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Introduction to Wood: Design Best Practices

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woodeducationinstitute.org

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Course Description

This presentation will provide an introductory review of allowable uses and best design practices associated with wood-frame construction. Design and detailing best practices will be explained to highlight factors that play important roles in the construction process and ultimate building performance. Discussion will also include optimal framing layouts, spacings and spans, truss design considerations, connection detailing and load path continuity.

Learning Objectives

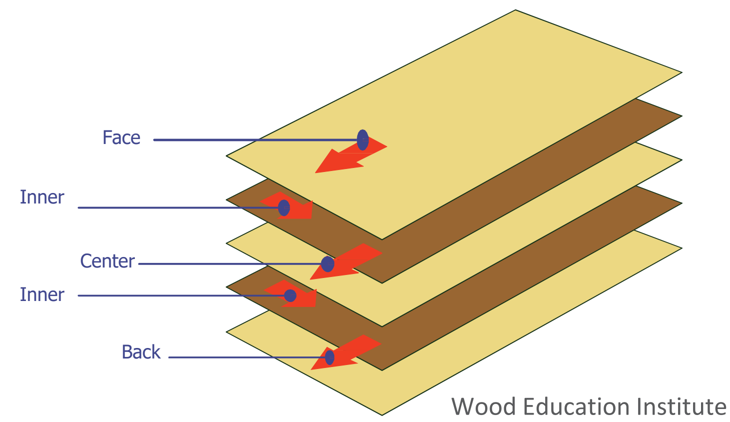
1. Discuss design considerations specific to wood framing such as moisture control and shrinkage accommodation.
2. Review design topics associated with wood trusses such as loading conditions and bracing requirements.
3. Analyze the impact that holes and notches have on structural wood members such as floor joists and wall studs and determine best locations for minimizing their impact on structural design properties.
4. Explore the variety of available wood building products and discuss how to efficiently utilize each.

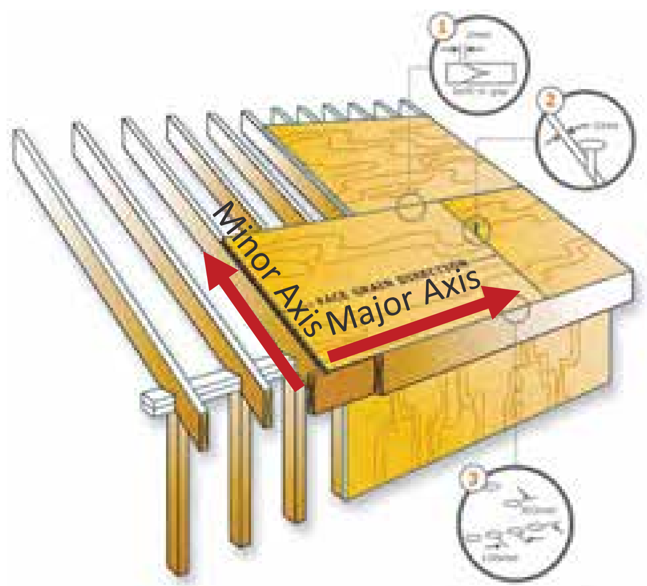
Outline

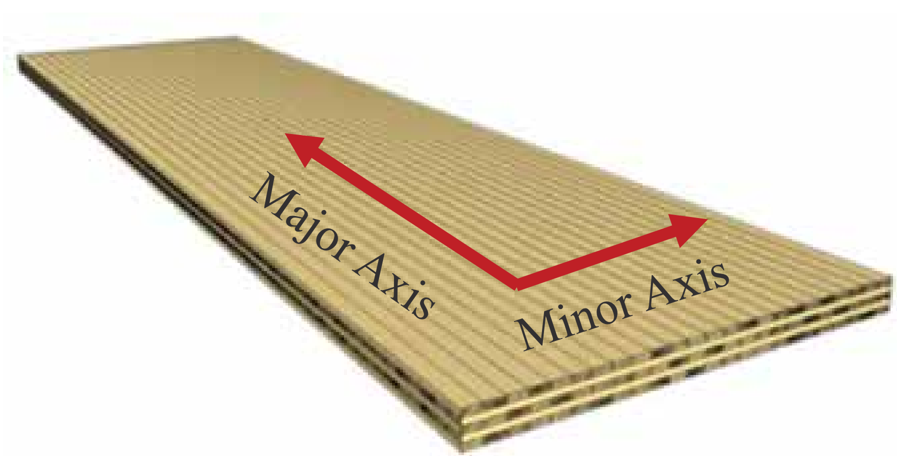
- Framing: Members & Layout
- Load Path Continuity
- Localized Stresses: Notches & Holes
- Blocking & Bracing
- Trusses
- Connections
- Moisture Best Practices

Member Orientation: Panels

- Due to multi-layer composition, most panel products have a major and minor axis
- Direction of grain in face plies/veneers generally determine direction of major axis







Panel Options

Wood Structural Panels
- Oriented Strand Board (OSB) and Plywood

Solid Sawn Decking
- 2x, 3x and 4x dimensional lumber
- Mechanically Laminated or Tongue & Groove

Panel Products:
- Mass timber panels (CLT, NLT, DLT, GLT, MPP)
- Structural Insulated Panels (SIPS)

Wood Structural Panels (WSP)

- Plywood - the original engineered wood panel (>100 years)
- Oriented Strand Board (OSB) - a second generation engineered wood panel
- Depending on thickness, loads, generally span 16” – 24”

Lumber Decking

- Code Acceptance for 2, 3 and 4 inch thick Tongue & Groove Lumber Decking per IBC 2012 2304.8
- Depending on thickness, loads, can span 8 ft+

3x6 Double T&G Pine
Photo Southern Wood Specialties

Mass Timber Panels

Nail Laminated Timber (NLT)

Glue Laminated Timber (GLT)

Mass Plywood Panel (MPP)

Cross Laminated Timber (CLT)

Dowel Laminated Timber (DLT)

Images Source: Structurecraft

Member Orientation: Framing

- Most framing members have a major and minor axis
- Most framing members are rectangular; larger dimension generally determines direction of major axis

Member Orientation: Framing

Framing Options

Solid Sawn Lumber

- Lumber (2”-4” thickness) and Timbers (5”x5” & larger)

Glulam

I Joists

Structural Composite Lumber

- LVL, PSL, LSL, OSL

Image Source: APA

Solid Sawn Framing

Design Routes:

IBC 2012 2308 – Conventional Light-Frame Construction

AWC NDS 2012/2015 – Engineered Design

AWC Wood Frame Construction Manual 2012/2015

- Design tools based upon NDS

Single or Multi-ply members can be used for floor, roof joists, beams, purlins, wall studs, plates, blocking, bracing

Solid Sawn Roof Framing Spans

IBC 2015 Table 2308.7.2(2) Rafter Spans for Common Lumber Species

TABLE 2308.7.2(2)—continued
RAFTER SPANS FOR COMMON LUMBER SPECIES
(Roof Live Load = 20 psf, Ceiling Attached to Rafters, L/Δ = 240)

RAFTER SPACING (inches)	SPECIES AND GRADE		DEAD LOAD = 10 psf					DEAD LOAD = 20 psf				
			2 × 4	2 × 6	2 × 8	2 × 10	2 × 12	2 × 4	2 × 6	2 × 8	2 × 10	2 × 12
			Maximum rafter spans[a]									
			(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)	(ft. - in.)
24	Douglas Fir-Larch	SS	8-3	13-0	17-2	21-10	Note b	8-3	13-0	16-7	20-3	23-5
	Douglas Fir-Larch	#1	8-0	12-6	15-10	19-5	22-6	7-5	10-10	13-9	16-9	19-6
	Douglas Fir-Larch	#2	7-10	11-9	14-10	18-2	21-0	6-11	10-2	12-10	15-8	18-3
	Douglas Fir-Larch	#3	6-1	8-10	11-3	13-8	15-11	5-3	7-8	9-9	11-10	13-9
	Hem-Fir	SS	7-10	12-3	16-2	20-8	25-1	7-10	12-3	16-2	19-10	23-0
	Hem-Fir	#1	7-8	12-0	15-6	18-11	21-11	7-3	10-7	13-5	16-4	19-0
	Hem-Fir	#2	7-3	11-5	14-8	17-10	20-9	6-10	10-0	12-8	15-6	17-11
	Hem-Fir	#3	6-1	8-10	11-3	13-8	15-11	5-3	7-8	9-9	11-10	13-9
	Southern Pine	SS	8-1	12-9	16-10	21-6	Note b	8-1	12-9	16-10	20-10	24-8
	Southern Pine	#1	7-10	12-3	16-2	18-11	22-6	7-5	11-1	14-0	16-5	19-6
	Southern Pine	#2	7-4	11-0	13-11	16-6	19-6	6-4	9-6	12-1	14-4	16-10
	Southern Pine	#3	5-8	8-4	10-6	12-9	15-1	4-11	7-3	9-1	11-0	13-1
	Spruce-Pine-Fir	SS	7-8	12-0	15-10	20-2	24-7	7-8	12-0	15-4	18-9	21-9
	Spruce-Pine-Fir	#1	7-6	11-9	14-10	18-2	21-0	6-11	10-2	12-10	15-8	18-3
	Spruce-Pine-Fir	#2	7-6	11-9	14-10	18-2	21-0	6-11	10-2	12-10	15-8	18-3
	Spruce-Pine-Fir	#3	6-1	8-10	11-3	13-8	15-11	5-3	7-8	9-9	11-10	13-9

Assumes Roof Live Load = 20 psf, Δ = L/240

Solid Sawn Roof Framing Spans

Rafter Spacing	Species and Grade	Size	Maximum Rafter Span
16”	Douglas-Fir Larch #2	2x8	18’-2”
		2x10	22’-3”
		2x12	25’-9”
24”	Spruce-Pine-Fir #2	2x8	14’-10”
		2x10	18’-2”
		2x12	21’-0”

Assumes Roof Live Load = 20 psf, Roof Dead Load = 10 psf, Δ = L/240

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

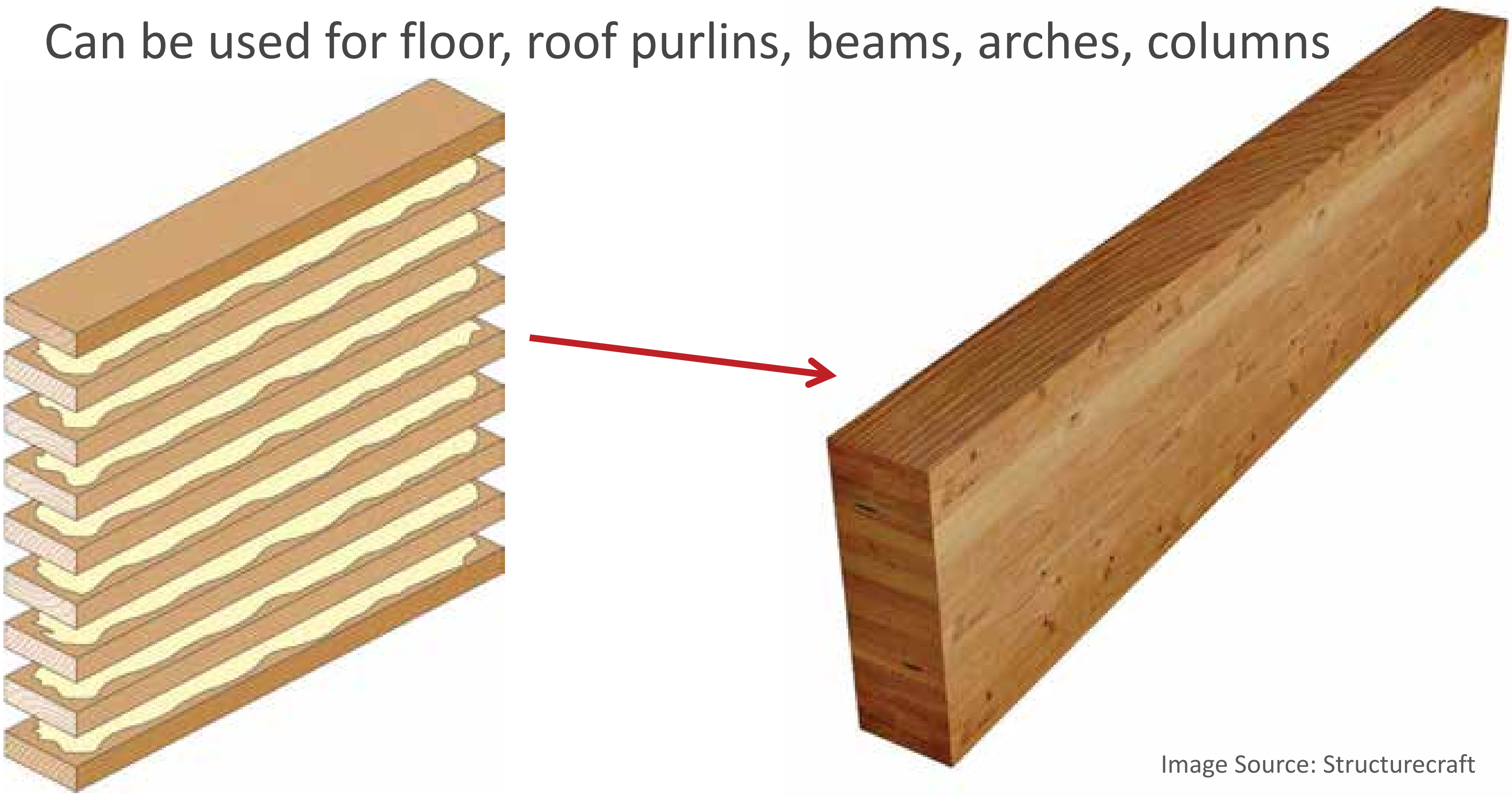


Image Source: Structurecraft

Glulam Sizes & Options

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 of 1½“ from 6” to 60”+

Note: Some glulam laminations are 1-3/8”

Typical Species

Douglas-Fir, Southern Pine, Spruce

Can be PT, or FRT, varies by manufacturer & treater

Can be cambered

Different Appearance Grades available

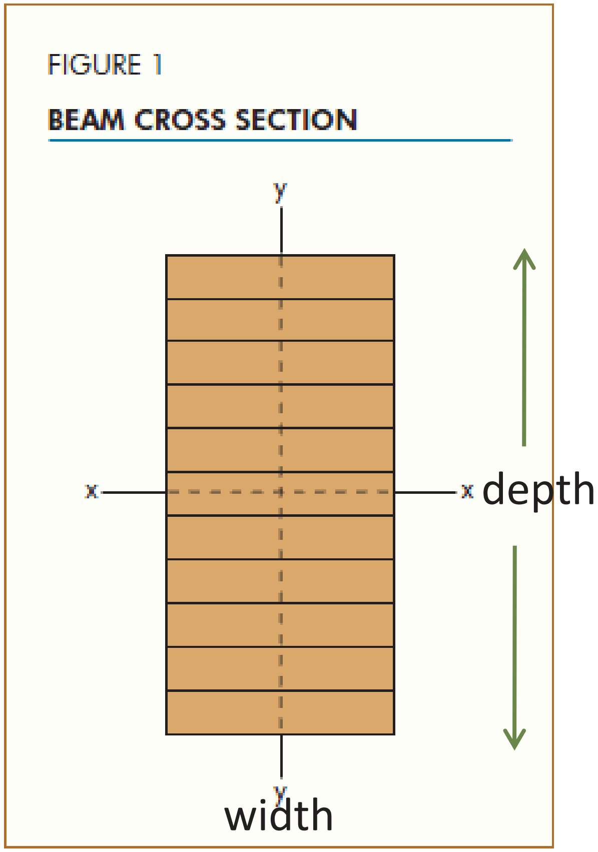
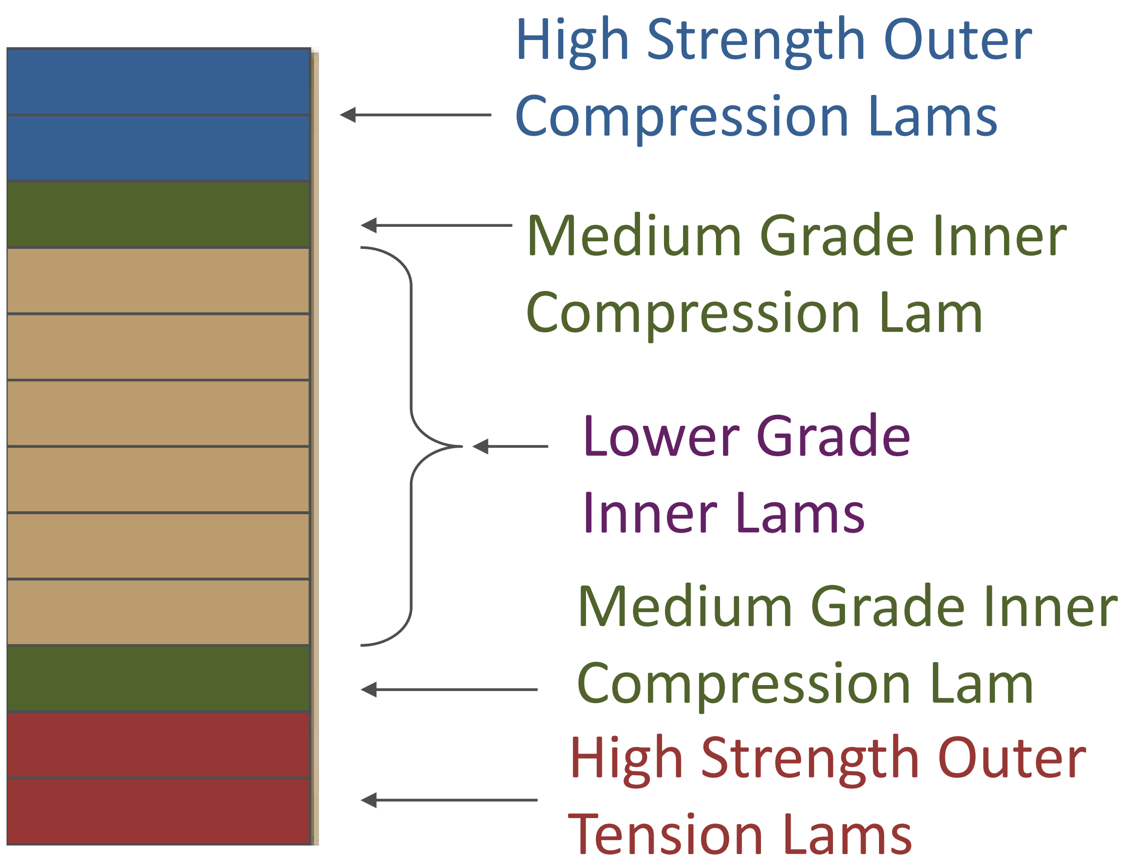


Image: APA Glulam Product Guide

Glulam Layup – Balanced & Unbalanced



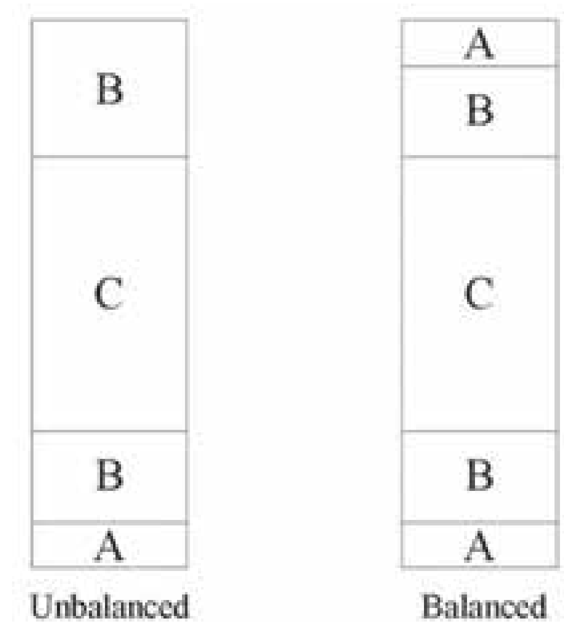
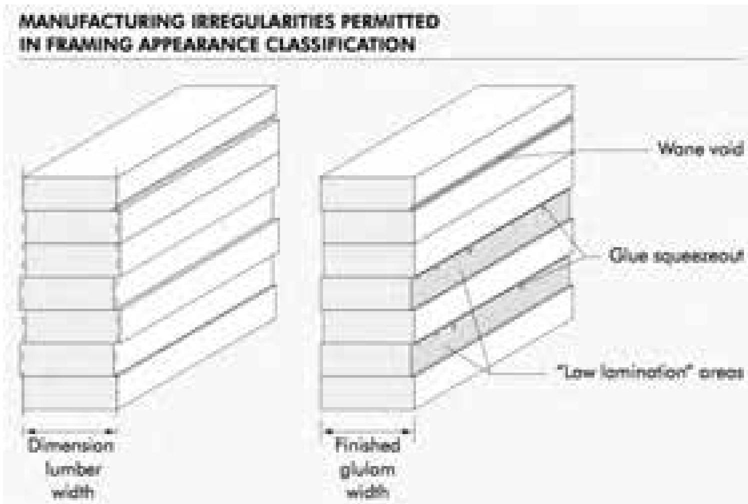


Image: AITC

Glulam Appearance Grades – APA EWS Y110



Framing Grade

Industrial Grade

Architectural Grade

Images: American Laminators

Premium Grade

Specifying Glulam Camber

- Glulam can be manufactured with camber to offset the anticipated dead load deflection
- Very important for long span members
- Glulam industry recommends camber = 1.5 times calculated dead load deflection (roof beams); 1.0 times (floor)

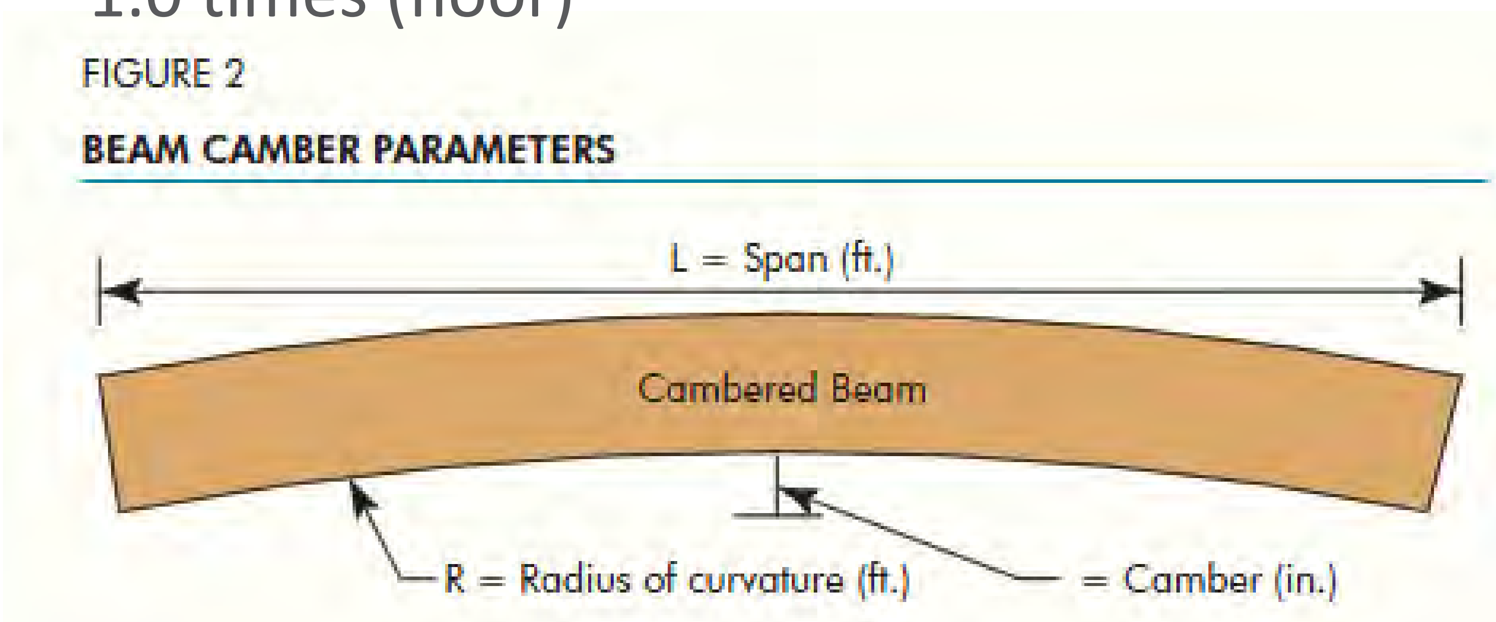
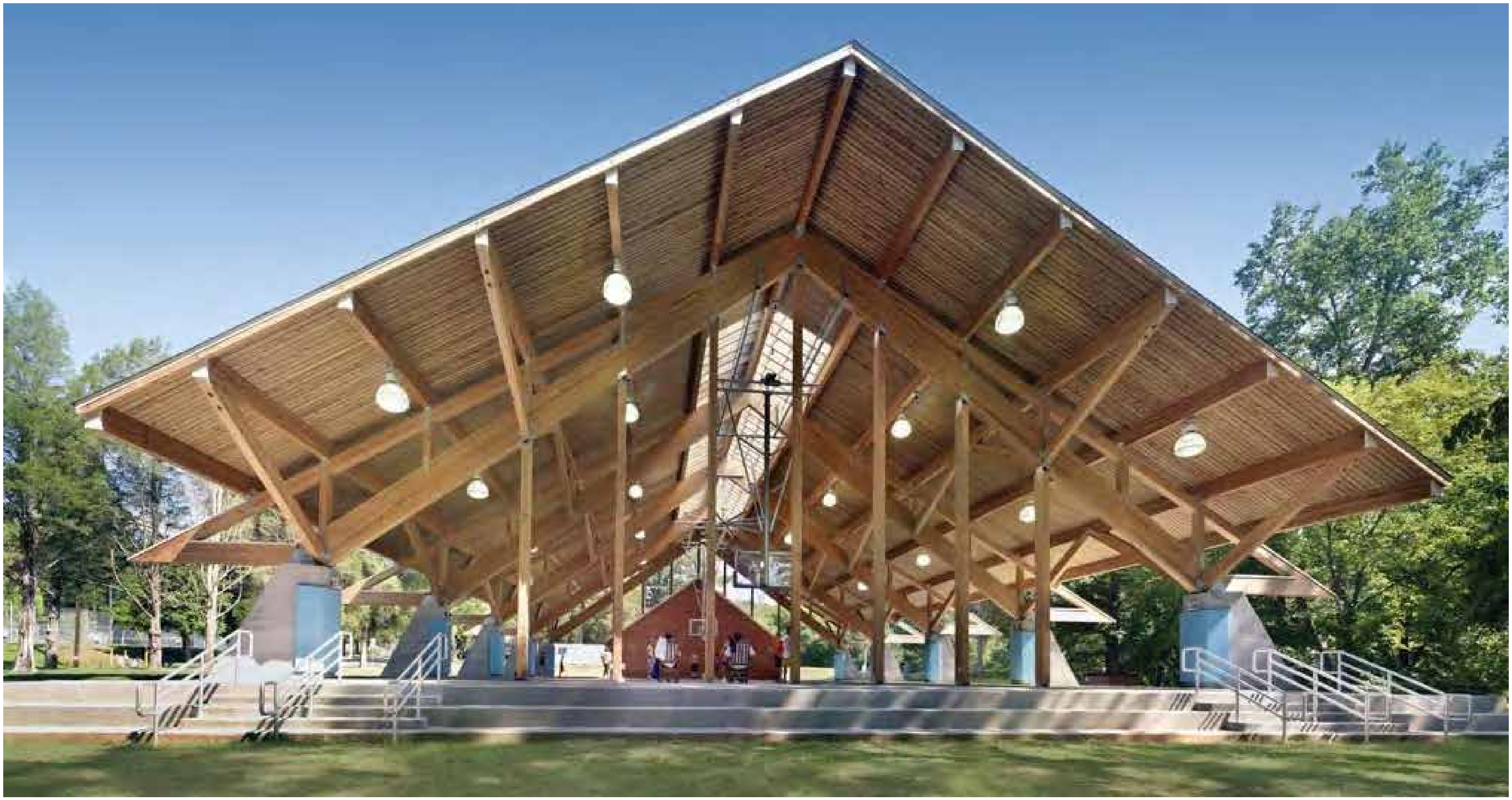


