Mass Timber Structural Systems

PART 1: Products and Framing Systems

January 13, 2026

Presented by

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Thesis, LEVER Architecture, Holes, Swinerton, Photo Bryan Aulick

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

AIA Approved Continuing Education

Course Description

This course is developed for architects and engineers to provide a better understanding of the scope of mass timber elements and their unique design considerations. Looking at the range of mass timber components, the course will cover the range of mass timber components and examine how they are manufactured, unique product features, and the variety of sizes, species, and structural grades. This includes coverage of CLT, NLT, structural glulam, and structural composite lumber (SCL), along with guidance on code compliance and additional design information. Additionally, the course outlines the variety of framing layouts in which mass timber components can be arranged, with important lessons for creating efficient mass timber plans early in the design process. Such layouts include bearing wall systems, post-and-beam, post-and-plate, and hybrid systems.

Learning Objectives

1. Understand the methods for how mass timber elements are manufactured and how that relates to the preliminary and final design of mass timber elements.
2. Be able to distinguish between various types of mass timber panel types and their inherent structural, acoustic, and fire protection qualities.
3. Learn different ways to layout mass timber framing systems to capture efficiencies in structural optimization with consideration given to building infrastructure systems (mechanical, electrical, plumbing and fire suppression).
4. Become familiar with the building codes, reference standards, and design guides necessary for mass timber floor, wall, beam and column elements.

Introduction

Mass timber products come premanufactured in many forms, including:

- Large panels (floor or wall “planks”)
- Glue-laminated timber (glulam) beams and columns
- Structural composite lumber (SCL) beams and columns

Mass timber refers to a category of wood framing styles typically characterized by large, fabricated wood panels paired with engineered wood product beams and columns.

Catalyst
MGA | Michael Green Architecture / KPFF
Photo Benjamin Benschneider

https://www.woodworks.org/resources/mass-timber-cost-and-design-optimization-checklists/

Potential Benefits	Project Goal ✓	Value Add ✓
Fast construction/shorter schedules; pre-fabricated and precise		
Exposed wood • Aesthetic value; potential for faster leasing and lease premiums; portfolio distinction • Biophilia; healthy indoor environment		
Lightweight structure, especially beneficial on sites with poor soils, for vertical additions above existing buildings, and for multi-story projects in high seismic regions		
Labor shortage solutions • Small crews for timber frame installation • Utilize more entry-level laborers when MEPF systems are fully designed, coordinated and pre-planned		
Just-in-time delivery and small staging/lay-down areas; ideal for dense urban areas		
Natural, renewable material; environmentally friendly with a lighter carbon footprint		
Support healthy forests and rural economies • Mass timber can be made from relatively small-diameter trees and those affected by insects or disease; creates a market incentive for forest thinning and other landscape restoration efforts that reduce the risk of high-severity wildfires		

WOODWORKS

Mass Timber Cost and Design Optimization Checklists

WoodWorks has developed the following checklists to assist in the design and cost optimization of mass timber projects.

The *design optimization* checklists are intended for building designers (architects and engineers), but many of the topics should also be discussed with the fabricators and builders. The *cost optimization* checklists will help guide coordination between designers and builders (general contractors, construction managers, estimators, fabricators, installers, etc.) as they are estimating and making cost-related decisions on a mass timber project. The *pre-design* checklist should be reviewed by the developer/owner, designers and builders.

1 De Haro
San Francisco, CA
ARCHITECT:
Perkins&Will
ENGINEERS:
DCI Engineers
CONTRACTOR:
Hathaway Dinwiddie

WoodWorks offers a wide range of resources at woodworks.org, many of which are referenced in this document. We also recommend that designers and builders download the following:

Mass Timber Design Manual[1] – Includes technical papers, continuing education articles, expert Q&As and more, and is updated regularly. Published in partnership with Think Wood.

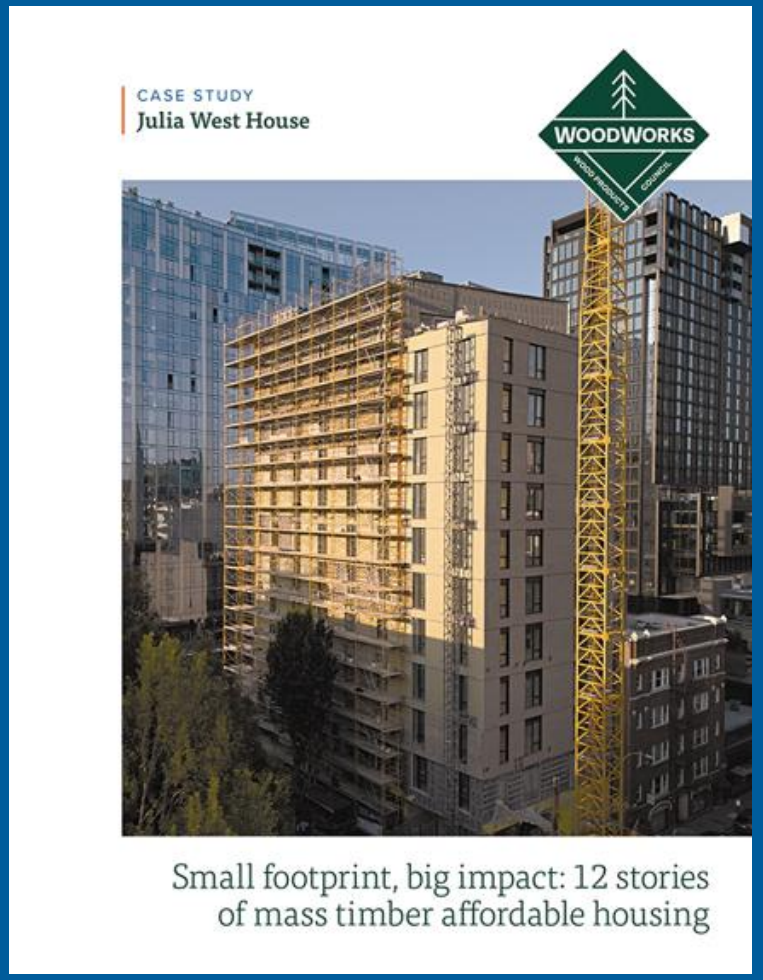
U.S. Mass Timber Construction Manual[2] – Provides a framework for the planning, procurement and management of mass timber projects.

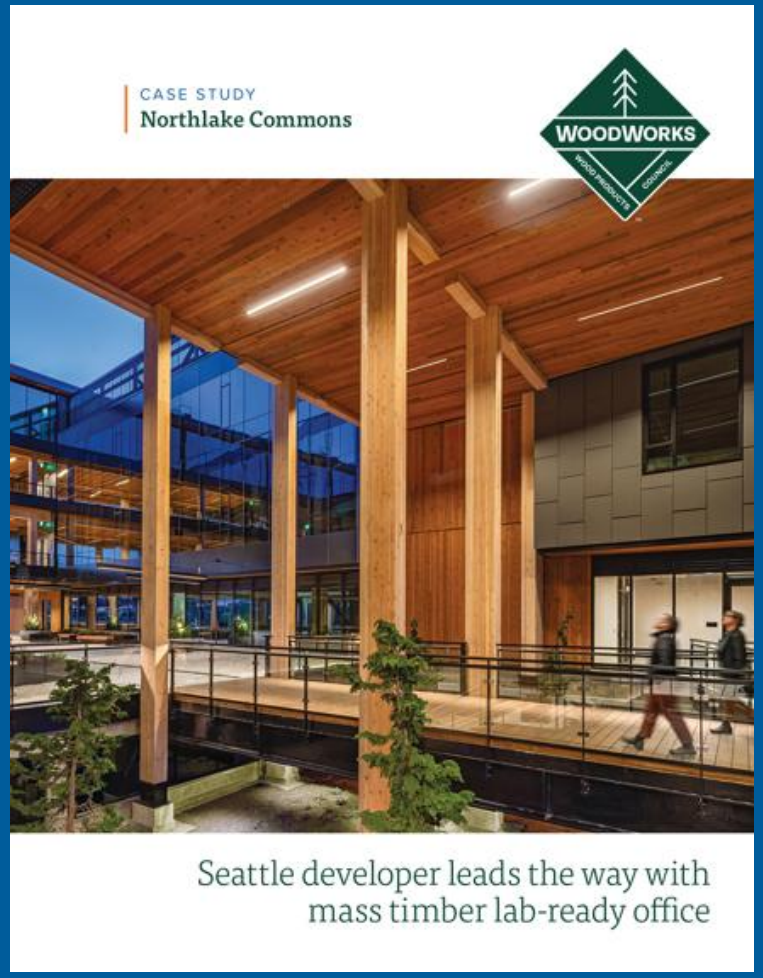
Photo: David Wakely

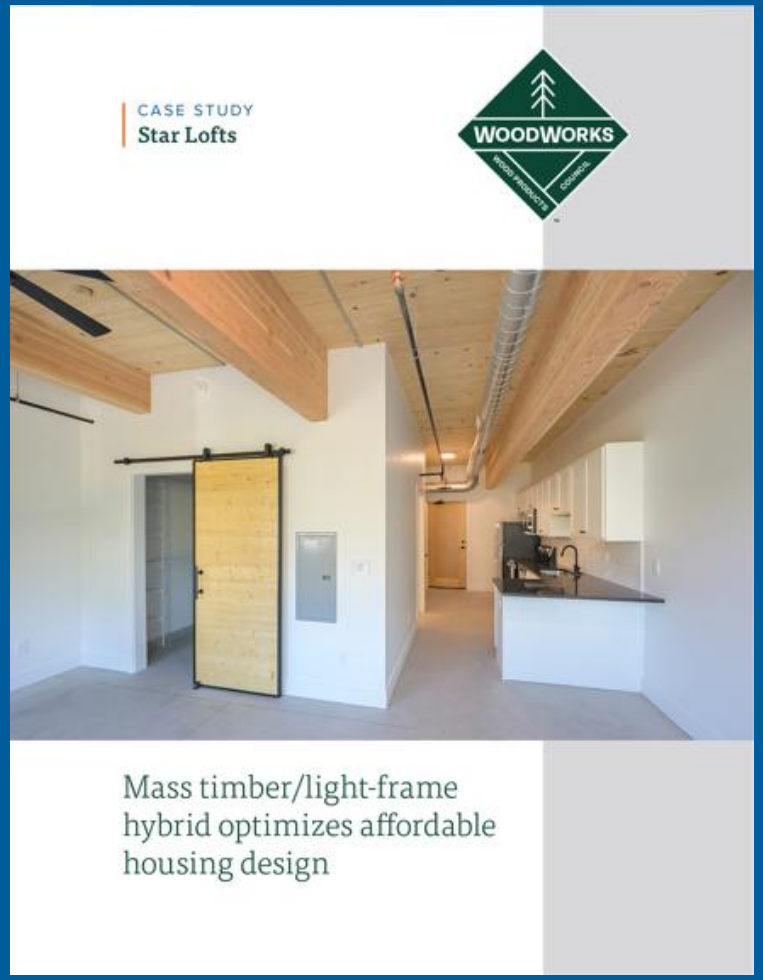
Photo: Erika Brown Edwards

33+ Mass Timber Case Studies on WoodWorks website

https://www.woodworks.org/search/?resourceTypes=Case%2520Studies







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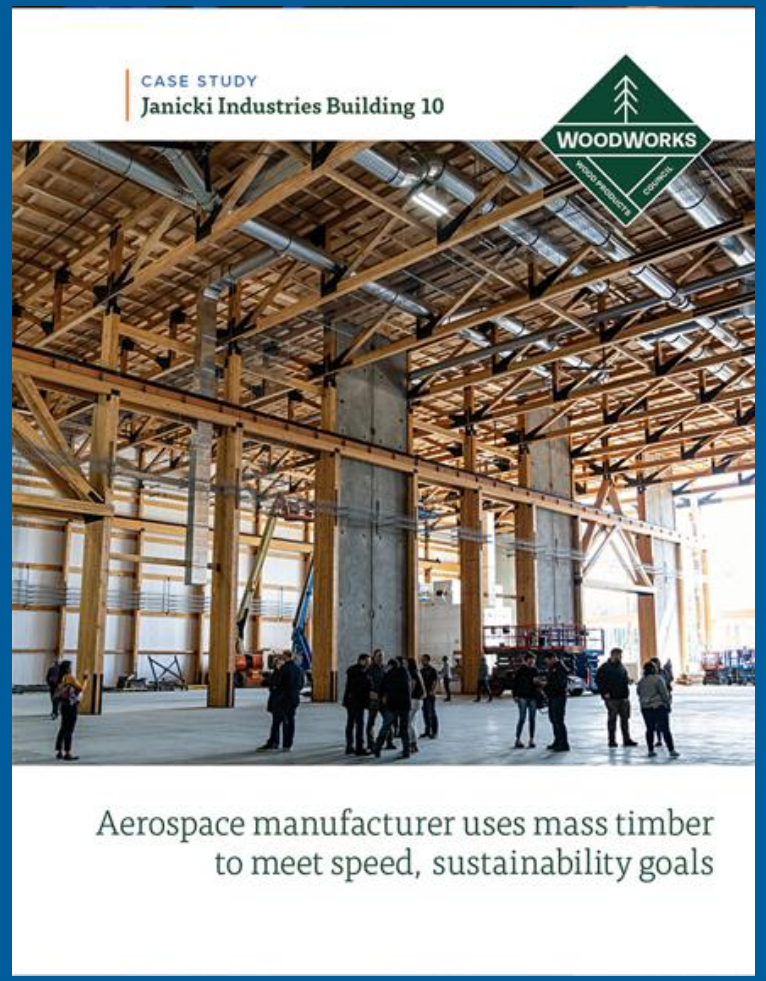
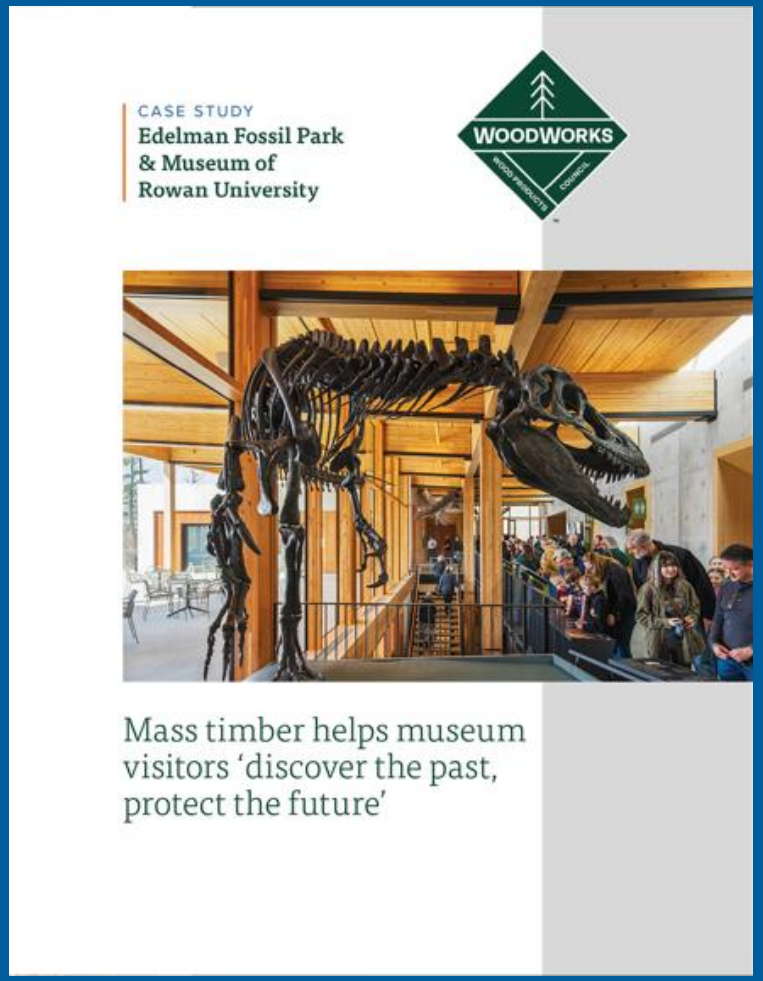
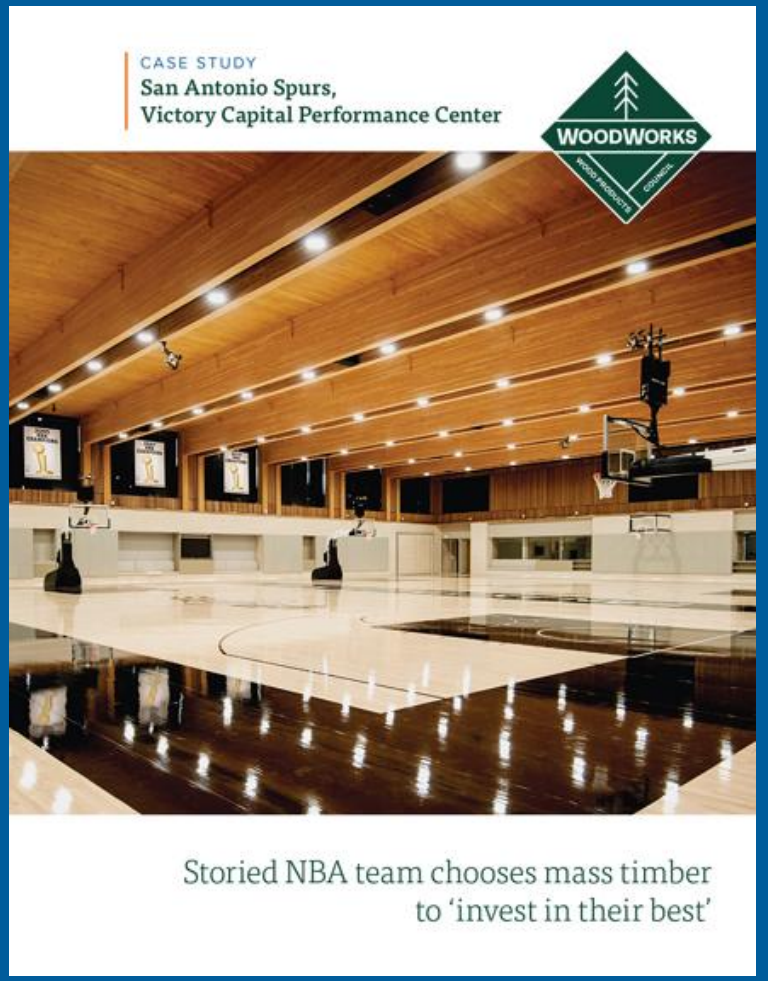






Mass Timber Structural Products

Photo credits: MPP from Freres Lumber.
All others StructureCraft Builders

Mass Timber Panel and Decking Products

Cross Laminated Timber
CLT (of sawn lumber)

Glue-Laminated Timber
GLT

CLT of SCL
(e.g. MPP & VLT)

Nail Laminated Timber
NLT

Dowel Laminated Timber
DLT

Timber Concrete Composite
TCC

Mass Timber Products

Framing

- Lumber
- Structural Glue Laminated Timber/ Glulam
- Structural Composite Lumber / SCL

Photo: Boise Cascade

Photo: Weyerhaeuser

Panels

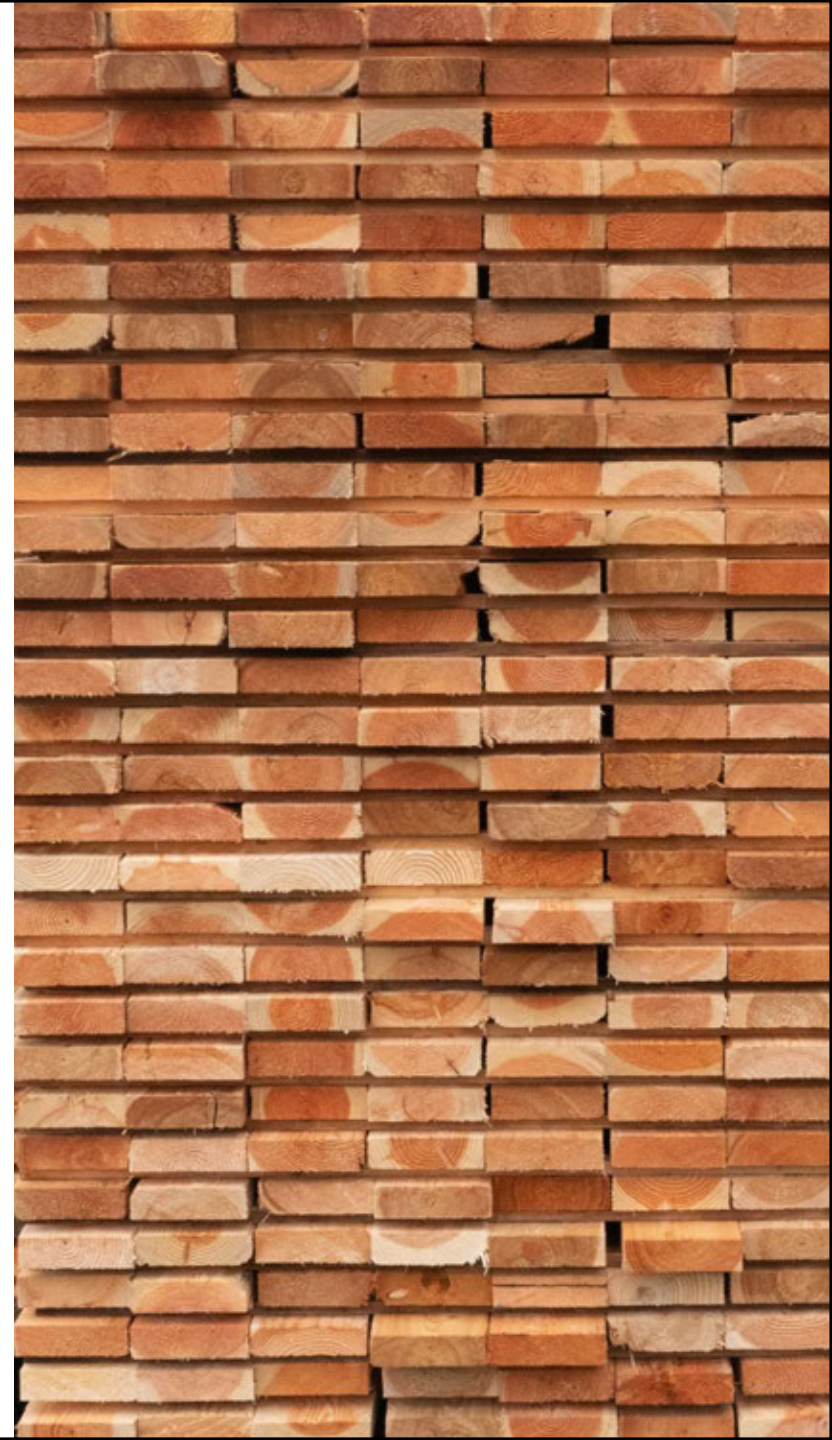
- Cross-Laminated Timber / CLT
- Nail-Laminated Timber / NLT
- Dowel-Laminated Timber / DLT
- Glue-Laminated Timber / GLT

The Canyons
Kaiser+Path / catena consulting engineers / R&H Construction
Photo Marcus Kauffman

Structural Sawn Lumber

Examples familiar to many:

- #2 Southern Pine 2-by-4
- #1 DFL 2-by-6



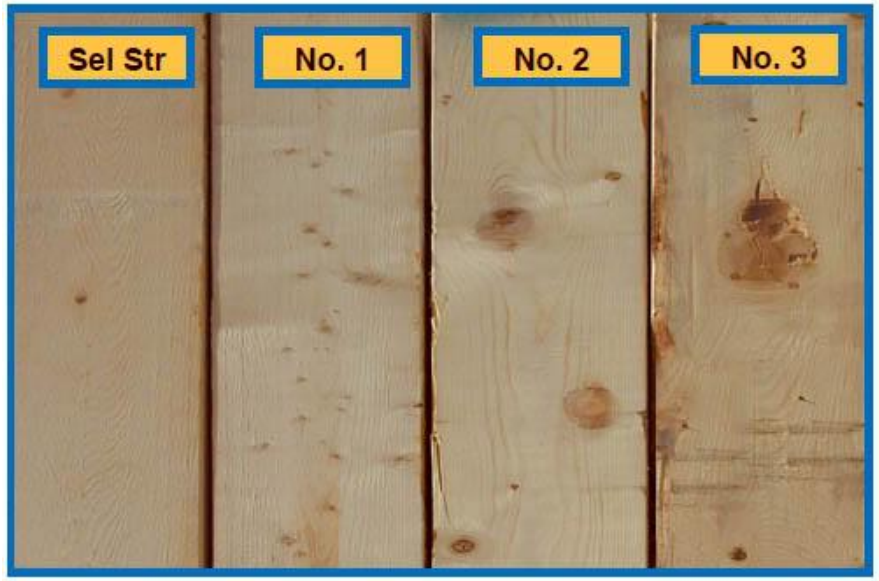
Structural Sawn Lumber Grades

Commercial Grade

Visually Graded

- Select Structural
- Dense No. 1
- No. 1
- No. 2
- No. 3
- …

Wood Education Institute



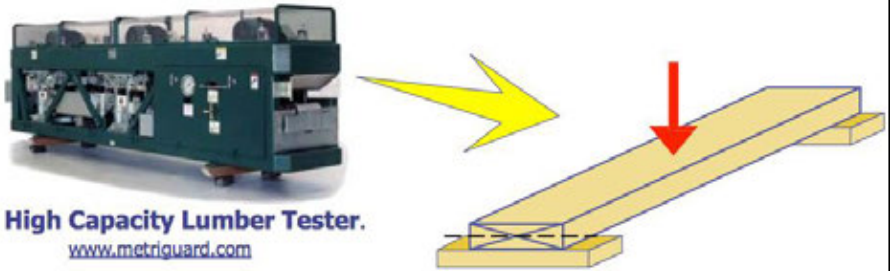
Mechanically Graded

- 2200f-1.9E
- 1950f-1.7E
- 1650f-1.5E

Machine Stress Rated (MSR) Lumber

- M-26
- M-21
- M-10

Machine Evaluated Lumber (MEL)



