Mass Timber

Will it change the way we build?
How will it change the way we build?
Headlines and Hypes

Michael Green: Why we should build wooden skyscrapers
TED2013 - 12:22 - Filmed Feb 2013
21 subtitle languages View interactive transcript

Is the age of mass timber construction really coming?

21-story HAUT building in Amsterdam, to be built

80-story wood skyscraper concept design in London, from Cambridge and PLP
What is this about?

How did we get here?

What does this mean for research and engineering practice?
There is Nothing New under the Sun.

-- Ecclesiastes 1:9

Wood has been a primary building material for centuries around the world.

Tall wood buildings are not new either.

Heddal Stave Church in Norway, built in 13th century

Hōryū-ji in Nara Japan, built around 700 AD (1400 years ago)
Old Tall Wooden Structures

• Pegoda of Fogong Temple in Shanxi, China
  • Built in 1056 AD (940 years old)
  • 220 ft tall (a 20-story modern building height)

US can do it too! Tillamook Air Museum: WWII, 192 ft tall
Buildings Markets Today

• Building market has changed
Wood Building Materials Today

- Glulam and composite lumber
- Joists
- Dimension Lumber
- Plywood and OSB panels
Typical Wood Building Today

• Concrete foundation
• Wood Joist to support floor
• Dimension lumber framed walls
• OSB/Plywood to cover walls and floors
• Up to 4~5 stories allowed
• All these are wood buildings covered with non-structural siding
• Although does not look like wood from outside

• Any modern buildings under 6 story in the U.S. are likely light framed wood building
Pros and Cons of Traditional Wood Buildings

**Cons**
- Lower quality control
- Weak
- Can burn

**Pros**
- Flexible
- Lightweight
- Low cost
Vulnerability against Natural Hazards
Limitation in Building Codes

• Per IBC, if not TYPE 1 construction (3 or 2 hr fire rating for most of the building components), cannot go over 5 stories!
Research to improve wood building

• Major efforts on addressing strength and design methodology

- Northridge Earthquake (1994)
- Understanding existing wood performance (1995-2005 approx.)
- CUREE Caltech Woodframe Project
- NEESWood (2005-2009)
- PBSD the tallest wood building that is practical
- Strengthen existing buildings
  - NEES-Soft
  - PBD for wind and rain damage
  - Other efforts
- Post 2010
Where we are now without mass timber

• Light-frame wood construction dominates low-rise market up to 6 stories
• **PBSD** to make the system strong (Both new and existing)
• Material is still weak
• Fire not addressed
• Quality/human error issue not addressed

Best we can do so far with wood (by 2010)
Here comes the disruptor!
Mass Timber Construction

Cross Laminated Timber is the key
How is Mass Timber a Game Changer?

• It opened new ways for wood construction by addressing:
High Precision Manufacturing + Installation

- CNC machined panels and joints

Accurate installation: Like steel construction
A Stronger Material

Connection

VS

Elements

[Images of construction materials and techniques]
Enough Trees for it?

Sustainable Forestry Management
Fire Resistance
2015 American Wood Council Fire Test

- Compartment fire test with gravity load
- Realistic fire load
- CLT with Gypsum board finish
Removing Drywall after fire
Other Benefits

- The first real building component actually behaves close to isotropic plates
- Light weight: About 1/5 of Concrete
- Easy to work with
- **Wood is Beautiful** and Sustainable
Apply to Tall Buildings:
A New Way to Build in 100 Years

Home Insurance Building, Chicago 1884. 10 Story, 138 ft
Ingalls Building, Cincinnati 1903. 16 story, 210 ft
Forte Building, Melbourne 2012. 10 story, 106 ft
Stadthaus building

- One of the few earlier CLT tall buildings
- Eight story CLT on one story concrete
- In London, UK
- CLT from Kreuz Lagen Holz (KLH), UK
- Gravity design to prevent progressive collapse

Stadthaus

- 9 Stories
- $6 million project cost
- Panel assembly: 4 carpenters in 27 days
- Full Construction: 49 weeks
- Pilot scheme for National House Building Council in UK
Wood Innovation and Design Center, Canada

- University of Northern British Columbia
- Eight-story 96 feet tall
- By Michael Green Architecture
- Combine CLT with Heavy Timber
- $25 million
1. Laminated veneer lumber mullion
2. Glulam column, 12” × 11½”
3. Carpet
4. ¼” acoustical underlayment
5. 99mm three-layer CLT panel
6. 13mm plywood (two-ply)
7. 99mm three-layer CLT panel
8. 169mm five-layer CLT panel
9. 25mm semi-rigid glass-fiber insulation board (two-ply)
10. Glulam beam, dimensions vary
Brocks Common @ UBC

- 18-story student dorm
- Tallest wood building in the world, for now
- Students moving in next Fall
Carbon 12

• Portland OR, 8 story residential
• Currently under construction, will finish Summer 2017
The Framework Project

- 12-story mixed use building in Portland OR.
- Using Post-tensioned Rocking Wall lateral system
Platte 15

• 5-story commercial
• In Denver near Pepsi Center
• Designed by a company in Golden CO
• Will start construction 2017
And More...

