

# Behaviour of Timber-Steel Composite Beams with Self-tapping Screw Shear Connections

Brendan Deeves and Joshua Woods

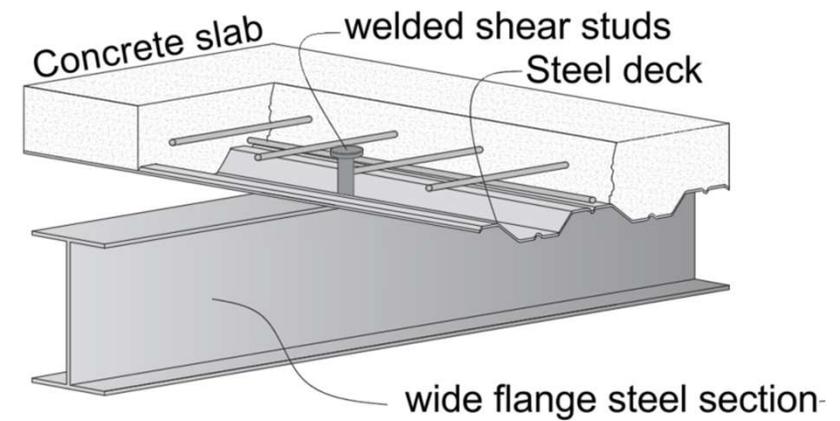
Department of Civil Engineering, Queen's University



MAY 9<sup>th</sup>, 2025

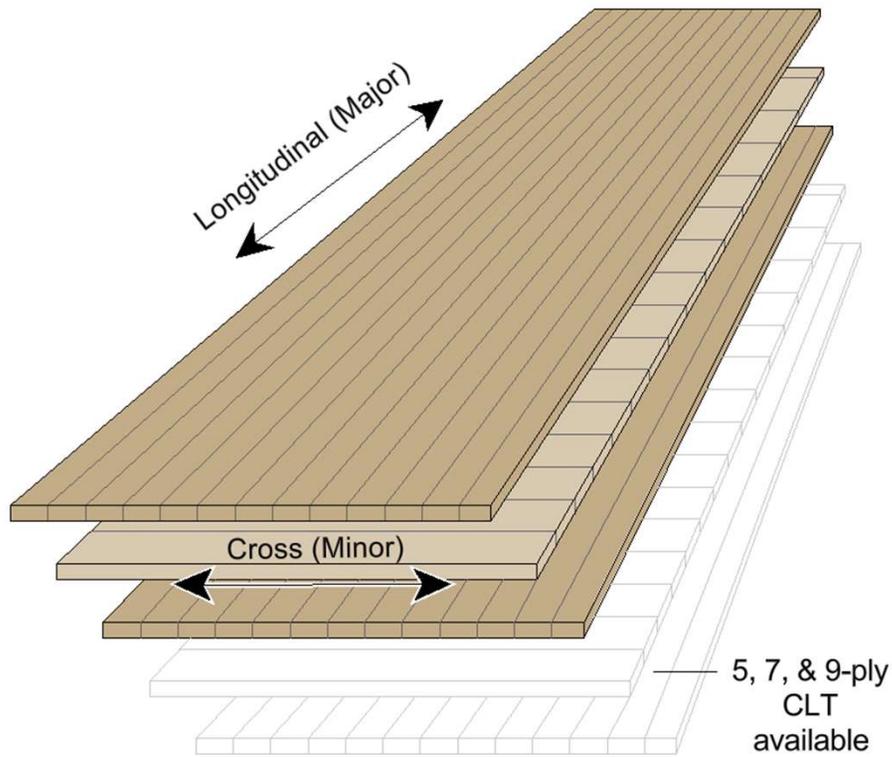


## Traditional concrete-steel composite systems in Canada



Disadvantages: concrete curing times, shoring, and embodied carbon

# Proposed hybrid timber-steel composite floor system



Cross-laminated Timber (CLT)

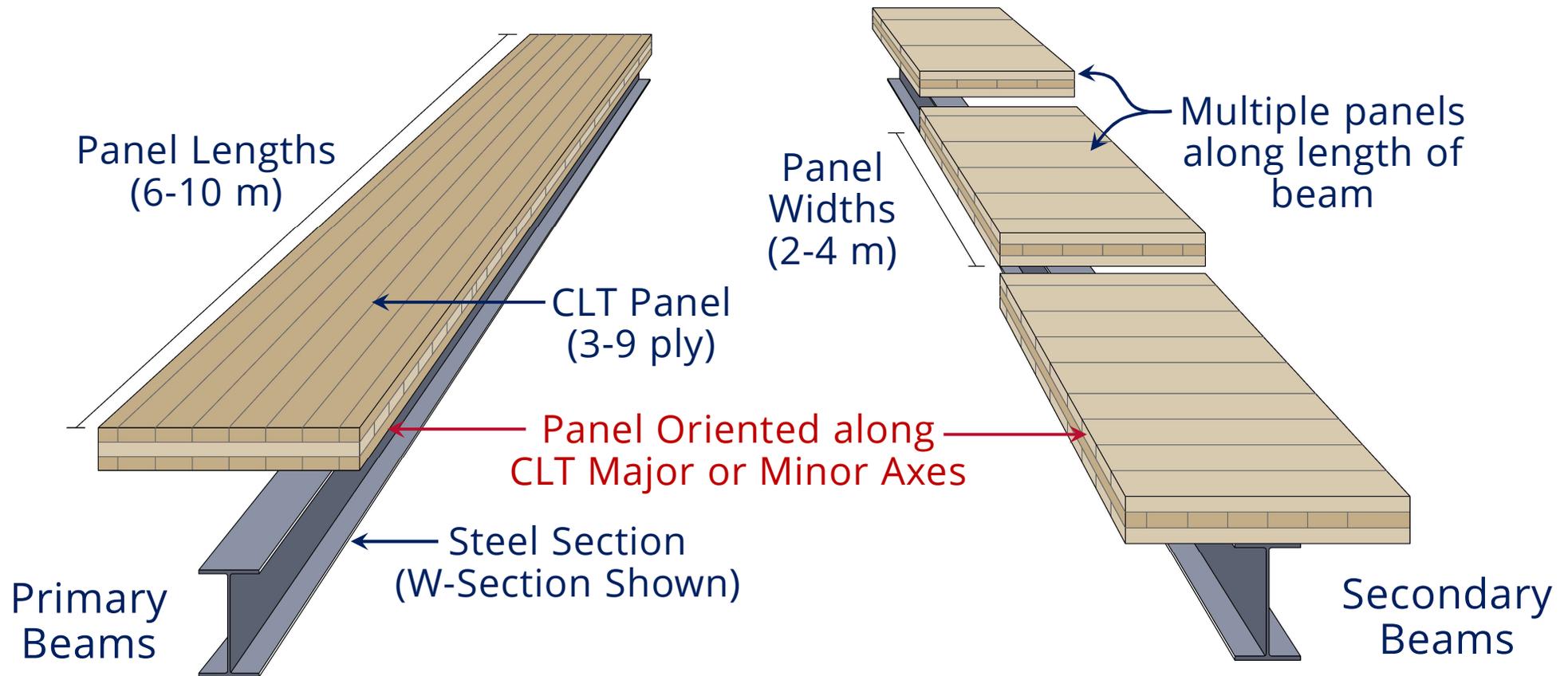


Laminated Veneer Lumber (LVL)



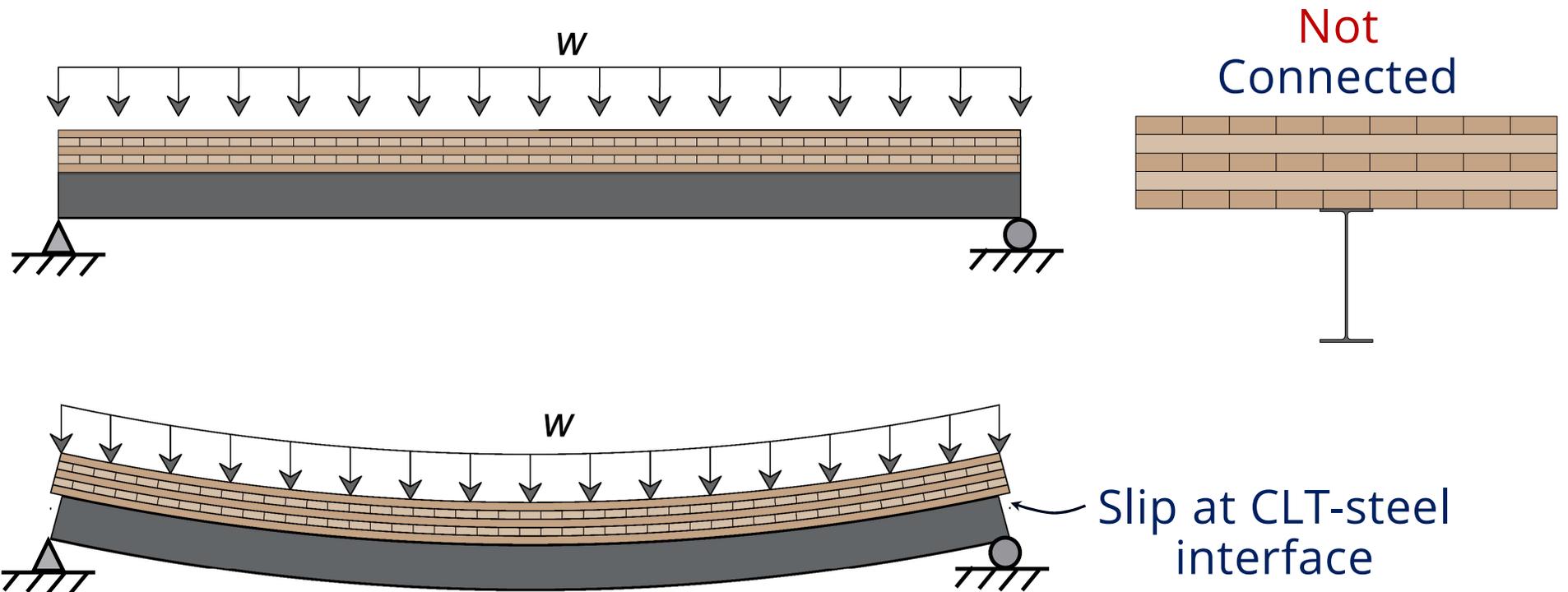
Dowel-laminated Timber (DLT)

## Proposed hybrid timber-steel composite floor system



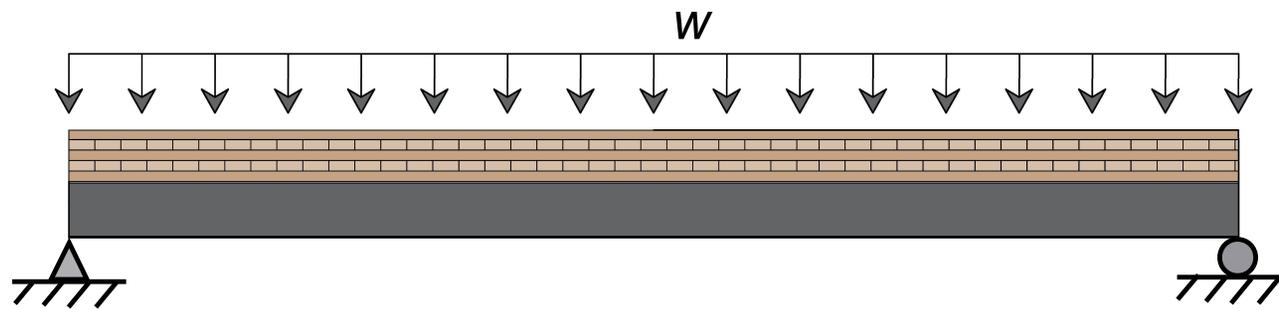
Advantages: speed of construction, aesthetics, embodied carbon

