Optimizing Mass Timber Connections

Presented by Brian Malone, PE

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Engineers & Builders

Optimizing Mass Timber Connections

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Optimizing Mass Timber Connections

Course Description

While mass timber projects are often motivated by their carbon benefits or exposed wood aesthetic, a deeper understanding of the cost drivers is key to their viability for most design teams. For example, the cost of connections can significantly affect the overall project cost. However, because mass timber connection design must consider structural objectives as well as aesthetics, fire rating requirements, constructability, shrinkage and swelling, and moisture protection, finding an effective and efficient solution may be challenging. To aid designers in this effort, WoodWorks has published a Mass Timber Connections Index with options for many common conditions. Created by structural engineers, architects and general contractors experienced with mass timber design and construction, it highlights lessons learned and presents carefully analyzed solutions to common situations. In this webinar, we will review the index in the context of cost, fire resistance, structural capacity, and constructability objectives, to help designers choose and detail the most appropriate connections for their projects.

Optimizing Mass Timber Connections

Learning Objectives

1. Exhibit how to use the information presented in the Mass Timber Connections Index.

2. Demonstrate efficient, effective and code-compliant lateral and gravity detailing practices for mass timber construction

3. Review solutions for combining architectural, structural, cost, and constructability requirements in mass timber details.

4. Evaluate options and considerations, including differential material movement and fire-resistance, when combining mass timber with steel or concrete.

Acknowledgements

WoodWorks – Wood Products Council (WPC)

- Karen Gesa – Technical Director,
  Project Resources & Solutions Division
- Scott Breneman – Senior Technical Director
  – Mass Timber

KL&A Engineers & Builders

- Greg Kingsley
- Chris Kendall
- Erin Kinder
- Brian Malone
- Craig Dixon
- Rachel Chaggaris

Swinerton Mass Timber

- Graham Montgomery
- Brendan Kelly
- Chris Evans

OZ Architecture

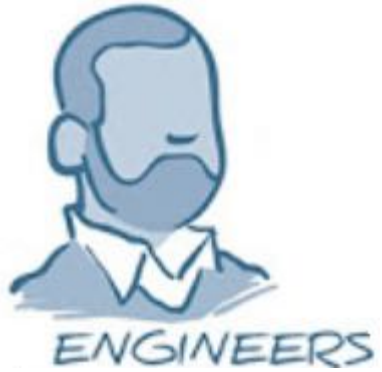
- Jacob Levy
- Joe Anastasi

Purpose

To understand the spectrum of available mass timber connections and aid in the selection of cost-optimal connections.

The Players

- Owner
- Architect
- General Contractor
- Mass Timber Supplier
- Structural Engineer



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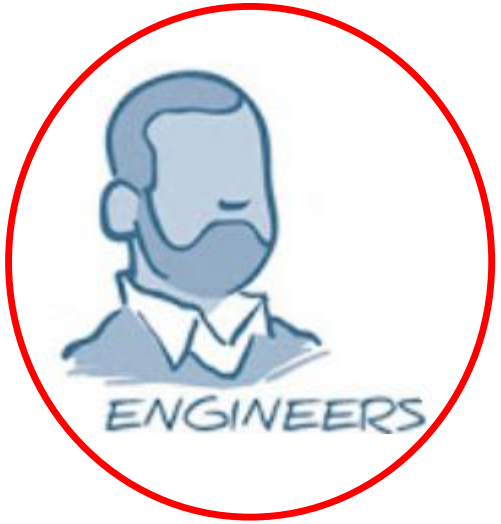
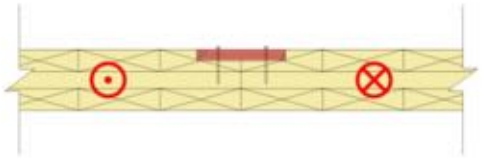


Mass Timber Connections Index

Go to WoodWorks.org and click on “Design & Tools”

https://www.woodworks.org/wp-content/uploads/Mass-Timber_CONNECTION_INDICES-N.pdf

106 structural connections

Connection Type	Image	Designer Notes	Class	Load	Cost	Const	Inspect	Fire
Panels Connect with Single Surface Spline		Purpose: Transfer of in-plane shear along the panel to panel joint. Description: Adjacent floor panels with routed surfaces are butted together. A plywood spline is fastened to both panels using partially threaded screws or nails. Notes: • Capacity of connection is controlled by shear capacity of dowel-type fasteners. • Double Surface Spline or Steel Surface Spline can be used for increased capacity. • Spline may be fully above panels without routed surface where floor or roof coverings allow. • Where using nails, consider specifying nail gun nails instead of common wire nails for constructability. • Where screws are used instead of nails, Cost increases and Constructability is moderate. • Typical minimum plywood thickness is ½” nominal. • Coordinate spline and rout width and thickness with panel supplier.	1	low	$	easy	easy	rated

Mass Timber Connections Index

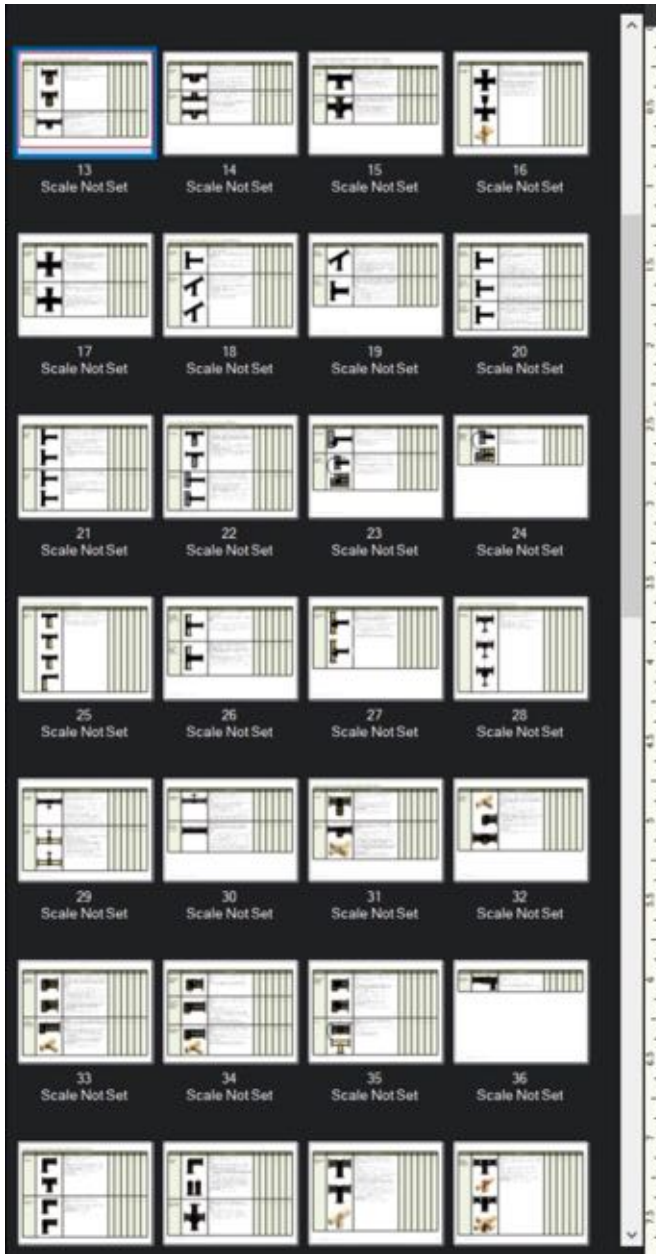
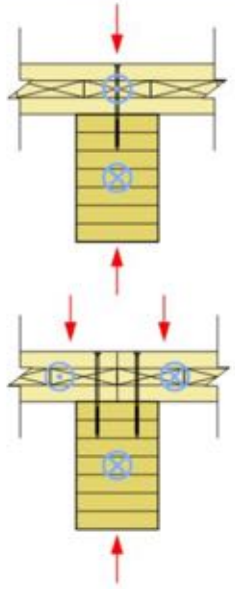
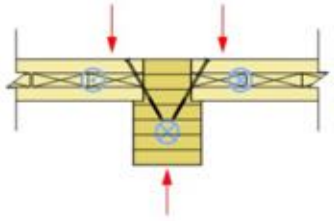


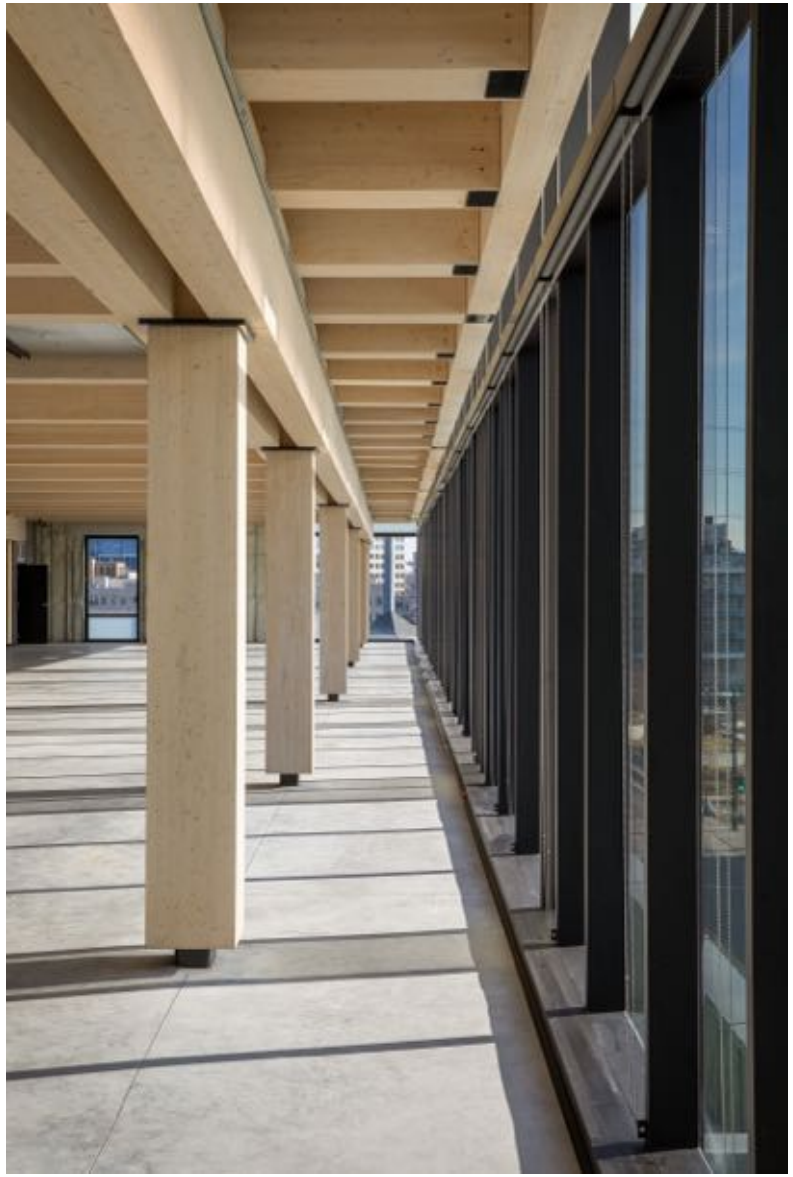
Table 2: Mass Timber Panel Support at Mass Timber Beam

Connection Type	Image	Designer Notes	Class	Load	Cost	Const	Inspect	Fire
2-1. **Panel Bears on Beam**		**Purpose**: Transfer of vertical loads from roof or floor panel to wood beam. Can also transfer shear along the length of the beam. **Description**: Roof or floor panel bears on top of wood beam. Positive attachment is made with partially-threaded screws. **Notes**: • Capacity of primary load path is controlled by perpendicular-to-grain bearing capacity of floor panel or beam. • Screws provide load path for in-plane loads.	1	High	$	Easy	Easy	Level II
2-2. **Panel Bears on Beam at Notch**		**Purpose**: Transfer of vertical load from roof or floor panel to wood beam. Can also transfer shear along the length of the beam. **Description**: Roof or floor panel bears on notch in wood beam and is connected with partially-threaded screws. **Notes**: • Capacity of primary load path is controlled by perpendicular-to-grain bearing capacity of floor panel or notch. • Reasonable minimum notch bearing width is 1". • Shop machined notch provides more reliable elevation control than applied bracket or ledger. • In panel design, consider that panel is not continuous across connection and multi-span conditions may not be achievable. • Beam must be designed for reduced net section.	1	Medium	$$	Easy	Easy	Level I

Connection Considerations

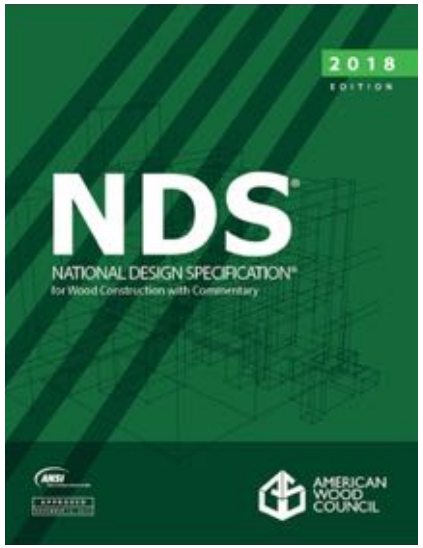
Design Considerations

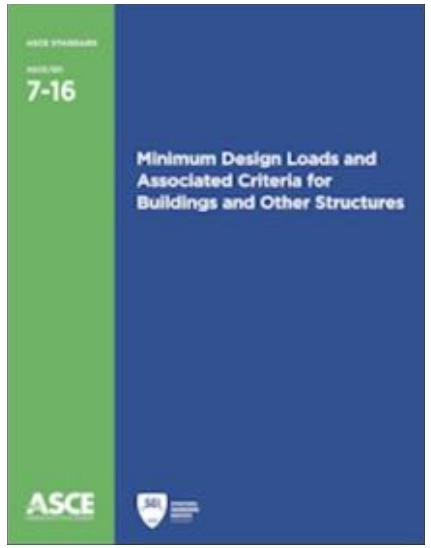
- Structural Design
- Aesthetics
- Construction Tolerance
- Constructability
- Moisture
- Fire Rating
- Inspections

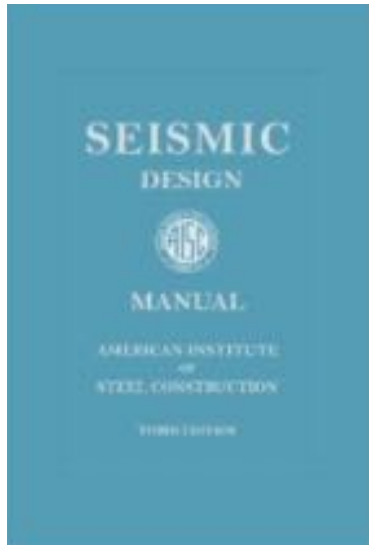


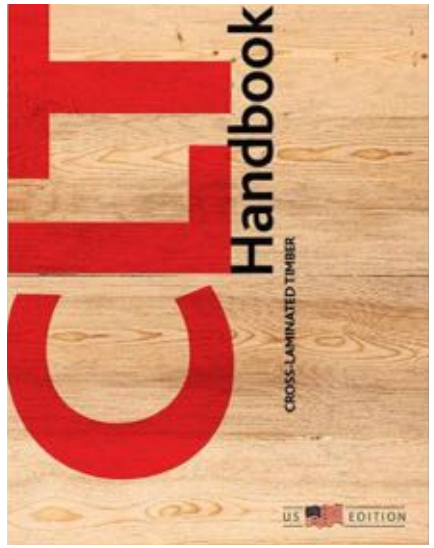
Structural Design

- IBC
- ASCE-SEI 7
- AWC NDS
- AISC
- APA T300
- CLT Handbook









Structural Design

Wood Design Reminders

- Bearing is Better than Dowel-Type Fasteners
- Parallel is Better than Perpendicular to Grain
- No Screw Withdrawal from End Grain
- Edge Distances and Spacing are Important
- Notch with Care