Structural Sawn Lumber Species & Species Groups

Species Group	Common Name	Scientific Name
Douglas Fir–Larch	Douglas-fir	*Pseudotsuga menziesii*
	western larch	*Larix occidentalis*
Hem–Fir	western hemlock	*Tsuga heterophylla*
	California red fir	*Abies magnifica*
	grand fir	*Abies grandis*
	noble fir	*Abies procera*
	Pacific silver fir	*Abies amabilis*
	white fir	*Abies concolor*
Southern Pine	loblolly pine	*Pinus taeda*
	longleaf pine	*Pinus palustris*
	shortleaf pine	*Pinus echinata*
	slash pine	*Pinus elliottii*
Spruce–Pine–Fir	black spruce	*Picea mariana*
	Engelmann spruce	*Picea engelmannii*
	red spruce	*Picea rubens*
	balsam fir	*Abies balsamea*
	subalpine (alpine) fir	*Abies lasiocarpa*
	jack pine	*Pinus banksiana*
	lodgepole pine	*Pinus contorta*

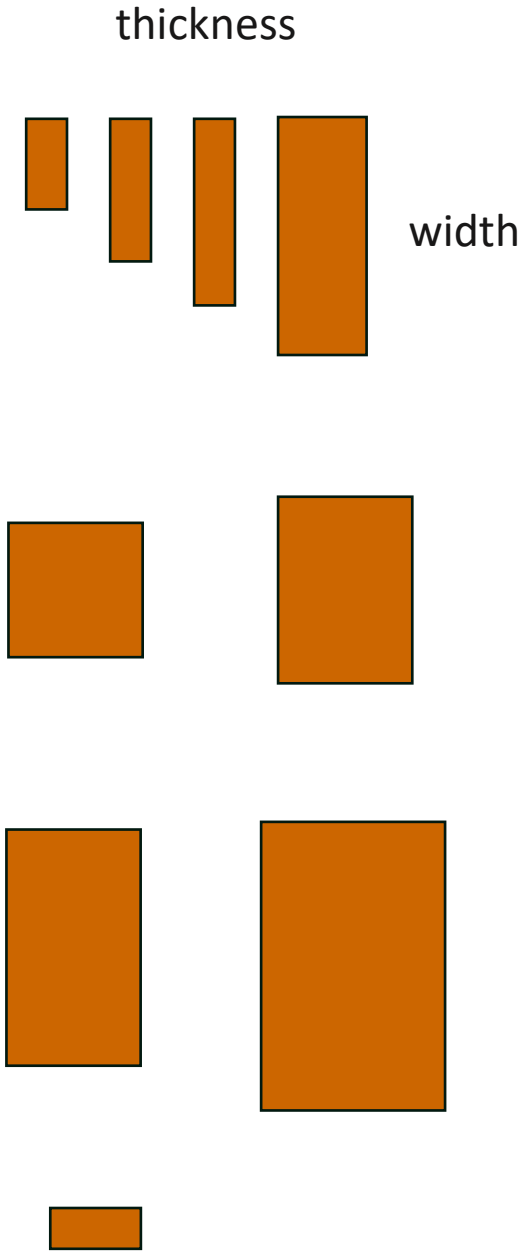
Excerpts from 2021 Wood Handbook (FPL GTR 282) Table 6-7

See also 2024 NDS Supplement Section 2.1

Structural Sawn Lumber Classification

Classification

Dimension Lumber	2x, 3x, 4x lumber
Posts & Timbers	6x6, 6x8, 8x8, 8x10, etc > 5” nominal thickness & square or within 2” of square
Beams & Stringers	6x10, 6x12, 8x12, 8x14, etc > 5” nominal thickness & width (depth) > 2” more than thickness
Decking	2x, 3x, 4x lumber T&G or similar. Intended for flatwise use



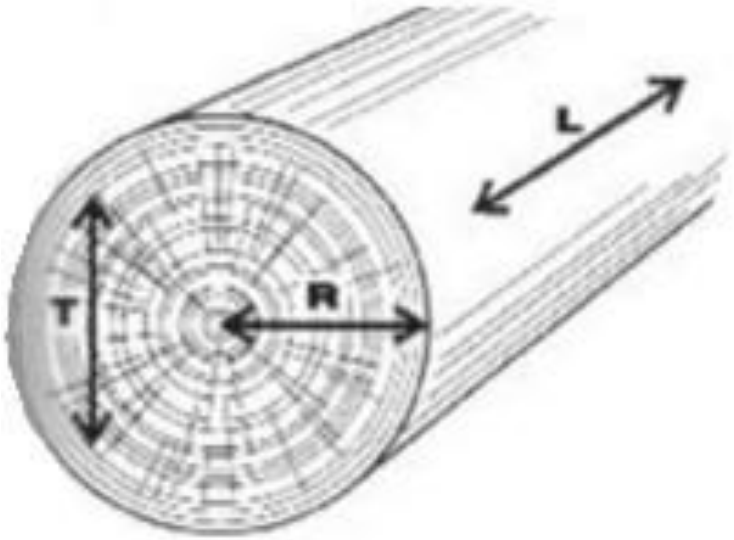
Nominal vs Actual Sizes of Dimensional Lumber

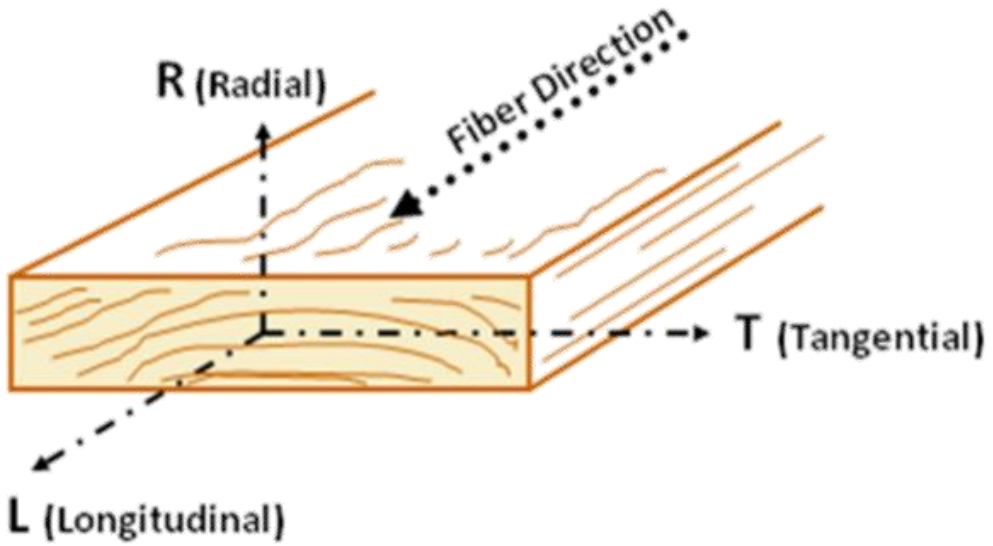
	Nominal	Minimum Dressed Size	
		Dry	Green
	2"	1-1/2"	1-9/16"
Thickness	3"	2-1/2"	2-9/16"
	4"	3-1/2"	3-9/16"
	4"	3-1/2"	3-9/16"
	6"	5-1/2"	5-5/8"
Width	8"	7-1/4"	7-1/2"
	10"	9-1/4"	9-1/2"
	12"	11-1/4"	11-1/2"

Structure of Wood & Lumber Products

Wood is orthotropic, meaning it behaves differently in its three orthogonal directions: Longitudinal (L), Radial (R), and Tangential (T)

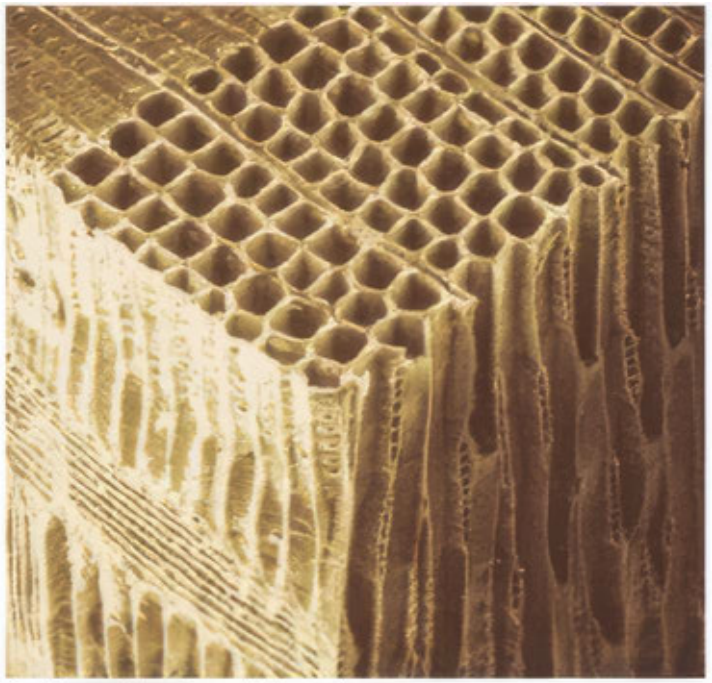
This is a direct result of the arrangement of wood cells.





Structure of Wood & Lumber Products

- Most wood cells are aligned along length (“parallel to grain”)
- Wood stronger parallel to grain
- Wood’s longitudinal cells are idealized as a bundle of straws
- Water moves faster parallel to grain (through straw)



Southern yellow pine cellular makeup

Source: USDA Forest Service Agricultural Handbook (1972)

Wood Education Institute

Changes in Wood Dimensions with Moisture Content

In construction, MC range of 28% down to equilibrium in range 6-10%

Wood shrinks in size as bound water evaporates.

Shrinkage varies in each of the three orthogonal directions:

- Longitudinal – very little change
- Tangential and Radial- shrink, with a bit more tangential shrinkage

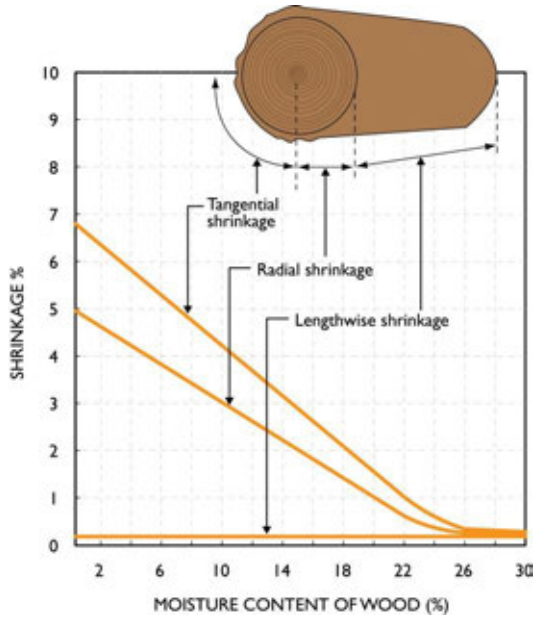


Image: RDH Building Science, Inc.

Width and Thickness change with MC

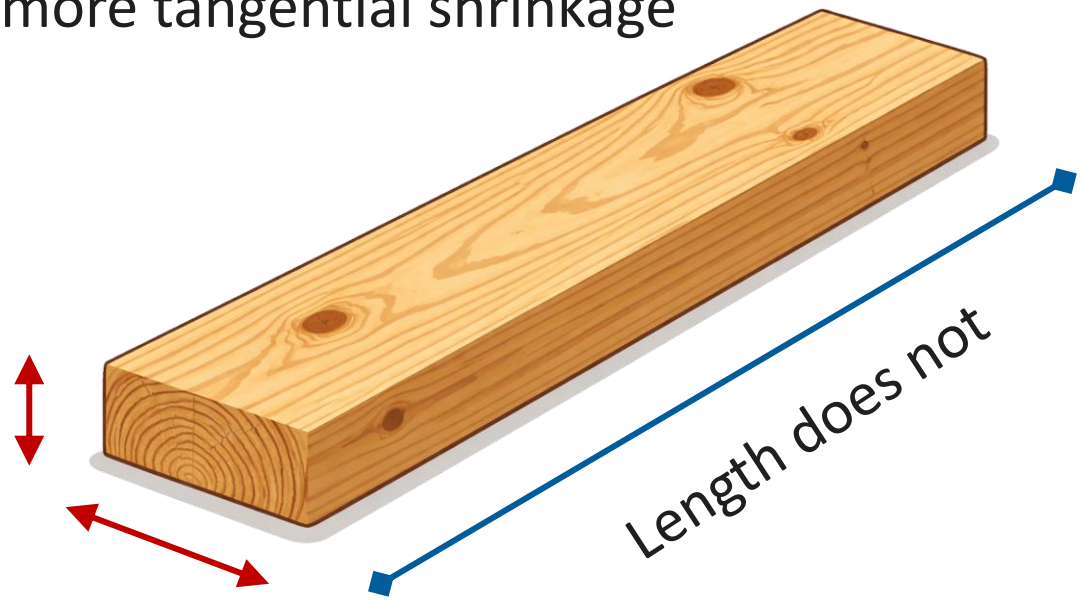


Image: WoodWorks

~ 0.2% to 0.25% change in size with 1% change in MC

Resources on Moisture Management and Shrinkage

Expert Tips

Mass Timber Moisture Management for Construction

Strategies for managing the unique moisture risks of mass timber building projects and developing a moisture management plan to implement during construction

Share Print

https://www.woodworks.org/resources/mass-timber-moisture-management-for-construction/

Solution Papers

Accommodating Shrinkage in Multi-Story Wood-Frame Structures

In wood-frame buildings of three or more stories, cumulative shrinkage can be significant and have an impact on the function and performance of finishes, openings, mechanical/electrical/plumbing (MEP) systems, and structural connections. However, as more designers look to wood-frame construction to improve the cost and sustainability of their mid-rise projects, many have learned that accommodating wood shrinkage is actually very straightforward.

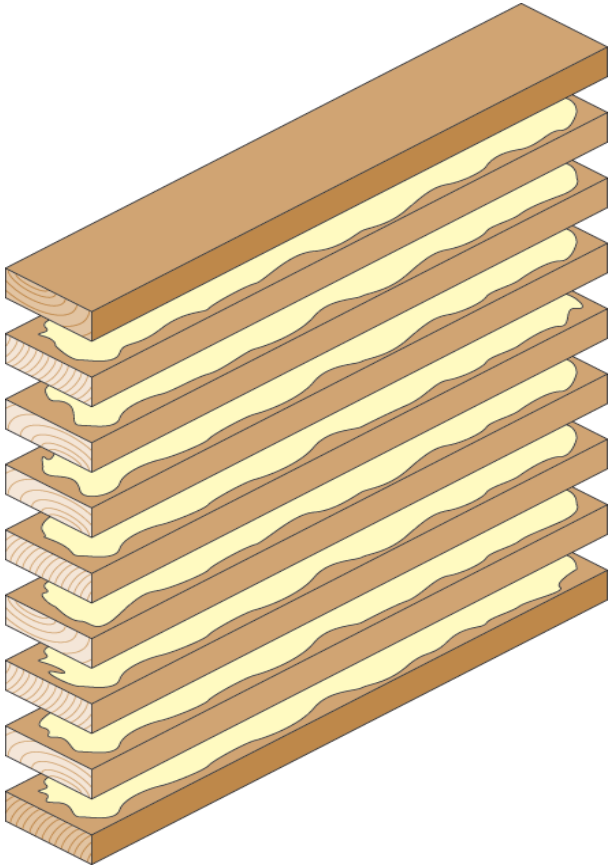
This publication describes procedures for estimating wood shrinkage and provides detailing options that minimize its effects on building performance.

https://www.woodworks.org/resources/accommodating-shrinkage-in-multi-story-wood-frame-structures/

Glulam

Platte Fifteen
Oz Architecture / KL&A Engineers & Builders / Adolfson & Peterson Construction
Photo JC Buck

Structural Glued Laminated Timber (Glulam)



wood laminations

+

structural adhesive

pressed, cured
and planed
to make
structural glulam

Glulam

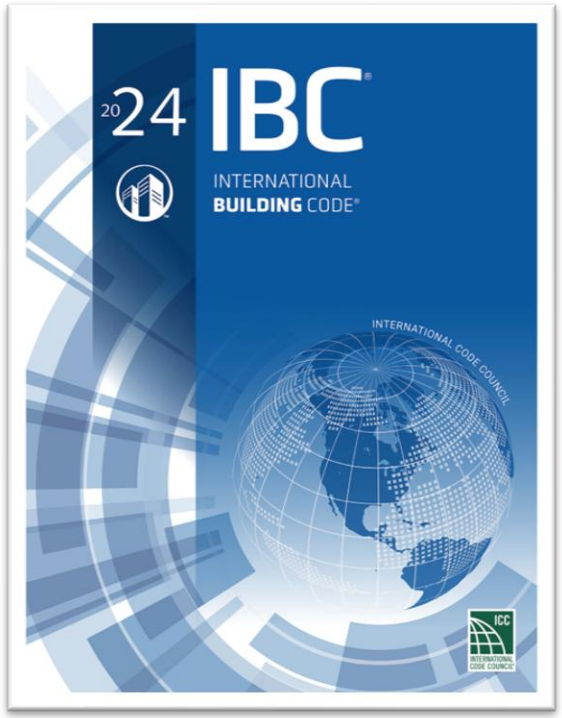
Mosaic Center, Edmonton AB. Reimagine/Fast+Epp

Glulam can be used as:

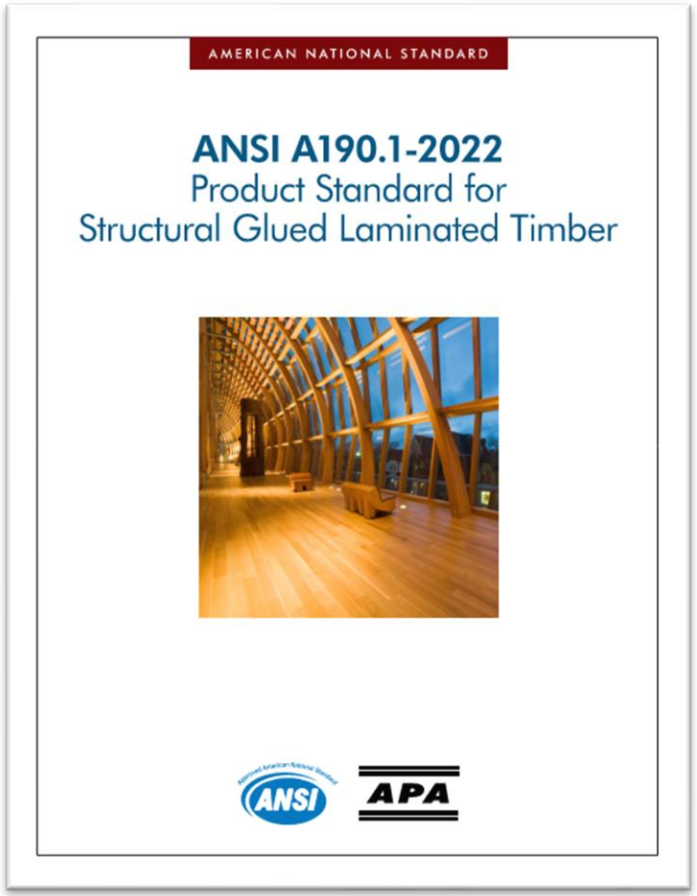
- Beams
- Columns
- Braces
- Arches
- Custom shapes
- Floor & roof decking (GLT)

Glulam

- In use in North America and Europe for over 100 years
- Recognized in IBC 2303.1.3 using ANSI/APA A190.1



International Building Code



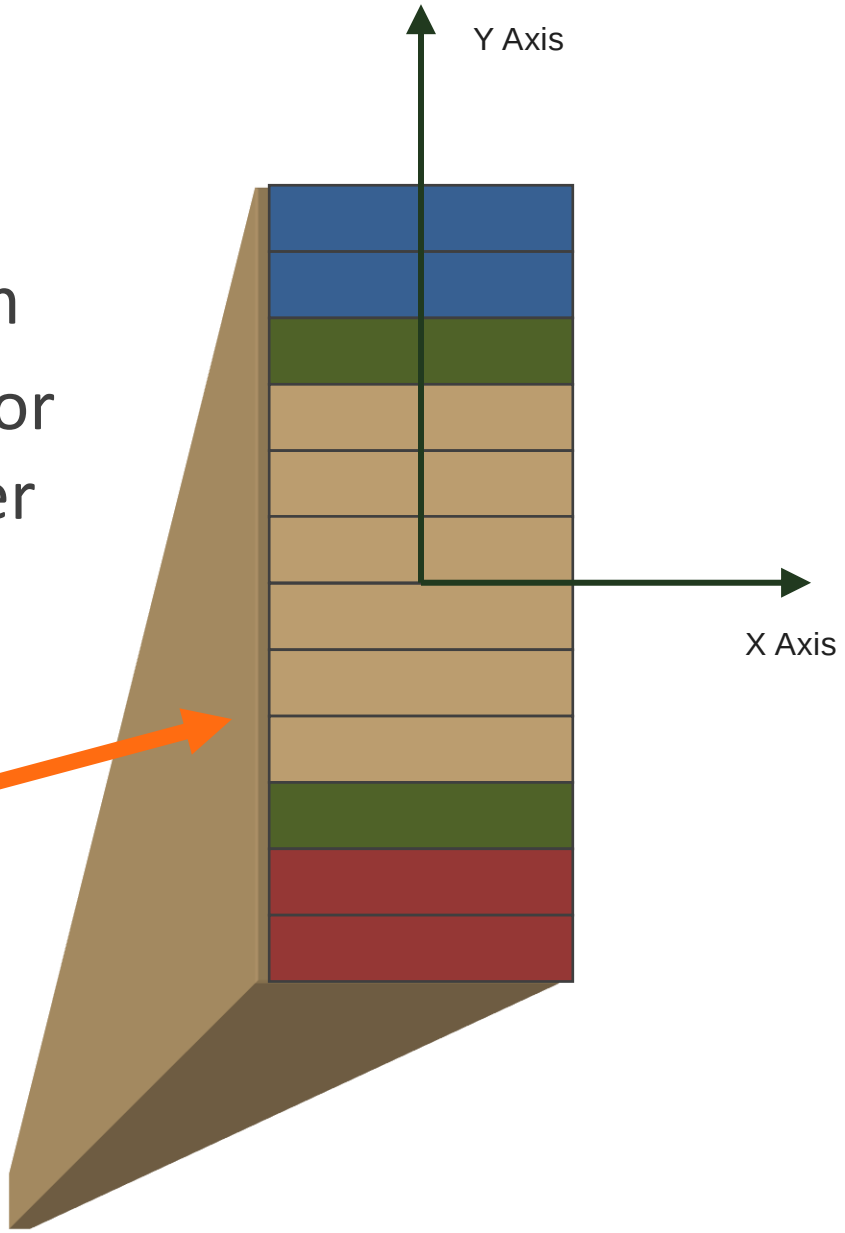
ANSI/APA A190.1

Secondary Standards

Glulam Layup

- Laminations commonly 2” nominal boards
- Sometimes thinner, especially in curved glulam
- Uses “lam-stock” which is graded specifically for use in glulam instead of structural sawn lumber grades.

Photo: WoodWorks



Glulam: Beam Layups

High Strength Compression Lams

Medium Grade Inner Lam

Lower Grade Inner Lams

Medium Grade Inner Lams

High Strength Tension Lams

unbalanced layup

Image: APA

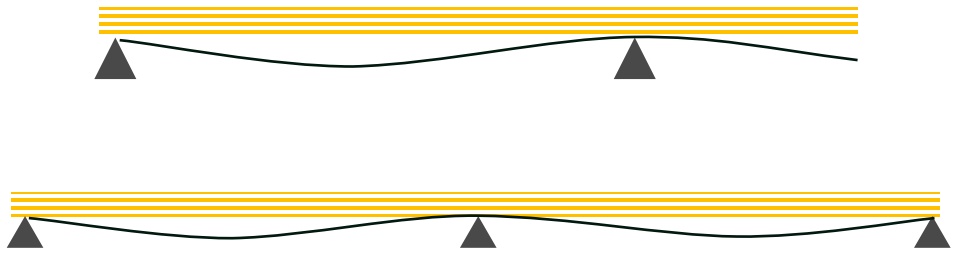
Unbalanced layups:

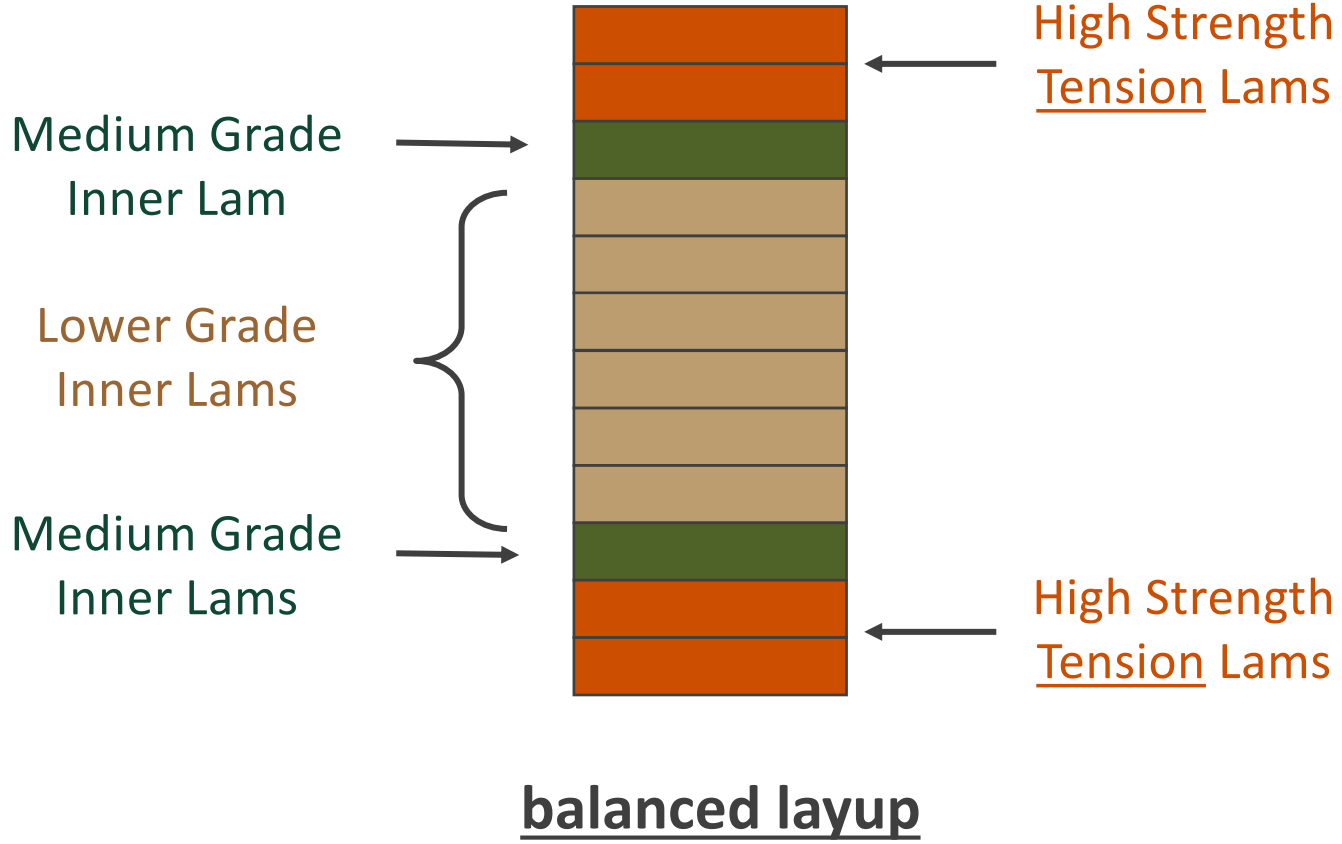
- Different positive vs negative bending strengths
- efficient for single-span beams
- Must be installed correctly.
- TOP label on top of beam

Glulam: Beam Layups

Balanced layups:

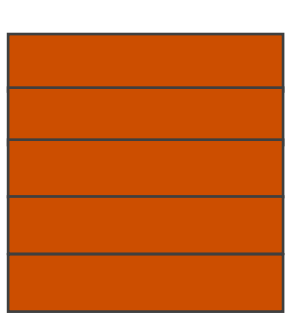
- single positive and negative bending strengths
- Good for multi-span beams and cantilevered conditions.