## Back to basics... composite beam behaviour

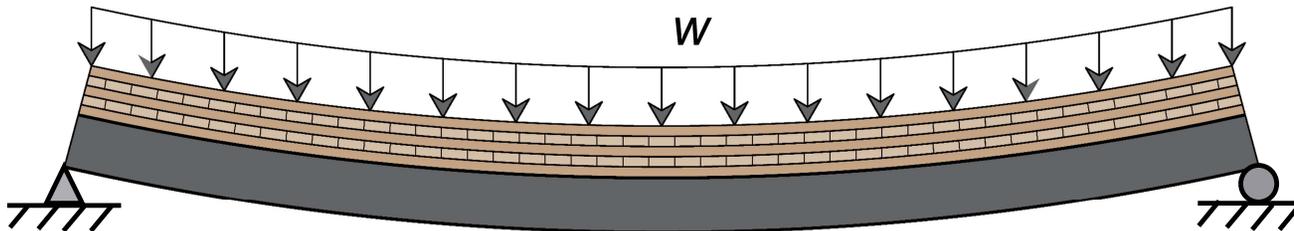
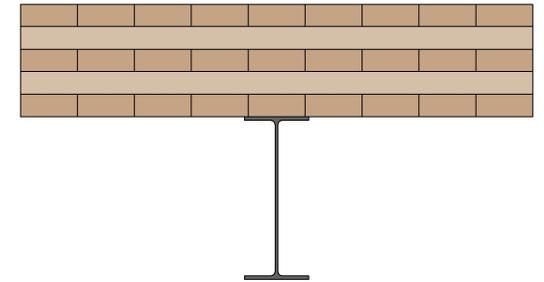


Without composite action:  $M_R = M_{R,CLT} + M_{R,Steel}$

## Back to basics... composite beam behaviour



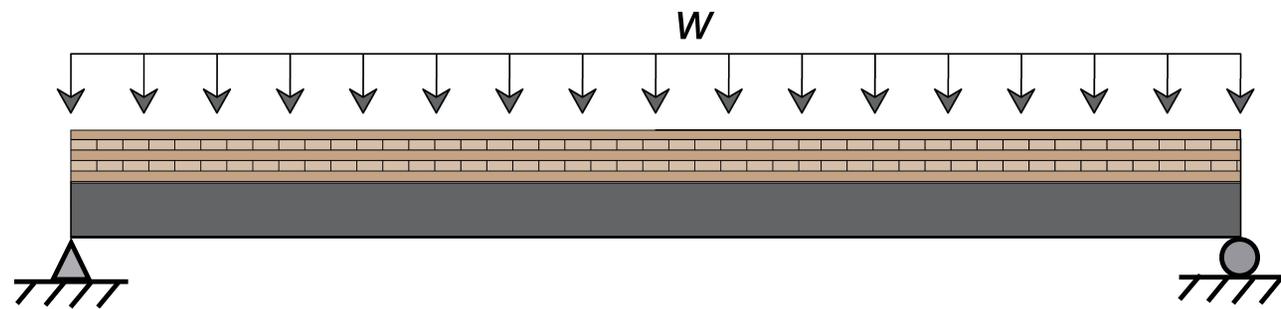
Rigidly  
Connected



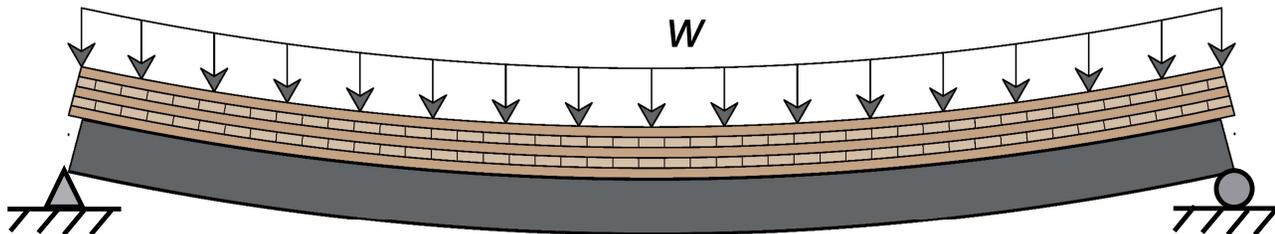
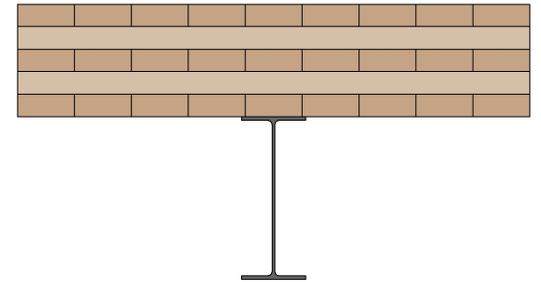
No Slip  
(Full Composite Action)

With full composite action:  $M_R = M_{R,Composite Section}$

## Back to basics... composite beam behaviour



Partially  
Connected



Some Slip  
(Partial Composite Action)

Partially composite beams are most common in practice

But how can we establish the shear connection in these systems?

Let's look and see what's happening in industry...



Photos from Nordic Structures / Element5

Hybrid timber-steel construction is on the rise...



Photos from Element5

## Recent publications:

### HYBRID STEEL-TIMBER FLOOR SYSTEMS

Smart Reference for Architects



Smarter.  
Stronger.  
Steel.



Remains a need for research  
and design guidance



### STATE OF ART ON STEEL – TIMBER – (CONCRETE) STRUCTURES

Technical Working Group 11.6  
Steel Timber Hybrid Structures

N° 145 | 2024

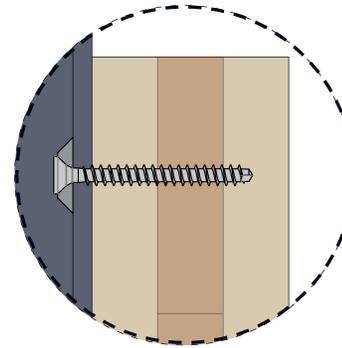
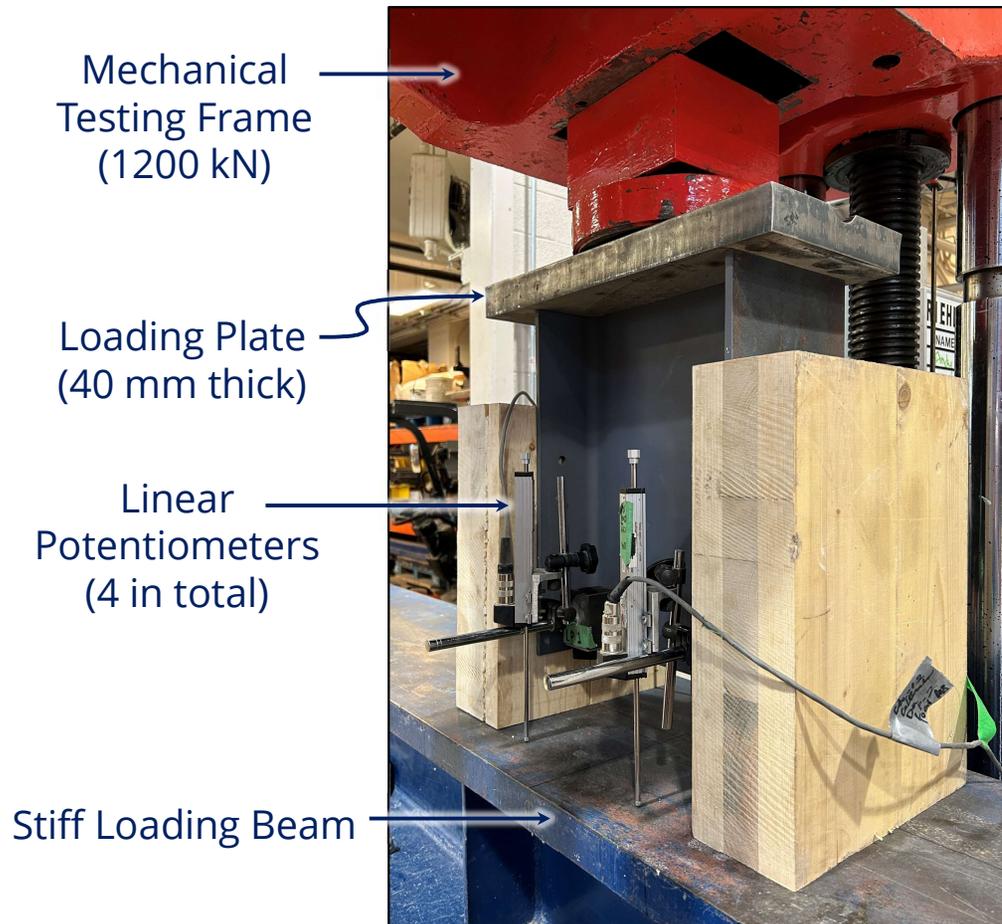


## Objectives of this work:

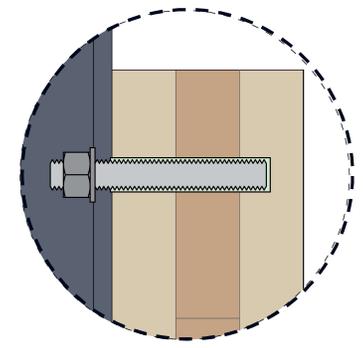
1. Study shear connection performance using self-tapping screws;
2. Conduct large-scale experiments on timber-steel composite beams;
3. Use advanced sensing to study the behaviour of composite beams;
4. Develop design methods for timber-steel composite floor systems.



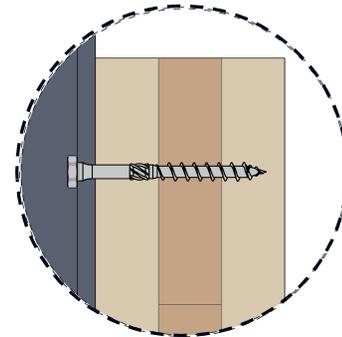
# Pushout Testing on Shear Connections



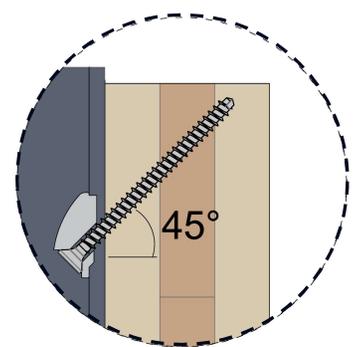
Fully-threaded Screws



Glued-in Rods

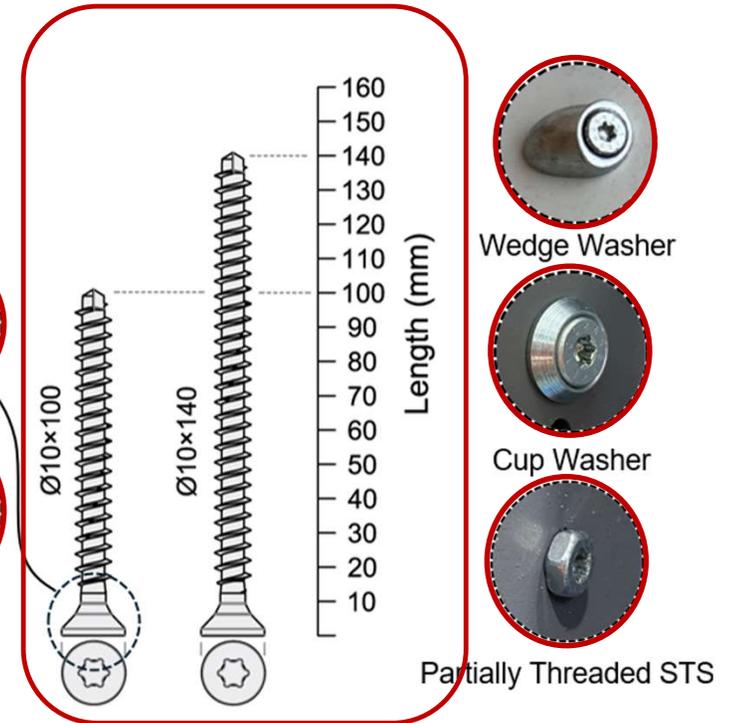
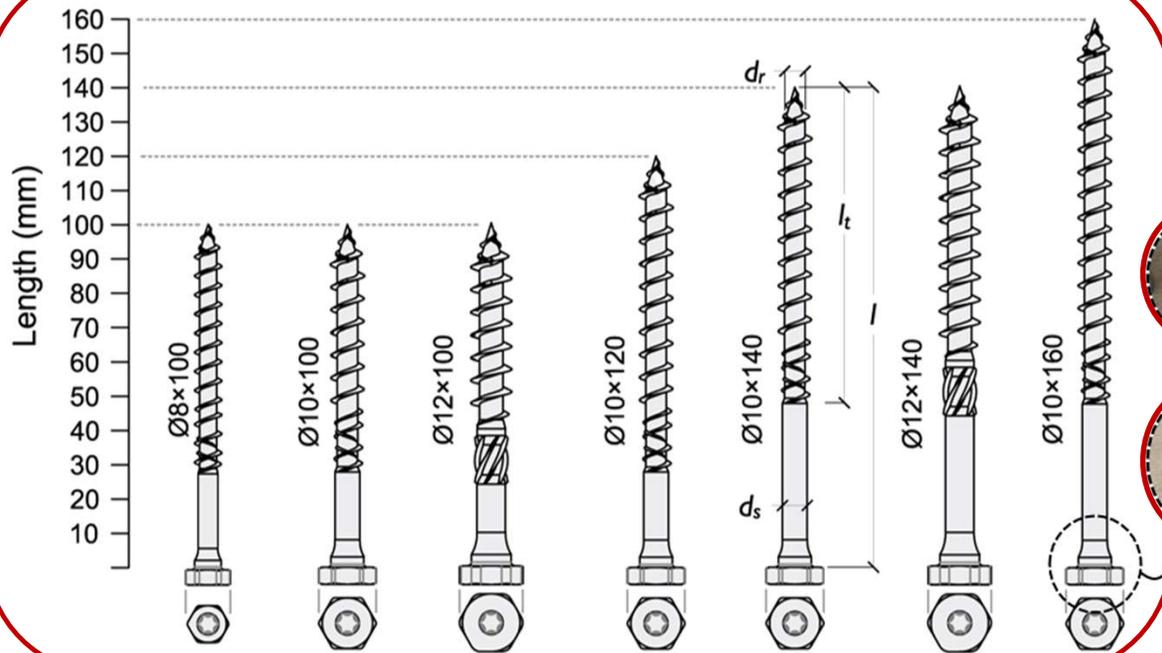


