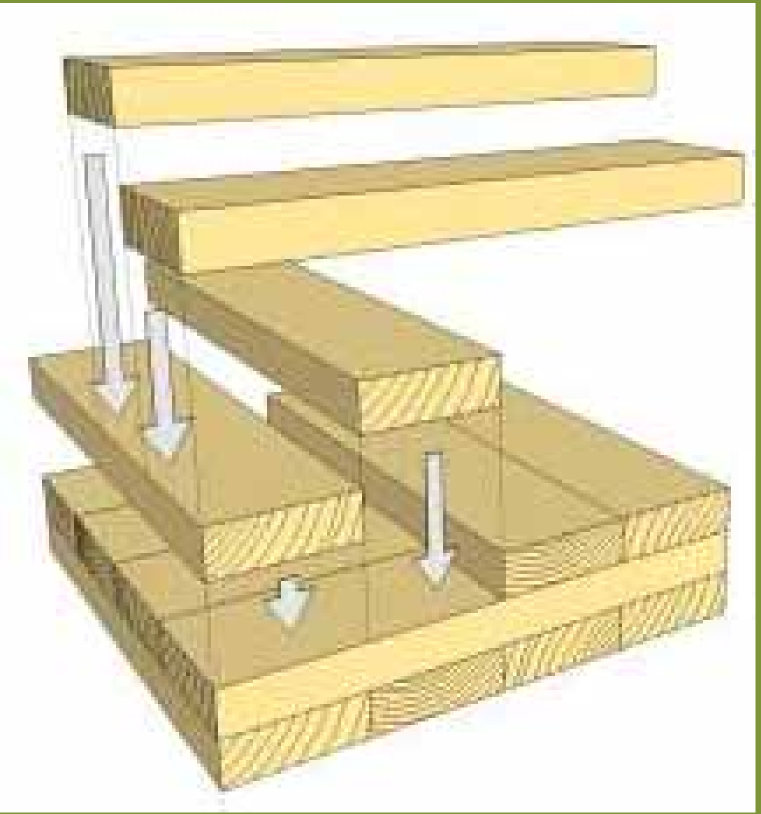
What is clt?