KEEP CALM
THERE'S MORE TO COME
### Fire Performance of Wood Structural Systems

**Session ID:** 16  
**Moderator:** Samuel Zelinka  
**Track:** [Wood and Timber/ Building Case Studies](#)  
**Date:** Thursday, April 6, 2017  
**Time:** 11:00 AM - 12:30 PM

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### Case-Studies: Recent Mass timber Building Projects in North America

**Session ID:** 3  
**Moderator:** Shiling Pei, Ph.D., P.E., Hans-Erik Blomgren P.E.,  
**Track:** [Wood and Timber/ Building Case Studies](#)  
**Date:** Thursday, April 6, 2017  
**Time:** 9:30 AM - 10:30 AM  
**Sponsoring Committee:** Wood Committee  
**Description:**

Structural design, approval and monitoring of UBC Tall Wood Building  
[View Abstract](#)  
Thomas Tannert, PhD, University of Northern British Columbia; Manu Moudgil, BSc, The University of British Columbia

**Integrated Design Building at UMASS Amherst: A large scale CLT building case study**  
[View Abstract](#)  
Jeff Langlois, P.E., Simpson Gumpertz and Heger, Inc.; Gregg Cohen, P.E., Simpson Gumpertz and Heger, Inc.

**THE FRAMEWORK PROJECT - PRACTICAL APPLICATION OF TALL RE-CENTERING MASS TIMBER WALLS IN THE UNITED STATES**  
[View Abstract](#)  
Eric McDonnell, PE, KPFF; Reid Zimmerman, PE, KPFF

**Building Taller with Heavy Timber: 4 Structural Case Studies**  
[View Abstract](#)  
Doug Steimle, P.E., Schaefer

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### Progress in Innovative Mass Timber and Timber Hybrid Structural Systems

**Session ID:** 25  
**Moderator:** Thomas Tannert, A.M.ASCE  
**Track:** [Research](#)  
**Date:** Thursday, April 6, 2017  
**Time:** 3:30 PM - 5:00 PM
Research Challenges for Mass Timber

- Durability and moisture
- Fire design and performance
- Tall building lateral performance
Understanding Mass-Timber Moisture in Realistic Building Configurations

Mass-Timber Moisture Monitoring Project

(Project period 2016~2019)

- A project recently funded by the U.S. Forest Service will conduct detailed building components moisture monitoring for three (3) mass-timber building projects in different climate zones of the U.S.
- The project is aiming at obtaining a benchmark moisture content data set for large scale mass-timber buildings in the U.S.

Construction to In-service Cycle Monitoring

Sensor will be installed as soon as CLT panel leave factory, and continue for years into service.

The data will tell us how wet mass-timber structures will be and how does moisture transfer across building envelope.
NEES-CLT Planning Project (2013~2015)

- Objective: Conduct technical preparation for enabling design and testing of 8-20 story resilient CLT buildings
- Website: NEESCLT.mines.edu

Shiling Pei
Dan Dolan
James Ricles
Richard Sauce
Jeffrey Berman
John van de Lindt
Marjan Popovski
Michael Willford
Hans-Erik Blomgren
Douglas Rammer
A Brief History of CLT Seismic Research

- CLT Invented in early 1990’s
- Research in Slovenia and Macedonia
- Wall tests, Shake table test of wall assembly
- Trento Province, Italy, SOFIE project
- Wall tests, Shake table tests at NIED 3-story, 7-story
- Canada/US Research on CLT, FPInnovations, Forest Products Lab
- Over strength factor, Numerical modeling methods, q factor
- Estimation of R factor for NBCC and ASCE7
- P695 on CLT shear wall
- Seismic Retrofit (NEESSoft)
- NEES CLT Planning
- Resilient Timber systems in NZ
- NHERI TallWood
- Tall buildings
- Resilient CLT systems
- CLT Building tests in Japan 3-5 story
- CLT Handbook
Performance Expectations

- Not necessarily the higher the better. **Balance of performance and cost**
- A three-tiered performance expectations for tall CLT buildings