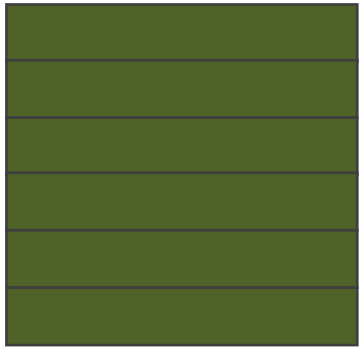




balanced layup

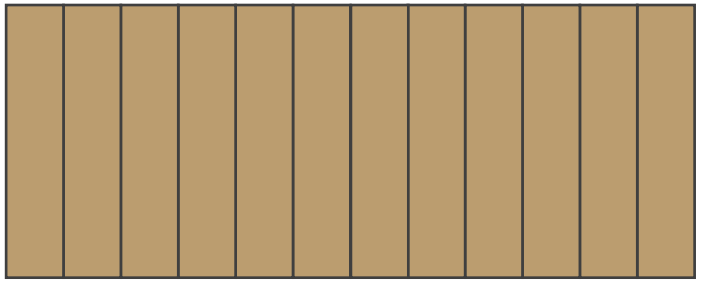
Glulam: Uniform Layups





primarily axial members
(columns and braces)

Square or close to square for column and braces



uniform layups used as horizontal GLT

“deep” glulam turn on side as GLT panel for floor or roof deck

Glulam Specs

Common Sizes

- Width: 3-1/8”, 3-1/2”, 5-1/8”, 5-1/2”, 6-3/4”, 7-1/4“, 8-1/2”, 8-3/4”, 10-3/4”, 12-1/4”, and wider..
- Depth:
  - Southern Pine: 4 layers = 5-1/2”+ @ 1-3/8” per layer
  - Other: 4 layers = 6”+ @ 1-1/2” per layer

Typical Species Groups

- Douglas-Fir, Southern Pine, SPF, Hem-Fir
- Also available in Cedar & others

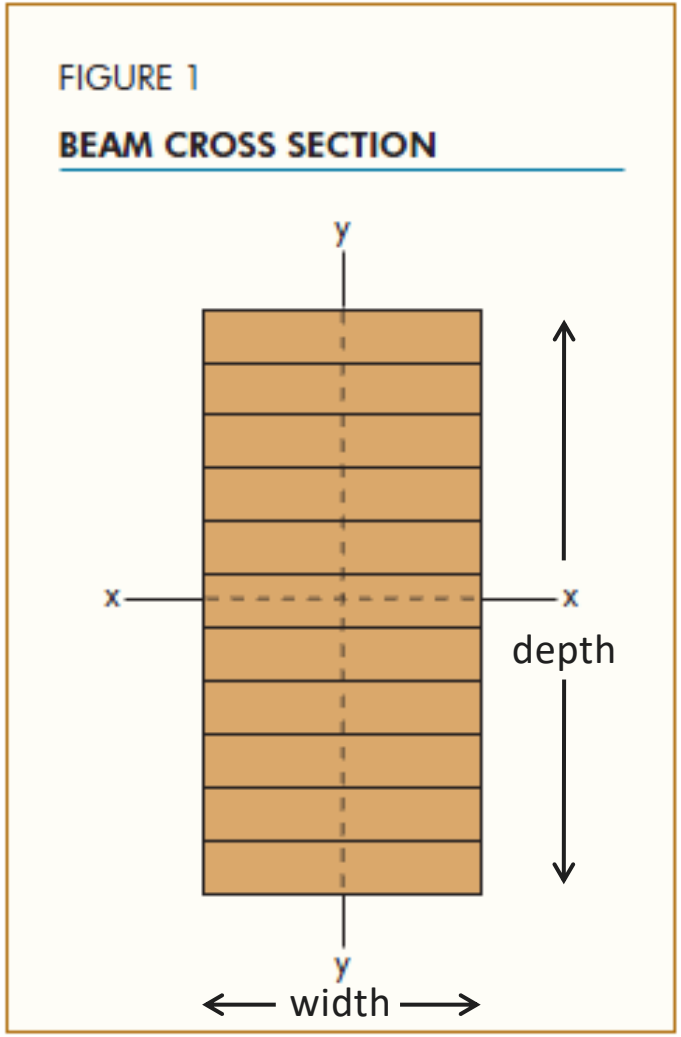
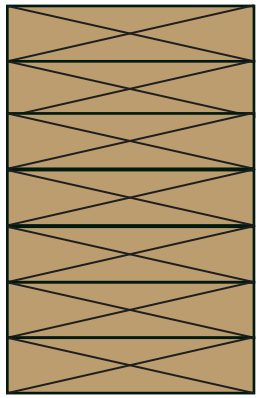


Image: APA Glulam Product Guide

Glulam Sizes: Influence of Width

Single Lam Width

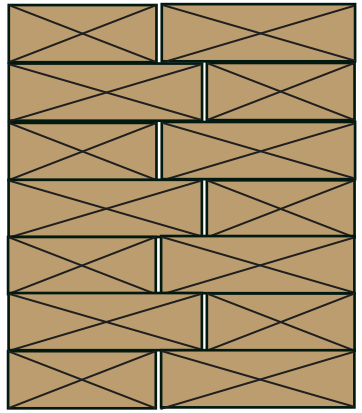


Width based on lumber sizes

Max width depends on manufacturer and lumber
~ 8-3/4“ to 10 ¾+”

Least $/volume

Split Lam

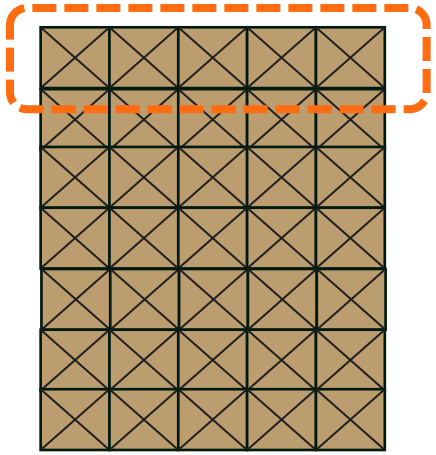


Width limit based on press size.

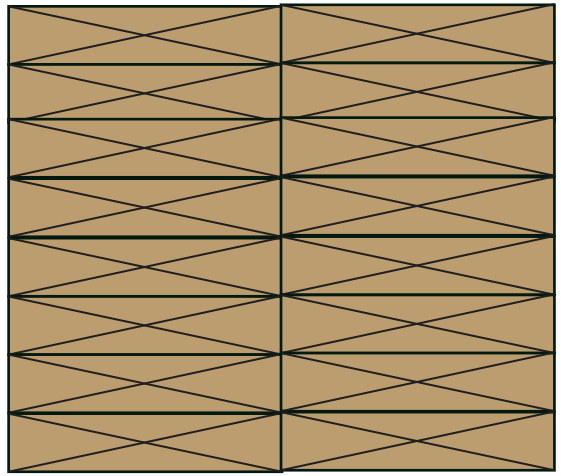
Max width depends on manufacturer
~ 14” to 24”+

Minor $/volume cost increase

Remanufactured



Block Glued

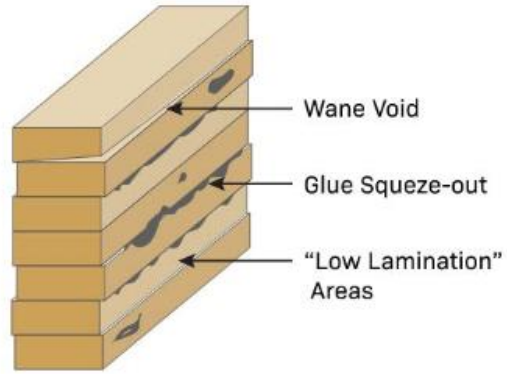


Secondary processing.
Glue 2 (or more) glulams together

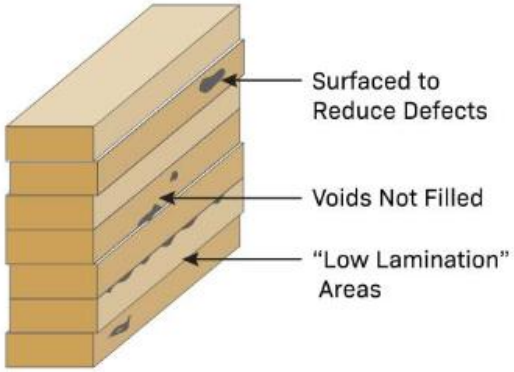
Max width depends on manufacturer

Major $/volume cost increase

Glulam Appearance Classifications
Defined in ANSI A190.1

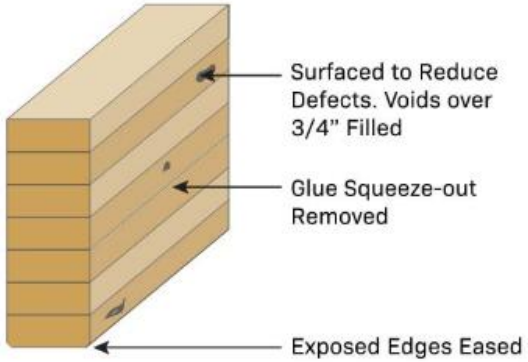


Framing Appearance



Industrial Appearance

Graphics: SmartLam



Architectural Appearance

Premium Appearance

Image: American Laminators

Characteristic	Framing	Industrial	Architectural	Premium
Surface Finish	Surfaced on two sides, on which the cumulative depth of misses, low laminations, and wane shall not exceed 10% of beam width at any bond line. Maximum area of low laminations shall not exceed 25% of the surface area of a side. Surfaced to meet conventional framing sizes.	Surfaced on two sides, on which the cumulative depth of misses, low laminations, and wane shall not exceed 10% of beam width at any bond line. Maximum area of low laminations shall not exceed 5% of the surface area of a side, and no more than two low laminations shall be adjacent to one another.	Exposed faces shall be surfaced smooth . No misses, wane, low laminations permitted. Architectural glulam is not sanded but can be added for an additional cost.	Exposed faces shall be surfaced smooth . No misses, wane, low laminations permitted. Laminations shall be selected to minimize loose knots, unsound knots, knotholes, pencil wane, bark inclusions, and voids that will be visible after final surfacing.
			As an option, Architectural and Premium glulam produced with the split lamination technique can come with a clear wood inlay on visual faces to disguise the joint.	
Voids	Not filled	Not filled	Voids over ¾" long shall be filled with wood-tone colored filler or with wood inserts. A void can exceed ¾" in length if area does not exceed ½ in^2.	In exposed surfaces, voids over ¾" long (or longer if its area does not exceed ½ in^2) shall be filled with a wood-tone colored filler or with clear wood inserts selected for similarity to the grain and color of the adjacent wood.
Knots	—	—	Wide face shall be free of loose knots, and open knots shall be filled.	On the wide face, knots shall be limited to 20% of the net face width of the lamination, and not over two maximum size knots or their equivalent shall occur in a 6 ft length.
Knot Holes	—	Loose knots and knot holes appearing on exposed face layers are not filled	—	—
Wane	Pencil wane permitted, not limited in length, but limited to one in ten pieces of lumber used.	Pencil wane permitted, not limited in length, but limited to one in ten pieces of lumber used.	Pencil wane shall be repaired, regardless of length. Wane ≤ 8" to be filled. Wane > 8" to receive wood inserts.	Pencil wane shall be repaired, regardless of length. Wane ≤ 8" to be filled. Wane > 8" to receive wood inserts.
Edge Gaps	—	—	Edge voids over 1/16" in wide faces exposed to view shall be filled.	Edge voids over 1/16" in wide faces exposed to view shall be filled.
Eased Edges	—	—	The edges of the member exposed to view in the final structure shall be eased with a minimum radius of 1/8" or equivalent chamfer.	The edges of the member exposed to view in the final structure shall be eased with a minimum radius of 1/8" or equivalent chamfer.

Table: Timberlab

Glulam Camber

Camber not that common in typical MT floors.
More common in long span roofs.

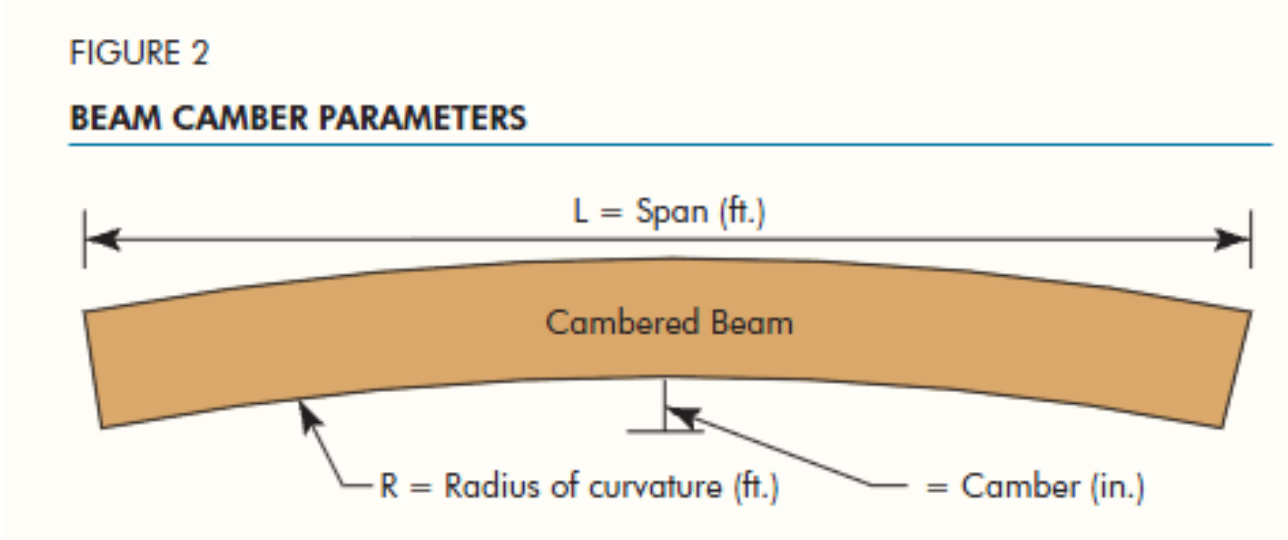


Image: APA Glulam Product Guide

- "Standard" camber for some manufacturers = 3500 or 5000 ft
- Pros of Camber:
  - Offset long-term deflections. Smaller member? Reduce ponding?
- Cons of Camber:
  - Not useful in cantilevers or multi-span conditions
  - Not compatible with some CNC and fabrication details
- Consider:
  - For long-span, single-span beam applications, 40 ft+
  - With compatible support details: bearing connections, knife plates. Not concealed hangers

Fire Rated Glulam

For unbalanced and balanced glulam beams, design team *must* document fire resistance rating requirement as part of glulam specification.

Achieving the FRR impacts the layup of the glulam.

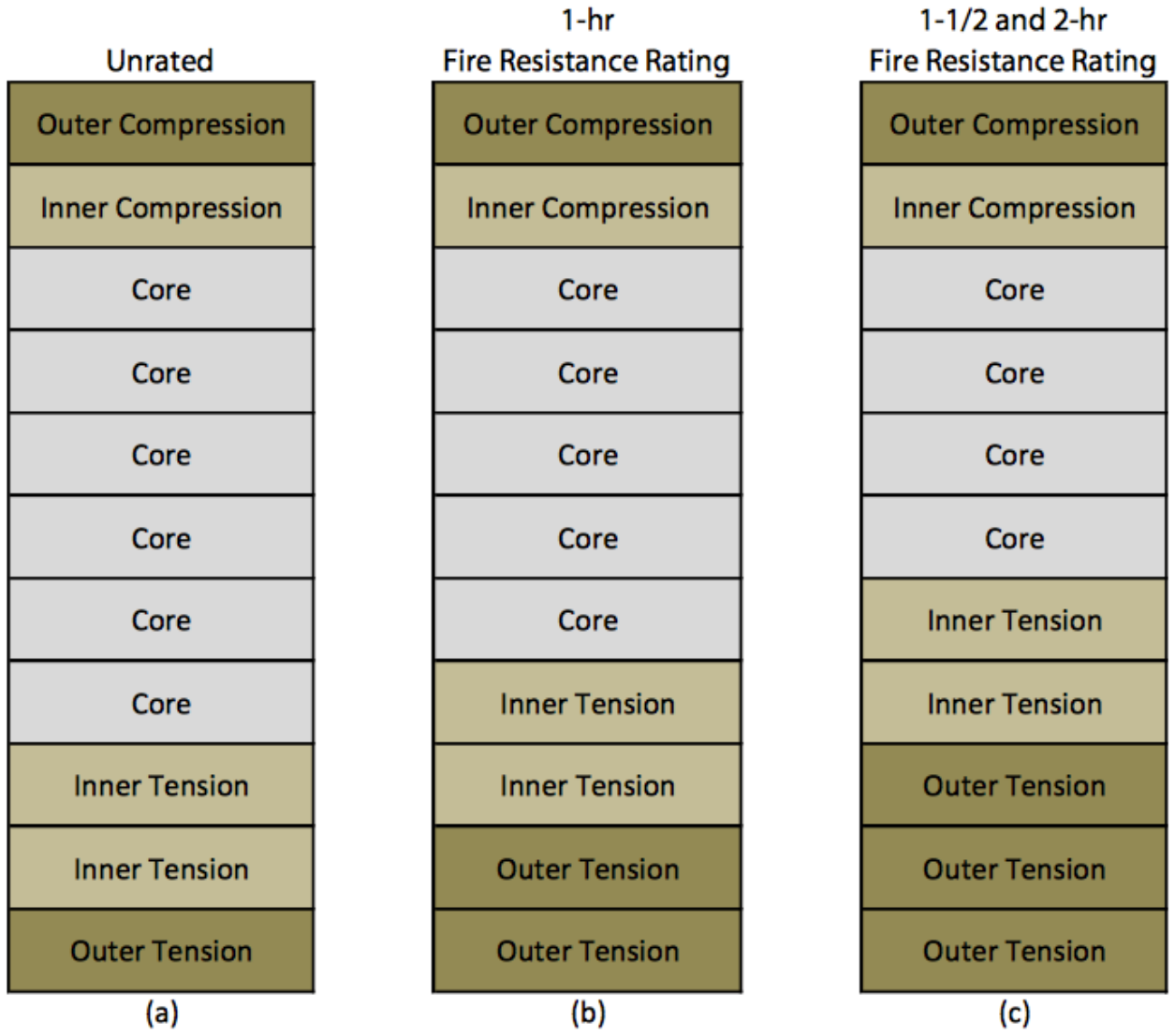


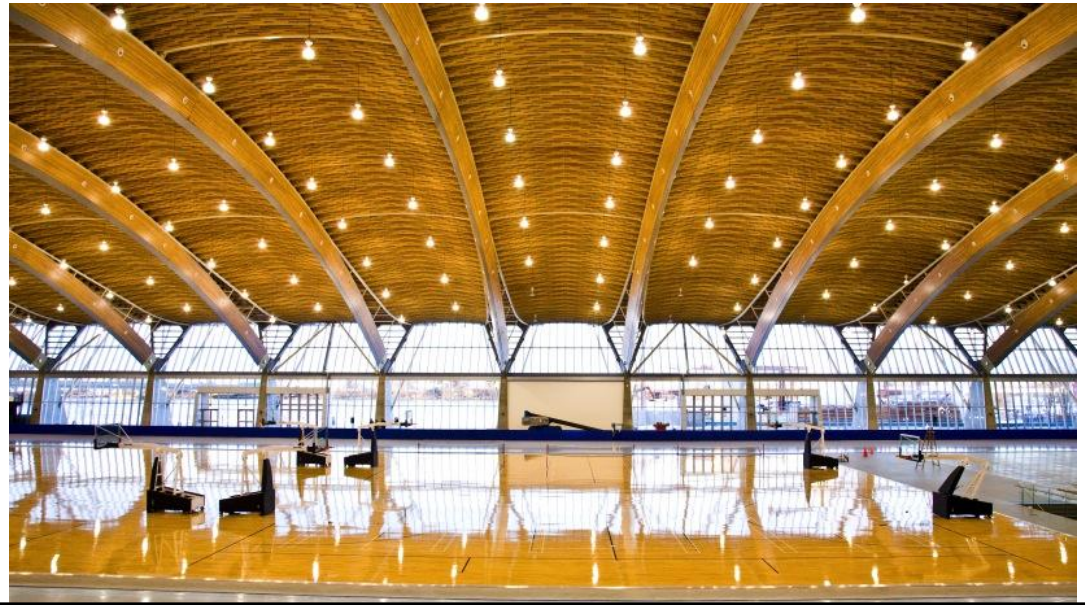
Figure 3-1 Typical glulam unbalanced beam layups

Source: AWC's TR 10

Glulam Options

- For exterior applications:
  - Preservative-treated (PT) available
  - Naturally durable species available: Alaskan yellow cedar, Port Orford cedar
- Can be arched, curved, tapered.. All requiring specialized engineering checks

Karsh Alumni and Visitors Center Duke University / Centerbrook Architects and Planners / LHC Structural Engineers / Photo Peter Aaron



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

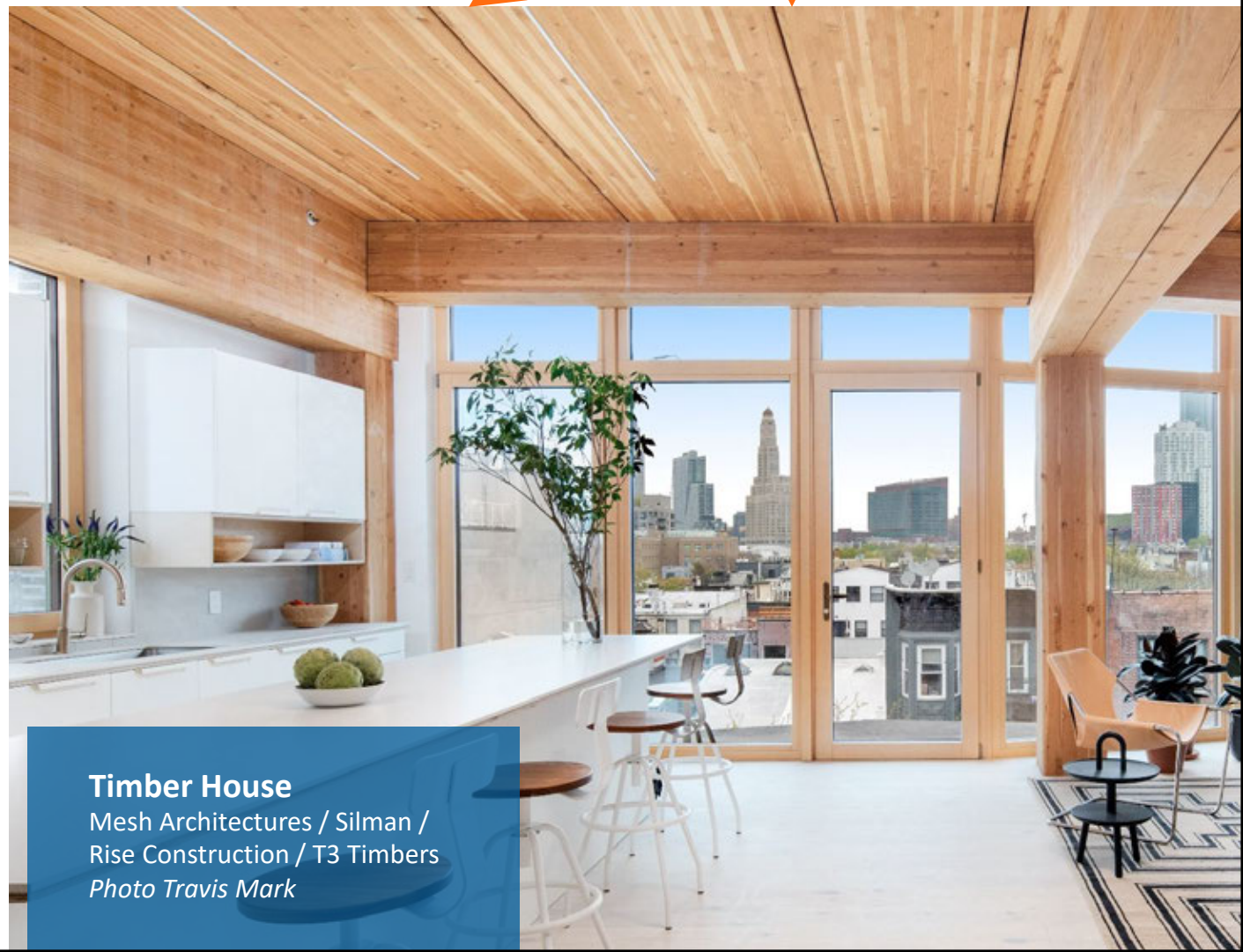
Glue Laminated Timber (GLT) Panels

Photo credit: Structure Fusion

Photo credit: Unalam

GLT (Glue-laminated Timber) Panels

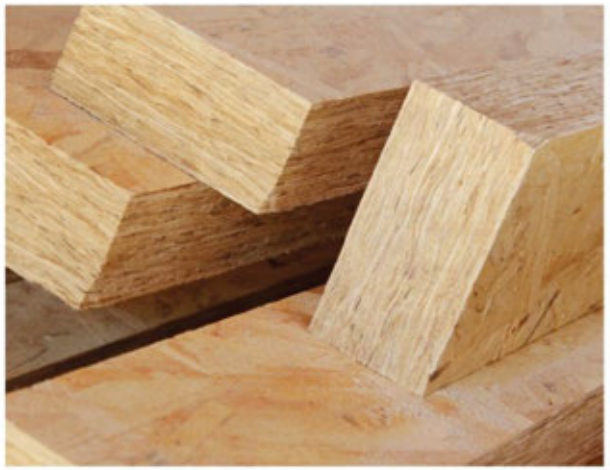
- Structural glulam “on side”
- Same codes and standards as glulam
- While in bending, use uniform layups
- Used as floor or roof deck
- Provide gaps between panels
- 12” to 48” wide, up to 60 ft length.



