Mass Timber

~~Will it change the way we build?~~

How will it change the way we build?

Headlines and Hypes

Is the age of mass timber construction really coming?

Science
Would you live in a wooden skyscraper?
By Warren Cornwall | Sep. 22, 2016 , 9:00 AM

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.

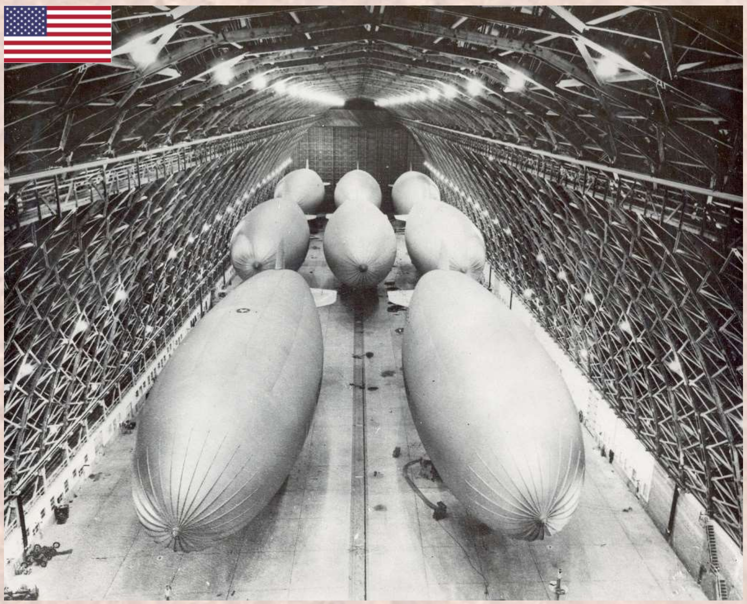
Heddal Stave Church in Norway, built in 13th century

Tall wood buildings are not new either.

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

Old Tall Wooden Structures

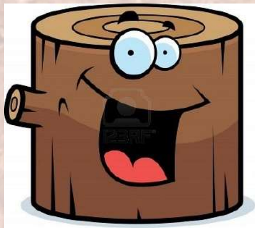
- Pegoda of Fogong Temple in Shanxi, China
  - Built in 1056 AD (940 years old)
  - 220 ft tall (a 20-story modern building height)

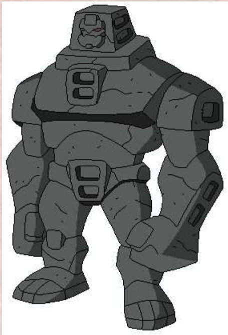


US can do it too! Tillamook Air Museum: WWII, 192 ft tall

Buildings Markets Today

- Building market has changed

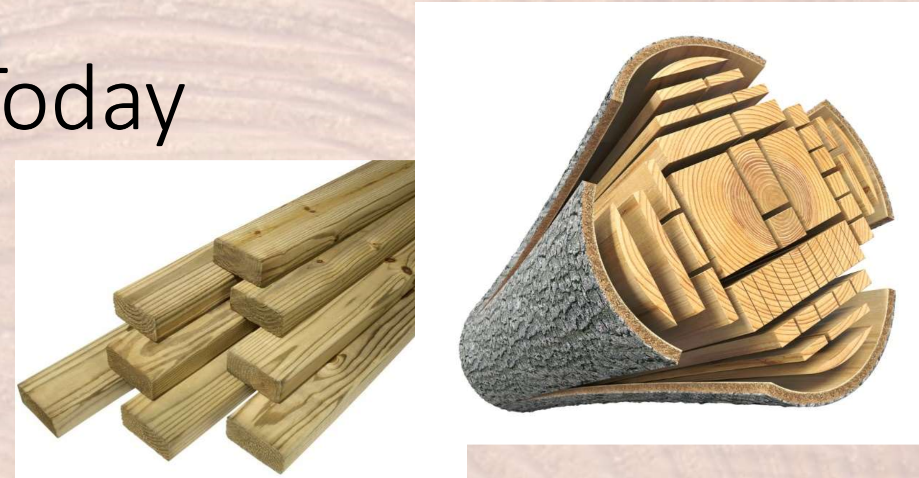




Wood Building Materials Today

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

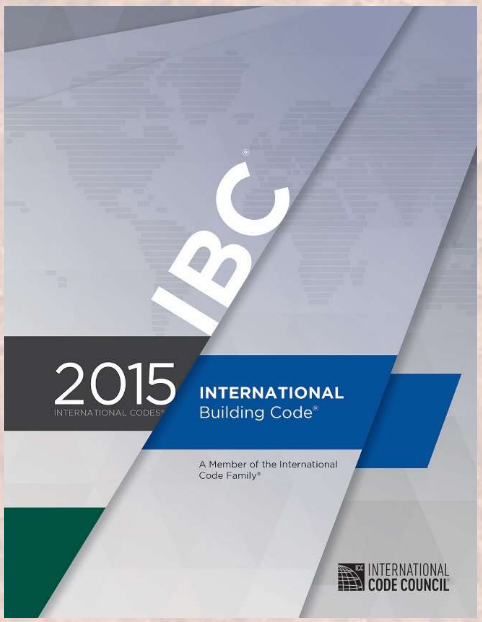
Pros

Flexible

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!



Not Possible
(Economical)

Research to improve wood building

- Major efforts on addressing strength and design methodology

Northridge Earthquake
1994

→

Understanding existing wood performance

CUREE Caltech Woodframe Project
1995-2005 (approx.)