Partially-threaded Screws  
(with and without glue)



Inclined Screws

# Pushout Testing on Shear Connections

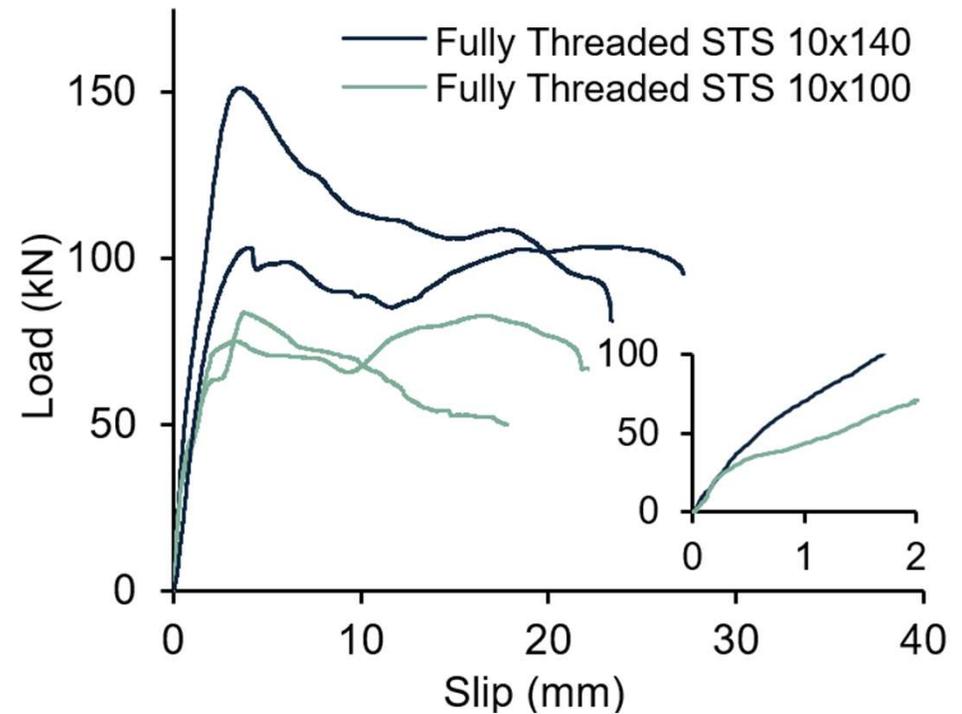
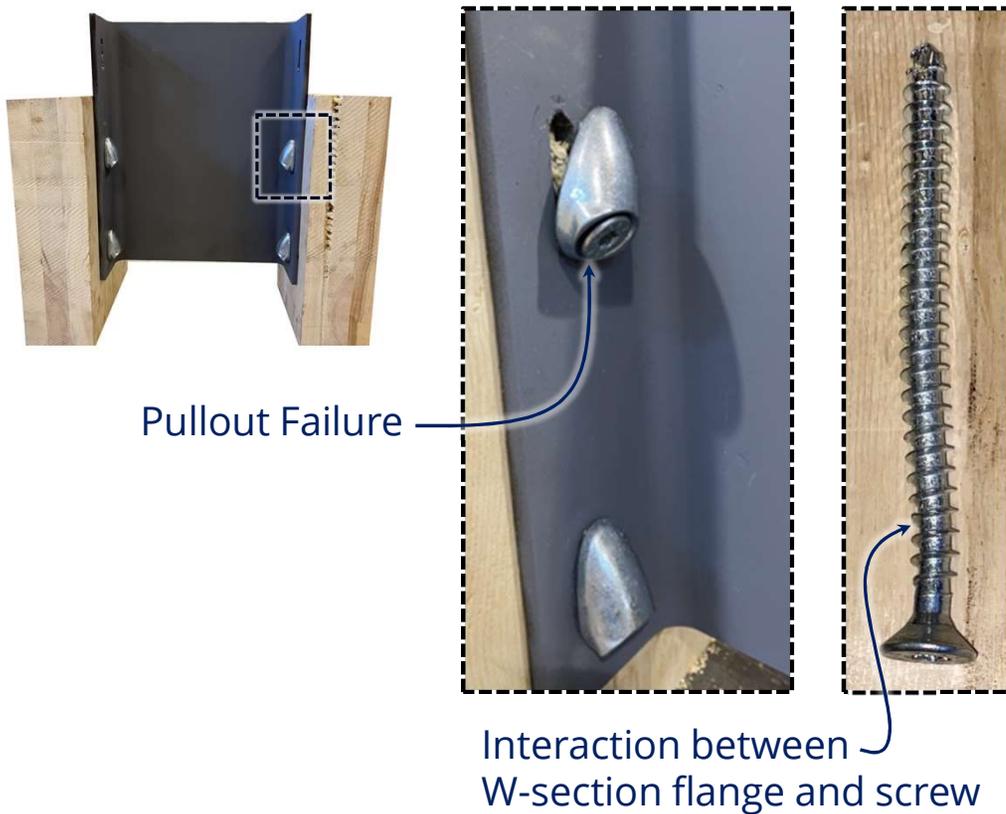


Self-tapping screw parameters considered:

1. Screw size (i.e., diameter and length)
2. Partially versus fully threaded screws
3. Straight versus inclined screws

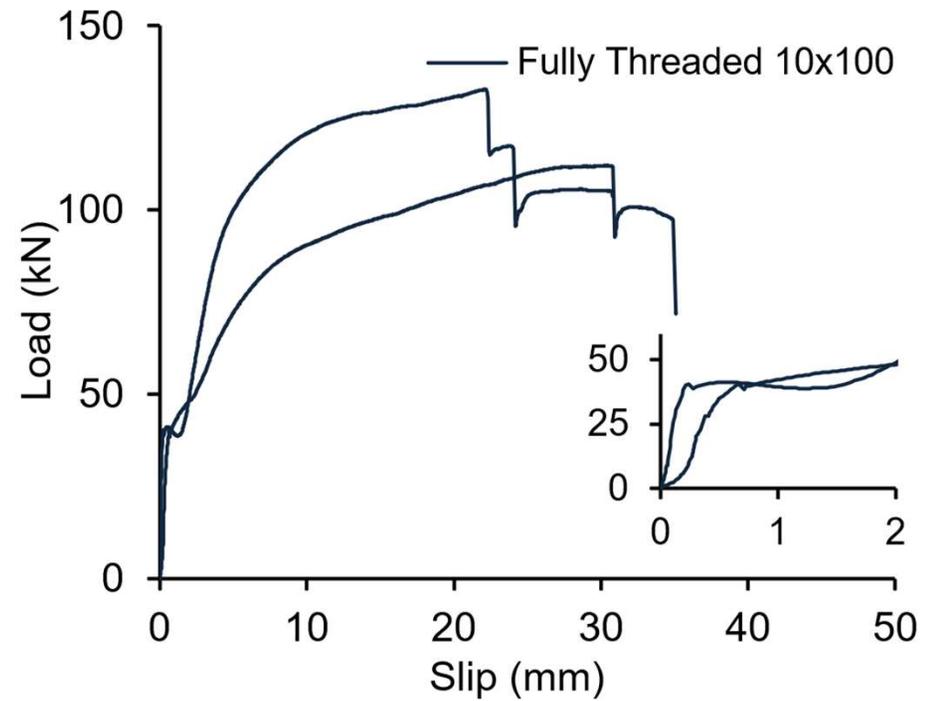
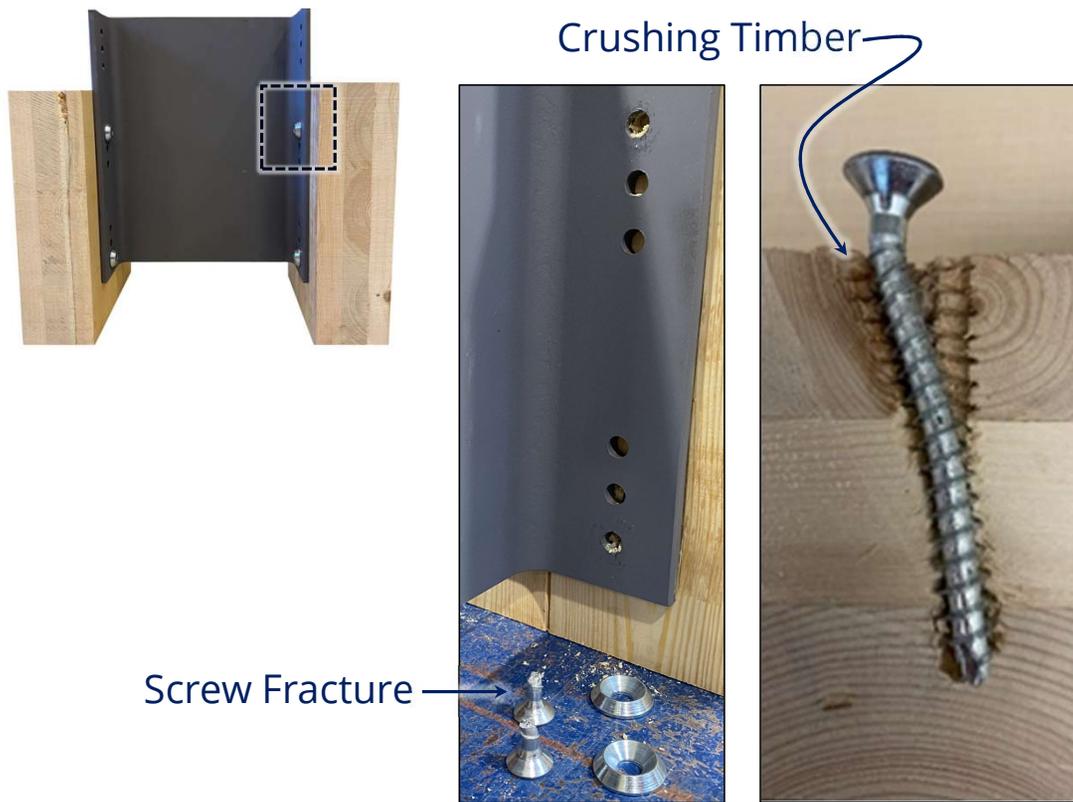
# Pushout Testing on Shear Connections