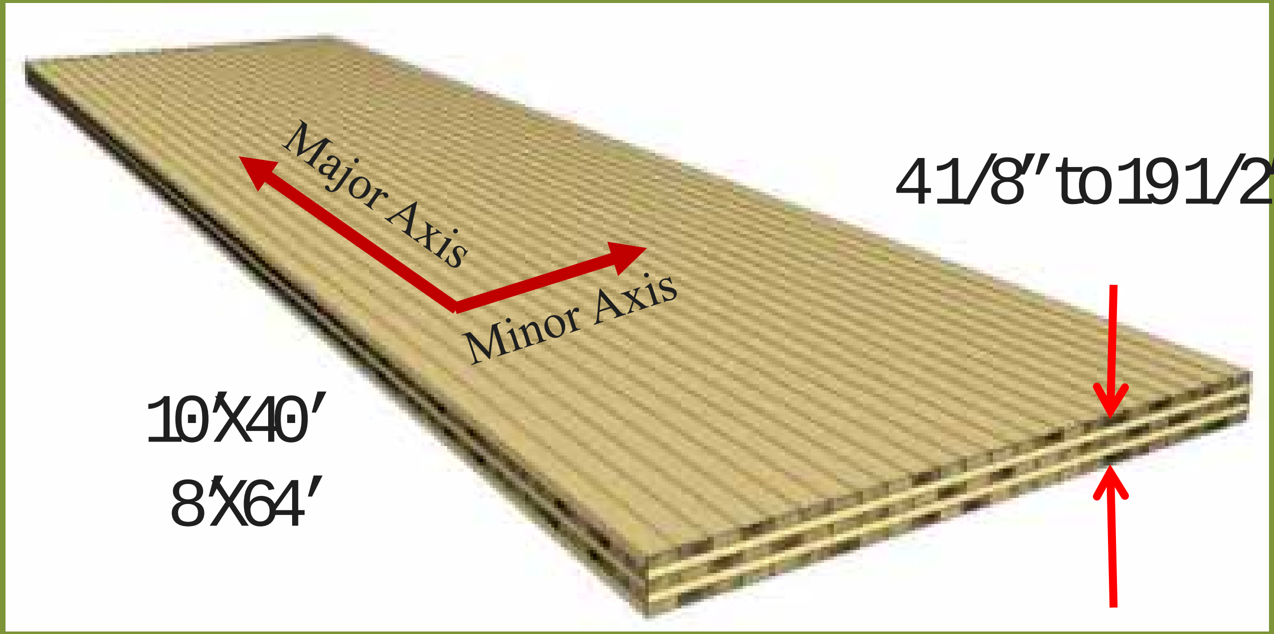
Solid wood panel

3 layers min. of solid sawn lams

90 deg. cross-lams

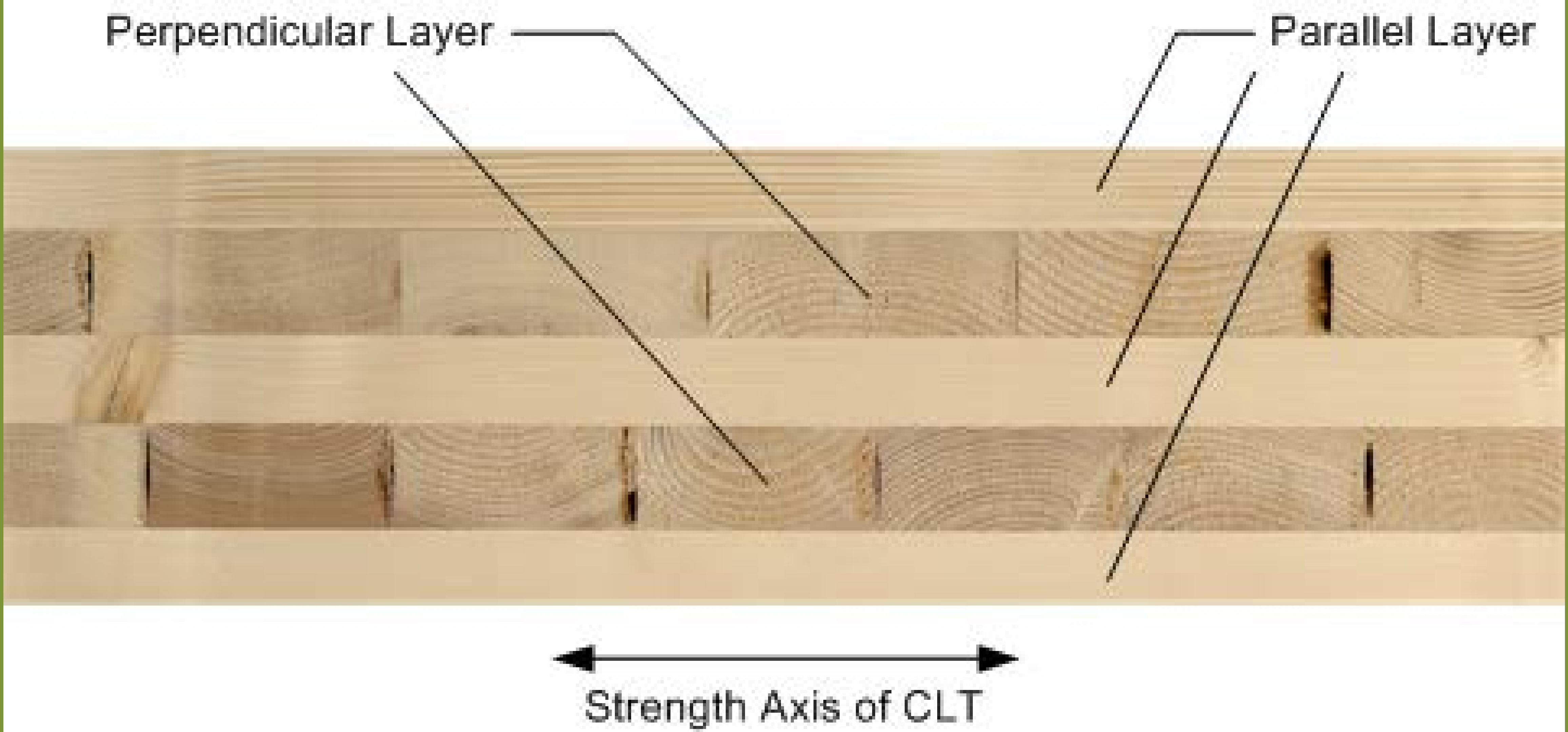
Similar to plywood sheathing





Mass timber products

Cross-laminated timber (CLT)



Mass timber products

Cross-laminated timber (CLT)

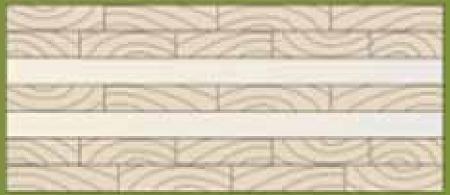
Common clt layups

3-ply 3-layer

5-ply 5-layer

7-ply 7-layer

9-ply 9-layer



7-ply 5-layer

9-ply 7-layer

Candlewood suites

Redstone arsenal, al

Image Credit: Lend Lease

Candlewood suites

Redstone arsenal, al

- 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

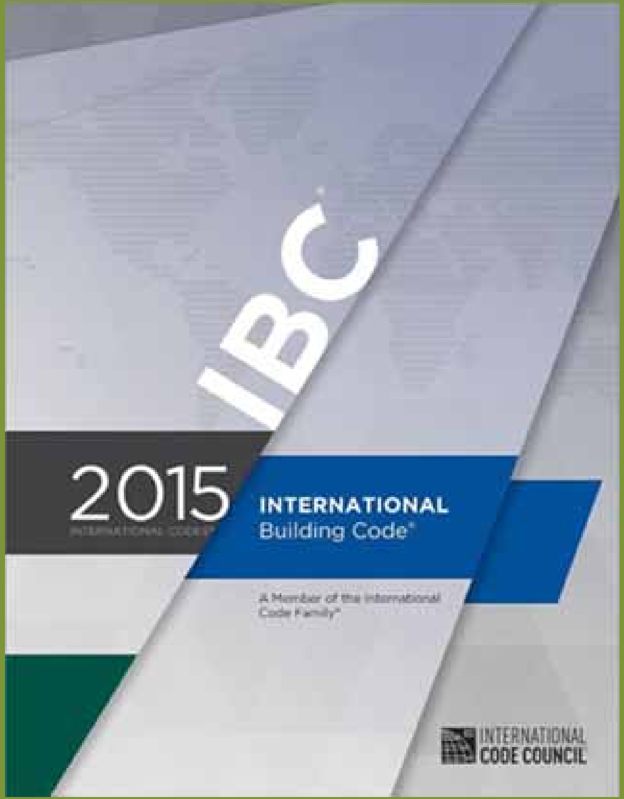
Image Credit: Lend Lease & schaefer

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.

How to use CLT – Single Span Floor

CrossLam Floor Panel Load Table							
	MAX. SPAN (ft)		FLOOR LIVE LOAD (lbs unfactored)				
	PANEL TYPE	SIZE (in)	40 RESIDENTIAL	50 OFFICE/ CLASSROOM	75 MECHANICAL ROOM	100 ASSEMBLY/ STORAGE	150 LIBRARY
single span	SLT3	3.90	**11.45**	**11.45**	10.56	9.78	8.69
	SLT5	6.65	**16.14**	**16.14**	**16.14**	15.52	13.85
	SLT7	9.41	**20.34**	**20.34**	**20.34**	**20.34**	18.77
	SLT9	12.17	**24.18**	**24.18**	**24.18**	**24.18**	23.56

SAMPLE SPAN TABLES – CONTACT PANEL MANUFACTURER FOR ACTUAL SPANS

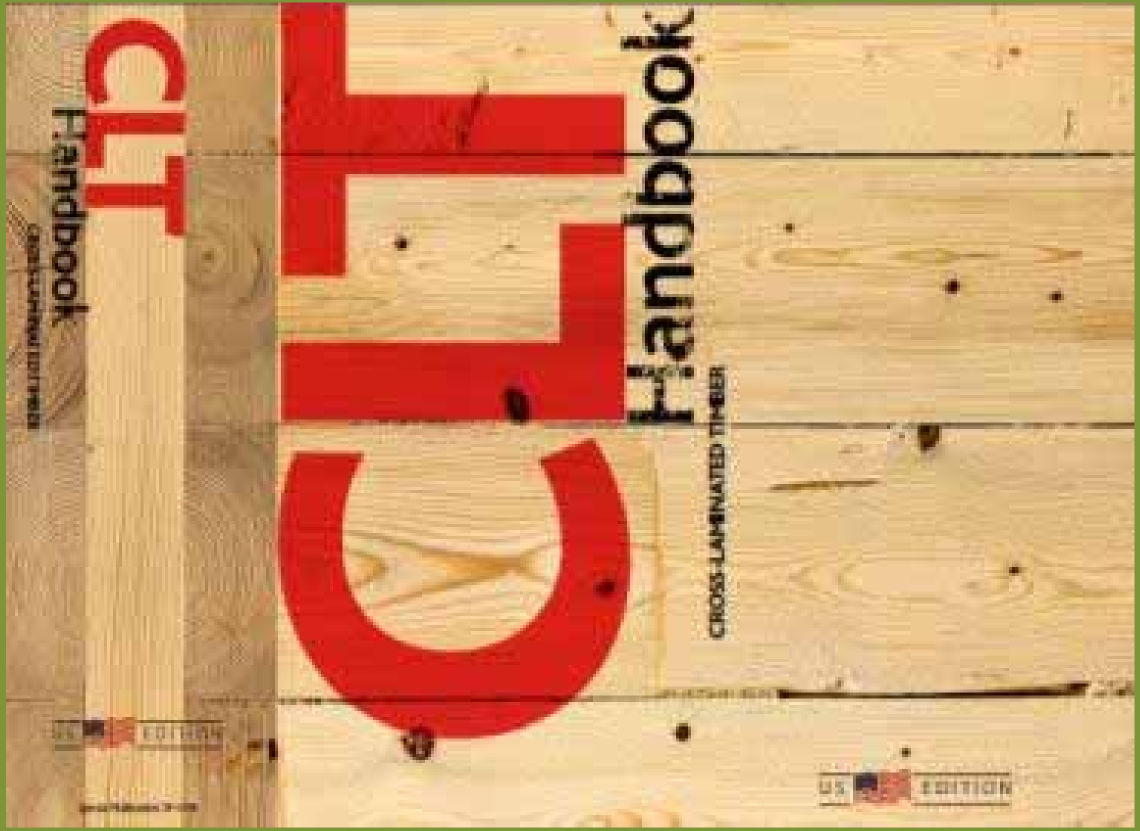
CrossLam Floor Panel Load Table with 2" Concrete Topping							
	MAX. SPAN (ft)		FLOOR LIVE LOAD (lbs, unfactored)				
	PANEL TYPE	SIZE (in)	40 RESIDENTIAL	50 OFFICE/ CLASSROOM	75 MECHANICAL ROOM	100 ASSEMBLY/ STORAGE	150 LIBRARY
single span	SLT3	3.90	10.99	10.60	9.81	9.19	8.27
	SLT5	6.65	**16.14**	**16.14**	15.52	14.60	13.22
	SLT7	9.41	**20.34**	**20.34**	**20.34**	19.75	17.98
	SLT9	12.17	**24.18**	**24.18**	**24.18**	**24.18**	22.60