→

PBSD the tallest wood building that is practical

NEESWood
2005-2009

→

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

Concept

CLT Panel

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

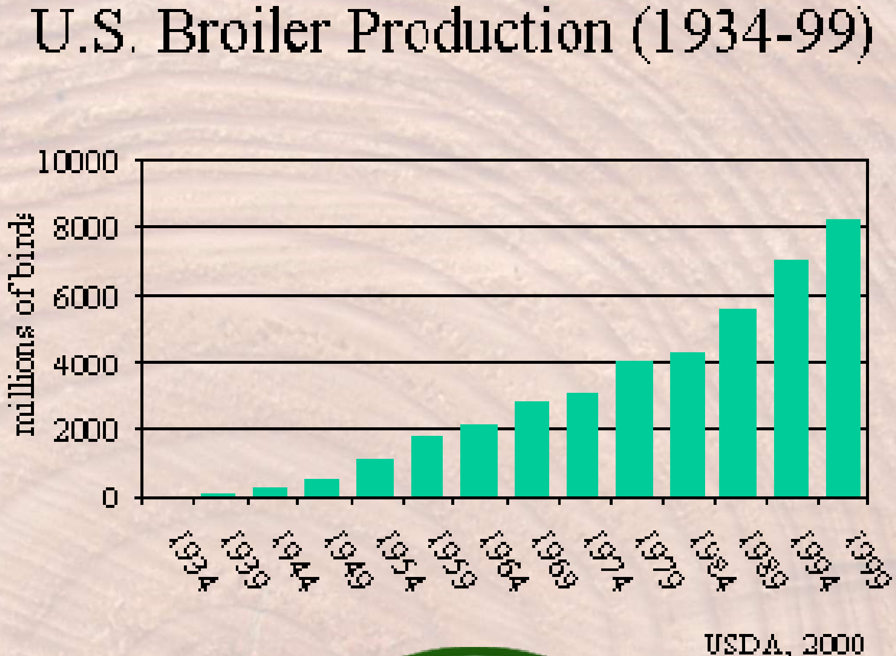
VS

Elements

Enough Trees for it?

Sustainable Forestry Management


EAT
MOR
CHIKIN


U.S. Broiler Production (1934-99)
millions of birds
10000
8000
6000
4000
2000
0
1934
1939
1944
1949
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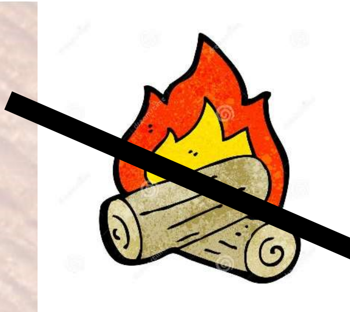
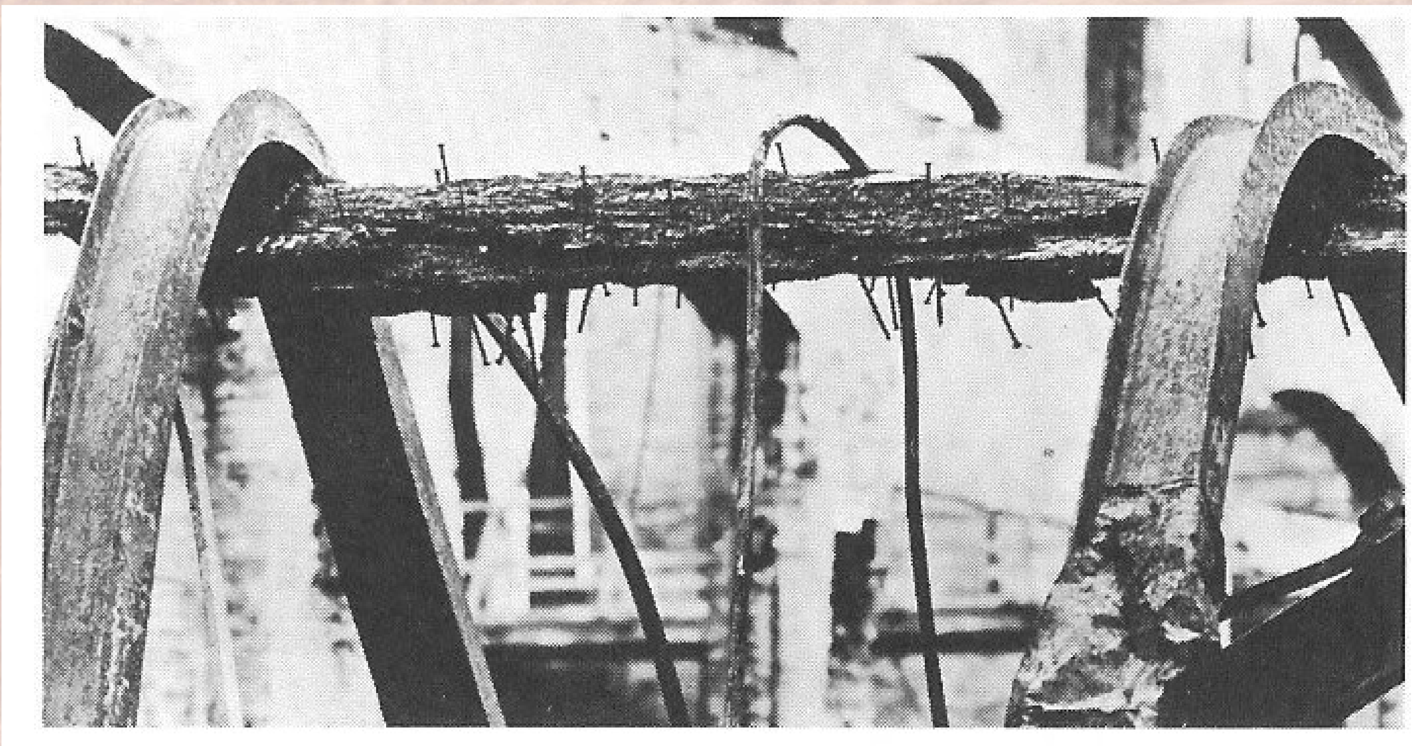
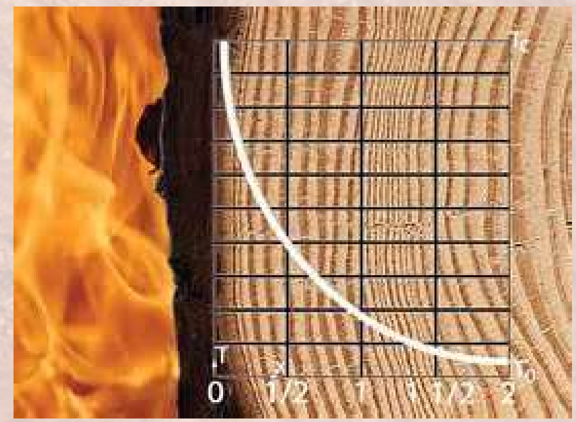
1959
1964
1969
1974
1979
1984
1989
1994
1999
USDA, 2000