Image: APA Glulam Product Guide

Spans of 100 feet or greater achievable

Flexibility of Shapes and Spans



YMCA Camp Thunderbird Duke Energy Pavilion, Lake Wylie, South Carolina
Photo: Stanley Capps

Flexibility of Shapes and Spans

Richmond Olympic Oval, Richmond, BC Photo: naturallywood.com

Flexibility of Shapes and Spans

The Cathedral of Christ The Light, Oakland, CA
Photo: Timothy Hursley, Cesar Rubio, and John Blaustein,

Flexibility of Shapes and Spans

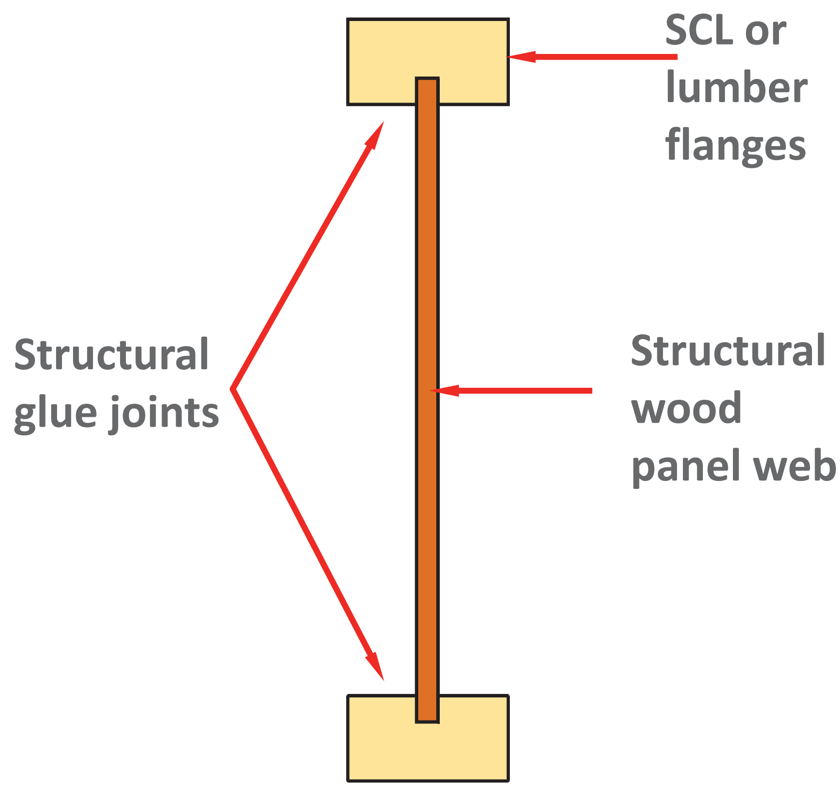
Lemay Museum, Tacoma, WA
Photo: Western Wood Structures

Pre Fabricated Wood I-Joists

Recognized in IBC 2303.1.2 using ASTM D 5055

Proprietary Products with Evaluation Reports

Can be used for floor, roof joists

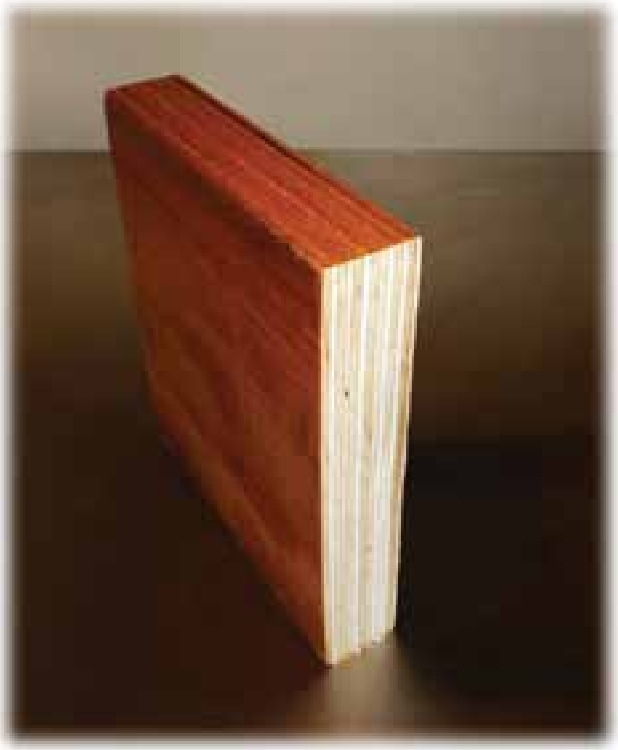


Structural Composite Lumber (SCL)

Recognized in IBC 2012 2303.1.9 / IBC 2015 2303.1.10 using ASTM D 5456

Proprietary Products with Evaluation Reports

Can be used for floor, roof beams & columns, tall wall studs



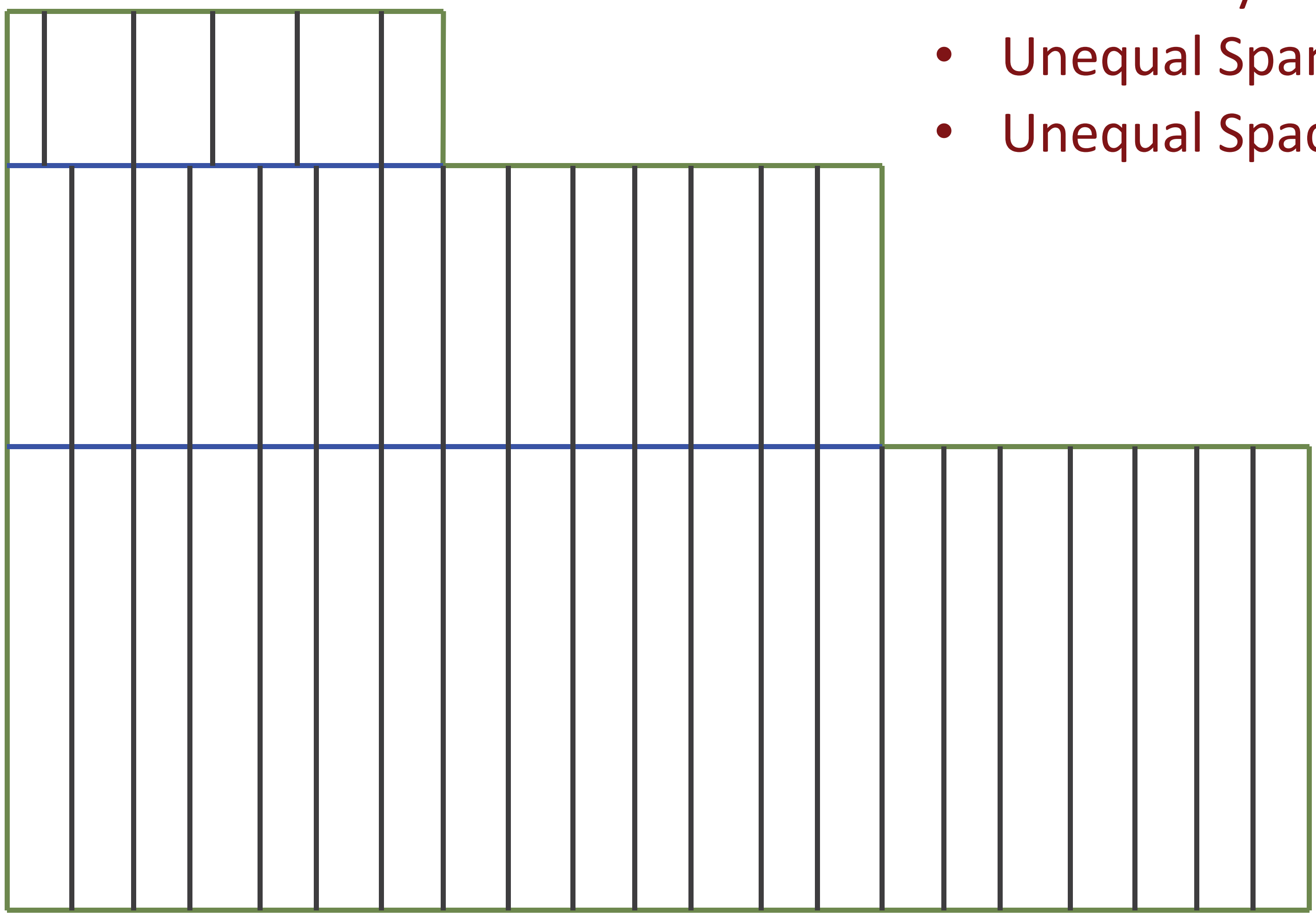
Laminated **V**eneer **L**umber

Parallel
Strand
Lumber

Laminated
Strand
Lumber

Oriented
Strand
Lumber

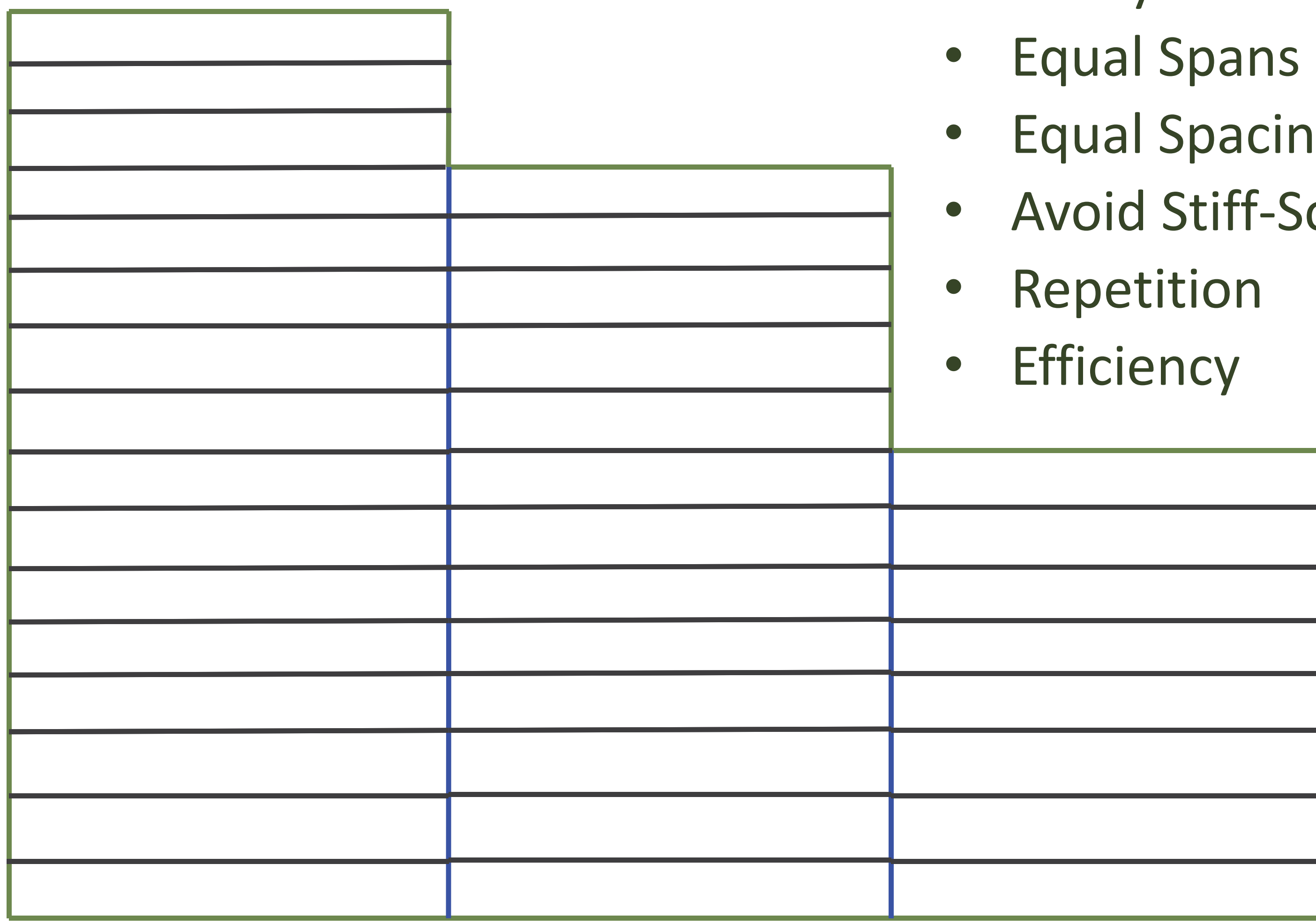
Framing: Layout, Spacing, Spans



Less Ideal Layout

- Unequal Spans
- Unequal Spacing

Framing: Layout, Spacings, Spans



Ideal Layout

- Equal Spans
- Equal Spacings
- Avoid Stiff-Soft Areas
- Repetition
- Efficiency

Load Path Continuity

- Structural loads (gravity and lateral) must follow a continuous load path from roof to foundation
- In multi-story construction, to work around building features, may require numerous load path “steps” in lieu of a single vertical load path

Load Path Continuity: Results & Impacts

- In many situations, general building layout is complete before structural design begins
- Understanding impacts of wall, column, opening layout on structural system efficiency will aid in providing more cost effective solutions

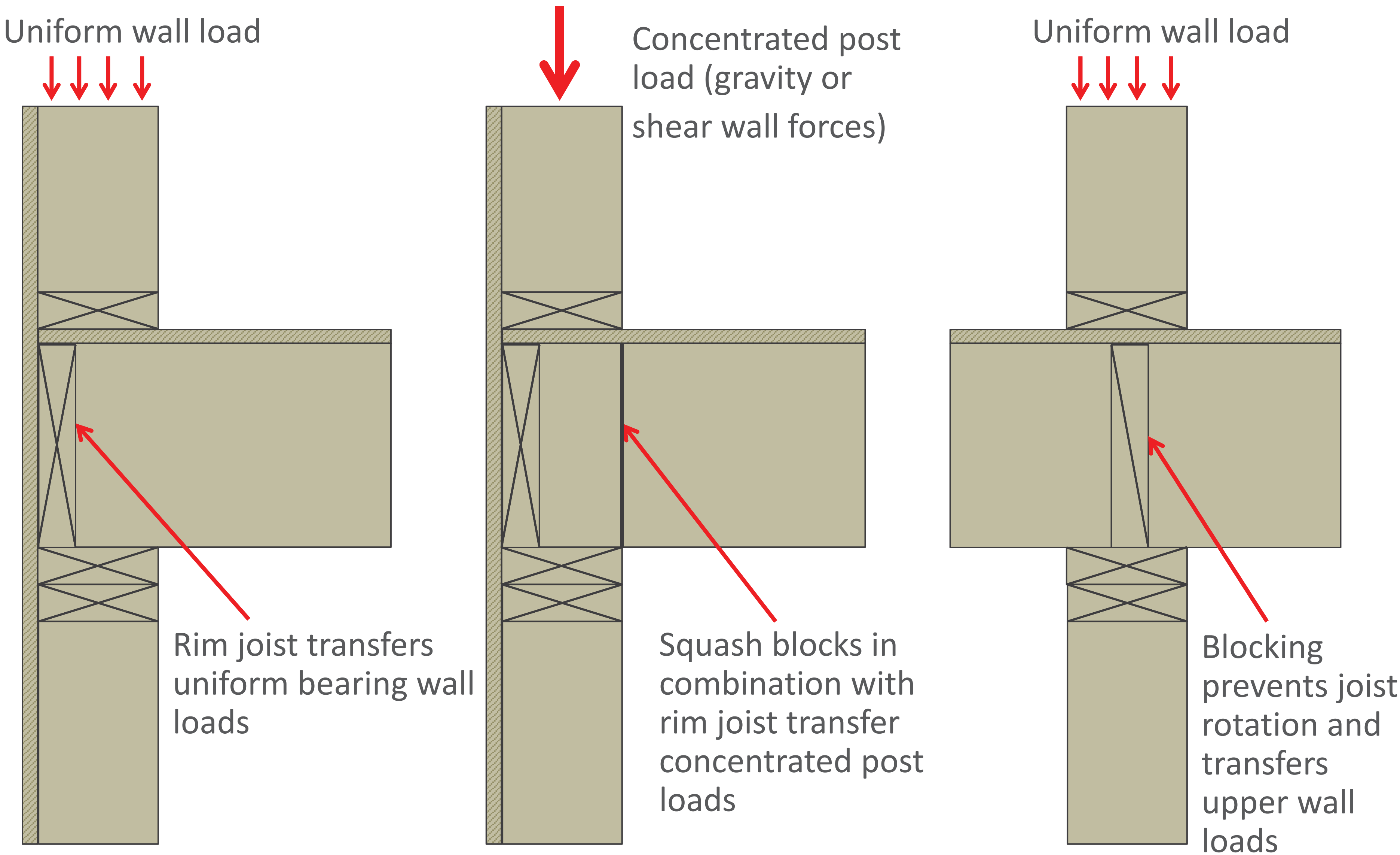
Library Square, British Columbia, Canada

JM Architects

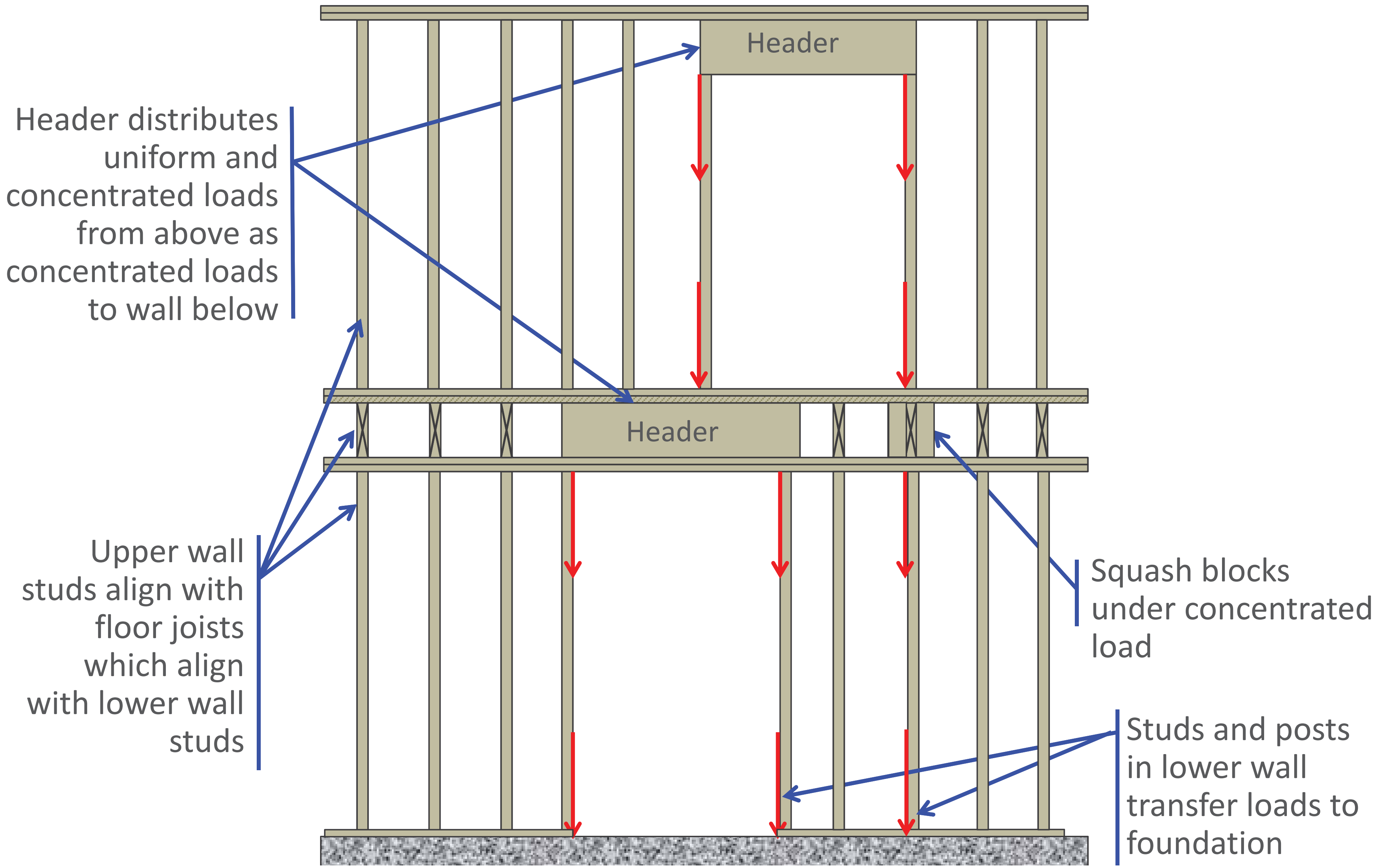
Wood Cube Apartments

Photo: IBA Hamburg

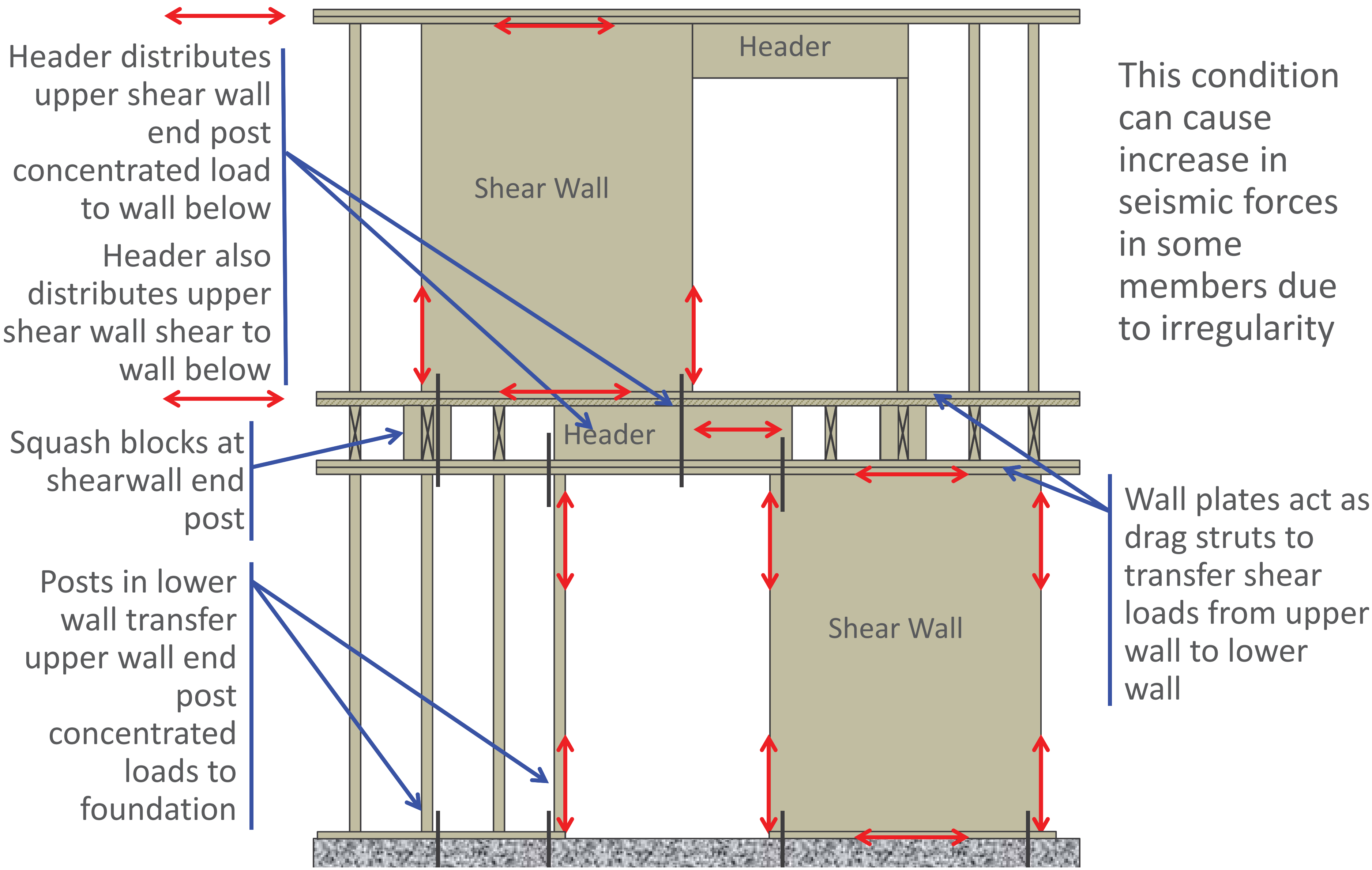
Load Path Continuity: Wall Loads



Gravity Load Path Continuity: Wall Elevation



Lateral Load Path Continuity: Wall Elevation



Spanning Members: Localized Stress

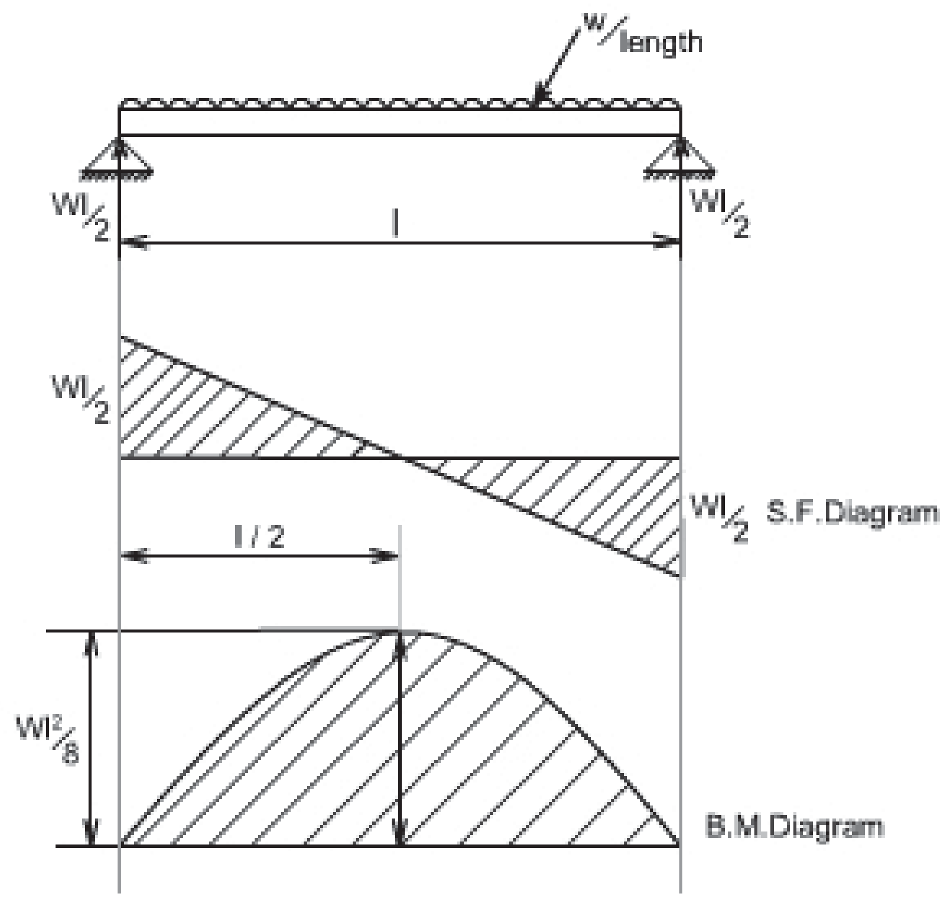
Under common, simple span, uniform loading conditions:

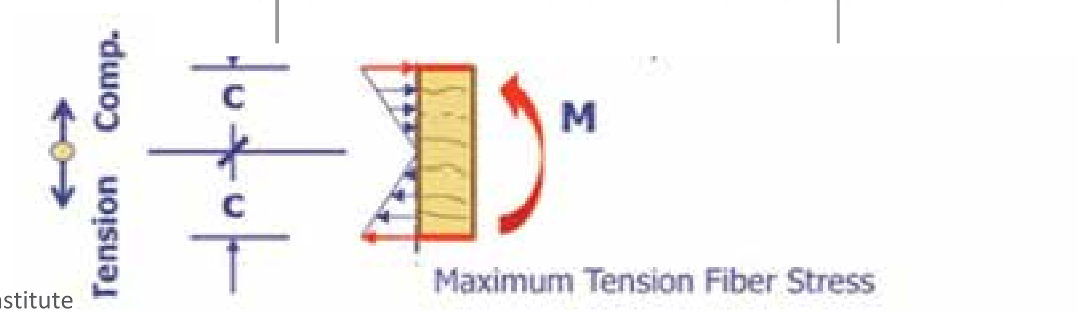
Moment: max. in cross section at outer fibers, max. in span at center

- Avoid notches and holes in middle of beam span, top and bottom of beam depth

Shear: max. in cross section at center, max. in span at ends

- Avoid large notches and holes in ends of beam span

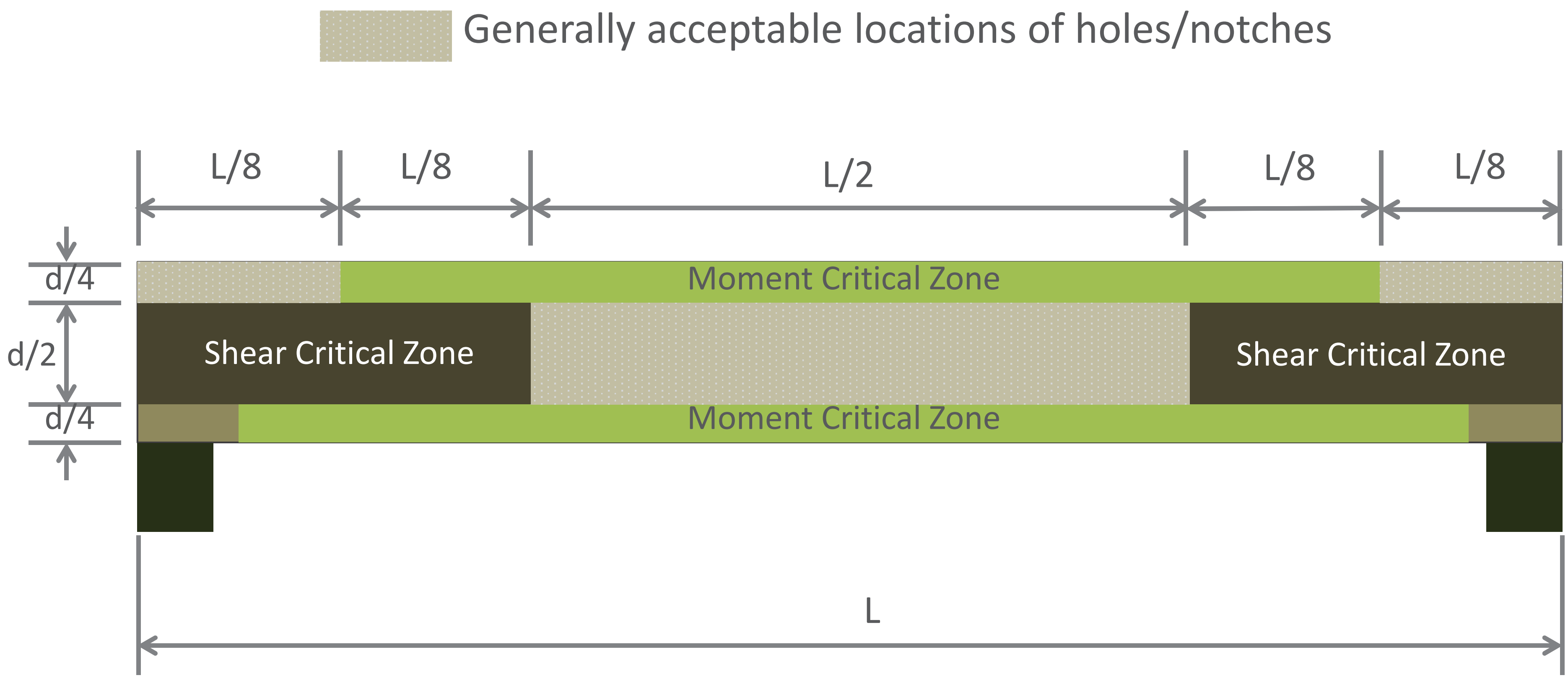




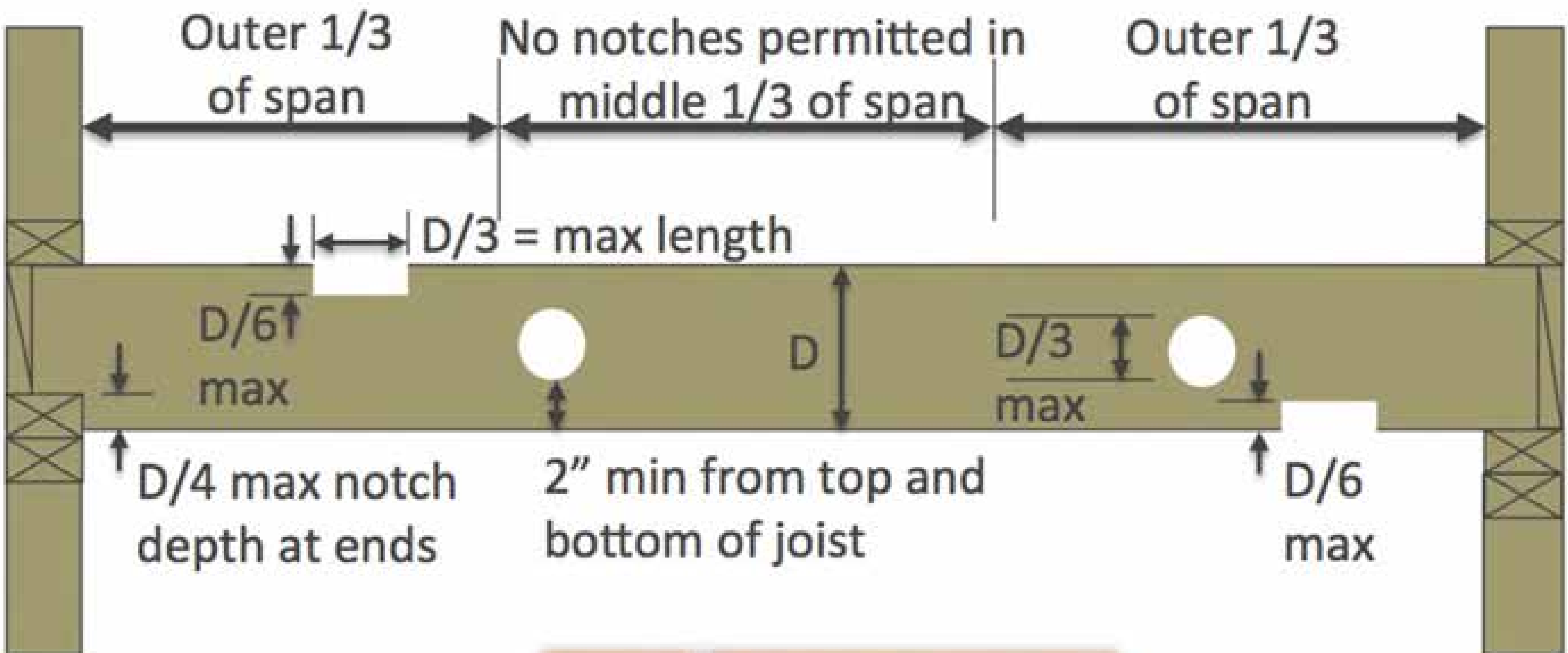
Spanning Members: Localized Stress

Moment critical zones: locations of maximum localized bending stresses which should not be affected with holes and notches

Shear: locations of maximum localized shear stresses which should not be affected with holes and notches



Allowable Floor Holes & Notches – IBC 2308

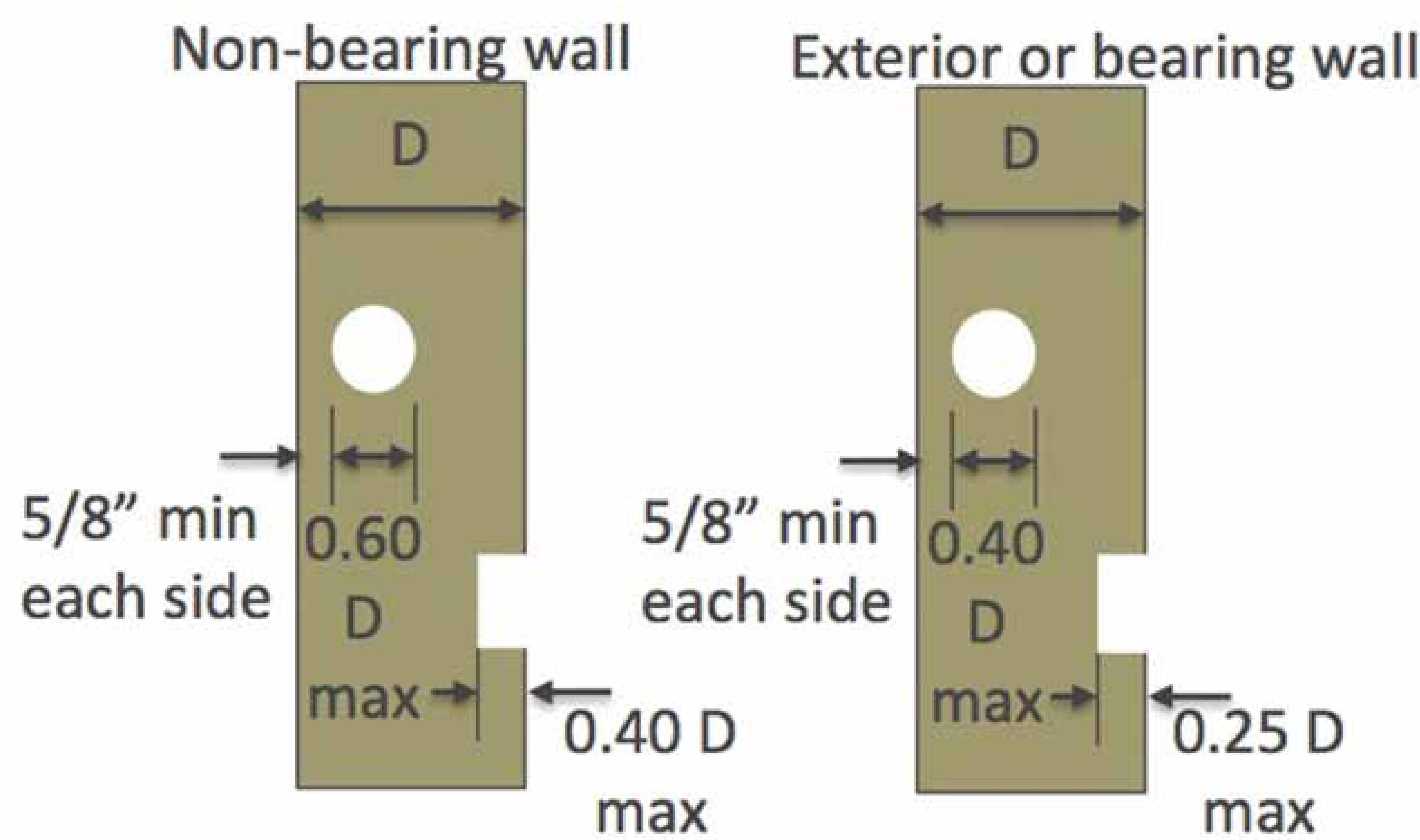


Per IBC 2012 2308.8.2
or IBC 2015 2308.4.2.4

Allowable Floor Holes & Notches – IBC 2308

Allowable Notches & Holes in Solid Sawn Floo			
Joist Size	Max Hole	Max Notch Depth	Max End Notch
2x6	1-3/4”	7/8”	1-3/8”
2x8	2-3/8”	1-1/8”	1-7/8”
2x10	3”	1-1/2”	2-1/4”
2x12	3-3/4”	1-7/8”	2-7/8’

Allowable Wall Holes & Notches – IBC 2308



Per IBC 2012 2308.9.10 & 2308.9.11
Per IBC 2015 2308.5.9 & 2308.5.10

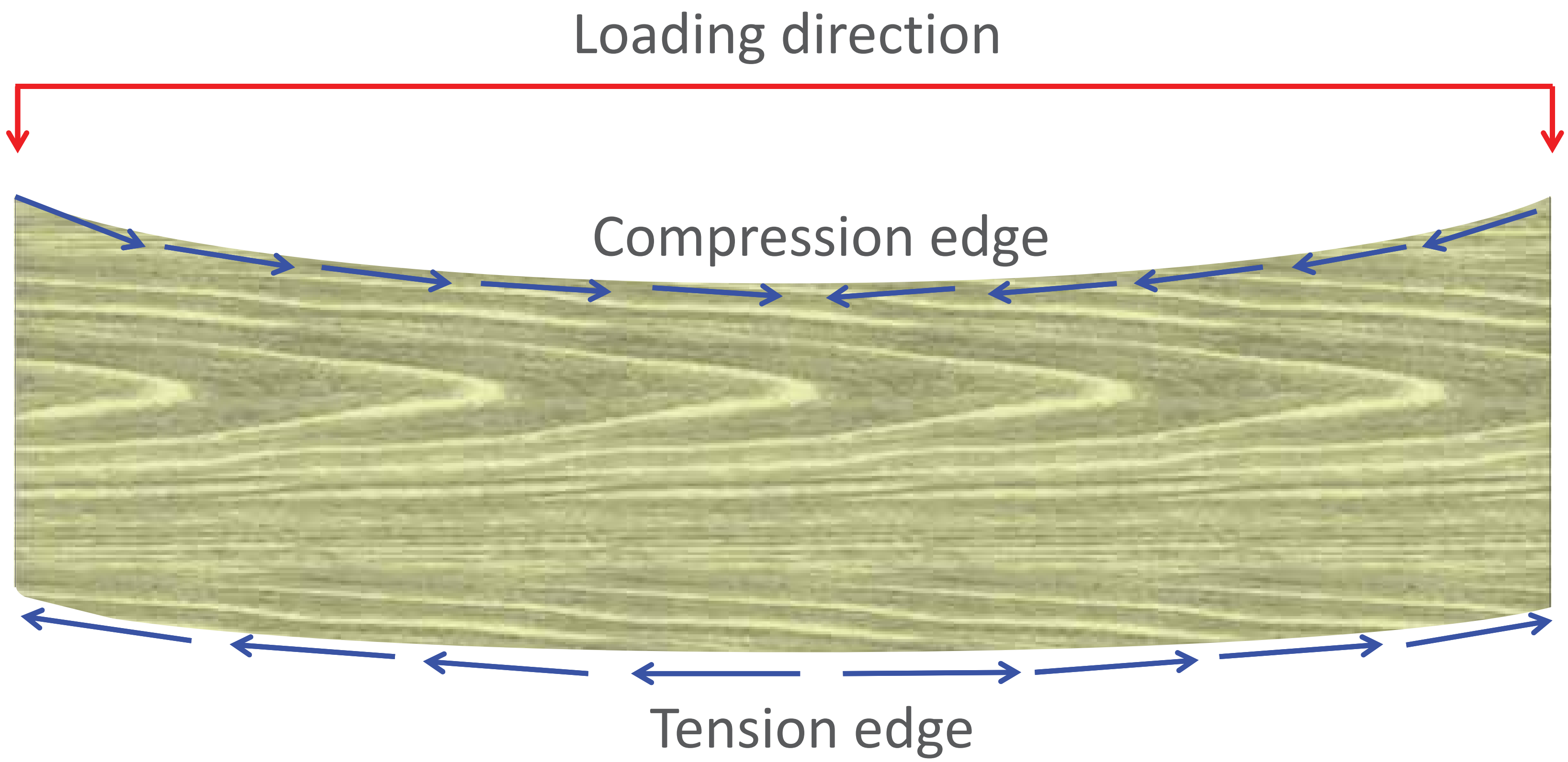
Allowable Wall Holes & Notches – IBC 2308

Allowable Notches & Holes in Solid Sawn Wall Studs
IBC 2012 2308.9.10 & 2308.9.11 / IBC 2015 2308.5.9 & 2308.5.10

Stud Size	Non-Bearing Wall		Exterior & Bearing Walls	
	Max Hole	Max Notch	Max Hole	Max Notch
2x4	2”	1-3/8”	1-3/8”	7/8”
2x6	3-1/4”	2-1/8”	2-1/8”	1-3/8”
2x8	4-1/4”	2-7/8”	2-7/8”	1-7/8”

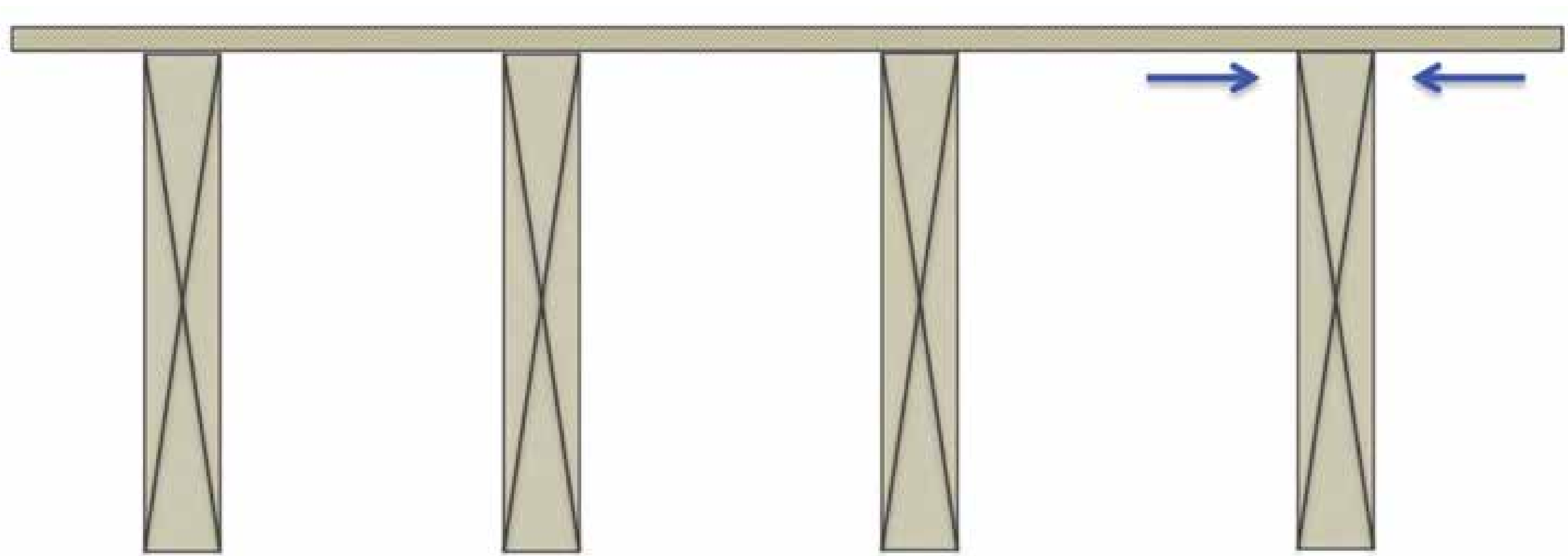
Floor Framing: Compression Edge Bracing

- Bending causes compression in one edge of member
- Compression can cause buckling; compression edge bracing resists buckling



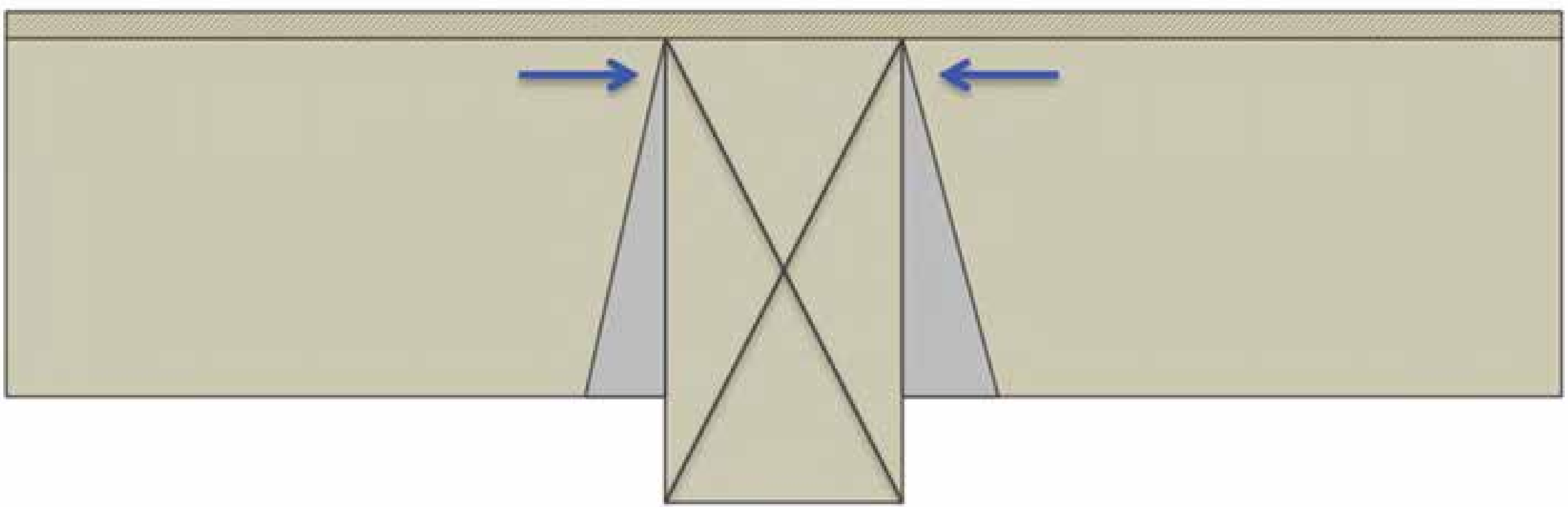
Floor Framing: Compression Edge Bracing

- Floor sheathing braces compression flange of floor joists
- Specify sheathing to framing fasteners sized to resist compression force



Floor Framing: Compression Edge Bracing

- Floor joists brace compression flange of floor beam
- Floor joists installed tight to beam resist beam compression force

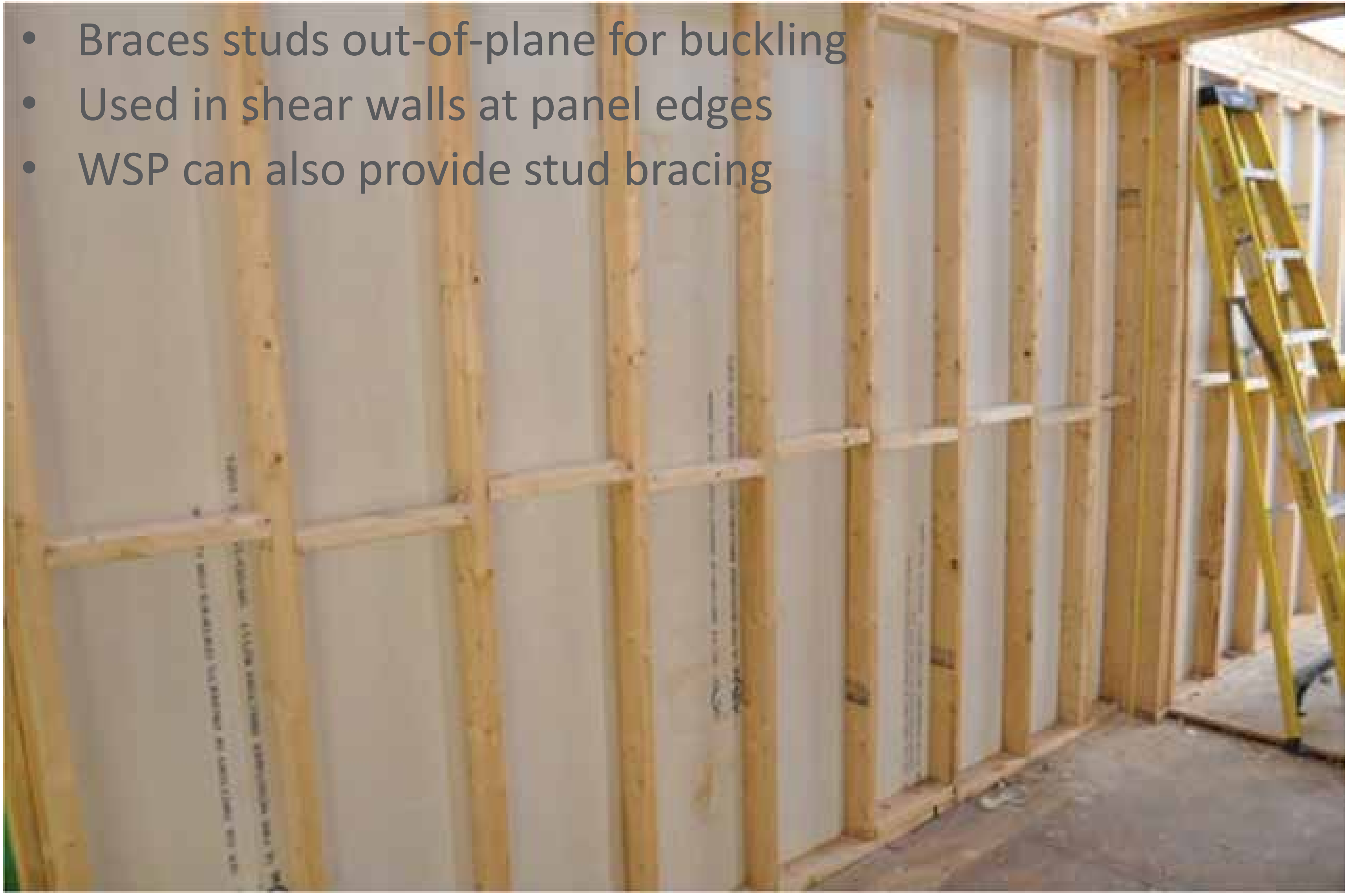


Floor Framing: Blocking & Bracing

- Stiffens floor & prevents joist rotation and out-of-plane buckling
- Required at joist ends and at each support per IBC 2012 2308.8.2 / IBC 2015 2308.4.2.3
- Best practice is to install at 8'-10' o.c. and at concentrated loads
- Solid blocking, wood cross bracing, light gauge steel cross bracing