Source: Structurlam CLT guide

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



www.rethinkwood.com

Mass timber products

Wood concrete composite

Photo Credit: alex schreyer

Mass timber products

Wood concrete composite

Photo Credit: alex schreyer

Mass timber products

Structural composite lumber (scl)

Lvl panel

Lsl panel

Photo credit: structurecraft

Mass timber products

Laminated veneer lumber (lvl)

Photo credit: brisco

Mass timber products

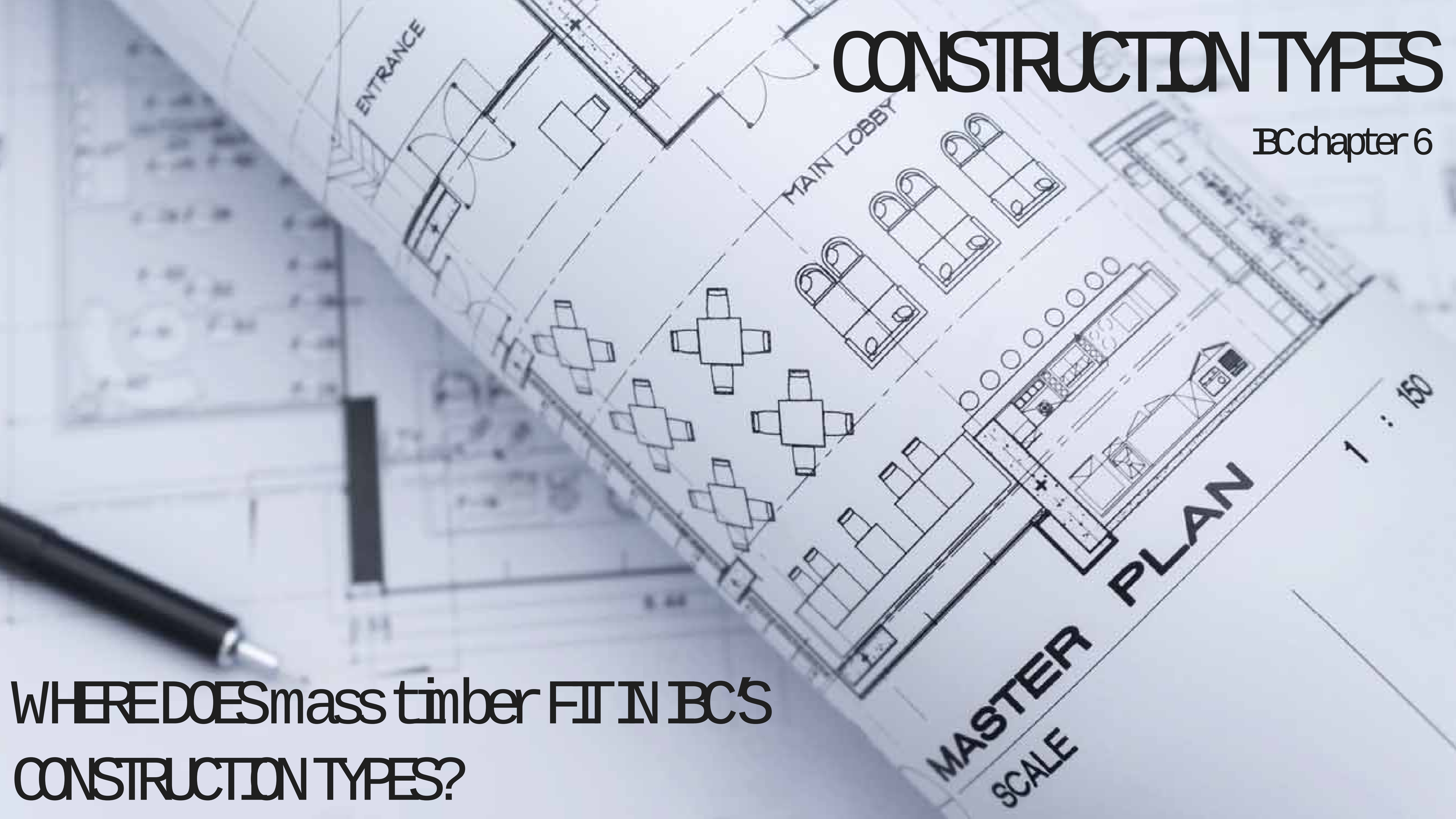
Laminated veneer lumber (lvl)

Photo credit: brisco

Mass timber design

Design topics

- Construction types
- Fire resistance
- Acoustics
- Shafts
- Mep detailing
- Building enclosure
- Lateral framing
- Connections
- Construction process



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)

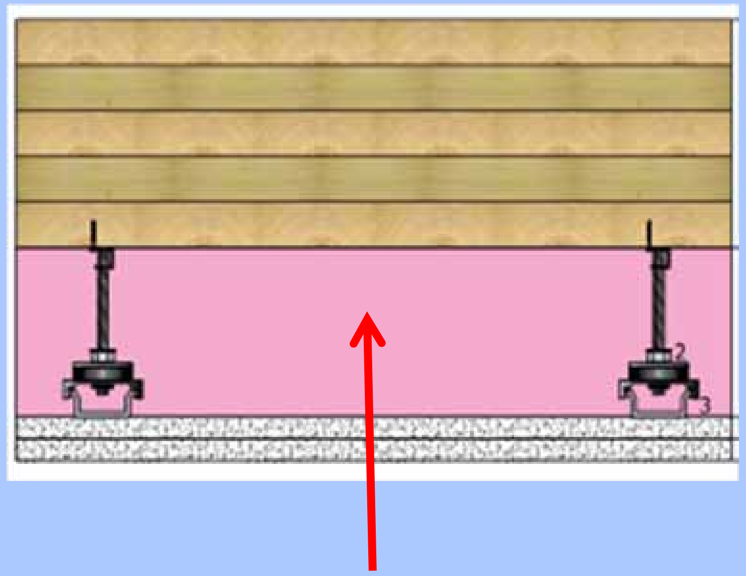
Construction types

IBC 602

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

HT Outside of Type IV Construction

- **In Type III & V Construction Requiring Fire Resistance Rating:**
- IBC 722.1 permits calculation of fire resistance for exposed wood members and wood decking performed in accordance with NDS Chapter 16.
  - Common applications are exposed timber floors and roofs in IIIA, VA construction
  - Reduced (non-charred) section is used for structural calculations
  - Protection of connections required per IBC 722.6.3.3

Federal Center South – Building 1202 , Seattle, WA
Photo Credit: Benjamin Benschneider

