Quantifying the Performance of Retrofit of Cripple Walls and Sill Anchorage in Single Family Wood-Framed Buildings

WORKING GROUPS 5 AND 6 – NUMERICAL STUDIES:
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MOTIVATION FOR THE PEER-CEA WOOD-FRAME PROJECT

One of the major contributors to earthquake damage to single-family wood-frame dwellings is attributed to the failure of cripple walls and foundation sill anchorage. This has been documented within reconnaissance reports over the last 50 years.

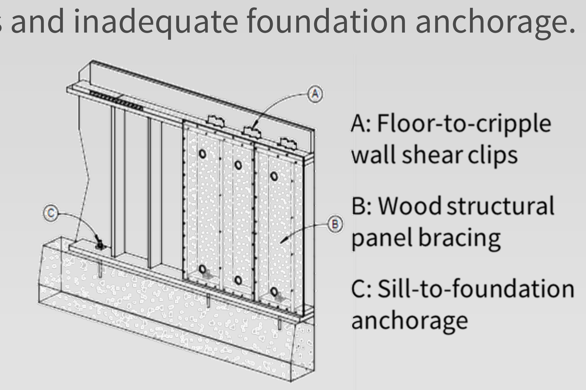
Cripple wall failure (2014 South Napa)

Cripple wall failure (1989 Loma Prieta)

Cripple wall failure (1987 Whittier Narrows)

Sill anchorage failure (1971 San Fernando)

The California Earthquake Authority's (CEA) continuing mission is to reduce risk of earthquake damage and loss and promote recovery through cost-effective insurance. This includes the retrofitting of single-family dwellings using the latest standards; such as the recent FEMA P-1100 guidelines. To this extent, a team assembled by the Pacific Earthquake Engineering Research (PEER) center is working for the CEA to quantify the reduction in losses due to retrofitting of single-family wood-frame dwellings with unbraced cripple walls and inadequate foundation anchorage.



Elements of a cripple wall retrofit (FEMA P-1100)

PROJECT WORKING GROUPS

The PEER-CEA Wood-Frame Project consists of seven distinct working groups combining efforts of numerous California universities and teams of practicing engineers with experience in older wood-frame structures.

- WG1/WG7: Literature review/ Reporting
- WG2: Inventory review and index building development
- WG3: Loading protocol and ground motion selection
- WG4: Experimental testing
- WG5: Structural modeling and analysis
- WG6: Loss modeling and loss function development

ANALYSIS FRAMEWORK AND OBJECTIVES

The project conducts seismic performance assessment using the assembly-based FEMA P-58 assessment approach which allows for uncertainties to be propagated from seismic demand to expected damage and repair/replacement costs.