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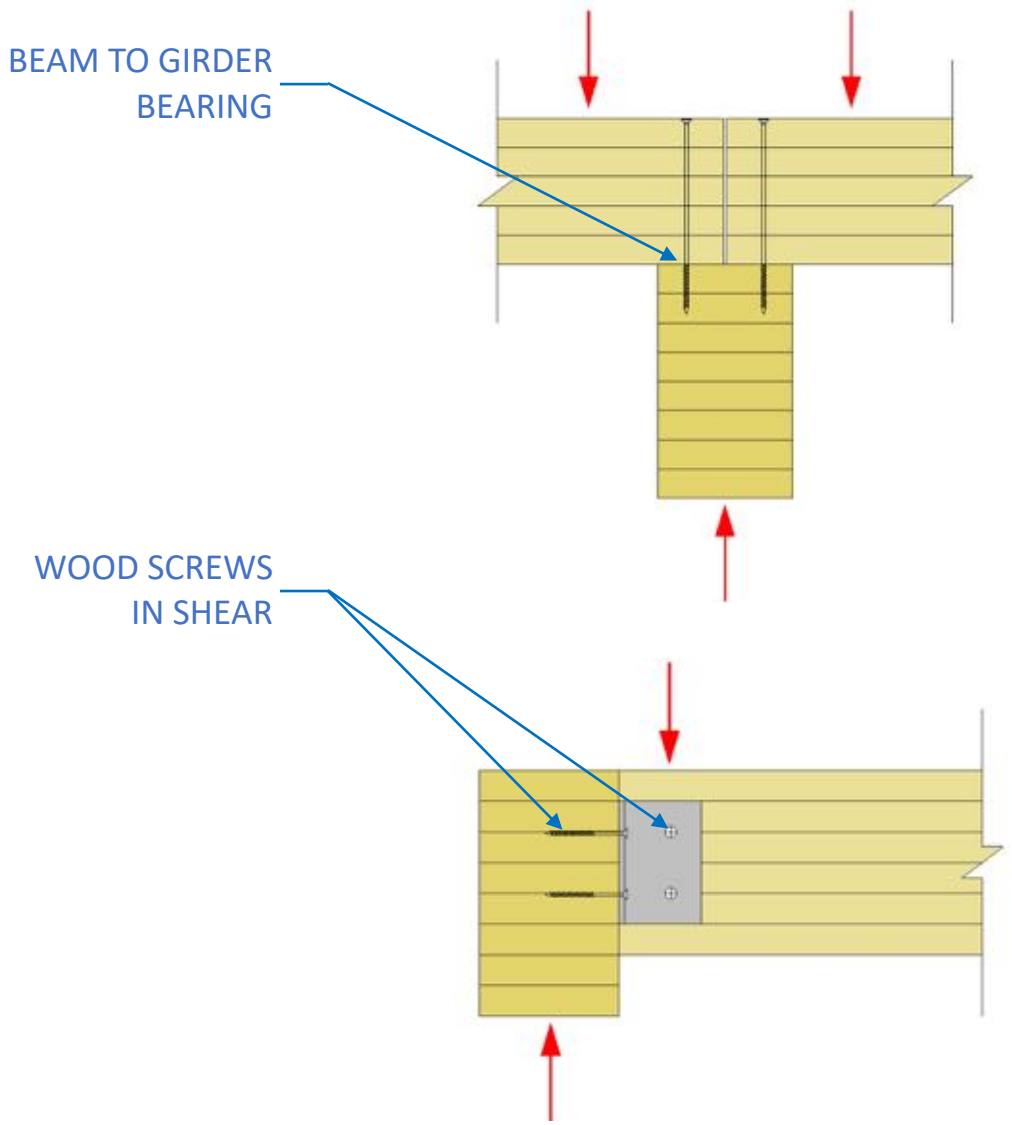

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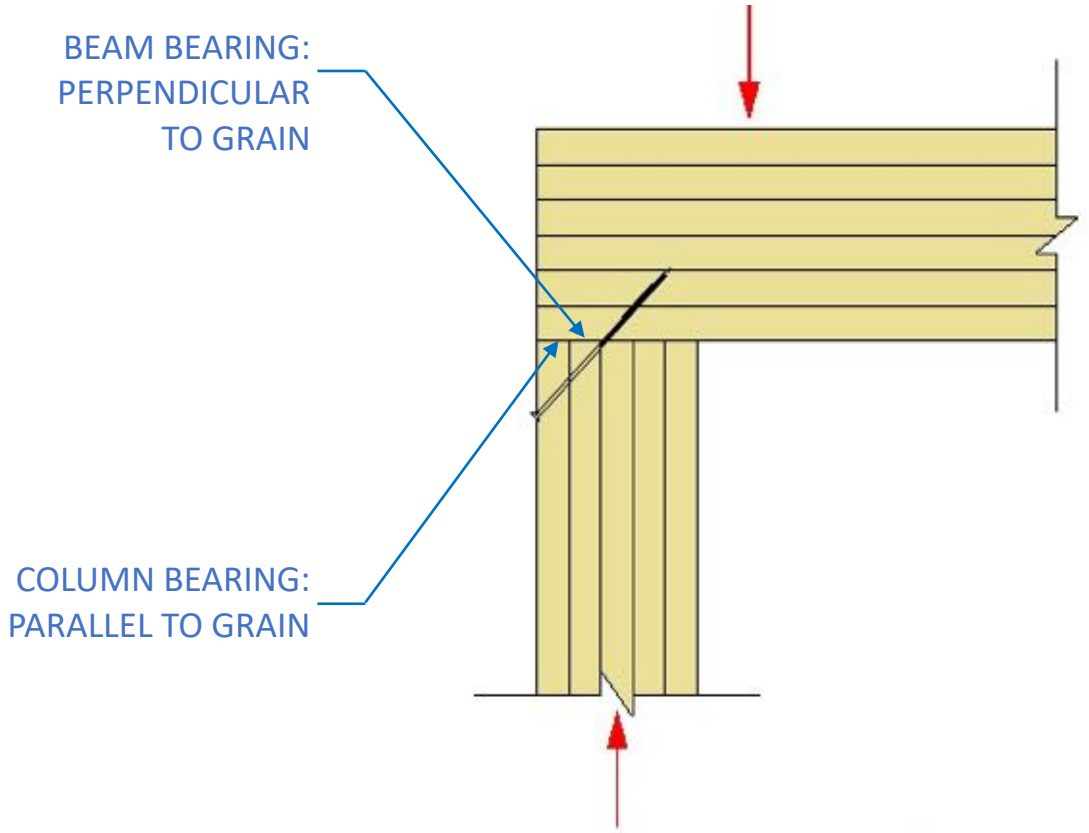

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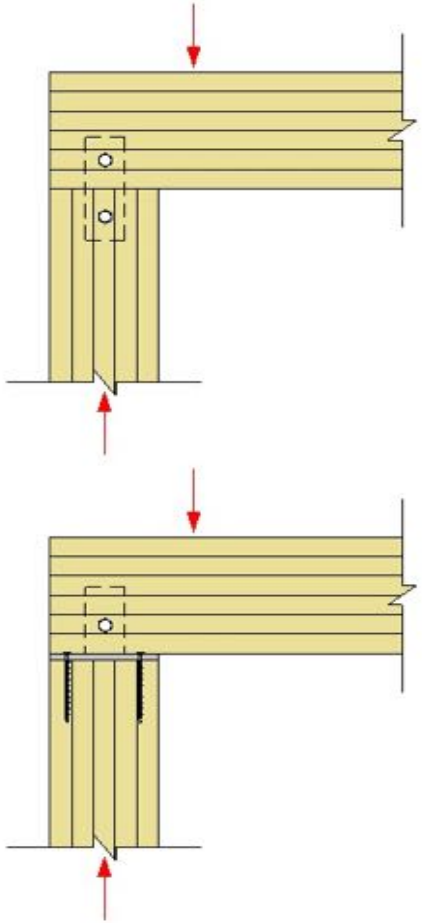
2018 AWC NDS, Section 12.2.2.3



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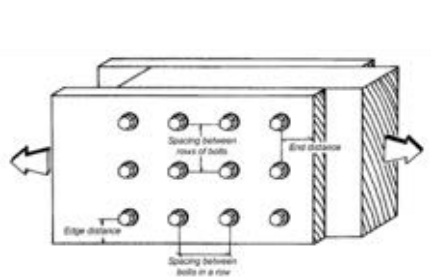
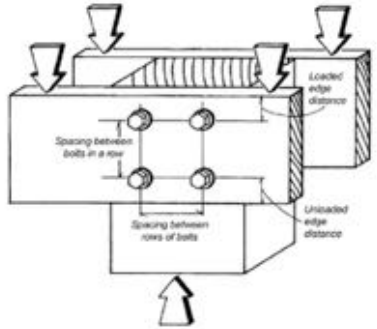
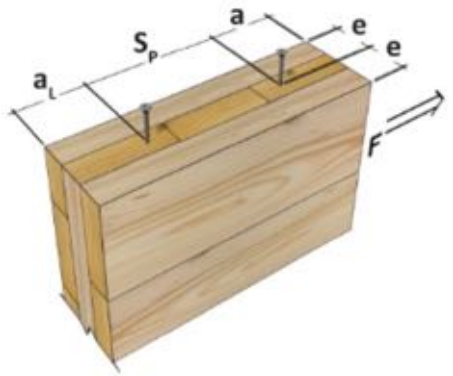
- 2018 AWC NDS, Section 12.5
- Manufacturer's Literature







Structural Design

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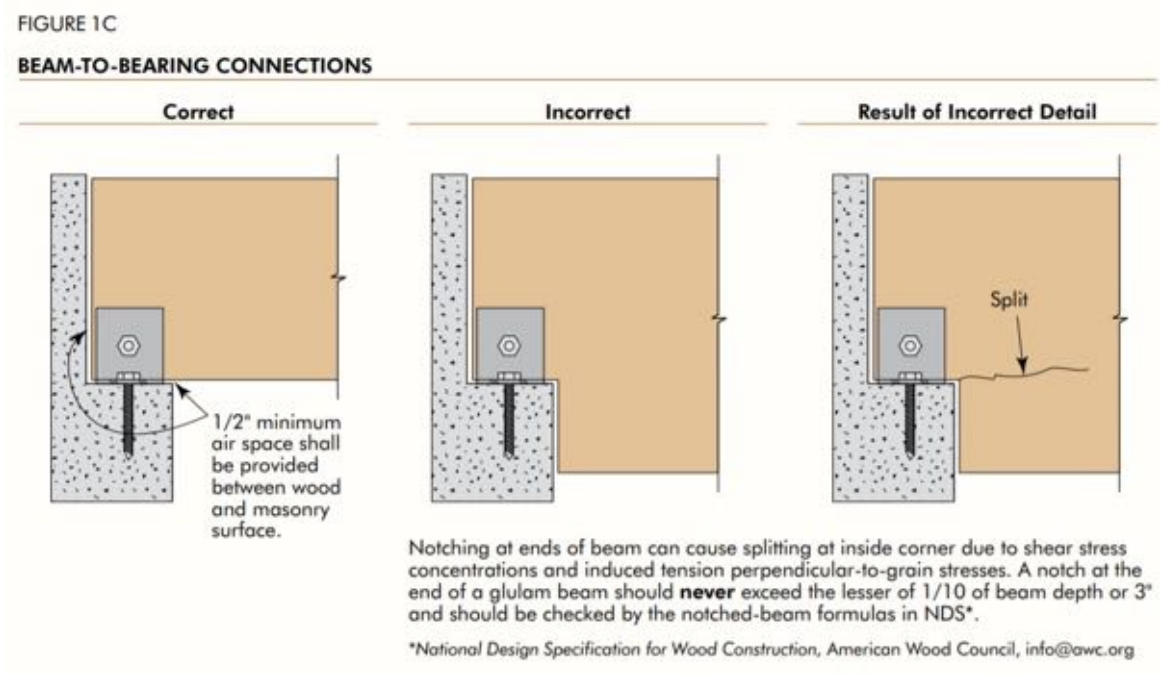
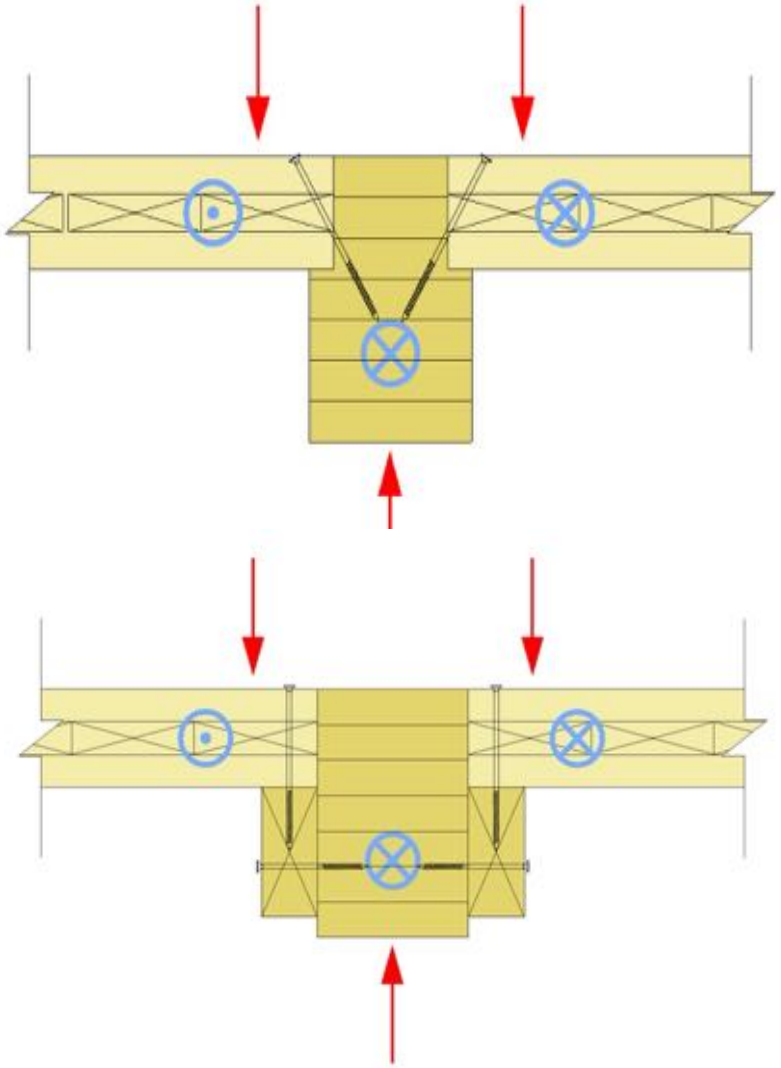
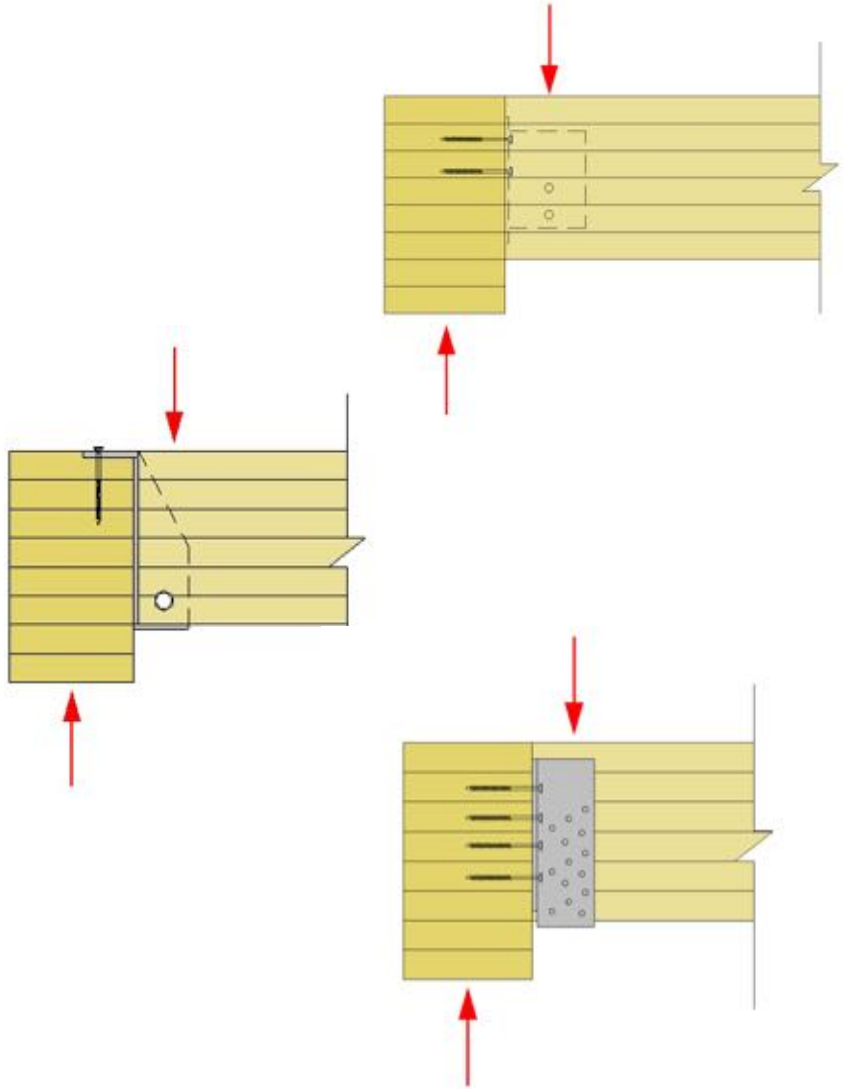
- 2018 AWC NDS, Section 5.4.5
- APA – The Engineered Wood Association (EWS) T300 *Glulam Connection Details Construction Guide*
- MTC Solutions *ASSY Screws as Tensile Reinforcement in Notched Beams*



(APA T300)

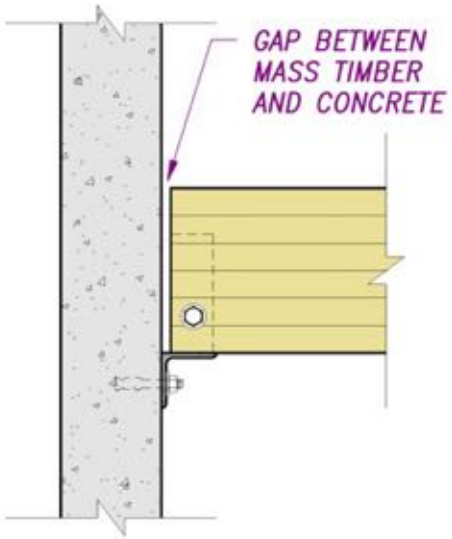
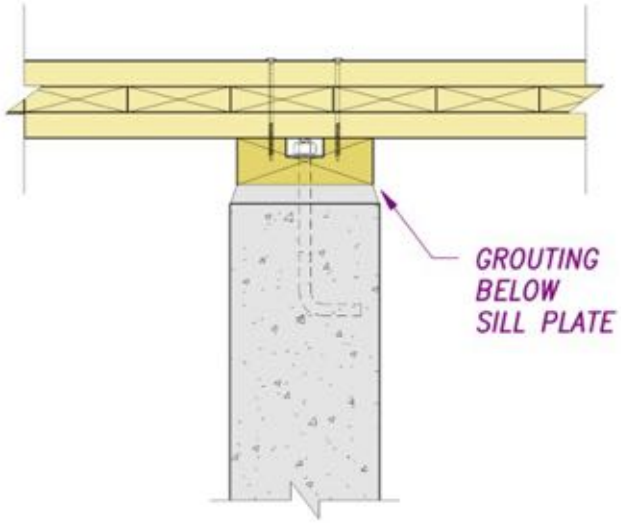
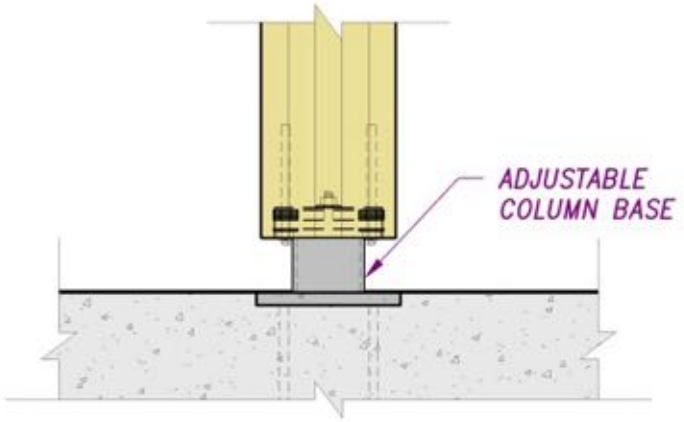
Aesthetics