Construction types

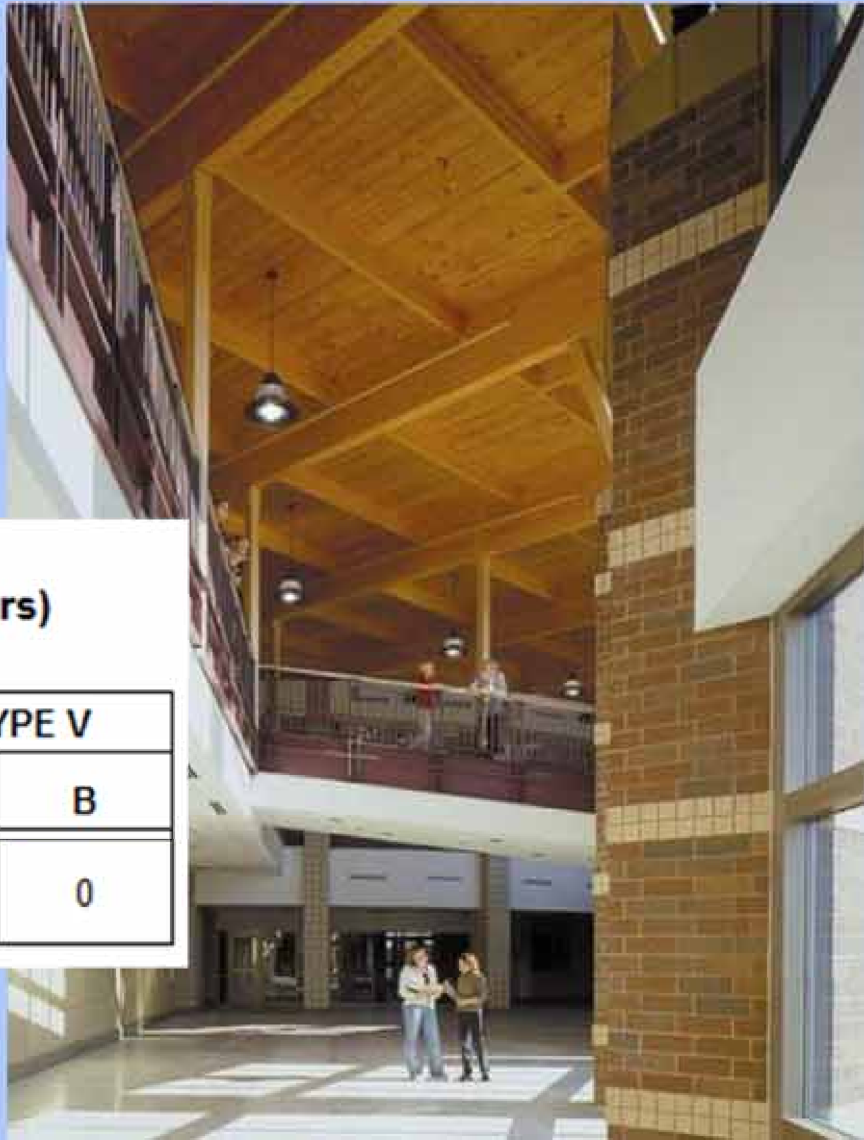
Ibc 601 & 603

MASS timber roofs (decks & secondary members) can be used where the required fire resistance rating is 1 hour or less in any construction type except 1a Per IBC Table 601 footnote c & Section 603.1

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[d]	B	A[d]	B	HT	A[d]	B
Roof construction and secondary members (see Section 202)	$1^1/_2$ [b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

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



Portland International Jetport, Portland, Maine

Architect : Gensler

Structural Engineer: Oest Associates

Timber Engineer: DeStefano & Chamberlain

Photos courtesy DeStafano & Chamberlain, Inc.

Case Study: Portland International Jetport

Portland International Jetport

- Location: Portland, ME
- LEED Gold
- Completed 2012

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

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)

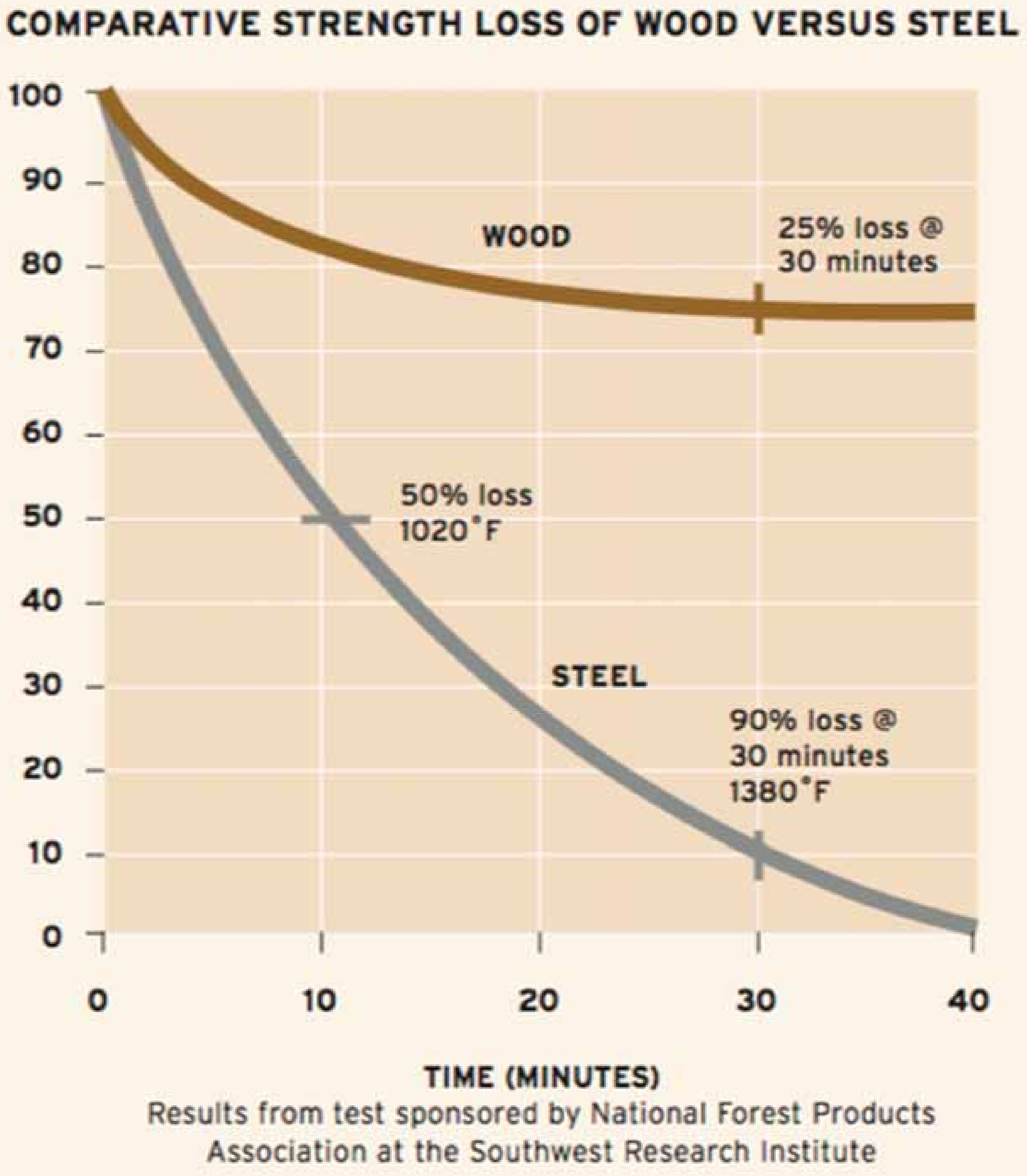
[3] Assumes 3 or more number of stories (IBC 506.4)