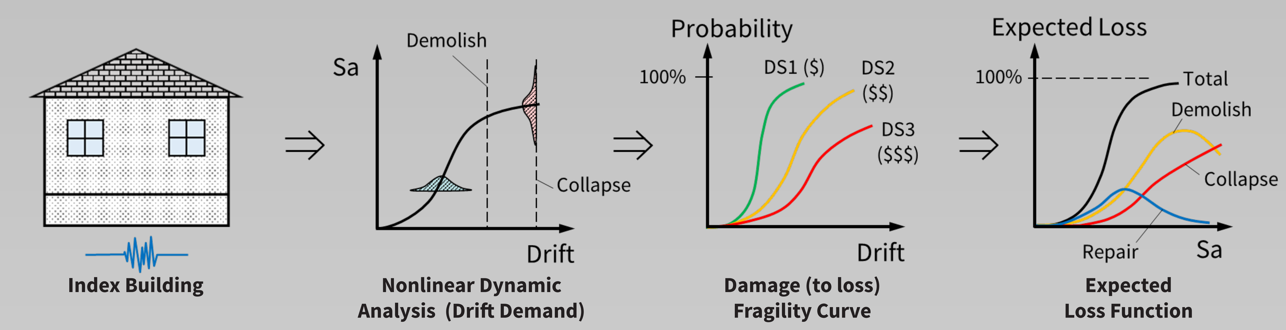
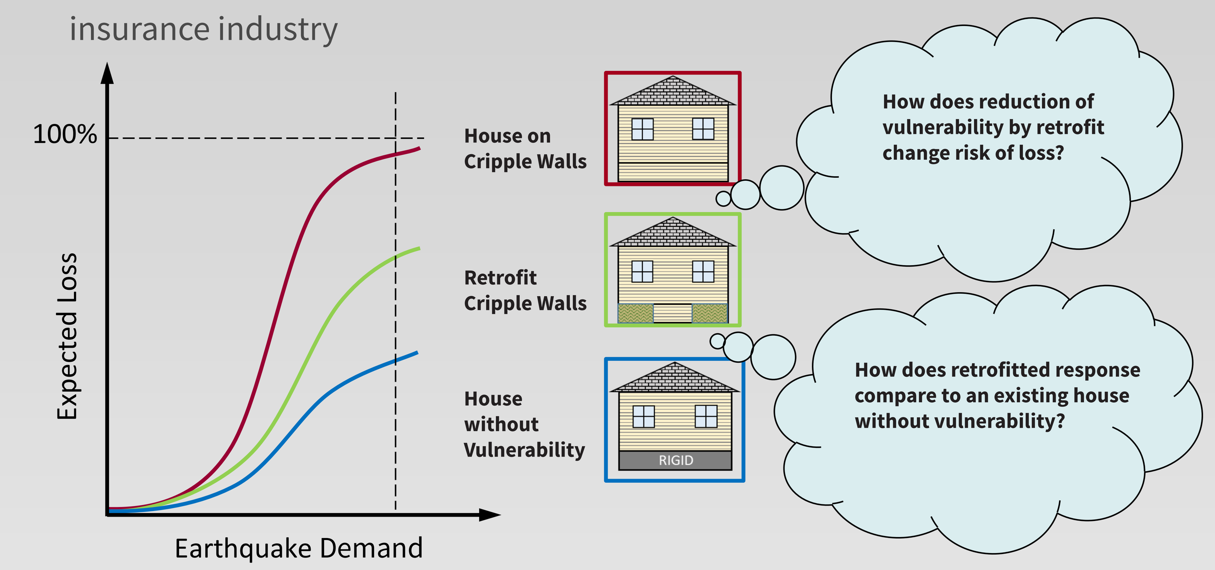


Illustration of performance assessment framework

Main objectives are to:

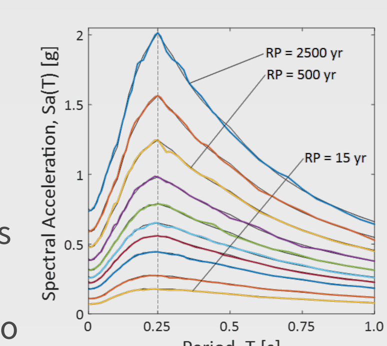
- Establish adjustment factors to relate the change in seismic losses due to retrofitting at different intensity levels
- Develop earthquake loss functions to quantify the effect of retrofit considering observable and unobservable variants used within the insurance industry



Example loss curves for existing and retrofit cripple wall dwellings and dwelling without bracing or anchorage vulnerability

SITE SELECTION AND SEISMIC HAZARD

- Sites are selected to span the range of seismicity expected across California
- Individual ground motion sets are selected to match site hazard from low to high return period intensities
- Record sets consider approximately 50 ground motions per intensity to obtain response statistics
- Local seismicity governs the retrofit design according to FEMA P-1100