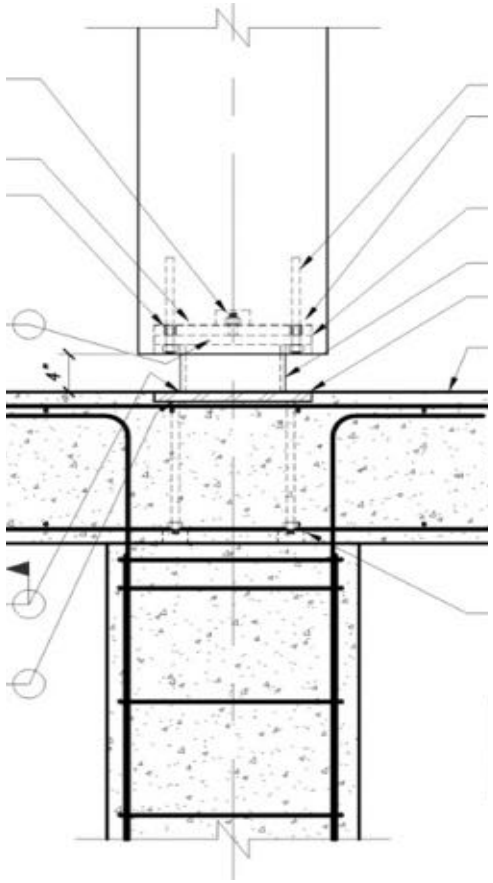
Aesthetics

Construction Tolerance

Solution	Gap between Mass Timber Beam and Concrete Wall	Grouting below Sill Plate at Mass Timber Panel to Concrete Wall	Adjustable Column Base at Mass Timber Column to Concrete
Connection Example			
	Beam Perpendicular to Wall Connected to Face of Wall	*Panel Bears at Top of Wall*	*Column Bears on Concrete with Adjustable Standoff Base*

Construction Tolerance

Construction Tolerance



Constructability

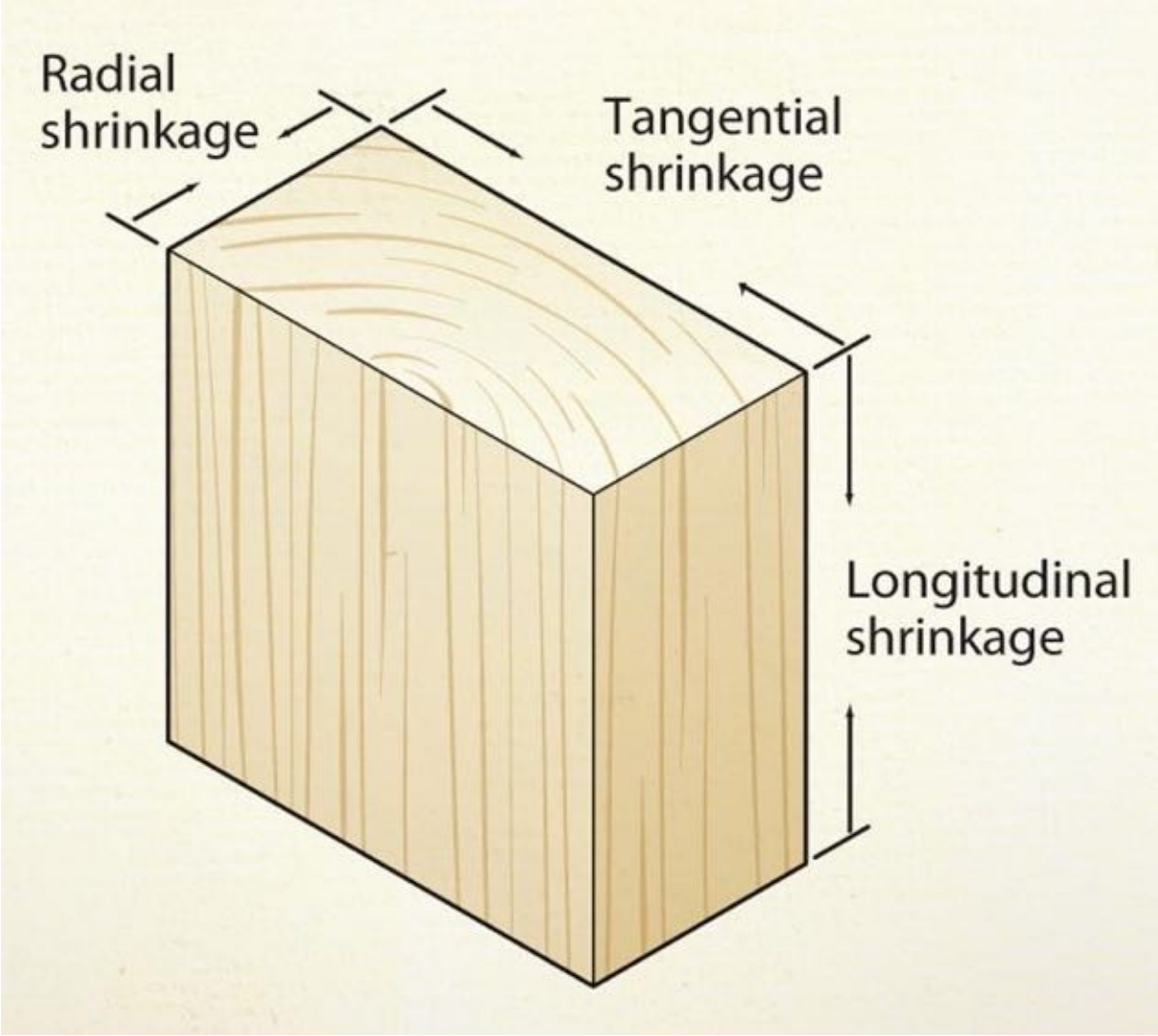
Erection

- Sequencing
- Ability to install

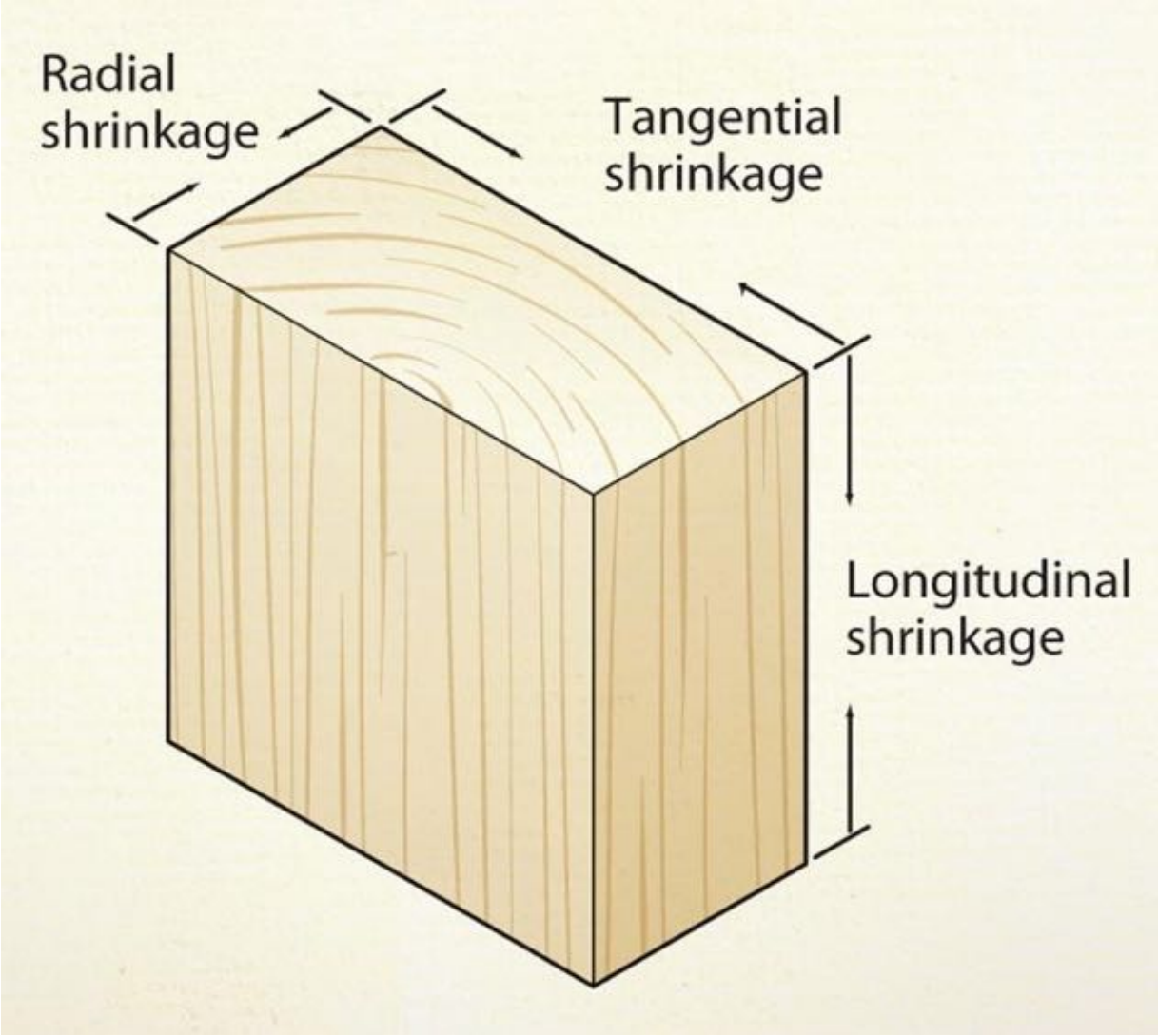
Contractor & Supplier

- Preferred connections
- Cut, notch, skew limitations
- Fastener type
- CNC capabilities

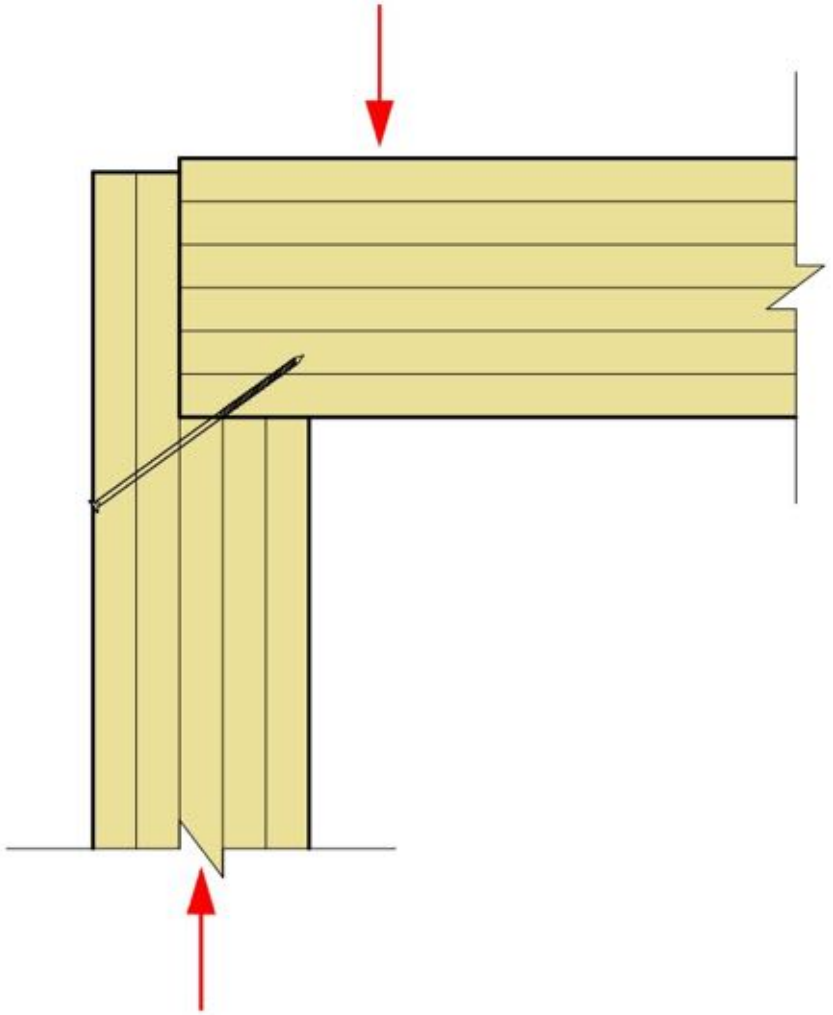
Moisture


Radial
shrinkage
Tangential
shrinkage
Longitudinal
shrinkage

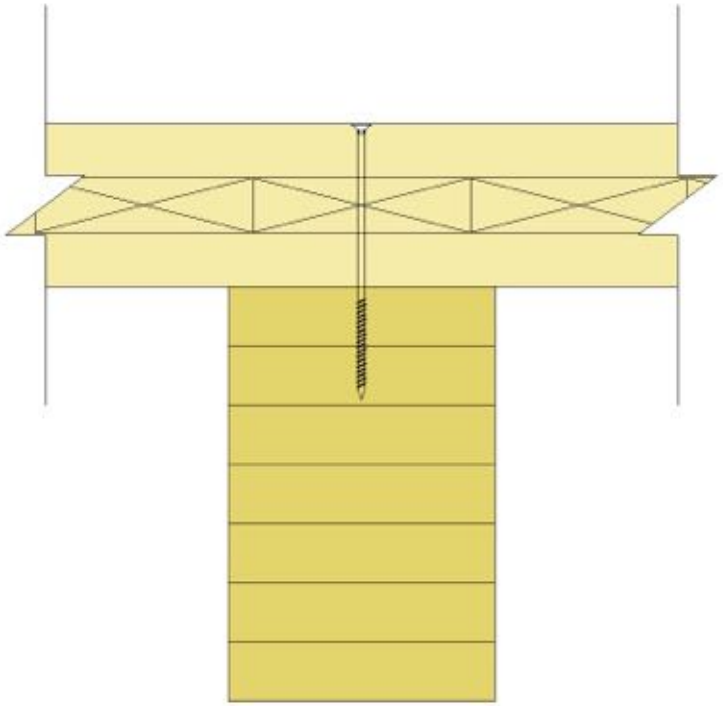
Moisture (or lack of)

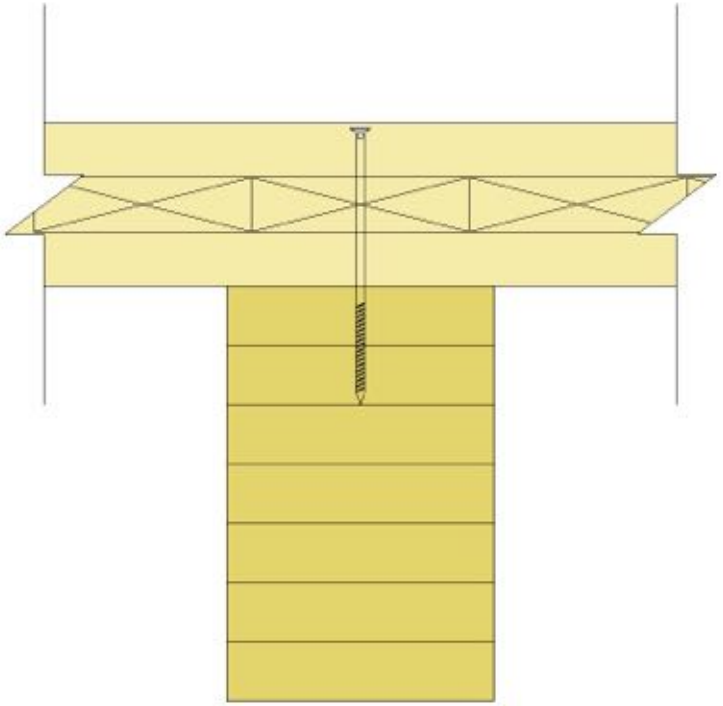


Moisture (or lack of)