Fire resistance

Photo Credit: fp innovations

Mass timber design

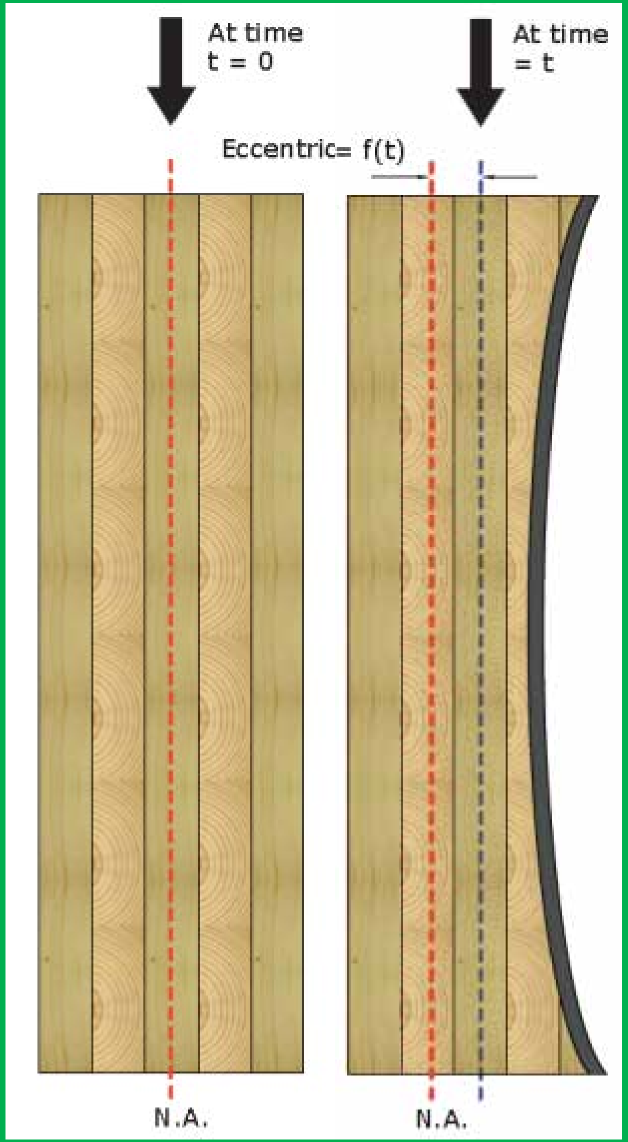
Fire resistance



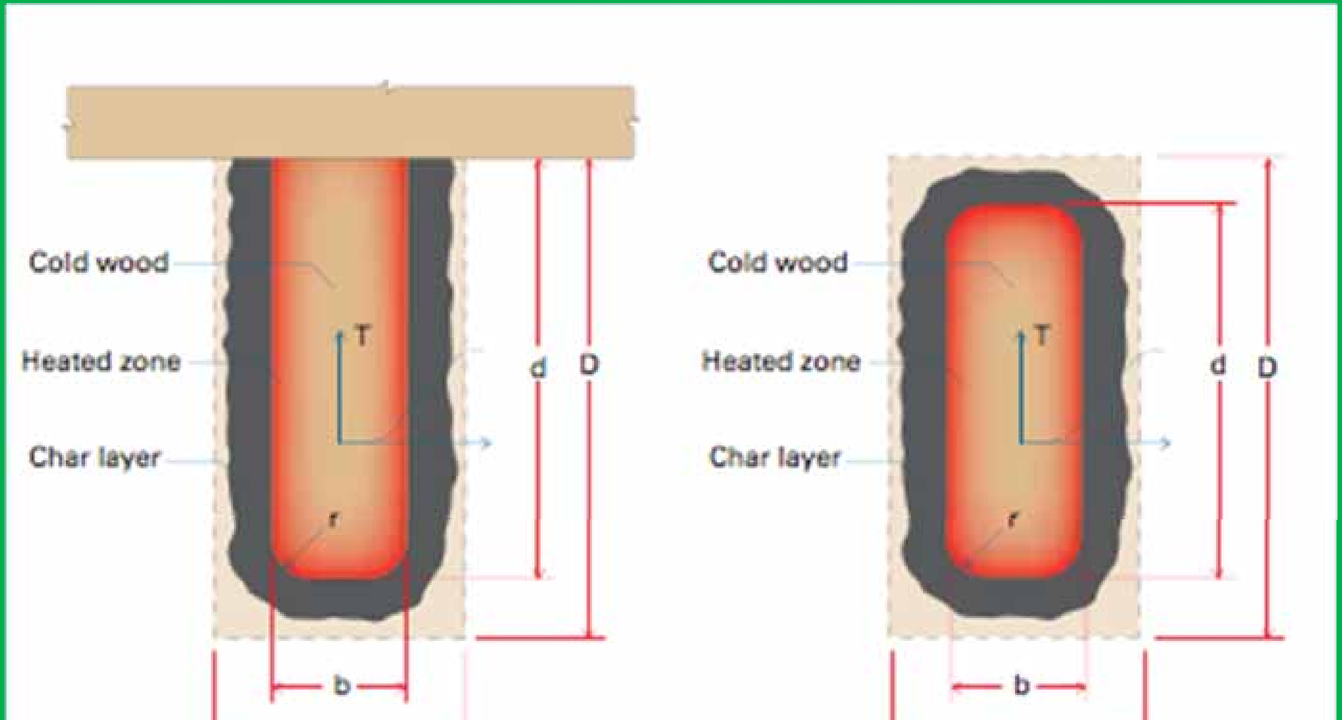
Source: Aitc

Mass timber design

Fire resistance



Similar to heavy timber, mass timber products have inherent fire resistance properties

