FULL-SCALE SHAKE TABLE TESTING
OF A TWO-STORY MASS-TIMBER
ROCKING WALL BUILDING

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What is CLT?

How about build with a ton of wood?

Like a solid wood house?

CLT was invented in the 1990’s in Europe, remained quite for a while, then ignited Global Mass Timber movement around 2010
In two ways:

- **Post+Beam+CLT**
  - Allows open floor plan and mixed use configuration
  - Lateral system typically separate from gravity system
  - 18-story Brock Commons at UBC

- **All CLT Platform Construction**
  - CLT load bearing walls and shear walls
  - Suitable for residential
  - 10-story Forte building in Melbourne AU
SEISMIC: TWO MAJOR EFFORTS

CODE COMPLIANT

House doesn’t collapse...

RESILIENCE

No repair needed... Even Better!

KEEP CALM AND GO BACK TO SLEEP
Objective: Develop and validate Resilience-based seismic design for tall CLT buildings

- Consensus on tall wood building
- Rocking wall component tested

Planning Project 2013~2015 (NSF)

FPL Mass-Timber Research Workshop 2015

NHERI TallWood Project Funded 2016 (NSF)
GAME PLAN

Project duration: 2016~2020

Define Tall Wood Archetypes

Investigative testing at system level

Two-story test at NHERI@UCSD
2017 Summer

Assembly test at NHERI@Lehigh
2017~2018

Full-scale 10-story validation Test (2020)

Resilient CLT Rocking wall system

Gravity columns

Detachable connection detail for segmental configurations

NHERI@UCSD Shake Table

Non-structural system and building envelop included but not shown

Individual Rocking Wall

Coupled Rocking Wall

25 ft

40 ft

Tons of R & D
(2018~2019)

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

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Overall Configuration Dictated by Research Objectives

- Seismically Resilient Rocking Wall System
- Total height 22 ft.
- 20x58 ft. diaphragms with different CLT panel layout
- Mass Timber gravity framing
- Steel foundation to extend the width of the shake table
- NHERI@UCSD Shake Table
- Shaking Direction
Phase 1: Post-tensioned Rocking wall

- Why 14?
- Day 1: Feel it out (test 1~5)  
  Baby steps
- Day 2: Public test 1 (test 6)  
  NSF public test
- Day 3: Public test 2 (test 7~8)  
  CA commissioner & congress woman
- Pushing the limit (test 9~14)  
  Still Day 3, after the visitors left

A total of 14 earthquake tests conducted

<table>
<thead>
<tr>
<th>ID</th>
<th>Ground Motion</th>
<th>Hazard level</th>
<th>PGA (g)</th>
<th>Sa @ 0.9 sec (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Northridge</td>
<td>MCE x 1.2</td>
<td>0.89</td>
<td>1.12</td>
</tr>
</tbody>
</table>

SLE: Service Level Earthquake (frequent)  
DBE: Design Basis Earthquake (Design code)  
MCE: Maximum Considered Earthquake (2500 yr return period)
Public Test Northridge x 2 (Test 6)
The MCE+ Shake (Test 14) 5% drift

Close up on Rocking Wall

Second story wall & column
Building Performance

- White noise period 0.85 sec
- Maximum drift 5% (test 14)
- Maximum base shear 430 kN (96 kips) (Building total weight 171 kips)
- Diaphragm mostly linear rigid
- Some PT bars yielded in MCE events
- No damage to wood

Removal of the Rocking Wall

No Damage after 14 earthquakes

Slight compression deformation at the rocking wall corner

Chipping of wood at the rocking wall corner
Phase 2: Katerra Wall (13 tests)

- A new Rocking wall design without post-tension
  
  But Easily Repairable
Response under MCE Northridge Shake
Repairable Damage @ Planned Locations
Summary

• This is not the end. It is not even the beginning of the end. But just the end of the beginning... of the NHERI Tall Wood Project.

• Now we have solid proof that mass timber structural system in an open floor plan building can be designed to achieve resilience against earthquakes.

• With significant amount of data and experience obtained through investigative testing, the project team will continue working on design method development, non-structural system detailing, numerical modeling, and the 10-story building for the 2020 validation test.
NEXT Step for NHERI TallWood

We are working on it...

Please wait while we do more R&D and design...
What to expect in 2020?

How about a 10-story building to shake and burn?

PLANNING TEAM

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Tara Hutchinson
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David Barber
ARUP

Brian Meacham
Consultant

Erica Fischer
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Mines
SHAKE & BAKE 2020

- Will be the tallest building ever tested on a shake table.
- And **YES**, we also plan to burn it.

Please contact us if you:

- Are interested in support these research efforts
  (Sponsorship)
- have a product, system, or idea you want to test
  (R&D Collaboration)
Acknowledgement

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• Thanks to the financial support or material donation from our collaborators on the Two-story testing program
Thank You! & Questions?

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NHERI TallWood Project updates:
Nheritallwood.mines.edu

Welcome to NHERI Tall Wood Project

A good INTERVIEW on the investigative 2-story building test in 2017 at NHERI@UCSD.

Shake table test Footage of the 2-story mass timber building test.

This is an NSF-funded project to develop and validate a resilient-based seismic design methodology for tall wood buildings. The project started in September 2016 and will last till 2020. The project team will validate the design methodology through shake table testing of a 10-story full-scale wood building specimen at NHERI@UCSD. It will be the world’s largest wood building tested at full-scale.

An NSF-funded planning project was completed in 2016 and provided the conceptual and technical preparation of this project. More information about the planning project and its (downloadable) deliverables can be found here: NEEDS Tall Wood Planning Project

Updates/Highlights

This is a brief list of the recent development in the project. Please check the RESEARCH tab for more details.

Or follow us on Facebook for updates for this project and more:

07/2017: Public test of the 2-story mass timber building completed, preparing for more testing.


06/2017: Full-scale 2-story building construction starts. CHECK IT OUT

06/2017: Research team arrive on site NHERI@UCSD to kick off full-scale 2-story mass timber building test.