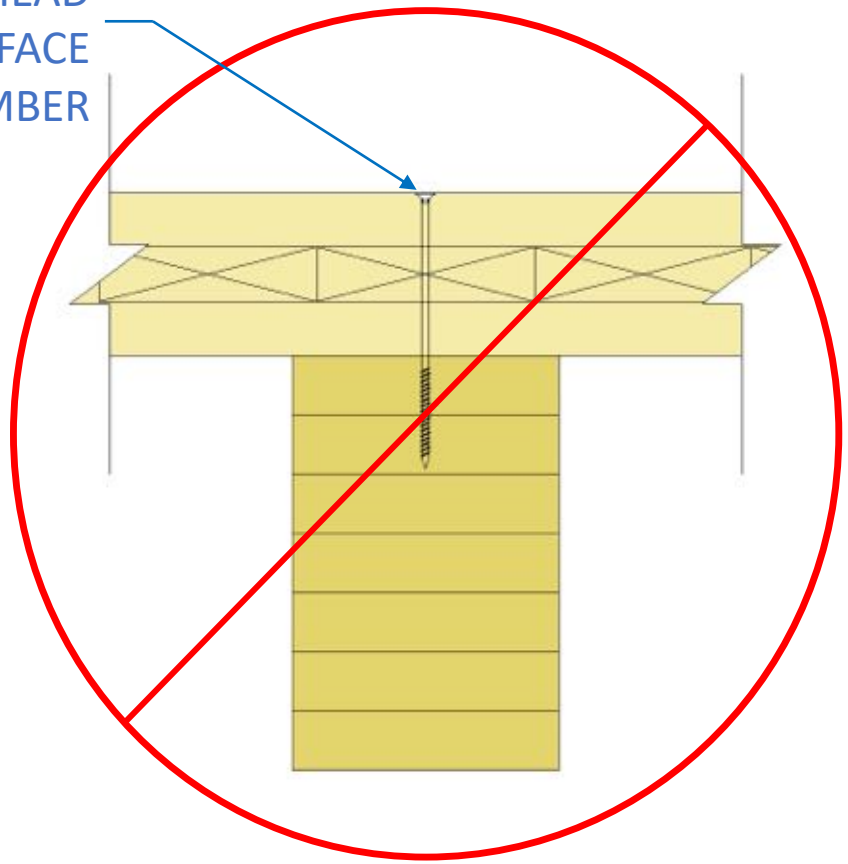
Moisture



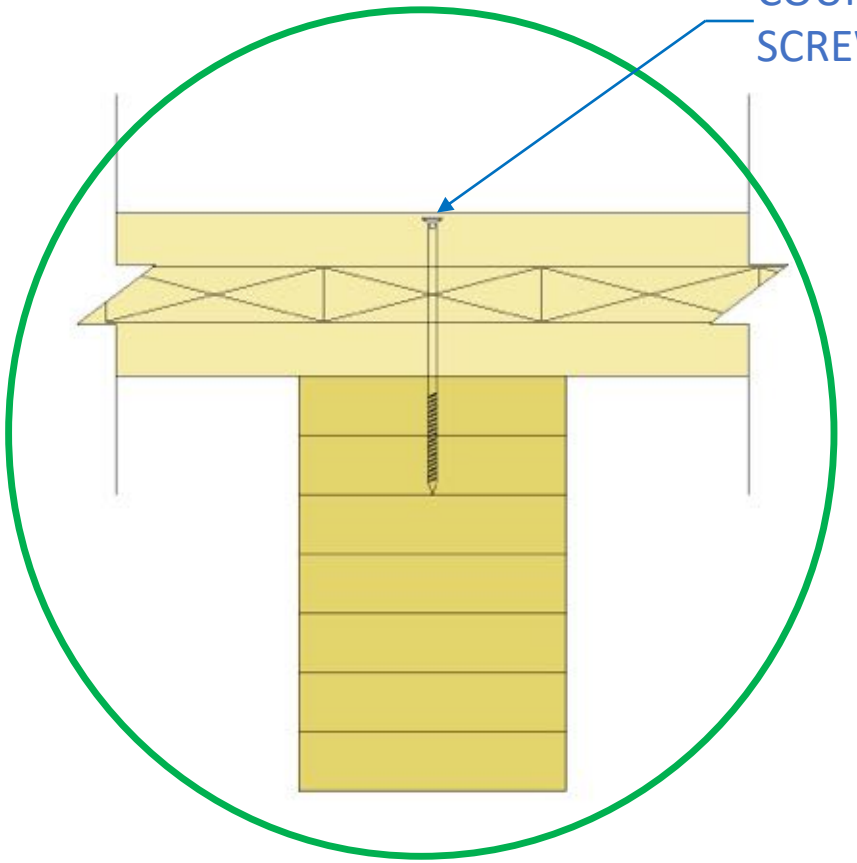


Moisture

SCREW HEAD ALIGNS WITH FACE OF MEMBER



COUNTERSINK SCREW



Moisture

Drying shrinkage through depth of 7-ply CLT floor:

Moisture

Aesthetic water damage:

Moisture

Fire Rating

TABLE 601

FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a,b]	2[a,b]	1[b]	0	1[b]	0	3[a]	2[a]	2[a]	HT	1[b]	0
Bearing walls Exterior[e,f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	3 3	2 2	2 2	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary members (see Section 202)	1 ½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1 ½	1	1	HT	1[b,c]	0

https://www.woodworks.org/wp-content/uploads/Inventory-of-Fire-Resistance-Tested-Mass-Timber-Assemblies-Penetrations.pdf

Inventory of Fire Resistance-Tested Mass Timber Assemblies & Penetrations

Following is a list of mass timber assemblies and penetration fire stopping systems in mass timber assemblies that have been tested for fire-resistance. Sources are noted at the end of this document. For free technical assistance on any questions related to the fire-resistance design of mass timber assemblies, or free technical assistance related to any aspect of the design, engineering or construction of a commercial or multi-family wood building in the U.S., email help@woodworks.org or contact the WoodWorks Regional Director nearest you: http://www.woodworks.org/project-assistance

Contents:

Inspections

Connection Index

Index Organization

Top to Bottom Support:

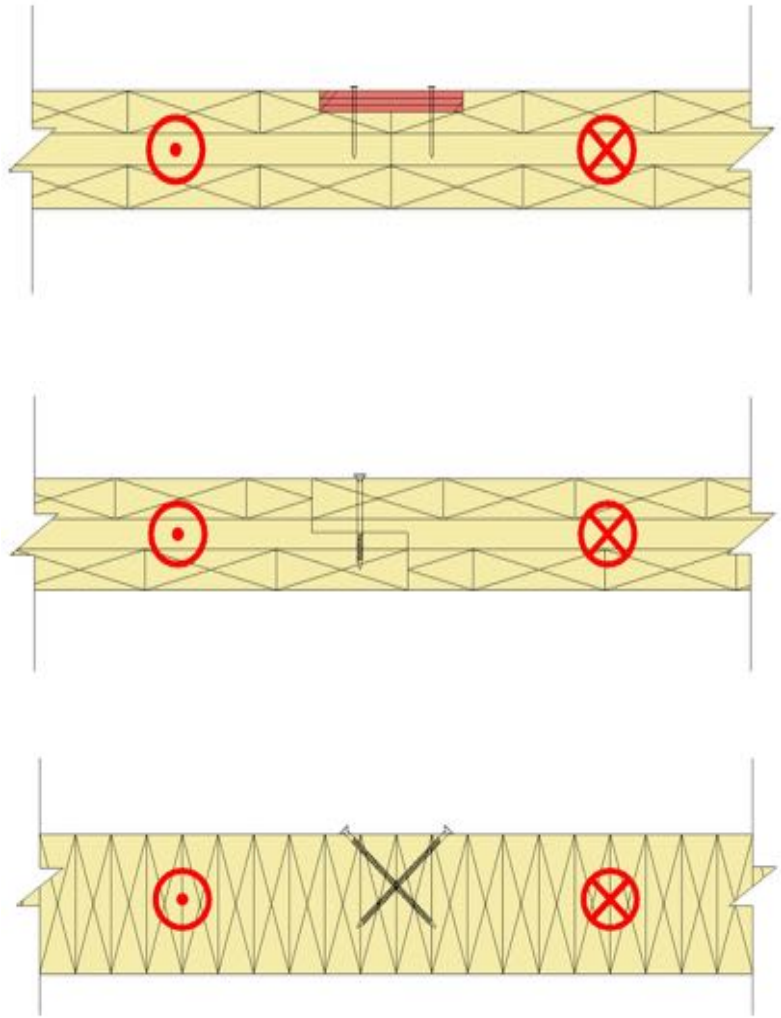
- Panel to Panel
- Panel Support
- Beam Support
- Supporting Other Framing Systems
- Wall Panel to Wall Panel
- Base Connections

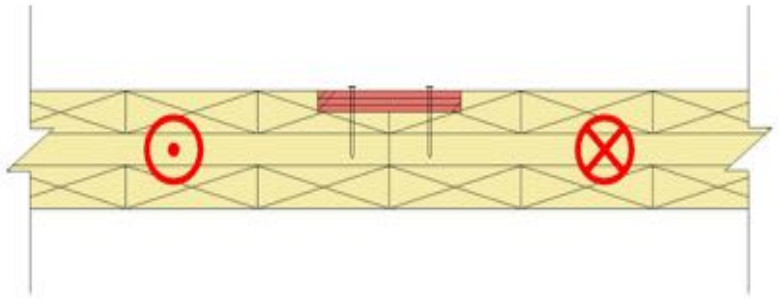
Connection Categories

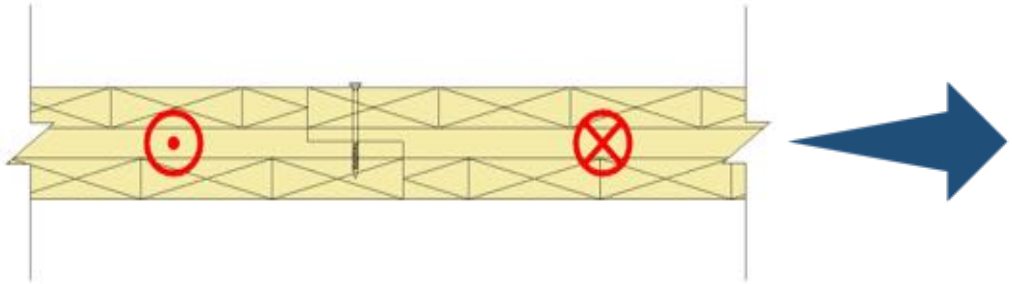
Panel to Panel Connections

- Diaphragm loads
- Many fasteners required
  - Consider fastener type
- Multiple fire-rated options

  https://www.woodworks.org/wp-content/uploads/Inventory-of-Fire-Resistance-Tested-Mass-Timber-Assemblies-Penetrations.pdf