Structural Composite Lumber (SCL)

Family of engineered wood products made from wood fiber into structural framing.

- Laminated Veneer Lumber (LVL)
- Laminated Strand Lumber (LSL)
- Oriented Strand Lumber (OSL)
- Parallel Strand Lumber (PSL)



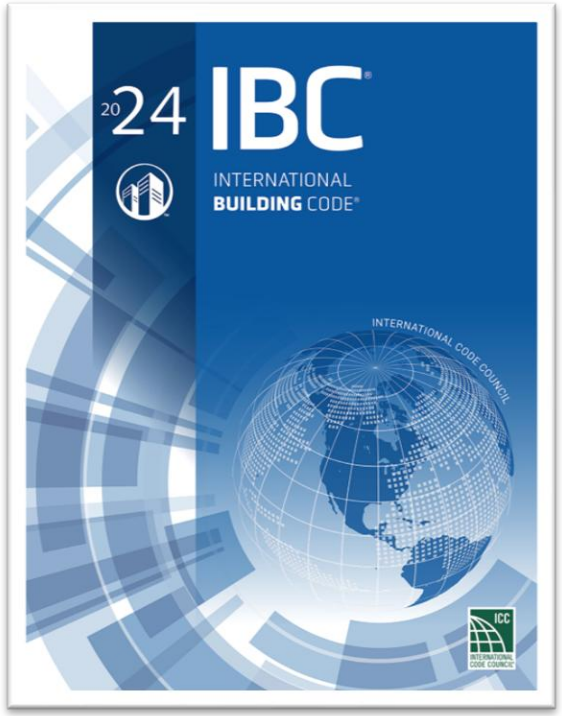
APA

Weyerhaeuser

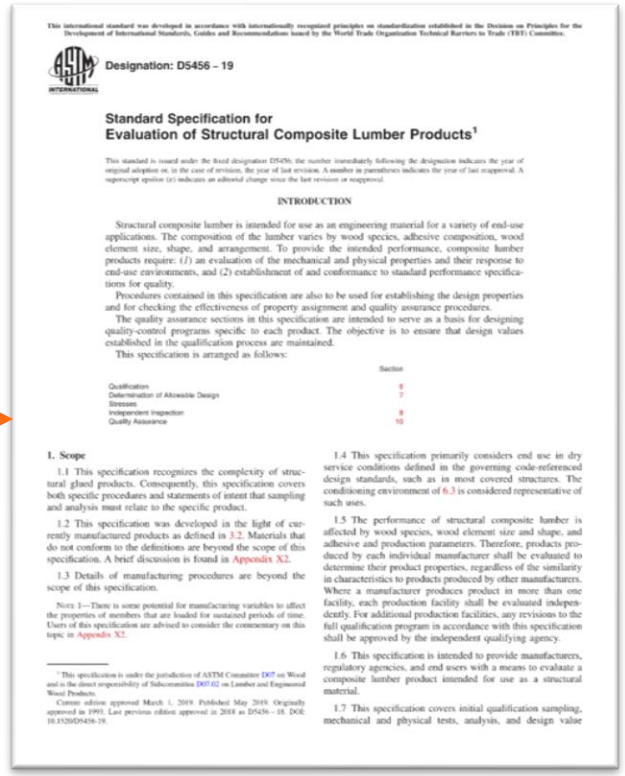
Weyerhaeuser

Structural Composite Lumber

- Recognized in IBC 2303.1.10 per ASTM D5456
- Standard defines how design values determined



International Building Code



Designation: D5456 – 19

Standard Specification for
Evaluation of Structural Composite Lumber Products[1]

INTRODUCTION

Structural composite lumber is intended for use as an engineering material for a variety of end-use applications. The composition of the lumber varies by wood species, adhesive composition, wood element size, shape, and arrangement. To provide the intended performance, composite lumber products require: (1) an evaluation of the mechanical and physical properties and their response to end-use environments, and (2) establishment of and conformance to standard performance specifications for quality.

Procedures contained in this specification are also to be used for establishing the design properties and for checking the effectiveness of property assignment and quality assurance procedures.

The quality assurance sections in this specification are intended to serve as a basis for designing quality-control programs specific to each product. The objective is to ensure that design values established in the qualification process are maintained.

This specification is arranged as follows:

1. Scope

ASTM D5456

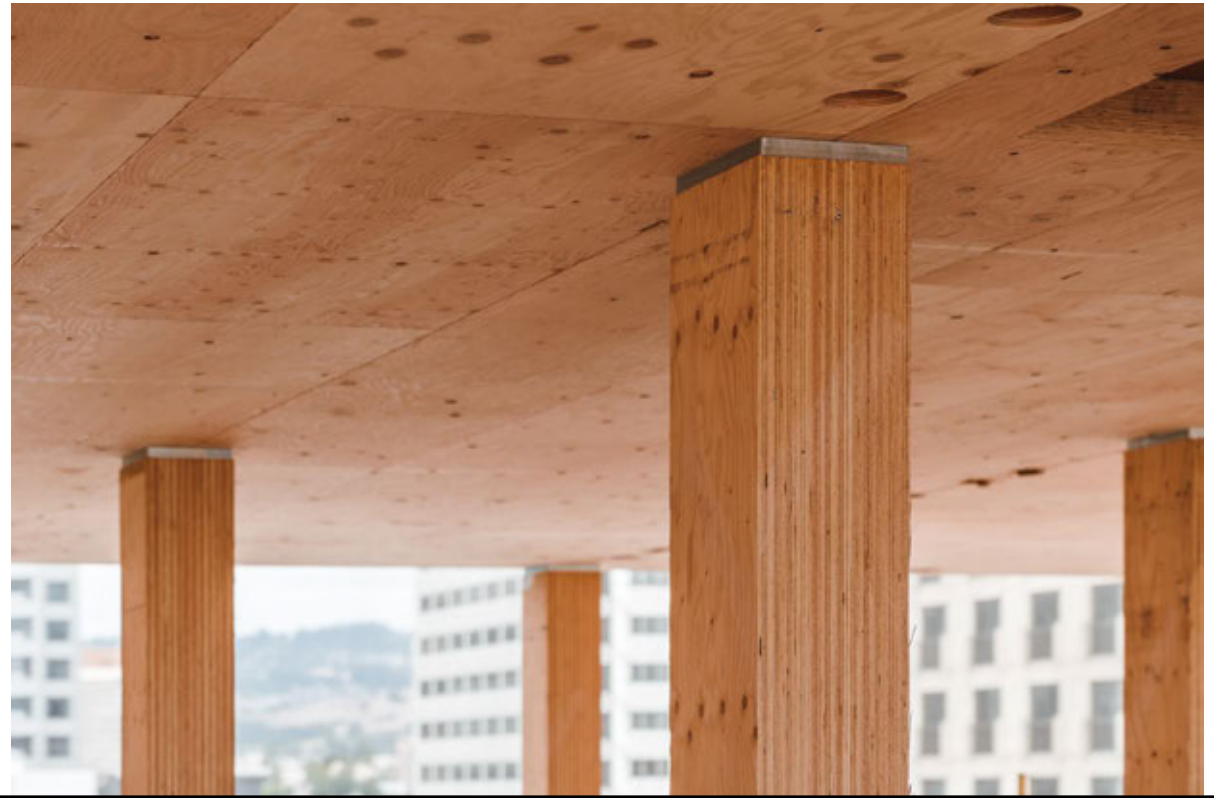
Proprietary
Product Reports

Structural Composite Lumber

Used as beams, columns, tall wall studs, etc.

LVL columns in
16 Story Mass Timber Building

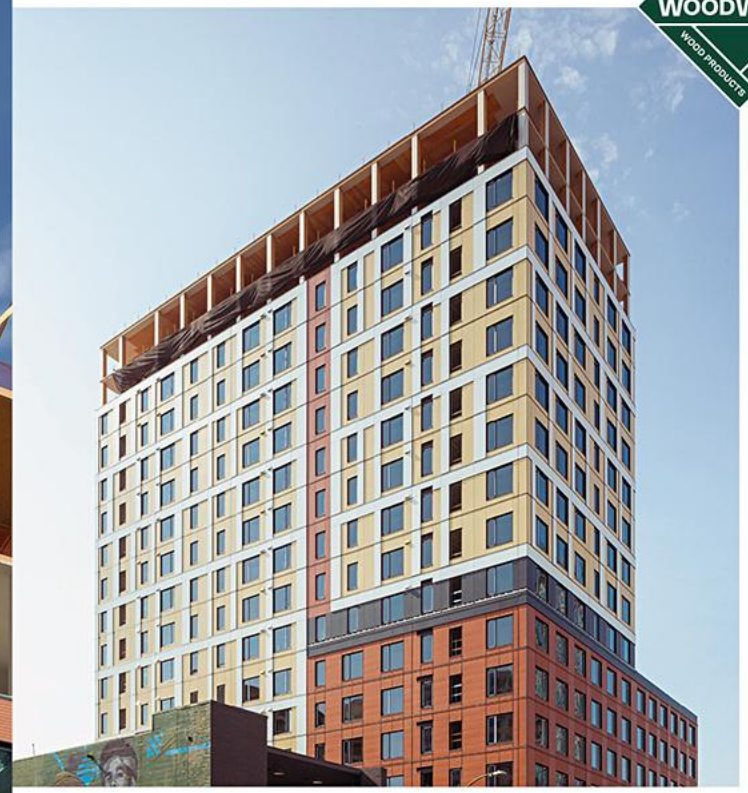
1510 Webster / oWow / DCI Engineers
Photo Flor Projects



https://www.woodworks.org/resources/1510-webster/

CASE STUDY

1510 Webster



16 stories of mass timber change the game for affordable housing

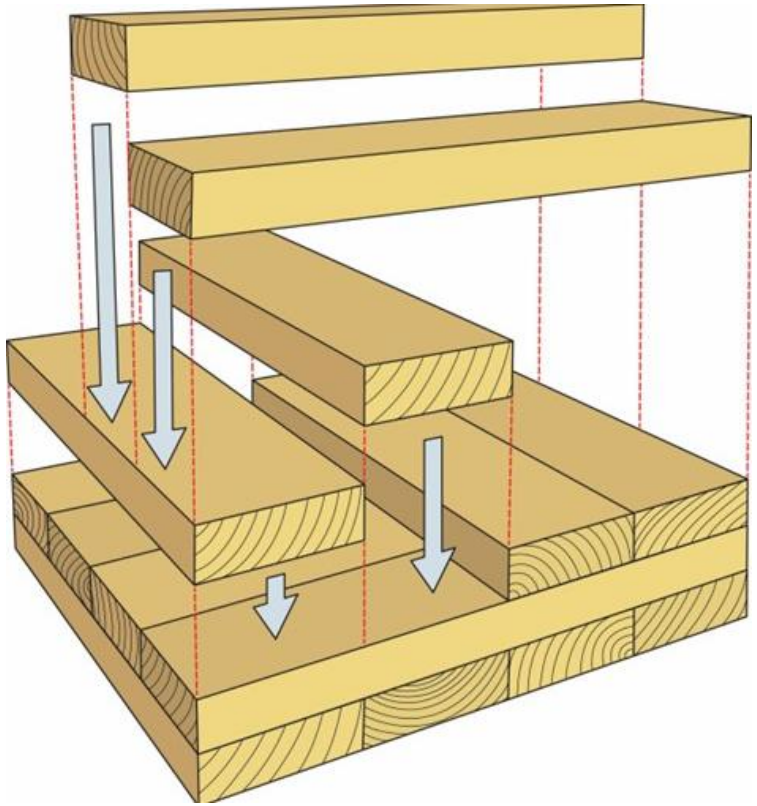
1510 Webster / oWow / DCI Engineers / Photo: Andrew Nelson

CLT

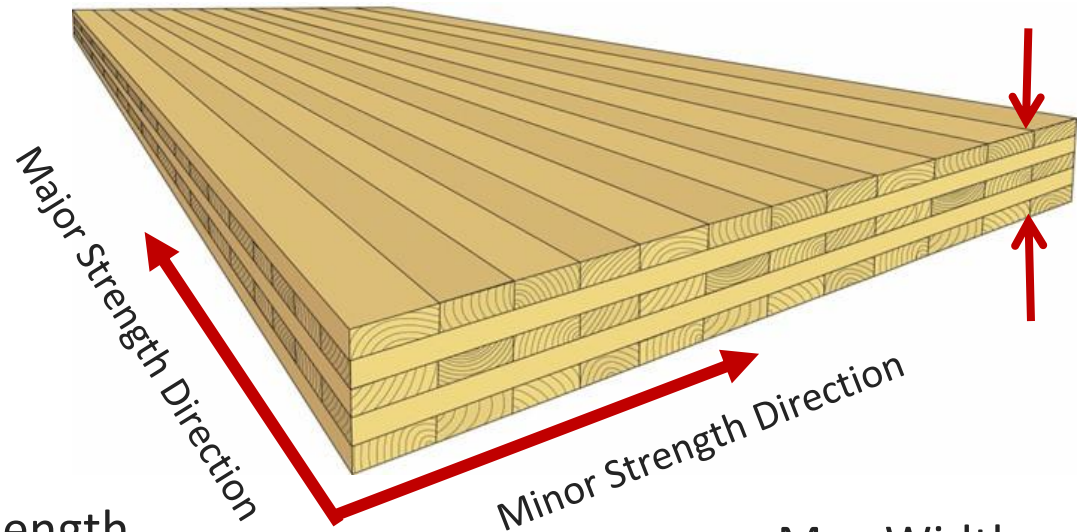
CSU Chico University Services
Dreyfuss + Blackford Architecture,
Buehler, Swinerton
photo Kyle Jeffers

What is Cross-Laminated Timber (CLT)?

3 or more layers (e.g. plies) of laminations (boards)
Alternating Layup
Glued with Structural Adhesives



Thickness
3 to 20 inches*



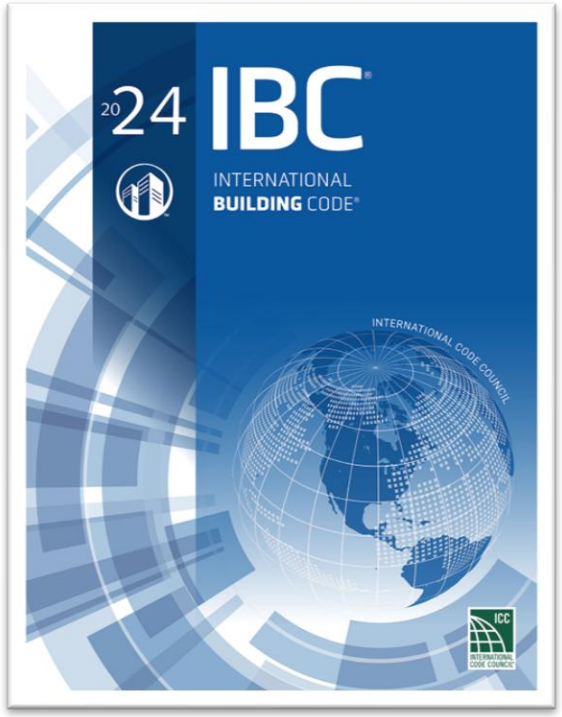
Max Length
16 to 64 feet*

Max Width
4 to 12 feet*

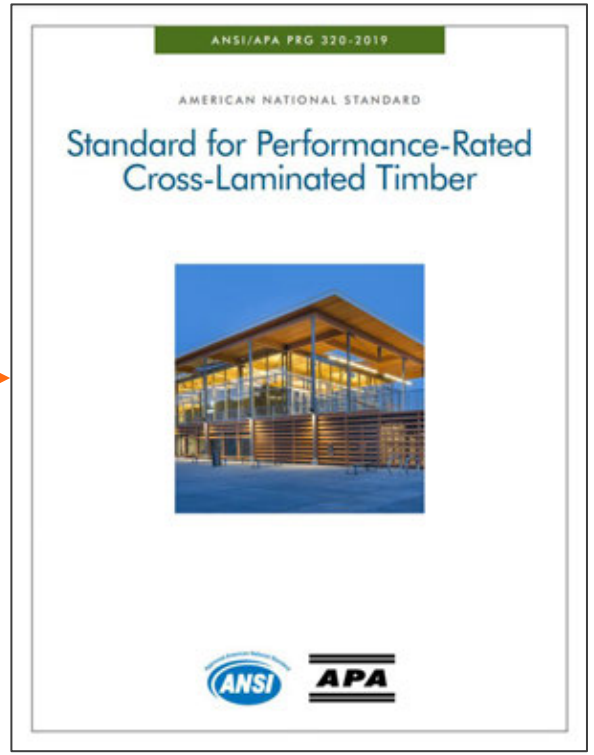
*All dimensions are approximate.
Consult with manufacturers

CLT Code Recognition

- CLT per ANSI/APA PRG 320 recognized in IBC 2303.1.4 since IBC 20215



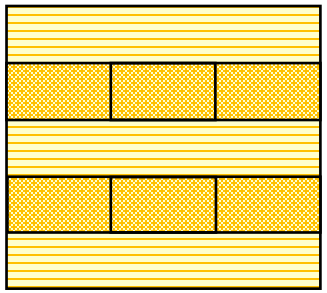
International Building Code



ANSI/APA PRG 320

Product Reports

What are the layers of CLT?



Cross-Laminated Timber
Solid sawn laminations

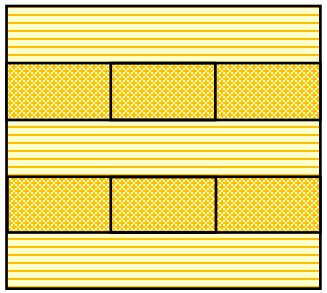
Cross-Laminated Timber
SCL laminations

Photo: Freres Lumber

Photo: LendLease

Photo: LEVER Architecture

What are the layers of CLT?



Cross-Laminated Timber
Solid sawn laminations

Cross-Laminated Timber
SCL laminations

Photo: Freres Lumber

CLT Grade

=

Material

CLT Layup

=

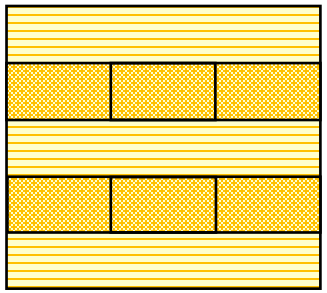
Arrangement

CLT Grade

=

Material

What are the layers of CLT?



Cross-Laminated Timber
Solid sawn laminations

Visually graded lumber, such as:

Doug-Fir Larch
Southern (Yellow) Pine
Spruce Pine Fir
Spruce Pine Fir (South)
Hem Fir

Machine graded lumber

In North America, 1 3/8” layers most common, and efficient

Cross-Laminated Timber
SCL laminations

Photo: Freres Lumber

Structural Composite Lumber

LVL, LSL, OSL, PSL all possible

To date, 1” LVL used

CLT Grade = Structural Material in the Panel

Basic grades (e.g. Examples) of solid sawn lumber in PRG 320-2019 standard

CLT Grade	Major Strength Direction	Minor Strength Direction
E1	1950f-1.7E MSR SPF	#3 Spruce Pine Fir
E2	1650f-1.5E MSR DFL	#3 Doug Fir Larch
E3	1200f-1.2E MSR Misc	#3 Misc
E4	1950f-1.7E MSR SP	#3 Southern Pine
E5	1650f-1.5E MSR Hem-Fir	#3 Hem-Fir
V1	#2 Doug Fir Larch	#3 Doug Fir Larch
V1(N)	#2 Doug-Fir Larch (North)	#3 Doug-Fir Larch (North)
V2	#1/#2 Spruce Pine Fir	#3 Spruce Pine Fir
V3	#2 Southern Pine	#3 Southern Pine
V4	#2 Spruce Pine Fir (South)	#3 Spruce Pine Fir (South)
V5	#2 Hem-Fir	#3 Hem-Fir

"E" grades from machine graded lumber

"V" grades from visually graded lumber

CLT Grade = Structural Material in the Panel

Custom grades by manufacturer are very common

Table 1. ASD Reference Design Values[a] for Lumber Laminations Used in SmartLam CLT (for Use in the U.S.)

	Laminations Used in Major Strength Direction								Laminations Used in Minor Strength Direction									
	Grade & Species	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	$F_{c\perp}$ (psi)	G	Grade & Species	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	$F_{c\perp}$ (psi)	G
V2M5	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42

Table 2. LSD Reference Design Values[a] for Lumber Laminations Used in Mercer CLT

CLT Grade	Strength Class	Species	Laminations used in Major Strength Direction						Laminations used in Minor Strength Direction						F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	$F_{c\perp}$ (psi)	G
			$F_{b,0}$ (MPa)	E (MPa)	$F_{t,0}$ (MPa)	$F_{c,0}$ (MPa)	$F_{v,0}$ (MPa)	$F_{s,0}$ (MPa)	$F_{b,90}$ (MPa)	E (MPa)	$F_{t,90}$ (MPa)	$F_{c,90}$ (MPa)	$F_{v,90}$ (MPa)	$F_{s,90}$ (MPa)						
1.4V	875[b]	SPF	11.8	9,500	5.5	11.5	1.5	0.50	7.0	9,000	3.2	9.0	1.5	0.50	200	575	135	45	335	0.36
		DF-L													200	575	135	45	335	0.36
1.8M	2100[c]	SPF	30.4	12,400	17.7	19.9	1.5	0.50	7.0	9,000	3.2	9.0	1.5	0.50	250	650	135	45	425	0.42
		DF-L													575	1,350	180	60	625	0.50
															550	1,100	125	40	455	0.43
															250	650	135	45	425	0.42
															450	1,150	135	45	425	0.42
																			565	0.55
																			335	0.36
																			405	0.43
																			405	0.43
																			455	0.43
																			405	0.42
																			405	0.42

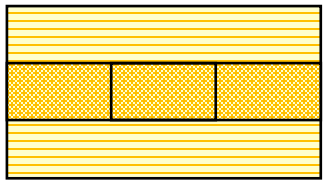
Table 1. ASD Reference Design Values[a] for Lumber Laminations Used in Element5 CLT (for Use in the U.S.)

CLT Grade	Laminations Used in Major Strength Direction									Laminations Used in Minor Strength Direction								
	Grade & Species	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	$F_{c\perp}$ (psi)	G	Grade & Species	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	$F_{c\perp}$ (psi)	G
E1M10 & E1M10.1	2100f-1.8E SPF	2,100	1.8	1,575	1,875	160	50	525	0.46	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42
E1M12, E1M12.1, & E1M12.2	1650f-1.5E SPF	1,650	1.5	1,020	1,700	135	45	425	0.42	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42
V2M7, V2M7.1, & V2M7.2	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42	No. 1/No. 2 SPF	875	1.4	450	1,150	135	45	425	0.42

CLT Layup = How are the layers arranged?

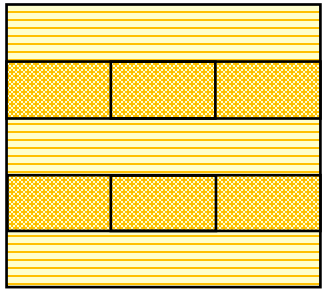
Most Suppliers
Most Designs
Least $/sf

3-ply

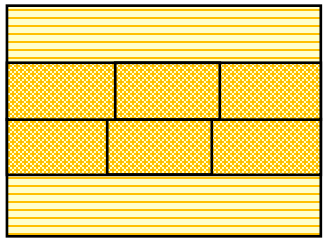


(3) 1 3/8”
= 4 1/8”

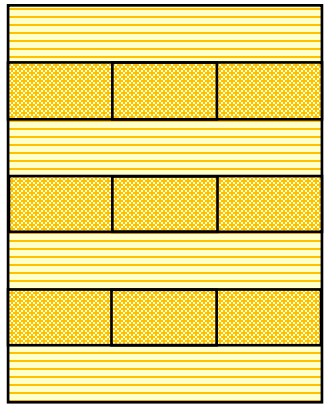
5-ply



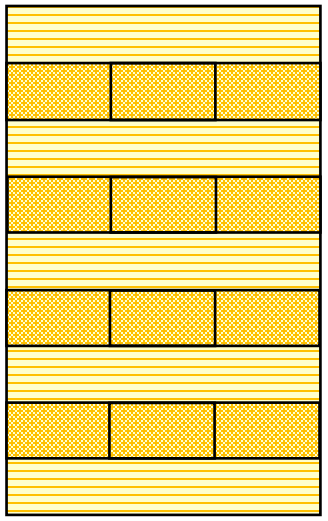
(5) 1 3/8”
= 6 7/8”



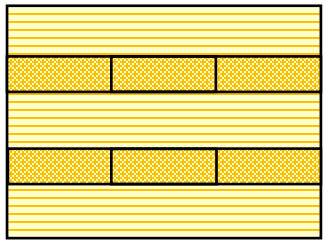
Adjacent layers in same direction



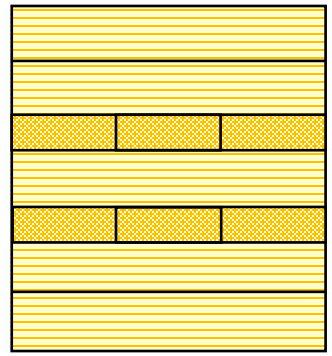
7-ply



9-ply



Non-uniform thickness



Combinations

Structural Grades vs Appearance?

