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AIA KnowledgeNet

Emerging Technologies in Wood and Bio-Based Building Products

by

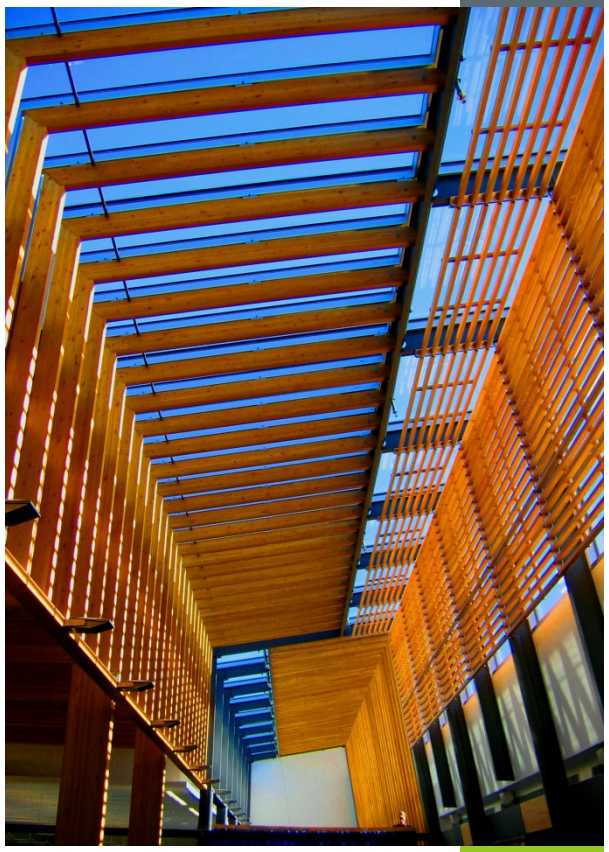
Peggi L. Clouston, Ph.D., M.A.Sc., P.Eng.
Associate Professor
Building and Construction Technology
Dept. of Environmental Conservation
clouston@umass.edu

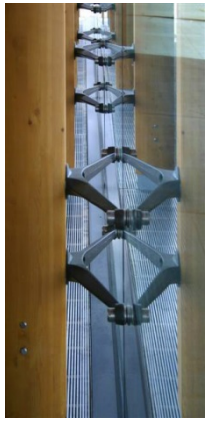
UNIVERSITY OF MASSACHUSETTS AMHERST 1863

Wood engineering

More structurally demanding applications today…








Prince George Airport, British Columbia

Photo credit: McFarlane Biggar Architects

Thompson Community Center, Richmond, British Columbia

Photo courtesy: Henriquez Partners Architects

Pushing boundaries

Proposed

Image credit: McFarlane Biggar Architects

Just completed

Primary drivers:

Sustainability
&
Innovation

Building and climate change

- Buildings in the U.S.:
  - *Use 36% of total energy*
  - *Use 30% of raw materials*
  - *Use 12% of potable water*
  - *Produce 30% of total waste*
  - *Emit 30% of greenhouse gases*

Source: Kats, Gregory, et al. “The costs and benefits of Green Buildings.”
A report to California’s Sustainable Building Task Force, Oct. 2003

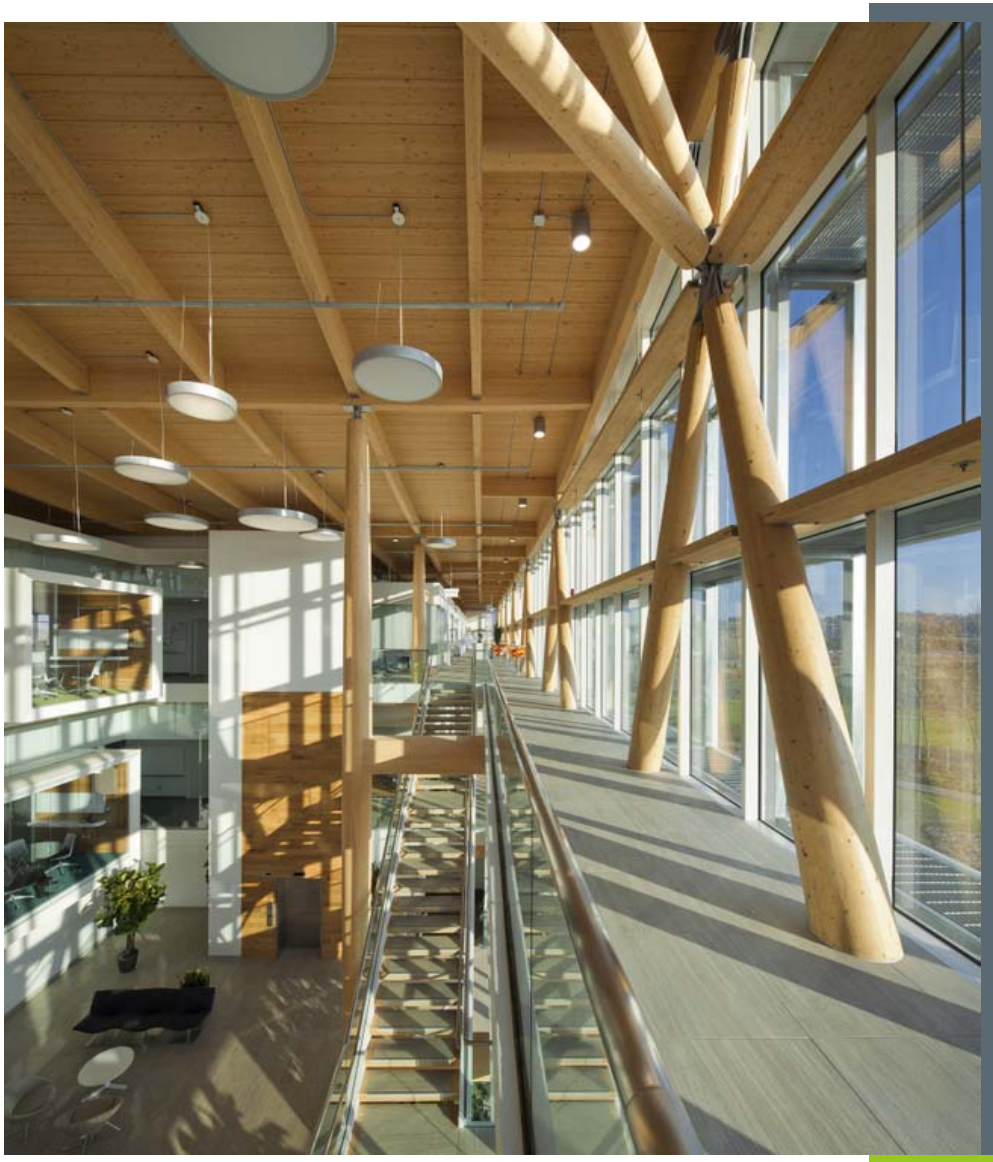
A green building is…

- *Energy efficient*
- *Resource efficient*
- *Durable*
- *Non-polluting*
- *Adaptable for many uses*
- *Beautiful and comfortable*
- *Healthy: few chemicals given off, no mold, fresh air*

Green home in Austria
Photo source: Prof. DDI Michael Flach

Green Building Awards

Office Building for GlaxoSmithKline Inc., Quebec Nordic CLT. Photo credit © Stéphane Groleau



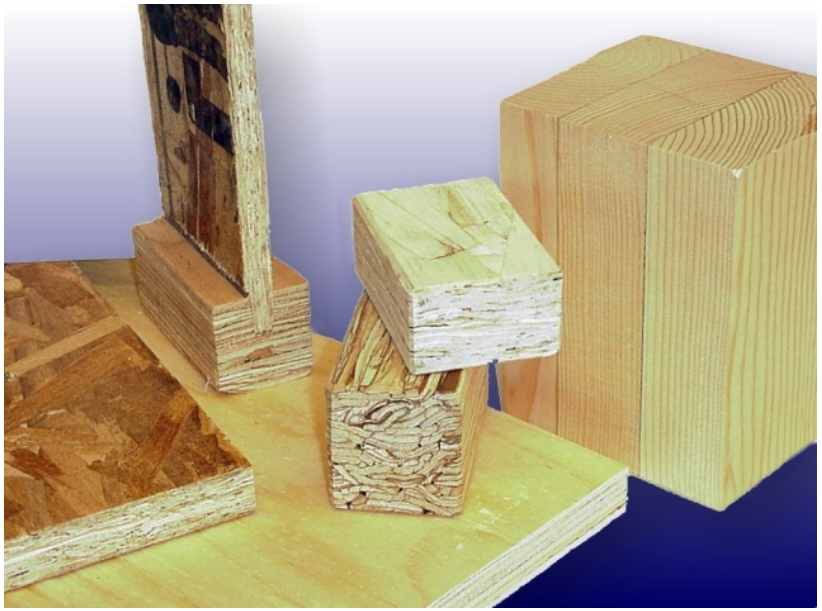
"Wood can help to earn points in categories typically found in green building rating systems— including certified wood, recycled/reused/salvaged materials, local sourcing of materials, waste minimization, indoor air quality, advanced building techniques and skills and life cycle impacts" …

Quote source: ReTHINK Wood

Sustainability and wood

- Wood products store carbon
- Life Cycle Assessment studies show wood to have a comparatively small environmental footprint
- Wood is the only major renewable building material
- Wood is recyclable and triggered biodegradable
- Wood creates a healthy indoor environment