## Inclined Fully Threaded Self-tapping Screws

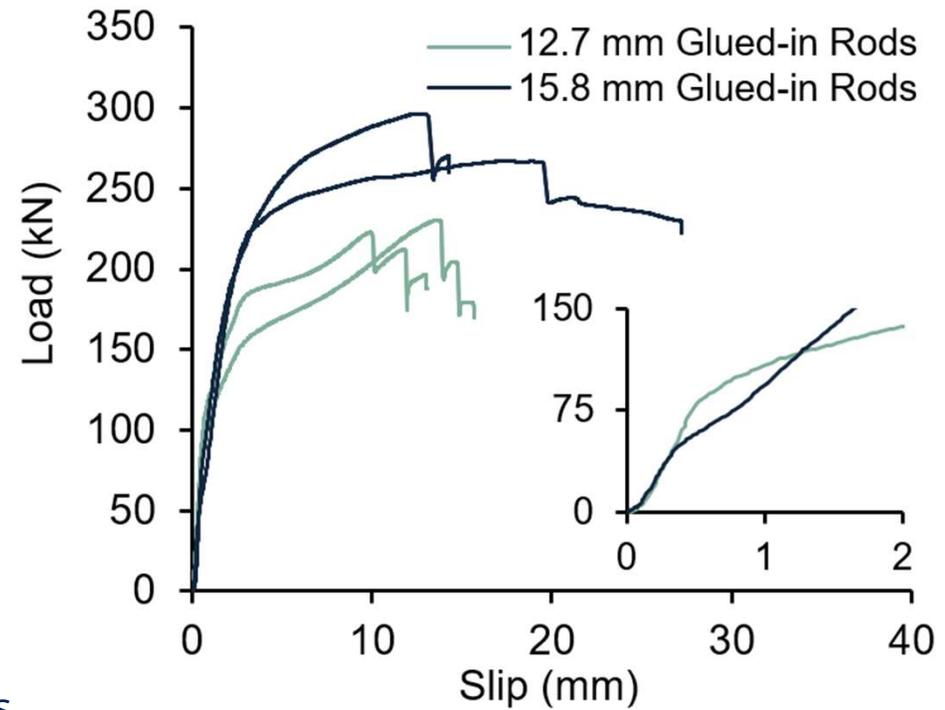
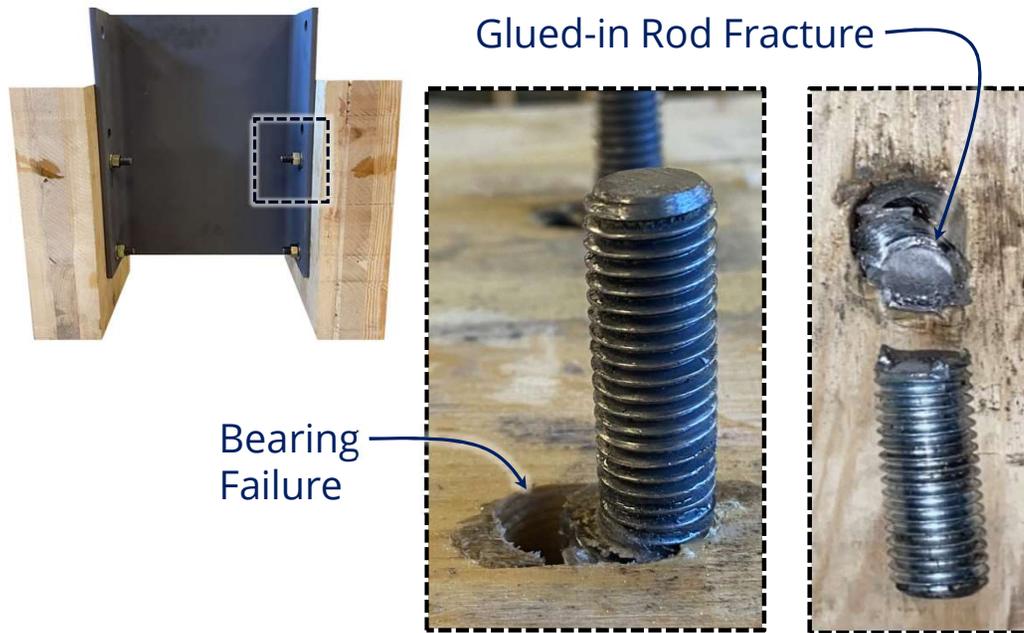


# Pushout Testing on Shear Connections

Straight Fully Threaded Self-tapping Screws



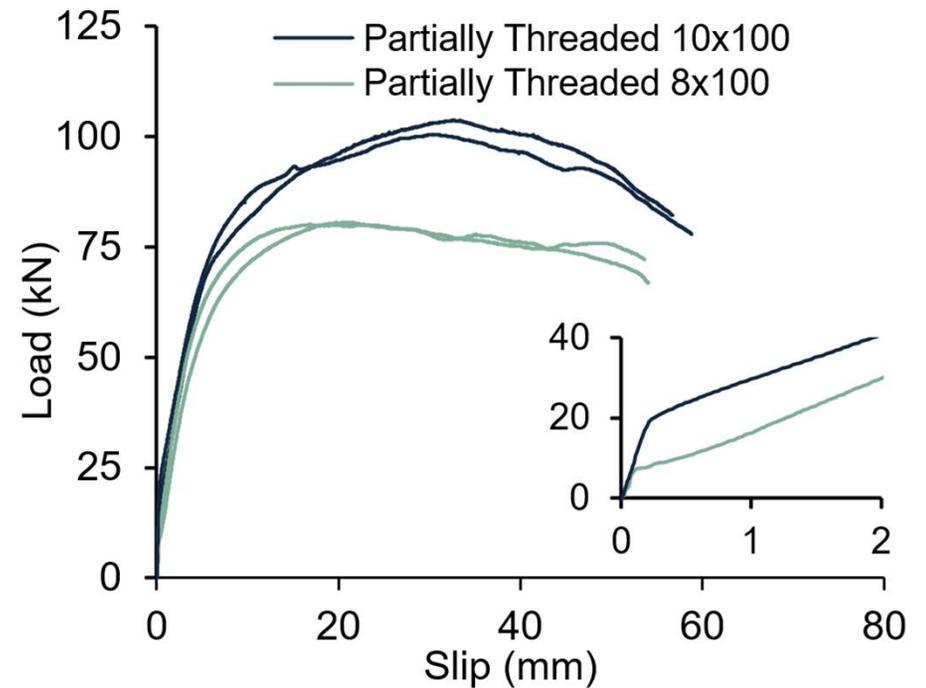
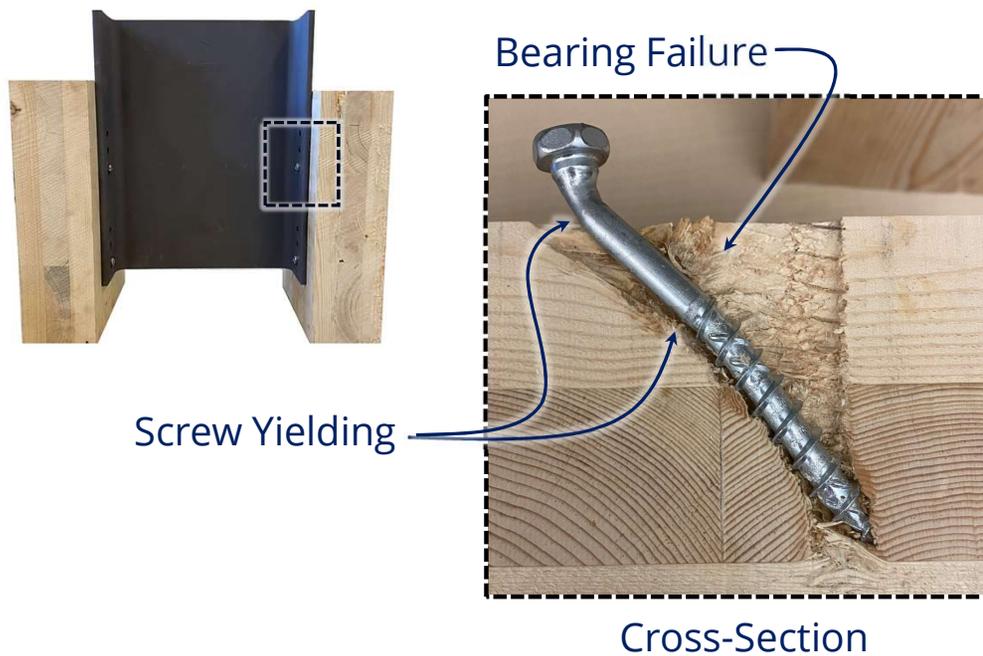
# Pushout Testing on Shear Connections



- Glued-in rod stiffness was 4-6 times higher than screws
- Many challenges associated with fabrication/installation

# Pushout Testing on Shear Connections

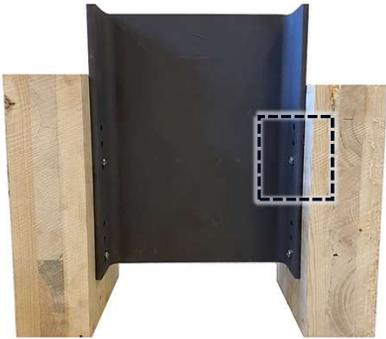
## Partially Threaded Self-tapping Screws



- 1/2 to 1/3 the stiffness of an inclined screw
- No need for a washer and easier installation

# Pushout Testing on Shear Connections

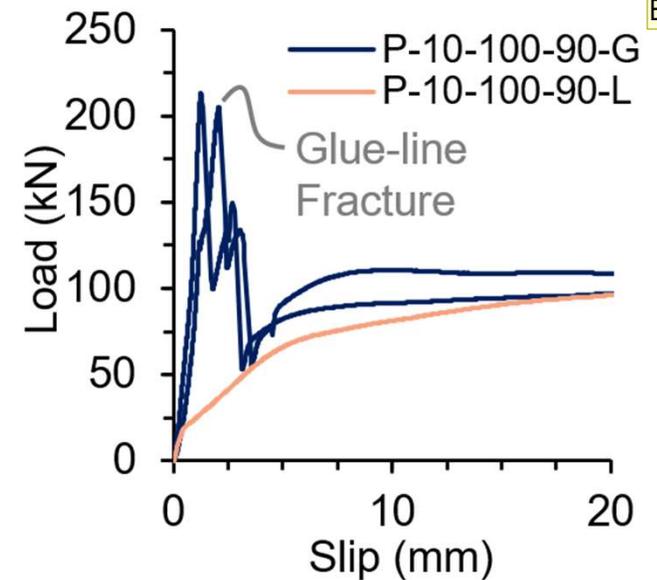
Partially Threaded Self-tapping Screws with Glue



CLT Panel Face



Steel Face



- Average bond stress at failure of 3.5 MPa
- Over 10 times stiffer than equivalent screwed connection

## Slide 18

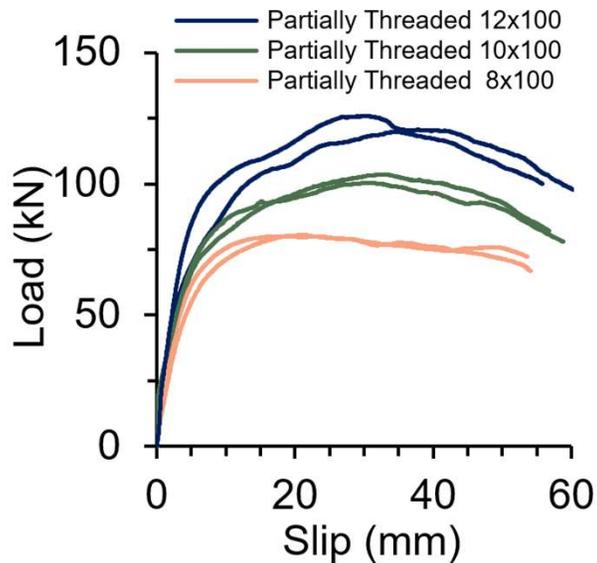
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**BD1** This fig. has the paper naming convention but the others don't  
Brendan Deeves, 2025-05-08T15:14:25.608

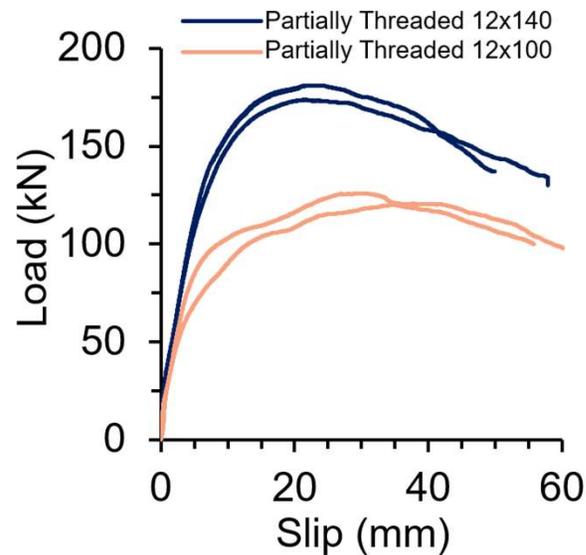
# Pushout Testing on Shear Connections

Examined the influence of several parameters on the load-slip behaviour of partially threaded screws