Fire Resistance







2015 American Wood Council Fire Test

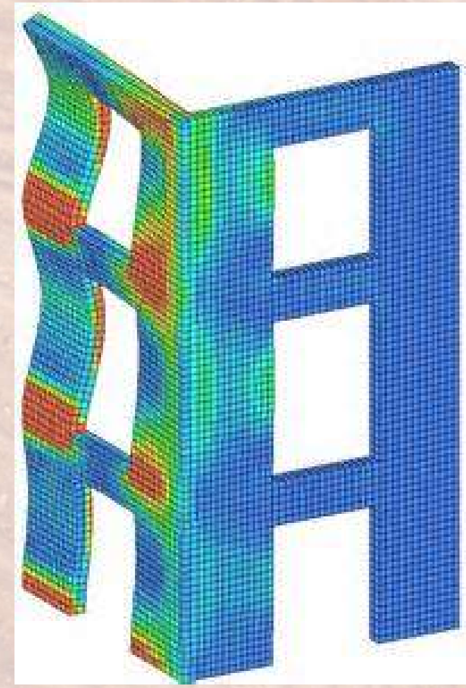
- Compartment fire test with gravity load
- Realistic fire load
- CLT with Gypsum board finish

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
- <u>Wood is Beautiful</u>

  <u>and Sustainable</u>



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

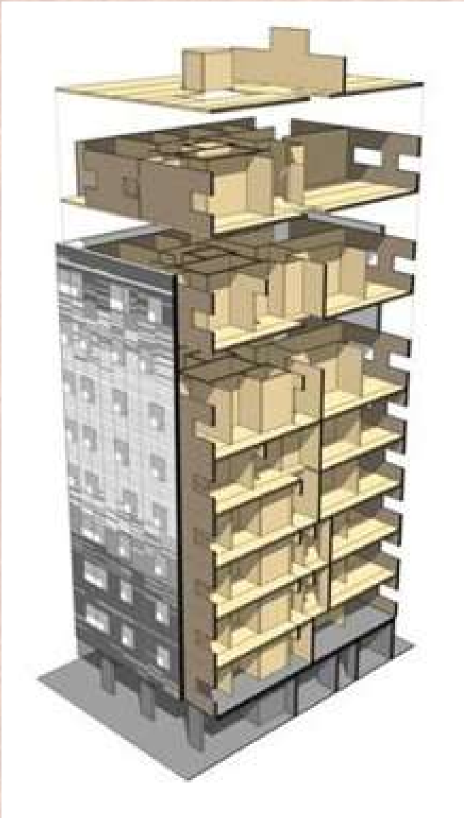
Forte Building, Melbourne 2012.
10 story, 106 ft