Carbon sequestration and storage



- Wood and wood products store carbon until they burn or biodegrade

Wood products are carbon negative

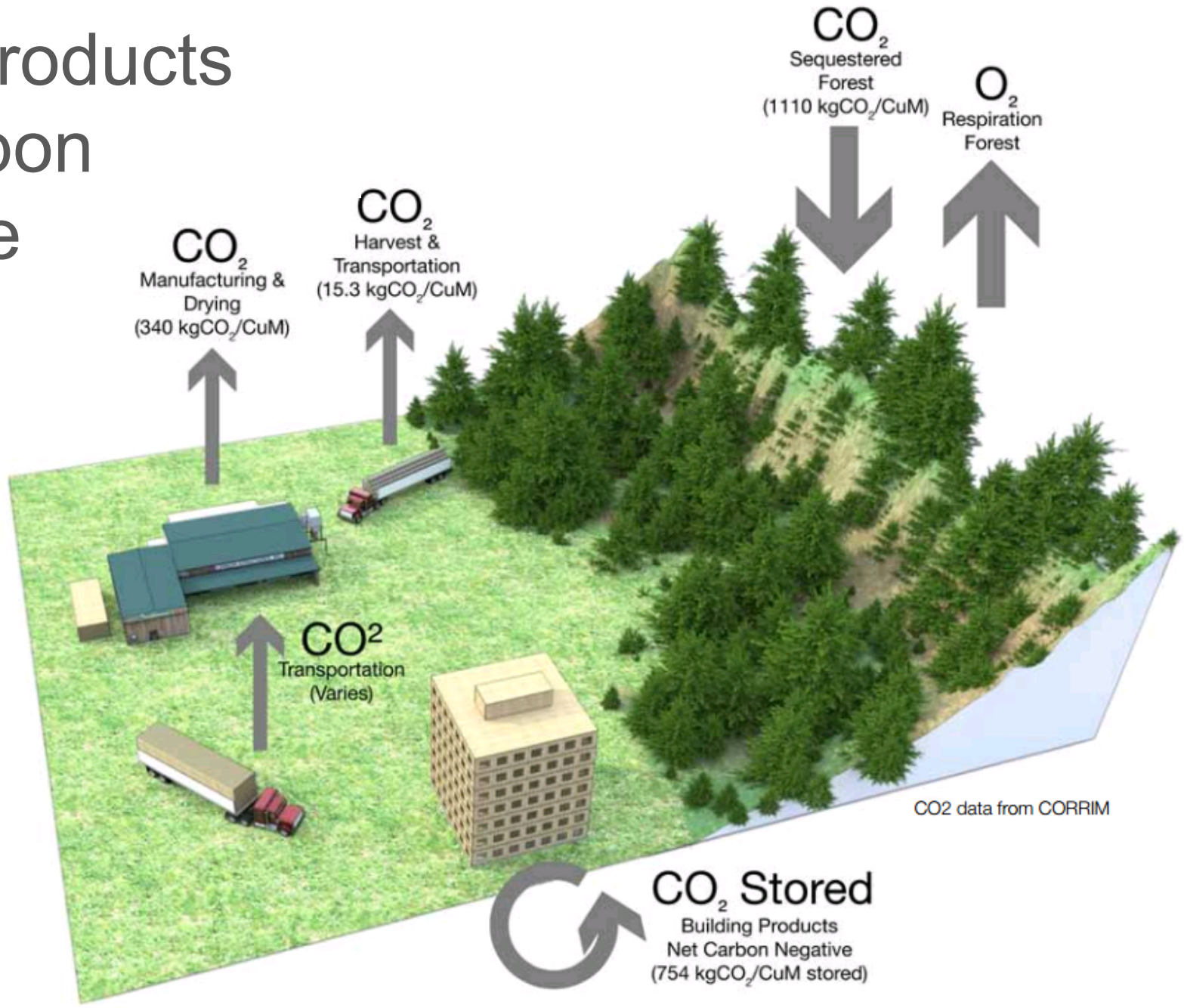


Image courtesy of Joseph Mayo of Mahlum | Architects Inc.

Life Cycle Assessment Study

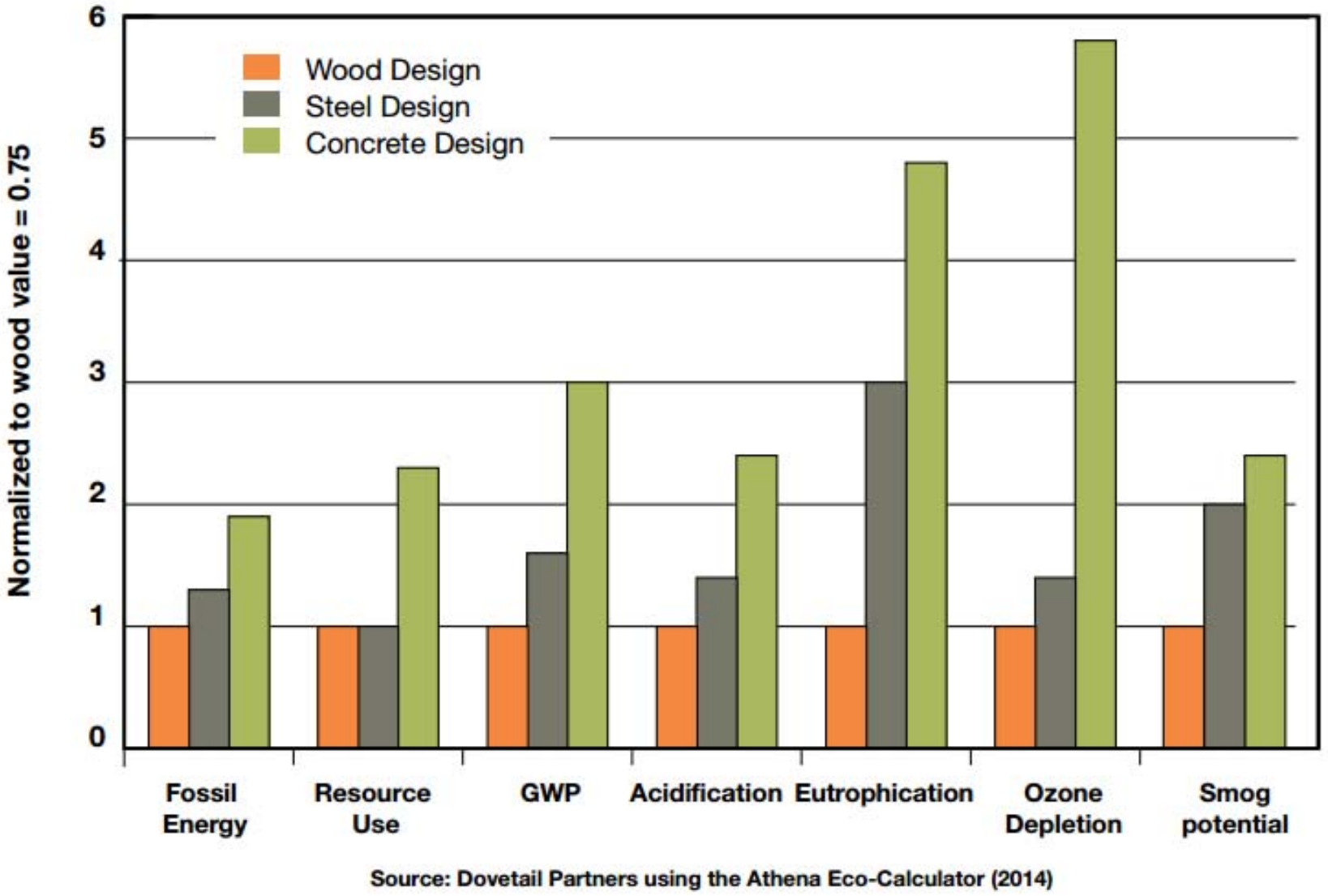


Image source: ReTHINK WOOD® – Building Green with Wood (Module 2)

Healthy Indoor Environment

- Dust and particulates
- Off gassing
- Humidity control
- Stress reducing effects:

http://woodworks.org/wp-content/uploads/Wood-Human-Health11.pdf

Image source: Prof. DDI Michael Flach

Innovation

Advanced Engineered Wood Composites

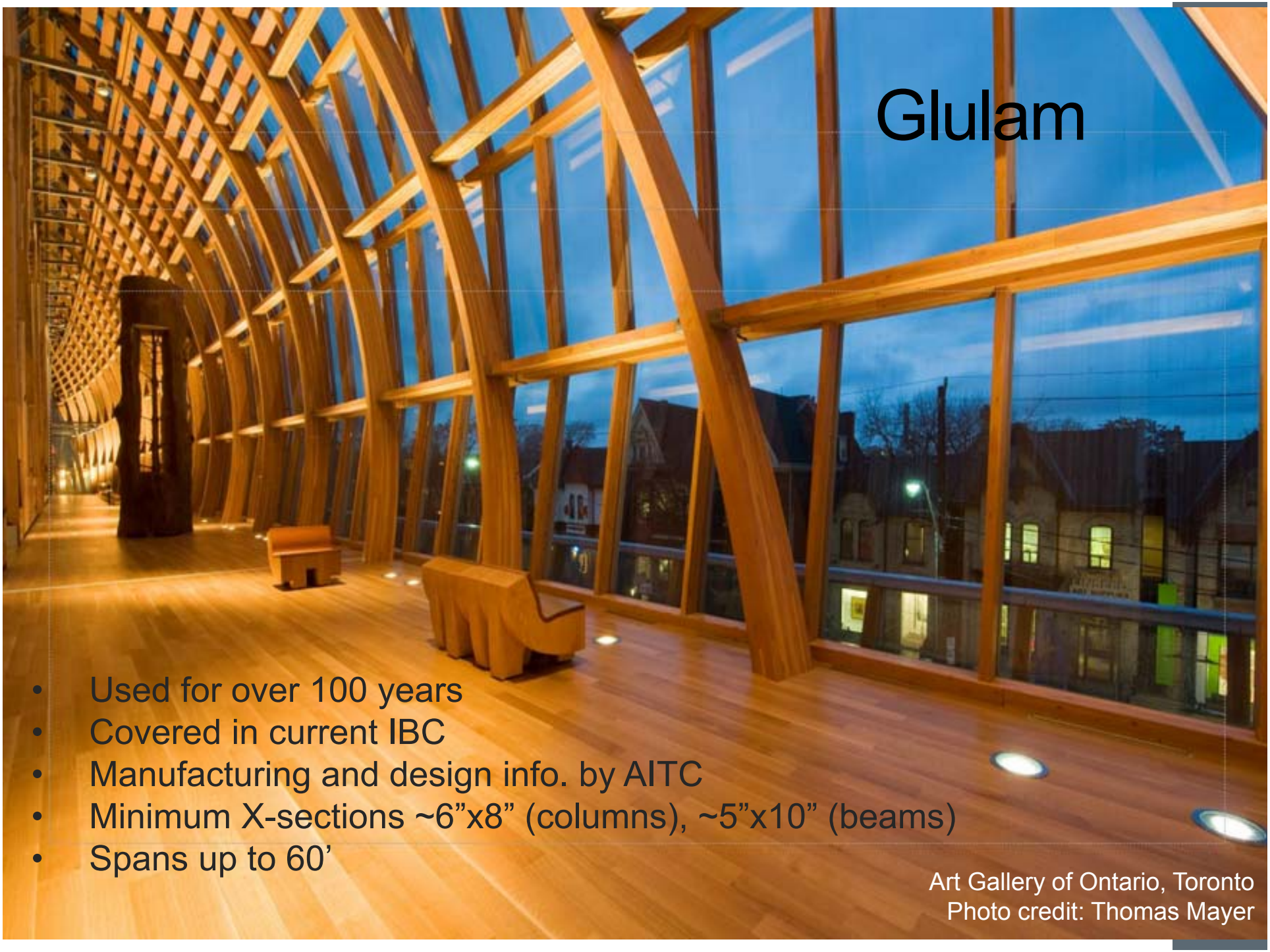
Mass timber

Cross Laminated Timber

Glulam

Parallel Strand Lumber

Glulam

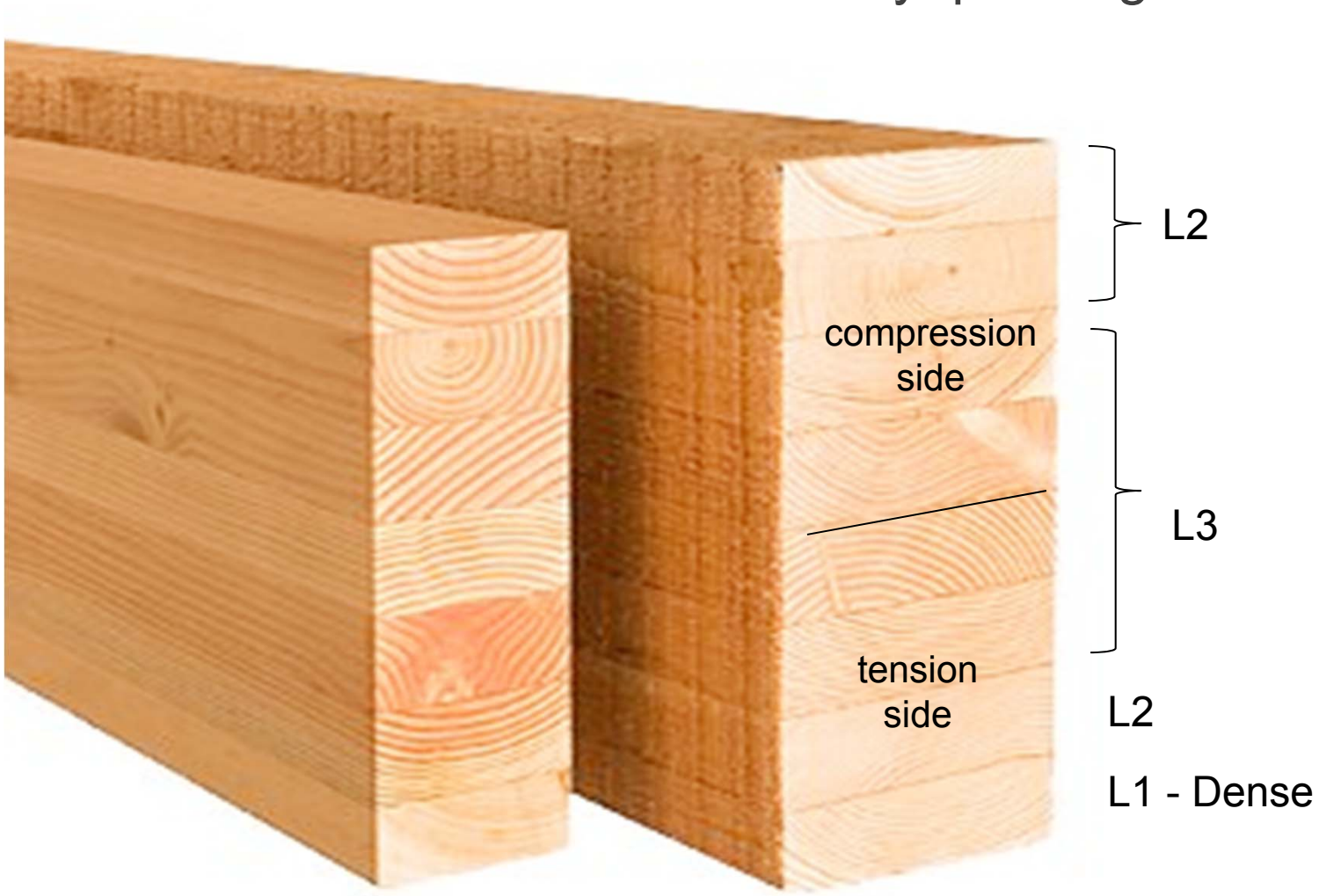


- Used for over 100 years
- Covered in current IBC
- Manufacturing and design info. by AITC
- Minimum X-sections ~6”x8” (columns), ~5”x10” (beams)
- Spans up to 60’

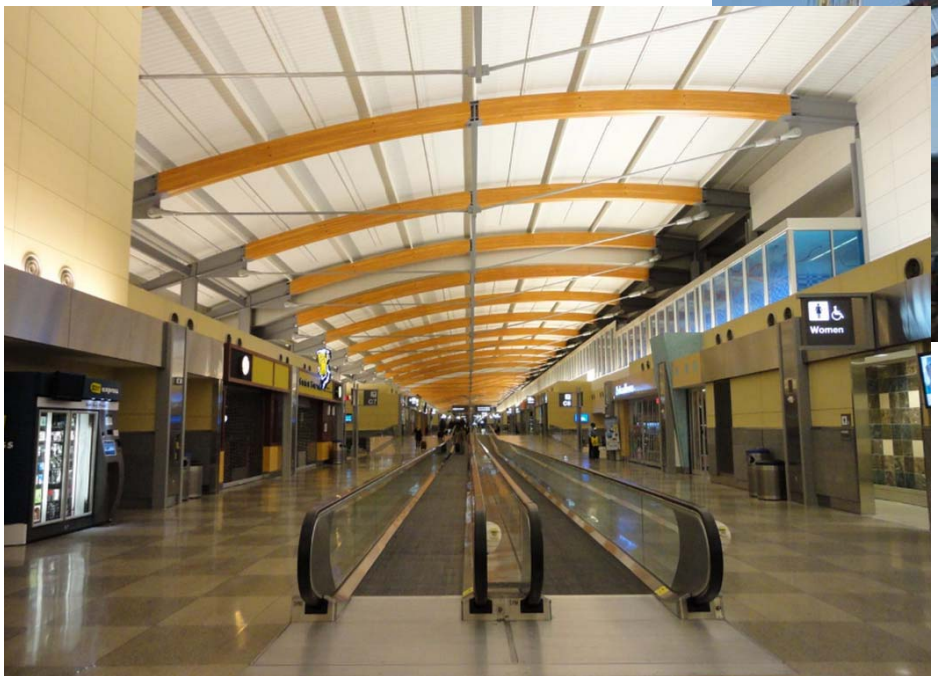
Art Gallery of Ontario, Toronto
Photo credit: Thomas Mayer

Glulam strength

- Defects are dispersed
- Layup is engineered



…with steel and concrete



Raleigh-Durham Airport

Photo source: Equilibrium Engineering

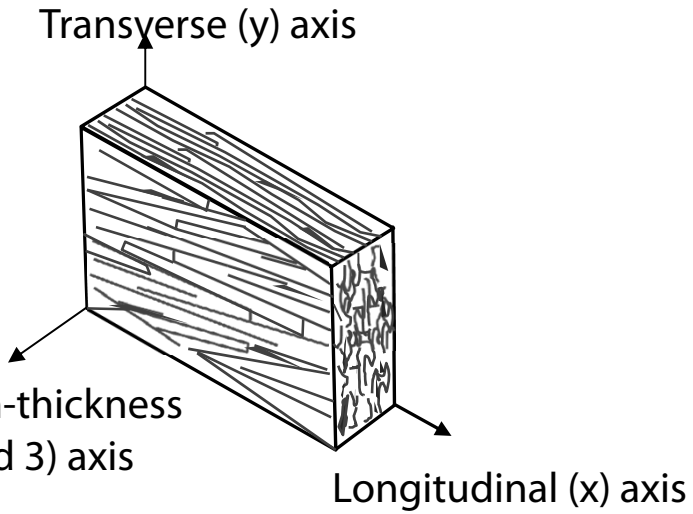
Parallel Strand Lumber (PSL)