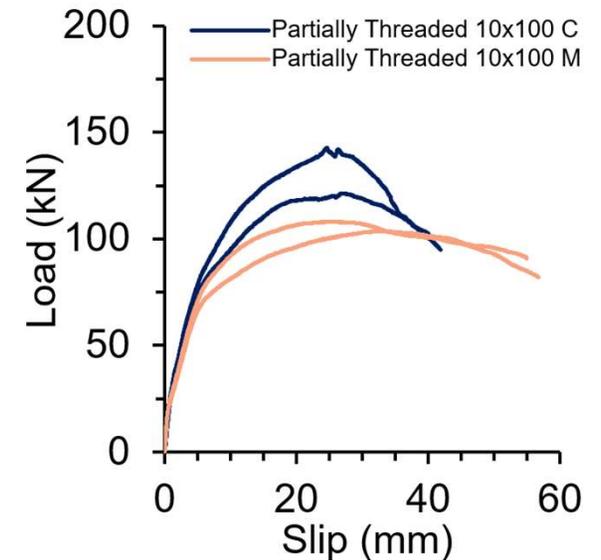
Screw Diameter:



Screw Length:



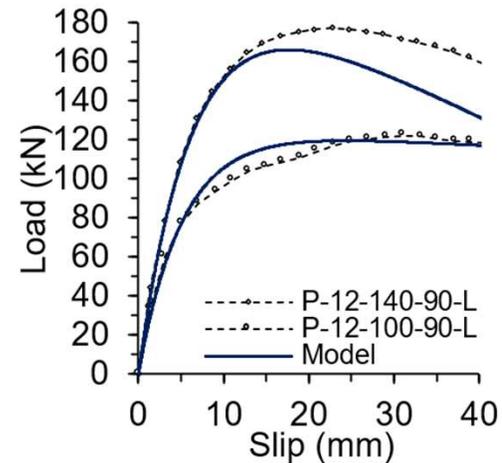
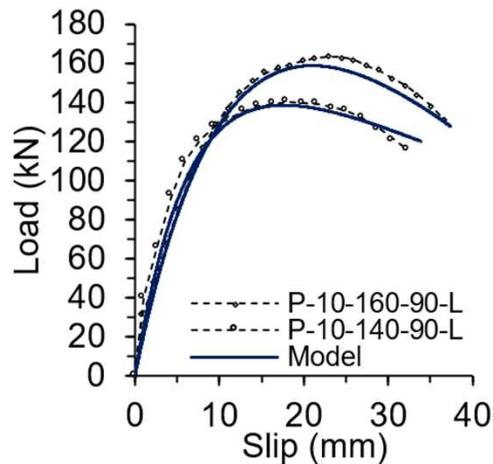
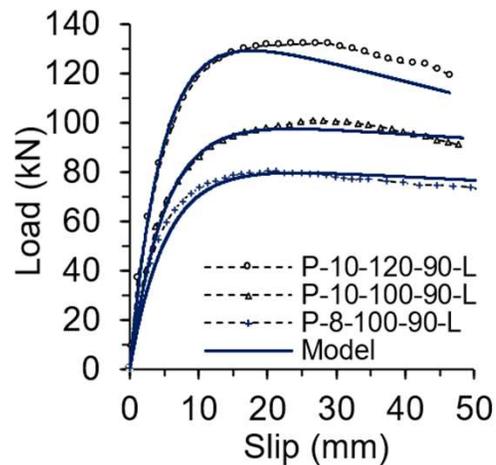
Major vs. Minor CLT:



# Pushout Testing on Shear Connections

Developed an empirical model to predict the load-slip response of partially threaded screws:

Is based on the model proposed by Foschi (1977): 
$$P(s) = \frac{1.51nd}{80} \left(\frac{l_t}{l}\right)^{.86} (m_0 + m_1s) \left[1 - e^{-\frac{ks}{m_0}}\right]$$



Submitted Paper:

Deeves, B. and Woods, J. (2025). Experimental Testing and Empirical Modelling of Steel-Timber Shear Connections with Self-tapping Screws. Journal of Construction and Building Materials. Submitted.

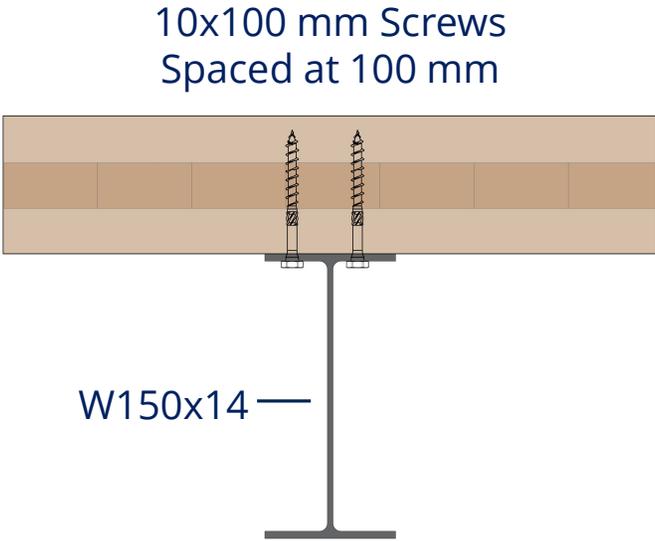
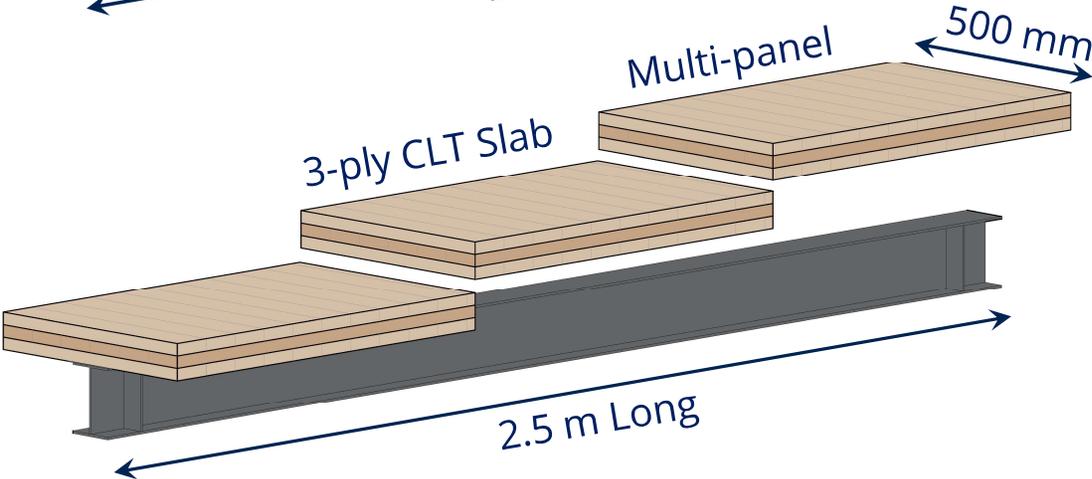
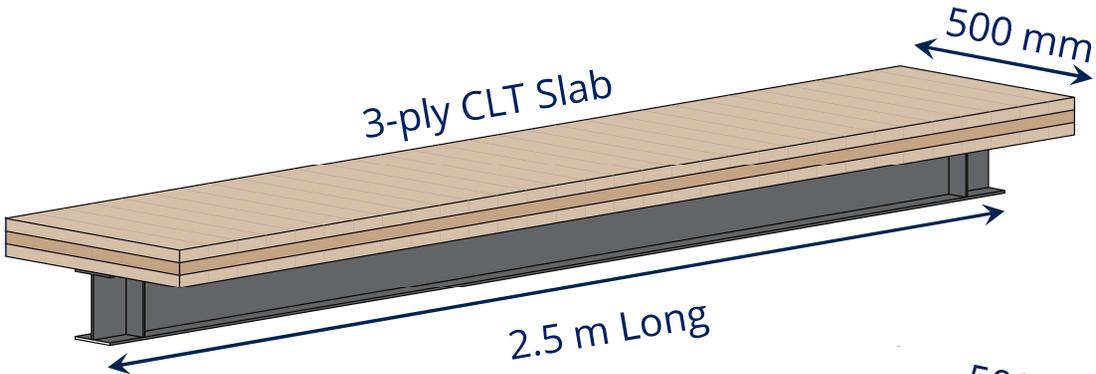
## Conclusions from Pushout Tests

1. Self-tapping screws can be used as a flexible shear connection in timber-steel composite floors systems with partial composite action.
2. Connections undergo significant slip before reaching their maximum capacity (this will have implications for design...).
3. Glued and screwed connections have very high stiffness.
4. Proposed empirical model is able to capture nonlinear load-slip response. Accurate prediction of stiffness and strength.



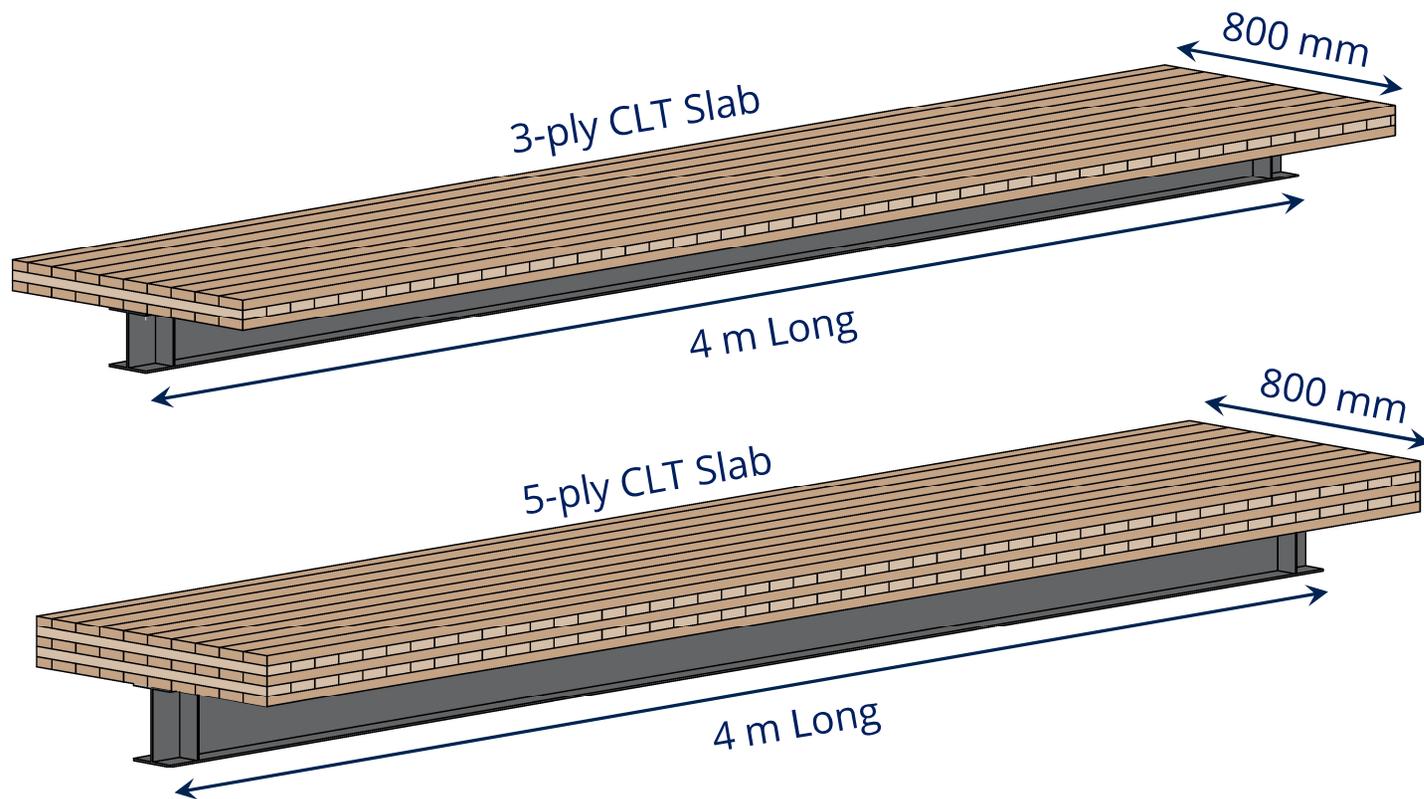
# Large-scale Composite Beam Tests

Minor axis oriented along the longitudinal axis of the steel beam

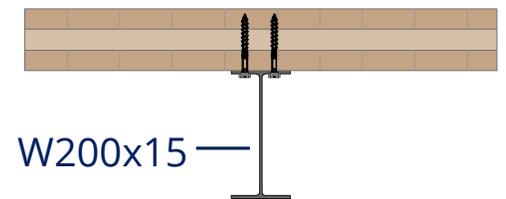


# Large-scale Composite Beam Tests

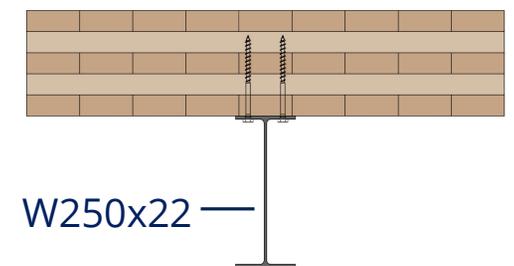
Major axis oriented along the longitudinal axis of the steel beam