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**

http://www.ecoerth.com/wp-content/uploads/2010/09/stadthaus.jpg

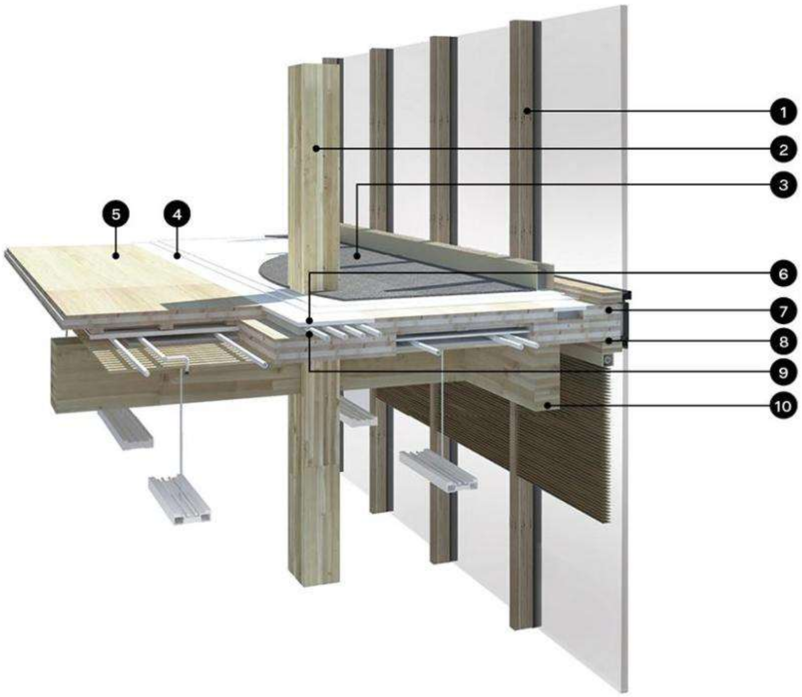
Stadthaus



- 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

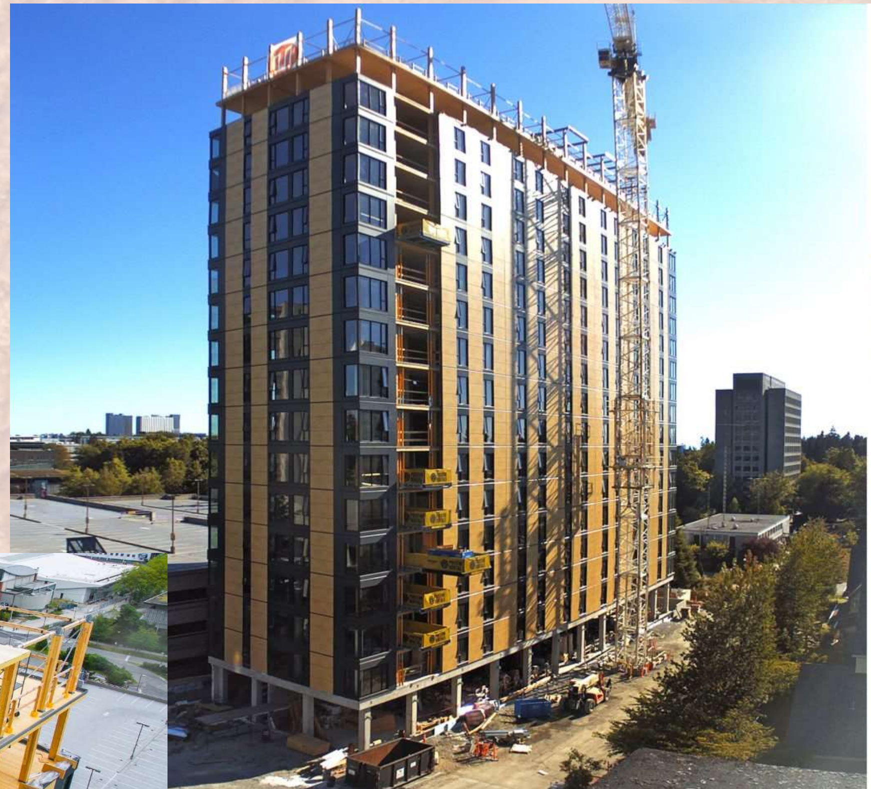
- University of Northern British Columbia
- Eight-story 96 feet tall
- By Michael Green Architecture
- Combine CLT with Heavy Timber
- $25 million

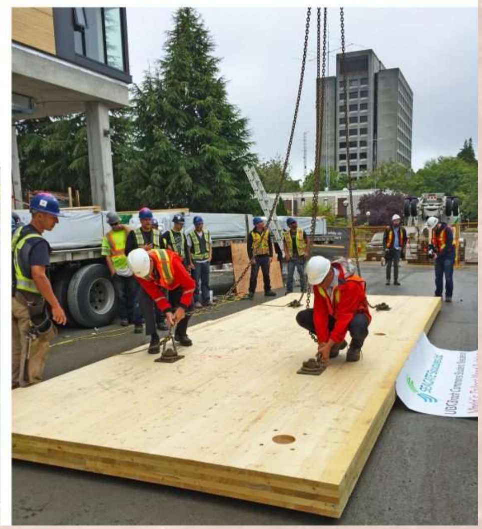


1. Laminated veneer lumber mullion
2. Glulam column, 12" × 11½"
3. Carpet
4. ¼" acoustical underlayment
5. 99mm three-layer CLT panel
6. 13mm plywood (two-ply)
7. 99mm three-layer CLT panel
8. 169mm five-layer CLT panel
9. 25mm semi-rigid glass-fiber insulation board (two-ply)
10. Glulam beam, dimensions 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…

Structures Congress 2017

Case-Studies: Recent Mass timber Building Projects in North American

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., Simposn 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

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

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

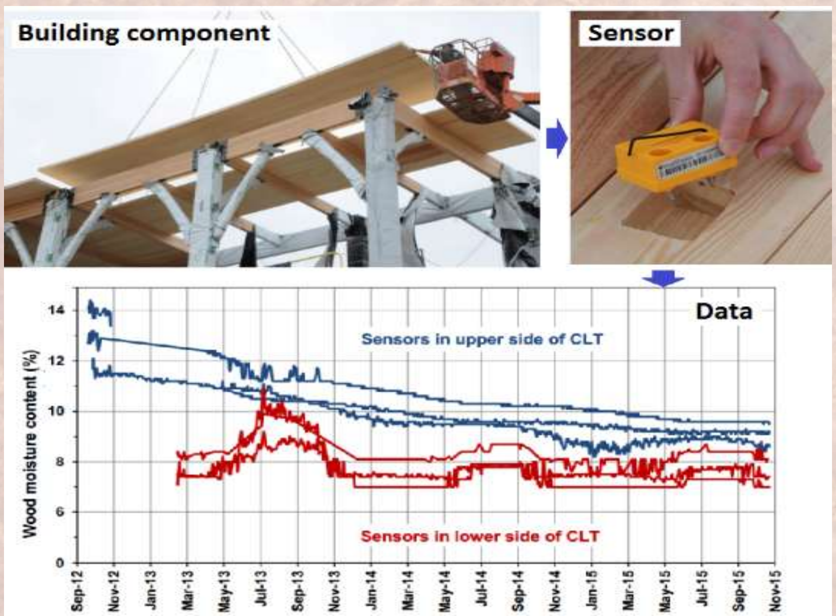
Tall building lateral performance

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.

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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