- Length is only limited to transportation constraints
- Beams fabricated as a large billet (12in x 18in) and resawn
- Can be laminated to larger sizes

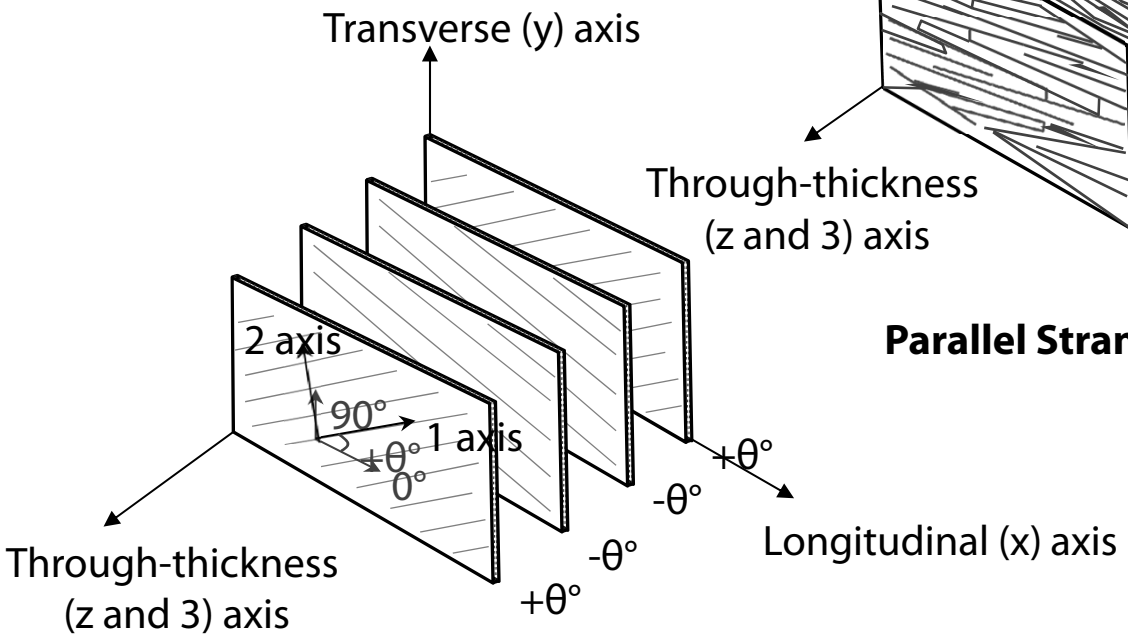
Forest Science Center,
University of British Columbia
Photo courtesy: A. Schreyer

UMass research on PSL

Close up view of PSL

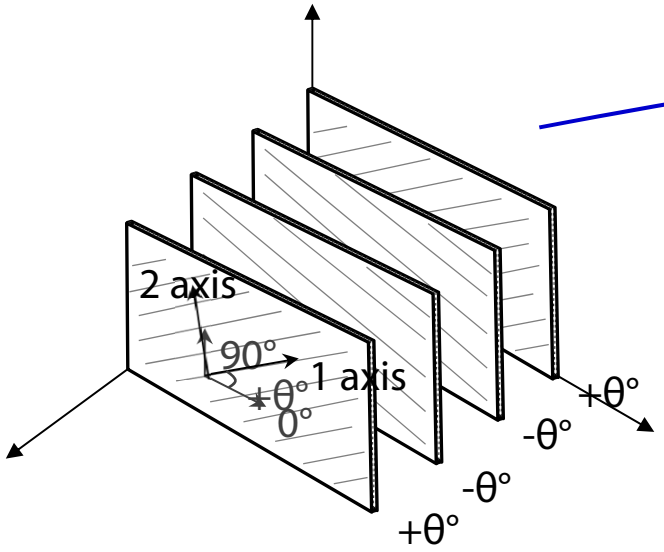


Parallel Strand Lumber, PSL

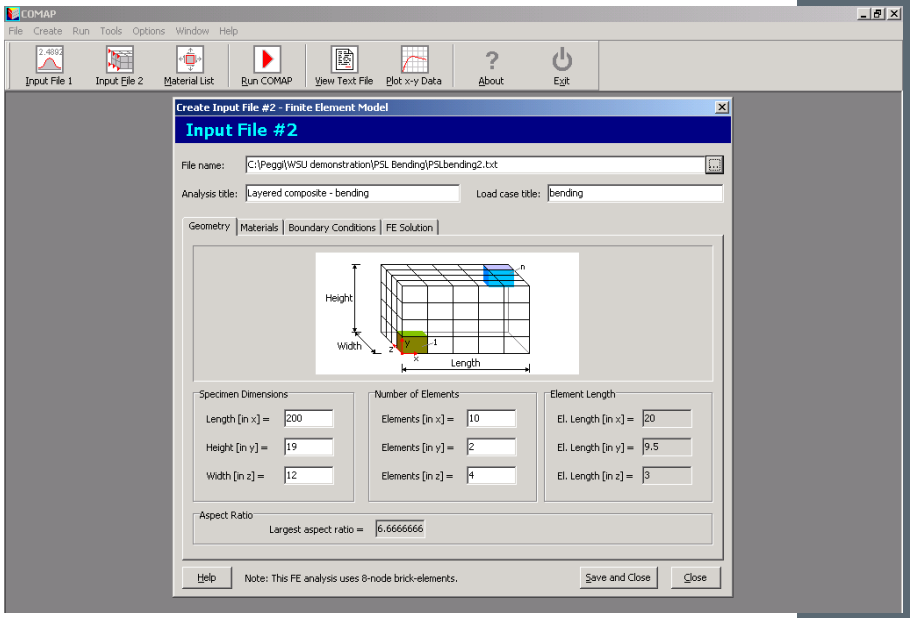


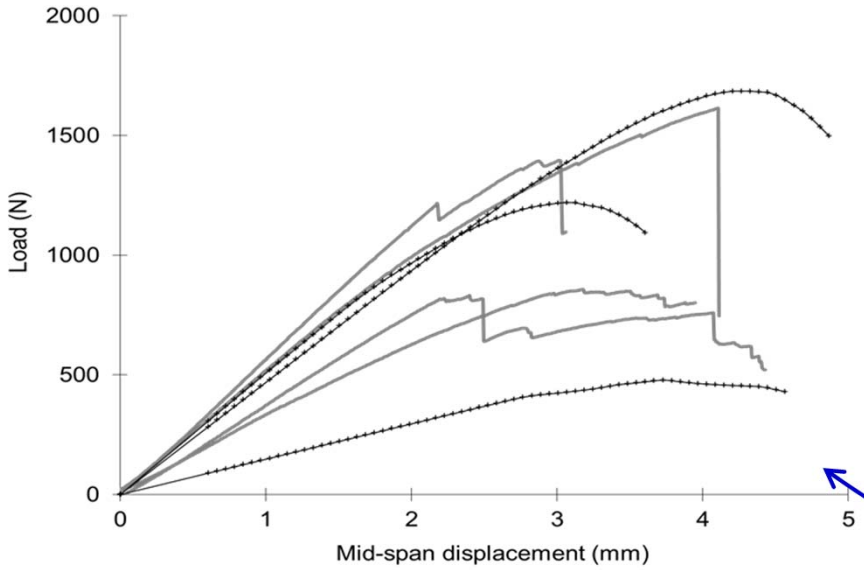
$[\pm\theta^\circ]_s$ **Angle-ply Laminate**