How does the selection of a CLT grade impact visual appearance of final product?

"E" grades from machine graded lumber

"V" grades from visually graded lumber

CLT Grade	Major Strength Direction	Minor Strength Direction
E1	1950f-1.7E MSR SPF	#3 Spruce Pine Fir
E2	1650f-1.5E MSR DFL	#3 Doug Fir Larch
E3	1200f-1.2E MSR Misc	#3 Misc
E4	1950f-1.7E MSR SP	#3 Southern Pine
E5	1650f-1.5E MSR Hem-Fir	#3 Hem-Fir
V1	#2 Doug Fir Larch	#3 Doug Fir Larch
V1(N)	#2 Doug-Fir Larch (North)	#3 Doug-Fir Larch (North)
V2	#1/#2 Spruce Pine Fir	#3 Spruce Pine Fir
V3	#2 Southern Pine	#3 Southern Pine
V4	#2 Spruce Pine Fir (South)	#3 Spruce Pine Fir (South)
V5	#2 Hem-Fir	#3 Hem-Fir

V Grades of CLT ARE NOT visually better than E grades of CLT

Impacts on Final Aesthetic of CLT

Lumber is a natural product with variations and character

Courtesy SMARTLAM

What can impact final look?

- Species or Species Group (DFL, SPF, HF, SP)
- Structural Grade (Select Structural, #1, #2, etc)
- Manufacturers process to control natural variation
- Construction process: moisture management & remedies
- Applied stains and finishes

Impacts on Final Aesthetic of CLT

Lumber is a natural product with variations and character

Courtesy SMARTLAM

What can impact final look?

- **Species or Species Group (DFL, SPF, HF, SP)**
- **Structural Grade (Select Structural, #1, #2, etc)**

CLT Grade

- Manufacturers process to control natural variation
- Construction process: moisture management & remedies
- Applied stains and finishes

Impacts on Final Aesthetic of CLT

Lumber is a natural product with variations and character

Courtesy SMARTLAM

What can impact final look?

- Species or Species Group (DFL, SPF, HF, SP)
- Structural Grade (Select Structural, #1, #2, etc)
- **Manufacturers process to control natural variation**
- Construction process: moisture management & remedies
- Applied stains and finishes

Appearance Classification

PRG 320 defines example CLT Appearance Classifications

Architectural Appearance – where appearance is important but not overriding consideration

Architectural Douglas Fir

Industrial Appearance – for use in applications where appearance is not a primary concern

Industrial Southern Pine

Consult with manufacturers for options available and cost impacts

Photos courtesy SMARTLAM

CLT Applications

- Floor and roof panels
- Wall panels
- *For dry use application only*
  - Interior or protected in final construction

Candlewood Suites at Redstone Arsenal
Lendlease / Schaefer Structural Engineers
Photo Lendlease

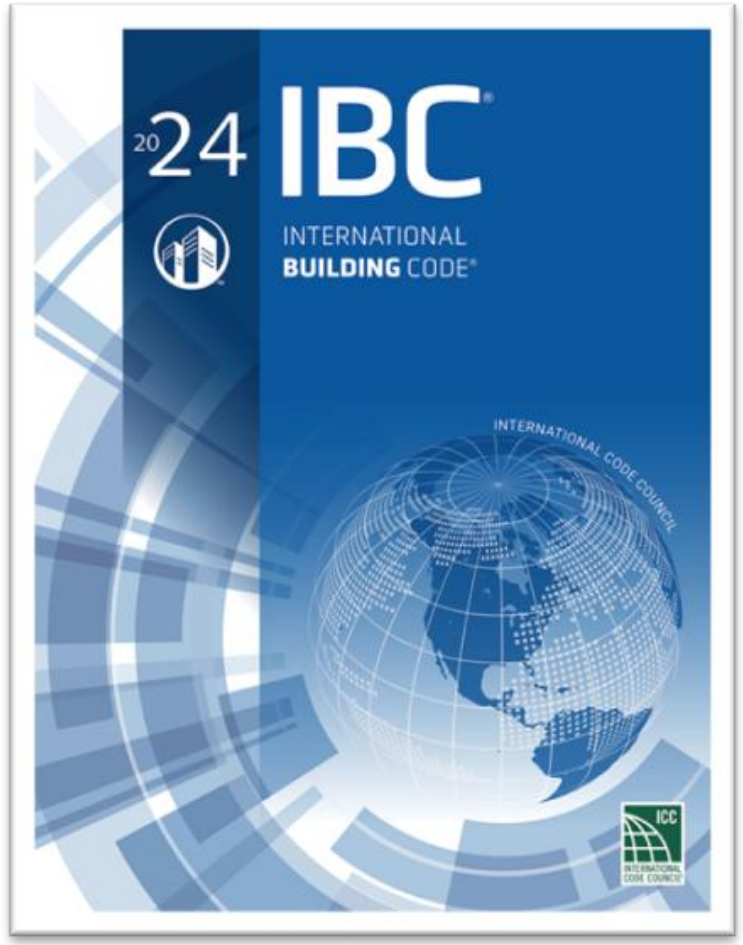
NLT (Nail-Laminated Timber)

Sarah Campbell Blaffer Foundation Center for Conservation at the Museum of Fine Arts
Lake|Flato Architects / Kendall/Heaton Architects (AOR) / Cardno Haynes Whaley / WS Bellows
Photo Peter Molick

Nail Laminated Timber (NLT)

- “2-by” lumber, installed at 1.5” on center
- Can use finger-jointed lumber to create panels longer than typical lumber
- IBC has “mechanically laminated decking” in IBC 2304.9.3 which is lumber on edge. Prescriptive nailing patterns between boards and to supports.

Photo Think Wood



Nail Laminated Timber (NLT) Panels

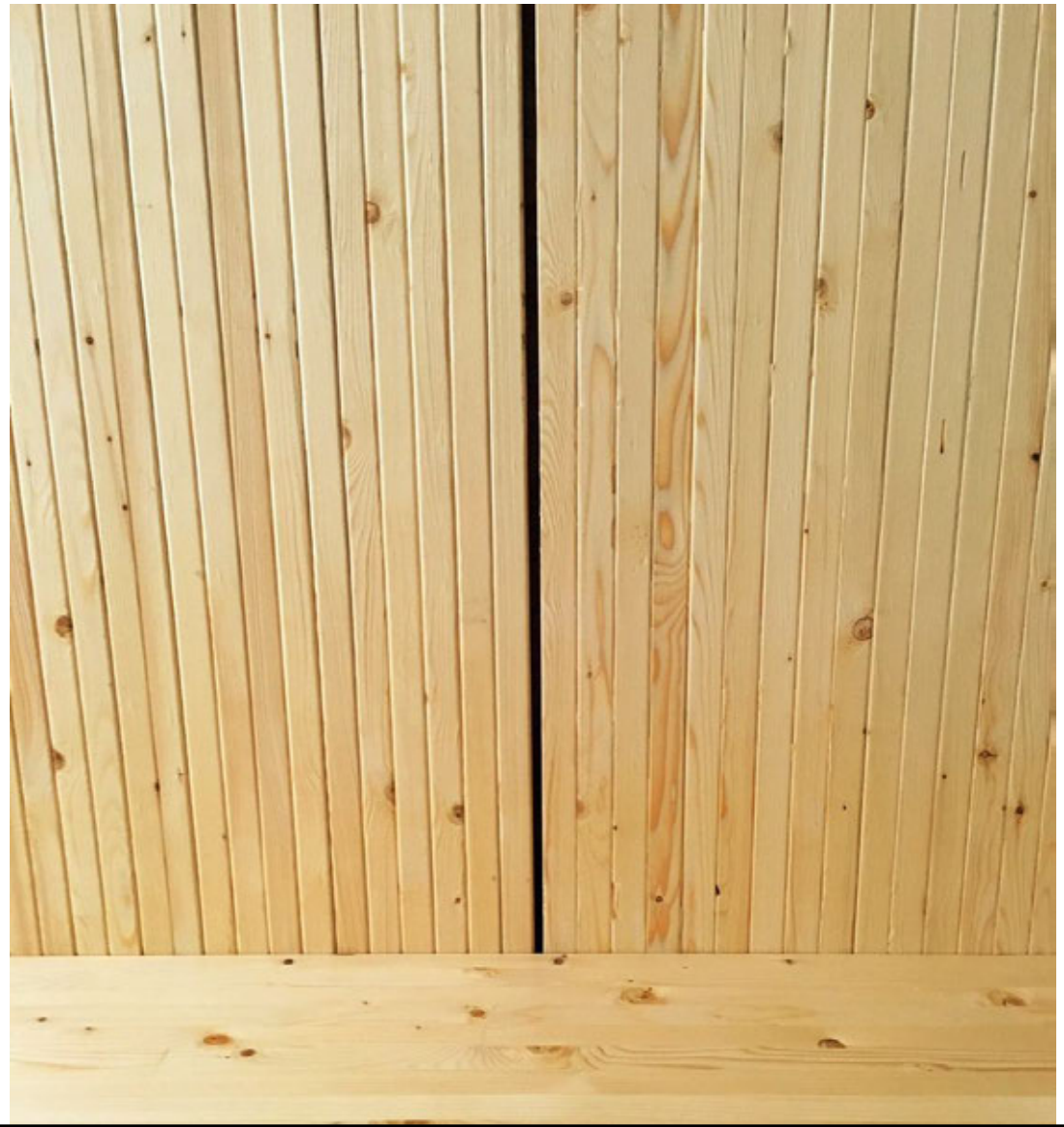
Construction options:

- On-site/ in-place

- Prefabricated offsite

Nail Laminated Timber (NLT) Panels

- Leave gaps between panels for perp-to-grain expansion for when it gets wet.



DLT (Dowel-Laminated Timber)

Photo: StructureCraft

The Soto
Hixon Properties / Lake|Flato Architects / BOKA Powell / StructureCraft / Danysh & Associates / Byrne Construction
Photo WoodWorks

Dowel-Laminated Timber (DLT) Panels

- Like NLT, but with larger wood dowels installed into drilled holes.
- 100% wood
- Supplied as fabricated panels
- Not directly recognized by the IBC.
  - Proprietary with ICC-ES report available.

Photo: StructureCraft

ICC EVALUATION SERVICE®

ICC-ES Evaluation Report

ESR-4069

Reissued January 2025

Subject to renewal November 2025

This report also contains:

- City of Chicago Supplement
- City of LA Supplement
- CA Supplement
- FL Supplement

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DIVISION: 06 00 00 — WOOD, PLASTICS AND COMPOSITES Section: 06 17 21— Dowel-Laminated Timber	REPORT HOLDER: STRUCTURECRAFT BUILDERS INC.	EVALUATION SUBJECT: DOWEL-LAMINATED TIMBER (DLT)	

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2018, 2015, 2012, and 2009 *International Building Code®* (IBC)
- 2018, 2015, 2012, and 2009 *International Residential Code®* (IRC)

Properties evaluated:

- Structural
- Fire Resistance

2.0 USES

StructureCraft DowelLam™ Dowel-Laminated Timber (DLT) is a mechanically laminated timber panel, pegged together by hardwood dowels, for use as floor and roof deck panels in Types III, IV (Heavy Timber) and V Construction, and in Types I and II Construction where permitted by IBC Section 603 and elsewhere in the code. StructureCraft DowelLam™ Dowel-Laminated Timber may also be used in structures regulated under the IRC when an engineered design is submitted in accordance with IRC Section R301.1.3.

3.0 DESCRIPTION

3.1 General:

StructureCraft Dowel-Laminated Timber panels described in this evaluation report consist of planed and finger-jointed sawn lumber laminations, set on edge and mechanically fastened together by inserting $^{3}/_{4}$-inch diameter profiled hardwood dowels running perpendicular to the wide faces of the laminations. The dowels are inserted into predrilled holes $^{1}/_{32}$ inch less than the $^{3}/_{4}$-inch dowel diameter to secure a tight fit. The moisture content of the lumber at the time of manufacture does not exceed 19 percent, and the dowels are dried to 5 to 8 percent moisture content prior to insertion. Once inserted, the dowels swell as they come into equilibrium with the higher moisture content of the surrounding lumber, providing additional friction for a tight fit of the dowel in the laminations.

The StructureCraft Dowel-Laminated Timber panels are available in thicknesses of 4 inches nominal (89 mm) to 12 inches nominal (286 mm), widths of 12 inches (305 mm) to 14 feet (4.3 m) and lengths up to 60.7 feet (18.5 m).

Dowel Laminated Timber Profile Options

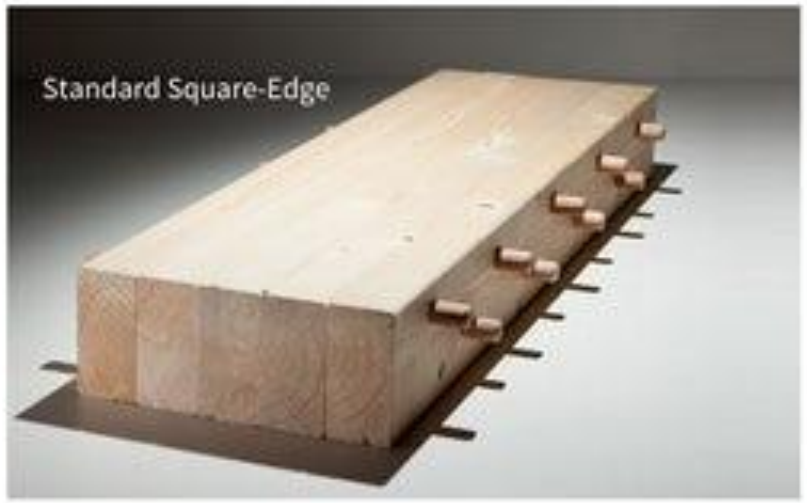


Photo credit: StructureCraft

Structural Design

Framing

- Lumber
- Structural Glue Laminated Timber/ Glulam
- Structural Composite Lumber / SCL

Cross Laminated Timber
CLT

Nail Laminated Timber
NLT

Glue Laminated Timber
GLT

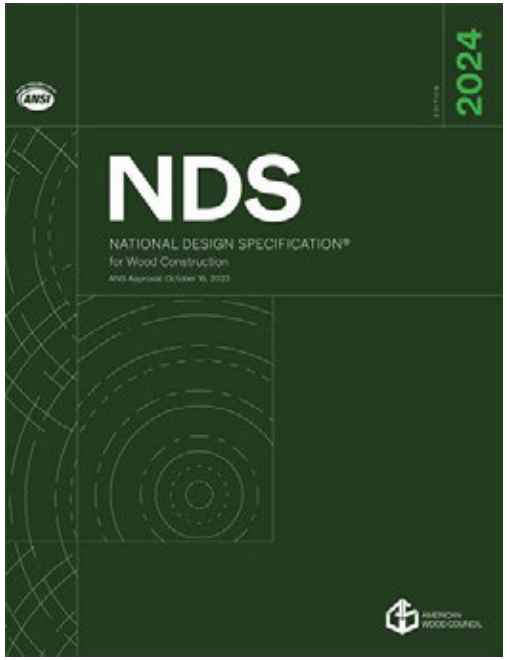
Boise Cascade

Weyerhaeuser

Panels

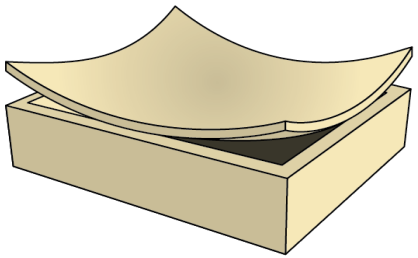
- Glue-Laminated Timber / GLT
- Cross-Laminated Timber / CLT
- Nail-Laminated Timber / NLT
- Dowel-Laminated Timber / DLT

Structural design of all these follow AWC's National Design Specification for Wood Construction (NDS)

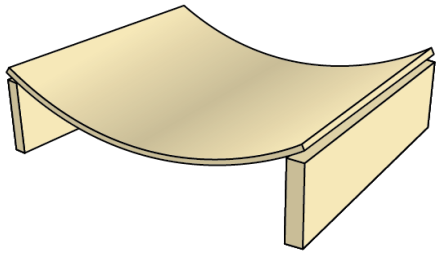


Comparison of MT Panel Types

CLT has strength in both "out-of-plane" directions

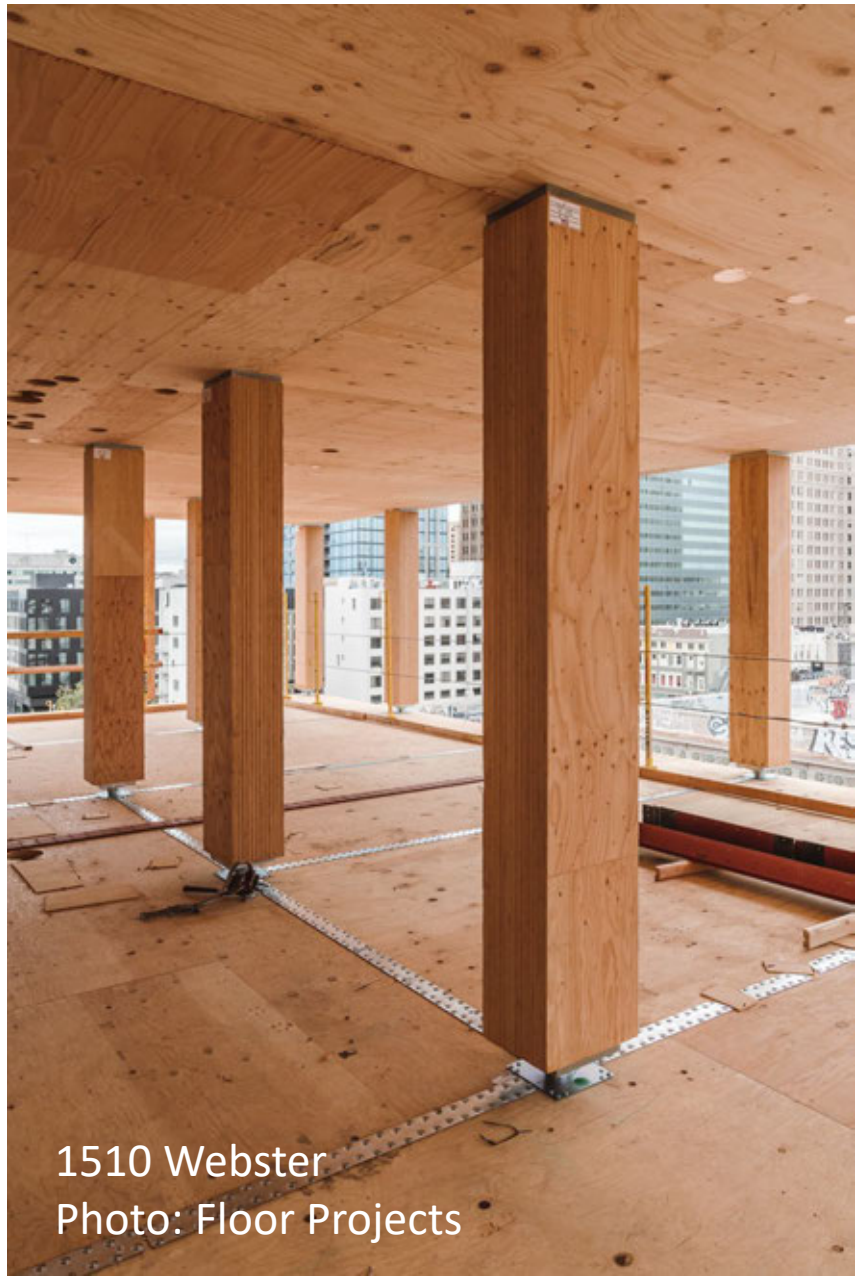


GLT, NLT, and DLT have strength in one "out-of-plane" direction



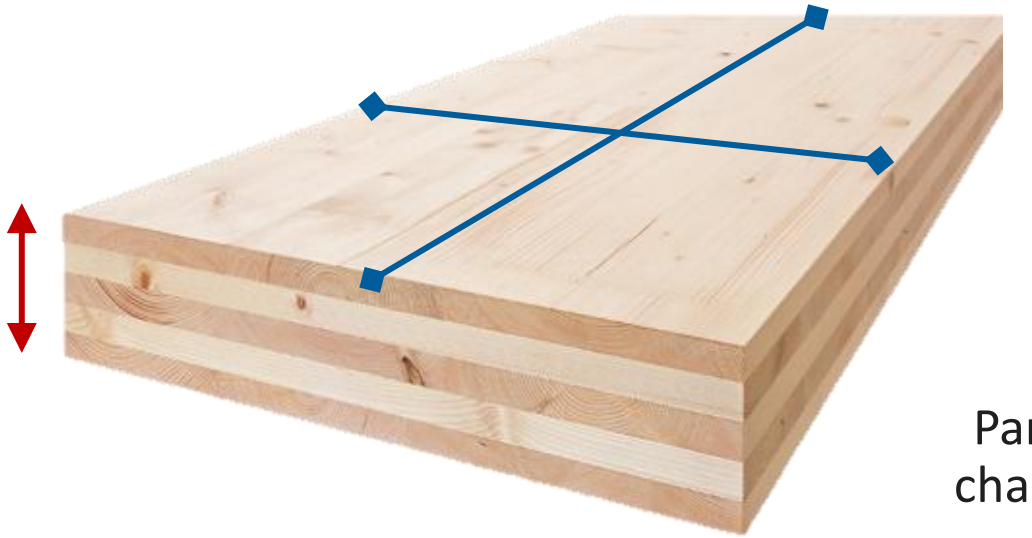
Two-Way Spanning of CLT

Mines Park Housing
Photo: WoodWorks

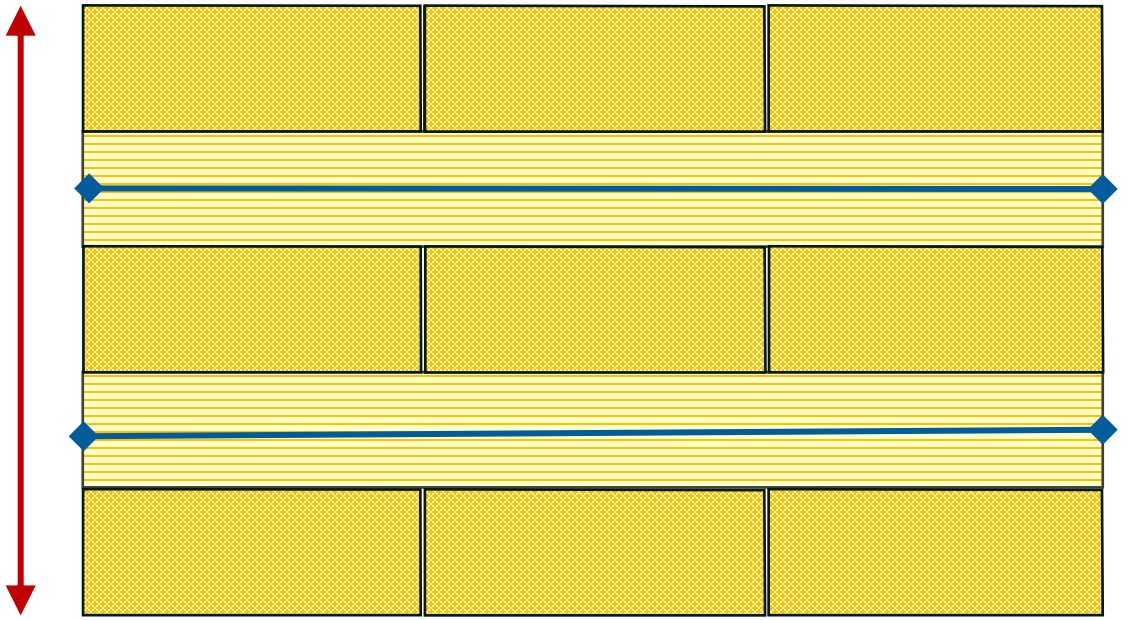


1510 Webster
Photo: Floor Projects

Impact of Moisture Content Changes on CLT

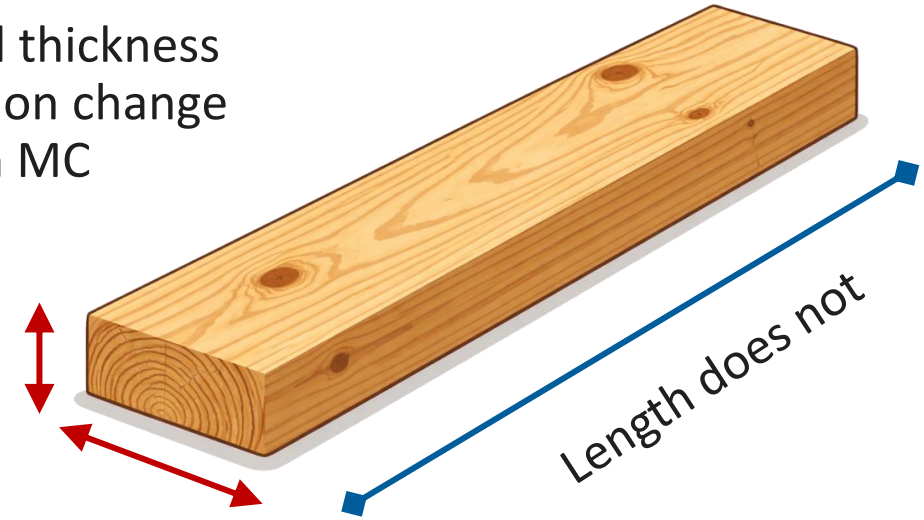


Panel thickness changes with MC

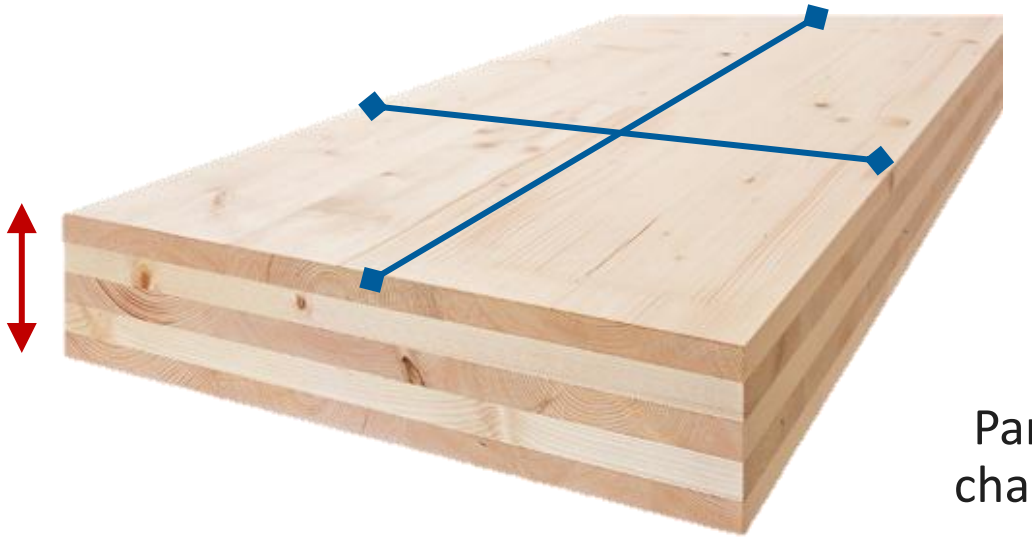


Panel length & width do not (much)