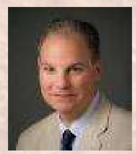
Shiling Pei

COLORADO SCHOOL OF MINES

Dan Dolan

WASHINGTON STATE UNIVERSITY

James Ricles



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Jeffrey Berman

UNIVERSITY of WASHINGTON

John van de Lindt

Colorado State

Marjan Popovski

FPInnovations

Michael Willford

Hans-Erik Blomgren

ARUP

Douglas Rammer

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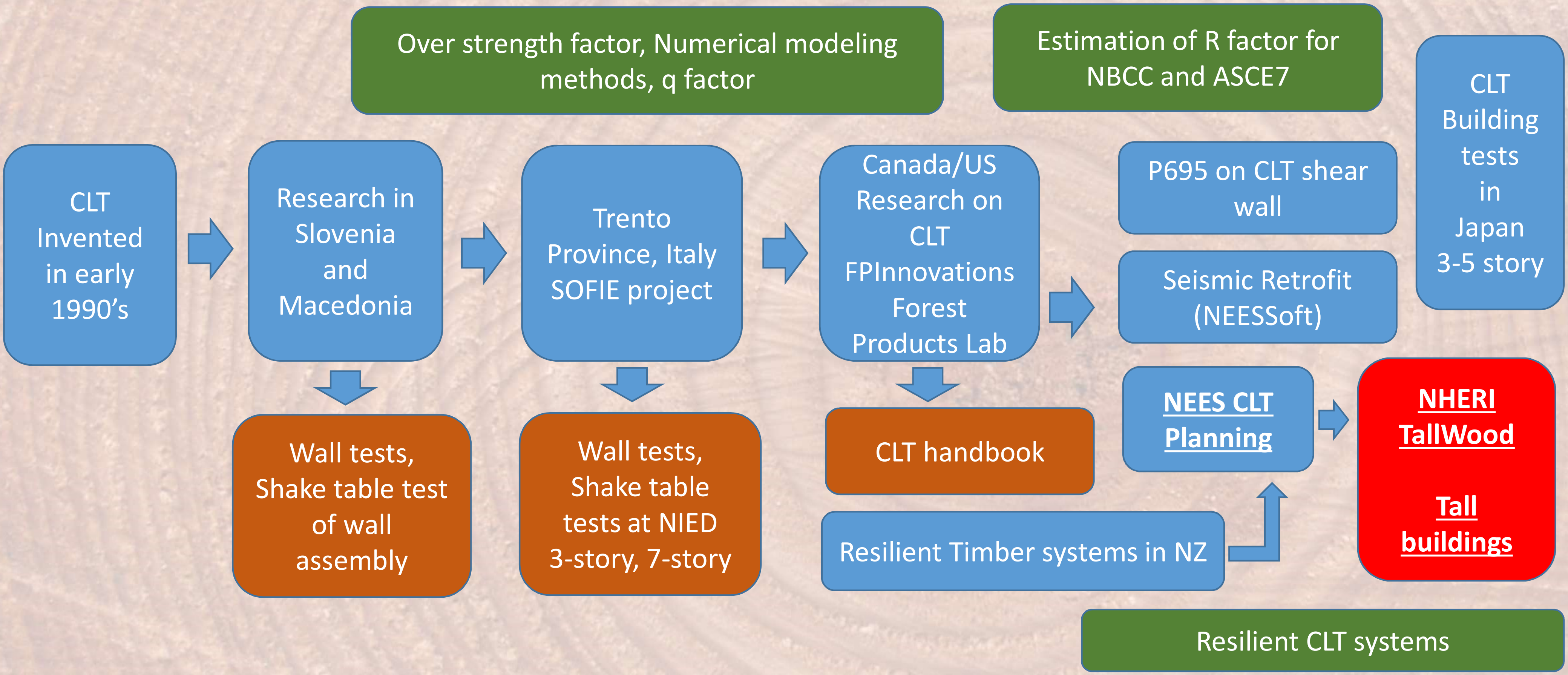
A Brief History of CLT Seismic Research



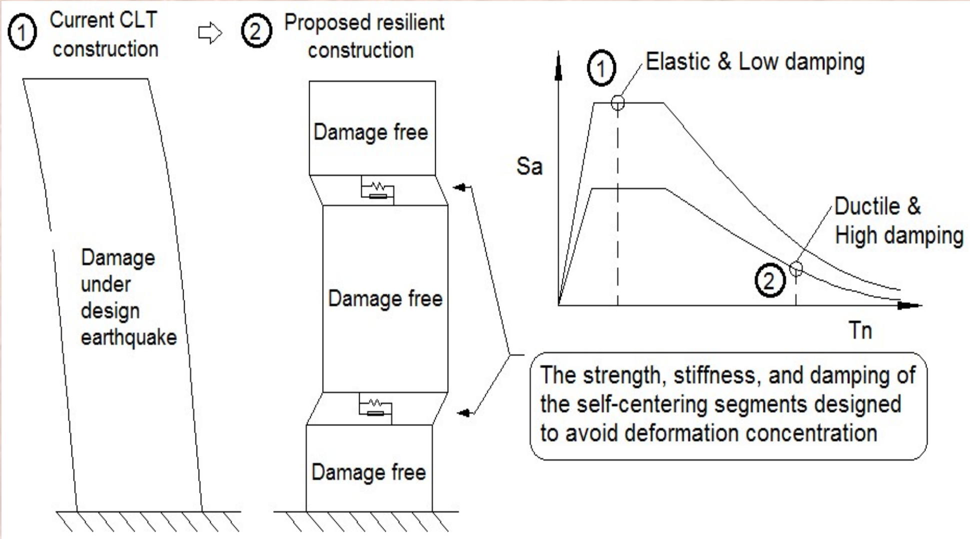
Performance Expectations

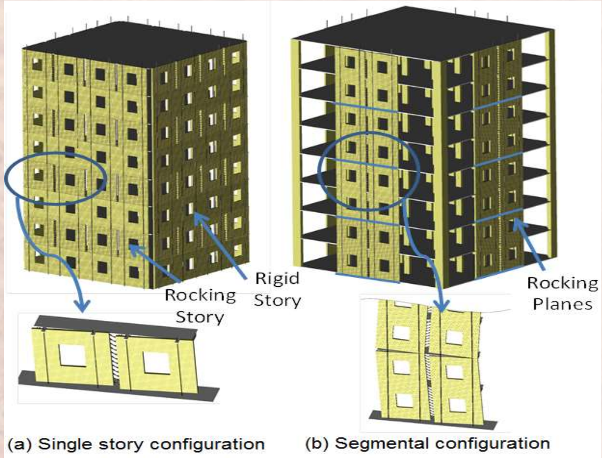
- Not necessarily the higher the better. Balance of performance and cost
- A three-tiered performance expectations for tall CLT buildings