Numerical simulation of strength

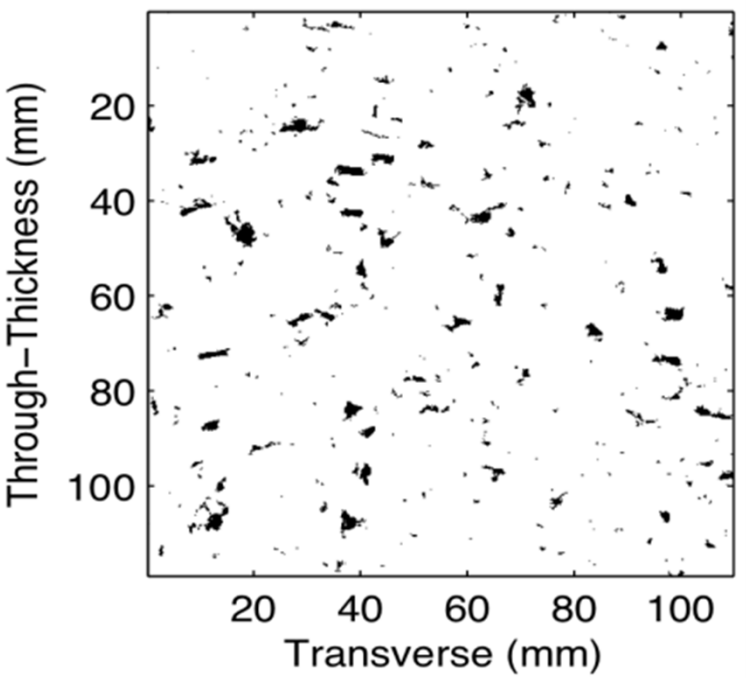


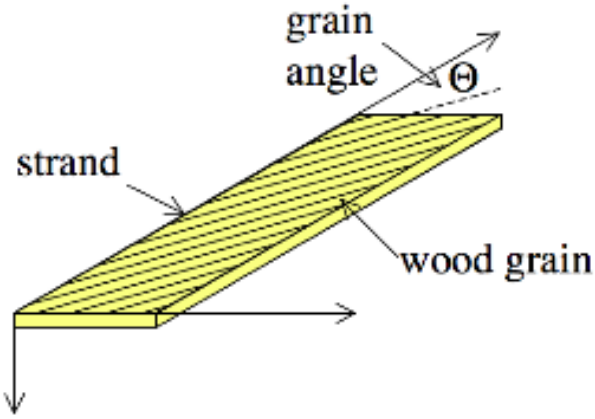
COMAP© – P. Clouston, 2004

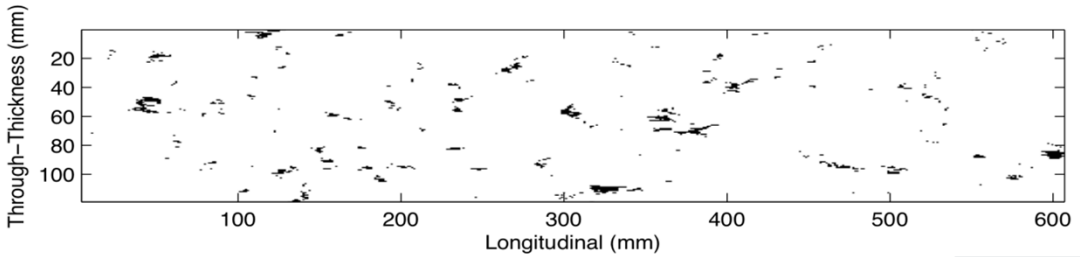


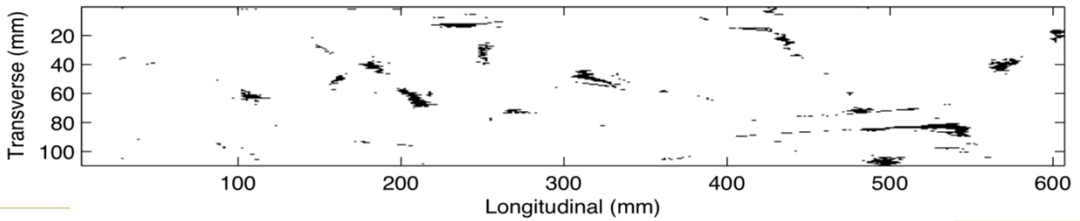


Mesostructural characterization

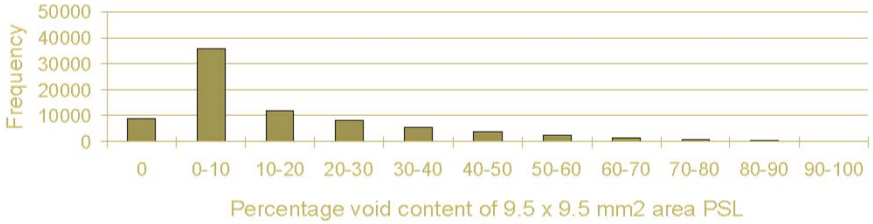




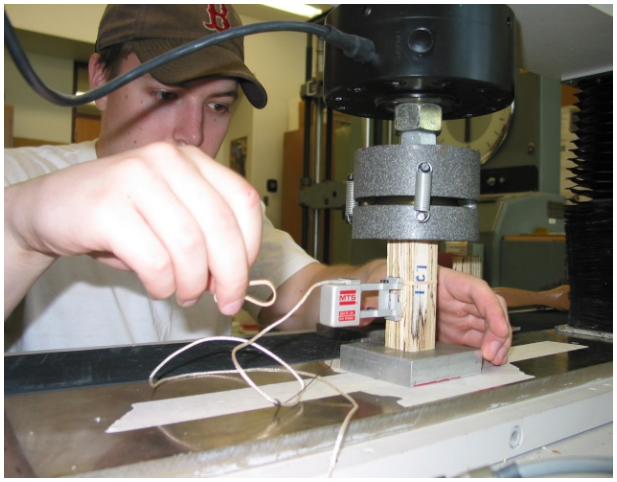


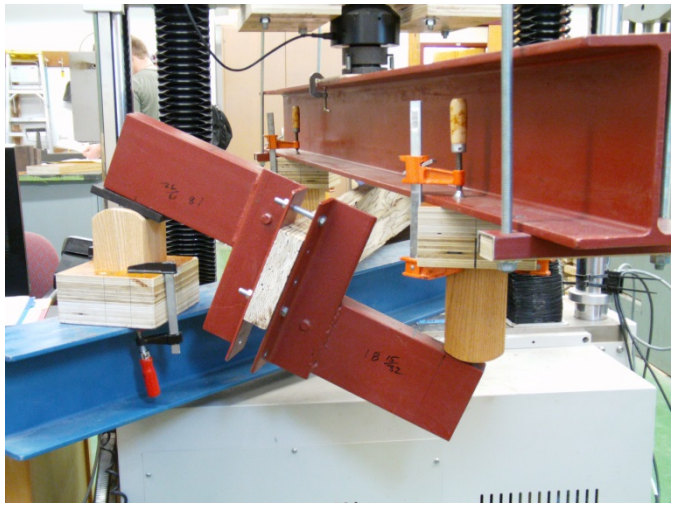


PSL void mesostrucures



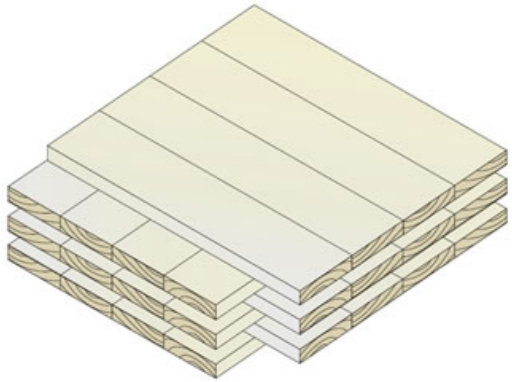
Experimental evaluation





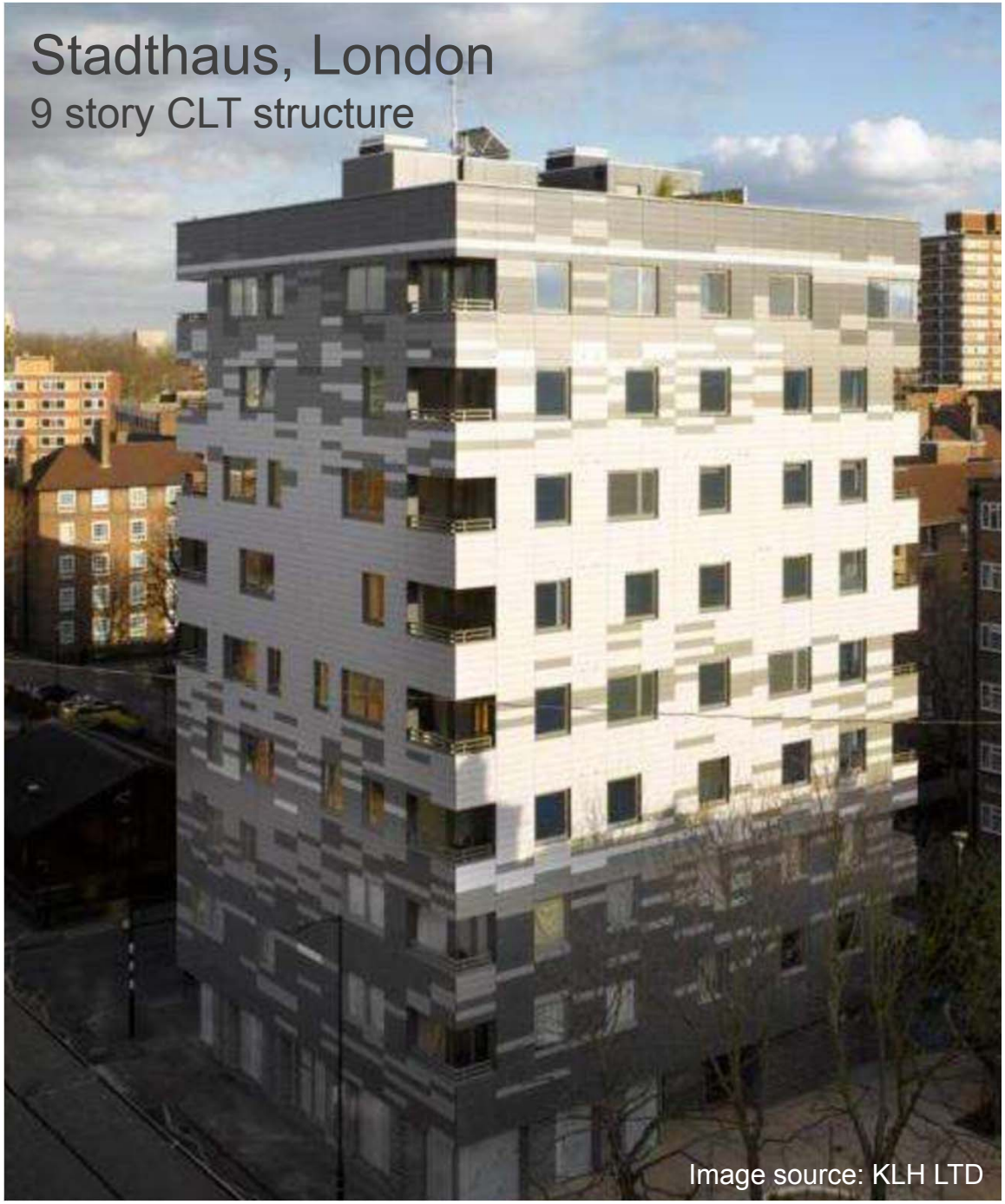
Modeling the Design Limit States of Structural Composite Lumber.
NSF Grant No. 0826265 (Clouston & Arwade)

Cross-laminated timber (CLT)



CLT project - Earth Sciences Building at the University of British Columbia, Vancouver. Source: Structurlam

- 3/5/7 layers
- ≥ 4in thick as floors and ≥ 3in as roofs
- panels up to 12ft by 60ft
- Adhesives in accordance with ANSI/APA PRG 320