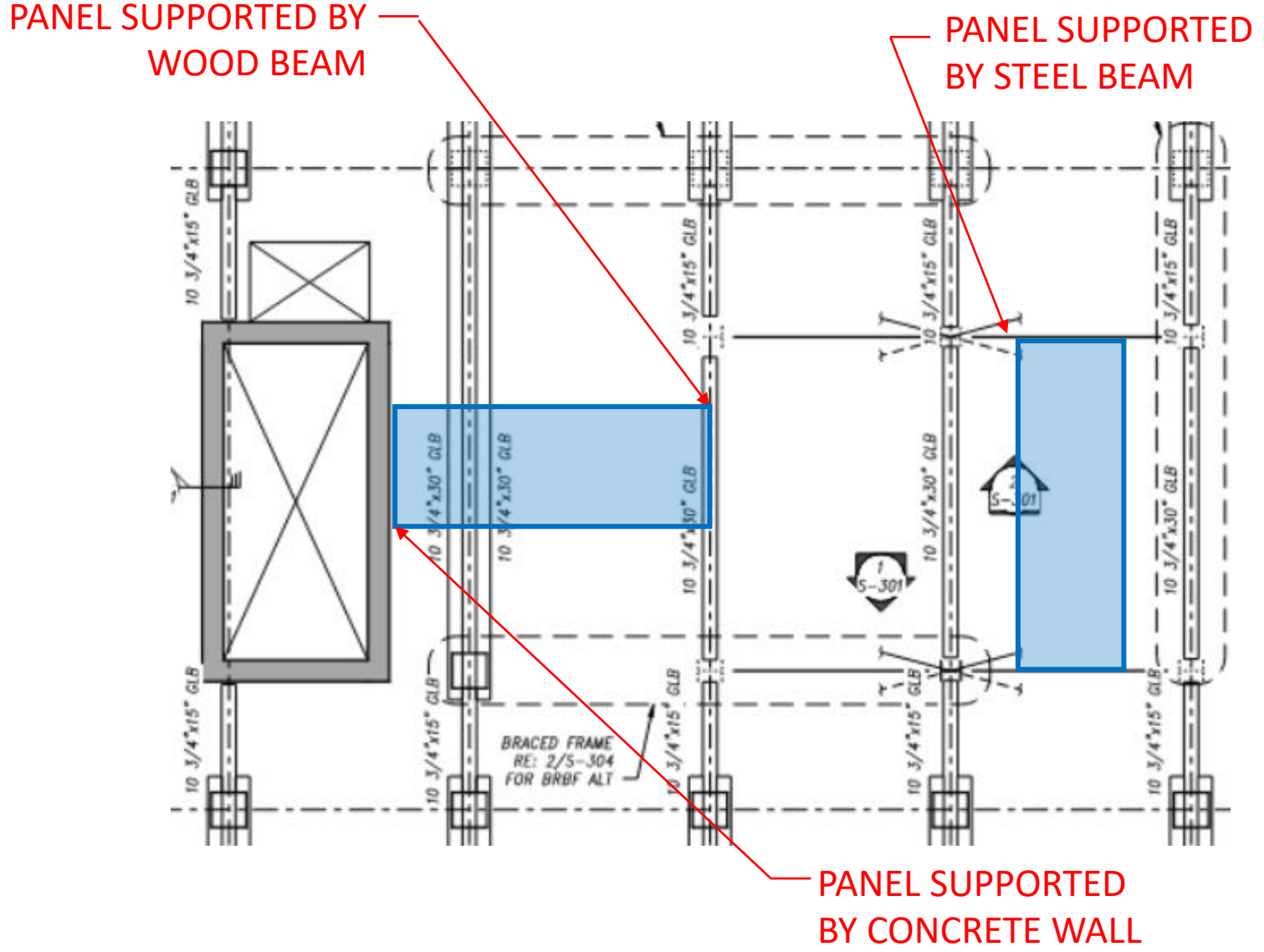






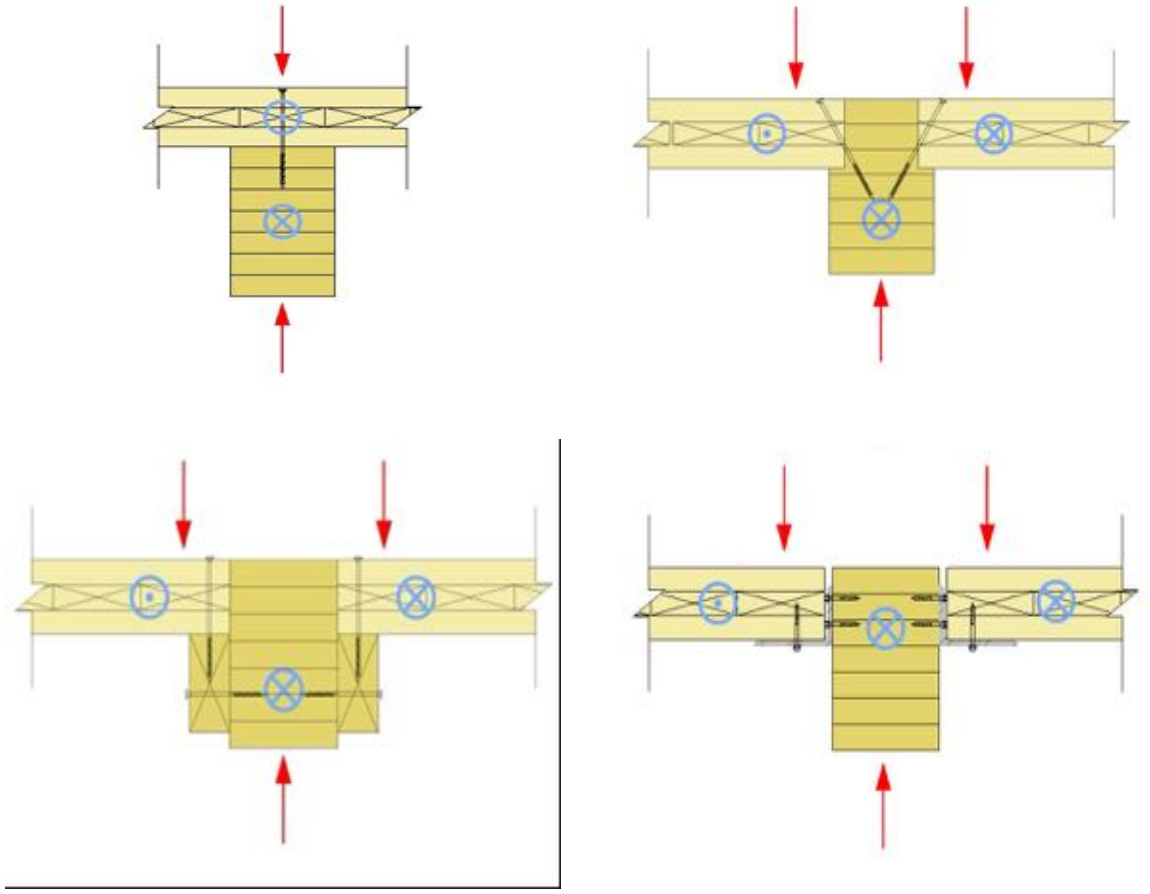
Panel Support

- Beam
- Column
- Wall Panel
- Concrete or Masonry
- Light Frame
- Steel Beam



Panel Support at Mass Timber Beam

- Overall floor depth
- Panel continuity
- Fire rating
- Aesthetics



Panel Support at Mass Timber Beam

Panel Support at Mass Timber Beam

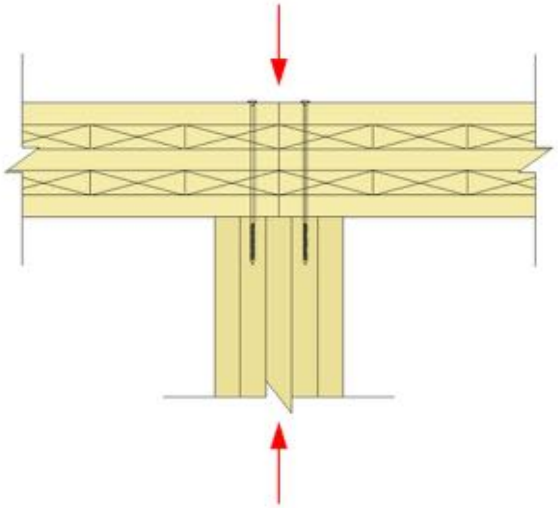
Panel Support at Mass Timber Beam

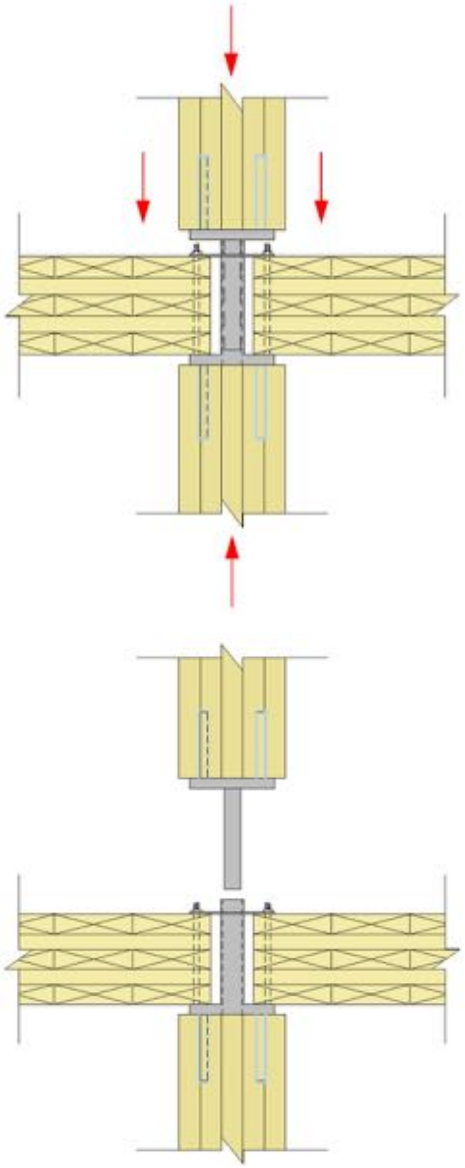
Panel Support at Mass Timber Beam

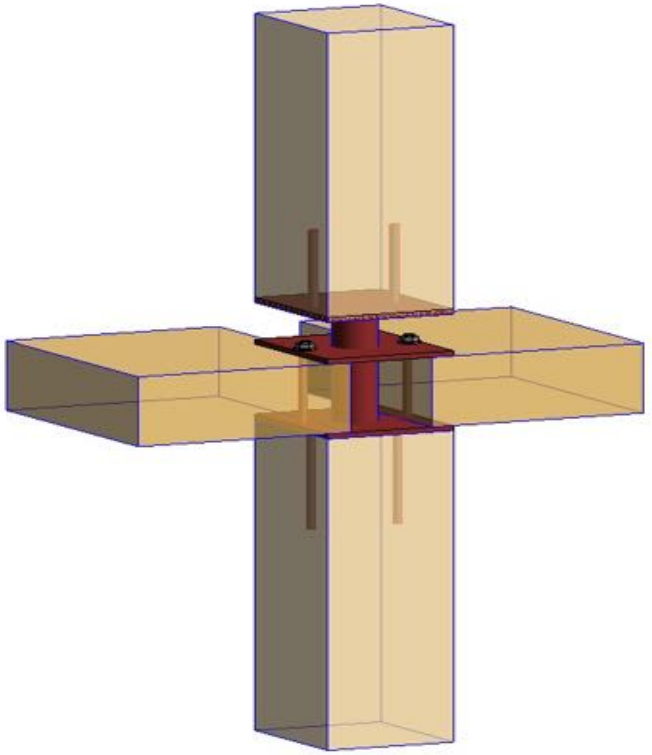
Panel Support at Mass Timber Column

Point Support of Panels

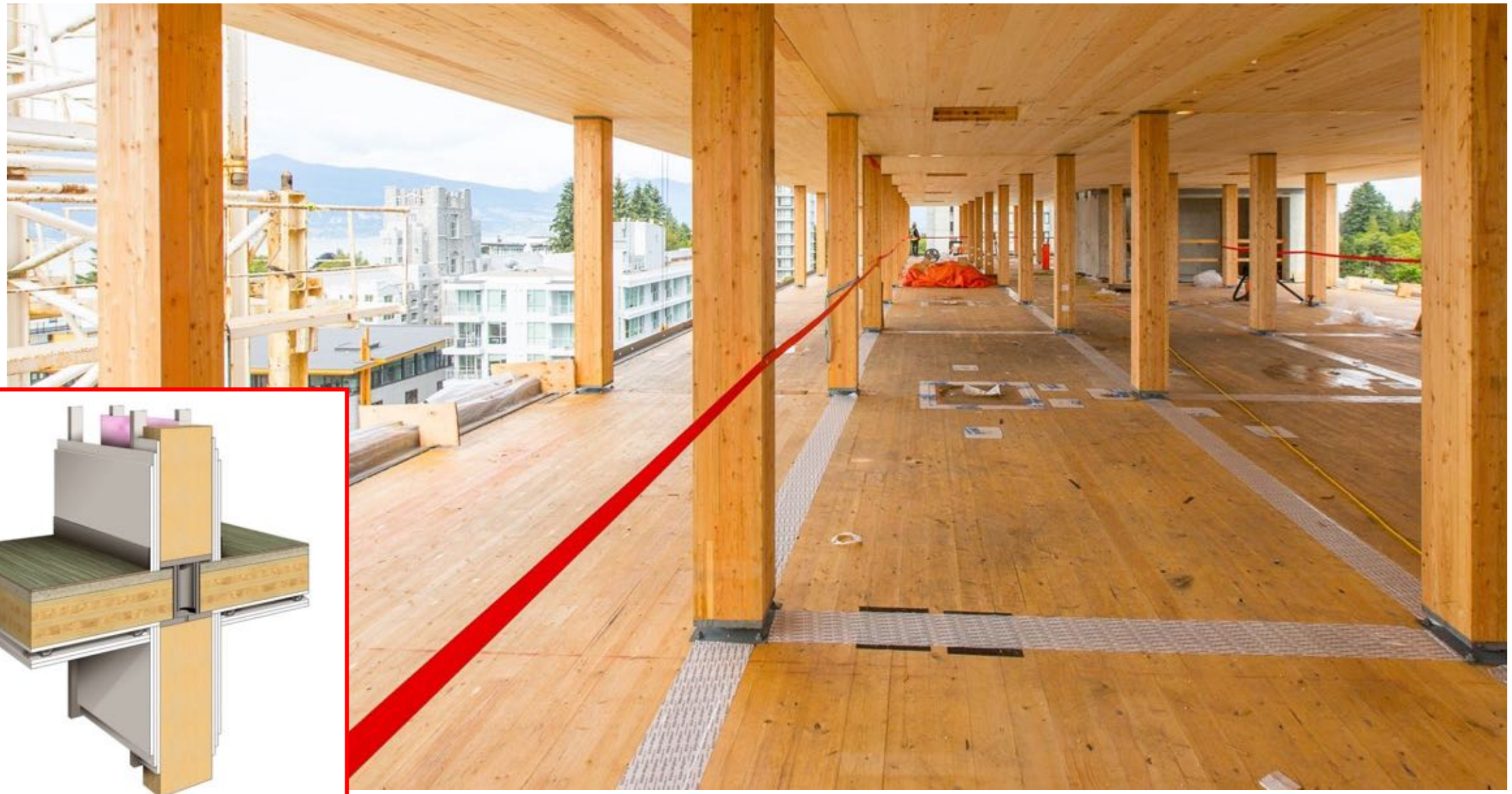
- 2-way panels







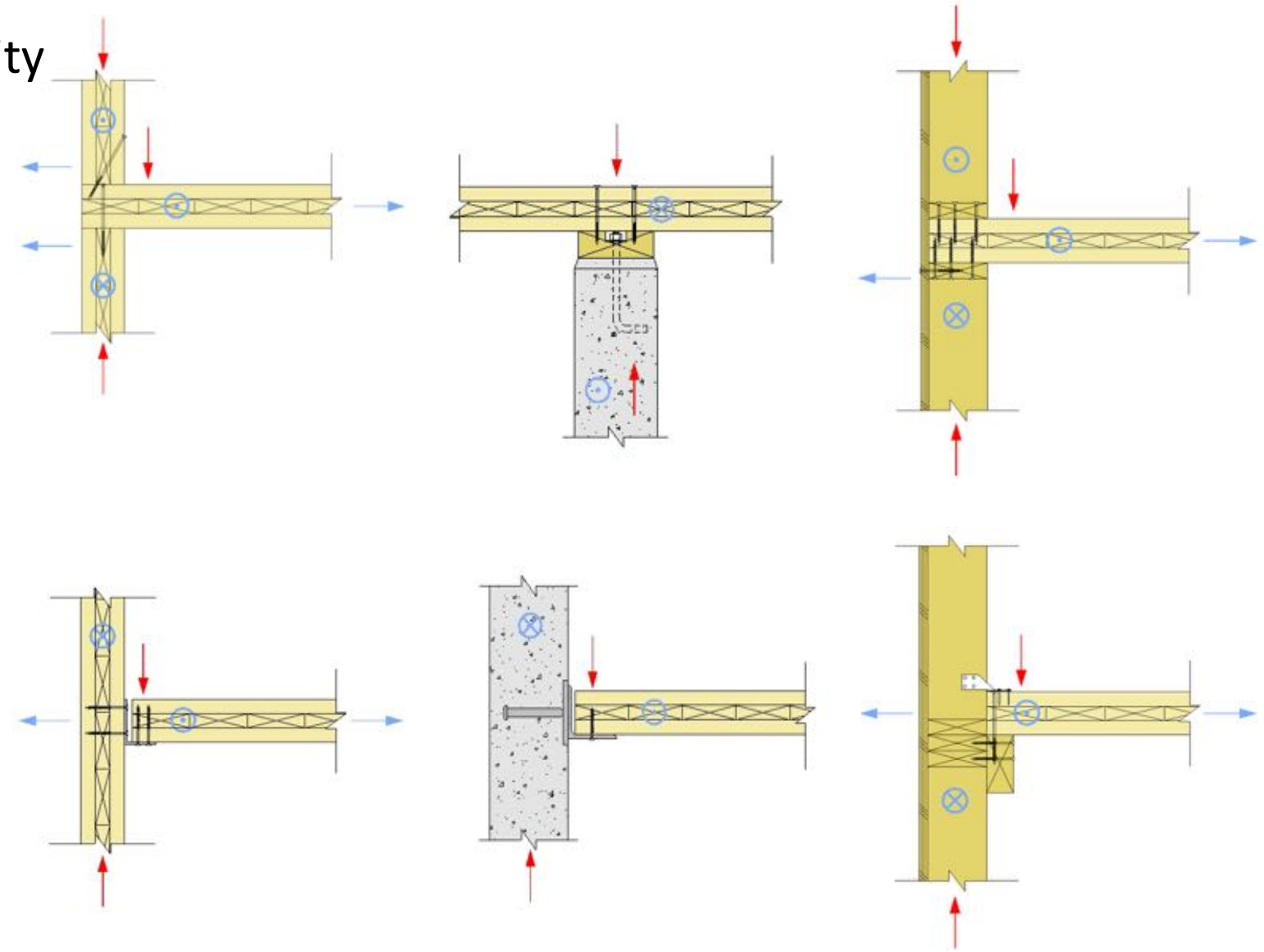
Panel Support at Mass Timber Column



Panel Support at Walls

Panels Supported by Walls – Gravity Support:

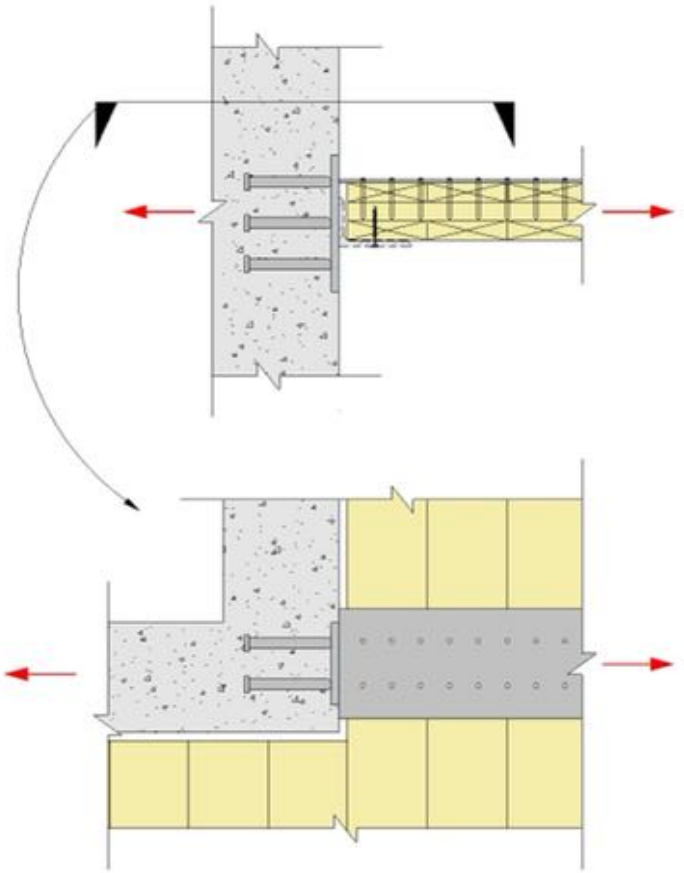
- Mass Timber Wall
- Concrete
- Masonry
- Light Frame



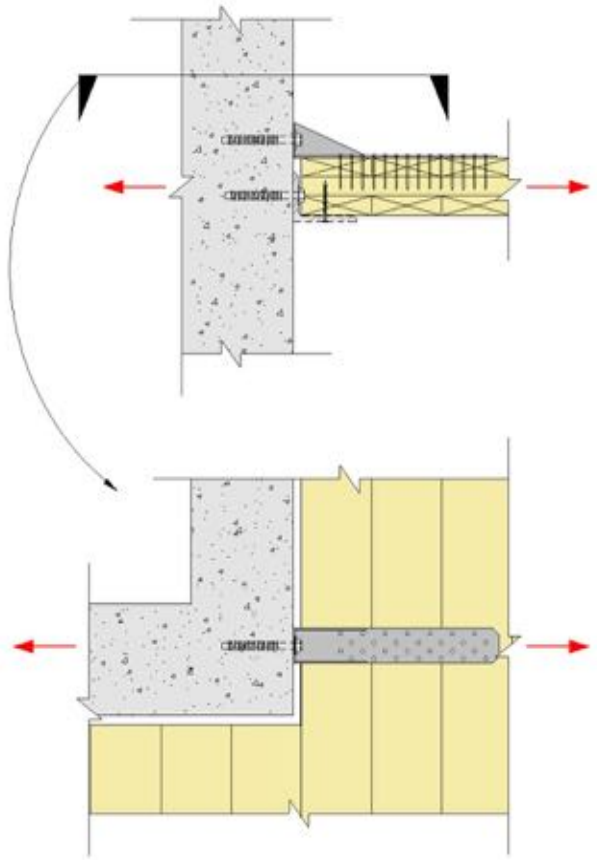
Panel Support at Walls

Panels Supported by Walls – Lateral Support:

- Custom Connector
- Proprietary Connector



Diaphragm to Shear Wall: Custom Connector



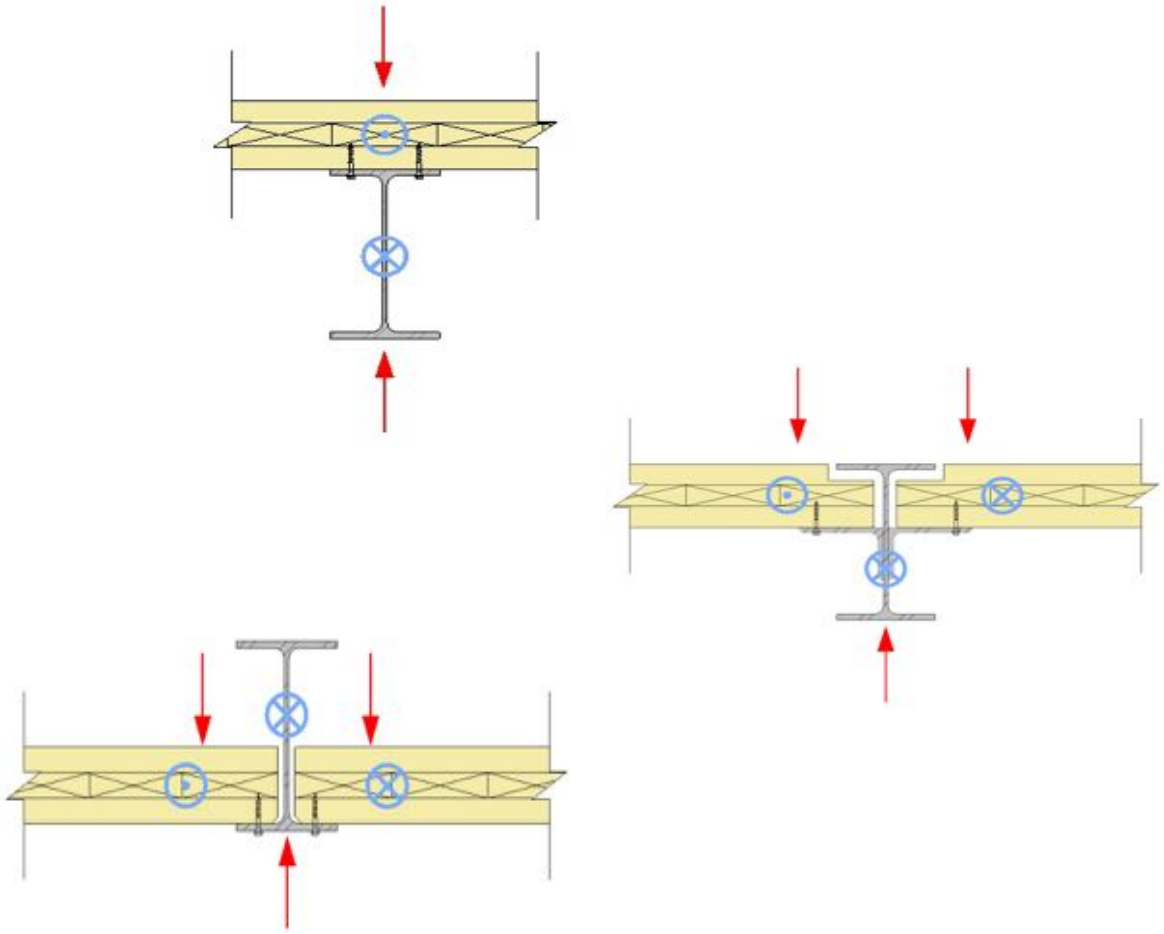
Diaphragm to Shear Wall: Proprietary Connector