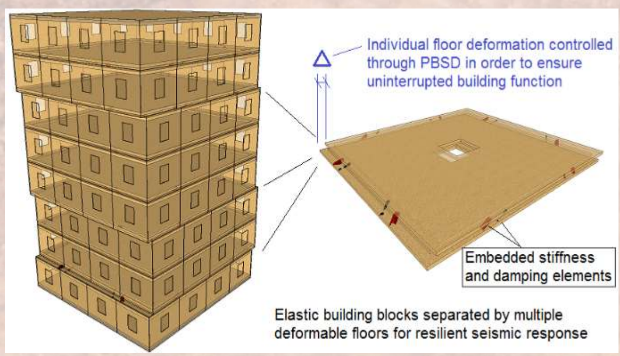
Seismic Hazard Levels (POE[1])	System performance	Structural components	Non-structural components	Estimated Repair Time[4]
Tier 1: Code Minimum (Optimizing current system and detailing, force-based design)				
Service Level	Immediate Occupancy:	Remain Elastic	Minor damage,	1~7 days
Tier 2: Code Plus (Innovative detailing or advanced protection systems, PBSD)				
Service Level Earthquake	Immediate Occupancy	Elastic	Minor damage, repairable	1~7 days
Tier 3: Resilience (Resilient structural systems implemented, PBSD)				
Service Level Earthquake (50% in 30 yrs.)	Continuous Operation	Elastic/Resilient system operational	No damage	0~30 min
Design Basis Earthquake (10% in 50 yrs.)	Immediate Occupancy	Resilient system operational	Minor contents damage	1~7 days
Maximum Considered Earthquake (2% in 50 yrs.)	Planned Damage[3]	Resilient system repair needed at planned locations	Moderate damage	1~2 months
Near Fault Ground Motions	Limited Damage Probability of Collapse negligible	Damage extended to unplanned locations, repair may be costly	Moderate damage	2~6 months

Try Two Resilient Systems

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

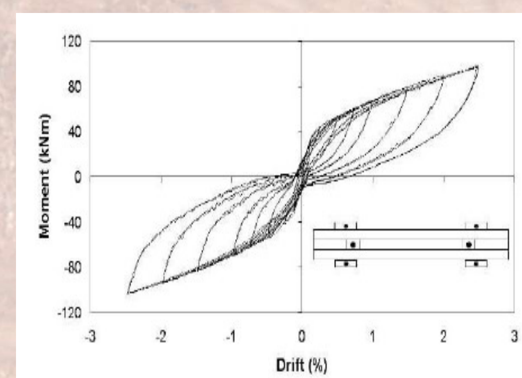






Rocking Wall Concept

- 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



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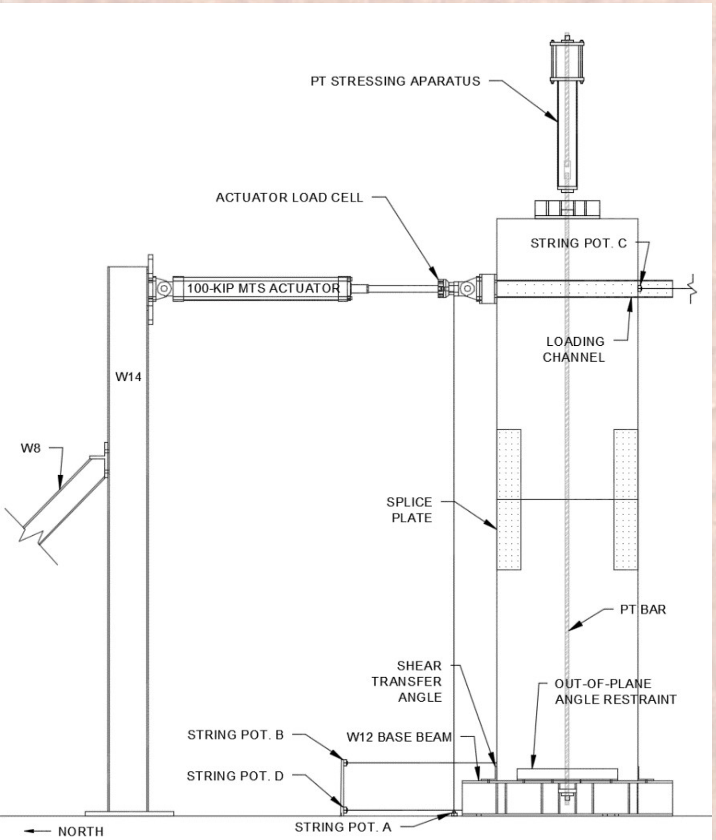
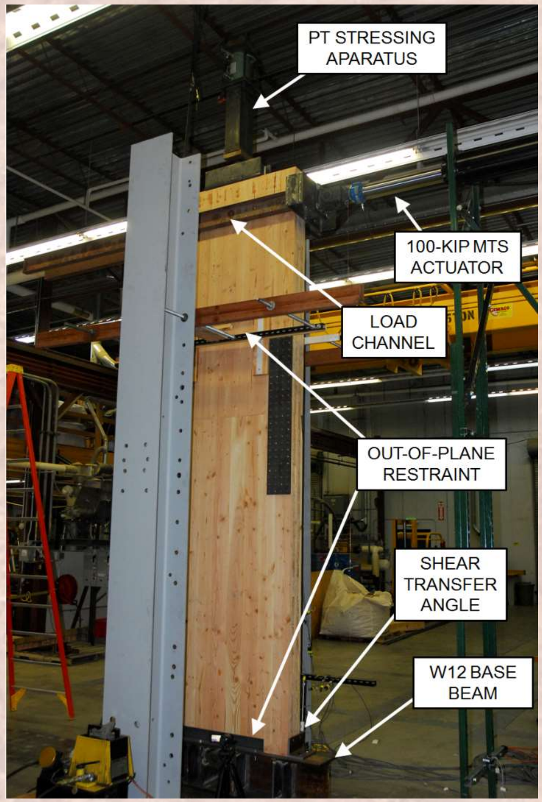
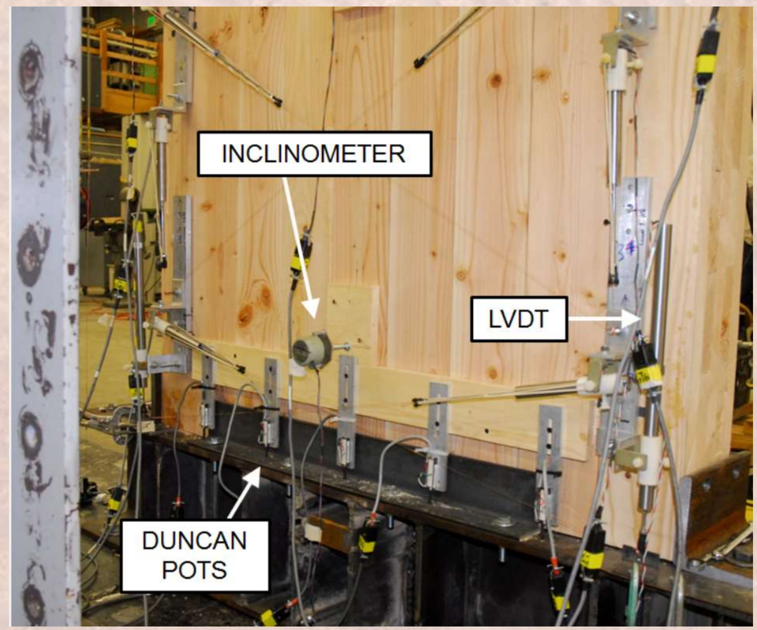
Test Setup