Proposed …

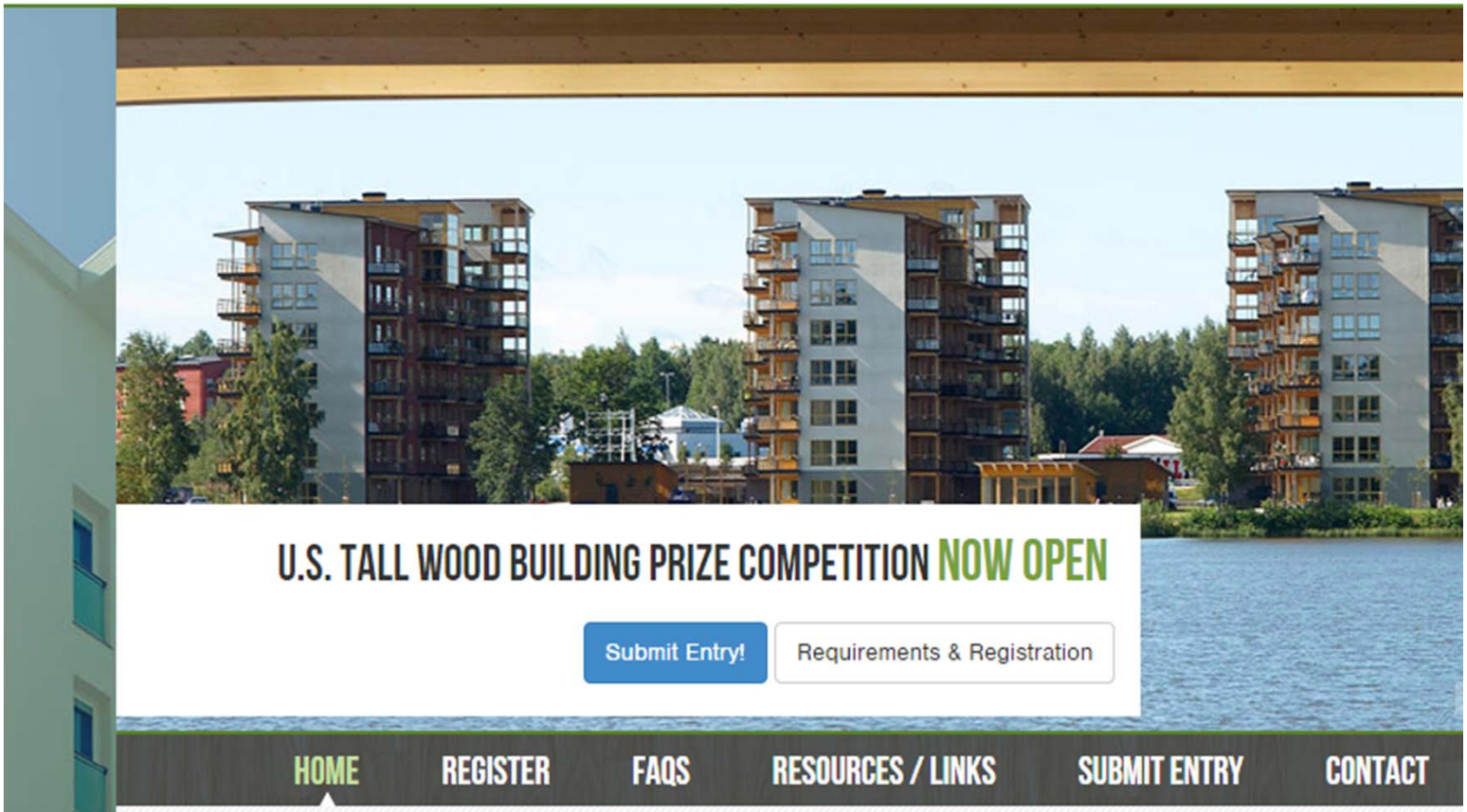
- Built in 9 weeks by four workers!

Forte, Melbourne

10 story CLT structure - the tallest in the world

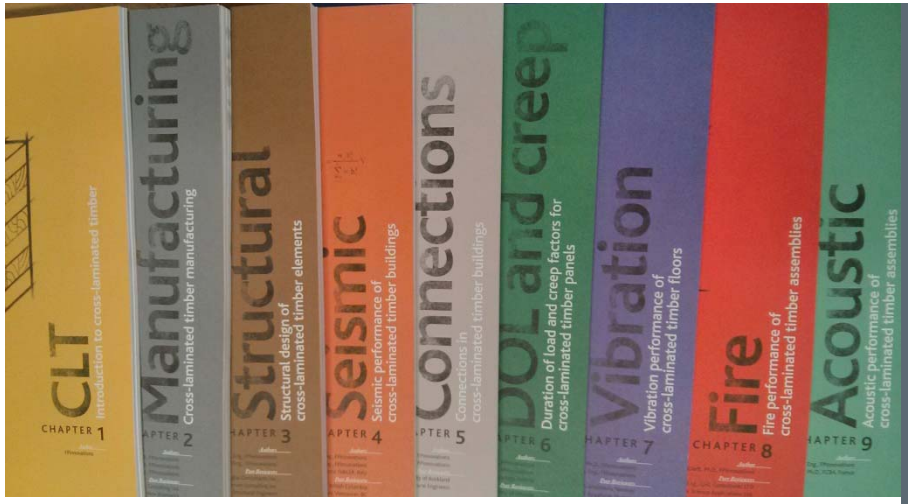
- Built in 10 weeks by five workers!

U.S. TALL WOOD BUILDING PRIZE COMPETITION



Building stronger markets for innovative new wood products supports sustainable forestry, helps buffer reduce greenhouse gas emissions, and puts rural America at the forefront of an emerging industry. Presently, markets for wood and other related forest products support more than one million direct jobs, many in America's forests. As these markets expand, so will the economic opportunities.

CLT information



- *ANSI/APA PRG 320-2011:*
  Standard for Performance-Rated Cross Laminated Timber – APA
- *APA Product Reports® – APA*
- *CLT Handbook (www.masstimber.com)*
- *Case studies and design examples:*

  (http://www.woodworks.org/design-with-wood/building-systems-clt/)
- *Research on 10-30 stories: "The Case for Tall Wood Buildings"*

  (http://www.woodworks.org/wp-content/uploads/CWC-Tall-Walls2.pdf)

Recent code changes accommodating greater heights with fewer limits

- *IBC already allows 65ft height, 5 story as Type IV - HT*
- *2015 International Building Code*
  - *CLT and SCL included (beside glulam) as Type IV - HT construction*
  - *SCL.and CLT permitted in Type IV parking podiums*
    - *Means **85ft, 6 story** with 5 stories apartment over one story open parking*
  - *Fire resistance rating requirements simplified ...*

Fire Protection

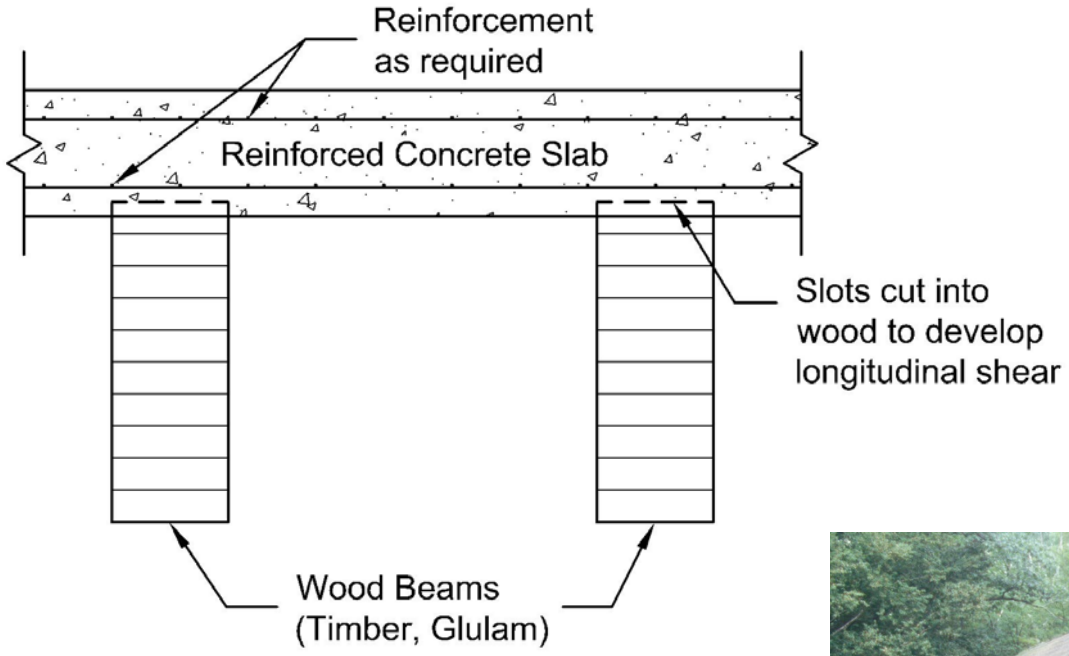

Photo source: FPInnovations

- *Char at a predictable rate:*
- *Adhesives per ANSI standard*
- *Minimum x-sections required*
- *Implications:*
  - *CLT possible fire wall construction*
    …7-layer CLT floor fully loaded exposed to fires for nearly 3 hours
  - *5 layer CLT wall + one exterior layer gypsum = 2 hours*