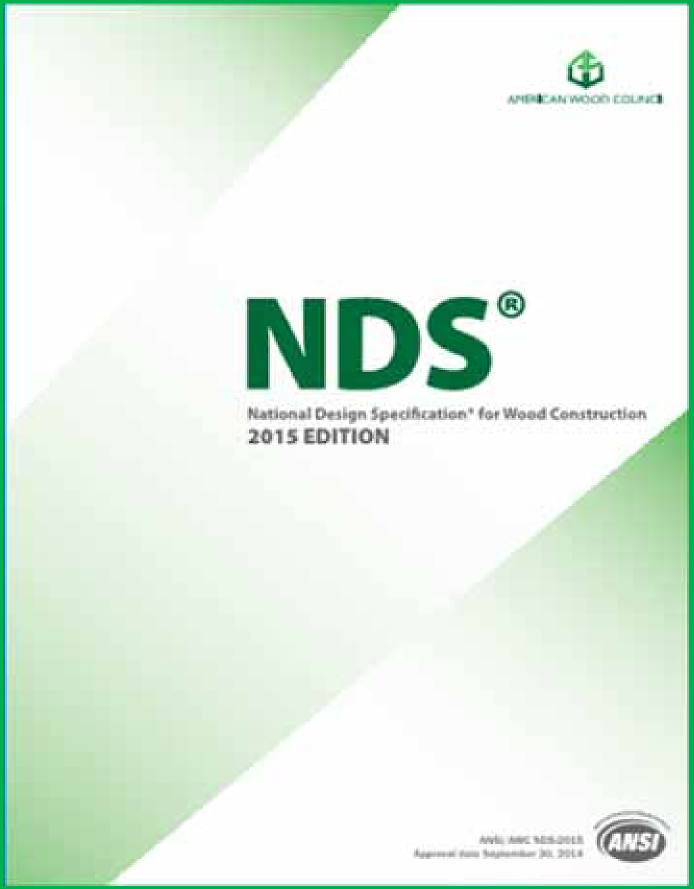


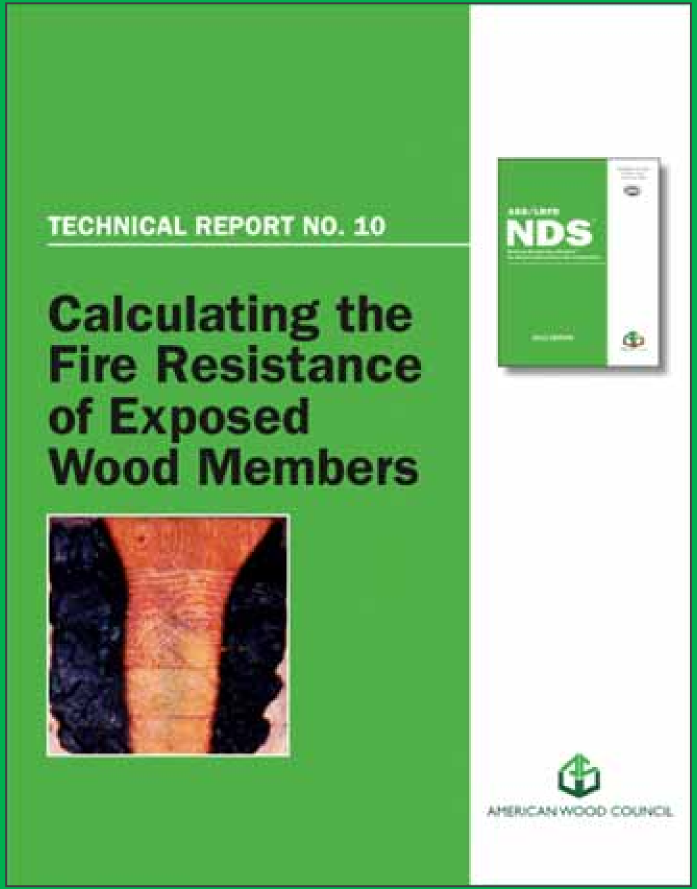
Source: AWC's TR10

Mass timber design

Fire resistance

For Exposed Wood Members: IBC 722.1 References AWC's NDS Chapter 16 (AWC's TR 10 is a design aid to NDS Chapter 16)





Mass timber products

ACOUSTICS

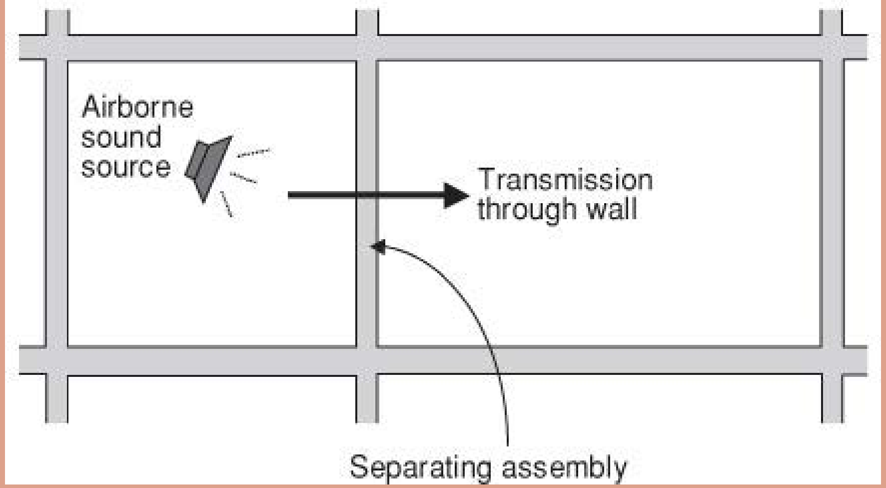
Mass timber design

acoustics

Air-borne sound:

- Sound Transmission Class (STC)

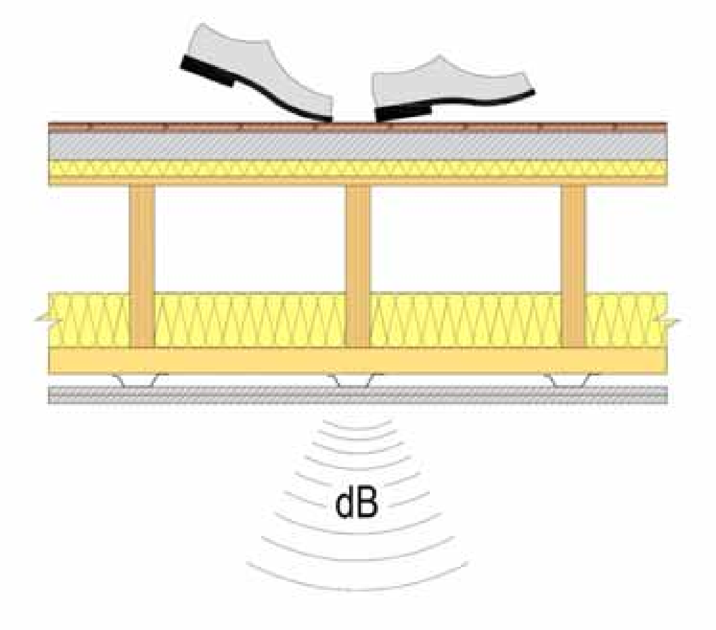
Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other



Structure-borne sound:

- Impact Insulation Class (IIC)

Evaluates how effectively an assembly blocks impact sound from passing through it



Mass timber design

Acoustics

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

Mass timber design

Acoustics

Acoustical mat often used to increase performance. Typically installed between mass timber panel and topping