10x100 mm Screws  
Spaced at 100 mm  
(with & without glue)

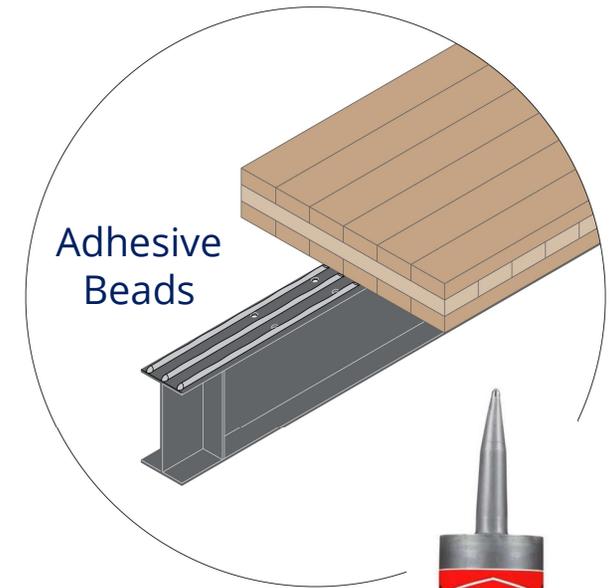
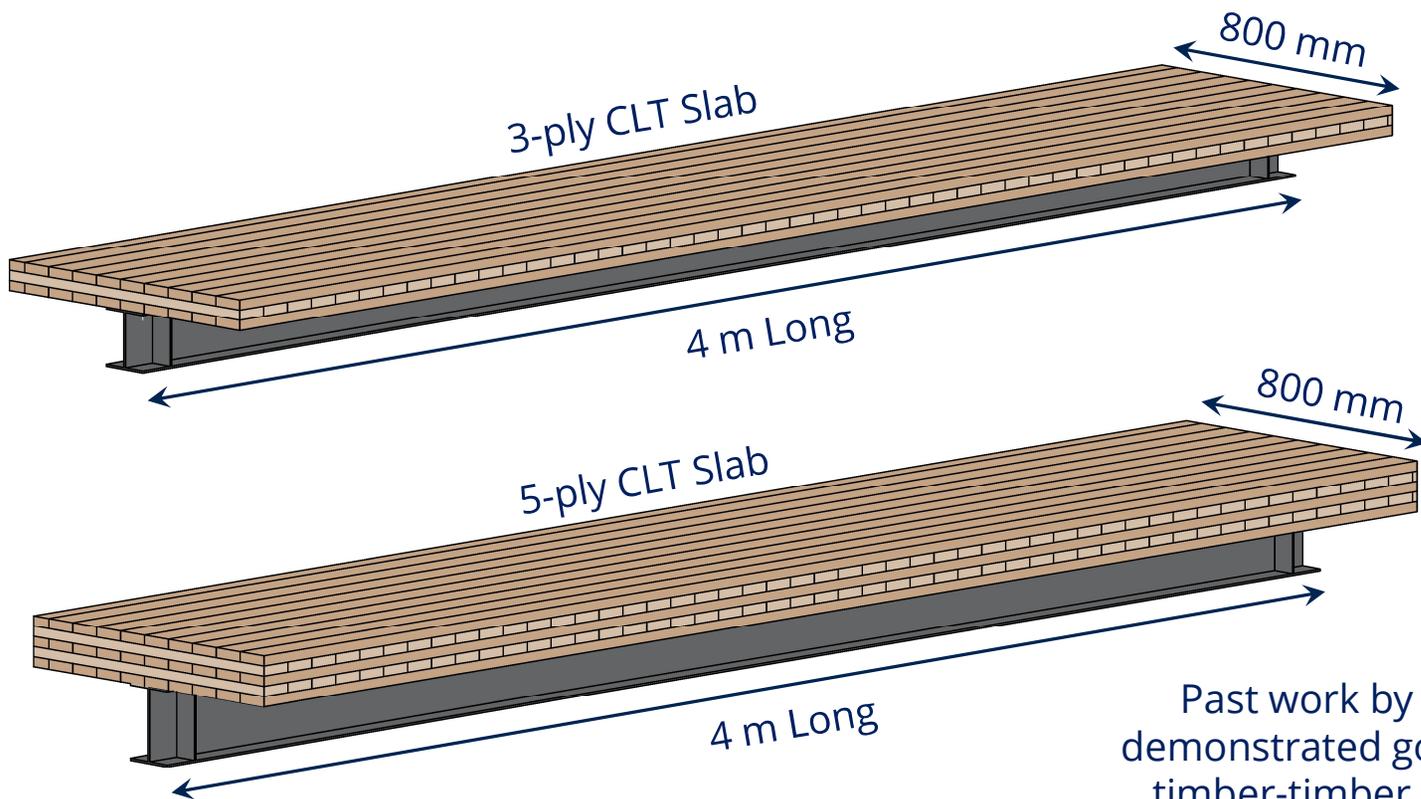


10x140 mm Screws  
Spaced at 100 mm  
(with and without glue)



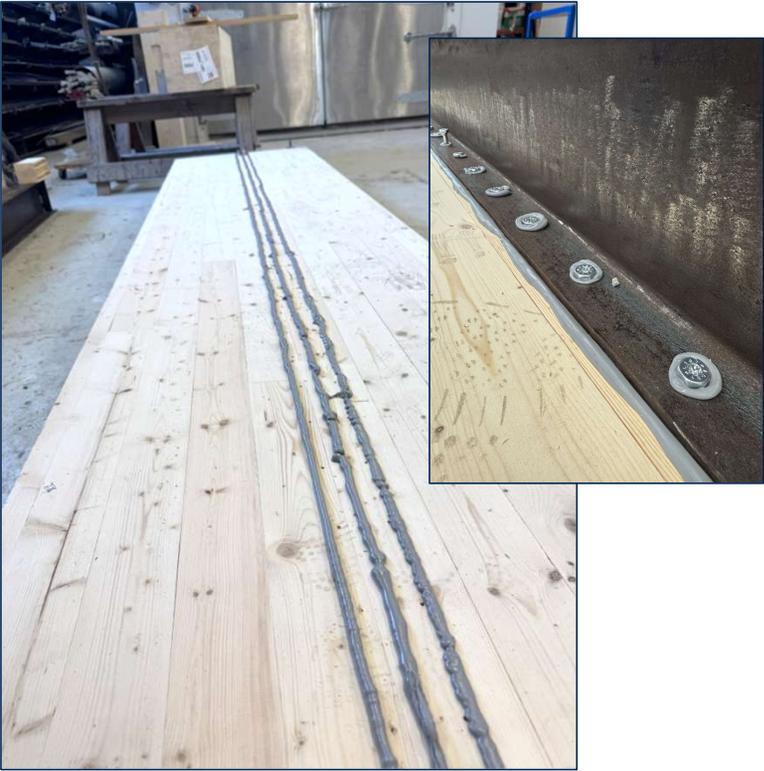
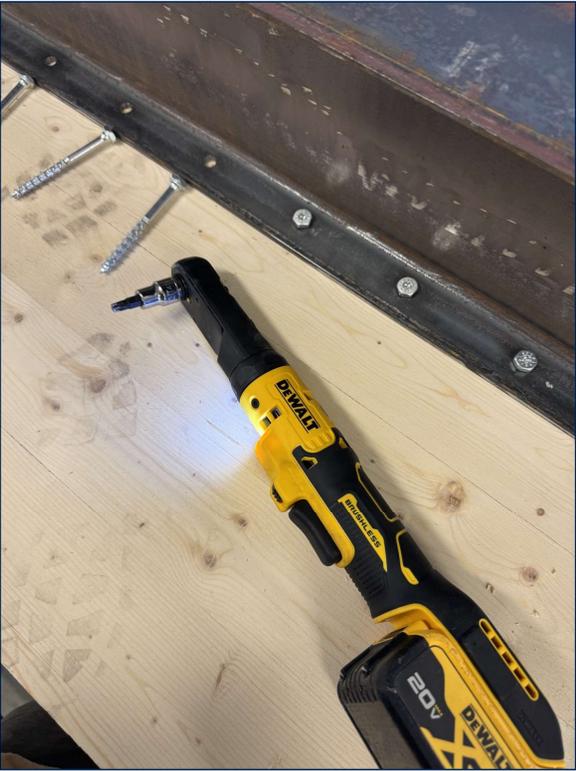
# Large-scale Composite Beam Tests

Major axis oriented along the longitudinal axis of the steel beam

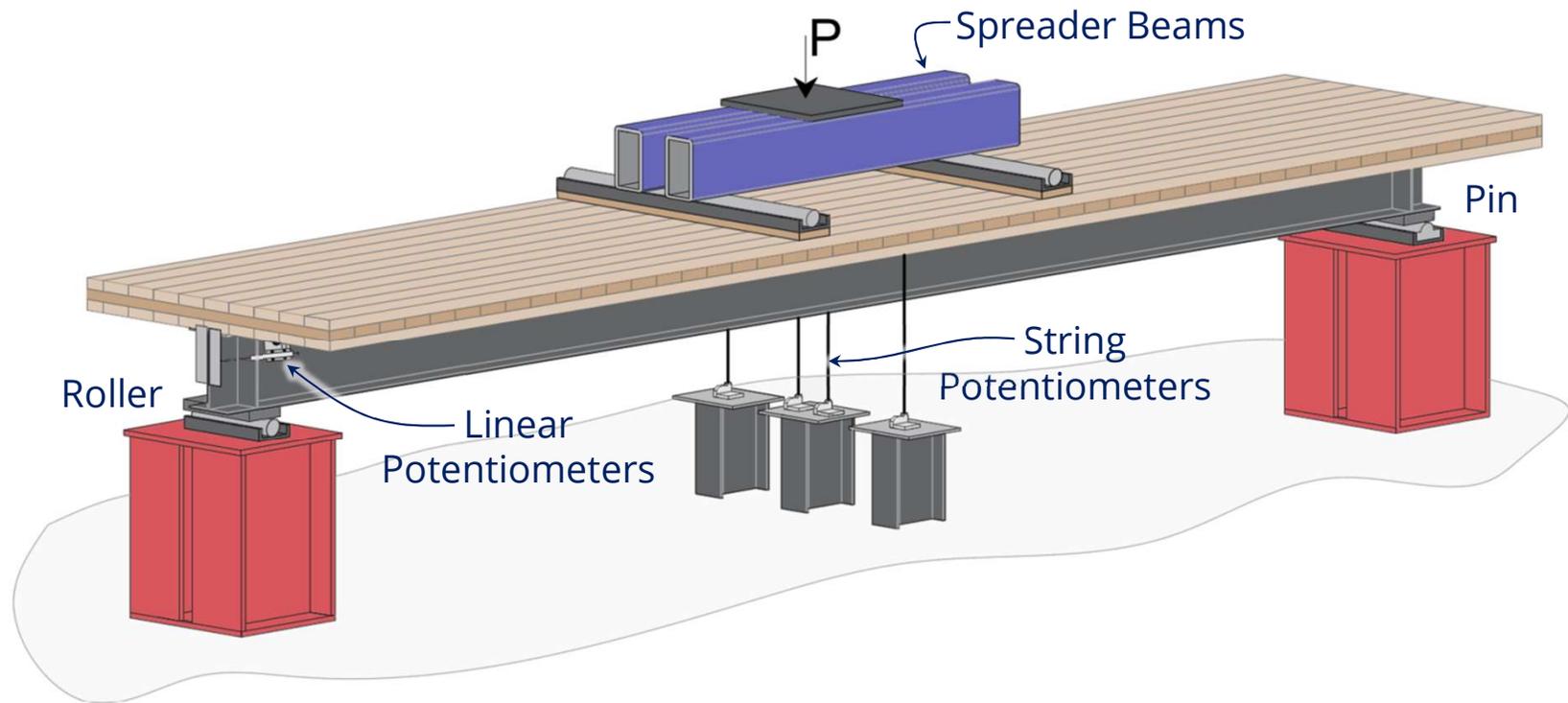


Past work by Hull et al. (2024) demonstrated good performance in timber-timber composite beams

