Emerging Technologies in Wood and Bio-Based Building Products

by

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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

30 story high wood structure

Just completed

Wood Innovation and Design Centre, Prince George, BC

Image credit: McFarlane Biggar Architects
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

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
“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
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:


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’
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
UMass research on PSL

Close up view of PSL

Parallel Strand Lumber, PSL

\([\pm \theta^\circ]_s \text{ Angle-ply Laminate}\)
Numerical simulation of strength

COMAP© – P. Clouston, 2004
Mesostructural characterization

PSL void mesostructures
Experimental evaluation

Modeling the Design Limit States of Structural Composite Lumber.
NSF Grant No. 0826265 (Clouston & Arwade)
Cross-laminated timber (CLT)
- 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
Stadthaus, London
9 story CLT structure

• Built in 9 weeks by four workers!

Image source: KLH LTD
Forte, Melbourne
10 story CLT structure - the tallest in the world

- Built in 10 weeks by five workers!
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

- **APA Product Reports® – APA**
- **CLT Handbook (www.masstimber.com)**
- **Case studies and design examples:**
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

- *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

Emerging technologies
Wood-concrete composite

Hybrid composite construction method

Reinforcement as required

Reinforced Concrete Slab

Slots cut into wood to develop longitudinal shear

Wood Beams (Timber, Glulam)

Used since 1930s in timber bridges

Photo: A. Schreyer
Composite action

- Partial composite action \(\rightarrow\) depends on fastener
- Analysis: Eurocode 5
Commercial shear connectors

Bertsche connector

SFS Intec VB Screws

HBV system

Photo credit: SFS Intec

Image: Bertsche System, GmbH

Photo credit: A. Schreyer
UMass WCC research
Load-slip results
Benefit of composite action

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<tr>
<th>Wood</th>
<th>Wood-concrete composite</th>
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<th>Strength</th>
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<td>Increase up to</td>
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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
Go UMass !!!

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

View from North Pleasant Street

Image credit: Leers Weinzapfel Associates
Bamboo

- Fastest growing plant currently known
  - 3-8 years to maturity for some species

- Specific strength greater than steel or wood

UMass research on bio-based composites

Photo credit: Luke Chan (creative commons)
Bamboo connection study

Traditional lashed

Concrete/mortar injected

Pierced

Guadua Tech Hub

German-Chinese house, Shanghai

Concrete-filled bamboo culms with bolts and clamps

Photos courtesy of MUDI architects, Shanghai
Laminated Bamboo Lumber study

Laminated Veneer Bamboo

Photo credit: Lamboo Inc.
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/