See: http://www.awc.org/Code-Officials/2012-IBC-Challenges/NGC-CLT-Report.pdf

Emerging technologies

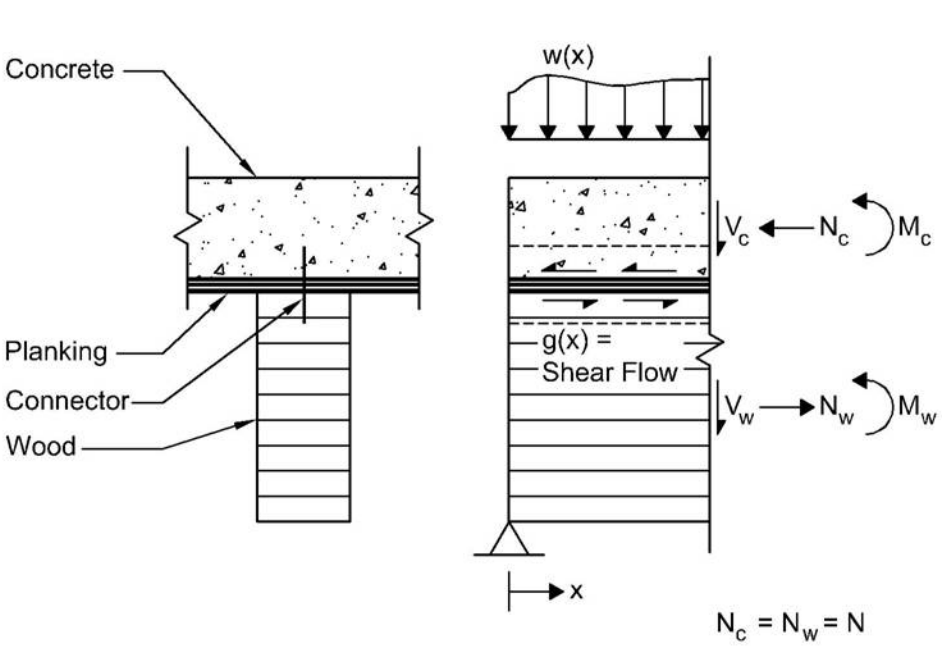
Wood-concrete composite

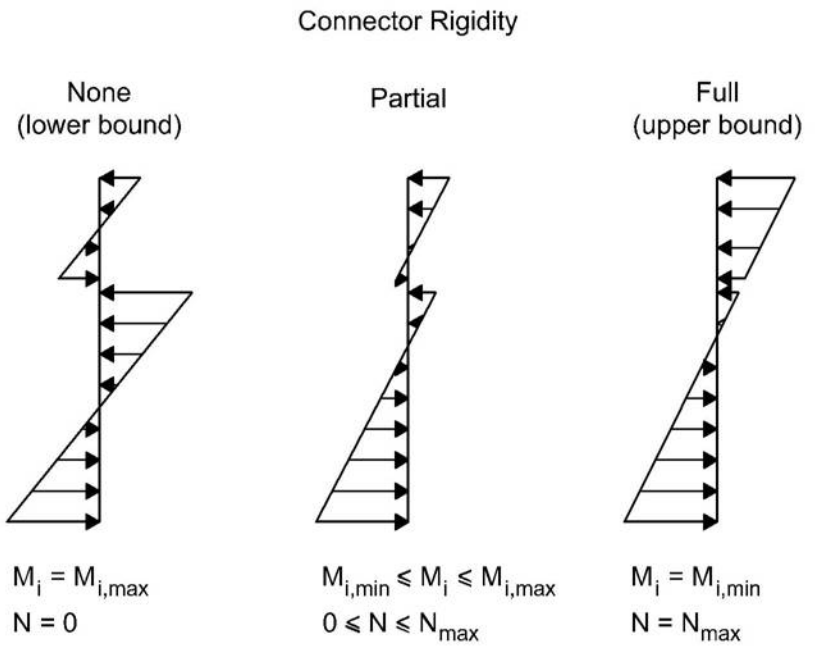


Hybrid composite construction method

Used since 1930s in timber bridges

Composite action





- Partial composite action → depends on fastener
- Analysis: Eurocode 5
  - Clouston and Schreyer (2008) ASCE Practice Periodical on Structural Design and Construction, Vol. 13, No. 4

Commercial shear connectors

Bertsche connector

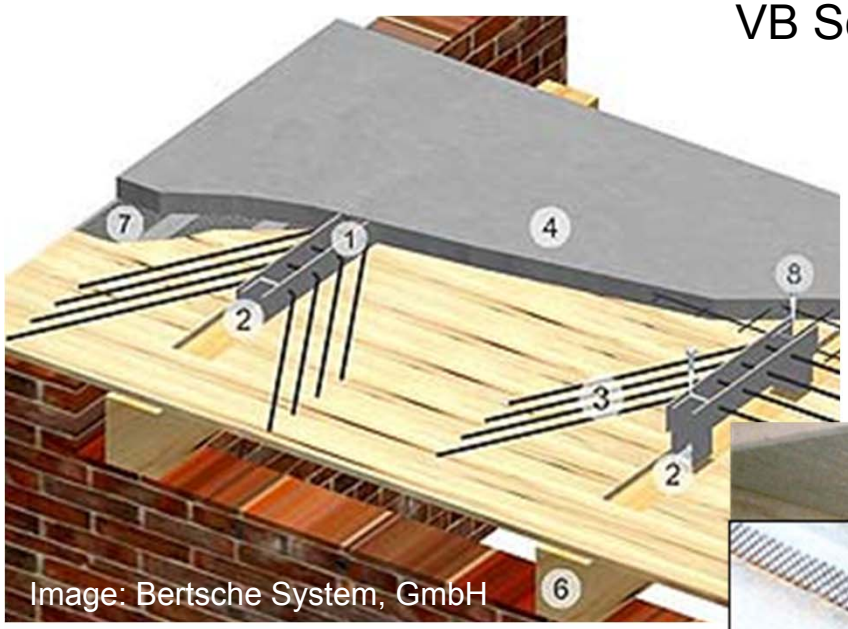


Image: Bertsche System, GmbH

SFS Intec
VB Screws

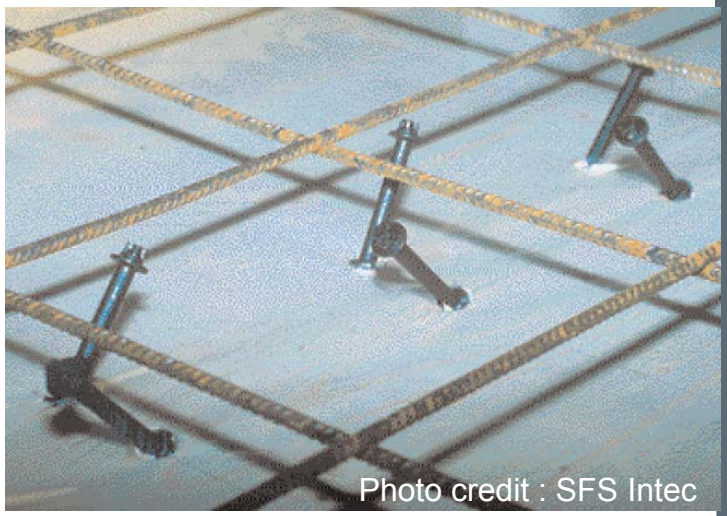
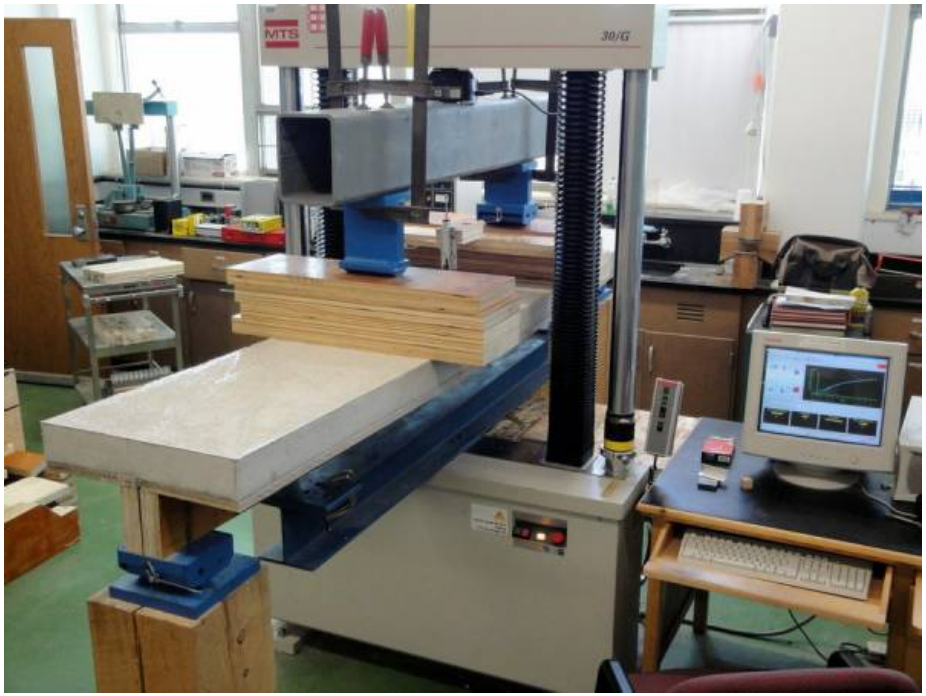


