NORTHRIDGE 20 SYMPOSIUM

Residential Wood-Frame and Soft Story Buildings

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January 16-17, 2014 - University of California, Los Angeles

Input provided by:

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Impact:
Issues from structural deficiencies

- Thousands of housing units rendered uninhabitable
- Many first floors (soft and weak) collapsed, particularly apartments
- Irregular shaped building caused problems
- Most fatalities occurred in soft-story woodframe buildings

Impact:
Non-structural observations

- Significantly more damage to finishes such as gypsum wall board (drywall) in houses than envisioned.

- Contents were damaged resulting in large losses

- A number of woodframe homes performed well (later benchmarked in the CCT and NEESWood projects)

Outcomes: Research Structure

- Research in woodframe
  - Structure of projects improved
    - Previously USDA, NSF – Individuals
    - PATH-NSF
    - CUREE-Caltech
    - NEESWood
    - NEES-Soft
    - Efforts in Canada (UBC, FPInnovations)
    - South America (Chile)
  - Projects became more linked with larger groups for consensus development

Soft-Story Collapse (NEES-Soft, Summer 2013)

Soft-Story Collapse (NEES-Soft, Summer 2013)

Outcomes: Design Code Changes

Majority of significant changes in the few years following

- Narrow wood walls no longer allowed
  - Allowed later with substantial “design penalty”
- Anchorage improvements including plate washers
- Realized how critical diaphragm design was with open front building collapses

Outcomes: Realizations

- Improved identification of irregularities and more restrictions when they ocurr
  - Weak and soft-story buildings
  - Irregular buildings
  - Hillside buildings

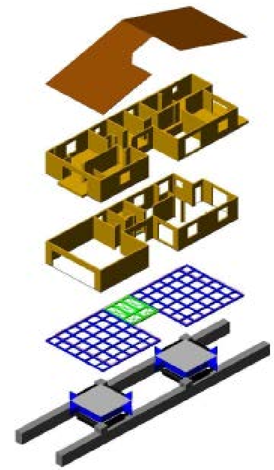
- Changes in the way wall finish / sheathing materials were allowed to combine for strength were put in place.

Outcomes: Some Broader Implications

- Development of better testing approach for wood
  - CUREE Protocol
- First consensus standard published in 2001
  - SDPWS
- Development of performance-based seismic design for woodframe
  - Tail end of the CUREE-Caltech project (2002)
  - NEESWood (2005-2009)
- Approach to determine seismic modification factors in current design approaches
  - FEMA P695 (2009) for all types of systems/materials

Outcomes: 2006 Benchmark Testing

- CUREE-Caltech Woodframe Project Index Building
- "Production townhouse" in 1980's or 90's, located in California
- Engineered construction designed according to 1988 UBC
- Contribution of stucco and gypsum wall board
- Test led by A. Filiatrault, UB



Benchmark Results

- Qualitative results: Is performance of design to recent code acceptable? Yes, the performance was generally good. There was no risk to life seen in the testing. Structural damage did occur at high ground motion levels. Damage should be repairable, but repair may be costly.

Ref. 2003 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and other Structures (FEMA 450), Section 1.1.1 Purpose:…to protect the health, safety, and welfare of the general public by minimizing earthquake-related risk to life….could result in both structural and nonstructural damage.

Slide credit: Kelly Cobeen, WJE

Outcomes: Performance-Based Seismic Design (Philosophy) for Taller Woodframe

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Next Steps – General Recommendations

- Existing buildings
  - Better guidance for seismic evaluations and retrofits
  - More comprehensive testing of archaic bracing systems is needed

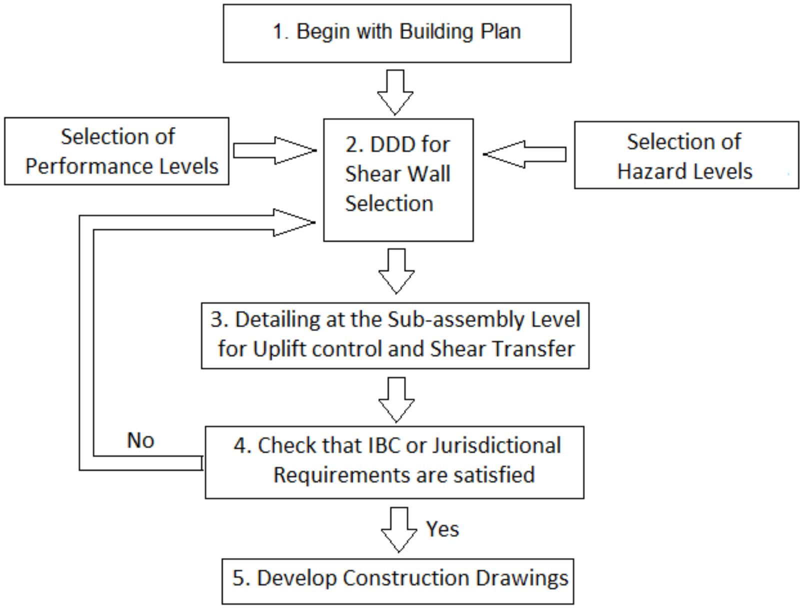
- Loading protocol for testing of wood assemblies may need revision
  - Collapse prevention now a focus rather than life safety

Next Steps – General Recommendations

- Comprehensive testing of floor diaphragms
- Designer guidance for selection of systems to achieve certain levels of **performance**
- Simplified rules for designers to distribute force and achieve certain levels of **performance**