Wall Framing: Blocking & Bracing

- Braces studs out-of-plane for buckling
- Used in shear walls at panel edges
- WSP can also provide stud bracing

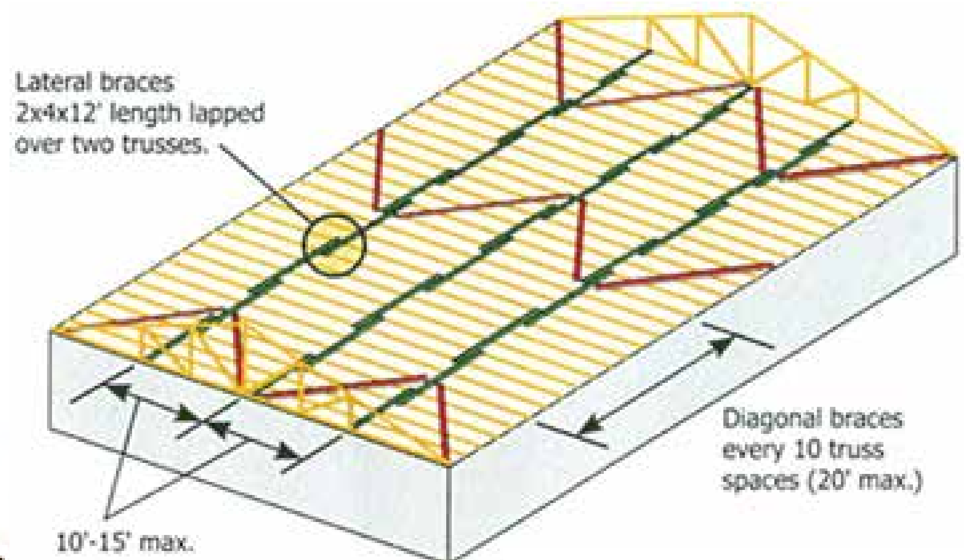


Trusses: Blocking & Bracing

- Trusses may require global and local bracing
- Global bracing provides overall roof/floor structure stability (unique to trusses often due to their size)
- Bottom chord bracing, sway bracing

Trusses: Blocking & Bracing

- Local bracing addresses webs in compression



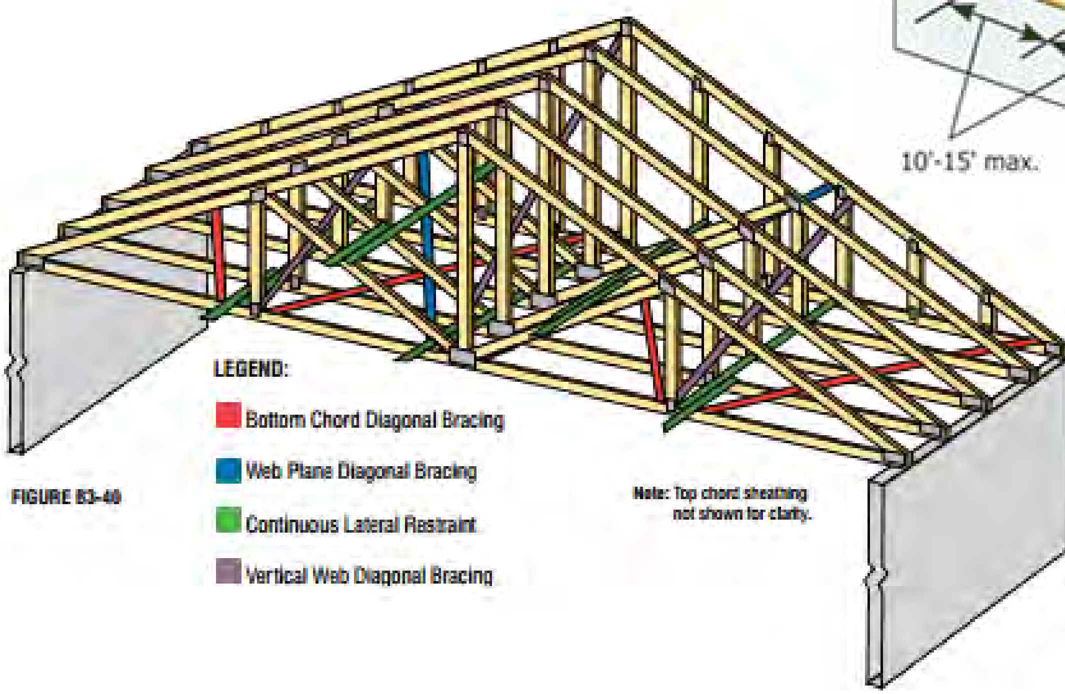
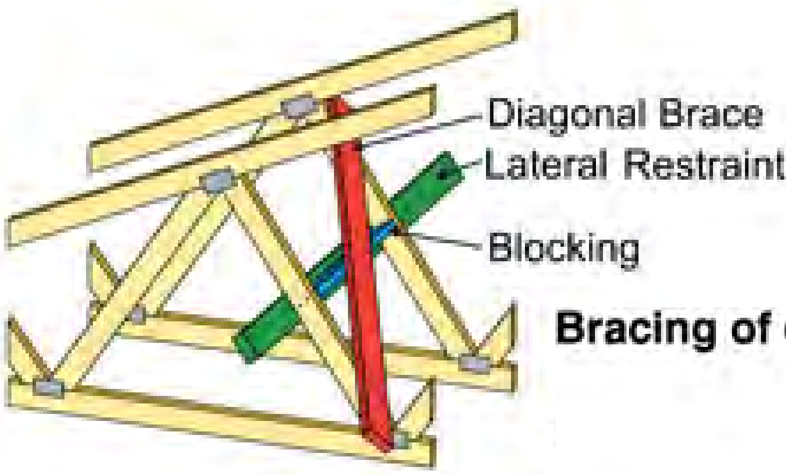


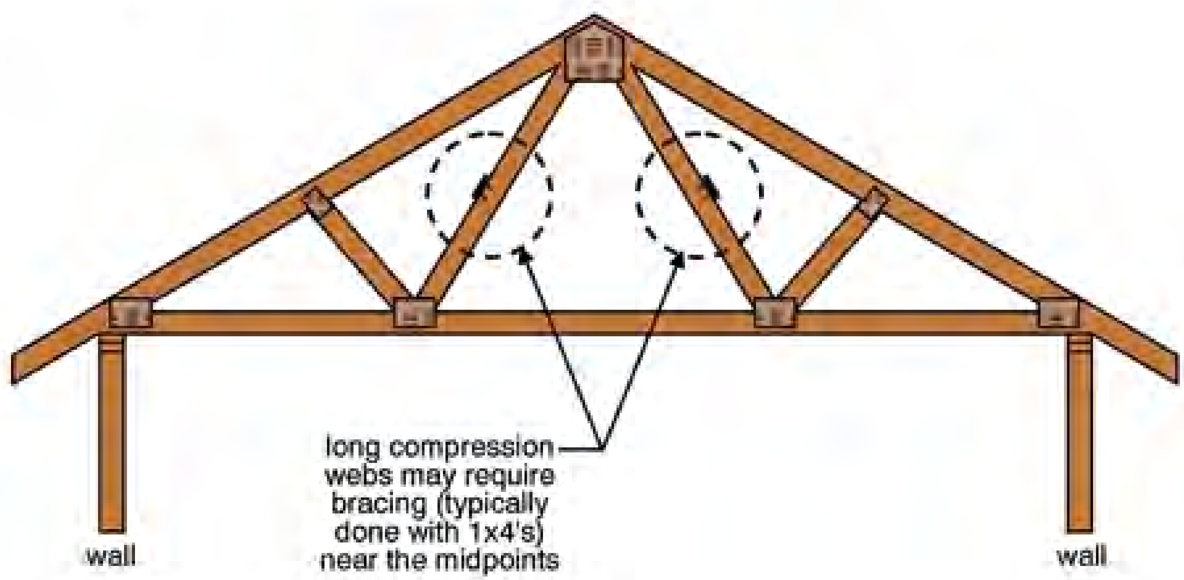
FIGURE B3-40

Trusses: Blocking & Bracing

- Additional diagonal bracing for web braces may be required

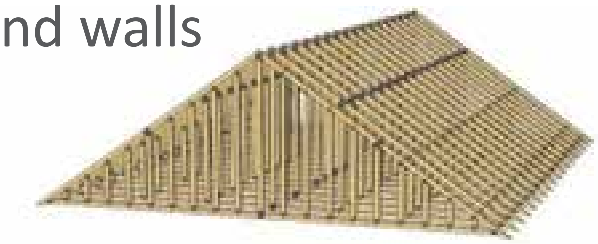


Bracing of compression webs



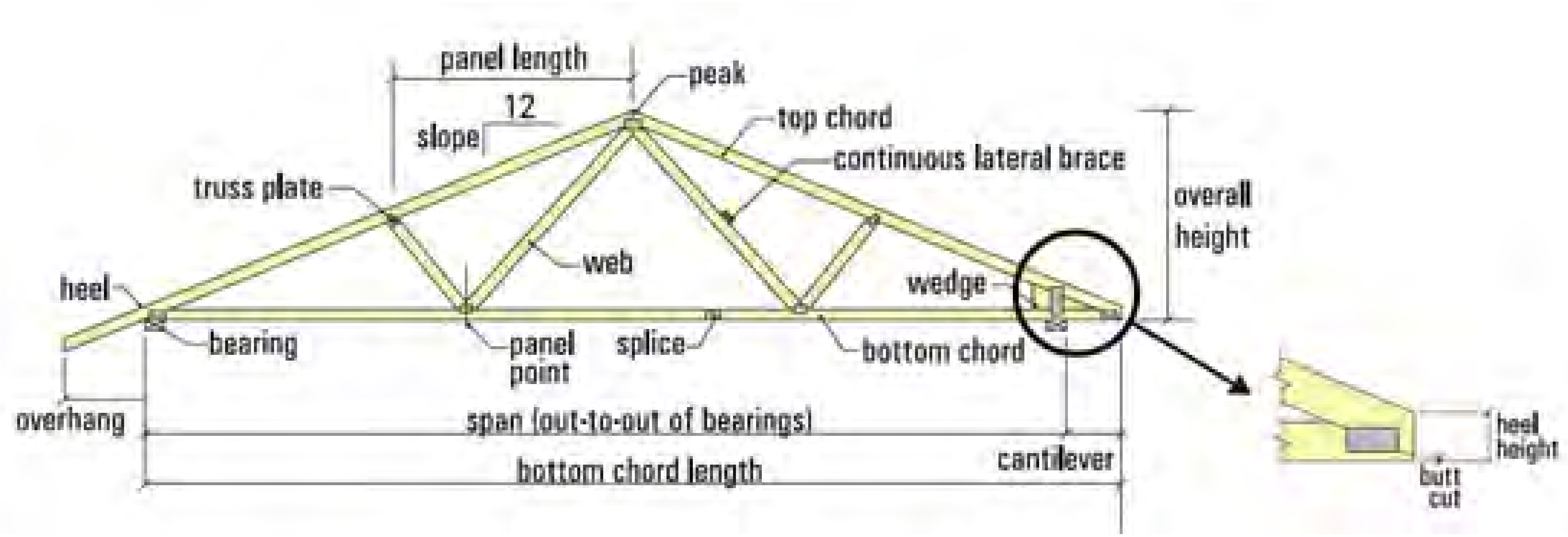
Trusses: Additional Bracing Considerations

- Piggyback trusses: typically required for trusses over 10' – 12' tall (transportation limitation)
- Gable end diagonal bracing at gable end walls
- Parallel chord truss strong backs
- Temporary construction bracing



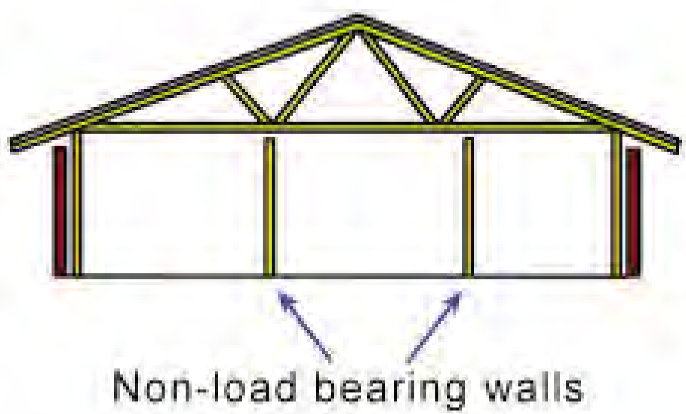
Trusses: Diagrams, Components

- Drawings should indicate truss dimensions (span, overhang, height), spacing, slope, bearing conditions, required web layout, loads, codes
- Three main components: chords, webs, & plates
- Applied components: sheathing, purlins, bracing, uplift connectors

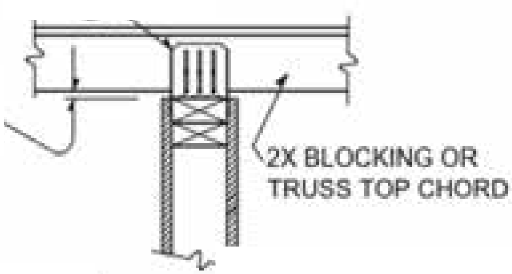


Non-Load Bearing Partitions

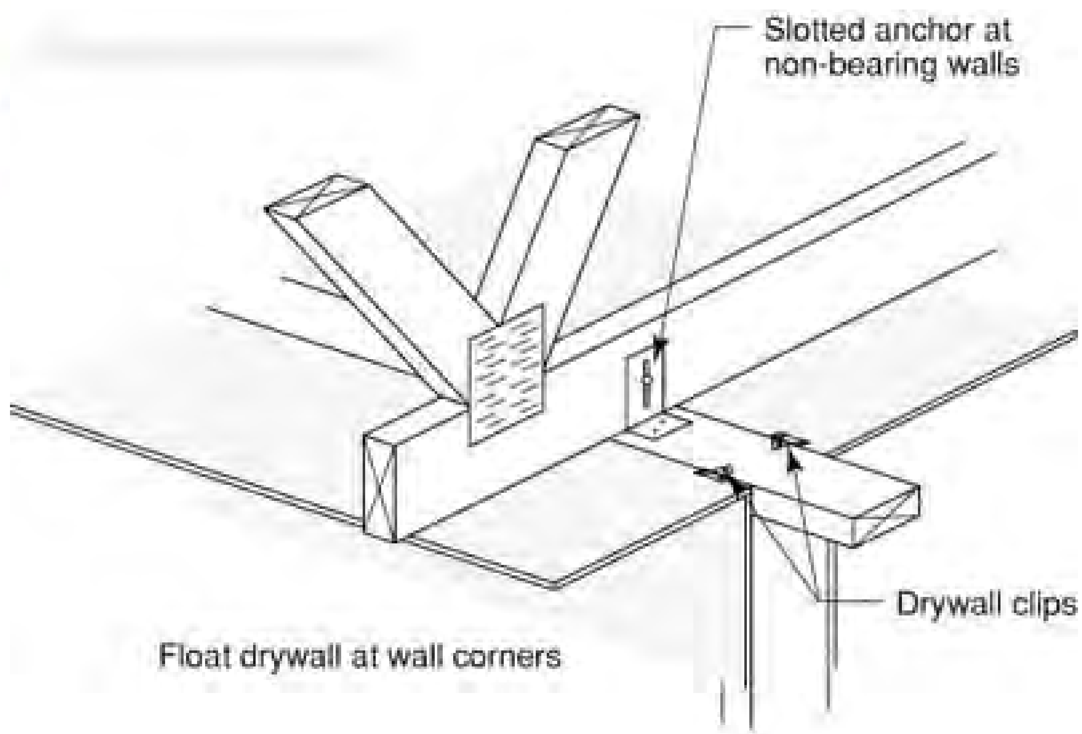
- Important to verify that “idealized” conditions are achieved
- Partitions remain non-load bearing
- Provide slip connections; limit finish damage, undesired structural load redistribution



Size gap per anticipated framing deflection

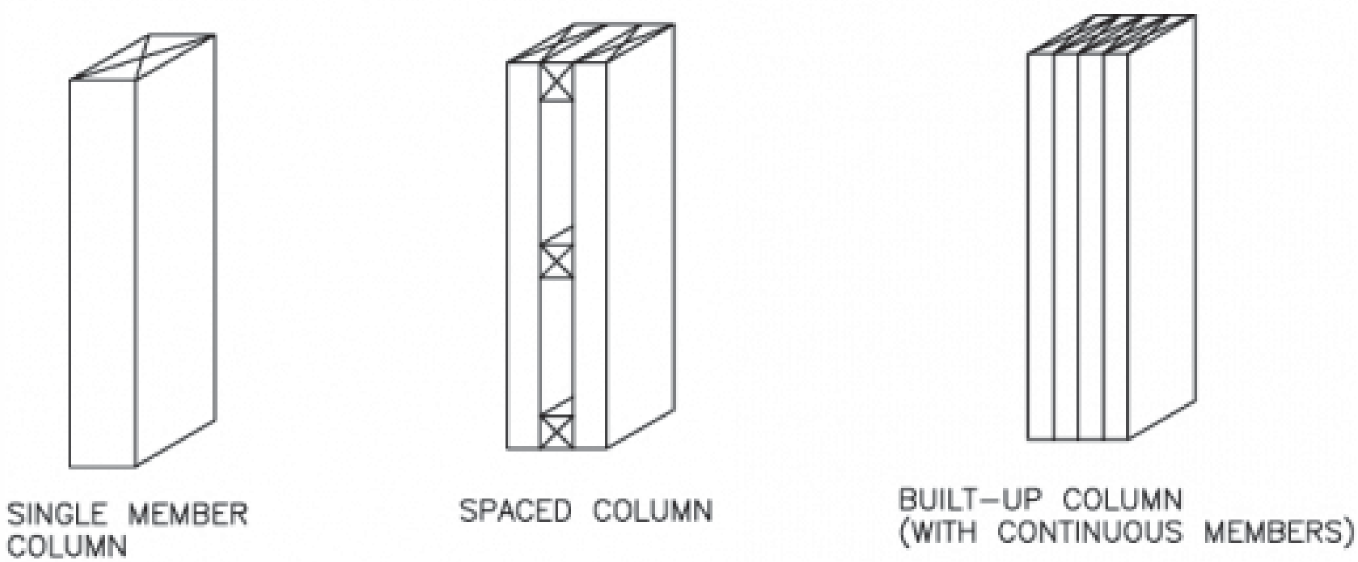


Top of Wall Detail



Built-Up Members

- Direction of load (perp. or parallel to multi-ply interfaces) determines fastener design
- Bending axis parallel to interface axes requires shear flow analysis
- Many ways to optimize multi-ply members: built-up, t-members, I-shape

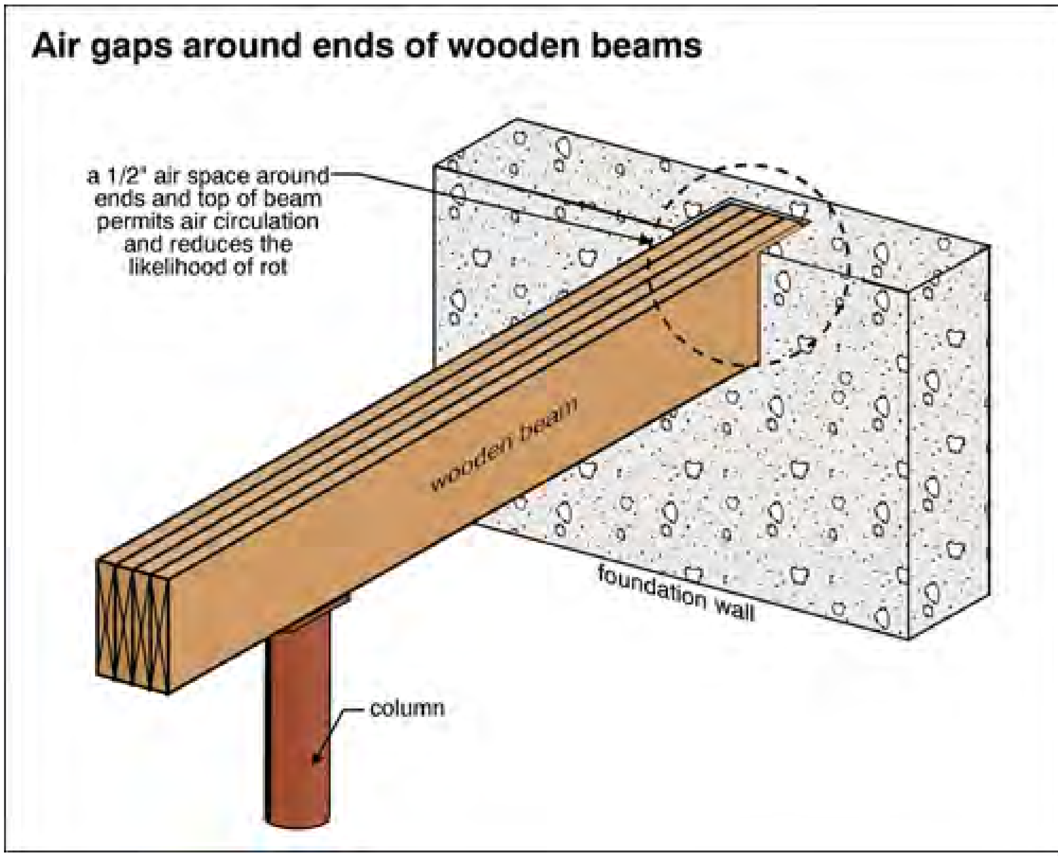


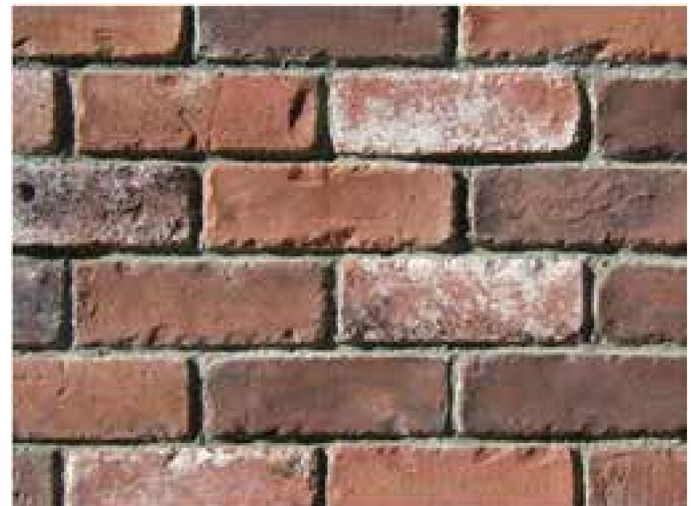
Wood in Contact with Other Materials

- IBC 2012 2304.11 / IBC 2015 2304.12 requires preservative treated or naturally durable wood when in contact with foundation walls

Wood in Contact with Other Materials

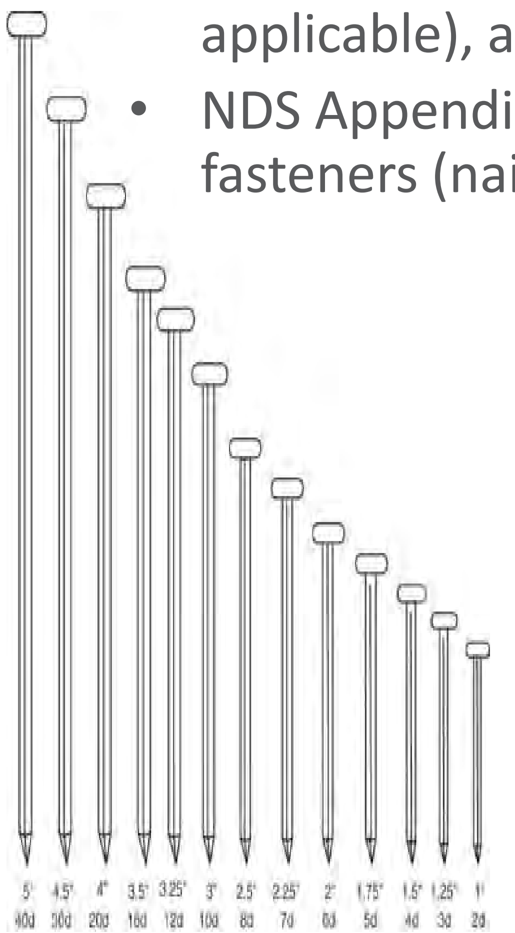
- Detail to allow drying, venting, differential movement
- Avoid moisture traps

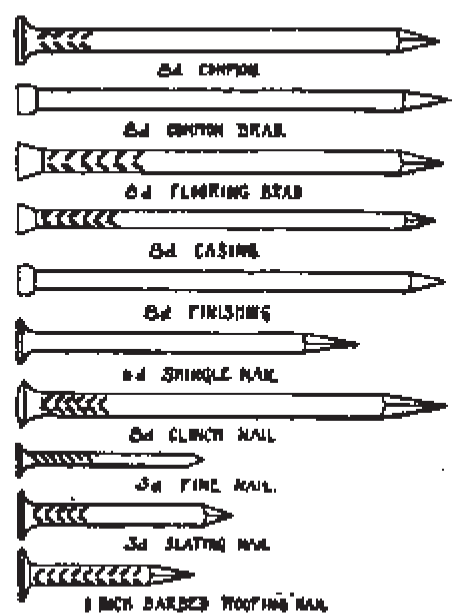


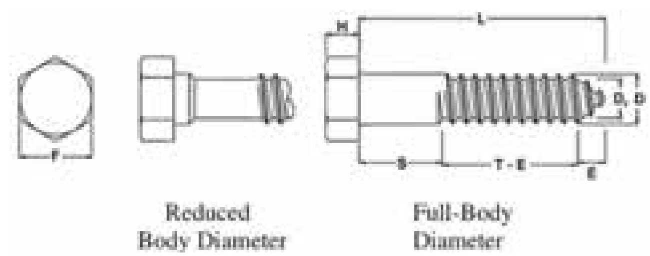


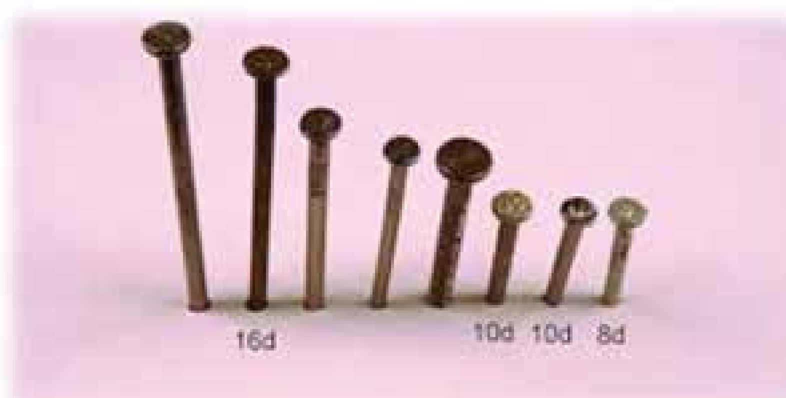
Connections: Specification

- Fastener specification should include all variables, not just a size (10d) as there can be many different options in a size group
- Fastener length, diameter, finish, material, thread length (if applicable), and thread pitch (if applicable) are all variables
- NDS Appendix L contains dimensions for typical dowel type fasteners (nails, wood screws, lag screws, bolts)



