PEER-CEA Wood-Frame Project: Numerical Simulations

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Outline

- End Goals and Numerical Framework
  - FEMA P-1100 to PEER-CEA
  - FEMA P-58 Performance Assessment Process
- What to Analyze?
  - Definition of Building Variants and Index Configurations
- How to Analyze?
  - Selected Sites and Ground Motions
  - Structural Modeling
  - Damage and Consequence Modeling for Older Wood-frame
- Example Results and Observed Trends

FEMA P-1100 to PEER-CEA

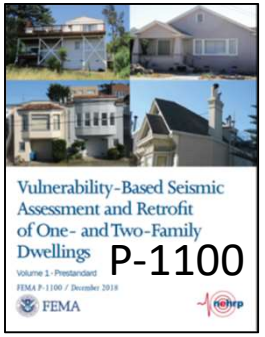
- The **FEMA P-1100** Prestandard (ATC-110 Project) represents the **engineering solution** to the unbraced cripple wall problem (**collapse prevention**)

- The **PEER-CEA Project** aims to understand what can be gained by adopting the engineering solution to **promote implementation** (**performance quantification**)

Steps Toward Implementation

PEER CEA

Engineering Solution

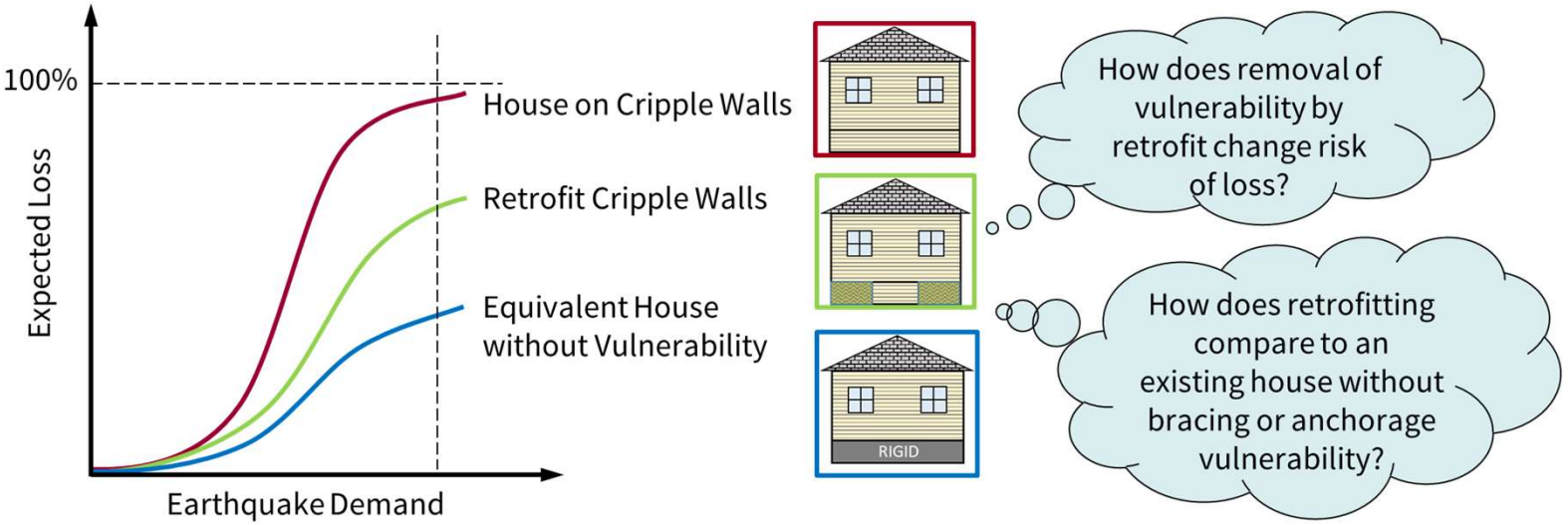


Reduced Vulnerability

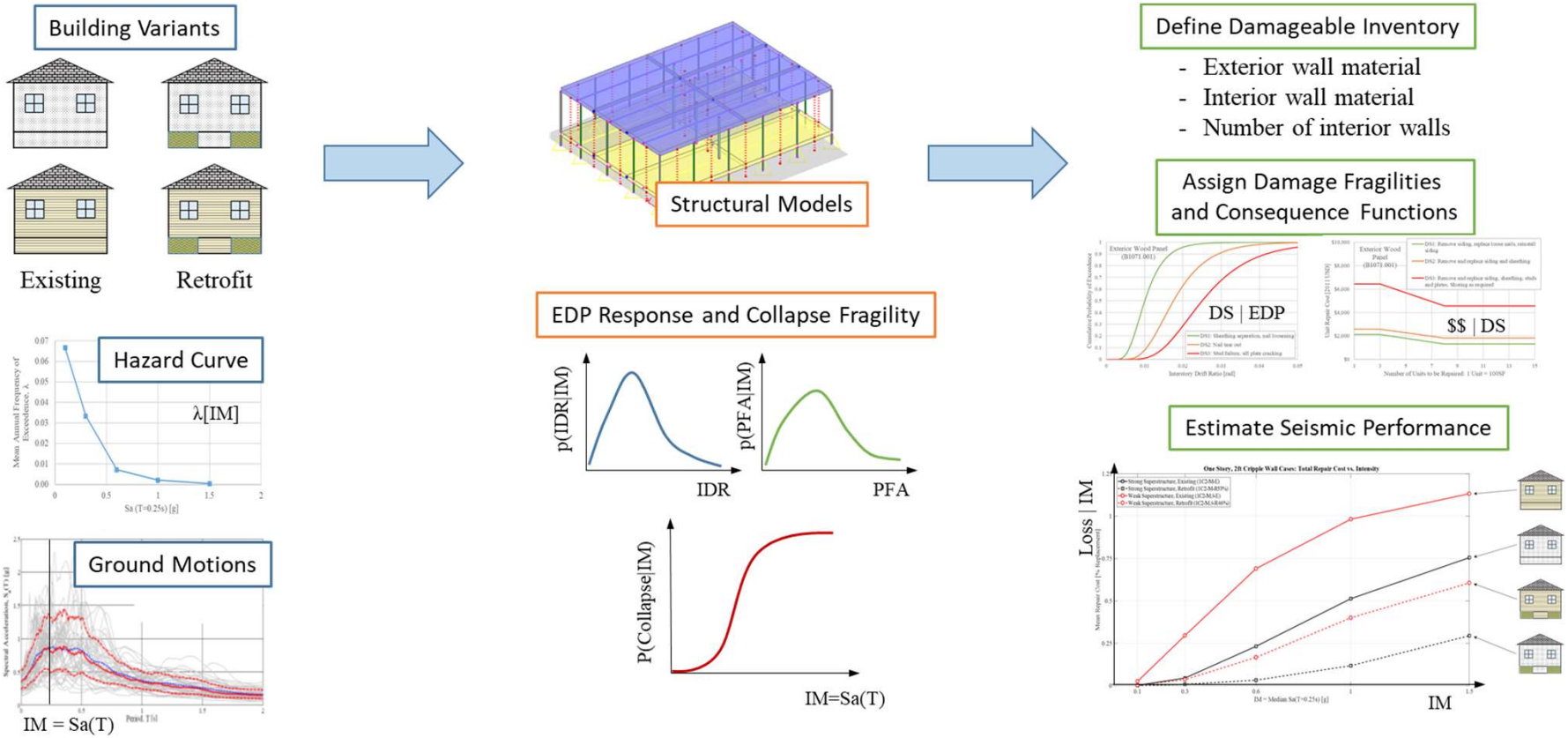
End Goals for Numerical Simulations

- Establish adjustment factors to relate the *change* in seismic loss due to retrofitting at different intensity levels

- Develop loss functions to quantify the effect of retrofit considering observable and unobservable variants used in the insurance industry



Overview of Building-Specific PBEE Framework (FEMA P-58)



What to Analyze?
Definition of Building Variants

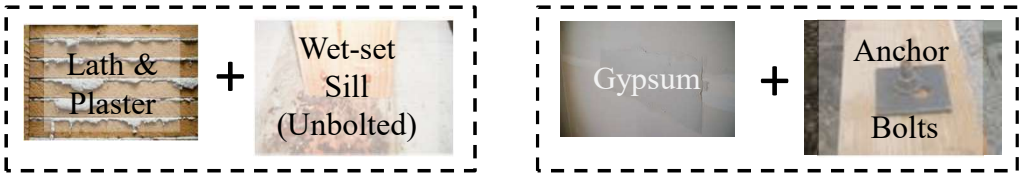
- **Primary Variants - Observable**
  - Age of Construction
  - Number of Stories
- **Secondary Variants - Observable**
  - Exterior material
  - Building (roof) weight
  - Sill bolting
  - Cripple wall height/ slope differential
- **Secondary Variants - Unobservable**
  - Siding/Sheathing Combinations
  - Construction Quality and Condition