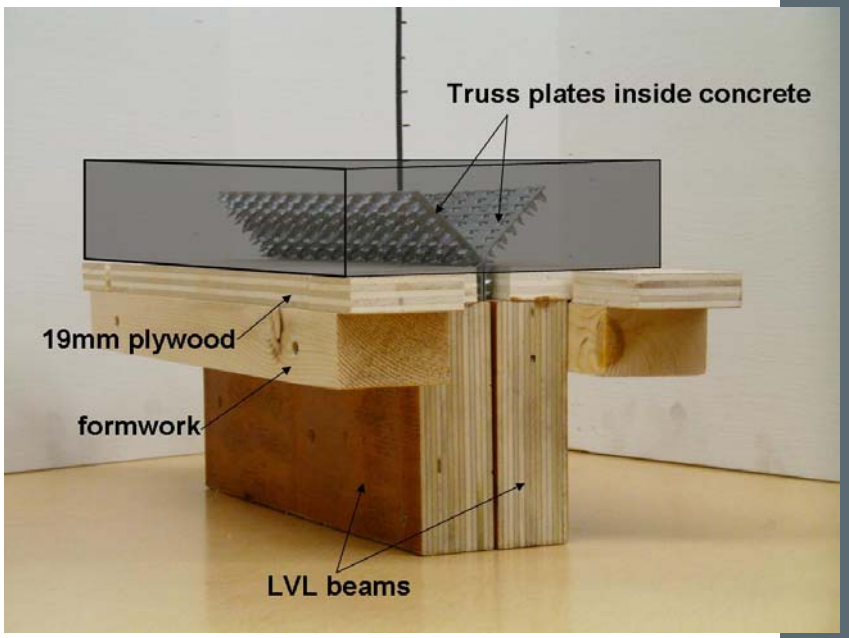
Photo credit : SFS Intec

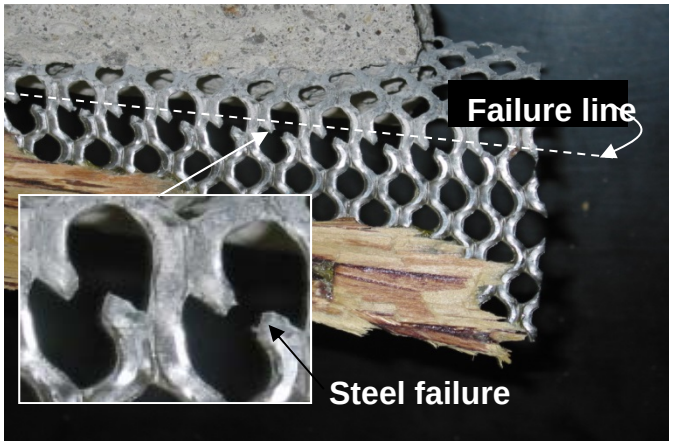
HBV system

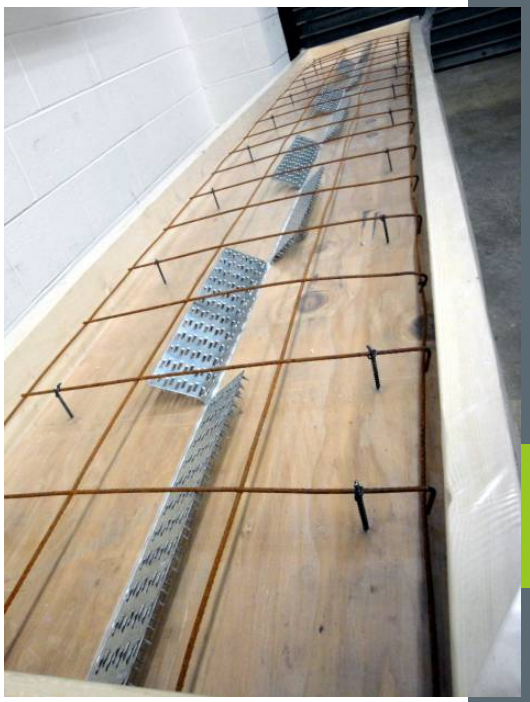
Photo credit : A. Schreyer

UMass WCC research

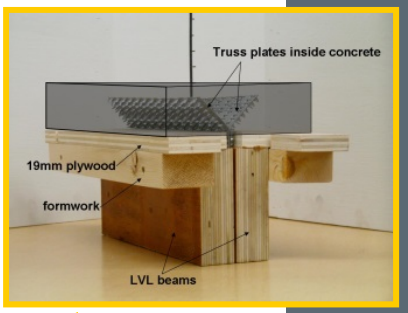




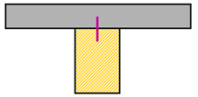




Load-slip results



Benefit of composite action

Wood	Wood-concrete composite	
		
→	Strength	Stiffness
	Increase up to **2** times	Increase up to **4** times

Earth Sciences Building, University of British Columbia

… the largest wood-concrete composite structure in North America

See more at:

http://www.perkinswill.com/node/1628

Photo credit : A. Schreyer

Go UMass !!!

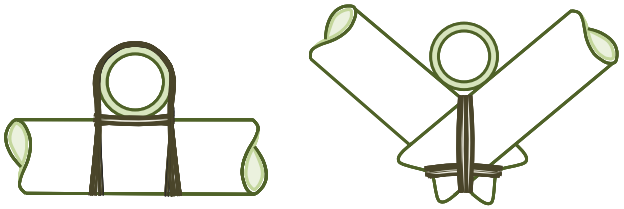
- New 2017 Integrated Design Building will be framed with CLT-concrete floors – the first of it's kind in the US!

UMass research on bio-based composites

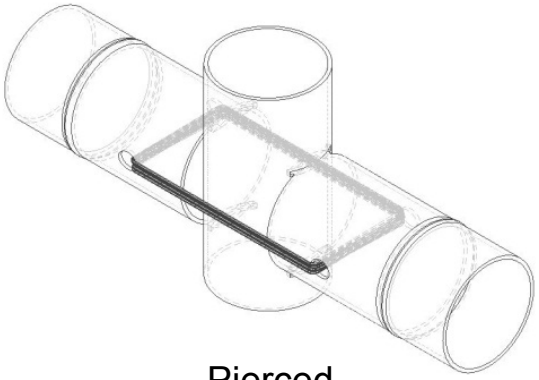
- Bamboo
  - Fastest growing plant currently known
  - 3-8 years to maturity for some species
  - Specific strength greater than steel or wood

Photo credit: Luke Chan (creative commons)

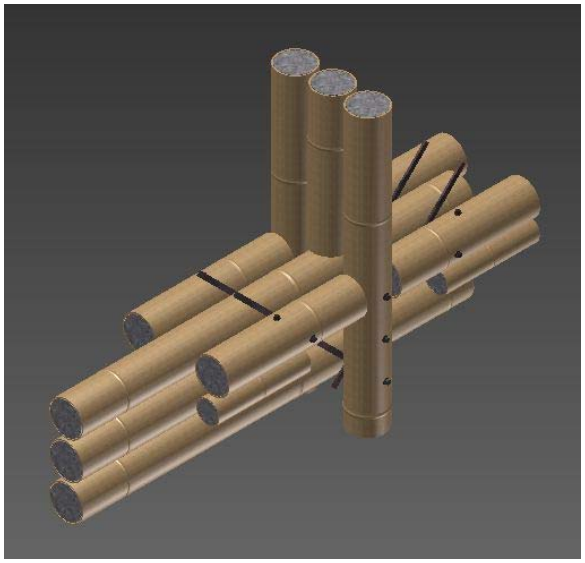
Bamboo connection study



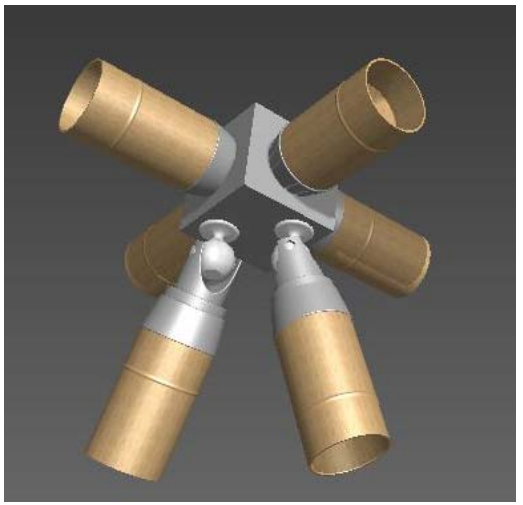
Traditional lashed



Pierced



Concrete/mortar injected



Guadua Tech Hub

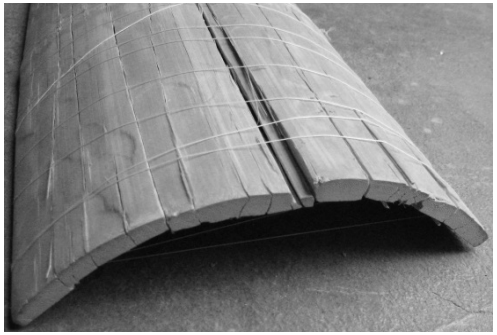
Disén, K. and Clouston P. 2014. “Building with Bamboo: a Review of Culm Connection Technology.” Journal of Green Building, 8(4), 83-93

German-Chinese house, Shanghai

Photos courtesy of MUDI architects, Shanghai

Concrete-filled bamboo culms with bolts and clamps

Laminated Bamboo Lumber study



Mahdavi, Clouston and Arwade (2011).
Journal of Materials in Civil Engineering, Vol. 23, No.7

Laminated Veneer Bamboo

Photo credit: Lamboo Inc.

Bamboo curtain wall system

Bio-based materials are the future

- Wood, hemp, flax, bamboo + biopolymers
- Building products, automotive, sports equipment
- Technological road map for U.S. DOE
  - 10% of all basic chemical building blocks will be renewable sources by 2020
  - **50% by 2050**

Laminated wood bike frame
Sylvan Cycles

"If the 19th century was the century of steel,
and the 20th century of concrete,
then the 21st century is about
engineered timber."

Alex de Ruke founder of dRMM Architects, London

More…

- http://www.rethinkwood.com/
- http://www.woodworks.org/
- http://bct.eco.umass.edu/
- http://biobasedbuilding.info/