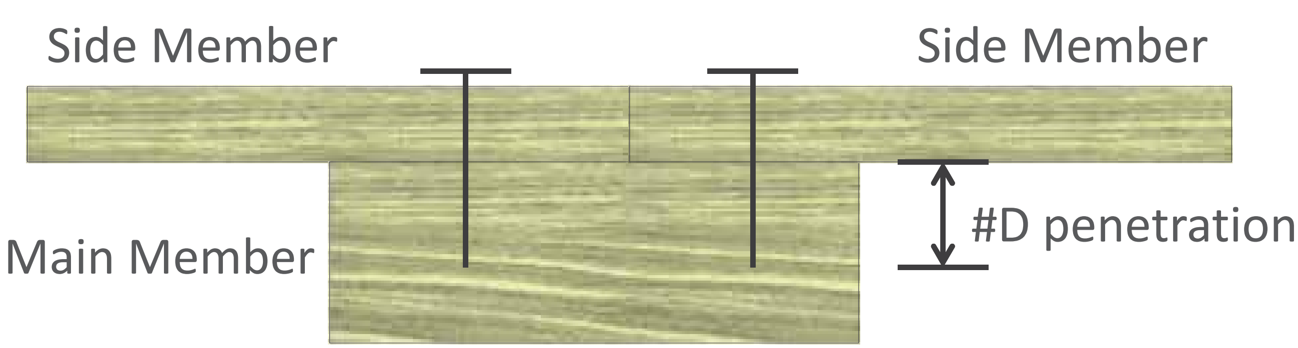


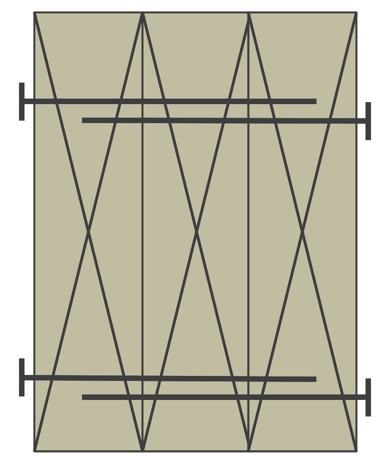




Connections: Length Specification

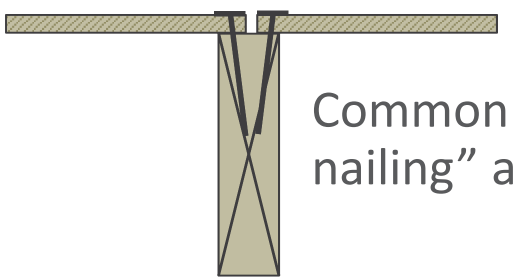
- Penetration measured as distance fastener extends in *Main Member*
- Minimum penetration generally 4D (lag screws) to 6D (nails, wood screws)
- Minimum penetration for <u>no capacity reduction</u> generally 8D (lag screws) to 10D (nails, wood screws)
- Consider effects of fasteners on both faces of multi-ply members – stagger (vertically, horizontally, or both)



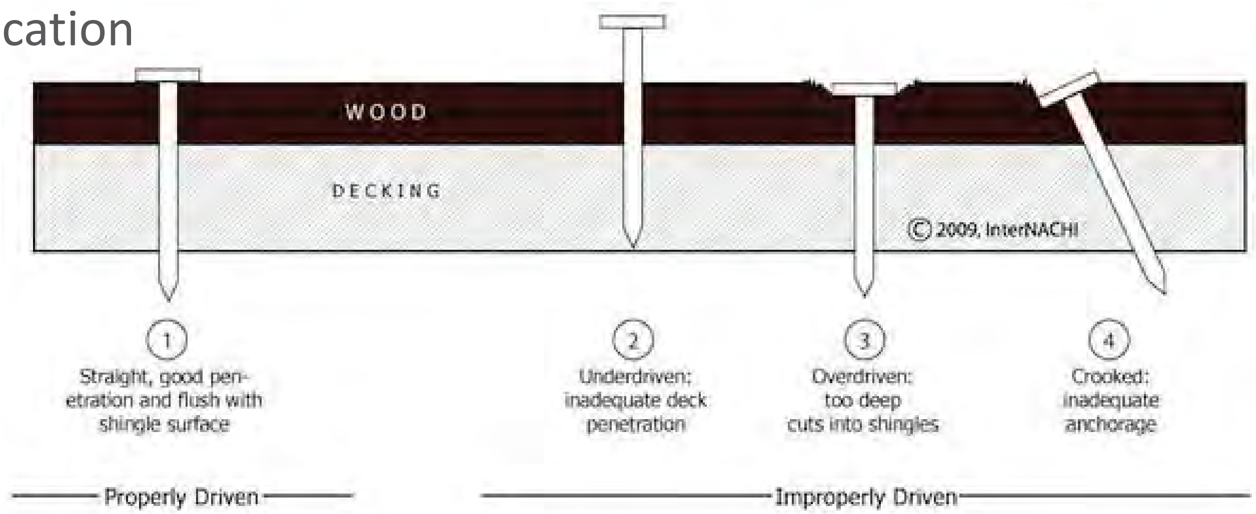


Connections: Proper Installation

- Fastener alignment and head seating are key to achieving full fastener capacity
- Detail connections to allow adequate edge, end distances, avoid wood splitting
- Per Teco, if 50% of fasteners are overdriven to 1/8”, over 8% reduction in shear capacity results

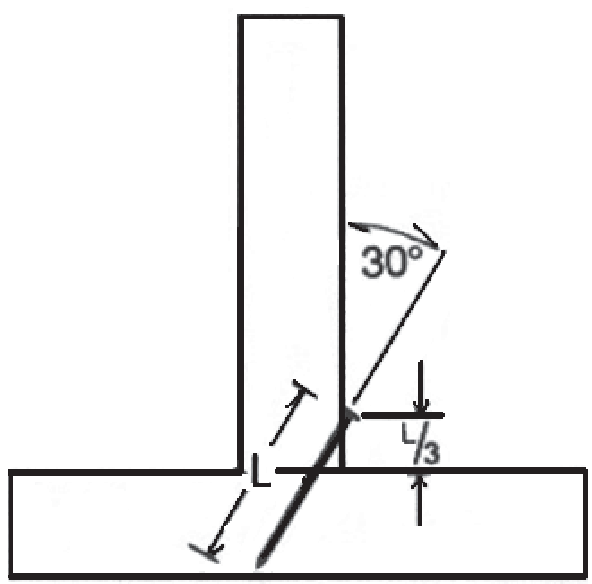


Common “slant nailing” application



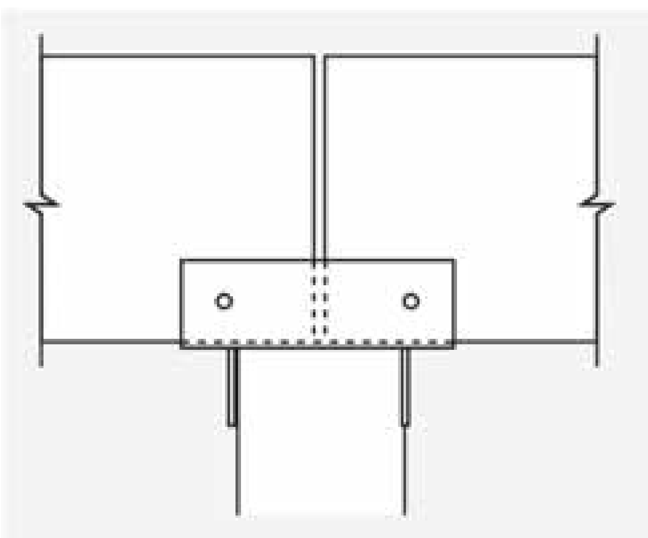
Connections: Toe Nails

- Recommended install 30° from side member longitudinal direction
- Nail penetrates side member a distance 1/3 its length from the joint
- Toe nail reduction factor, C_{tn}, = 0.67 for withdrawal, 0.83 for shear (NDS 2012 11.5.4 / NDS 2015 12.5.4)



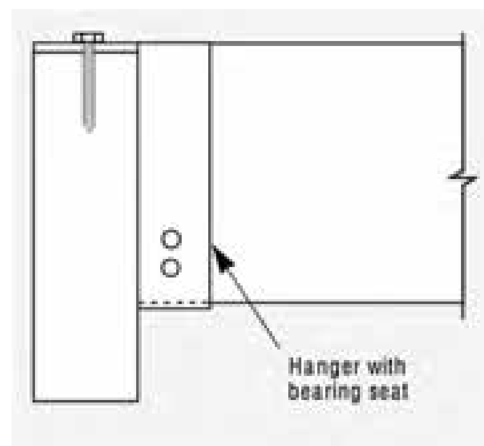
Connections: Shrinkage

- Consider shrinkage in connected members
- Avoid restraining shrinkage in connection – place connections on one edge of member rather than on both edges
- Best practice is to connect to lower half of beams, use of slotted holes aids in avoiding shrinkage cracks
- Single row of fasteners (vs. multiple rows) in non-dried lumber recommended



Source: APA

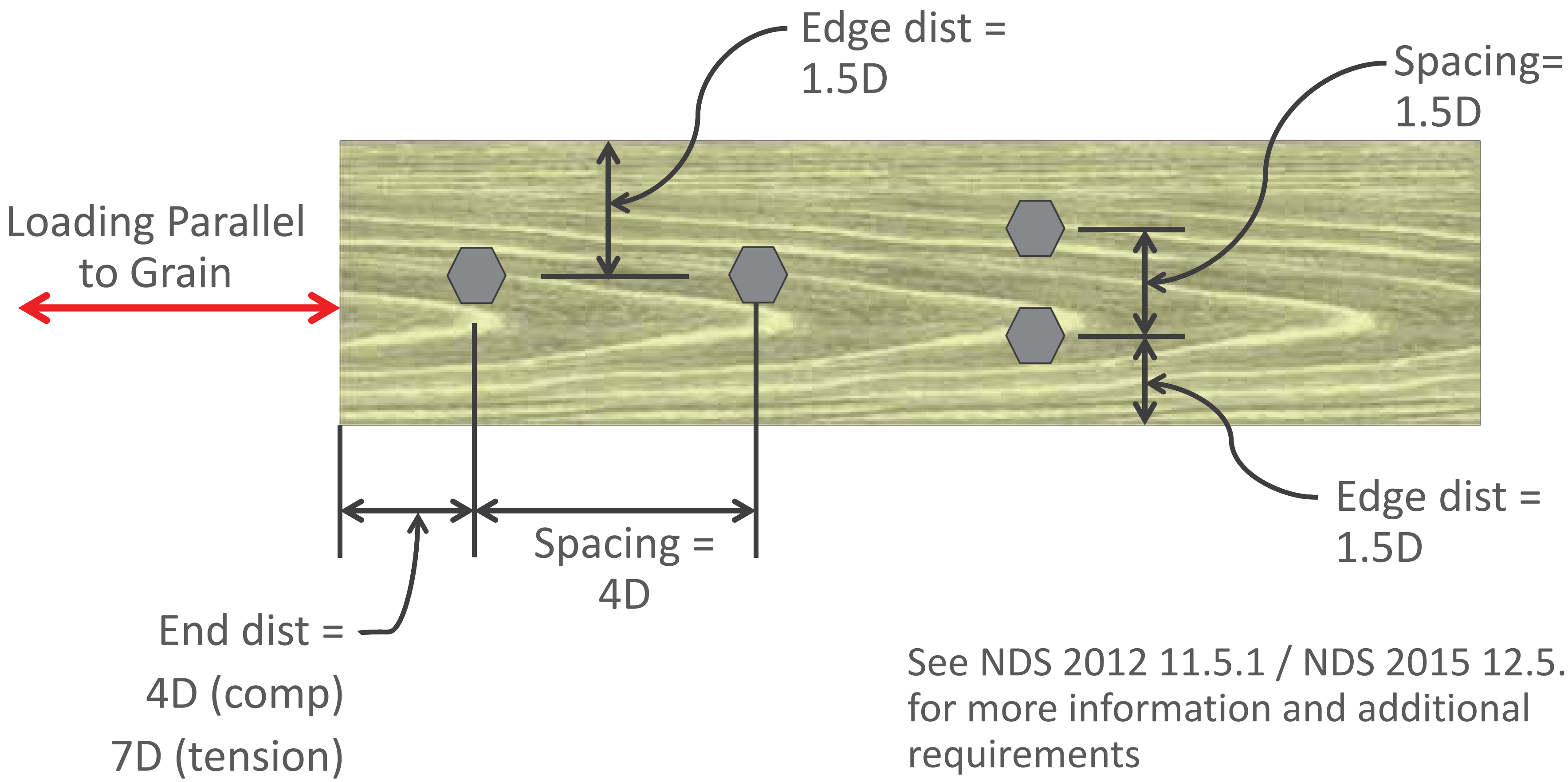
Source: Strongtie.com



Source: APA

Dowel Type Connections: Location

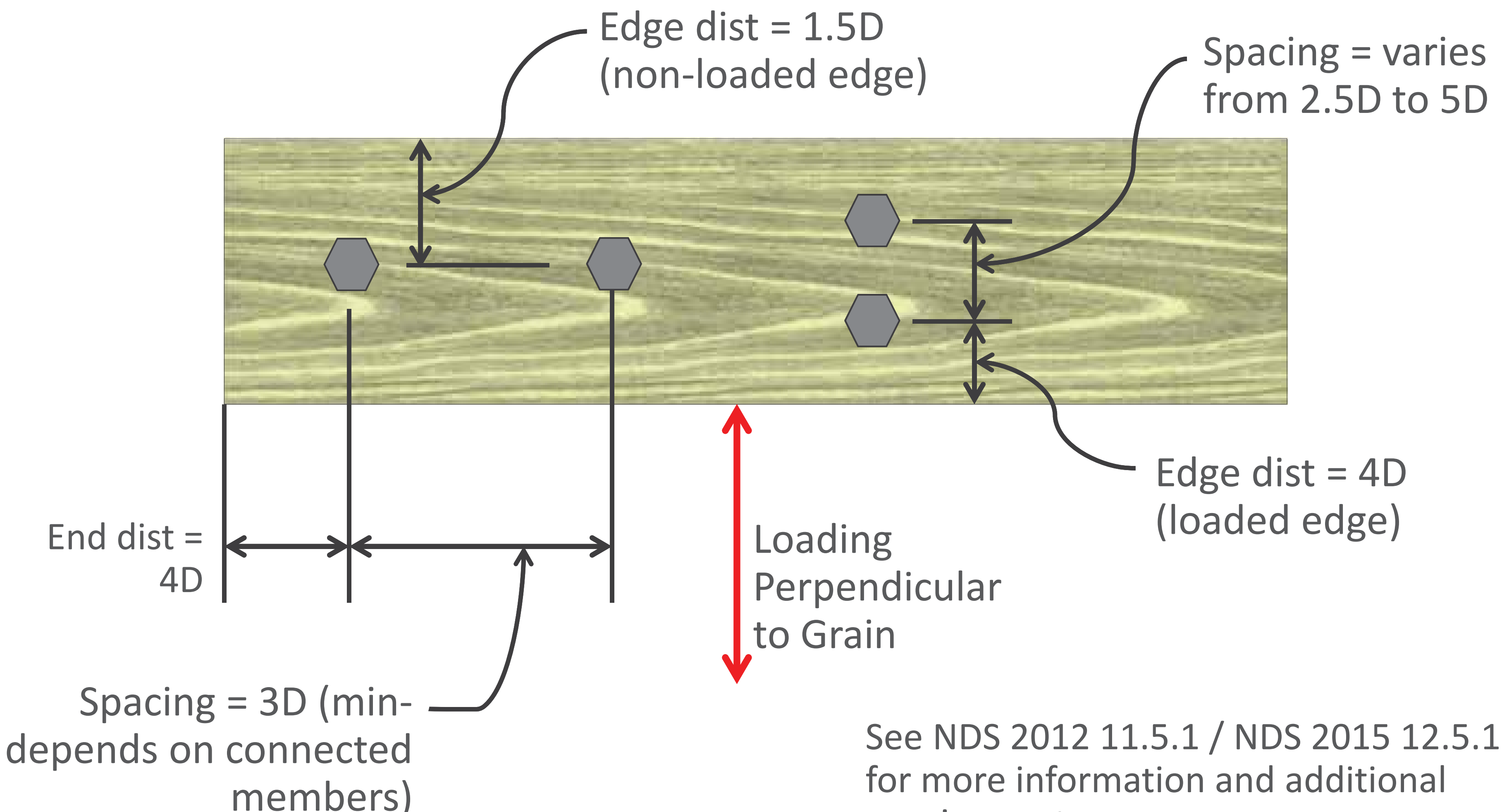
- Three main location considerations: spacing, edge distance, end distance
- Spacing considerations between fasteners in a row and between rows of fasteners



See NDS 2012 11.5.1 / NDS 2015 12.5.1 for more information and additional requirements

Dowel Type Connections: Location

- Loading perpendicular to grain fastener location considerations



See NDS 2012 11.5.1 / NDS 2015 12.5.1 for more information and additional requirements

Moisture Control Considerations

- Detail connections to avoid moisture traps
- Avoid end grain exposure to moisture by use of hold off past bases, beam end caps

Moisture Control Considerations

- Minimize storage of material on site where rain and standing water can increase moisture content
- Keep unused framing material covered
- Immediately remove any standing water from floor framing after rain showers

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Anthony Harvey, PE
Regional Director
anthony.harvey@woodworks.org

Visit www.woodworks.org for more educational materials, case studies, design examples, a project gallery, and more

Copyright Materials

Introducing Cross Laminated Timber

New Opportunities for Timber Construction

Anthony Harvey, PE

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This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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

Course Description

Cross laminated timber (CLT) is an engineered wood building system designed to complement light- and heavy-timber framing options. Because of its high strength and dimensional stability, it can be used as an alternative to concrete, masonry and steel in many building types. This presentation will introduce CLT with a series of project examples that demonstrate its use and associated benefits in a range of applications. Information on manufacturing, specification and code-related considerations will also be discussed.

Learning Objectives

1. Review completed CLT projects that demonstrate a range of applications and system configurations.
2. Discover how CLT can be used under current and future building codes and standards.
3. Discuss benefits of using CLT in place of concrete and steel, including structural versatility, prefabrication, lighter carbon footprint and reduced labor costs.
4. Discuss the fire characteristics of CLT, including the benefits of charring, current seismic approaches that can be used for CLT buildings, and how the acoustic and moisture performance of CLT assemblies can inform the design of a project.

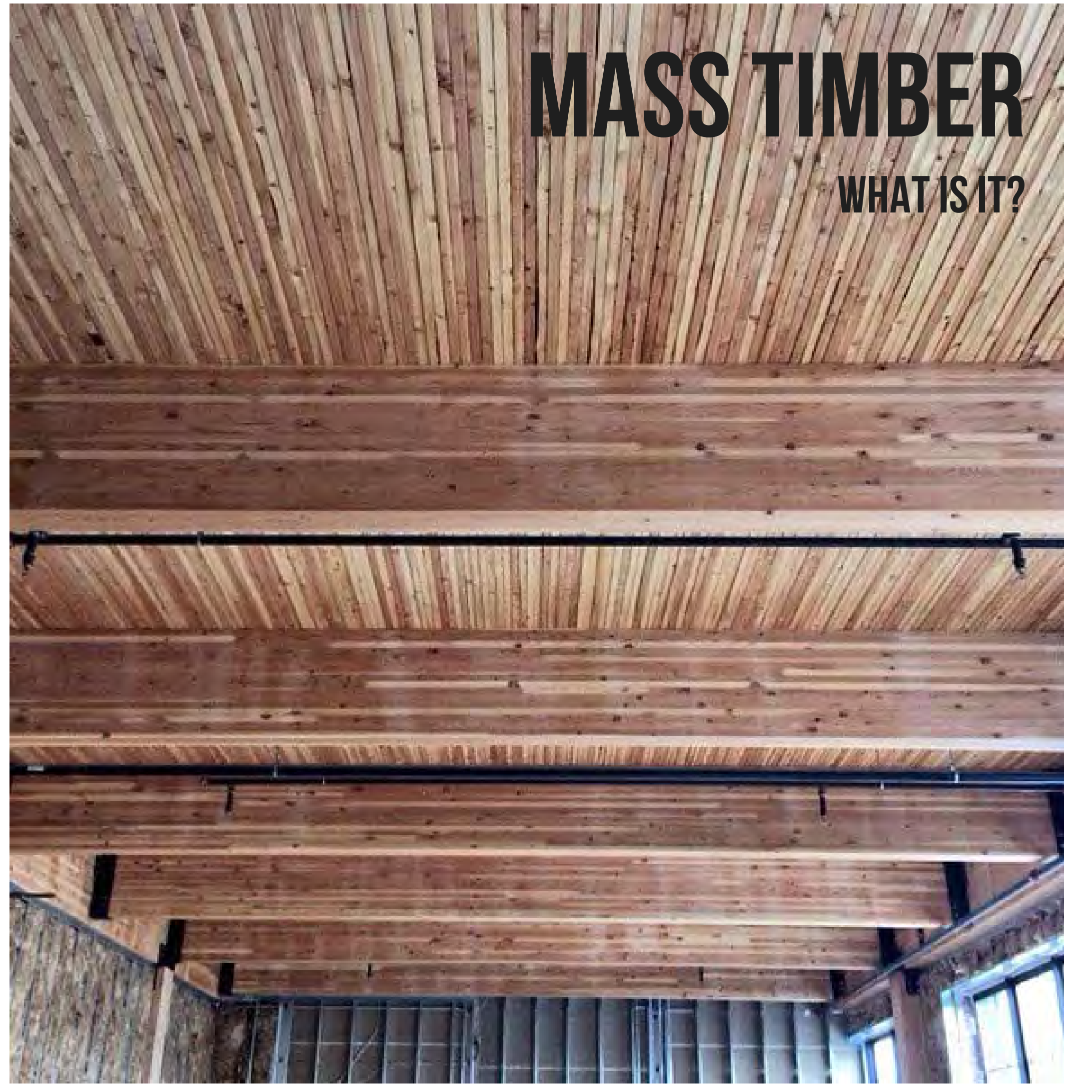
Outline

- What is CLT?
  - Mass Timber
  - The Appeal
  - History
  - Availability
- Using CLT
  - Project Examples
  - Best applications
  - Cost effective design
  - Building Codes and Standards

Outline

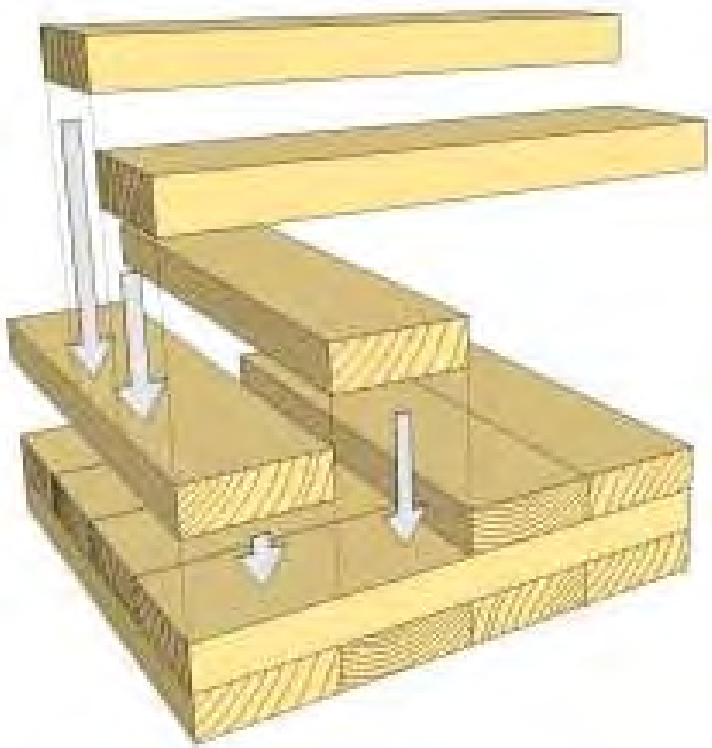
- What is CLT?
  - Mass Timber
  - The Appeal
  - History
  - Availability
- Using CLT
  - Project Examples
  - Best applications
  - Cost effective design
  - Building Codes and Standards

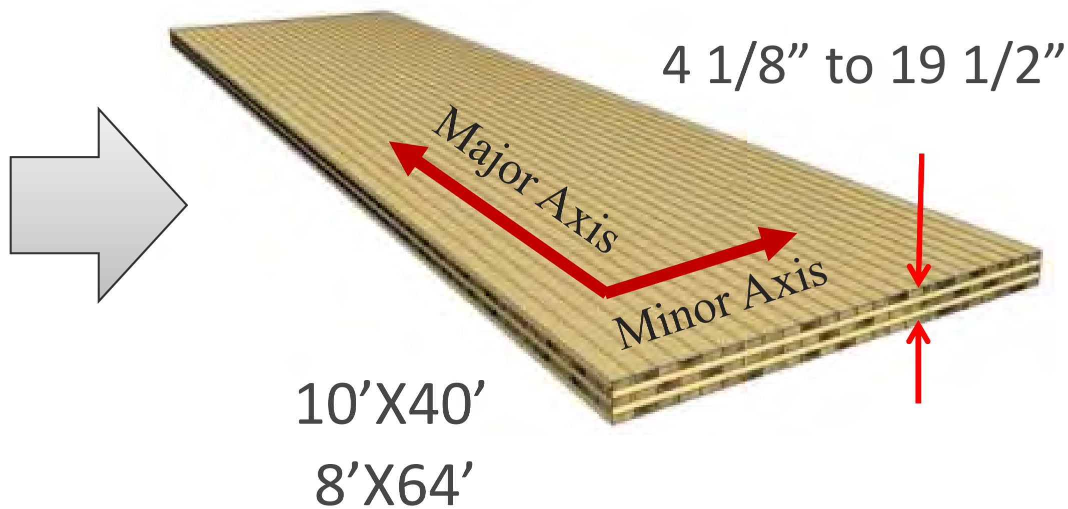
MASS TIMBER IS A CATEGORY OF FRAMING STYLES OFTEN USING SMALL WOOD MEMBERS FORMED INTO LARGE PANELIZED SOLID WOOD CONSTRUCTION INCLUDING CLT, NLT OR GLULAM PANELS FOR FLOOR, ROOF AND WALL FRAMING



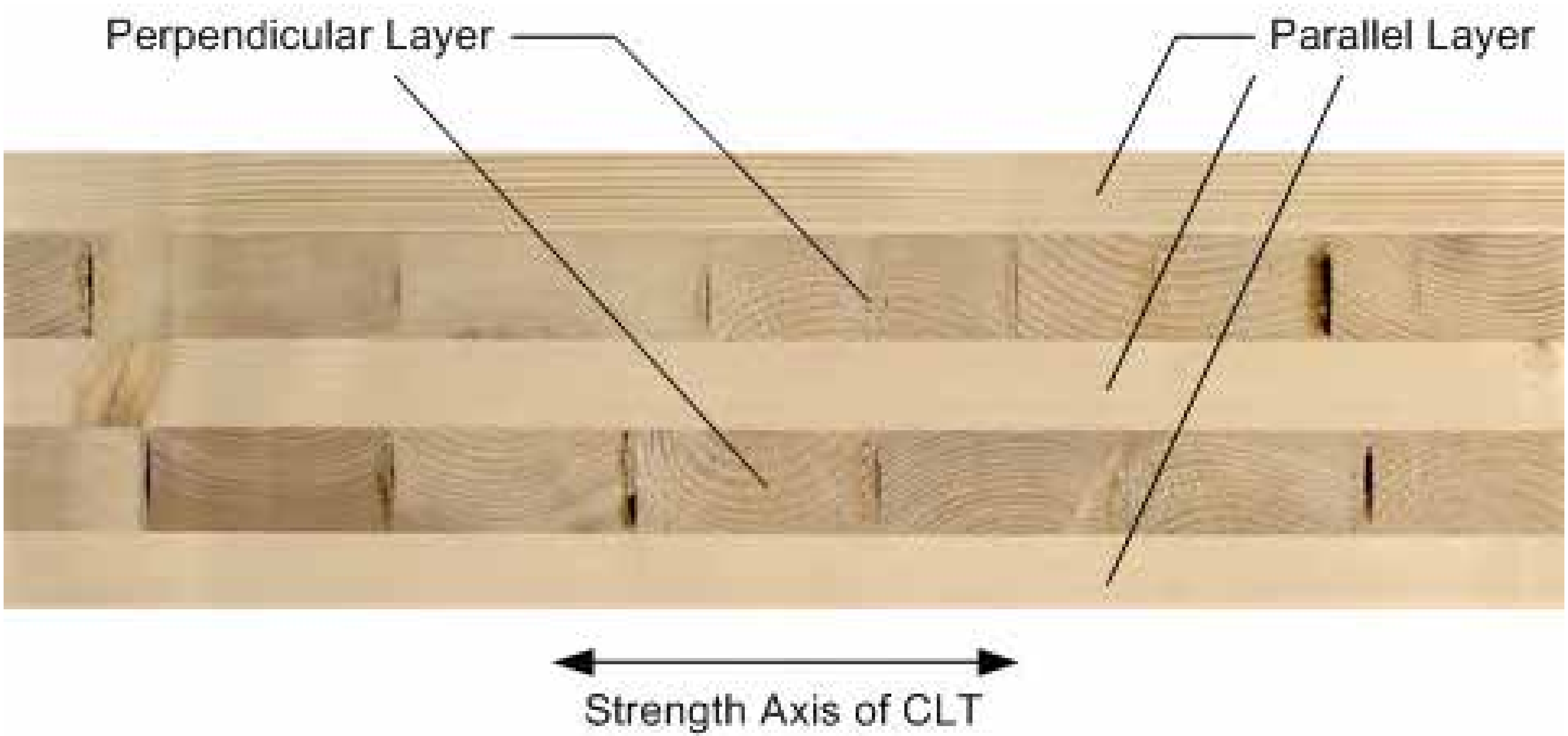
What is Cross Laminated Timber (CLT)?