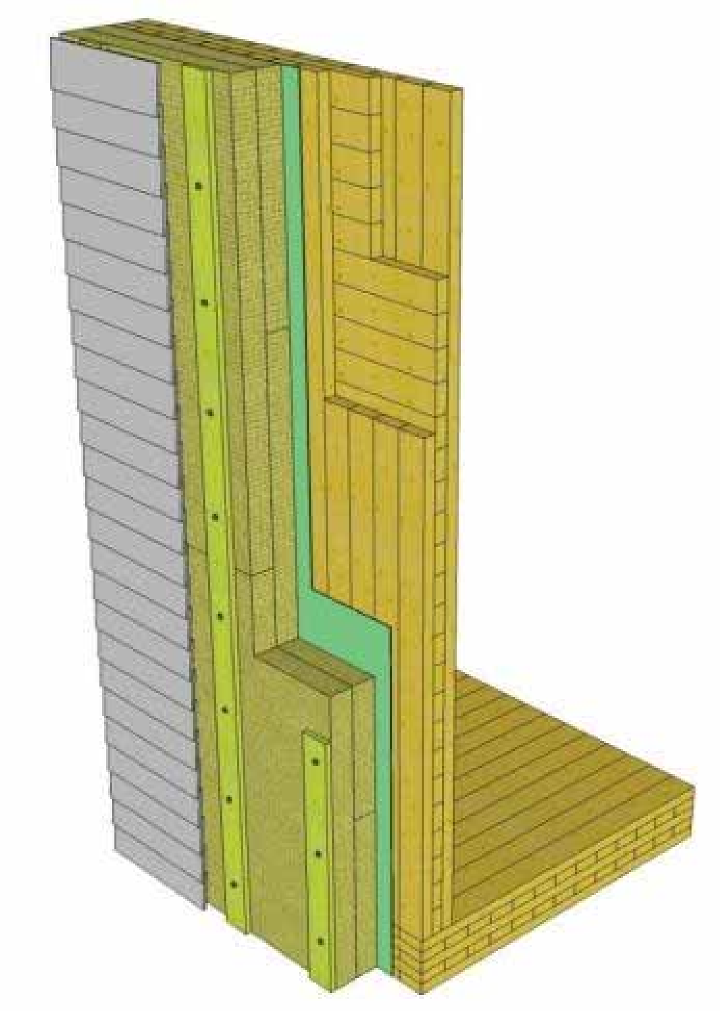
Mass timber shafts

Photo Credit: alex schreyer

Mass timber shafts

Photo Credit: alex schreyer

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

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

Central core – concrete shearwalls

Photo Credit: structurecraft

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 wood shearwalls

Photo Credit: woodworks

Mass timber design

connections

Photo Credit: alex schreyer

Photo Credit: myticon

Mass timber design

connections

Beam to beam connections

Photo Credit: alex schreyer

Mass timber design

connections

Beam to column & column to column connections

Photo Credit: John Stamets

Mass timber design

connections

column to foundation connections

Photo Credit: alex schreyer

Mass timber design

connections

Photo Credit: myticon

Panel to beam connections


TIME FOR
CASE STUDY

Tamedia Headquarters, Zurich Switzerland
Design Team: Shigeru Ban & IttenBrechbuhl, Creation Holz GmbH
Photo: Didier Boy de la Tour

Source: Survey of International Tall Wood Buildings, 2014

Tamedia Headquarters, Zurich Switzerland
Design Team: Shigeru Ban & IttenBrechbuhl, Creation Holz GmbH
Photo: Didier Boy de la Tour

Source: Survey of International Tall Wood Buildings, 2014

Churches

St. Martha Catholic Church – Porter, TX

Design Team : Turner Duran Architects, Pinnacle Structural Engineers

Photo Credit: G. Lyon Photography, Inc.

- 45,000 sf
- Glulam trusses & columns, T&G decking

Aquatic Centers

West Vancouver Aquatic Centre
Design Team: Hughes Condon Marler Architects, Fast and Epp Engineers
Photo Credit: Nic Leboux, Gary Otte, Martin Tessler

- Curved glulam beams and wishbone columns provide vertical and lateral support
- $7.5 Million total cost

Aspen Art Museum, Aspen, CO, USA
Design Team: Shigeru Ban Architects, Turner Construction

ALBINA YARD

PORTLAND, OR

4 stories
16,000 sf
Green Roof

ARCHITECT: Lever Architecture
IMAGE CREDIT: Lever Architecture

- 20'x20' Grid
- CLT floor panels with electrical conduit poured into lightweigh gypsum topping
- Wood shearwall core with open front design for glazing wall