Conditional mean spectra for 10 return periods at single site

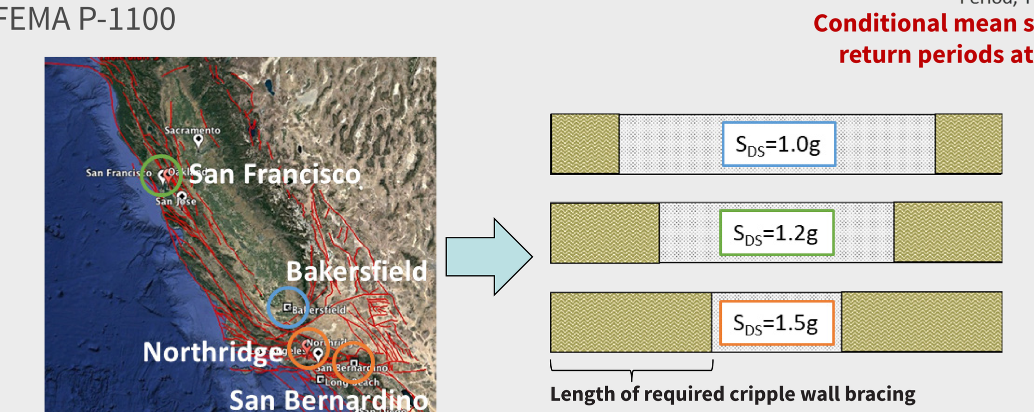
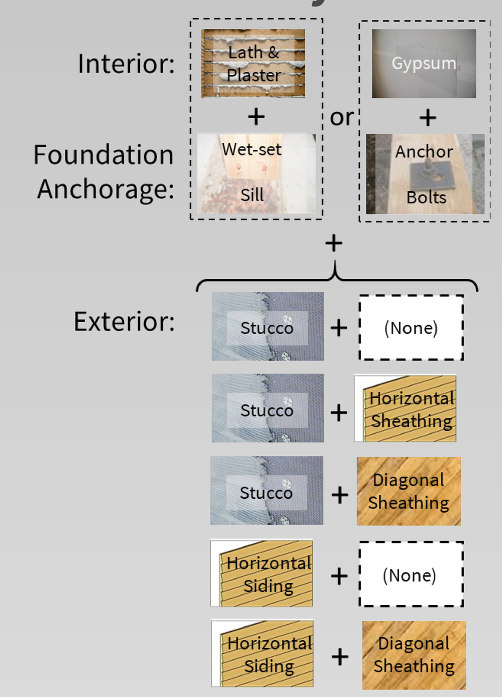


Illustration of site-dependent retrofit designs based on seismicity

STRUCTURAL ANALYSIS

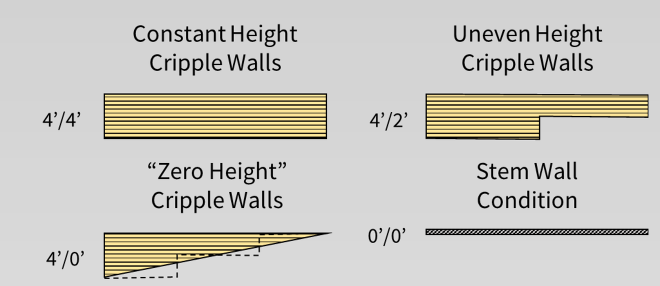
What to Analyze?



Sheathing combinations for the 1940-1955 era

Building variants consider a range of expected conditions:

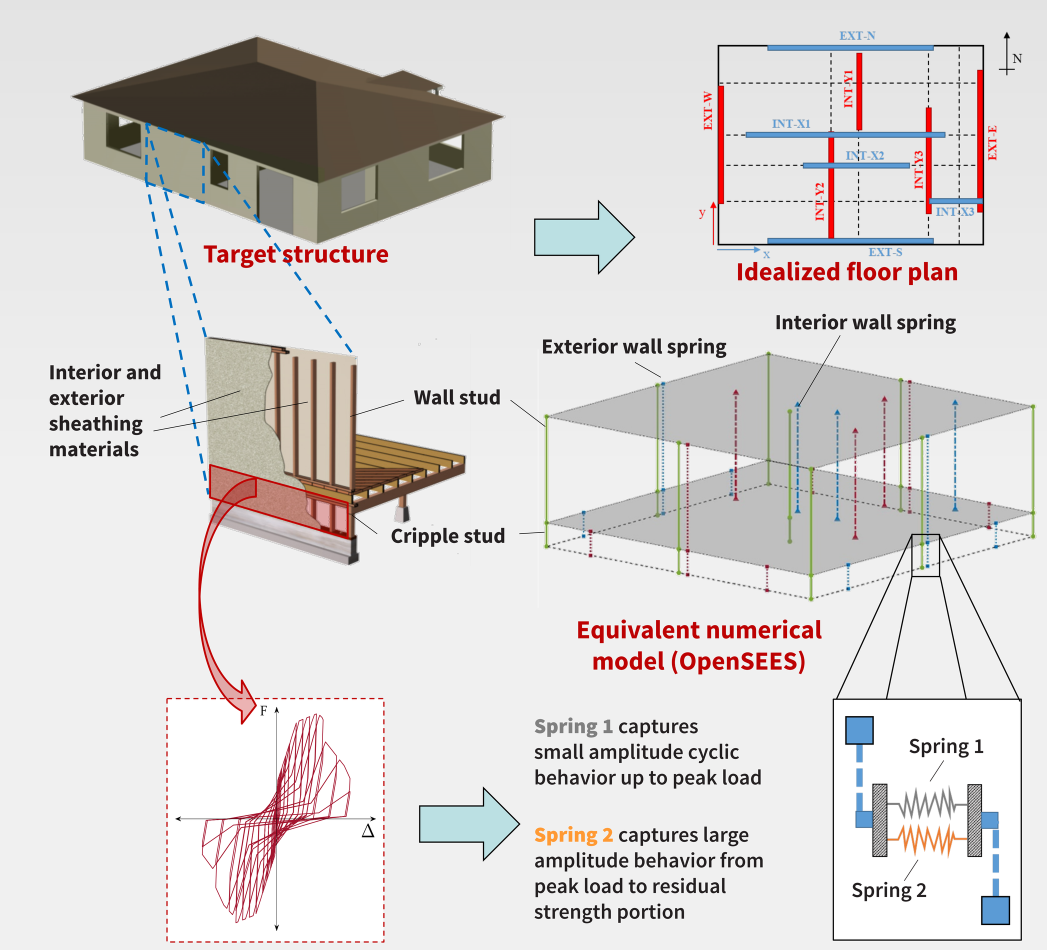
- Era of construction
- Number of stories
- Cripple wall geometry
- Roof weight
- Interior finish
- Exterior finish
- Foundation anchorage
- Material quality



Different classes of cripple wall geometry

How to Analyze?

Structural models must preserve mass, strength and stiffness properties of each variant. Models must be explicit enough to return response quantities used for loss assessment, yet simple enough for a large number of analyses.



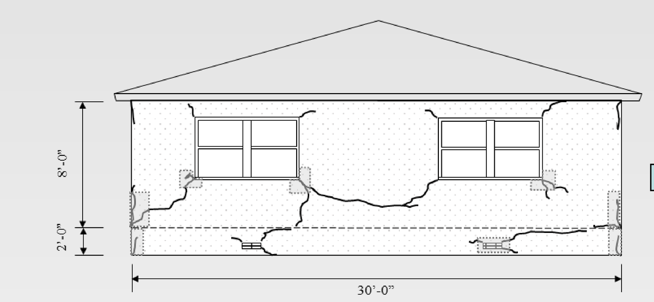
Modeling of materials must capture cyclic behavior at both small (onset of damage) and large (collapse) levels of displacement demand. Calibration to experimental results using two parallel springs (Pinching4) to capture full range of hysteretic response provides versatility for capturing a range of materials.

LOSS MODELING AND PERFORMANCE ASSESSMENT

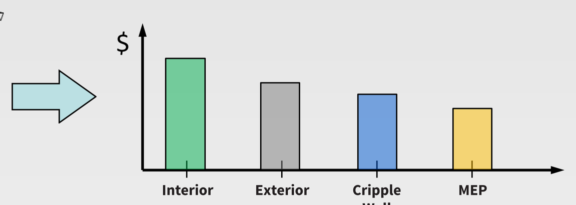
The project framework applies modern methods to older structures. This poses a number of added challenges compared to contemporary construction:

- Definition of damage states for repair effort thresholds of older materials
- Adjusting existing (and limited) fragility and consequence functions to reflect damage states
- Properly accounting for partial failures (e.g., cripple wall collapse, sill plate failure) in terms of economic consequences
- Accounting for uncertainty in both observable and unobservable variants in realistic proportions to the building stock

Use of experimental data to improve damage fragilities for plaster on wood lath interior



Example of stucco damage scenario prepared for claims adjuster workshop



Example scenario cost assessment from adjuster workshop

The project team is collaborating with claims adjusters, cost estimators and insurance loss modelers in order to improve the current state of structural and economic loss modeling of houses with cripple wall bracing and sill anchorage in California.

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