- Solid wood panel
- 3 layers min. of solid sawn lams
- 90 deg. cross-lams
- Similar to plywood sheathing



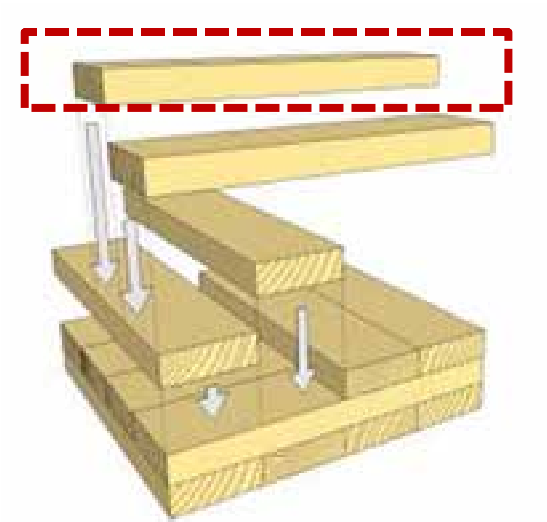


CLT Composition




CROSS LAMINATED TIMBER
LUMBER IN CLT IS FINGER JOINTED
TYPICALLY NOT EDGE GLUED

Structural Composition of CLT



Laminations: (Per PRG 320-2012)

5/8” to 2” thick

2.4” - 9.5” wide

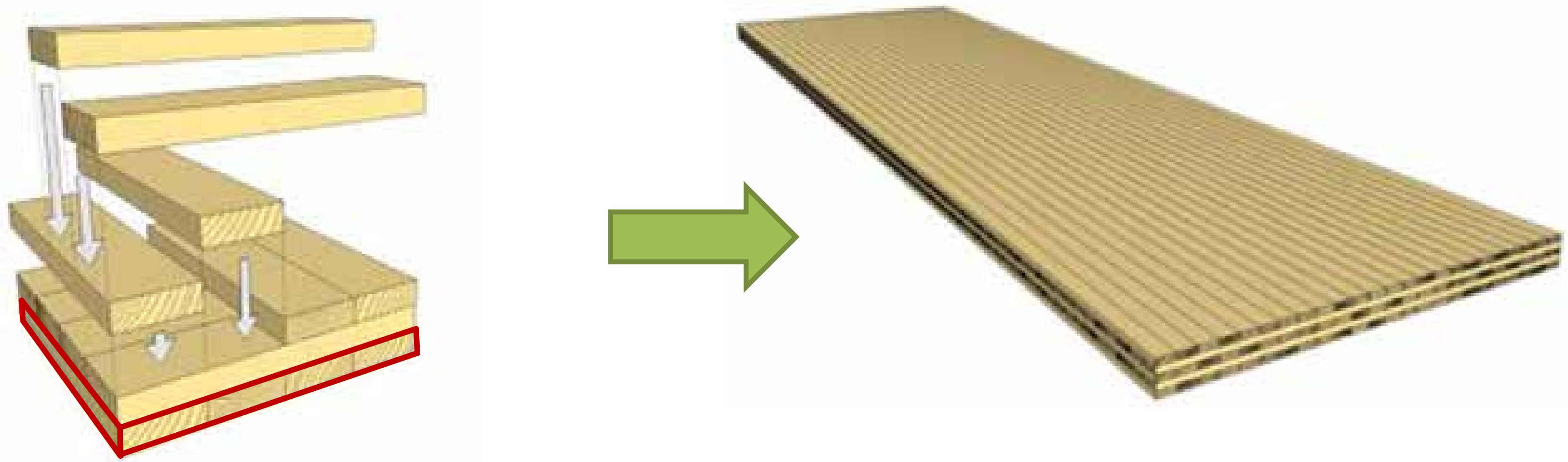
Machine Stress Rated or Visually Graded Dimensional Lumber or SCL

Dried to 12% Moisture Content before layup.

A common NA thickness is 1 3/8” (planed 2x stock)

PRG 320 provides thickness to width requirements of laminations

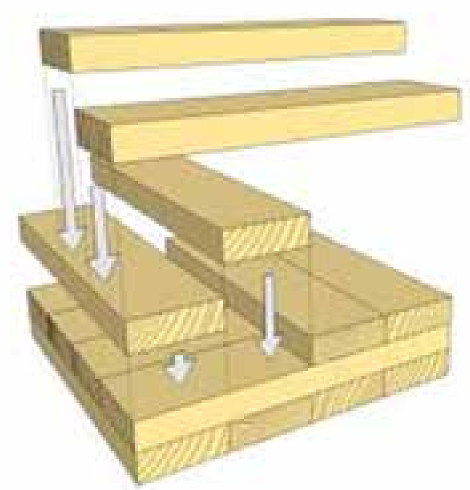
Structural Composition of CLT

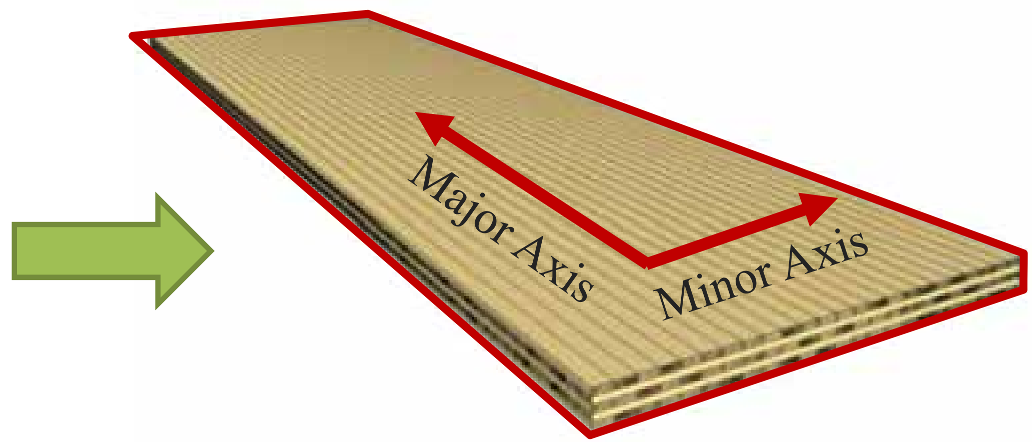


Layers: (Per PRG 320-2012)

- Oriented in orthogonal arrangement
- Odd number of symmetric layers most common
- Double parallel exterior layers permitted
- Unbalanced layup permitted
- Reference glu-lam adhesive standard (AITC 405)

Structural Composition of CLT





Panels, also known as Billets.

20 inch max thickness in PRG 320
Up to 8 ft or more wide per manufacturer and shipping
Up to 40 ft or more long per manufacturer and shipping
Major axis: stronger, stiffer, usually long direction
Minor axis: less strong and stiff, usually short direction

MASS TIMBER PRODUCTS

CROSS-LAMINATED TIMBER (CLT)

COMMON CLT LAYUPS

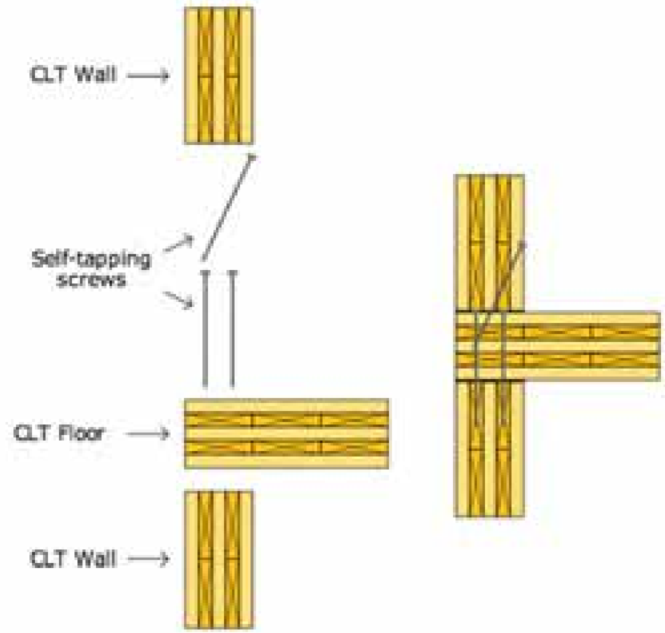
3-PLY 3-LAYER

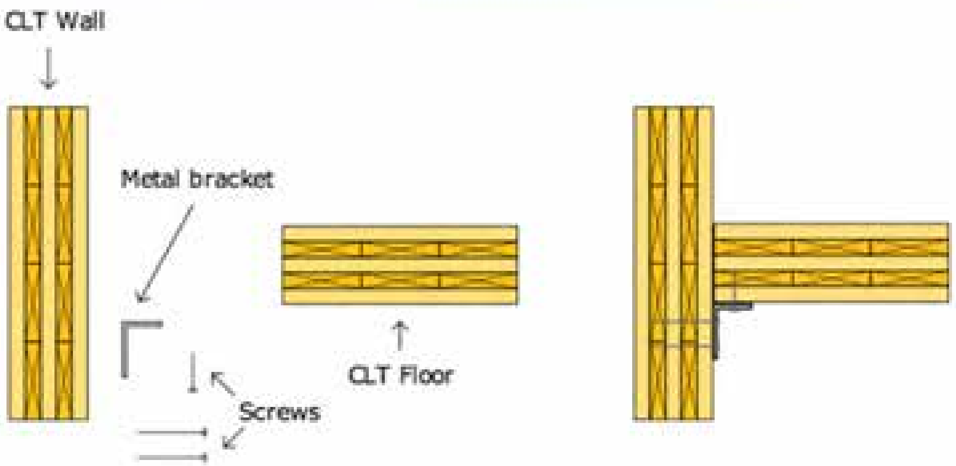
5-PLY 5-LAYER

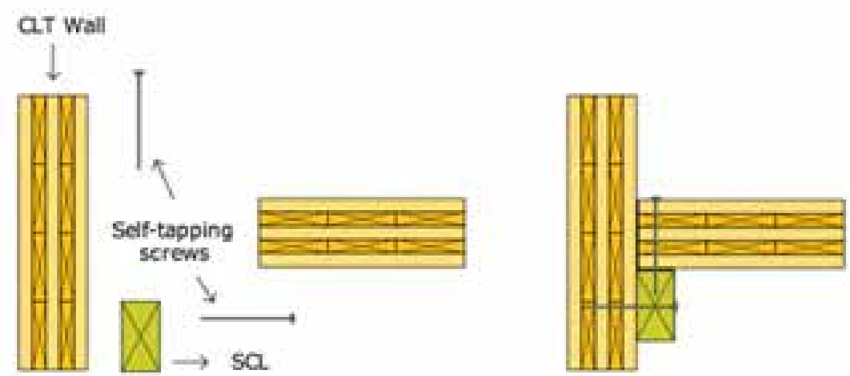
7-PLY 7-LAYER

9-PLY 9-LAYER

How to use CLT - Assembly







Source: US CLT Handbook

What is the appeal of CLT?

Sustainability

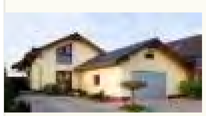
- Embodied Carbon

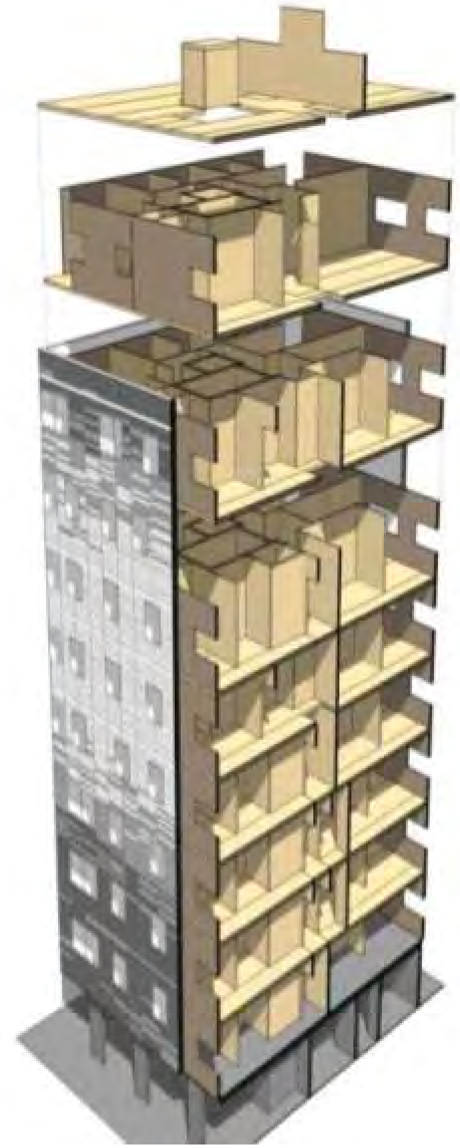
Performance

Construction Efficiency

Reduced Embodied Carbon

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



Stadhaus, London, UK
Architect: Waugh Thistleton Architects
Photo credit: Waugh Thistleton Architects


BULLITT CENTER
SEATTLE, WA
PHOTO CREDIT: BULLITT CENTER

BULLITT CENTER

SEATTLE, WA

BUILDING INFO:

OFFICE BUILDING

4 STORIES MASS TIMBER OVER 2 STORIES CONCRETE

52,000 SF

NET ZERO

LIVING BUILDING CHALLENGE CERTIFIED

TYPE IV CONSTRUCTION

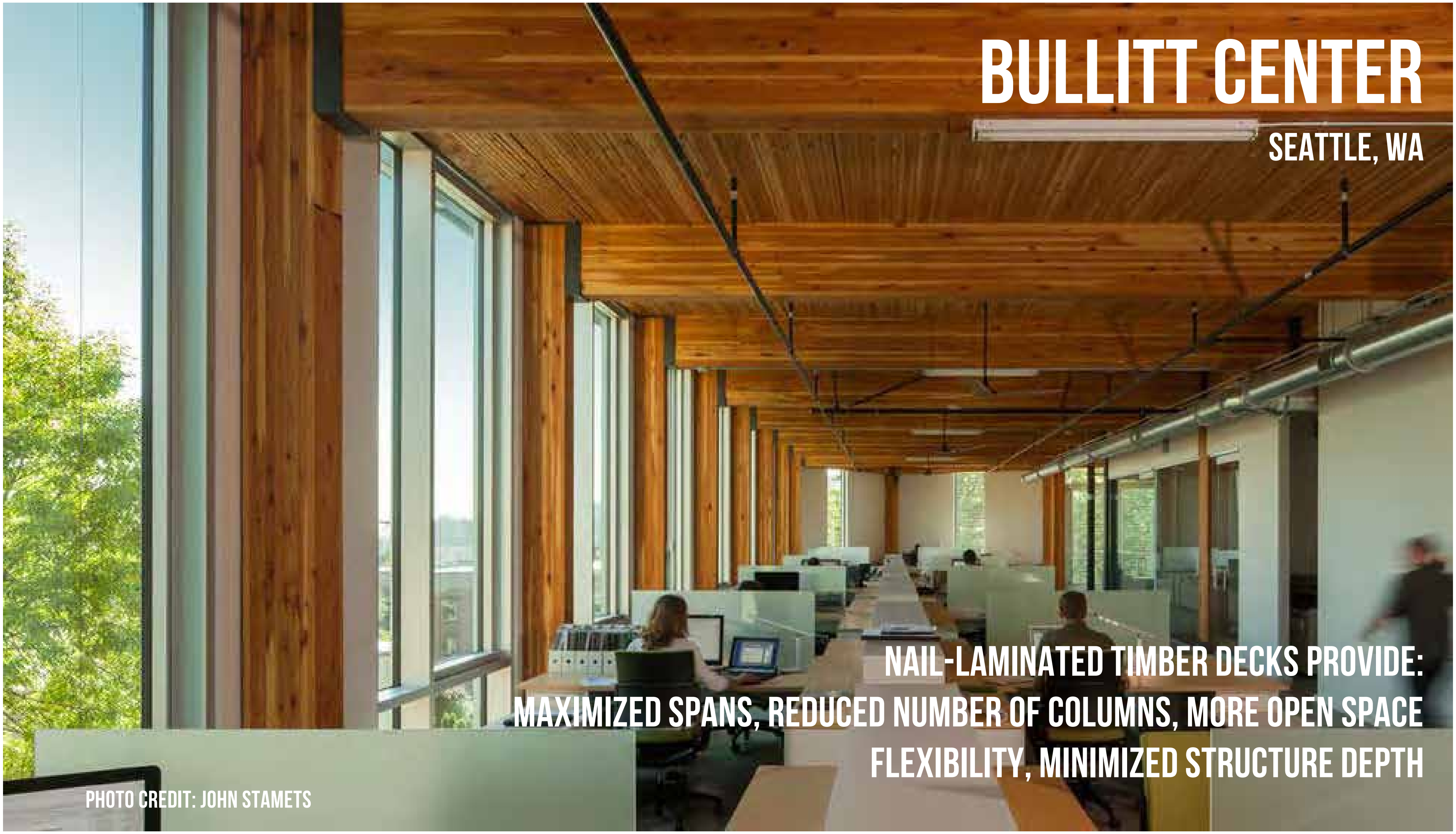
250 YR DESIGN LIFE

COMPLETED 2013

250 YEAR STRUCTURE

HEAVY TIMBER, CONCRETE & STEEL

PHOTO CREDIT: MILLER HULL PARTNERSHIP


BULLITT CENTER
SEATTLE, WA
NAIL-LAMINATED TIMBER DECKS PROVIDE:
MAXIMIZED SPANS, REDUCED NUMBER OF COLUMNS, MORE OPEN SPACE
FLEXIBILITY, MINIMIZED STRUCTURE DEPTH
PHOTO CREDIT: JOHN STAMETS

What is the appeal of CLT?

Sustainability

- Reduced Embodied Carbon
- Minimal waste production

Performance

Construction Efficiency

Minimal Waste

Why are designers drawn to CLT?

Sustainability

- Reduced Embodied Carbon
- Minimal waste production
- Highly Energy Efficient

Performance

Construction Efficiency

Energy Efficient

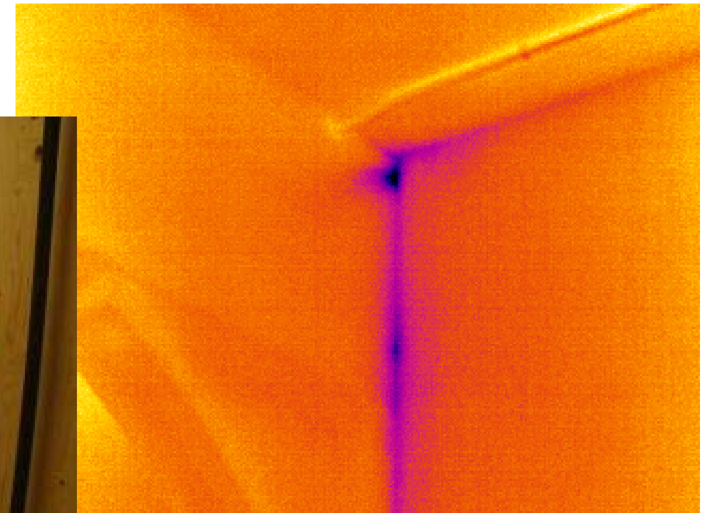


Table 2

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

What is the appeal of CLT?

Sustainability
- Reduced Embodied Carbon
- Minimal waste production
- Highly Energy Efficient

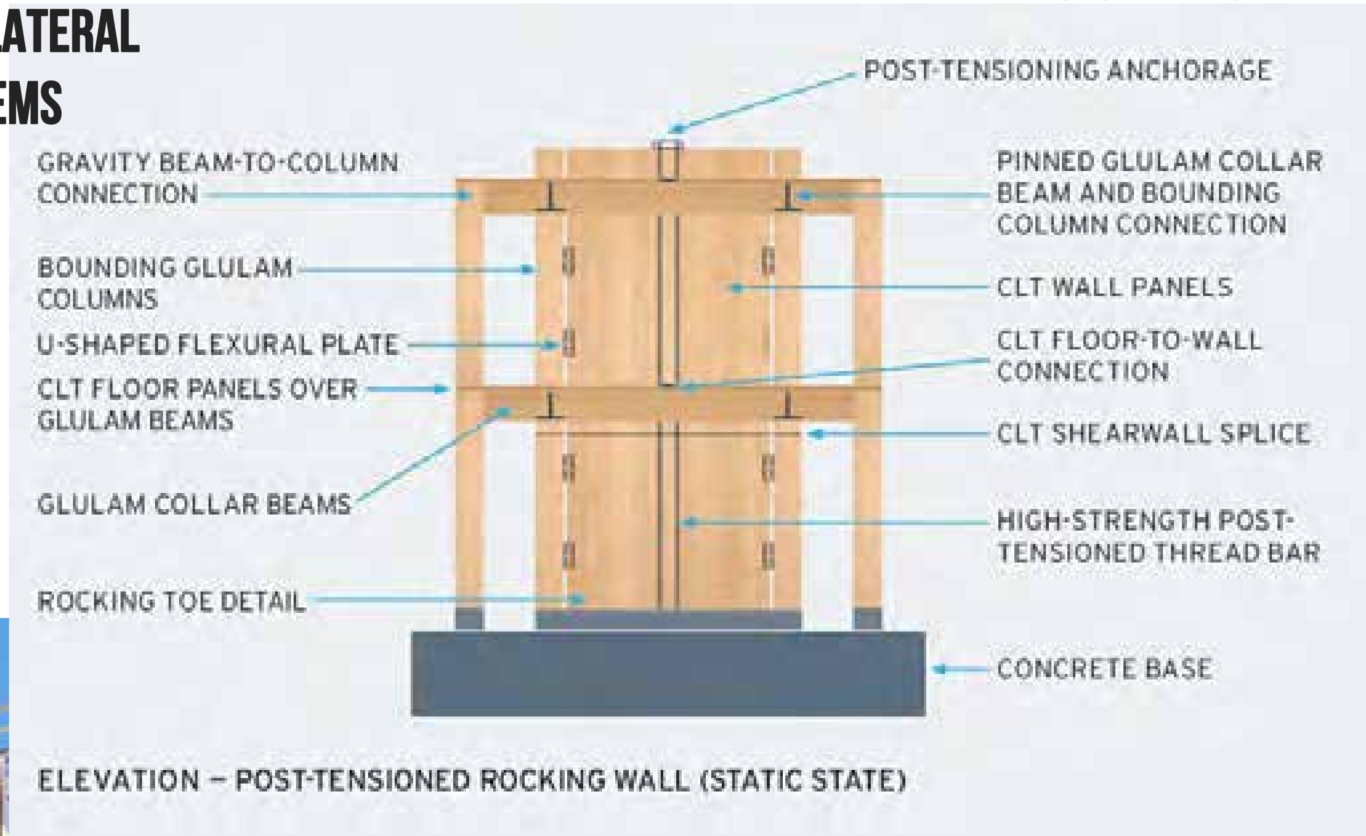
Performance
- Disaster Resilient

Construction Efficiency

MASS TIMBER APPEAL

DISASTER RESILIENT

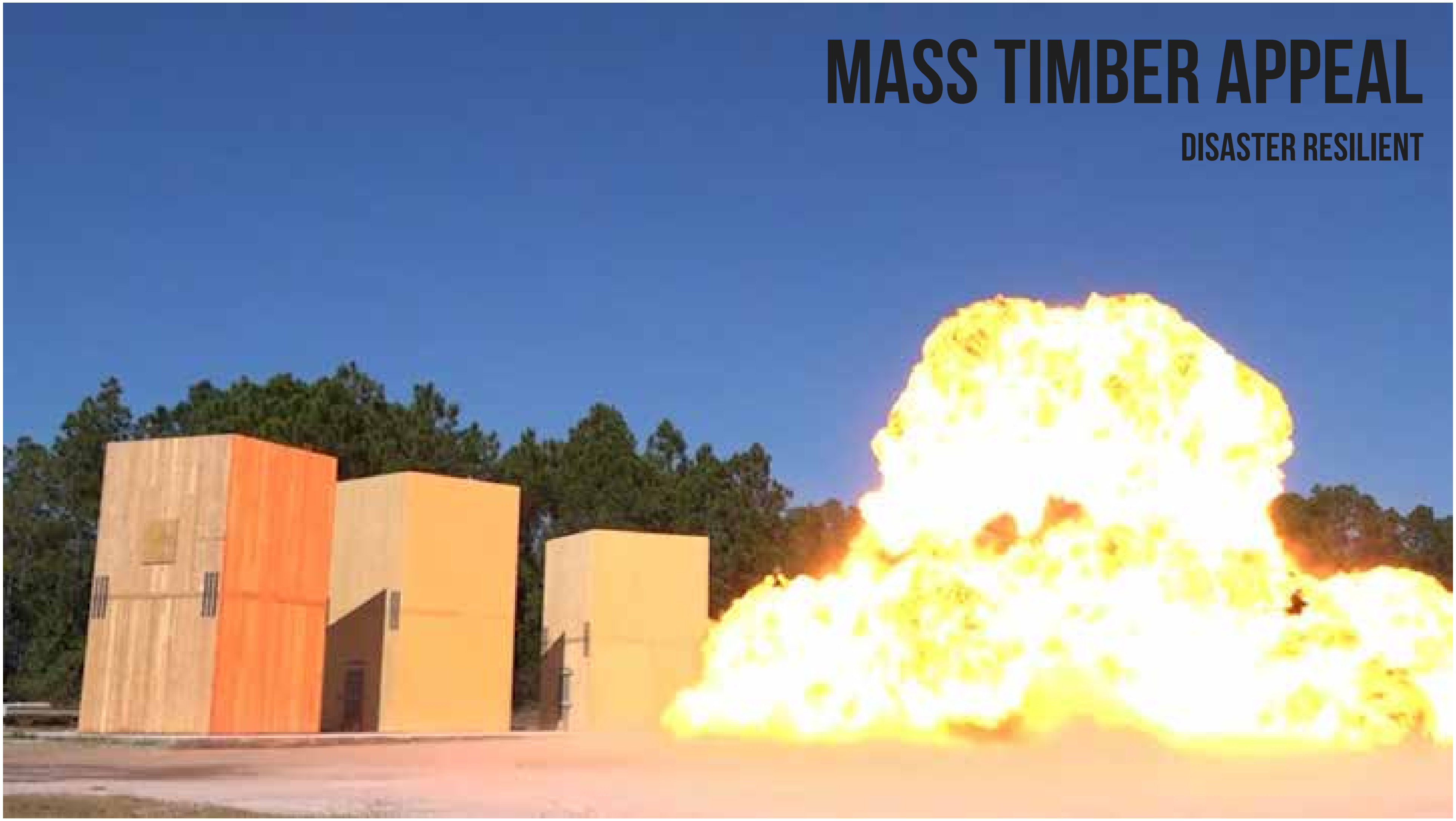
INNOVATIVE MASS TIMBER LATERAL FORCE RESISTING SYSTEMS



CLT ROCKING SHEAR WALL CONCEPT

SOURCE: KPFF

MASS TIMBER SHAKE TABLE TEST AT UCSD


MASS TIMBER APPEAL
DISASTER RESILIENT

CANDLEWOOD SUITES

REDSTONE ARSENAL, AL

IMAGE CREDIT: IHG® Army Hotels, Lendlease

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

What is the appeal of CLT?