<table>
<thead>
<tr>
<th>Seismic Hazard Levels (POE)</th>
<th>System performance</th>
<th>Structural components</th>
<th>Non-structural components</th>
<th>Estimated Repair Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tier 1: Code Minimum (Optimizing)</strong></td>
<td>Service Level Earthquake (50% in 30 yrs.)</td>
<td>Immediate Occupancy</td>
<td>Remain Elastic</td>
<td>Minor damage, repairable</td>
</tr>
<tr>
<td><strong>Tier 2: Code Plus (Innovative detailing or advanced protection systems, PBSD)</strong></td>
<td>Service Level Earthquake (50% in 30 yrs.)</td>
<td>Immediate Occupancy</td>
<td>Elastic</td>
<td>Minor damage, repairable</td>
</tr>
<tr>
<td><strong>Tier 3: Resilience (Resilient structural systems implemented, PBSD)</strong></td>
<td>Service Level Earthquake (50% in 30 yrs.)</td>
<td>Planned Damage</td>
<td>Resilient system repair needed at planned locations</td>
<td>Moderate damage</td>
</tr>
<tr>
<td></td>
<td>Design Basis Earthquake (10% in 50 yrs.)</td>
<td>Immediate Occupancy</td>
<td>Resilient system operational</td>
<td>Minor contents damage</td>
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<tr>
<td></td>
<td>Maximum Considered Earthquake (2% in 50 yrs.)</td>
<td>Planned Damage</td>
<td>Resilient system repair needed at planned locations</td>
<td>Moderate damage</td>
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<tr>
<td></td>
<td>Near Fault Ground Motions</td>
<td>Limited Damage Probability of Collapse negligible</td>
<td>Damage extended to unplanned locations, repair may be costly</td>
<td>Moderate damage</td>
</tr>
</tbody>
</table>
Try Two Resilient Systems

- Adding ductility and energy dissipation
- Remain damage free at large deformation
Rocking Wall Concept

• Prestressed timber system pioneered in New Zealand (Buchanan et al.), including prestressed LVL walls.
• Rocking wall/frame system had success in steel and concrete.
• A self-centering system with large drift capacity
Test Setup
Specimen 3 - High $V_{dec}$ and Low $K_{dec}$

PT bar yielded at 4.8% drift

CLT damage at 9.5% drift
Outcome of the Planning Project

- Framework is using Rocking walls

<table>
<thead>
<tr>
<th>TEAM</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Owner:</td>
<td>The Framework Project, LLC</td>
</tr>
<tr>
<td>Land Owner:</td>
<td>Beneficial State Bancorp</td>
</tr>
<tr>
<td>Development Team:</td>
<td>project^</td>
</tr>
<tr>
<td>Architect:</td>
<td>LEVER Architecture</td>
</tr>
<tr>
<td>Structural Engineer:</td>
<td>KPFF Consulting Engineers</td>
</tr>
<tr>
<td>M/E/P:</td>
<td>PAE Consulting Engineers</td>
</tr>
<tr>
<td>Affordable Housing/Investor:</td>
<td>Home Forward</td>
</tr>
<tr>
<td>Fire and Timber Engineer:</td>
<td>Arup</td>
</tr>
<tr>
<td>General Contractor:</td>
<td>Walsh Construction</td>
</tr>
</tbody>
</table>

- Phase II funding obtained from NSF
Phase II: NHERI TallWood Project (2016~2020)

- Objective: Develop and validate Resilience-based seismic design for tall CLT buildings
- Website: Coming soon....
Full Scale Shake Table Testing of A Ten-story CLT Building to Validate Resilient Seismic Design Methodology

Components testing at NHERI@Lehigh Structural Lab (expected 2017)

Archetype Meeting at Portland OR 11/2016

Full-scale 10-story building test at NHERI@UCSD shake table (expected 2019~2020)

- Both individual and coupled rocking walls included
- Intentional un-symmetric design to induce torsion
- Include two configurations: Monolithic and Segmental
Seeking Funding for Fire Test

• Collaboration with FPL, UCSD and WPI.

Multi-scale Testing Program

Material
Facility: FPL
New Knowledge:
Char rate, Adhesive effects, etc.

Connections
Facility: FPL
New Knowledge:
Fire-induced structural degradation

Compartments
Facility: WPI + NFRL
New Knowledge:
Post-earthquake commercial compartment performance, wood exposure impact.

Full scale building test
Facility: UCSD
New Knowledge:
System level tall wood building fire performance, Vertical fire spread, building envelope and exterior fire performance.

Unique data set from the world’s largest wood building fire test.
For Pay-load projects/proposals if there is a suitable idea