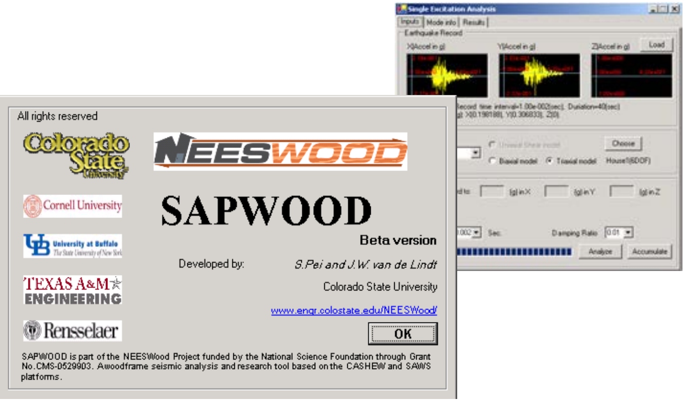
Outcome: Performance-Based Seismic design for Woodframe Buildings

- Filiatrault and Folz (2002)
- Pang and Rosowsky (2007)
- Pang et al (2010)
- Bahmani and van de Lindt (2013)

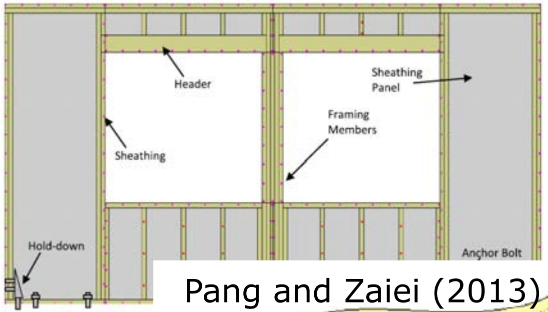


Next Steps: Solving Challenges for PBSD/PBSR

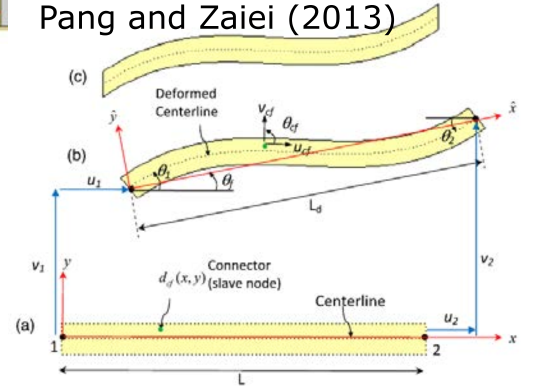
- Even in light of the progress made in the last few years, two major challenges remain:
  - The need to further improve nonlinear time history models
  - The need to package PBSD of mid-rise woodframe buildings in a more design-friendly format, i.e. with parallels to the National Design Specification (NSD) for Wood.



Pei and van de Lindt (2007)



Pang and Zaiei (2013)



Next Steps: Improve retrofit methodologies for soft-story buildings

- Pros:
  - Experimentally demonstrated in NEES-Soft project
  - Easy to use / Quick, so falls within typical woodframe engineering fee structure (big +)
- Cons:
  - Database approach, so engineering is not transparent to designers
  - Performance limitations since it focuses on bottom story only retrofits

Next Steps: Hybrid Systems

- Hybrid systems for tall buildings are on the horizon
  - 14 stories
  - Resilient
  - Sustainable
- Workshop in Seattle next week
- Needs extensive development

NSF NEES

Workshop Announcement

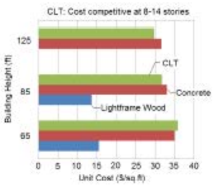
Engineering Resilient Tall CLT Buildings in Seismic Regions

Time: January 24, 2014 (See Detailed Agenda Attached)

Location: Arup @ 403 Columbia St Suite 220, Seattle, WA

Introduction

Cross Laminated Timber (CLT) is a naturally sustainable material that has been used in Canada, Europe, and Australia to rapidly construct multi-story wood buildings. There is increasing interest in the U.S. in utilizing CLT in 8~14 story residential and commercial buildings due to its appeal as a potential locally-sourced, sustainable, and economically competitive building material. However, existing multi-story CLT construction occurred in regions of low seismicity. A viable path to enable resilient tall CLT buildings in seismic regions is not clear – this provided the impetus for the workshop!



Who should attend?

Structural engineers, researchers, architects, urban planners, and wood industry representatives who share an interest in identifying the challenges and opportunities in pursuing earthquake resistant tall CLT building in West Coast of the U.S.

Participants of the workshop will provide inputs to develop a roadmap to enable seismically resilient tall CLT buildings in the next 4~8 years.

COLORADO SCHOOL OF MINES LEHIGH UNIVERSITY WASHINGTON STATE UNIVERSITY UNIVERSITY of WASHINGTON Colorado State University

ARUP FPInnovations

Outcome: Summary of recommendations

- Engineering – Applied research needed
  - Further codify performance-based seismic design – simplified rules for designers.
  - Better guidance for seismic evaluations and retrofits
  - More comprehensive testing of archaic building materials
  - Testing of floor diaphragms
  - Better loading protocols that focus on collapse risk
  - Simplified mechanisms for force distribution.

Outcome: Summary of recommendations

- Broader
  - Continue move toward comprehensive seismic risk reduction through soft-story woodframe retrofitting
    - May not be clear to stakeholders that retrofits do not protect their interests and safety at code-level.
    - To do this efficiently – the engineering studies on the previous slide are necessary.
  - Extend retrofitting to other locations based on risk rankings and to other woodframe building types, e.g. SFD
  - Facilitate taller resilient wood buildings with advanced technologies such as cross laminated timber, etc.

Thank you!

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Funding acknowledgments for the studies presented can be found on the project Websites and in project reports.