Sustainability

- Reduced Embodied Carbon
- Minimal waste production
- Energy Efficient

Performance

- Disaster Resilient
- Fire Resistant

Construction Efficiency

Fire Test Results

- ASTM E119 Fire Endurance Test
  - 5-Ply CLT (6-7/8" thick)
  - 5/8" Type X GWB each side
  - 2 hour target
  - Actual 3 hours 6 minutes

- 2015 NDS Chapter 16 includes char rates for CLT to achieve up to 2 hour fire rating

Fire Testing Laboratory

TEST REPORT

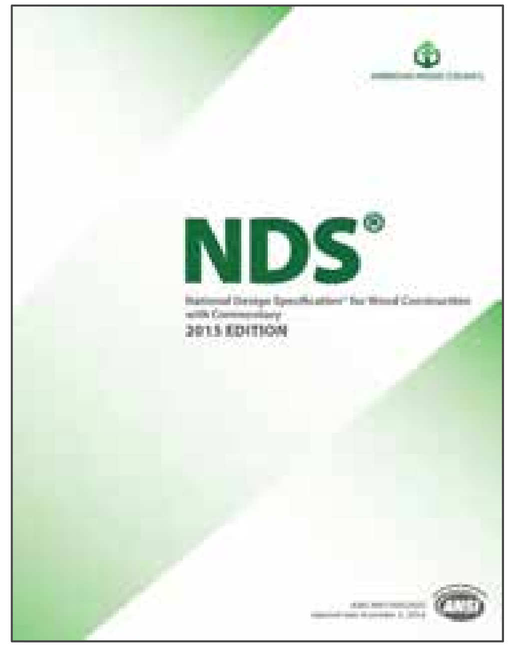
American Wood Council

Standard Methods of Fire Tests of Building Construction and Materials

ASTM E 119 – 11a

Highly Successful CLT Fire Test

As part of a project to produce a U.S. design manual for cross-laminated timber (CLT), AWC conducted a very successful ASTM E119 fire endurance test on a CLT wall at NGC Testing Services in Buffalo, NY. The wall, consisting of a 5-ply CLT (approximately 7-inches thick), was covered on each side with a single layer of 5/8" Type X gypsum wallboard. The wall was loaded to the maximum attainable by the test equipment, although it remained significantly below the full design strength of the CLT specimen. It was then exposed to a standard fire that reaches over 1800 degrees Fahrenheit in the first 90 minutes of exposure. While only seeking a 2-hour rating, as required by the targeted building code provisions, the test specimen lasted 3 hours 6 minutes. This may open up additional possibilities in a few specialized locations where a 3-hour fire resistance rating might be required. The test culminated nearly a month of intense planning and cooperation by the North American wood products industry to get the test run in advance of the recent ICC hearings where an AWC-proposed code change to specifically recognize CLT was approved.



CLT is Defined – 2015 IBC

SECTION 202
DEFINITIONS

CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of at least 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.

Add new text as follows:

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified as required in ANSI/APA PRG 320-2011.

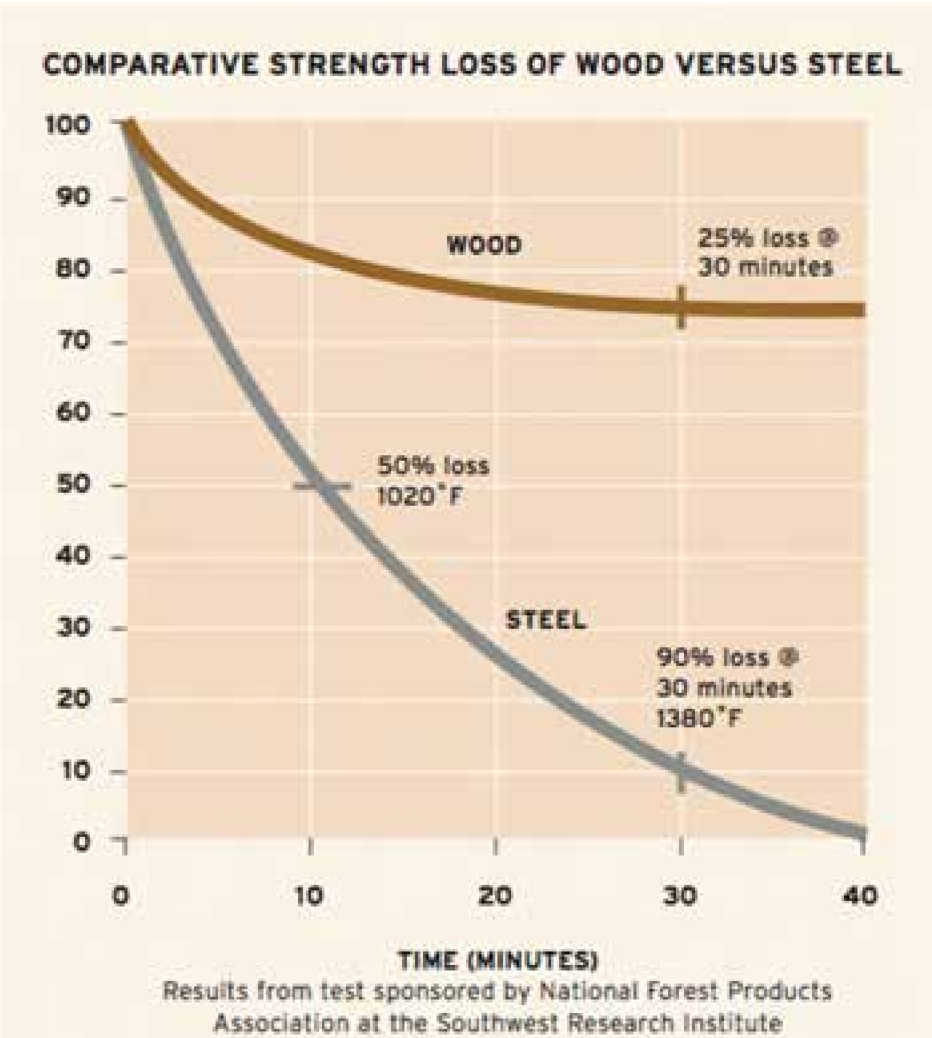
Add new standard to Chapter 35 as follows:

ANSI

ANSI/APA PRG 320-2011 Standard for Performance-Rated Cross-Laminated Timber

MASS TIMBER DESIGN

FIRE RESISTANCE



SOURCE: AITC

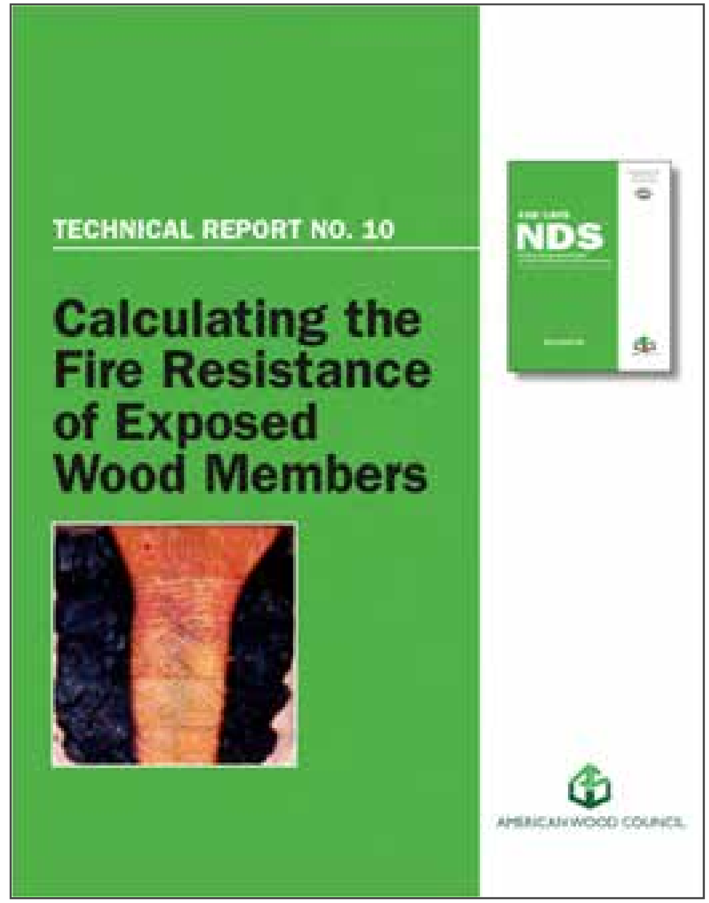
Achieving One Hour Equivalency for Protected Construction

NDS Chapter 16
Fire Design of Wood Members

FIRE DESIGN OF WOOD MEMBERS

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

OR →

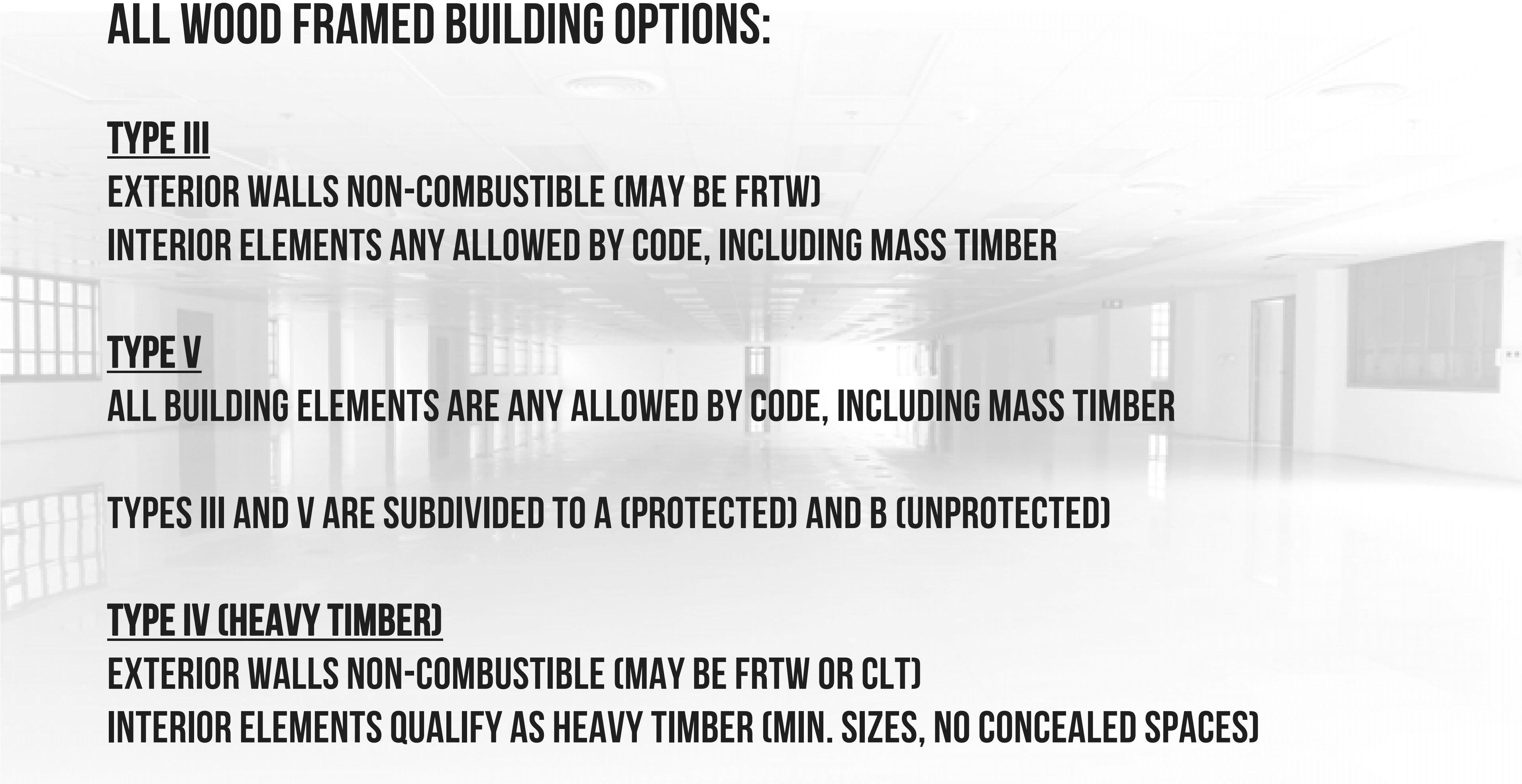


TR 10

Available from AWC website

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

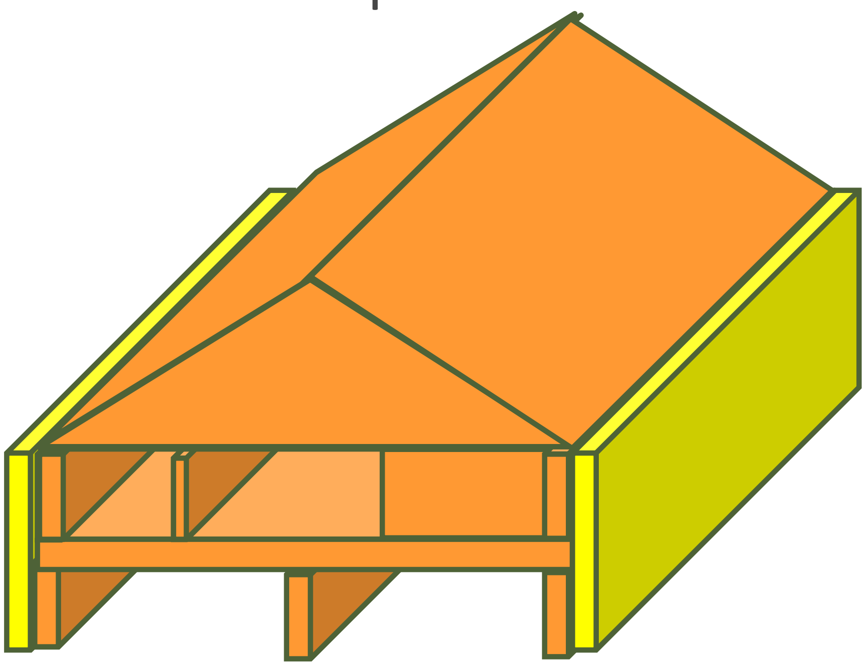
TYPES III AND V ARE SUBDIVIDED TO A (PROTECTED) AND B (UNPROTECTED)

TYPE IV (HEAVY TIMBER)

EXTERIOR WALLS NON-COMBUSTIBLE (MAY BE FRTW OR CLT)
INTERIOR ELEMENTS QUALIFY AS HEAVY TIMBER (MIN. SIZES, NO CONCEALED SPACES)

Type IV Construction – IBC 602.4

Exterior walls are of noncombustible materials and interior building elements are of solid or laminated wood without concealed spaces. FRT wood or Cross Laminated Timber*-2015IBC is permitted in exterior walls, where 2hr fire rating or less is required



*Exterior surface of CLT is protected by FRT sheathing, ½” gypsum, or other non-combustible materials

- Non combustible Exterior walls
- Interior walls-solid without concealed spaces

- Fire Retardant Treated exterior walls or Cross laminated Timber (CLT)-2015 IBC are allowed if fire rating is 2hr or less

- Heavy Timber

Concealed Space Limitations on HT

Type IV Construction requires that interior elements be without concealed spaces:

- Concealed spaces include dropped ceilings, attics, chases, others

Concealed space requirement does not apply to any other construction type. If using heavy timber elements in non type IV construction, concealed spaces are permitted but may be required to be sprinklered

Source: US CLT Handbook

Example of concealed space created by dropped ceiling

What is the appeal of CLT?

Sustainability

- Reduced Embodied Carbon
- Minimal waste production
- Highly Energy Efficient

Performance

- Disaster Resilient
- Good Fire Resistance
- High performing Acoustics

Construction Efficiency

CLT Acoustics

Sound Insulation of Bare CLT Floors and Walls

Number of layers	Thickness (in.)	Assembly type	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

Source: US CLT Handbook

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

Why are designers drawn to CLT?

Sustainability

- Reduced Embodied Carbon
- Minimal waste production
- Highly Energy Efficient

Performance

- Disaster Resilient
- Good Fire Resistance
- High performing Acoustics
- Structural Flexibility

Construction Efficiency

Structural Flexibility

Photo Credit: APA

What is the appeal of CLT?

Sustainability	• Reduced Embodied Carbon • Minimal waste production • Highly Energy Efficient
Performance	• Disaster Resilient • Good Fire Resistance • High performing Acoustics • Structural Flexibility
Construction Efficiency	• ~75% lighter than concrete

75% Lighter Weight Than Concrete

What is the appeal of CLT?

Sustainability	• Reduced Embodied Carbon • Minimal waste production • Highly Energy Efficient
Performance	• Disaster Resilient • Good Fire Resistance • High performing Acoustics • Structural Flexibility
Construction Efficiency	• ~75% lighter than concrete • Reduced construction time

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)

Franklin Elementary School, Franklin, WV

- 45,200 ft^2 2 story elementary school
- 8 weeks to construct

FRANKLIN ELEMENTARY SCHOOL

FRANKLIN, WV

PHOTO CREDIT: PAM WEAN, MSES ARCHITECTS

Photo Credit: Pam Wean, MSES Architects

- 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

What is the appeal of CLT?

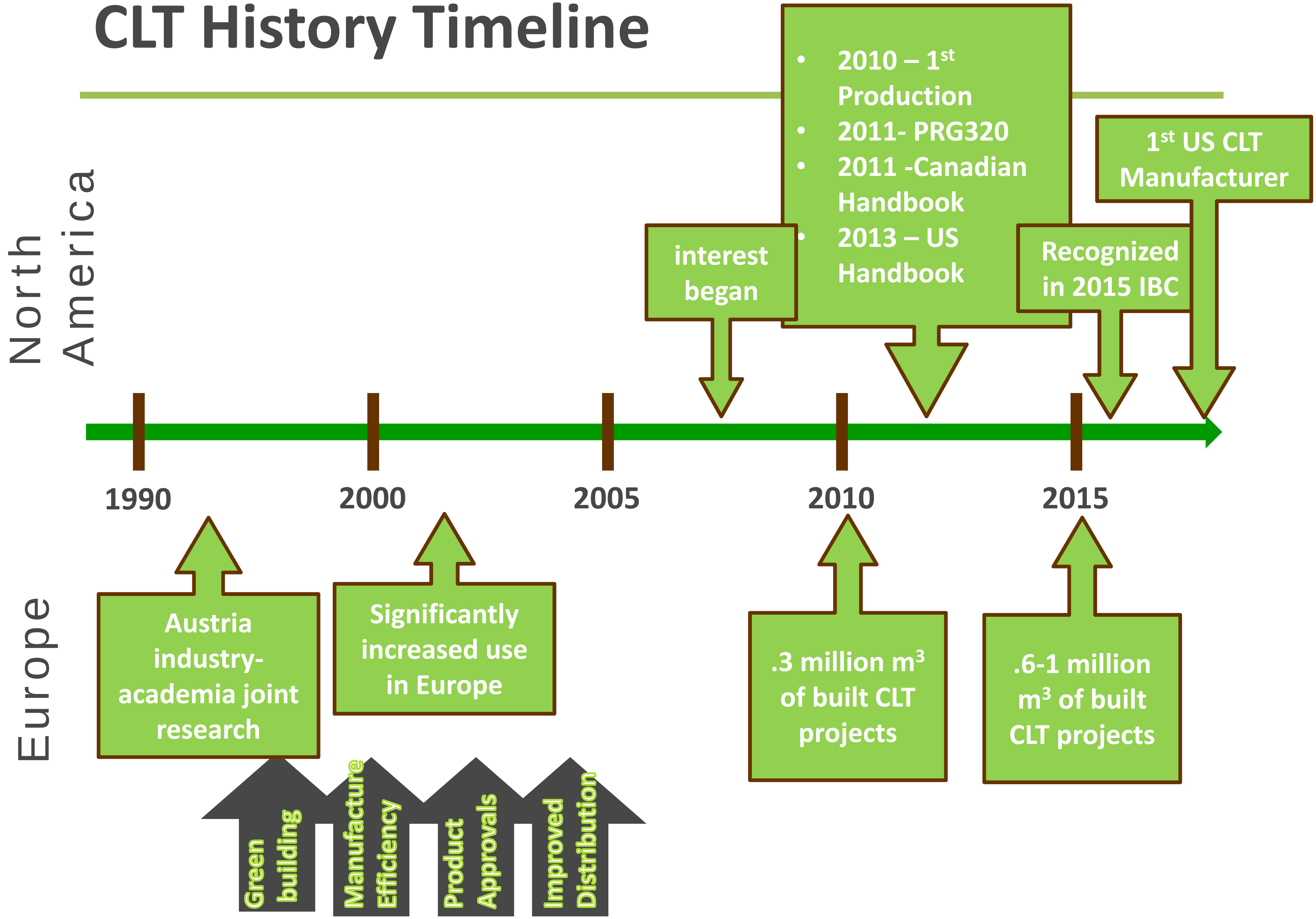
Sustainability	• Reduced Embodied Carbon • Minimal waste production • Highly Energy Efficient
Performance	• Disaster Resilient • Good Fire Resistance • High performing Acoustics • Structural Flexibility
Construction Efficiency	• ~75% lighter than concrete • Reduced construction time • Pre-fabricated and Precise

CLT: A Prefabricated Material

- 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

CLT History Timeline



Product Availability

Outline

- What is CLT?
    - Mass Timber
    - The Appeal
    - History
    - Availability
- Using CLT
    - Project Examples
    - Best applications
    - Cost effective design
    - Building Codes and Standards

Mass Timber Building Options

Promega Feynman Center, The Crossroads, Madison, Wisconsin
Photos: Aitor Sanchez/EwingCole

New Stanford Heat Recovery Center
Stanford, CA

Stanford Heat Recovery Center
Photo: Structurlam

CLT Roof Panels used over entrance/walkway

Part of 125,000 sf building that is expected to reduce campus carbon emissions by 50% and save an estimated $300M over the next 35 years

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

Chicago Horizon Pavilion
Photos: Tom Harris

Chicago Horizon Pavilion
Photos: Aaron Forrest

Total roof structure thickness 8-1/4”

Spans up to 30 feet between columns at points

ALBINA YARD

PORTLAND, OR

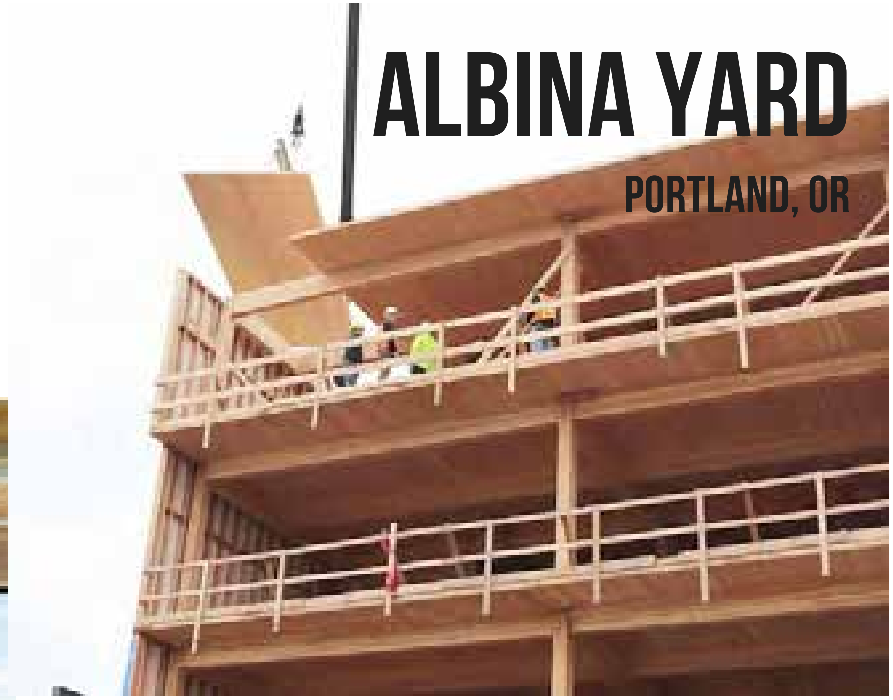
4 STORIES
16,000 SF
GREEN ROOF

ARCHITECT: LEVER ARCHITECTURE
IMAGE CREDIT: LEVER ARCHITECTURE

ALBINA YARD

PORTLAND, OR

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



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

SOURCE: LEVER ARCHITECTURE[1]