# Large-scale Composite Beam Tests



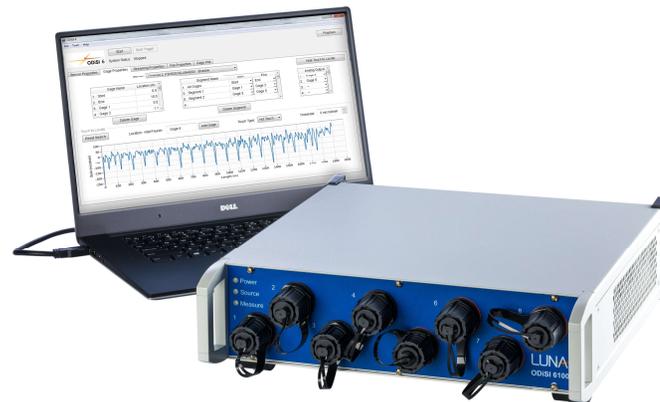
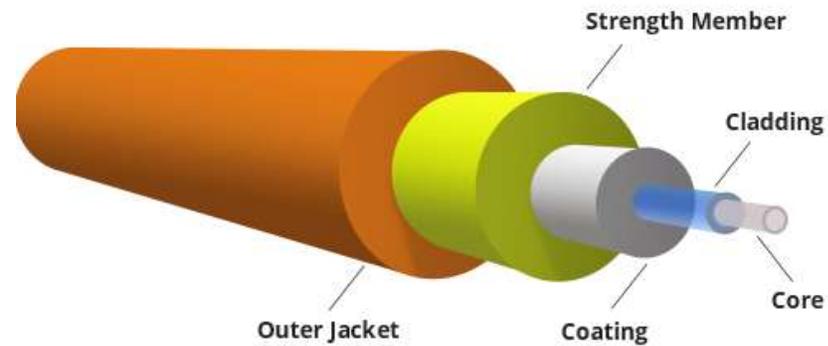
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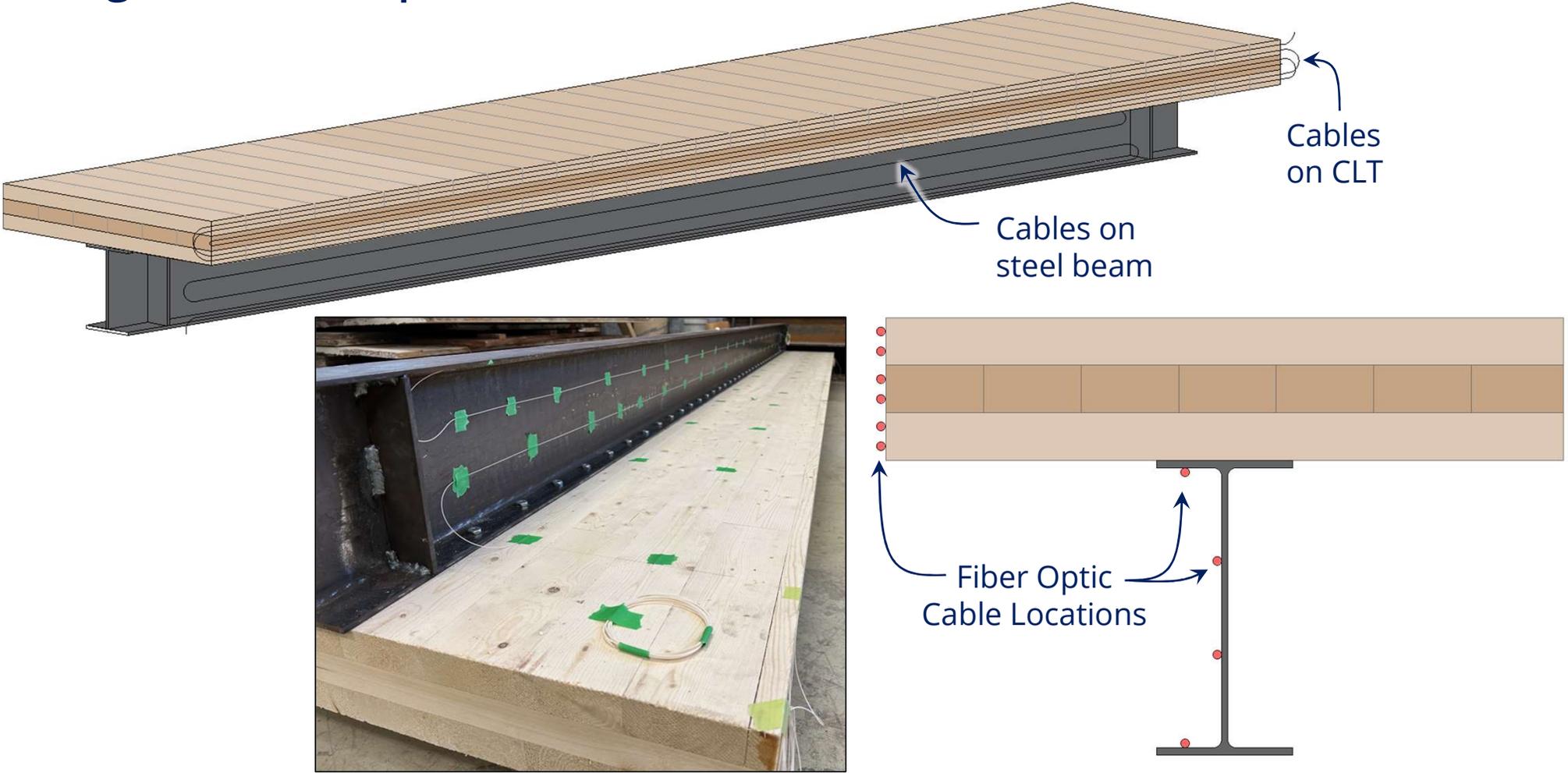
# Distributed Fiber Optic Sensing

## Advantages:

- 2.6 mm gauge spacing
- 20 m of fibre (1 channel)
- 1  $\mu\epsilon$  resolution
- 50 Hz sample rate
- Inexpensive (\$0.2 / m)
- Simple to install

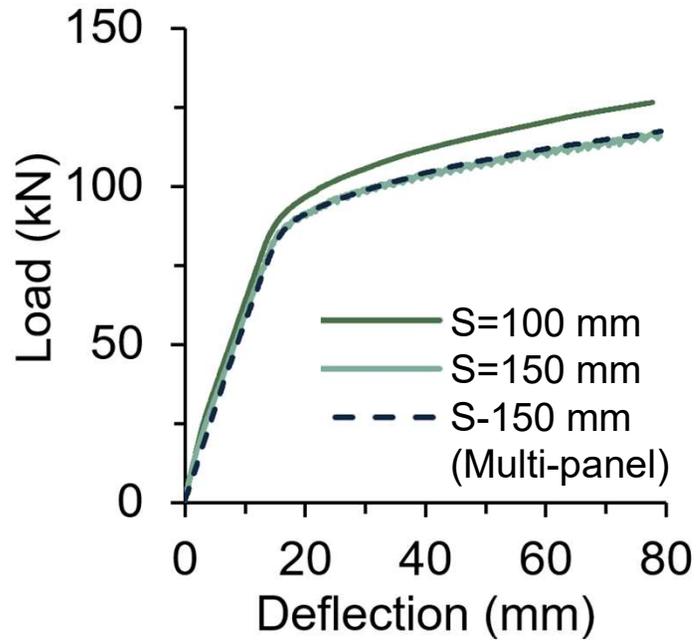


# Large-scale Composite Beam Tests



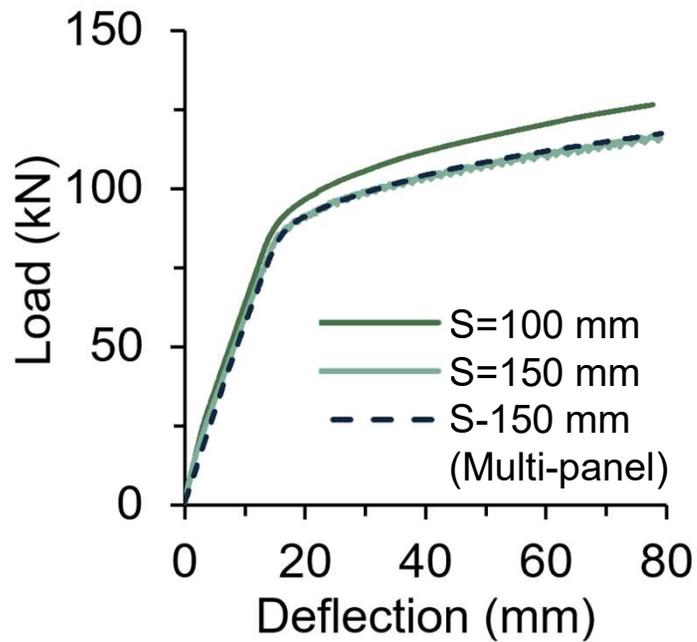
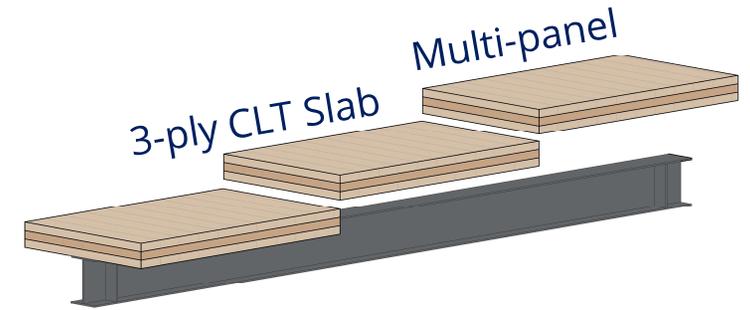
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Minor Axis Beams with 3-Ply CLT Slab