Panel Support at Walls

Panel Support at Steel Beam

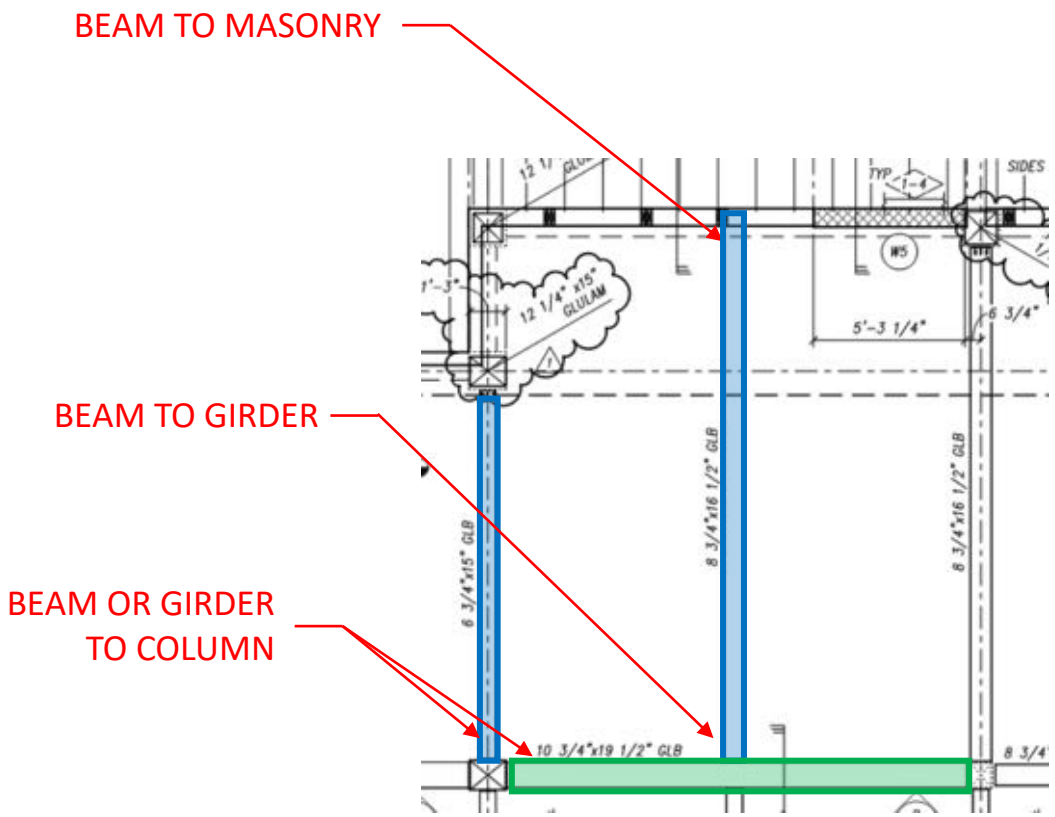
Hybrid Structural System

- Reasons
  - Structural Depth
  - MEP coordination
  - Aesthetics



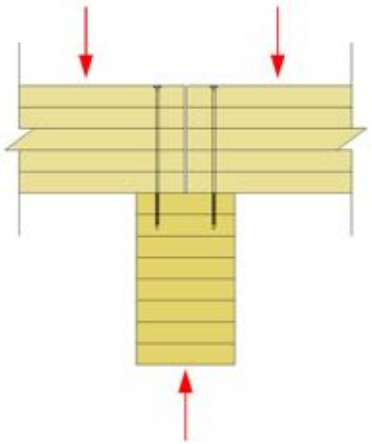
Beam Support

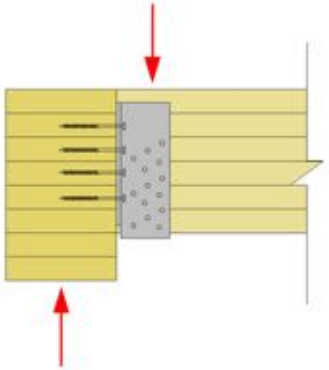
- Mass Timber Girder
- Mass Timber Column
- Mass Timber Wall Panel
- Concrete or Masonry
- Light Frame
- Steel Frame

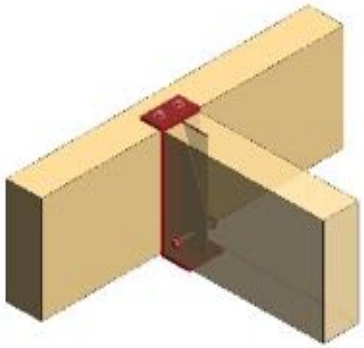


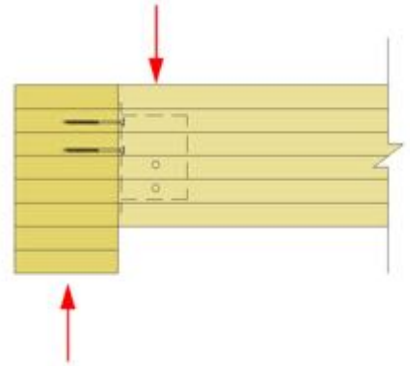
Beam Support at Girder

- Largest Section
- Many connections applicable to other Beam Support Conditions
  - Column
  - Wall Panel

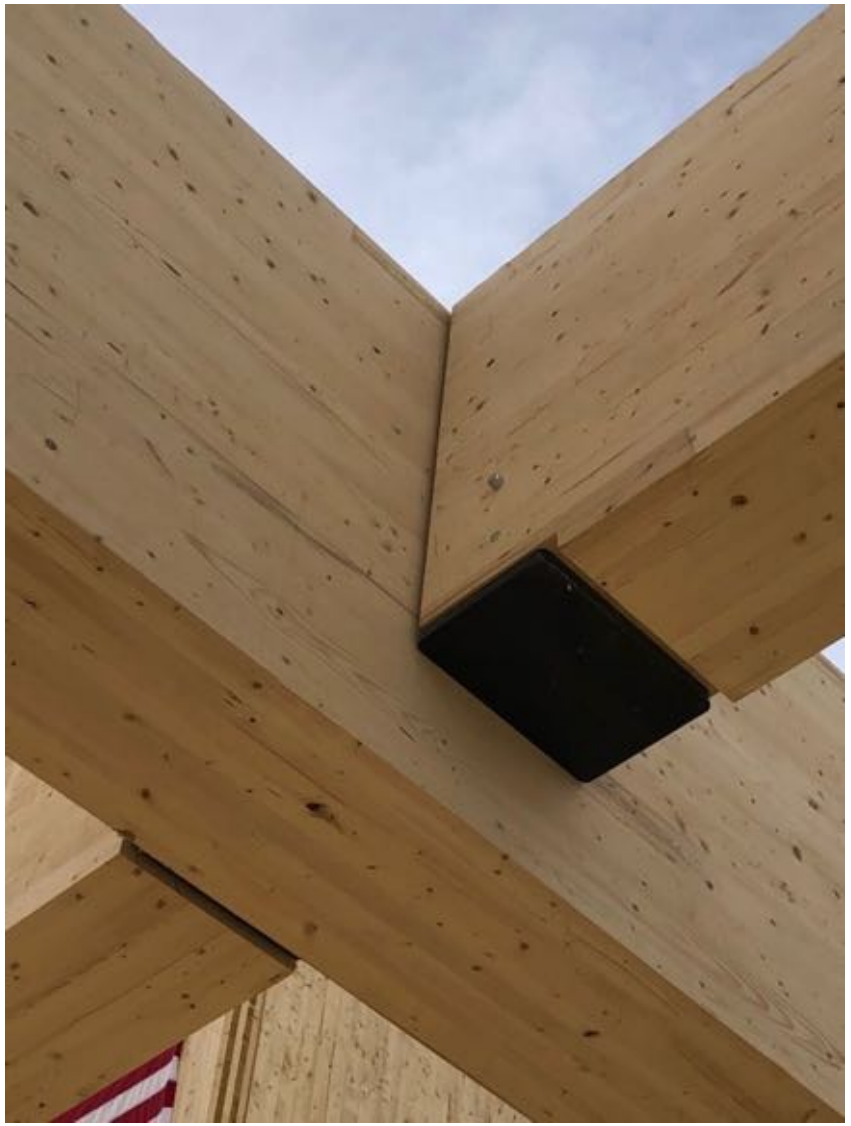






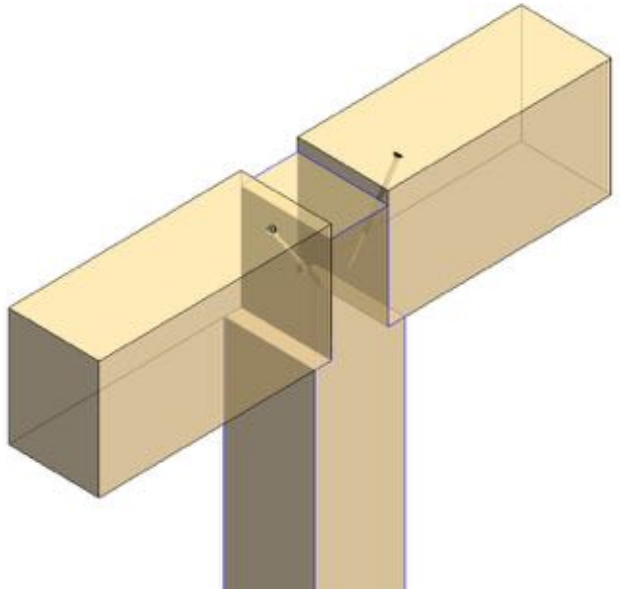


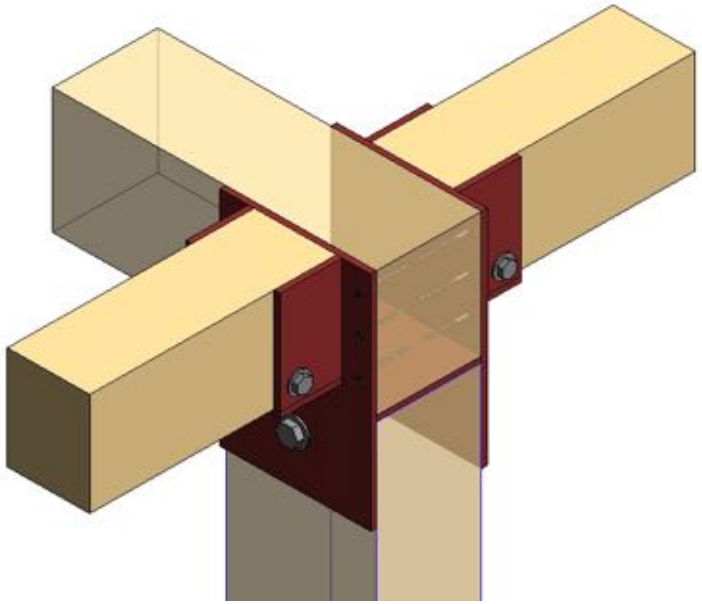
Beam Support at Girder



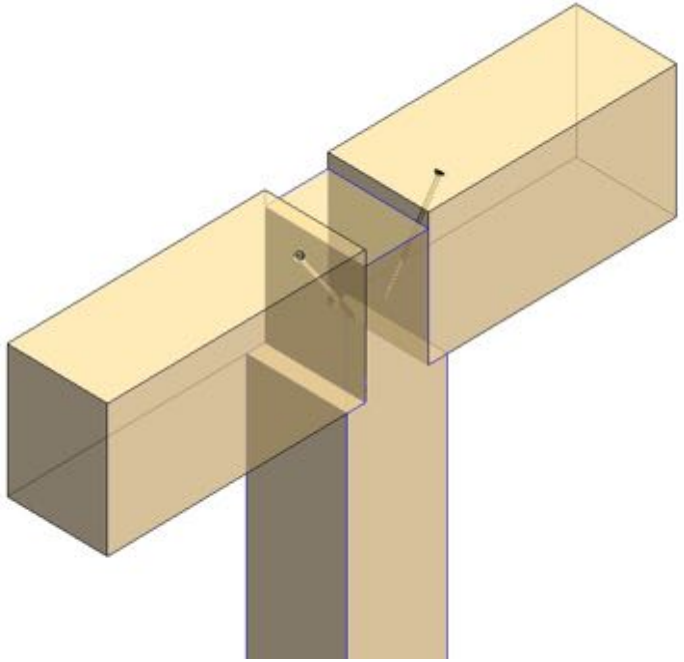
Beam Support at Column

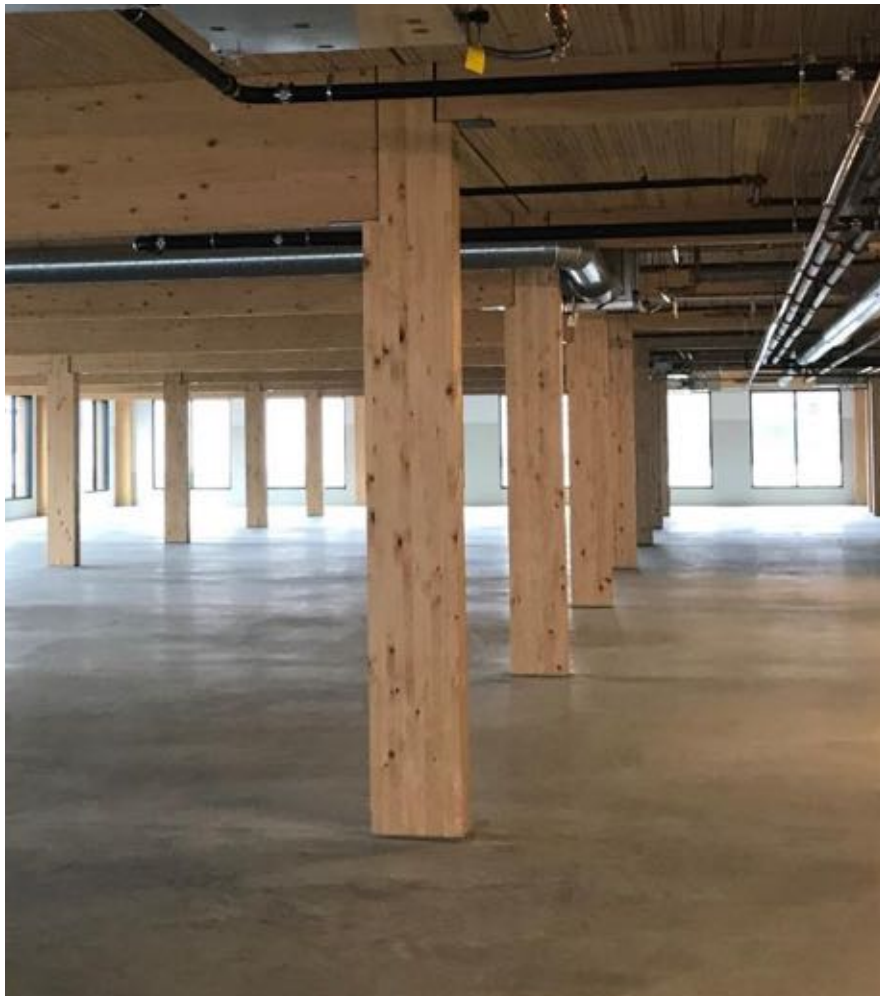
- Many alternate options
- Aesthetics
- Loads
- Ceiling height