Width and thickness of lamination change with MC

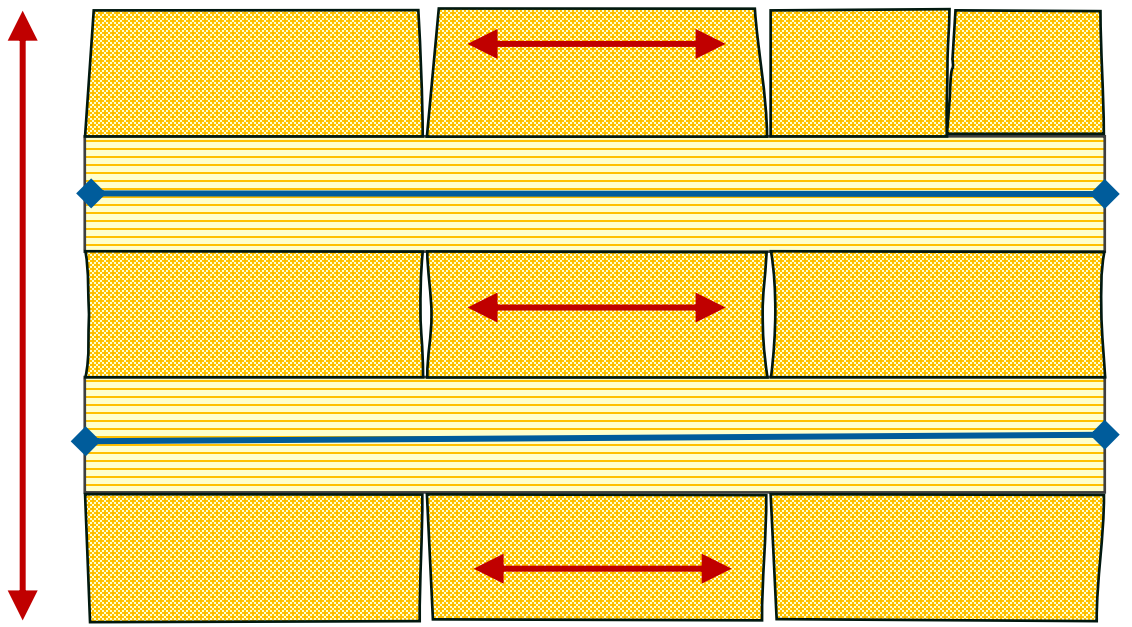


Impact of Moisture Content Changes on CLT



Panel thickness changes with MC

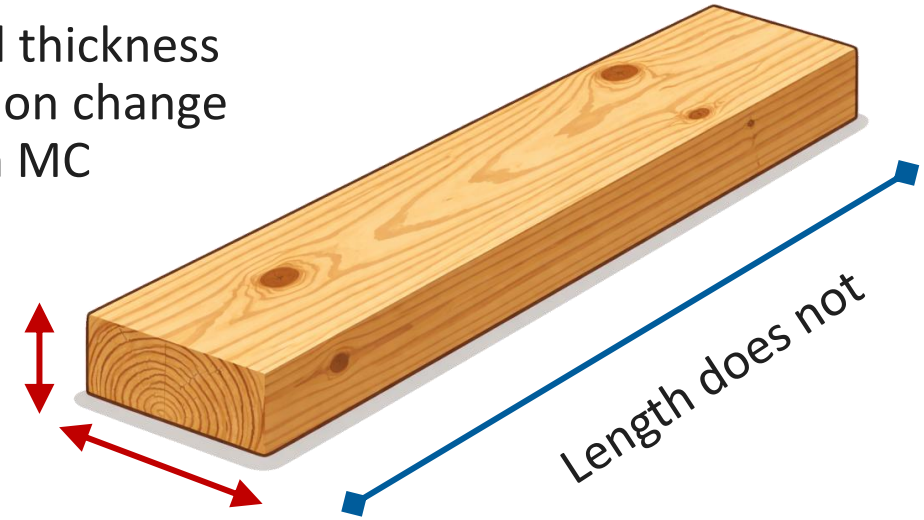
Increase in gaps between laminations or surface checking



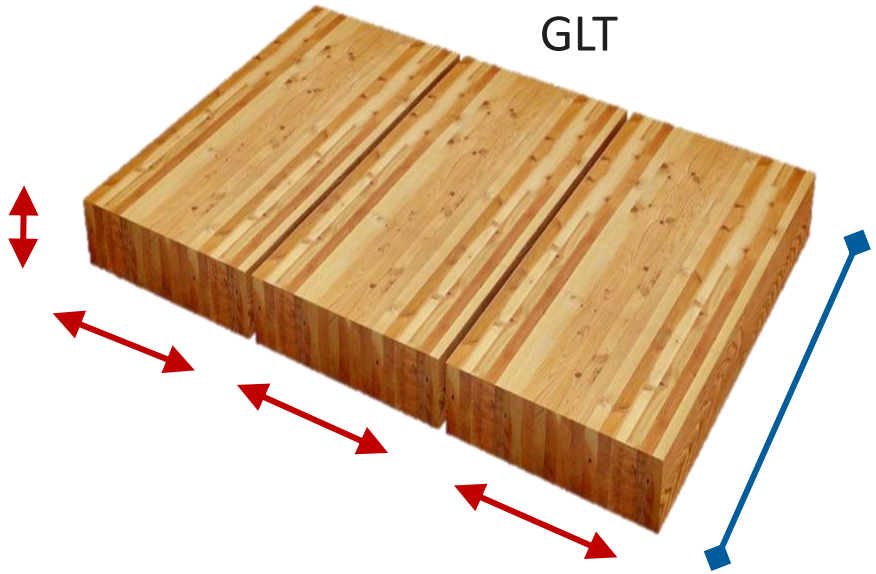
Panel length & width do not (much)

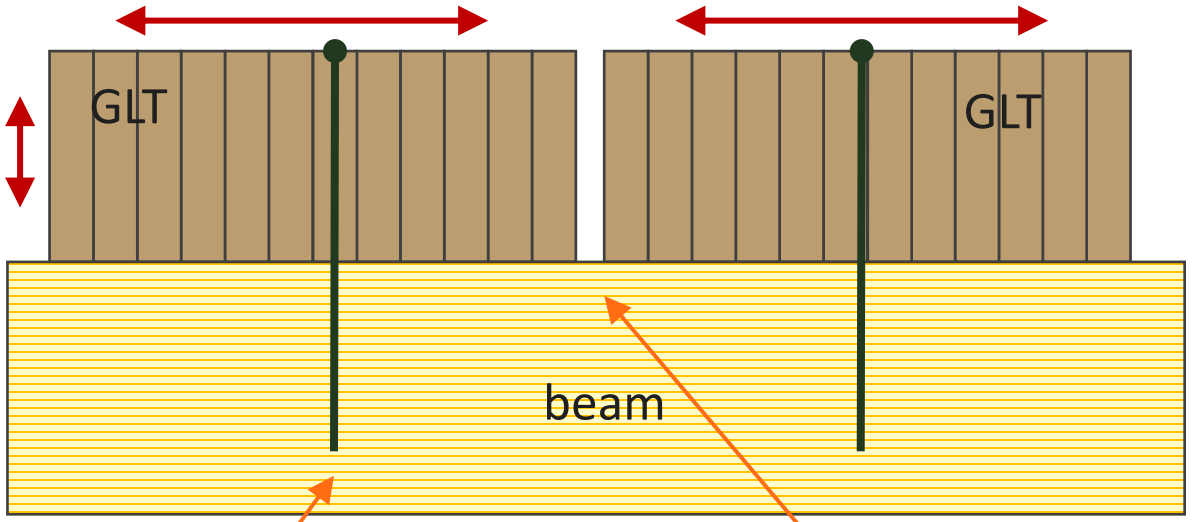
12% to 8% MC -> ~1/8” or less per foot

Width and thickness of lamination change with MC

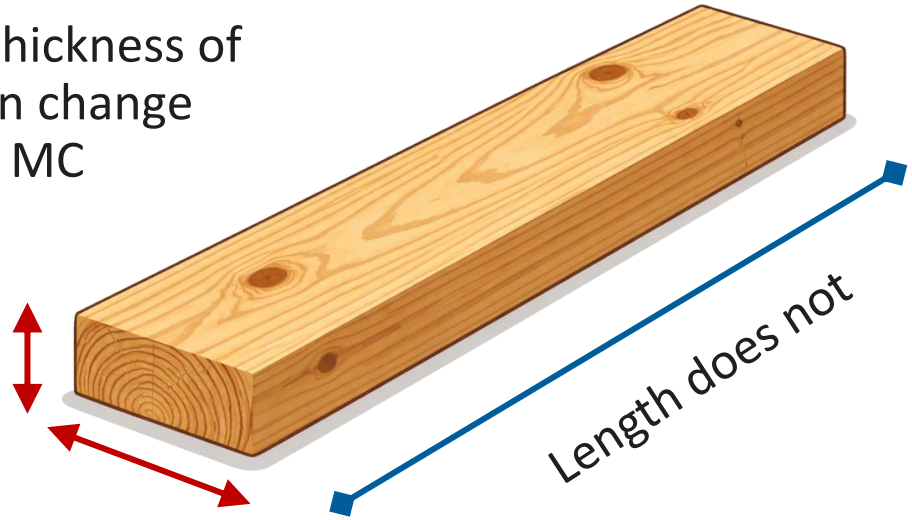


Impact of Moisture Content Changes on GLT





Width and thickness of lamination change with MC



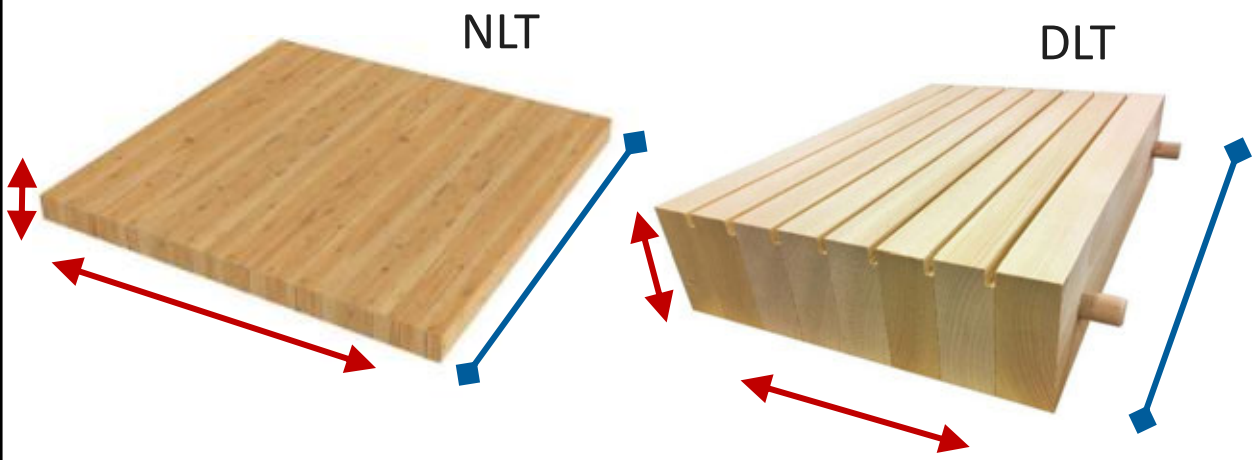
Connect down near the middle of GLT

Provide gaps sized in-case it gets wet.

Wider panel, bigger gap

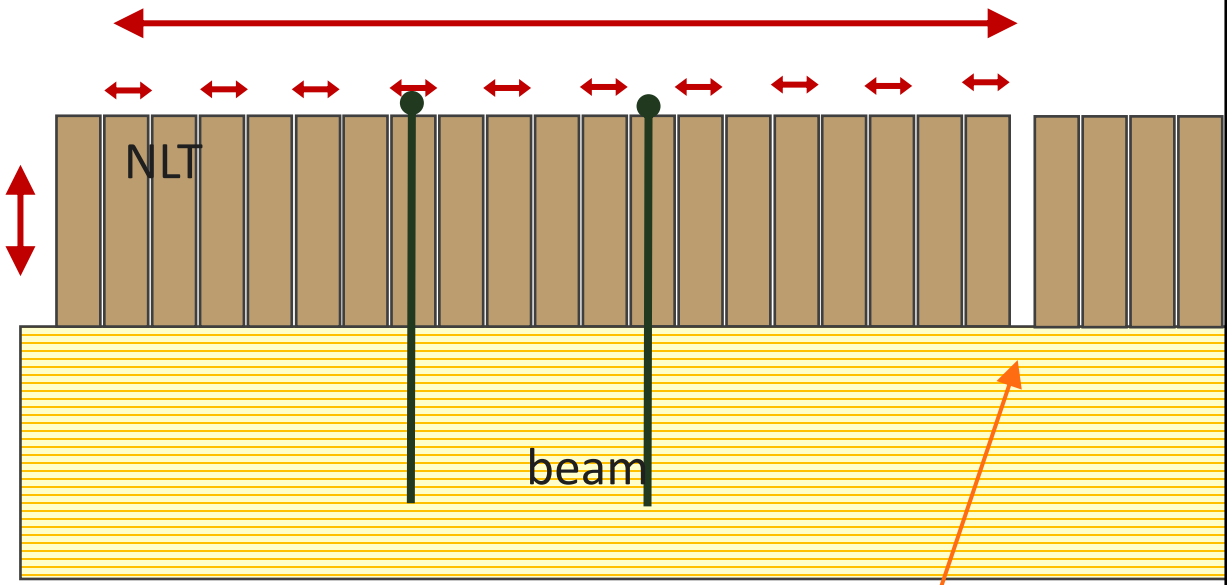
Normal shrinkage and swelling calcs apply

Impact of Moisture Content Changes on NLT/DLT

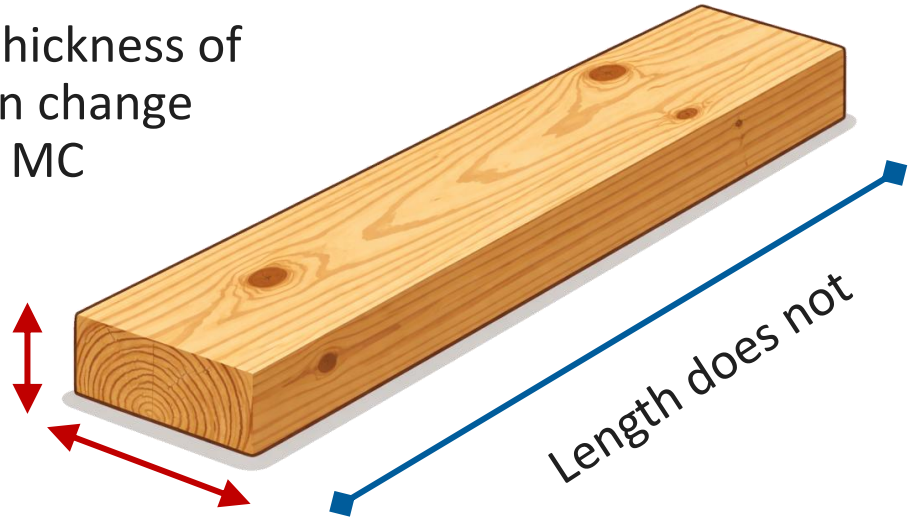


NLT & DLT <u>not</u> pressed tight and glued.

Room for some local swelling and shrinkage between boards



Width and thickness of lamination change with MC



Consult with manufacturer for shrinkage calcs

Provide gaps sized in-case it gets wet.

Wider panel, bigger gap

Comparison of MT Panel Types

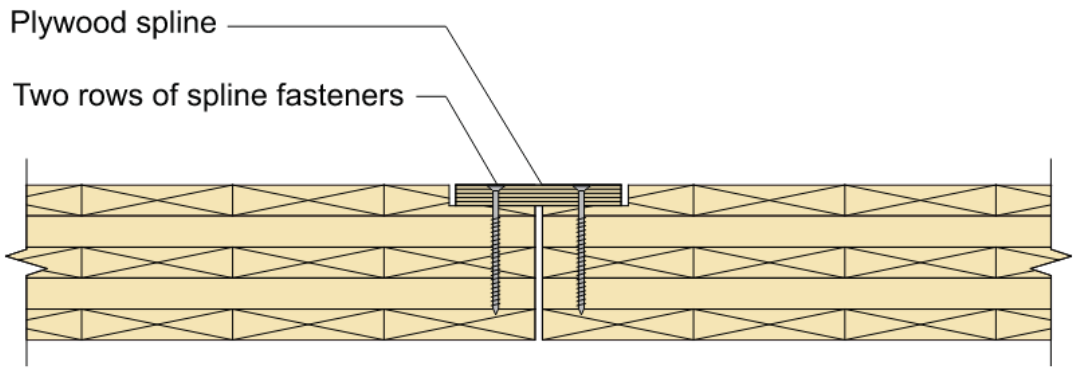


Figure: WoodWorks CLT Diaphragm Design Guide

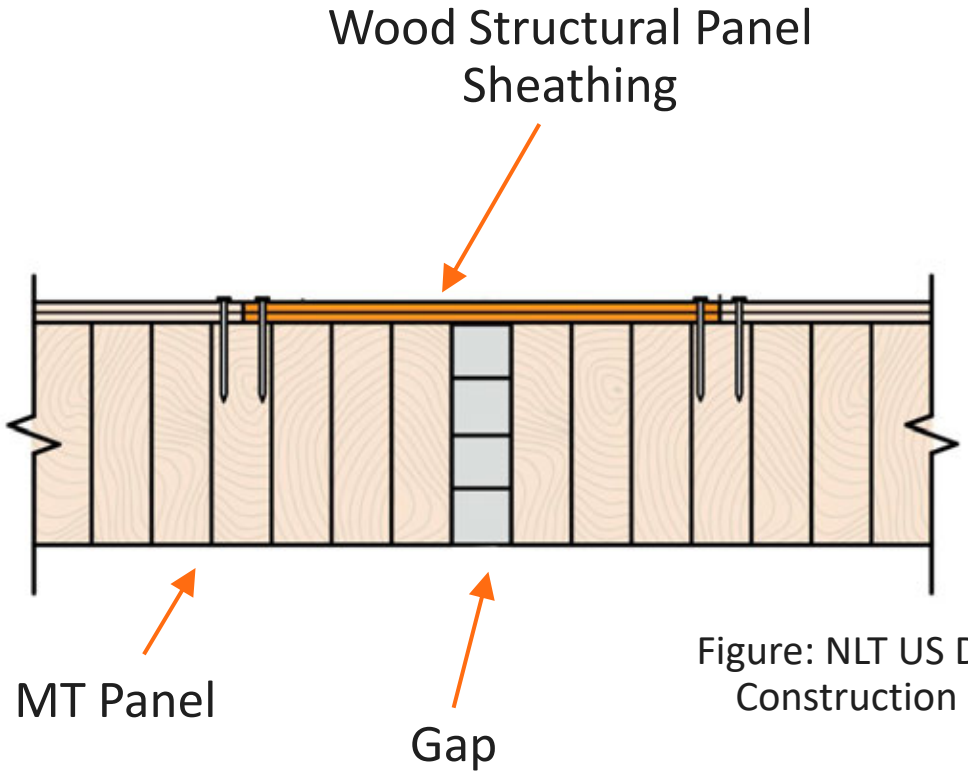


Figure: NLT US Design & Construction Guide

CLT has in-plane strength and doesn't need structural sheathing applied.

GLT, NLT, and DLT have limited in-plane strength and almost always topped with WSP sheathing.

Mass Timber Framing Systems

Mass Timber Floor and Roof Framing Systems

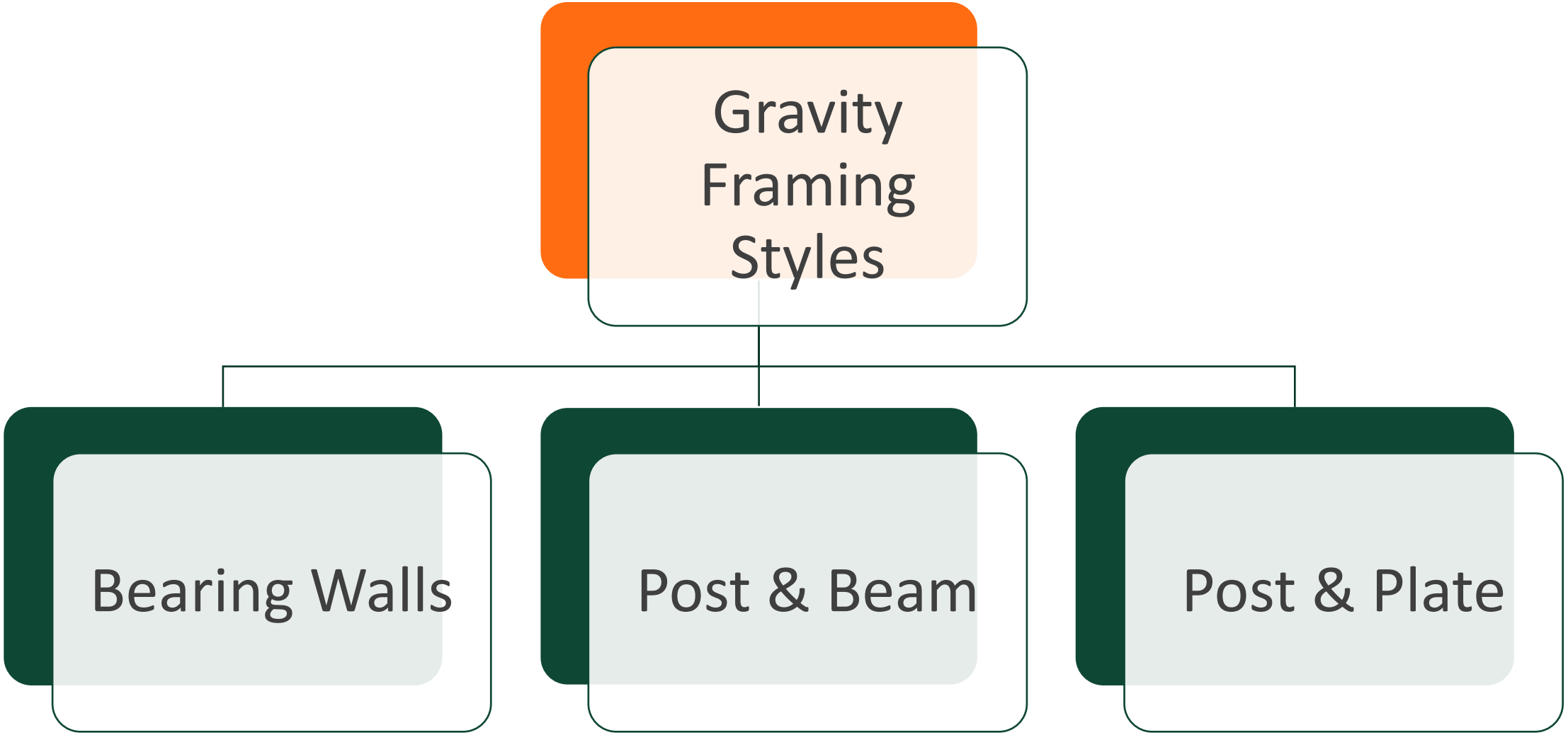


Photo: Lendlease

STRUCTURAL SOLUTIONS | MT Panels on MT Bearing Walls - “Honeycomb”

Photo: Stantec Architecture

Photo: John Klein

Photo: Ema Peter

Photo: WoodWorks

STRUCTURAL SOLUTIONS | MT Panels on Beams and Posts - P O S T + B E A M

Photo: Seagate Structures

STRUCTURAL SOLUTIONS | POST + PLATE

Key questions affecting structural layout:

Structural capacity: For example, achievable spans of MT floor panels

Panel	Common Floor Span Ranges*	
	Single Span	Multi-Span
3 ply CLT (4 1/8")	10 to 13 ft	12 to 15 ft
5 ply CLT (6 7/8")	15 to 18 ft	18 to 21 ft
3" SCL CLT	8 to 10 ft	10 to 13 ft
4" SCL CLT	10 to 13 ft	12 to 15 ft
5" SCL CLT	13 to 15 ft	15 to 18 ft
6" SCL CLT	14 to 18 ft	17 to 21 ft
2x4 NLT/DLT (3 1/2")	10 to 12 ft	12 to 14 ft
2x6 NLT/DLT (5 1/2")	15 to 17 ft	17 to 20 ft
3 1/8" GLT	9 to 11 ft	10 to 13 ft
5 1/8" GLT	14 to 16 ft	16 to 19 ft

*Examples from efficient framing layouts in business, educational and residential occupancies. NOT for final design. Allowable spans depend on loading, grade and layup of panel, and performance

multi-span panels and beams often perform better than single span

POWERPOINT IS NOT THE CODE!