ALBINA YARD

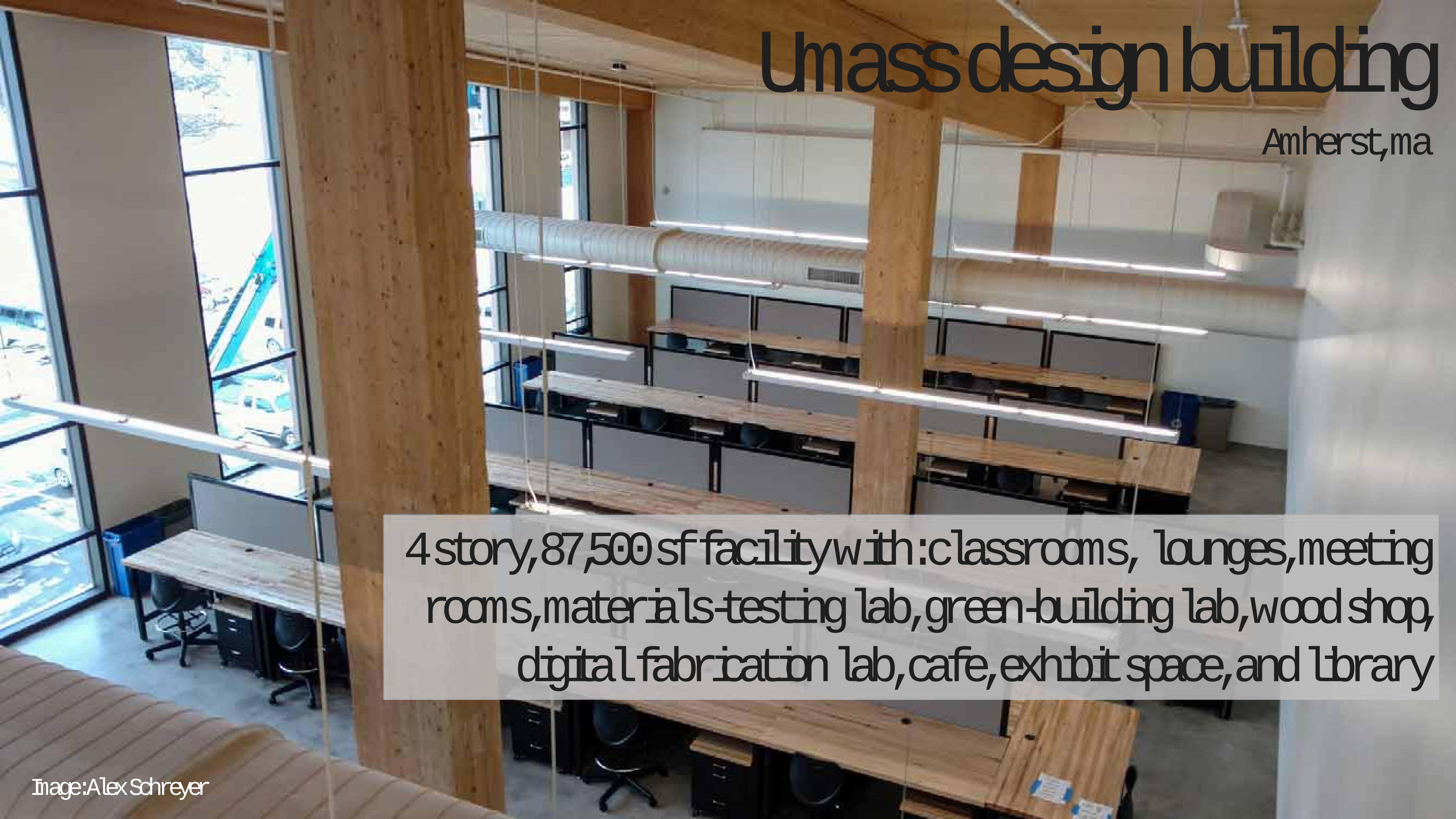
PORTLAND, OR

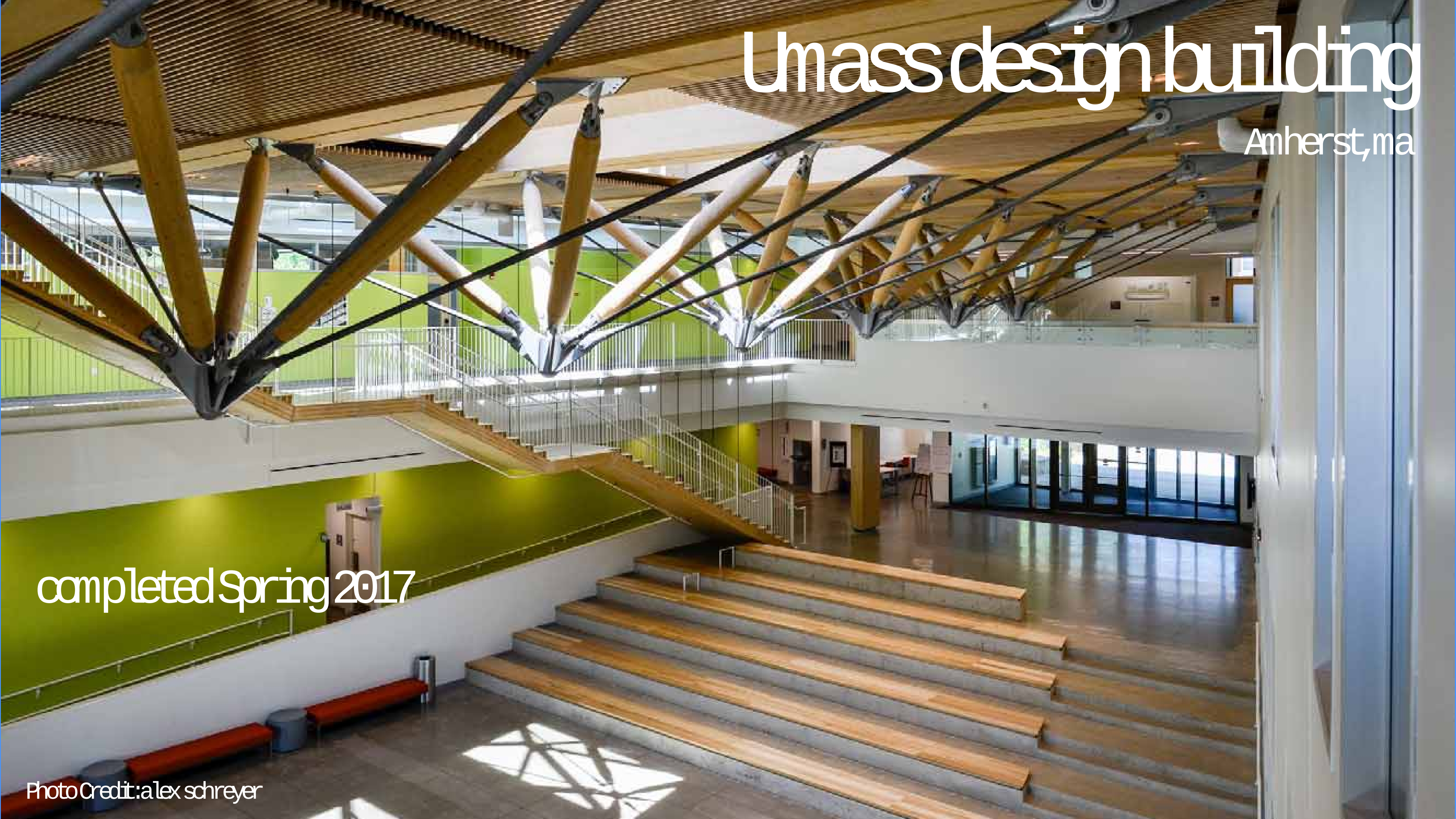
ARCHITECT: Lever Architecture
IMAGE CREDIT: WoodWorks

Umass design building

Amherst, ma

Image Credit: Alex Schreyer


Umass design building
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


t3minneapolis
Minneapolis, mn
Image Credit: Michael Green Architects/Hines Group

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

t3 minneapolis

Minneapolis, mn

Image Credit: StructureCraft/Hines/Michael Green Architect


t3 minneapolis
Minneapolis, mn
Image Credit: Ema Peter

Photo credit: naturally:wood

Historic Tall Wood-Butler Brothers Building

1906, 9 stories, 500,000 sf

Modern TallWood-Carbon 12

2017, 8 stories, 32,000 sf

Portland, OR

Photos:
Baumberger Studio/PATH
Architecture/Marcus Kauffman

Modern Tallwood-Framework

2018 Start, 12 stories, 90,000 sf

Portland, OR

Images:
Lever Architecture

TALL Wood In the Building Code

At end of 2015, ICC approved creation of ad hoc committee to explore tall wood buildings and potential related code provisions

Ad hoc committee has held several in-person meetings since July, 2016; frequent conference calls

Objective is submission of code changes for the 2018 Group A Cycle (IBC) in January, 2018 – changes for 2021 IBC

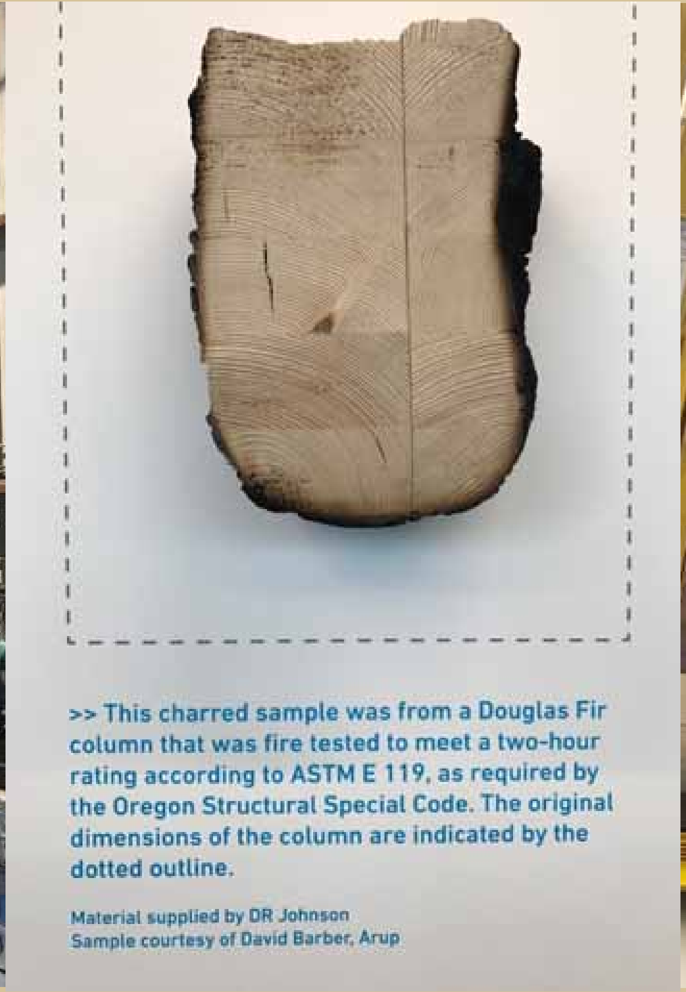
TALL Wood In the building Code

Testing & research aiding ad hoc efforts in development of code change proposals for prescriptive code allowances of tall wood

Mass Timber Fire Testing at ATF Lab – Spring/summer 2017

TALL Wood In the building Code

Framework project testing



Beam to Column Fire Testing

Beam to Column Seismic Testing

BROCK COMMONS

VANCOUVER, BC

EXPECTED COMPLETION:
SUMMER 2017
18 STORIES
174 FT
156K SQ.FT.

Photo credit: acton ostry architects

BROCK COMMONS

VANCOUVER, BC

17 stories of timber installation

Started june 6, 2016

Finished august 10, 2016

BROCK COMMONS

Last clt panel install

VANCOUVER, BC

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Marc Rivard

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