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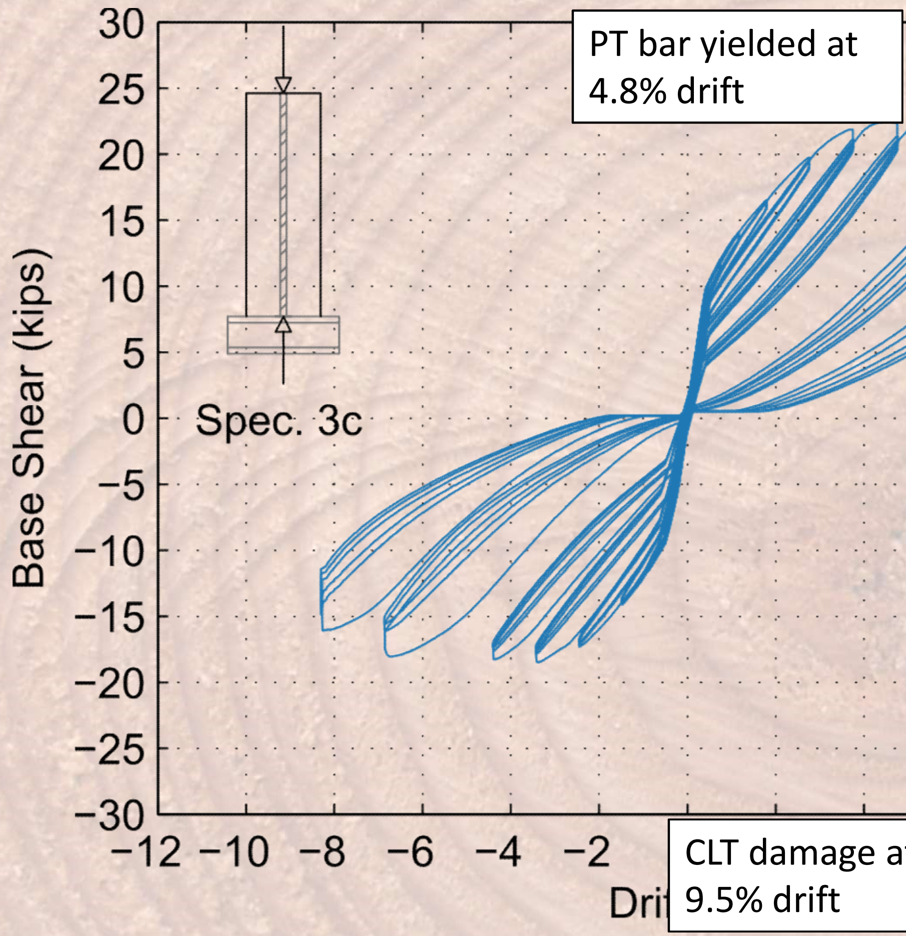
Specimen 3 - High V_{dec} and Low K_{dec}



PT bar yielded at 4.8% drift

CLT damage at 9.5% drift

Outcome of the Planning Project

- Framework is using Rocking walls

TEAM

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

- 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….

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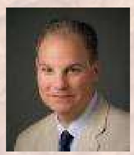

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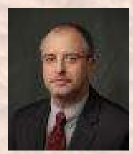

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kpff

Andy Buchanan

PTL

Douglas Rammer

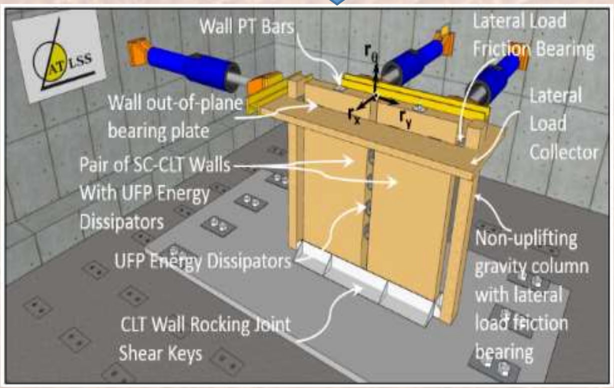
FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

