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EFFECT OF GROWTH RING ORIENTATION ON THE ROLLING SHEAR PROPERTIES OF WOODEN CROSS LAYER UNDER TWO-PLATE SHEAR TEST

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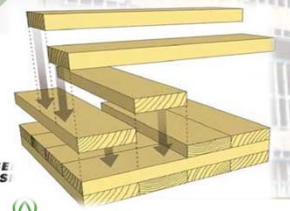
Cross Laminated Timber (CLT)

9-storey, London (2009)

10-storey, Melbourne (2012)

Airport, Fort McMurray (2014)



- Minimize swelling and shrinkage deformation
- Achieve balanced load-carrying capacity in different directions

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Applications of CLT

- Panels (wall assemblies)
- Load bearing plates (roof or floor elements)

In beam application of short span-to-depth ratio or concentrated load (header, lintel,etc.)

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Failure of a CLT beam under bending

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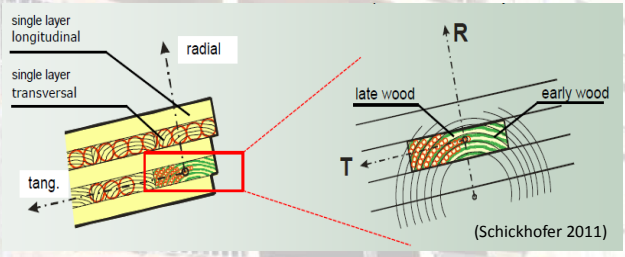
What is rolling shear?

- The shear stresses leading to shear strain in the radial-tangential (*rt*) plane



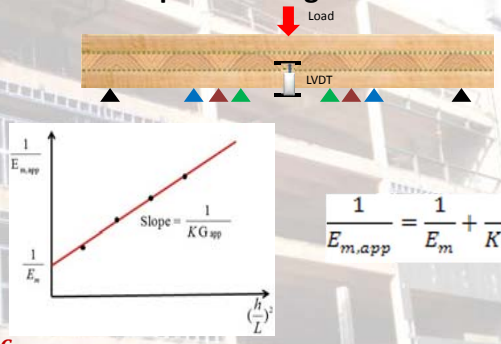
Problem statement

- Low rolling shear modulus (*G*) governs CLT floor design (CLT Handbook 2011)
- Low rolling shear strength (τ) is critical under concentrated load

An appropriate method is required to measure the rolling shear properties of cross layer for design!

Two testing methods in ASTM

1. **Variable span bending test: *ASTM D198***

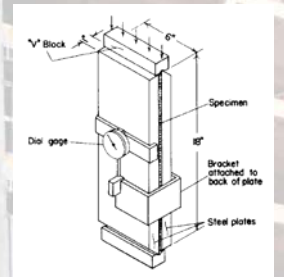


$$\frac{1}{E_{m,app}} = \frac{1}{E_m} + \frac{1}{KG_{app}}\left(\frac{h}{L}\right)^2$$

- ***G***
- Good estimation of the deflection of a beam at a small span-to-depth ratio (< 8) using the shear analogy method (Zhou et al. 2014)

Two testing methods in ASTM

2. **Two-plate shear test: *ASTM D2718***



- Rolling shear modulus

$$G = \frac{t}{Lw}\frac{P}{\Delta}$$

- Rolling shear strength

$$\tau = \frac{P_{max}}{Lw}$$

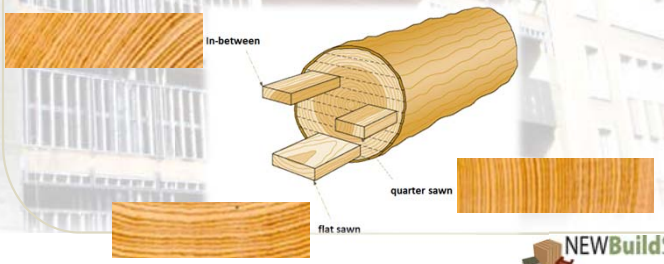
- ***G*** and τ
- Good estimation of the deflection of a beam at a large span-to-depth ratio (>14) using the shear analogy method (Zhou et al. 2014)

Factors influencing rolling shear properties

- Material
  - Species, density, growth ring orientation, …
- Manufacturing parameters
  - Dimension, thickness-to-width, with/without edge glue, layup, …

Objective

To evaluate the effect of growth ring orientation on the rolling shear modulus and strength of wood cross layer in downscaled CLT specimens



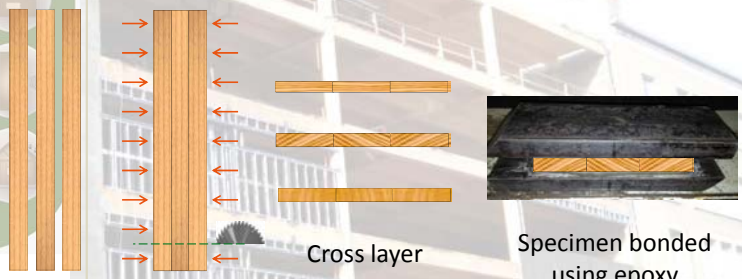
Scope of work

- ❑ Phase 1: using small-scaled specimens to evaluate two potential methods: variable-span bending and two-plate shear
  - evaluate the effect of growth ring orientation and laminate thickness on the rolling shear properties under two-plate shear test
- ❑ Phase 2: full-scale specimens to verify the findings from phase 1