FIRST TECH CREDIT UNION

HILLSBORO, OR

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

5 STORIES
156,000 SF

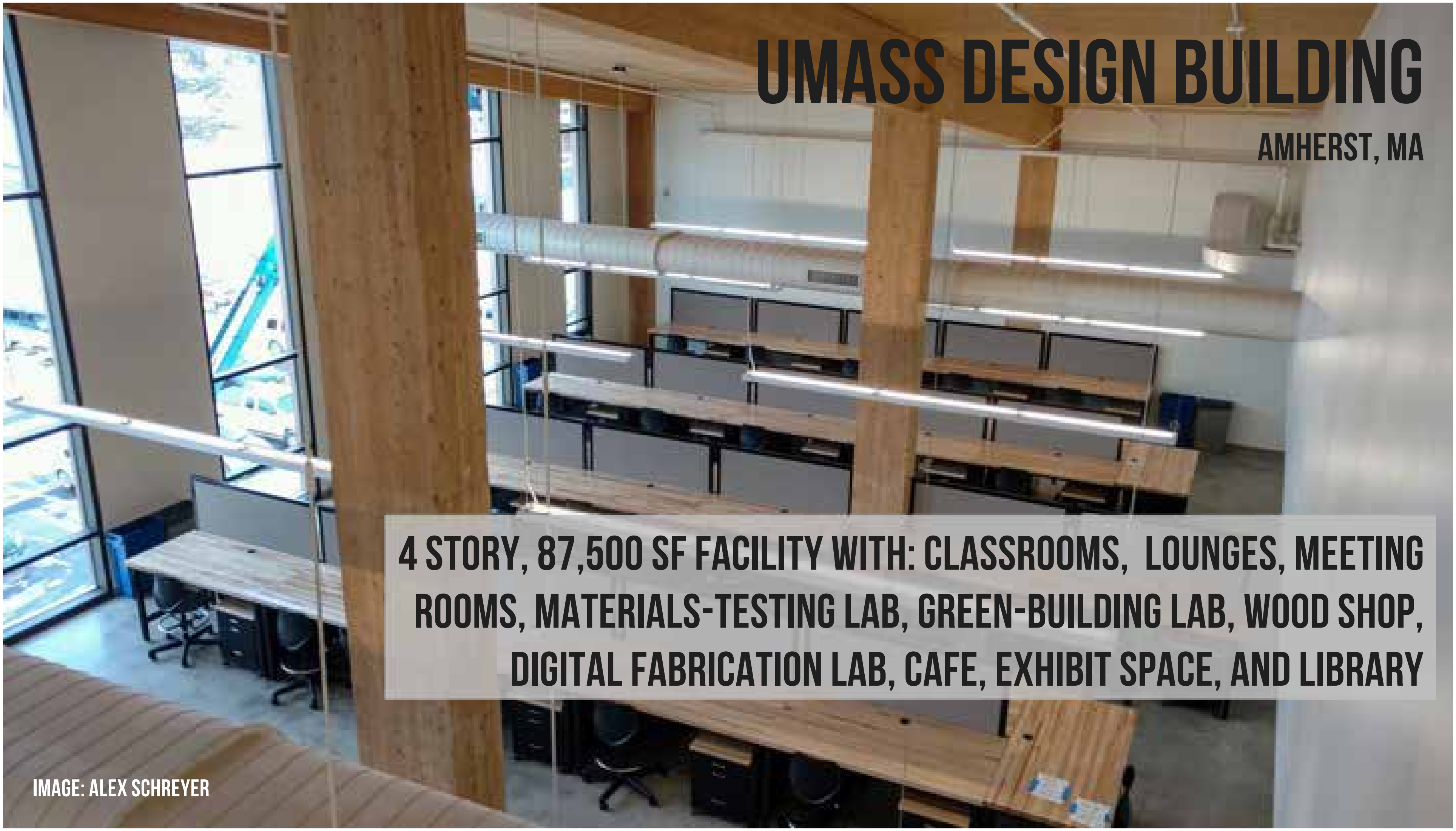
FIRST TECH CREDIT UNION

HILLSBORO, OR

ARCHITECT: HACKER
IMAGE CREDIT: STRUCTURLAM

COMPLETED 2017 – 156,000 SF
626 PANELS & 988 GLULAMS


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 JAN 2017
PHOTO CREDIT: ALEX SCHREYER

UMASS DESIGN BUILDING

AMHERST, MA

PHOTO CREDIT: ALEX SCHREYER


U OF ARKANSAS STUDENT DORMS
FAYETVILLE, AR
IMAGE CREDIT: MODUS STUDIO


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


IMAGE CREDIT: MODUS STUDIO/LEERS WEINZAPFEL ARCHITECTS

Wood Innovation Design Center

Prince George, British Columbia

8 Levels/6 Stories

97 feet tall

Completed Fall 2014

Architect: Michael Green Architecture
Structural Engineer: Equilibrium Consulting
Contractor: PCL Constructors Westcoast
Photos: Ema Peter Photography


WOOD INNOVATION DESIGN CENTER
PRINCE GEORGE, BC
PHOTO CREDIT: ED WHITE


WIDC MEP ACCOMMODATION
PHOTO CREDIT: EMA PETER

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

Forte', Victoria Harbor, Melbourne, Australia

Architect: Lend Lease

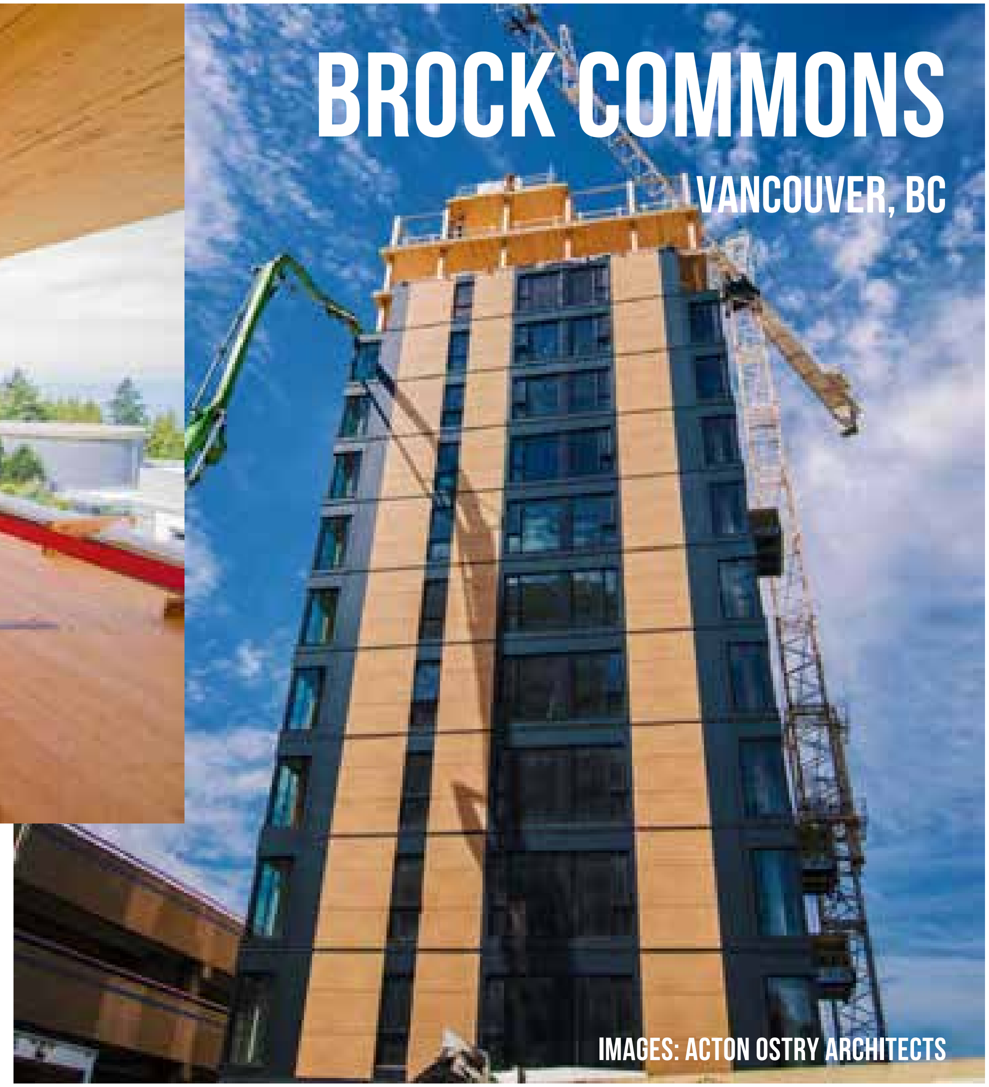
Forte', Victoria Harbor, Melbourne, Australia
Architect: Lend Lease


MODERN TALL WOOD-CARBON 12
2017, 8 STORIES, 32,000 SF
PORTLAND, OR
PHOTOS:
BAUMBERGER STUDIO/PATH
ARCHITECTURE/MARCUS KAUFFMAN

BROCK COMMONS

VANCOUVER, BC

18 STORIES
174 FT
156K SQ.FT.



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

BROCK COMMONS

VANCOUVER, BC

17 STORIES OF TIMBER INSTALLATION
STARTED JUNE 6, 2016
FINISHED AUGUST 10, 2016

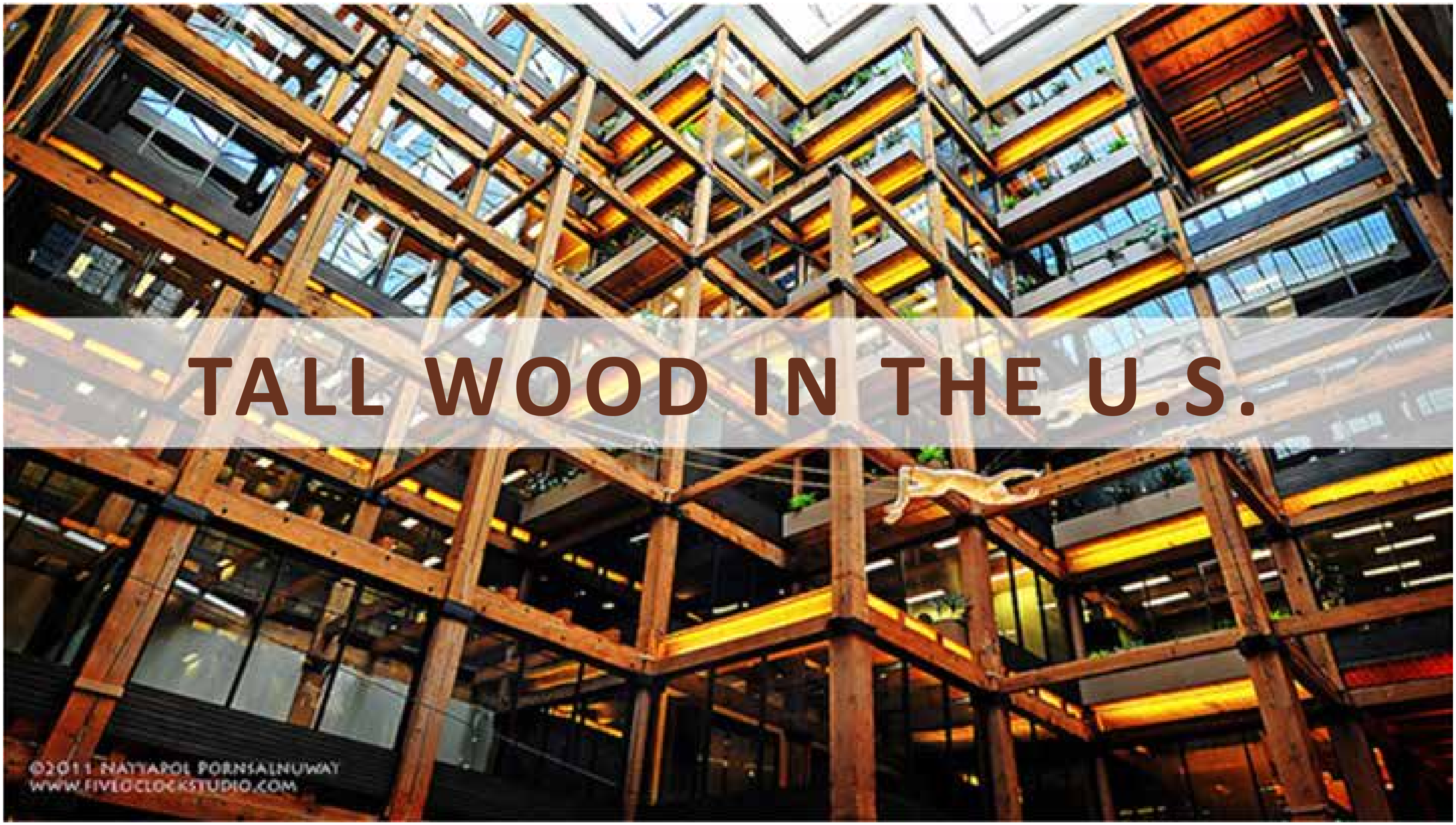
BROCK COMMONS

VANCOUVER, BC

CLT as an alternate to Concrete/Masonry

U.S. BUILDING CODE STATUS

TALL WOOD IN THE U.S.



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

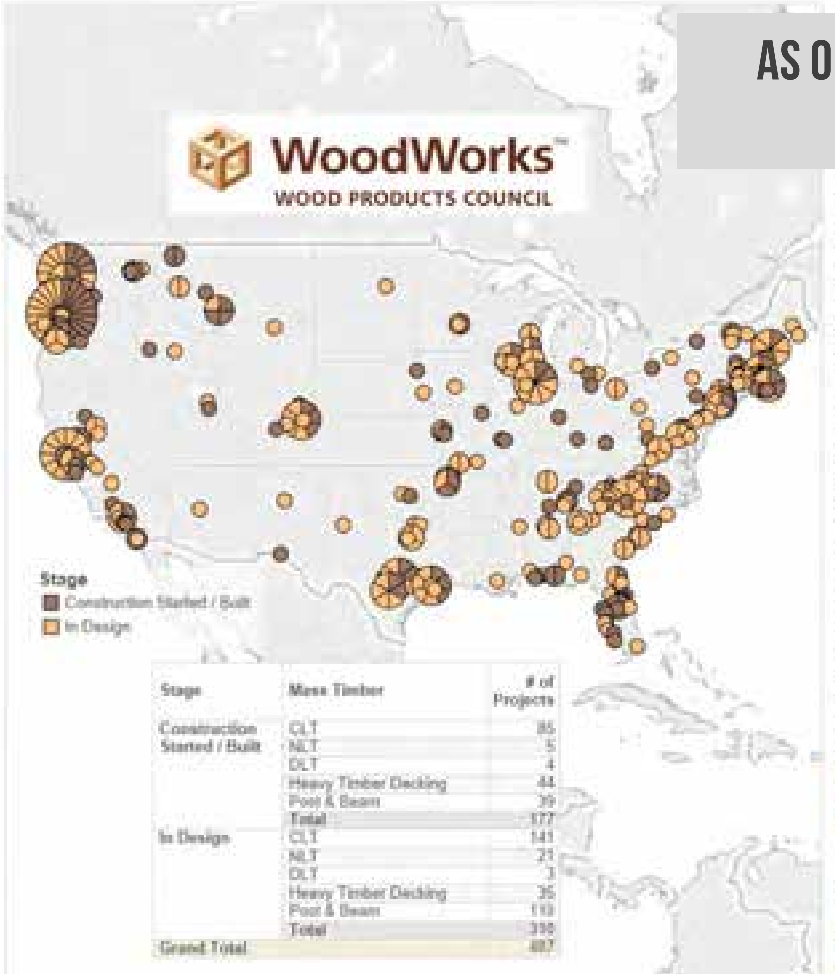
New Building Types

US CLT Handbook

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

Mass Timber Projects In Design and Constructed in the US (December 2018)

AS OF DECEMBER 2018, 487 MASS TIMBER PROJECTS DESIGNED, UNDER CONSTRUCTION OR BUILT



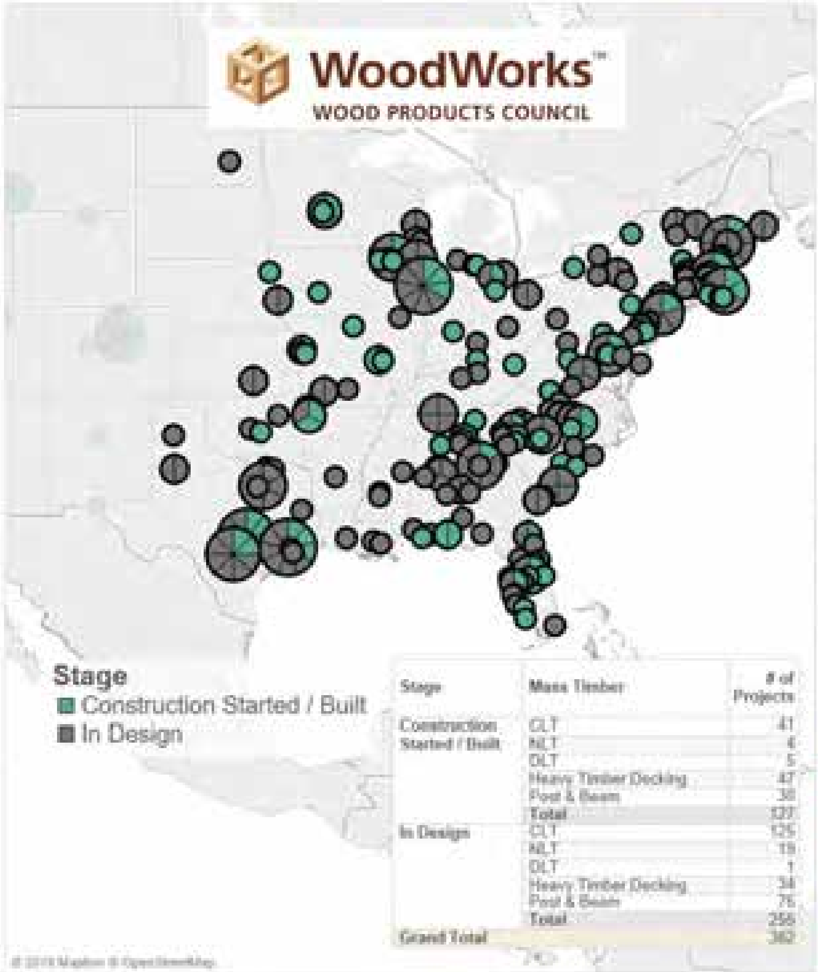
Stage	Mass Timber	# of Projects
Construction Started / Built	CLT	85
	NLT	5
	DLT	4
	Heavy Timber Decking	44
	Post & Beam	39
	Total	177
In Design	CLT	141
	NLT	21
	DLT	3
	Heavy Timber Decking	35
	Post & Beam	110
	Total	310
Grand Total		487

[illegible]	Construction Started / Built	[illegible]
	In Design	7
CT	Construction Started / Built	3
	In Design	5
DC	Construction Started / Built	2
	In Design	1
DE	In Design	1
FL	Construction Started / Built	15
	In Design	13
GA	In Design	11
HI	In Design	1
IA	In Design	1
ID	Construction Started / Built	1
	In Design	2
IL	Construction Started / Built	4
	In Design	10
IN	Construction Started / Built	1
KS	In Design	1
KY	Construction Started / Built	1
LA	In Design	1
MA	Construction Started / Built	15
	In Design	21
MD	Construction Started / Built	1
	In Design	6
ME	Construction Started / Built	1
	In Design	6
MI	Construction Started / Built	1
	In Design	2
MN	Construction Started / Built	1
	In Design	2
MO	Construction Started / Built	4
	In Design	4
NH	In Design	1
NJ	In Design	3
NM	In Design	1
NY	Construction Started / Built	5
	In Design	10
OH	Construction Started / Built	1
	In Design	3
OK	Construction Started / Built	1
	In Design	1
OR	Construction Started / Built	18
	In Design	20
PA	Construction Started / Built	2
	In Design	2
RI	Construction Started / Built	1
	In Design	1
SC	Construction Started / Built	5
	In Design	7
TN	Construction Started / Built	3
	In Design	2
TX	Construction Started / Built	12
	In Design	20
UT	Construction Started / Built	1
	In Design	1
VA	Construction Started / Built	1
	In Design	9
VT	Construction Started / Built	1
	In Design	7
WA	Construction Started / Built	17
	In Design	23
WI	Construction Started / Built	2
	In Design	13
WV	Construction Started / Built	2
WY	In Design	1

Considering mass timber for a project?
Ask us anything.

For free project support, contact:
help@woodworks.org
woodworks.org/project-assistance

Mass Timber Projects In Design and Constructed in the US (July 2019)



Stage	Mass Timber	# of Projects
Construction Started / Built	CLT	41
	NLT	4
	DLT	5
	Heavy Timber Decking	47
	Post & Beam	30
	Total	127
In Design	CLT	125
	NLT	19
	DLT	1
	Heavy Timber Decking	34
	Post & Beam	76
	Total	255
Grand Total		382

	Construction Started / Built					In Design					
State	CLT	DLT	Heavy Timber Decki..	NLT	Post & Beam	CLT	DLT	Heavy Timber Decki..	NLT	Post & Beam	Grand Total
AL	2		1			4		1	1	2	11
AR	3					2		1		1	7
CT	3					6			1		10
DC	1				1	1	1			1	5
DE						2					2
FL	1		7		6	4		5		4	30
GA		1				5		4		5	15
IA		1									1
IL	2		2		1	4		1	2	4	16
IN					1						1
KS						2				1	3
KY					1	2					3
LA										3	3
MA	8		4		2	15		3	2	2	37
MD					1	2		2	1		6
ME					1	10		2		2	15
MI	2					1				4	7
MN			1	1						2	4
MO	1		3		1	3			1		9
MS						2				1	3
NC	3		5	1	3	11		7		3	33
ND										1	1
NE	1					1				1	3
NH									1		1
NJ					1	2				1	4
NY	2		1	1	1	12			4	2	23
OH			1			1		1		3	6
OK	1					1				1	3
PA			3							3	6
RI	2										2
SC			4	1	2	3		2		2	14
TN	2		1			3			1		7
TX	2	3	5		4	15		4		19	53
VA	2		1		1	3		1	1	2	11
VT			1			3				2	8
WI	1		5			4			4	4	19
WV	1		1								2
Grand..	41	5	47	4	30	125	1	34	19	76	382

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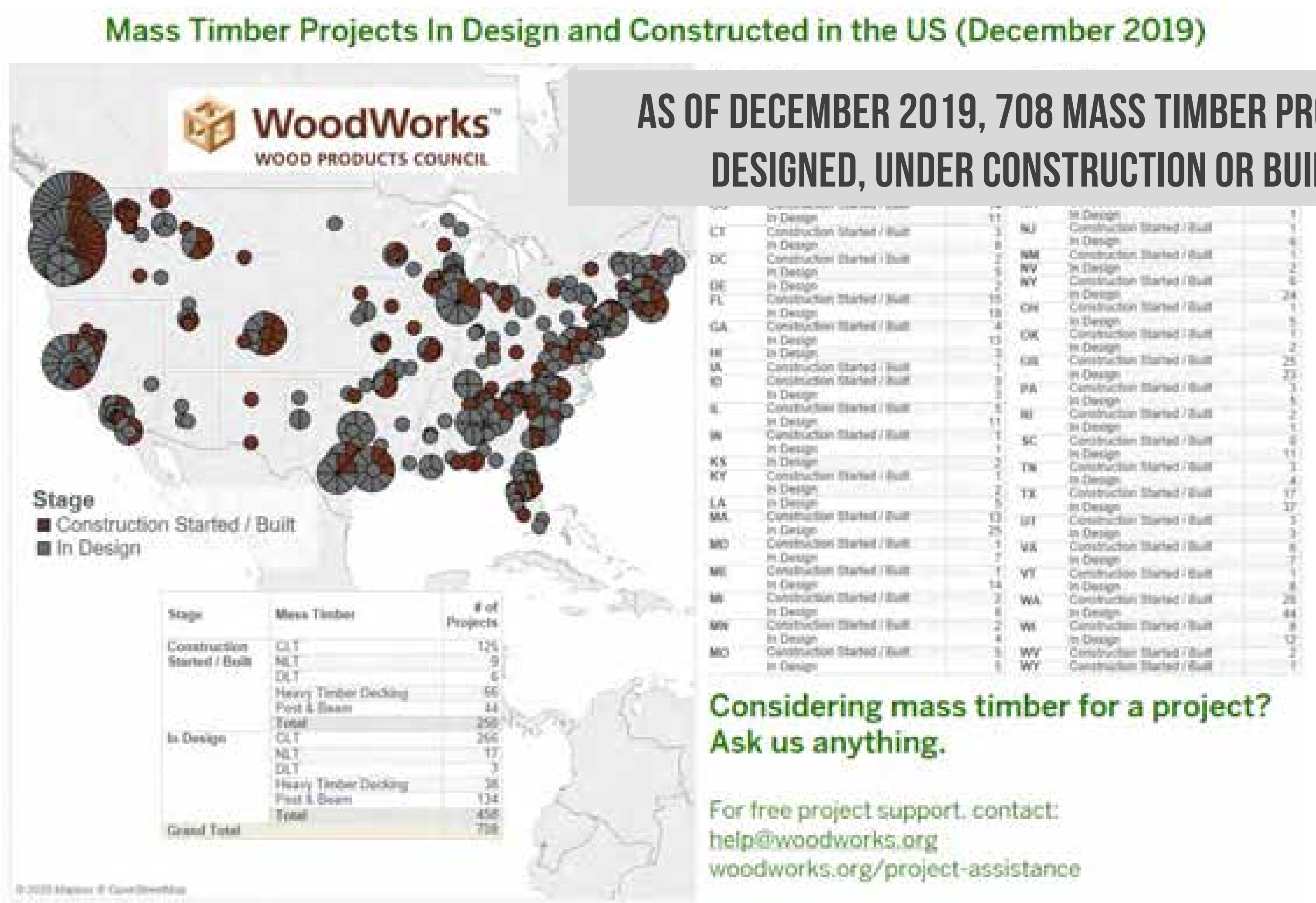
woodworks.org/project-assistance

AS OF DECEMBER 2019, 708 MASS TIMBER PROJECTS DESIGNED, UNDER CONSTRUCTION OR BUILT



Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Anthony Harvey PE
Regional Director
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