Key questions affecting structural layout:

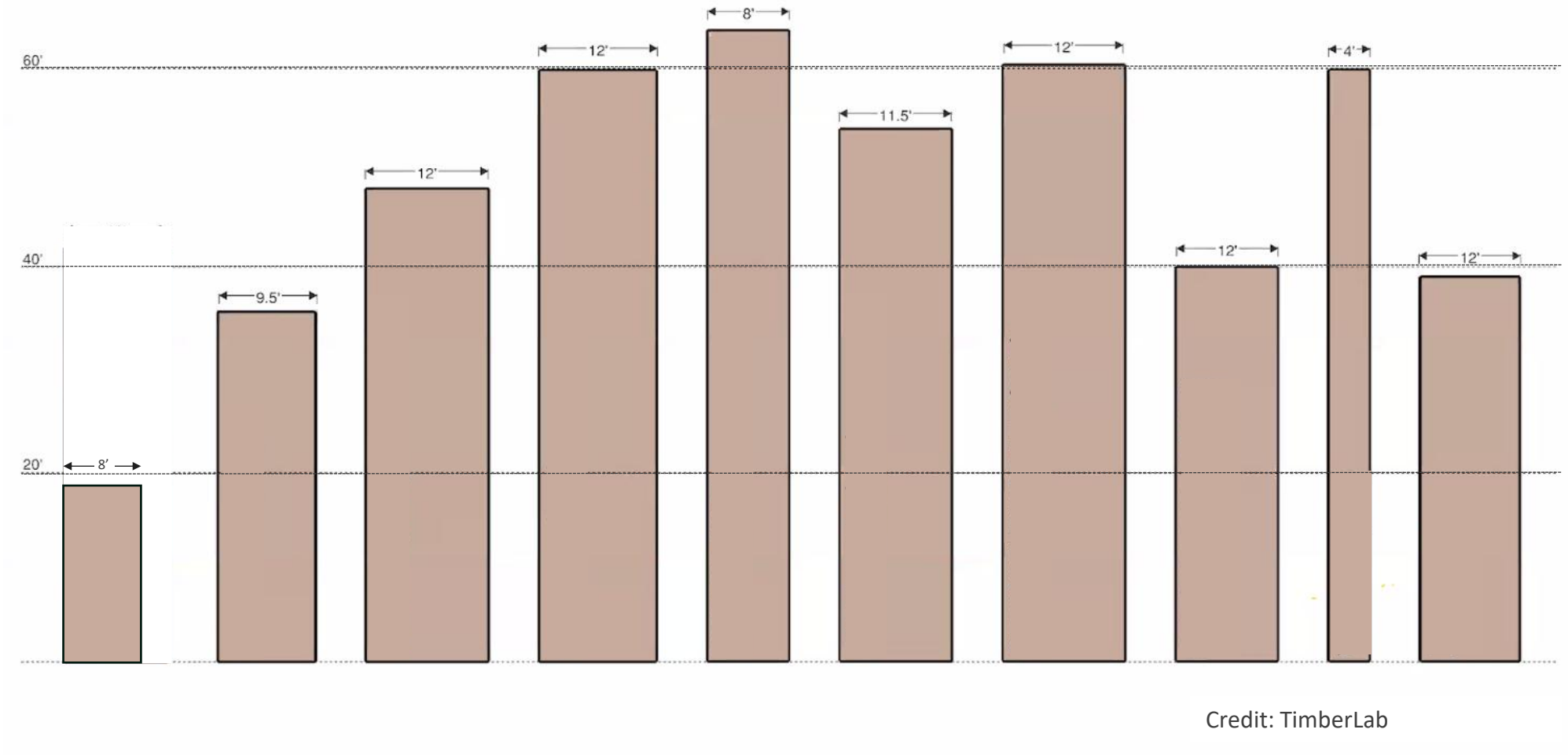
- What is IBC Construction Type?
  - Is it IBC Heavy Timber? (any Type IV) -> must meet defined minimum sizes
  - What is the fire resistance rating? (0, 1, or 2 hour FRR most common)

- Is the timber exposed?
  - Exposed timber likely has aesthetic goals that influence products selected
  - Exposed timber meets FRR through structural capability of member in fire scenario

Showing FRR of exposed structural timber member typically includes a structural fire design check based on the project-specific loading, spans, and supports.

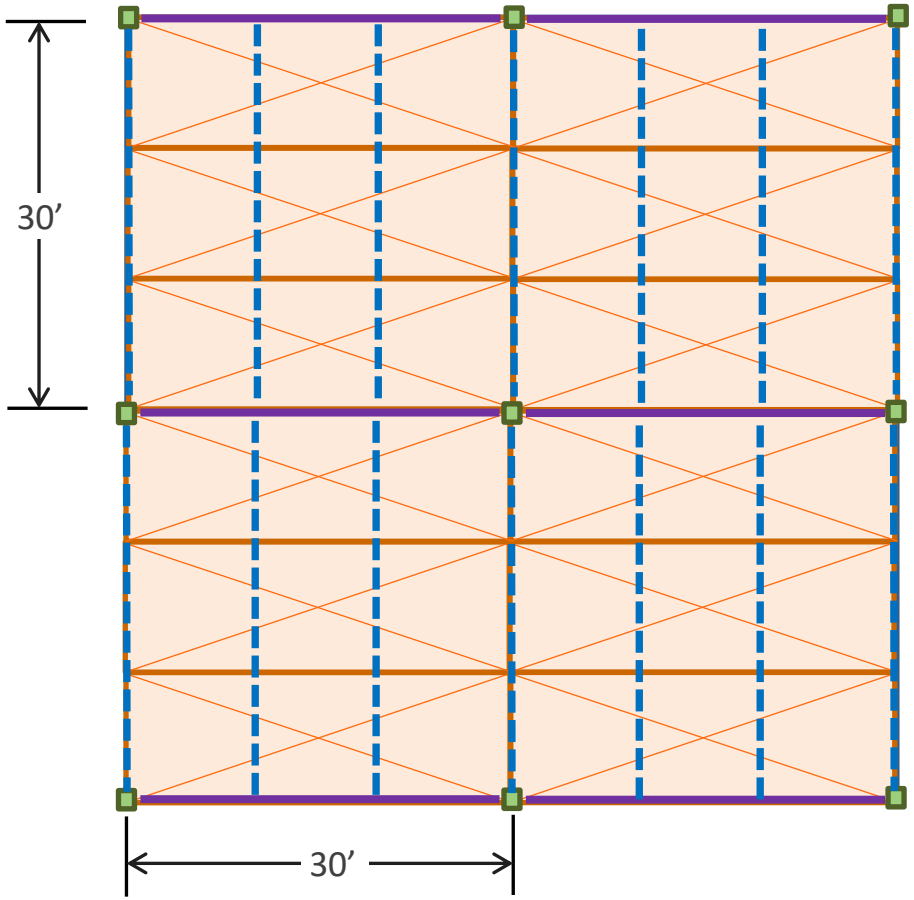
Key questions affecting structural layout:

Size limitations based on manufacturing and transportation: CLT Panel



Credit: TimberLab

Post and Beam Floor Layout – Purlin & Girders



Columns

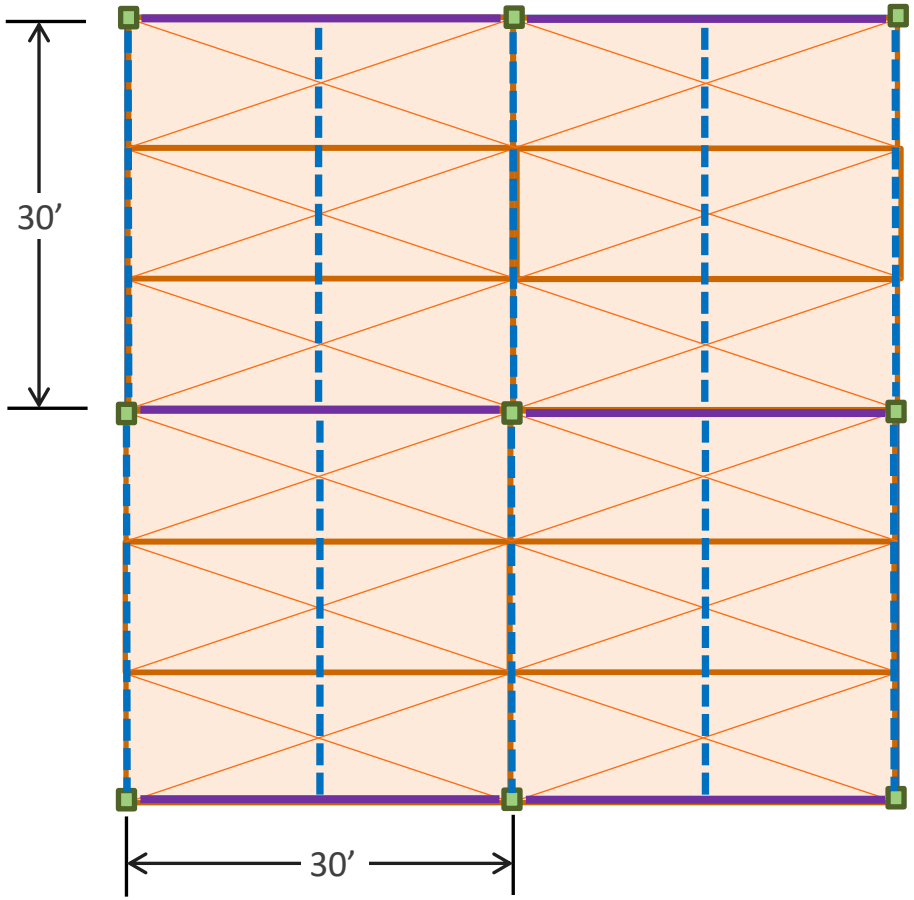
Girders

CLT Panels

Purlins/Joists

Purlins @ ~10 ft on center with 3-ply (4 1/8”) CLT or similar panel can work well in 0 hr FRR floor

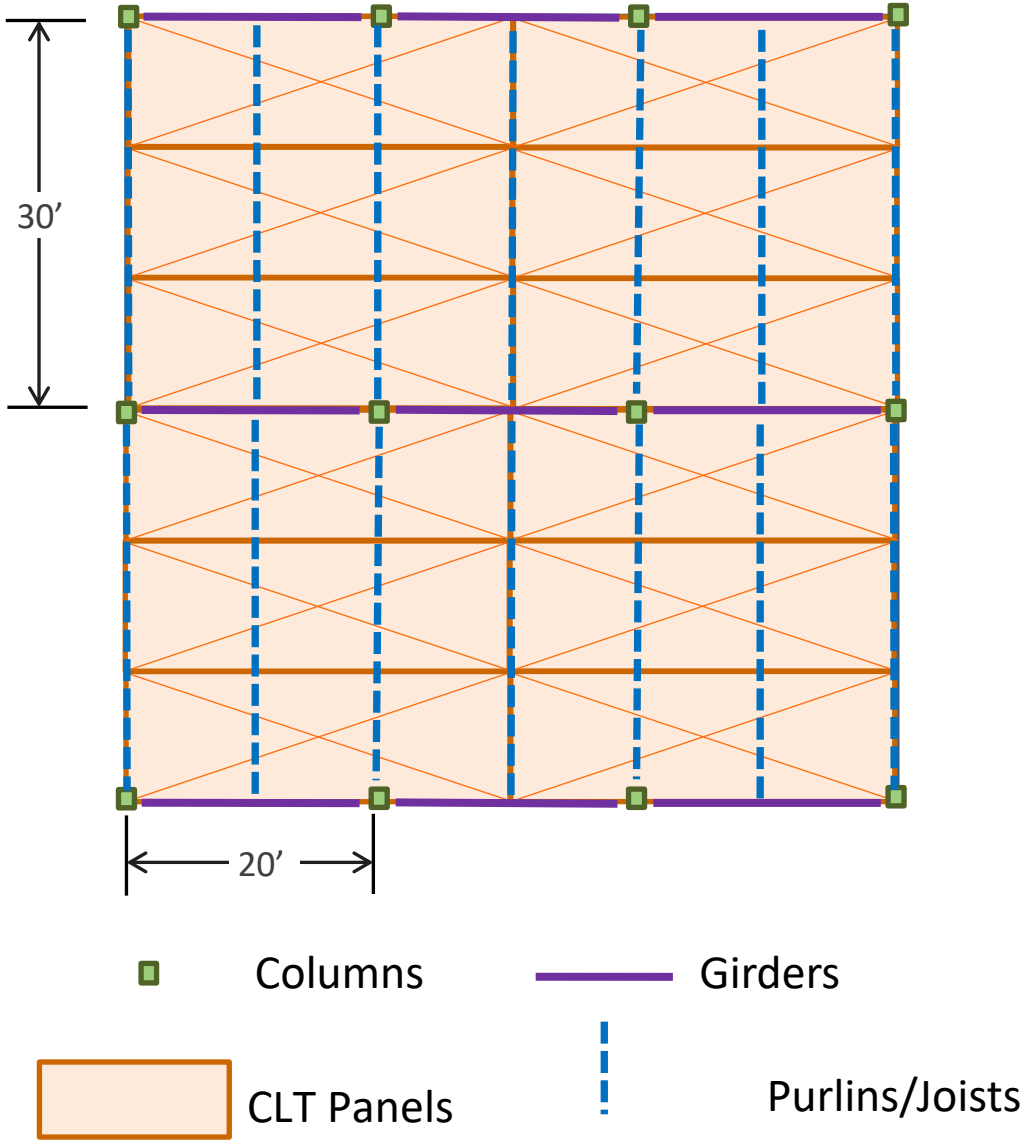
Post and Beam Floor Layout – Purlin & Girders




University of Denver Burwell Center
Photo: WoodWorks

Purlins @ ~15 ft on center with 5-ply (6 7/8”) CLT or similar panel can work well in 1 or 2 hr FRR floor

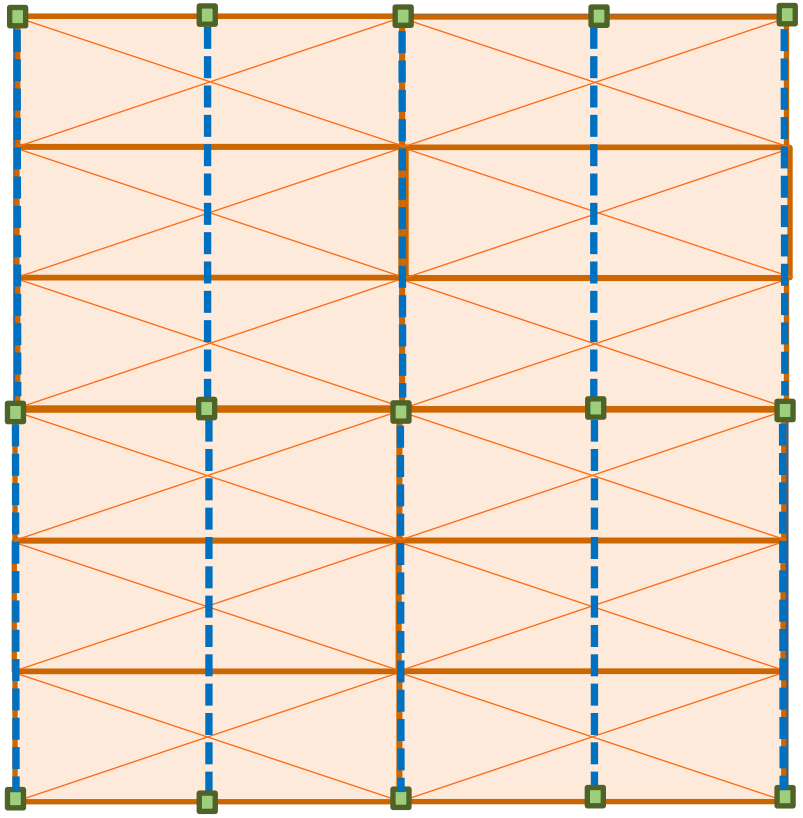
Post and Beam Floor Layout – Purlin & Girders



Near equal purlins and girder length leads to deeper girders.

Long purlin, short girder can have more equal beam depths.

Post and Beam Floor Layout – Beam only



Columns

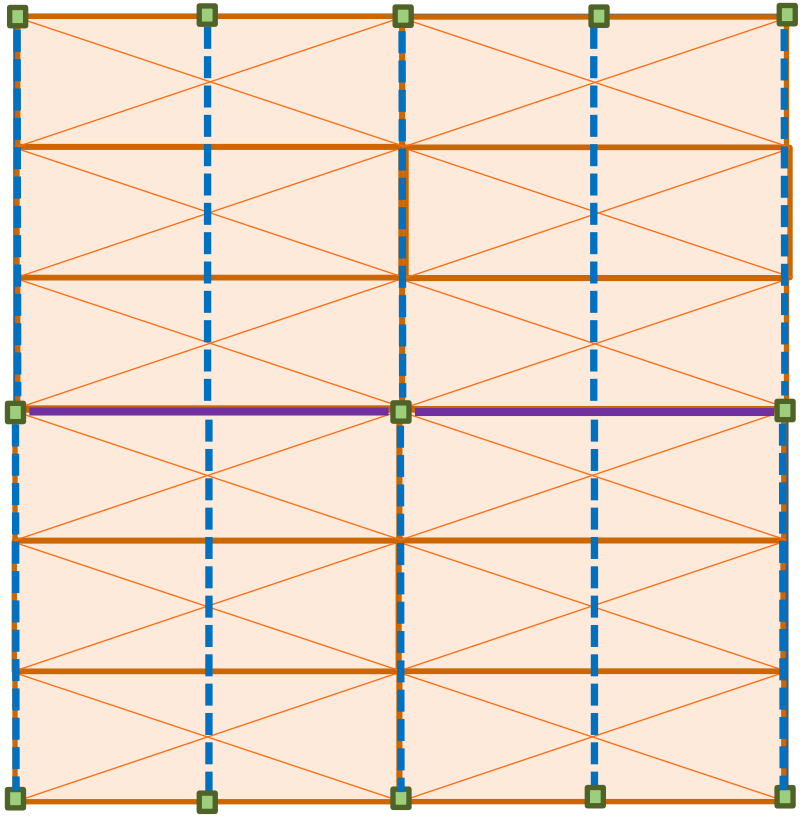
Girders

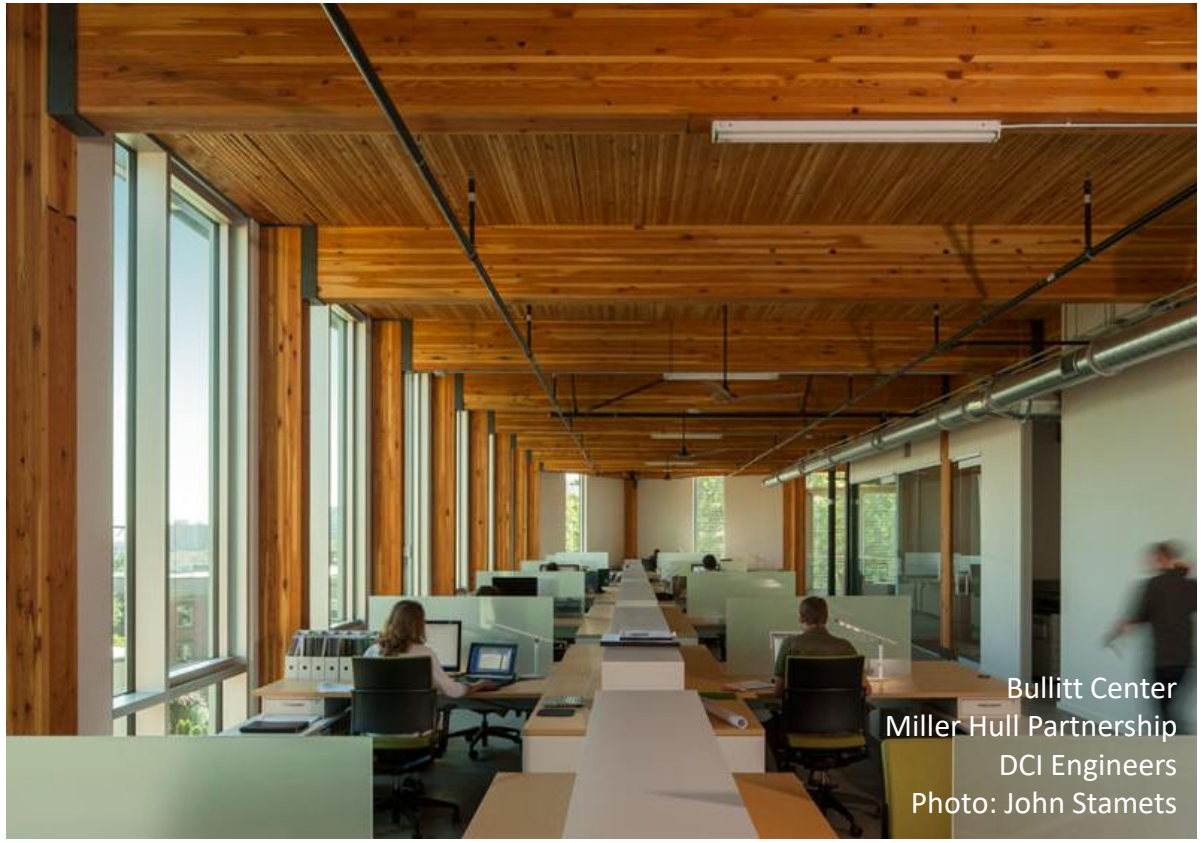
CLT Panels

Purlins/Beams

1-way beams can provide high-windows at exterior

Post and Beam Floor Layout – Beam only.





Columns

Girders

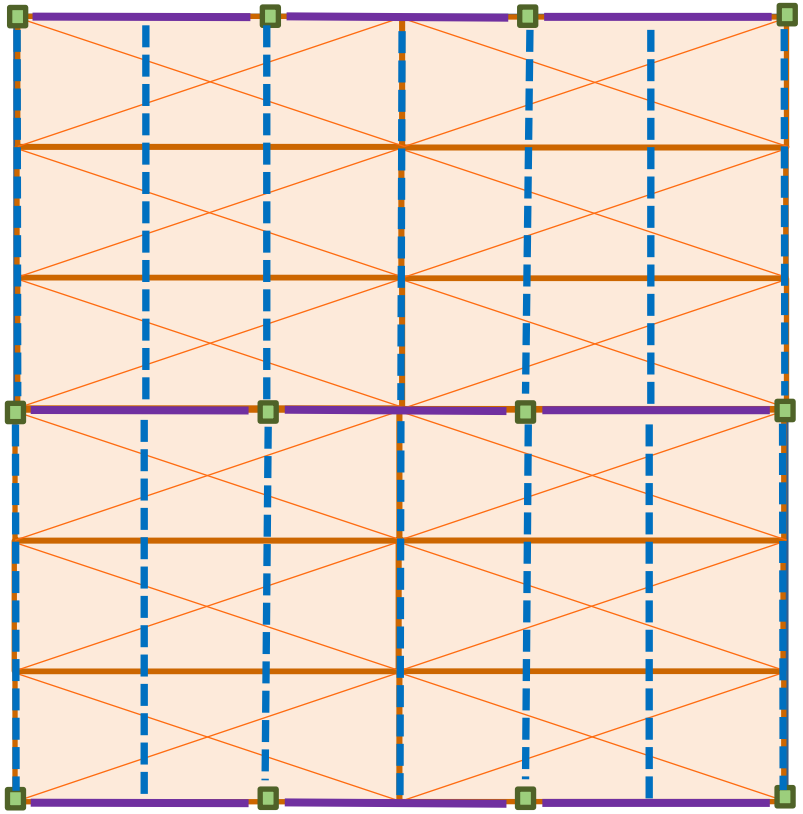
CLT Panels

Purlins/Beams

1-way beams can provide high-windows at exterior

Bullitt Center has NLT over beams at 11’6”, with interior only girders.

Post and Beam Floor Layout –Dropped Girders



Columns

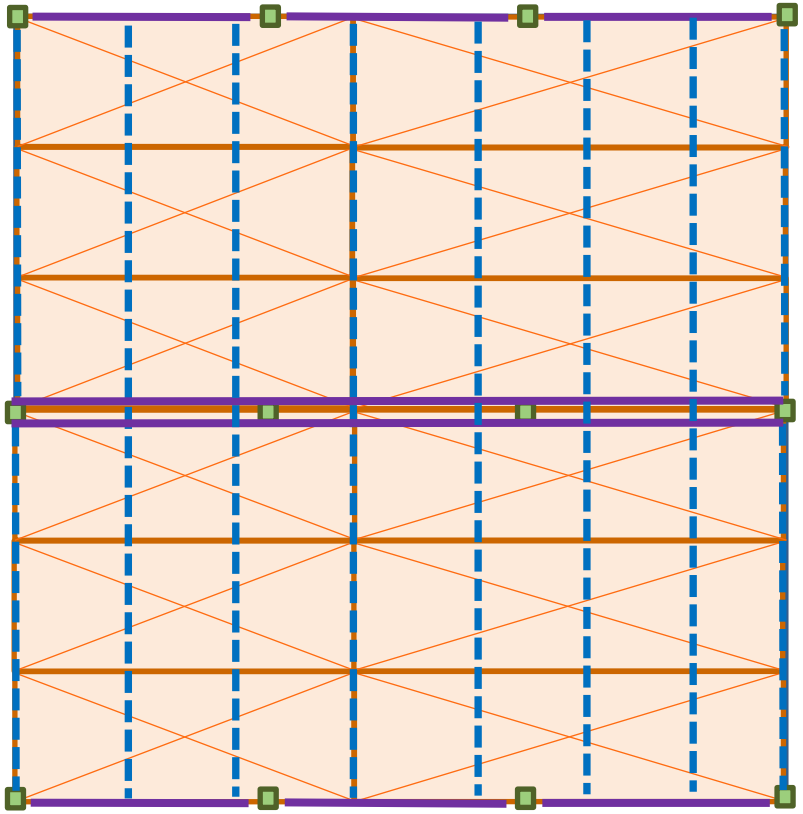
Girders

CLT Panels

Purlins/Joists

Dropped girders (AKA stacked beams) create space for MEP to run over the girder without the need for penetrations or unsightly routing below.