Materials

- ❑ Black spruce (*Picea mariana*) lumber
  - Moisture content: 12%
  - Density: 0.420 to 0.445 g/cm^3
- ❑ Wood strip
  - 9mm think, 36mm wide
  - Growth ring orientations: flat, in-between, and quarter
- ❑ Adhesive
  - one-component polyurethane (ISOSET SX-1050)

Specimen preparation



Strips

Edge gluing (PUR) and cross cutting

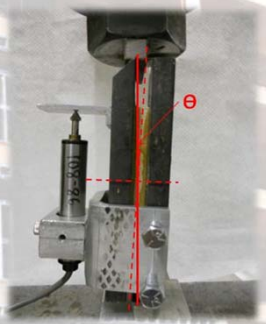
Cross layer

Specimen bonded using epoxy

9 specimens/group

Method

- Two plate shear tests



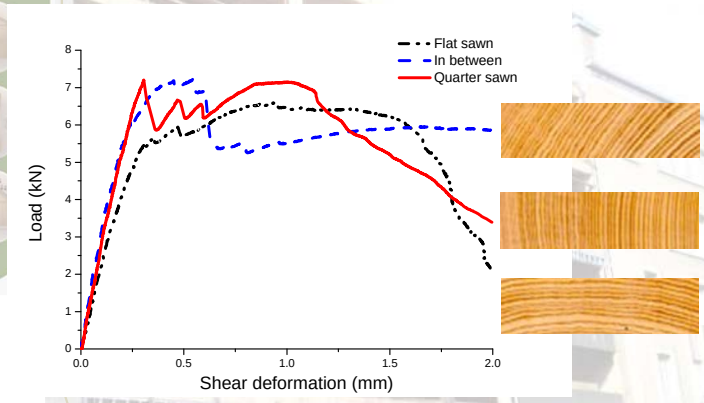
- 10-mm-stroke LVDT
- Loading speed: 0.5 *mm/min*

$$G_{rt} = \frac{t}{Lw}\frac{\Delta P}{\Delta y}$$

$$\tau = \frac{cos\theta\ P_{max}}{Lw}$$

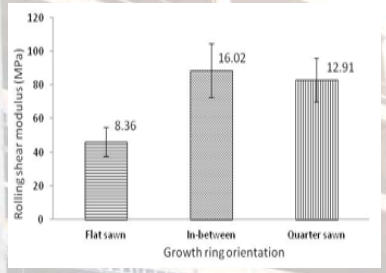
(Sretenovic et al. 2005)

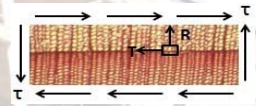
Results: load vs. deformation



- Similar peak load
- Smaller Initial slope of flatsawn specimens

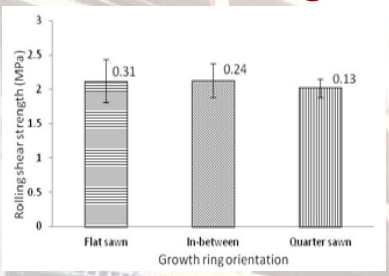
Results: rolling shear modulus

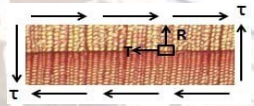




Source of Variation	SS	df	MS	F	p-value
Between Groups	4747.6	2	2373.7764	9.9109	0.0013
Within Groups	4311.2	18	239.5103		
Total	9058.7	20			

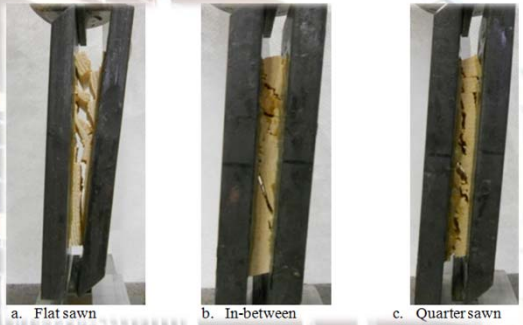
Results: rolling shear strength





Source of Variation	SS	df	MS	F	p-value
Between Groups	0.0917	2	0.0459	0.7256	0.4976
Within Groups	1.1379	18	0.0632		
Total	1.2296	20			

Results: failure mode



- typical rolling shear failure
- cracks initiated and propagated in different ways to some degree in specimens with different growth ring orientations

Conclusions

- The growth ring orientation of cross layer
  - had a statistically significant effect on the rolling shear modulus; and
  - did not have a statistically significant effect on rolling shear strength;
- The cross layer of in-between growth ring orientation had the average rolling shear modulus (89 MPa) and strength (2.12 MPa); and
- Specimens with different growth ring orientation showed a typical rolling shear failure.

Benefit to CLT manufacturers

In production and application of CLT, more attention may be paid to the cutting pattern of logs to get the wood laminates of larger portion of in-between (45^0) growth ring orientation.

- In reality, logs available are smaller and smaller in diameter

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Thank You and Questions?

- Zhou, Q.Y., Gong, M., Chui, Y.H., and Mohammad, M. 2014. Measurement of rolling shear modulus and strength of cross laminated timber. *Journal of Construction and Building Materials* 64: 379-386.
- Zhou, Q.Y., Gong, M., Chui, Y.H., and Mohammad, M. 2014. Measurement of rolling shear modulus and strength of downscaled cross laminated timber using bending and two-plate shear tests. *Wood and Fiber Science* 46(2): 259-269.