NHERI TallWood

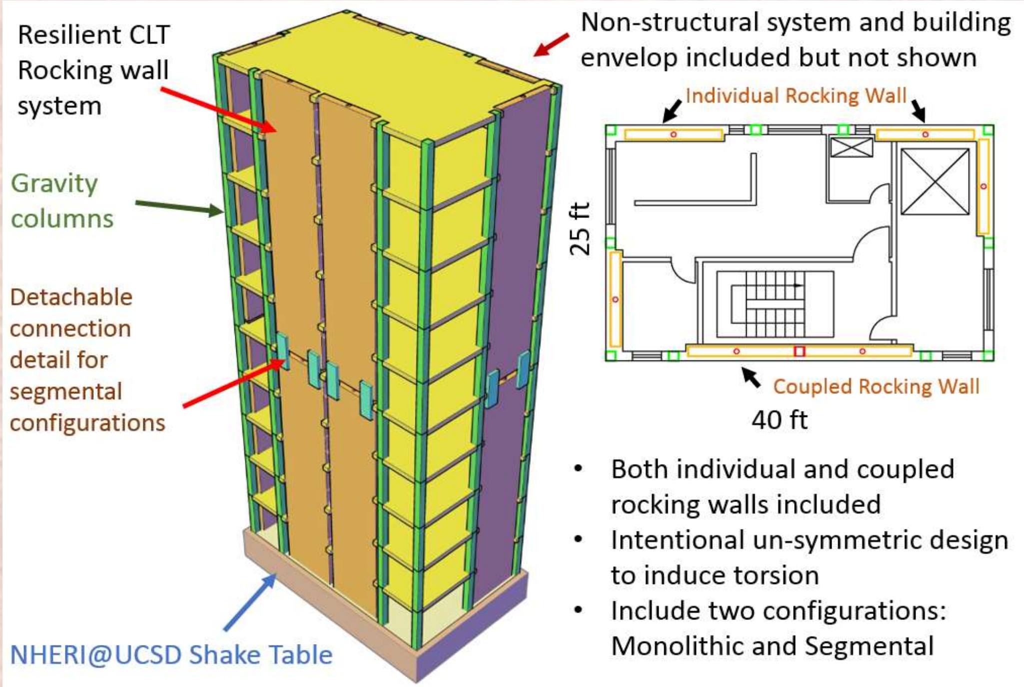
NHERI

Full Scale Shake Table Testing of A Ten-story CLT Building to Validate Resilient Seismic Design Methodology

Archetype Meeting at Portland OR 11/2016



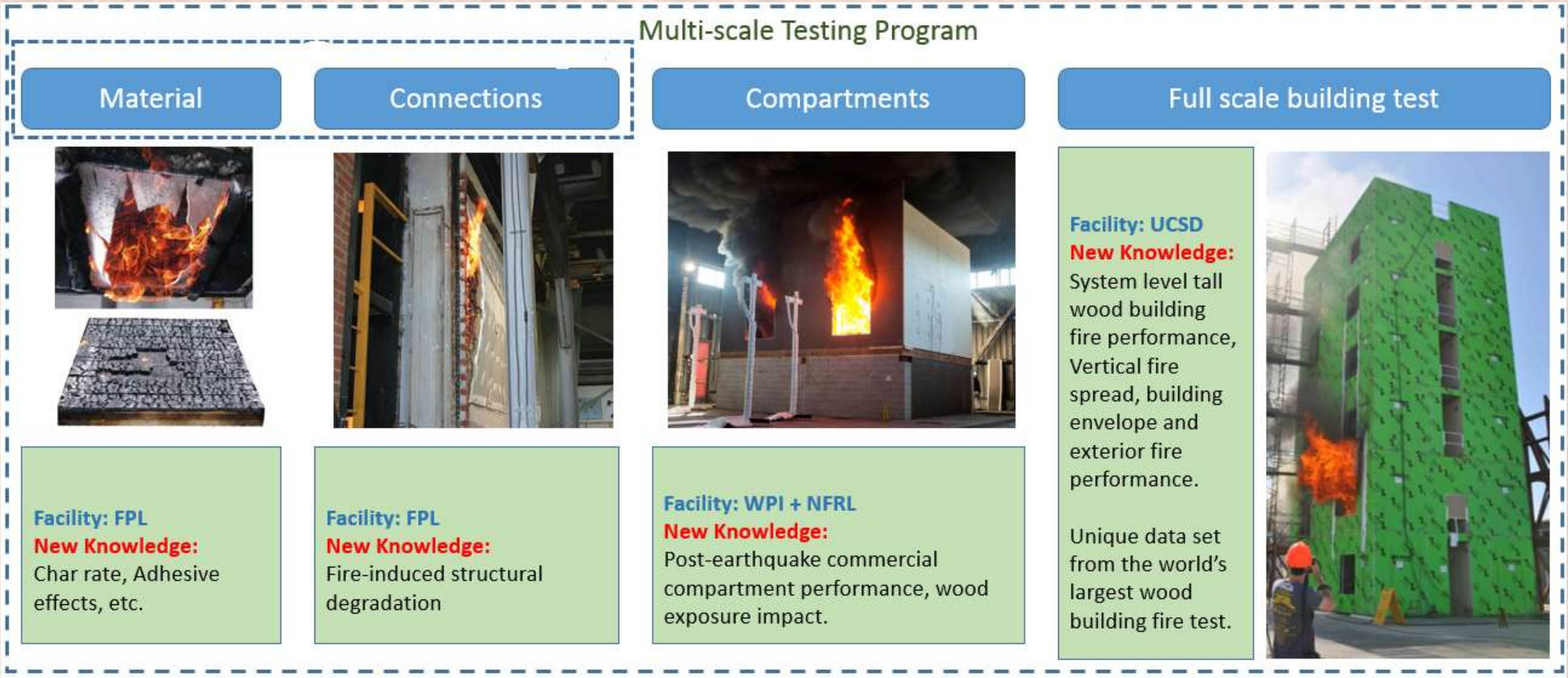
Components testing at NHERI@Lehigh Structural Lab (expected 2017)



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

Seeking Funding for Fire Test

- Collaboration with FPL, UCSD and WPI.



You're Invited

For Pay-load projects/proposals if there is a suitable idea