Post and Beam Floor Layout –Doubled Girders



Columns

Girders

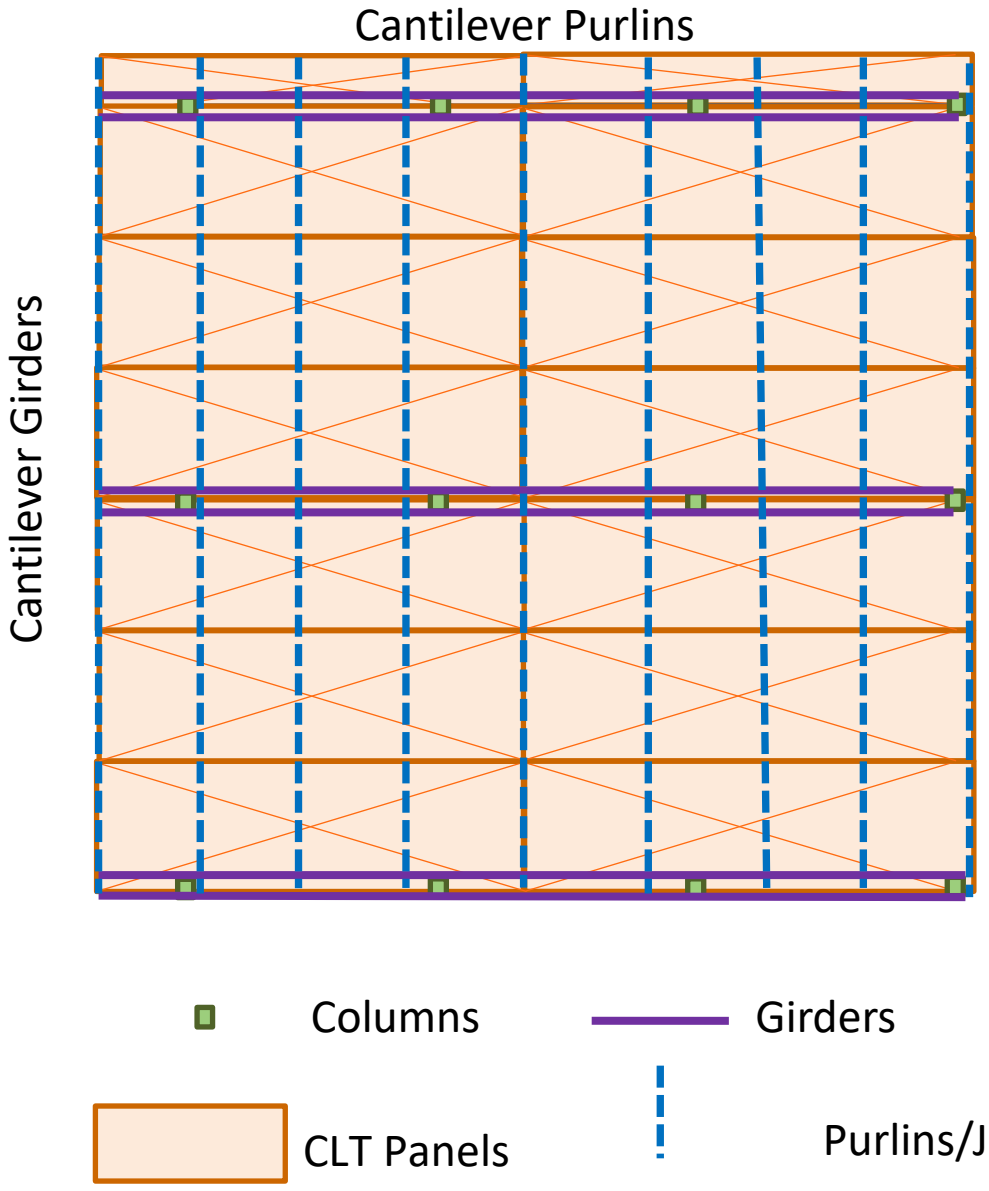
CLT Panels

Purlins/Joists

Platte Fifteen
Oz Architecture / KL&A Engineers & Builders / Adolfson & Peterson Construction
Photo JC Buck

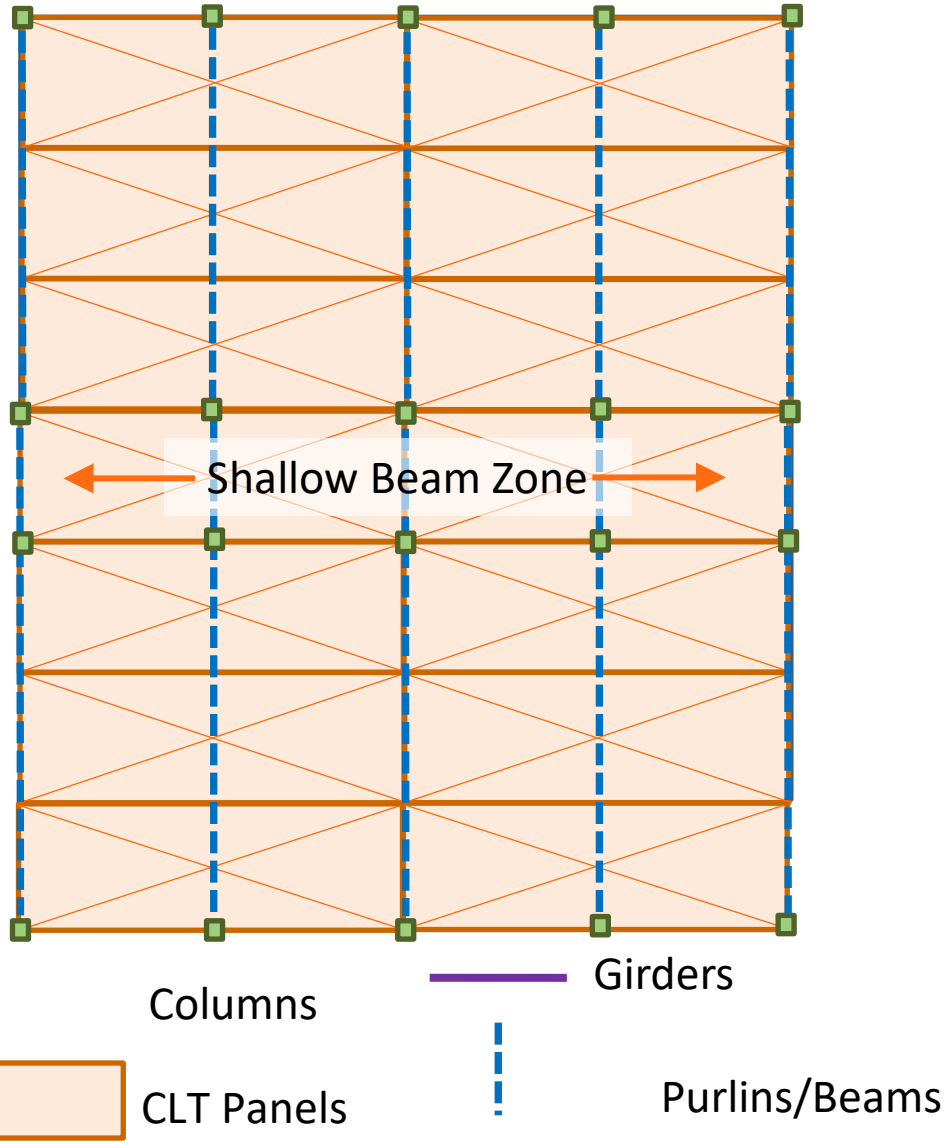
Dropped and doubled multi-span girder with multi-span purlin over top

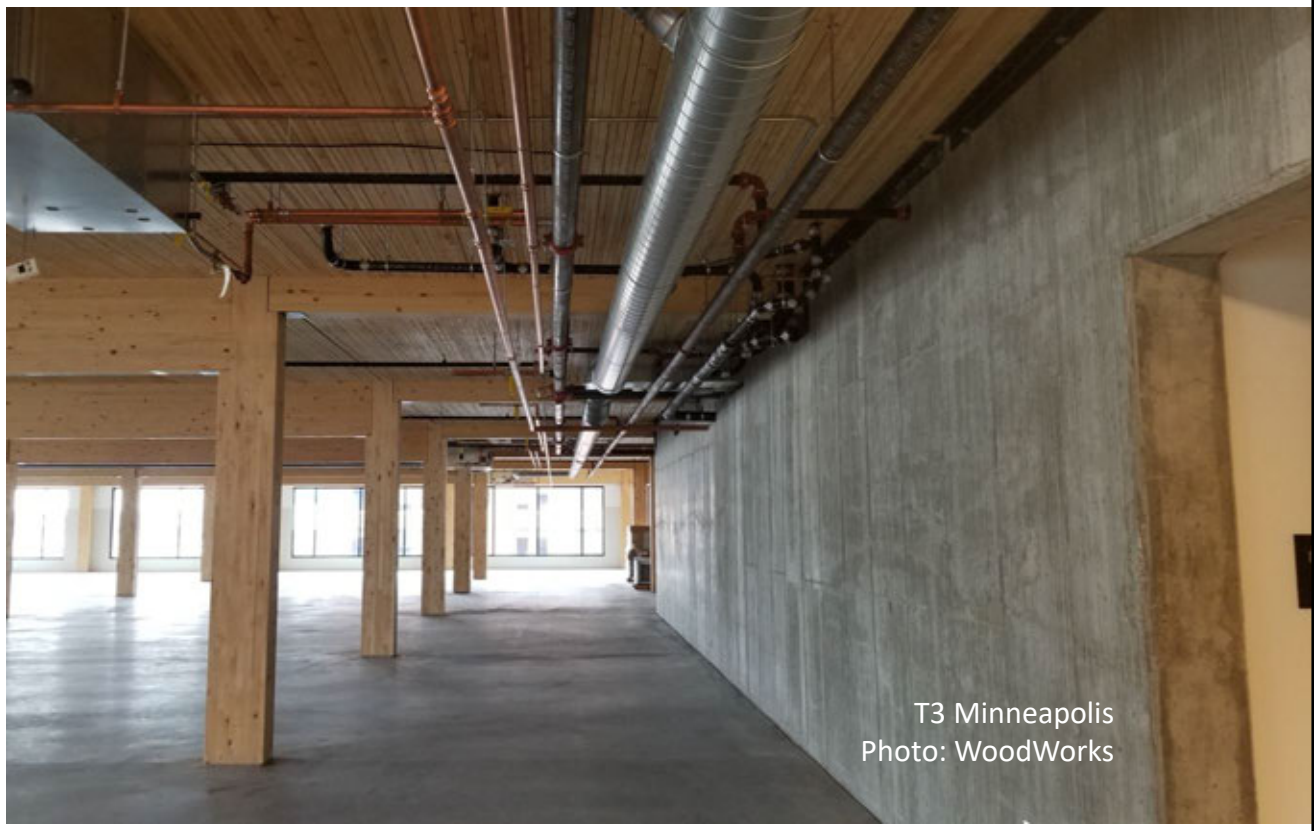
Post and Beam Floor Layout –Dropped Girders



Can cantilever double girder past outermost column.
Can cantilever purlin over girder past outermost girder.

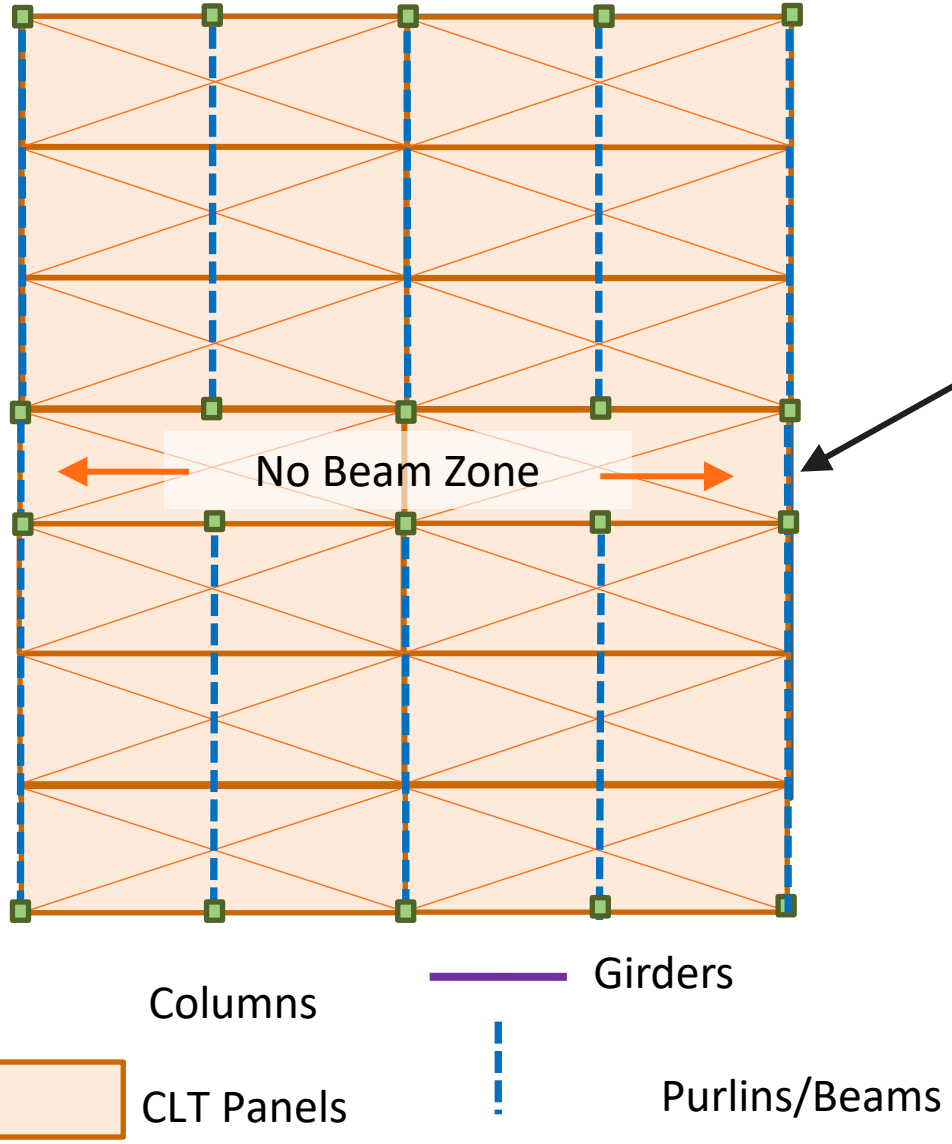
Post and Beam Floor Layout – Shallow Beam MEP Zone





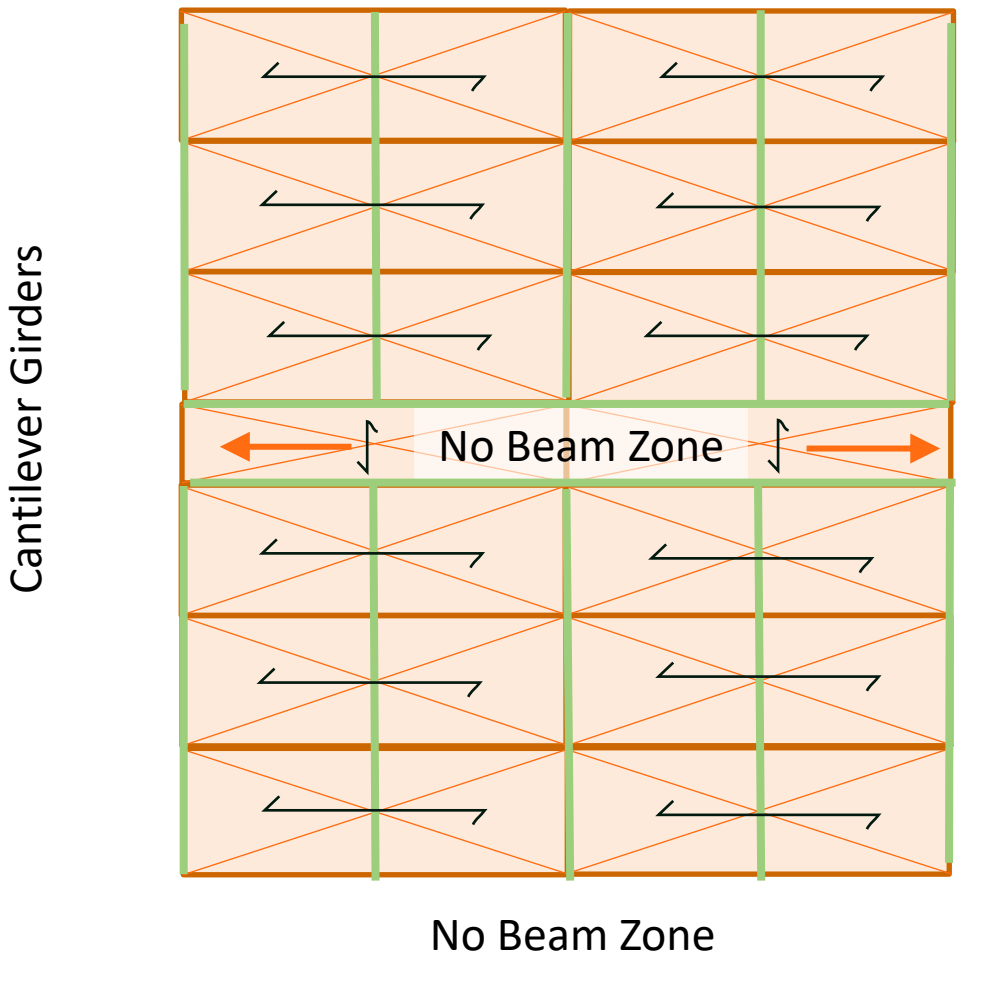
Placing row of columns near each other or near core walls can be used to create a shallow beam zone for MEP distribution

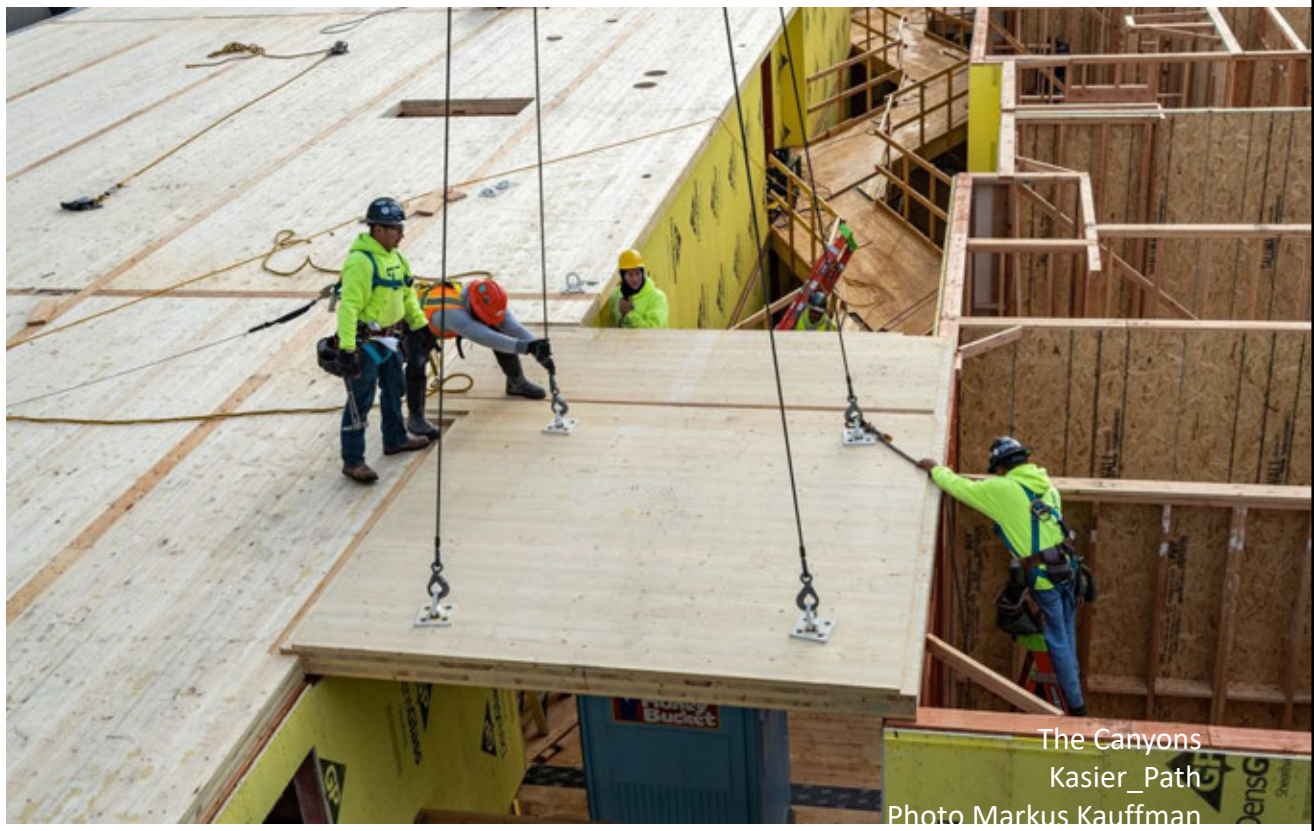
Post and Beam Floor Layout –Beamless MEP Zone



With Point Supported CLT this can be taken to 11 by having a no beam zone with proper engineering.

CLT Panel Layout – CLT Span Short Direction





A similar beamless zone is achieved with bearing walls adjacent to the corridor in multi-family arrangement

https://www.woodworks.org/resources/integrating-mepf-in-mass-timber-buildings/

T3 Minneapolis
MGA | Michael Green Architecture / DLR Group
Magnusson Klemencic Associates / StructureCraft

Julie Gorham, PE, *Excel Engineering*
in collaboration with
WoodWorks – Wood Products Council

Integrating MEPF in Mass Timber Buildings

Techniques for Incorporating Building Infrastructure Systems in Exposed Wood Structures

The opportunity to leave structural elements exposed in a mass timber building offers tremendous design possibilities. It also brings creative challenges not seen with other building types, such as how to expose as much of a mass timber ceiling as possible and keep it relatively uncluttered to emphasize the beauty and biophilic properties of the natural wood panels. This requires careful attention to mechanical, electrical, plumbing, and fire suppression systems (MEPF), either to hide them in concealed areas or incorporate them in a way that suits the architectural design.

This paper explores strategies being used to incorporate MEPF in U.S. mass timber buildings. While there is no "best" approach, effective integration considers the impacts of services on all aspects of the project, including aesthetics, structural performance, fire protection requirements, grid utilization, reconfigurability, and cost. MEPF options should be considered early and often during the design of a mass timber building to avoid issues later.

Elements commonly left exposed:

- Ducting for forced air distribution and exhaust
- Sprinklers (piping and heads)
  - Easier to meet requirements for distribution, density, and coverage of sprinkler lines and heads
- Electrical conduit
  - Exposed more frequently in office and institutional buildings

Elements commonly concealed (e.g., with dropped ceilings, topping slabs, soffits, chases, and within walls):

- Plumbing supply and drain lines
  - Dropped ceilings common in bathrooms and kitchens, which are often stacked story-to-story
- Data and low-voltage cabling
- Hydronic piping
- Electrical conduit

Photo: Chad Davis

Common Approaches to MEPF in Exposed Wood Structures

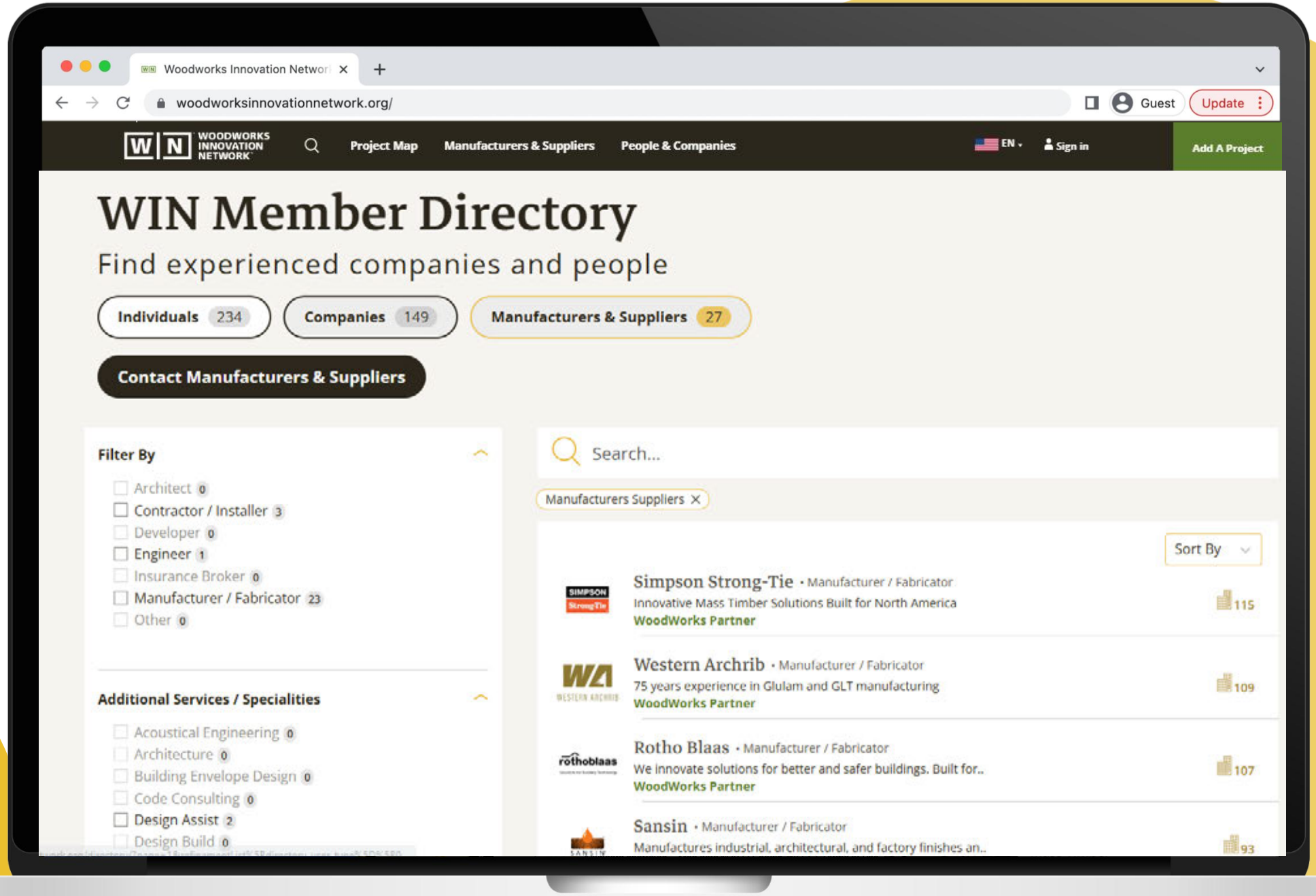
In a multi-family building, designers often expose mass timber ceilings in living rooms, bedrooms, dining areas, and hallways of dwelling units, and use dropped ceilings in kitchens, bathrooms, and corridors to conceal the heavier concentration of MEPF systems. In office, retail, assembly, and institutional buildings, it is common to expose mass timber ceilings in all areas except bathrooms, mechanical rooms, and other spaces with significant MEPF systems.

DPR Office / SmithGroup / Buehler Engineering

https://www.woodworks.org/resources/structural-design-of-mass-timber-elements-gravity-design-examples/

Thesis / LEVER Architecture / Holmes / Swinerton
Photo: Lara Swimmer

WOODWORKS INNOVATION NETWORK.ORG



QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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