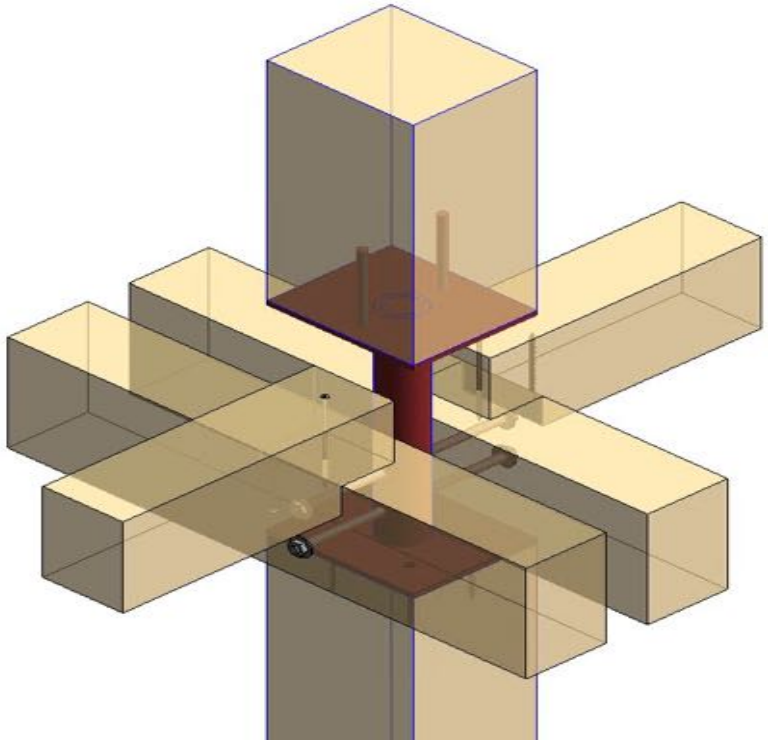


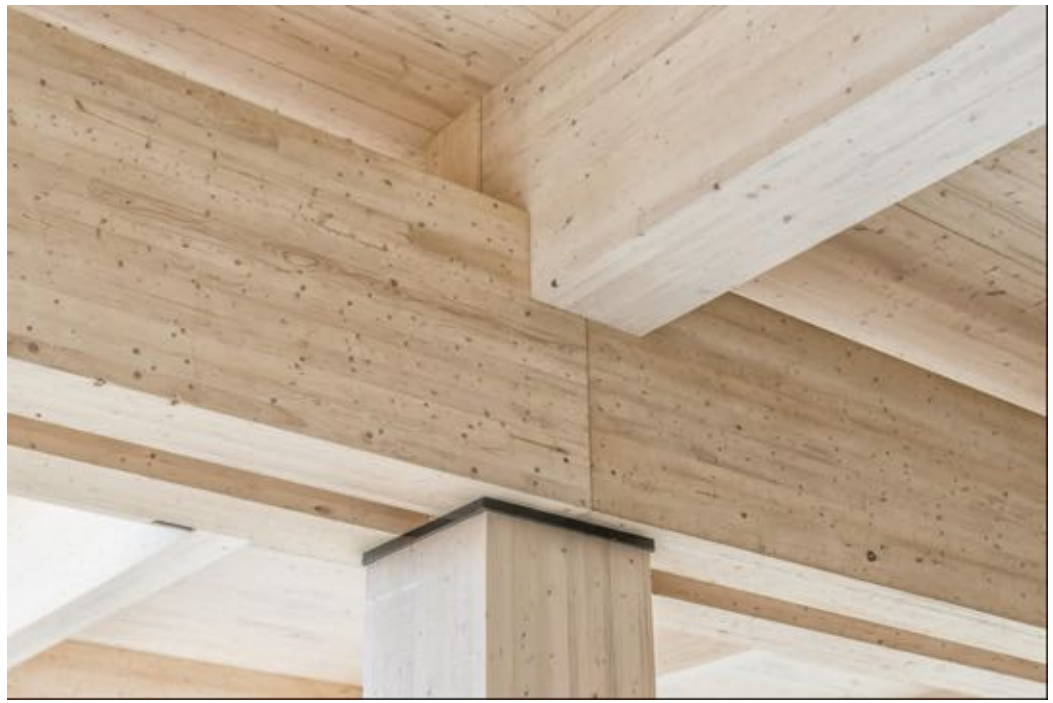
Beam Support at Column



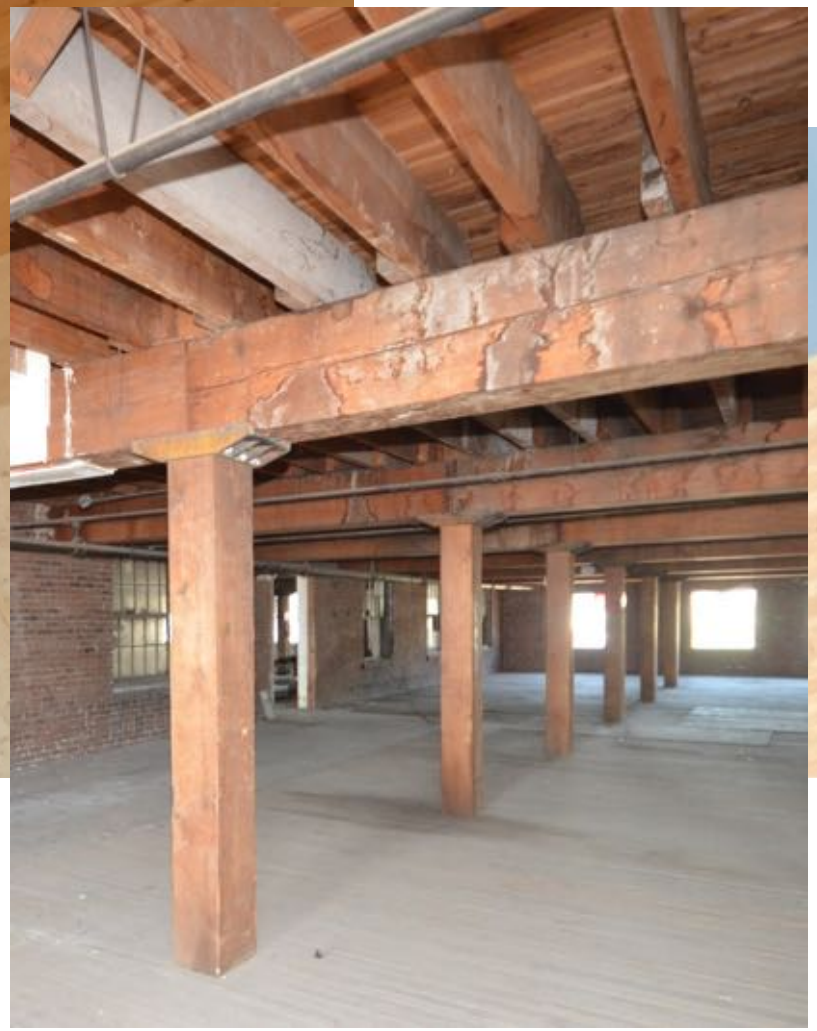


Beam Support at Column





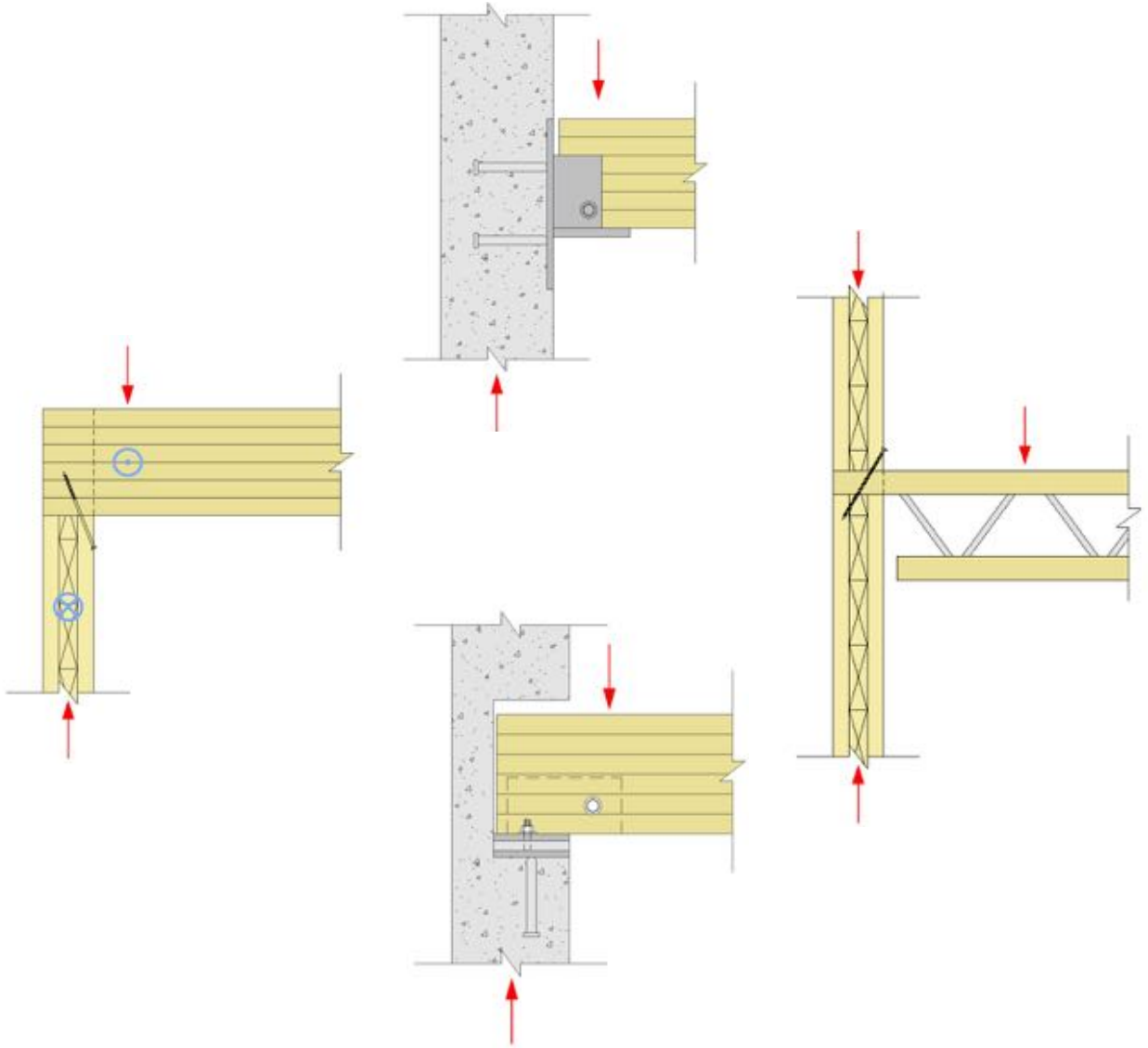
Beam Support at Column



Beam Support at Walls

Beam Supported by Wall:

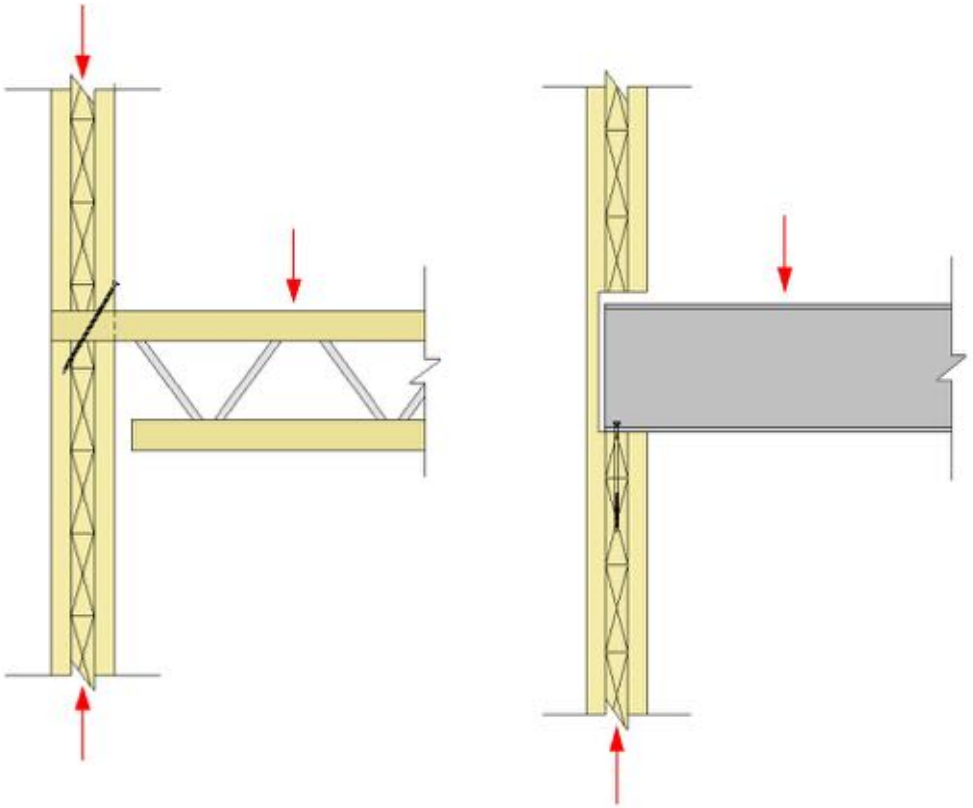
- Mass Timber Wall
  - See also Beam Supported by Girder
- Concrete or Masonry
  - Tolerances
  - Moisture
- Light Frame



Supporting Other Framing Systems

Supporting Other Framing Systems:

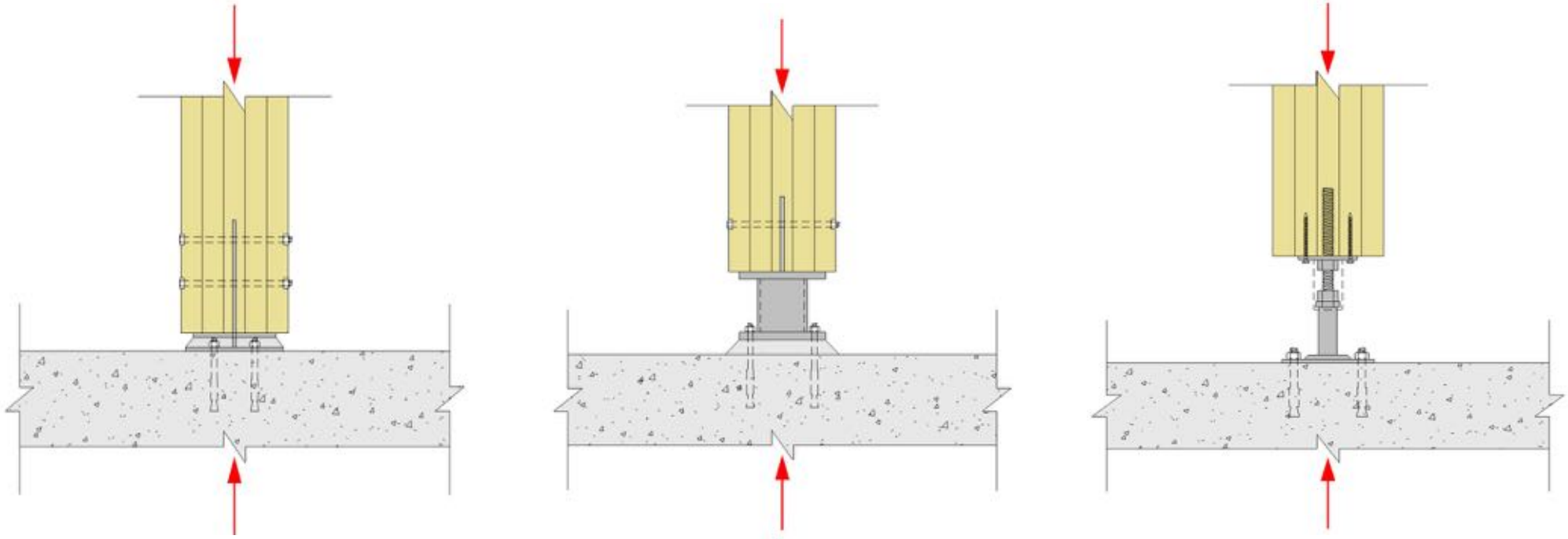
- Light Frame/Trusses
- Steel Frame



Base Connections

Base Connections:

- Column at Concrete
- Wall Panel at Concrete



Connection Categories

Connection Information

Connection Information

Connection Type	Image	Designer Notes	Class	Load	Cost	Const	Inspect	Fire
Panels Connect with Single Surface Spline		Purpose: Transfer of in-plane shear along the panel to panel joint. Description: Adjacent floor panels with routed surfaces are butted together. A plywood spline is fastened to both panels using partially threaded screws or nails. Notes: • Capacity of connection is controlled by shear capacity of dowel-type fasteners. • Double Surface Spline or Steel Surface Spline can be used for increased capacity. • Spline may be fully above panels without routed surface where floor or roof coverings allow. • Where using nails, consider specifying nail gun nails instead of common wire nails for constructability, or collated screws instead of individual screws. • Where screws are used instead of nails, Cost increases and Constructability is moderate. • Typical minimum plywood thickness is ½" nominal. • Coordinate spline and rout width and thickness with panel supplier.	1	medium	$	easy	easy	Level I

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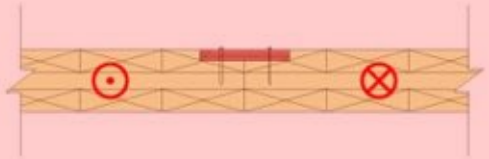
Panels Connect with Single Surface Spline		Purpose: Transfer of in-plane shear along the panel to panel joint. Description: Adjacent floor panels with routed surfaces are butted together. A plywood spline is fastened to both panels using partially threaded screws or nails. Notes: • Capacity of connection is controlled by shear capacity of dowel-type fasteners. • Double Surface Spline or Steel Surface Spline can be used for increased capacity. • Spline may be fully above panels without routed surface where floor or roof coverings allow. • Where using nails, consider specifying nail gun nails instead of common wire nails for constructability, or collated screws instead of individual screws. • Where screws are used instead of nails, Cost increases and Constructability is moderate. • Typical minimum plywood thickness is ½" nominal. • Coordinate spline and rout width and thickness with panel supplier.	1	medium	$	easy	easy	Level I