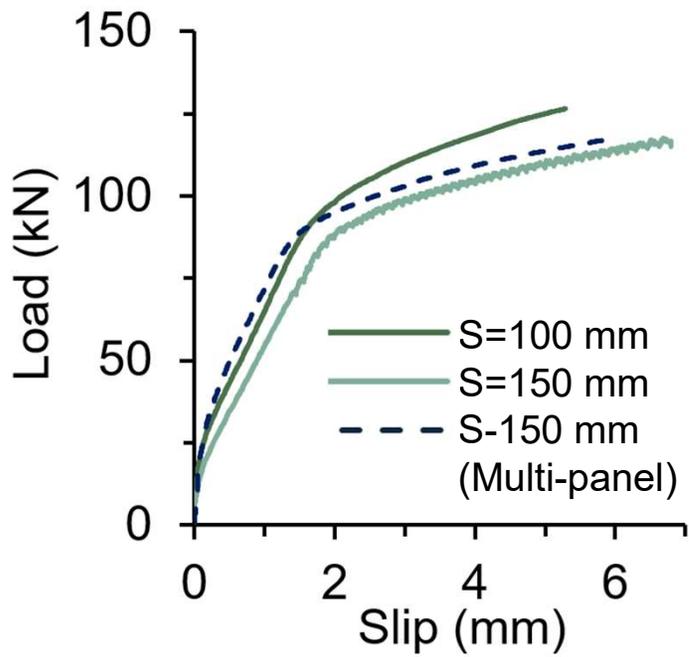
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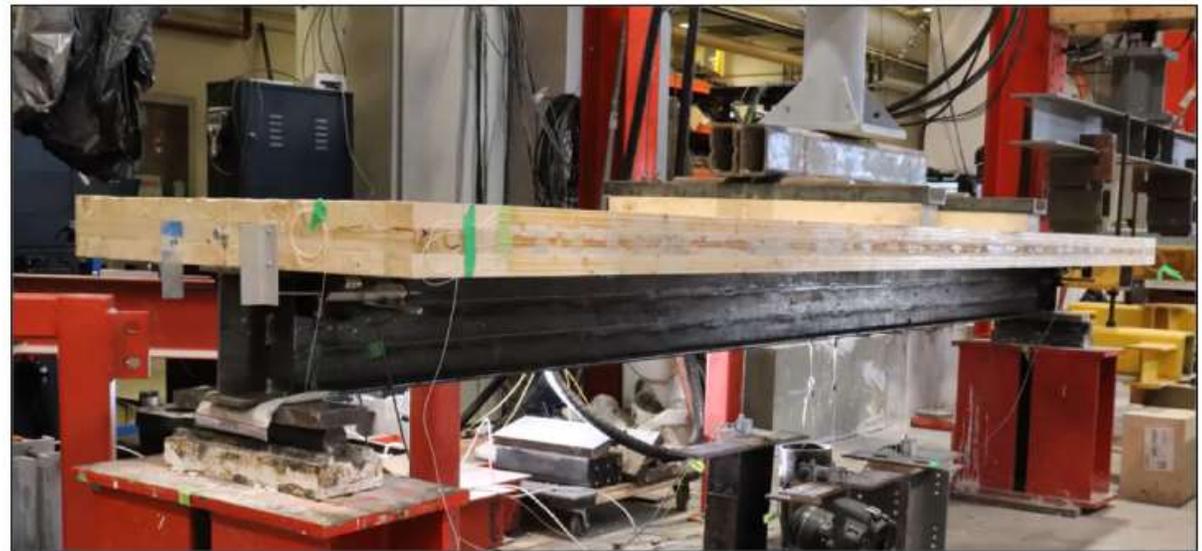
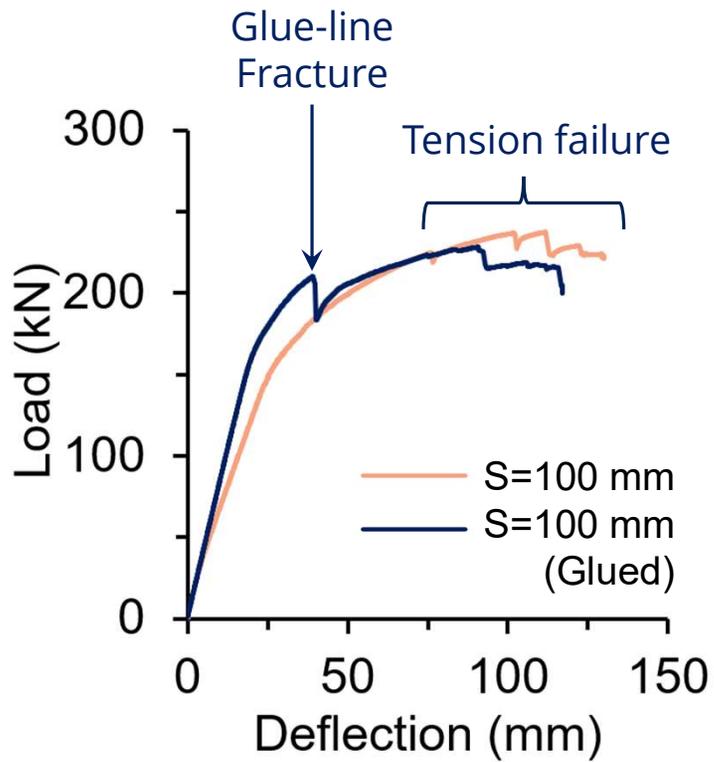
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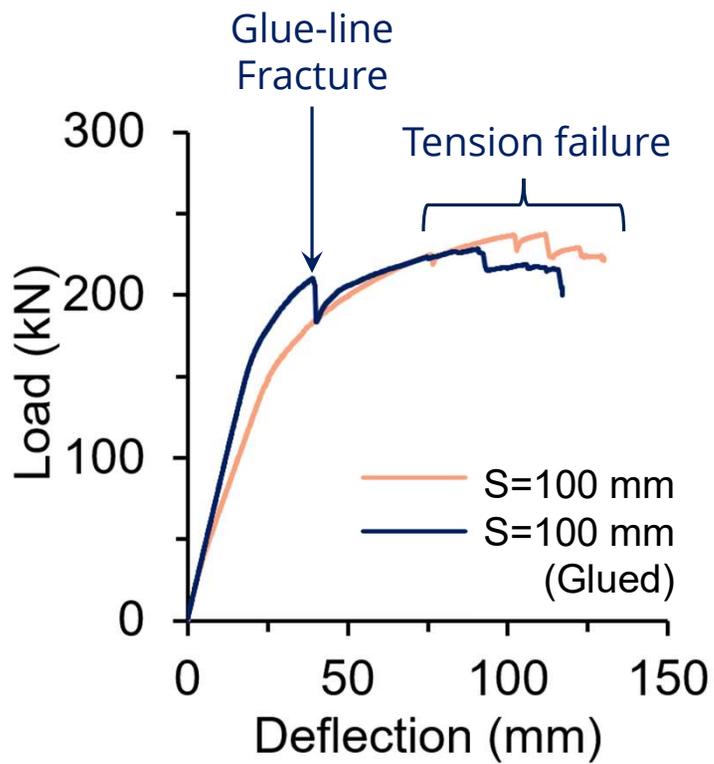
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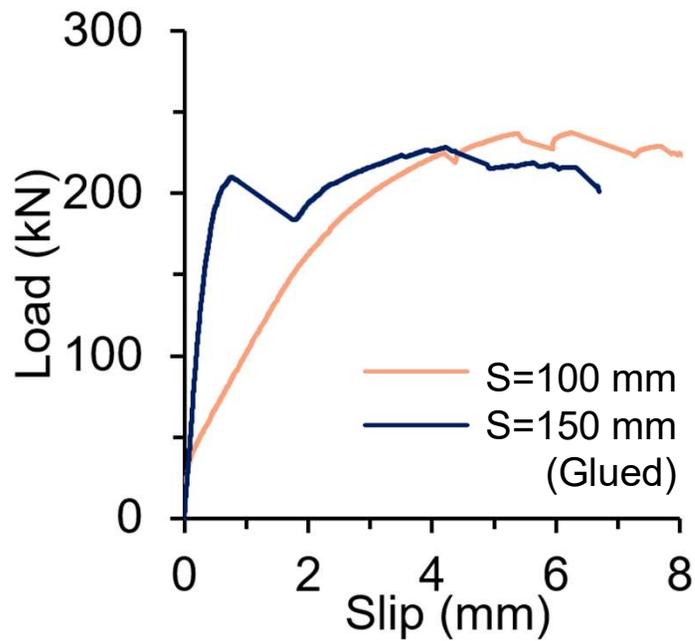
# Large-scale Composite Beam Tests

Major Axis Beams with 3-Ply CLT Slab



# Large-scale Composite Beam Tests

Major Axis Beams with 3-Ply CLT Slab



Visual Representation of Slip without Glue



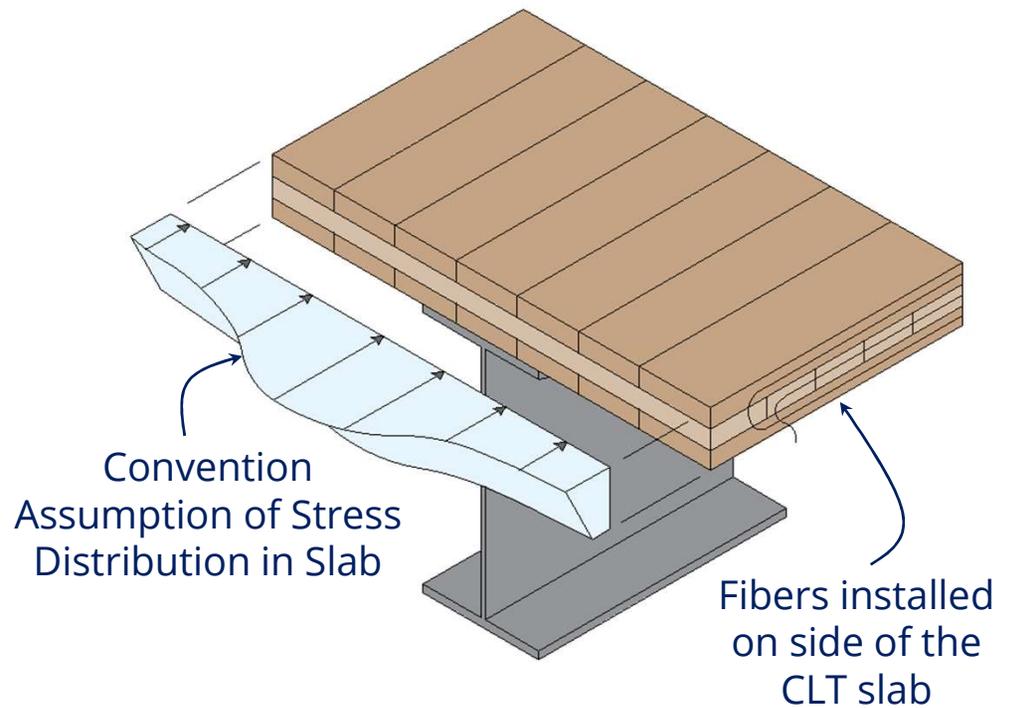
# Large-scale Composite Beam Tests

Major Axis Beams with 3-Ply CLT Slab (with glue)

Slip between layers of CLT

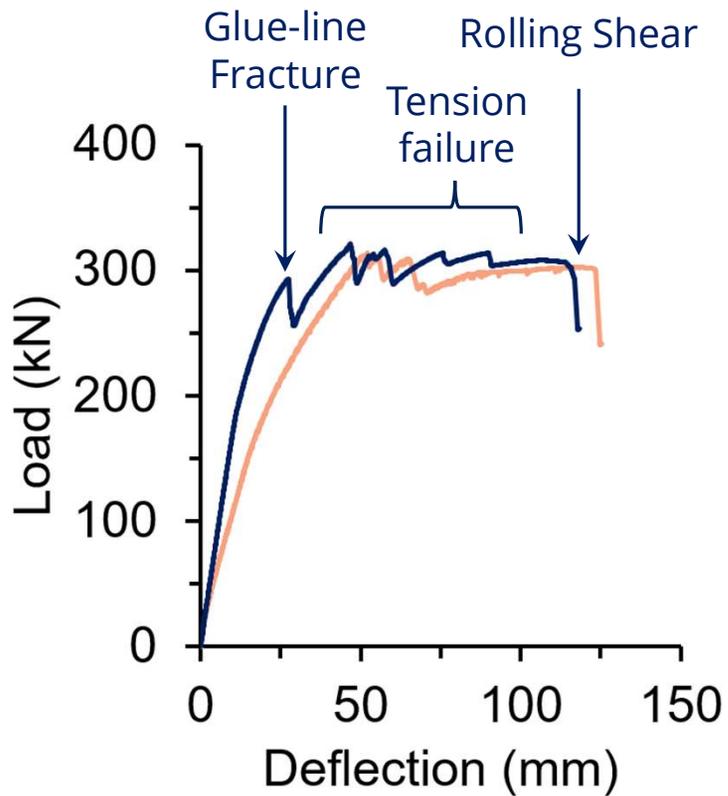
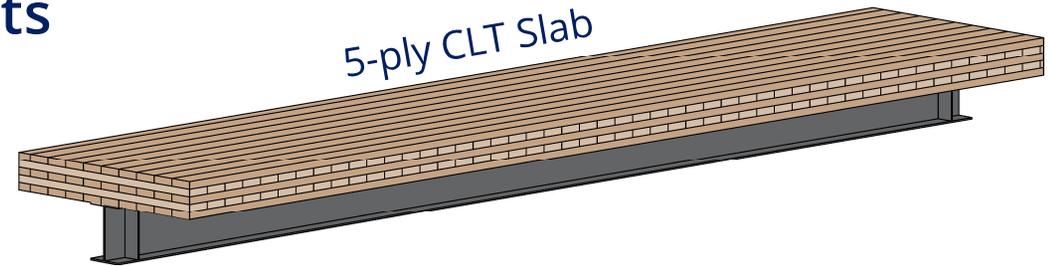


Beam End View after Testing



# Large-scale Composite Beam Tests

Major Axis Beams with 5-Ply CLT Slab



## Conclusions

1. Timber-steel composite beams exhibit ductile behaviour and achieving partial composite action with screws is possible.
2. Failure modes in beams with 3-ply CLT was tension and 5-ply CLT tension/rolling shear. Influence of panelization was negligible.
3. Beams with glued shear connection likely exhibit full composite action up to fracture of glue-line, but edge-glued CLT plays a role
4. Existing approaches used to evaluate the strength of composite beams can be applied to timber-steel composite beams.

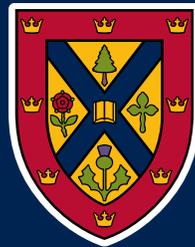


All of this work was done by Brendan Deeves!

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Questions?



Queen's  
UNIVERSITY