- Load path: Primary loads

Secondary loads

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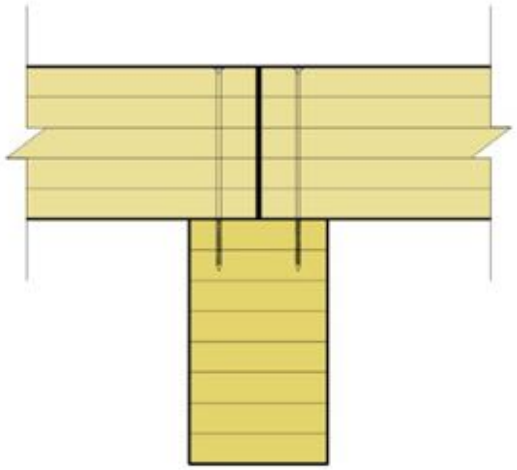
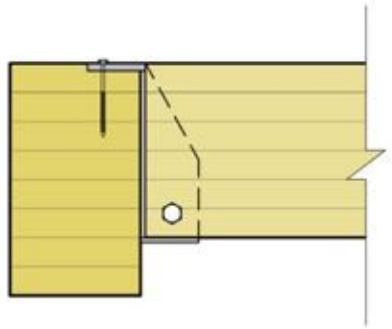
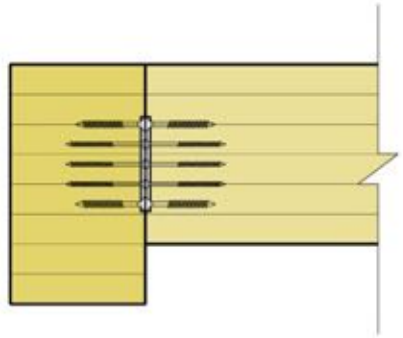
Connection Class

Connection Class	**Class 1**	**Class 2**	**Class 3**
Class Description	Requires only mass timber elements and fasteners	Utilizes steel fabricated elements, with components such as angles and plates, and includes fasteners	Prefabricated proprietary connectors
Connection Example			
	Beam Bears on Girder	*Beam Bears on Steel Bearing Seat with Knife Plate*	*Beam Connected to Girder with Proprietary Concealed Connector*

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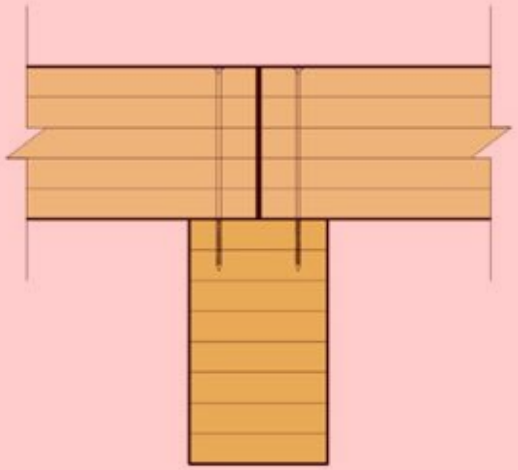
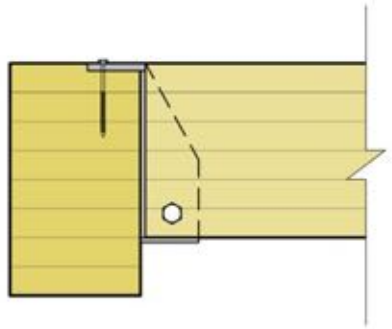
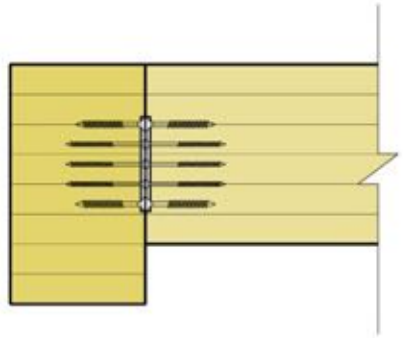
Connection Example	 *Beam Bears on Girder*	 *Beam Bears on Steel Bearing Seat with Knife Plate*	 *Beam Connected to Girder with Proprietary Concealed Connector*

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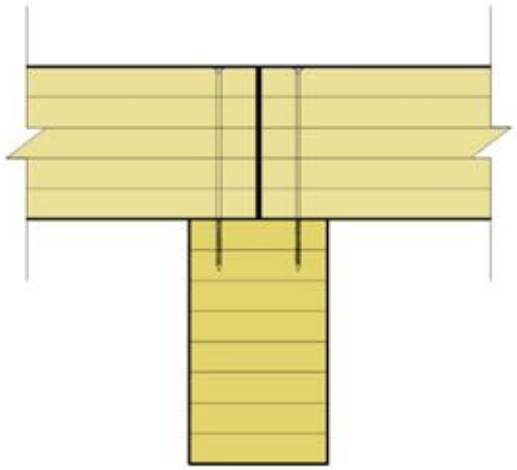
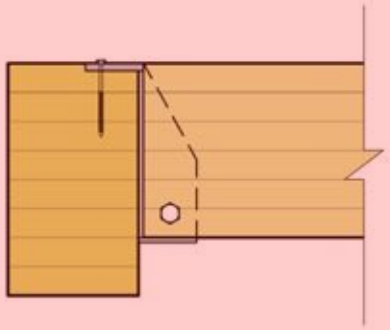
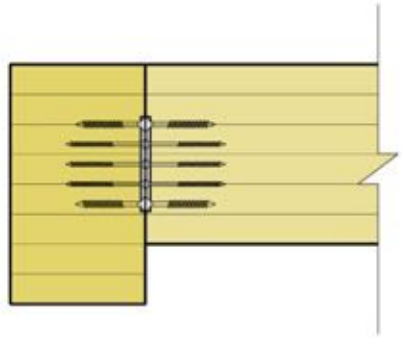
Connection Example			
	Beam Bears on Girder	*Beam Bears on Steel Bearing Seat with Knife Plate*	*Beam Connected to Girder with Proprietary Concealed Connector*

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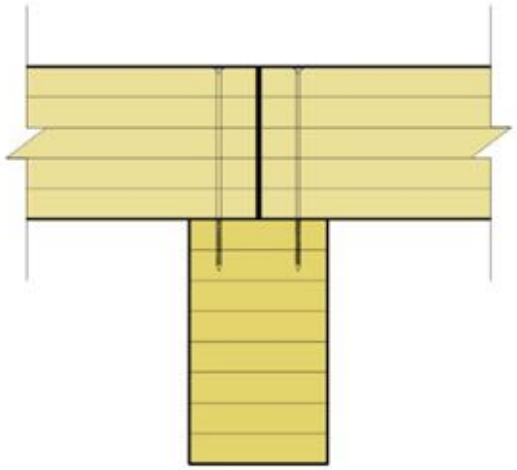
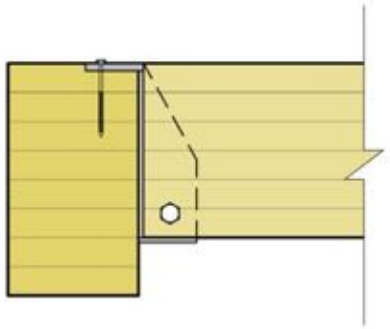
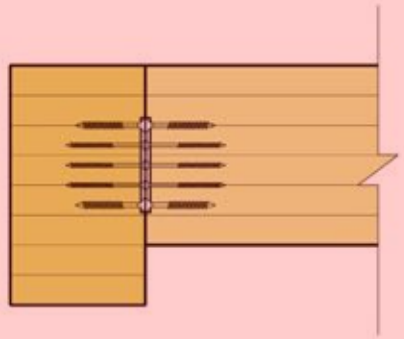
Connection Example			
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Connection Information

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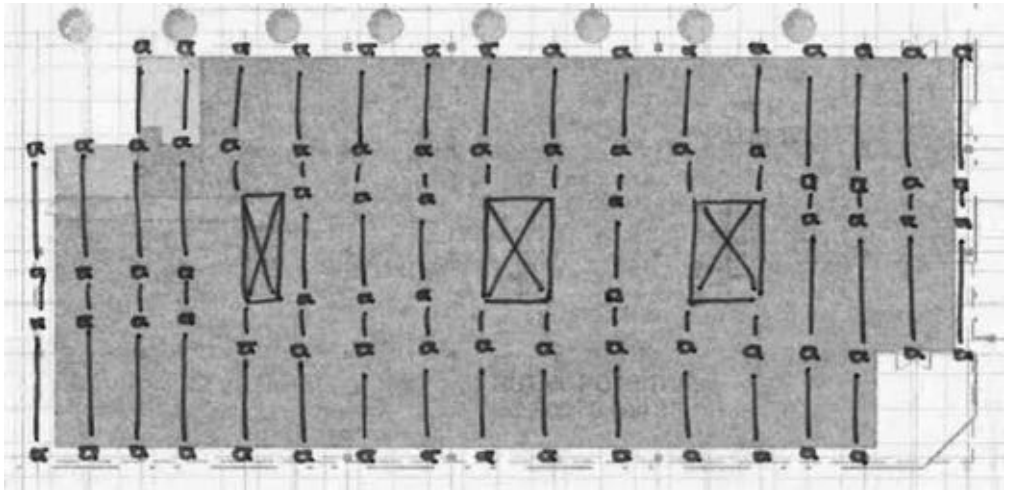
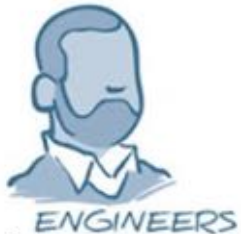
Panels Connect with Single Surface Spline		Purpose: Transfer of in-plane shear along the panel to panel joint. Description: Adjacent floor panels with routed surfaces are butted together. A plywood spline is fastened to both panels using partially threaded screws or nails. Notes: • Capacity of connection is controlled by shear capacity of dowel-type fasteners. • Double Surface Spline or Steel Surface Spline can be used for increased capacity. • Spline may be fully above panels without routed surface where floor or roof coverings allow. • Where using nails, consider specifying nail gun nails instead of common wire nails for constructability, or collated screws instead of individual screws. • Where screws are used instead of nails, Cost increases and Constructability is moderate. • Typical minimum plywood thickness is ½" nominal. • Coordinate spline and rout width and thickness with panel supplier.	1	medium	$	easy	easy	Level I

Back to our Players

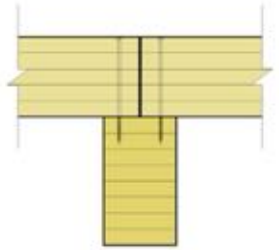
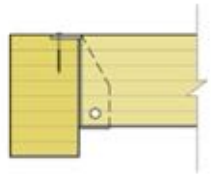
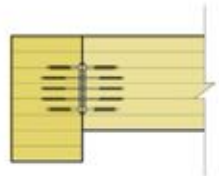




Cost Considerations

What Affects Cost?

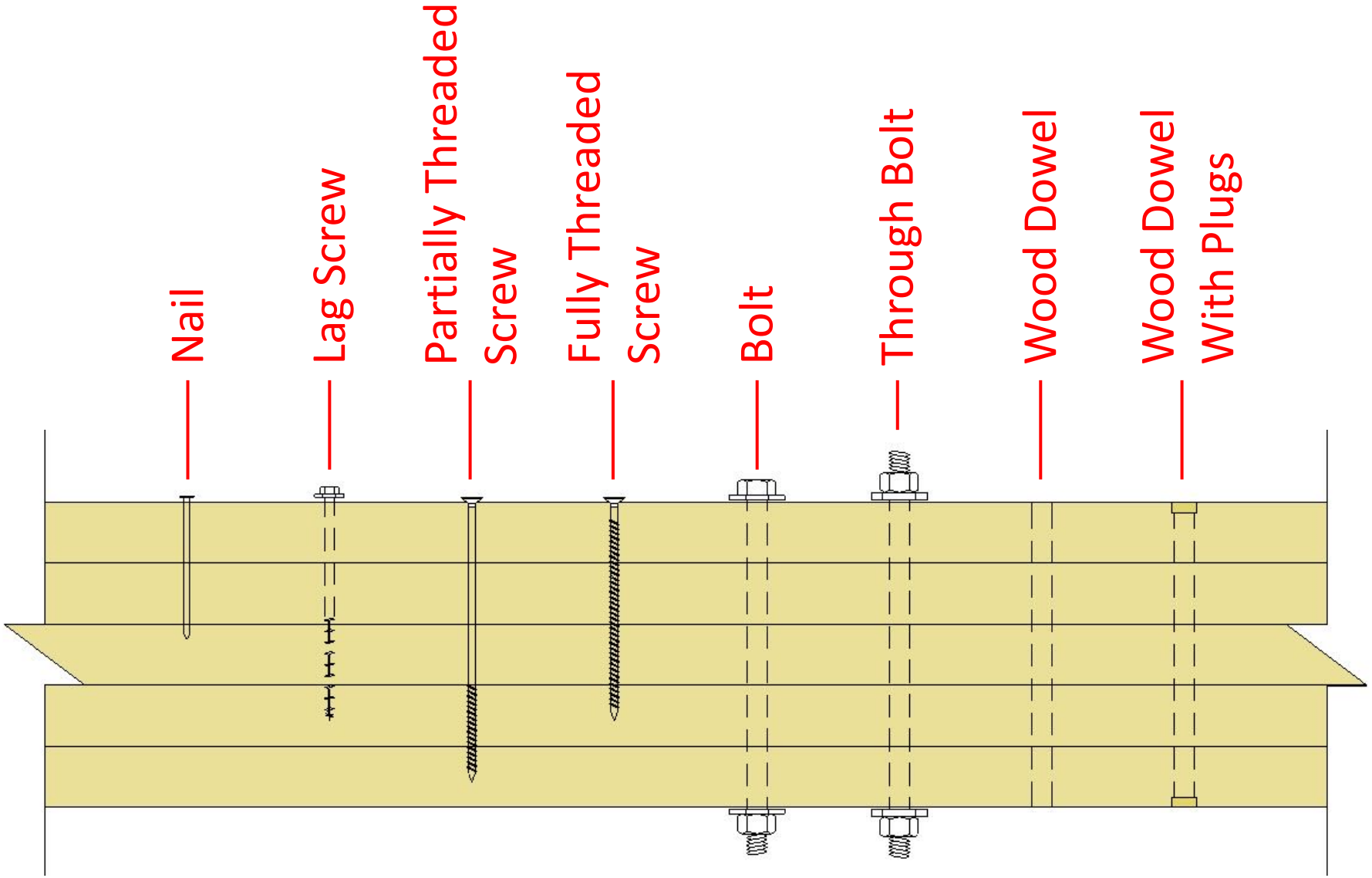
- Fasteners
- Interface with Other Materials
- Class!

Connection Class	Class 1	Class 2	Class 3
Class Description	Requires only mass timber elements and fasteners	Utilizes steel fabricated elements, with components such as angles and plates, and includes fasteners	Prefabricated proprietary connectors
Connection Example			
	Beam Bears on Girder	*Beam Bears on Steel Bearing Seat with Knife Plate*	*Beam Connected to Girder with Proprietary Concealed Connector*

Fasteners

- Load type
  (shear, tension, etc)
- Load magnitude
- Aesthetics

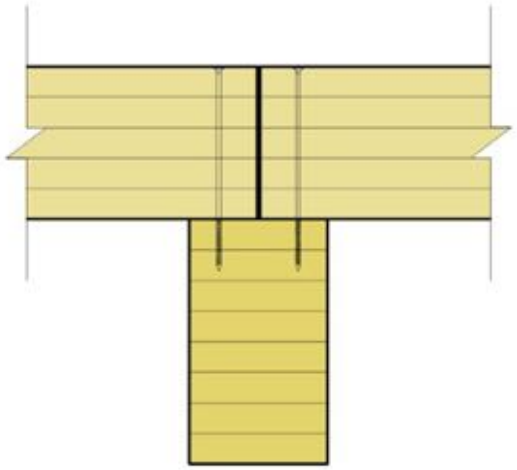
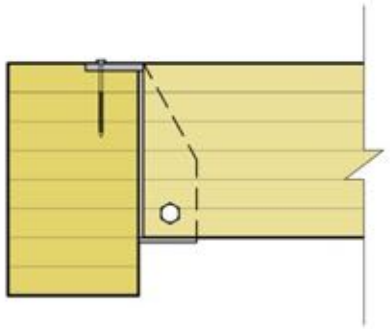
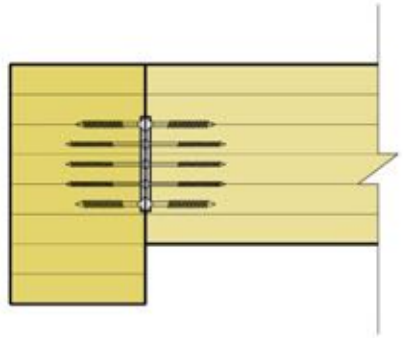
Fasteners


Nail
Lag Screw
Partially Threaded Screw
Fully Threaded Screw
Bolt
Through Bolt
Wood Dowel
Wood Dowel With Plugs

Interface with Other Materials

- Tolerance

Class

Connection Class	**Class 1**	**Class 2**	**Class 3**
Class Description	Requires only mass timber elements and fasteners	Utilizes steel fabricated elements, with components such as angles and plates, and includes fasteners	Prefabricated proprietary connectors
Connection Example			
	Beam Bears on Girder	*Beam Bears on Steel Bearing Seat with Knife Plate*	*Beam Connected to Girder with Proprietary Concealed Connector*


Putting it all Together

Optimal Connection

THANK YOU!

This concludes The American Institute of Architects Continuing Education Systems Course

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SWINERTON MASS TIMBER

OZ ARCHITECTURE URBAN DESIGN INTERIOR DESIGN