Credit: Evan Reis, Working Group 2 - Index Buildings

What to Analyze?
Definition of Building Variants

Construction Era (3): Pre-1940 1940-1955 1956-1970

Interior/
Sill Anchorage:



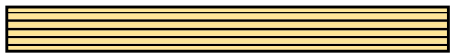
Exterior:

Cripple Wall Classification:

WORK IN PROGRESS

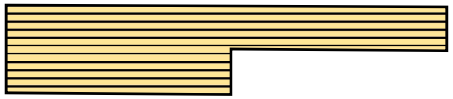
Constant Height Cripple Walls

2’/2’



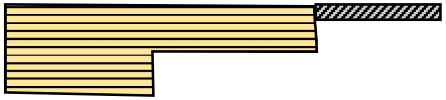
Uneven Height Cripple Walls

4’/2’



“Zero Height” Cripple Walls

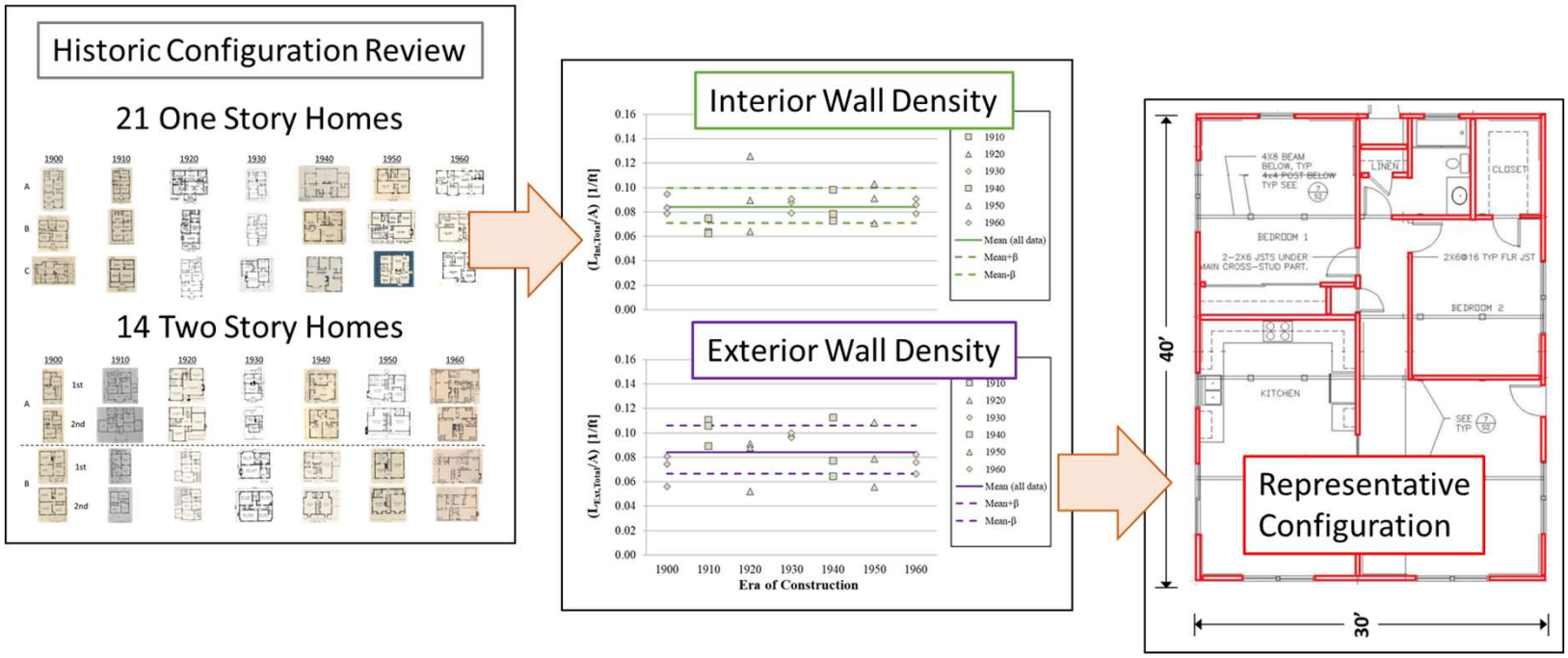
4’/0’



Credit: Evan Reis, Working Group 2 - Index Buildings

What to Analyze?
Baseline Superstructure Configurations

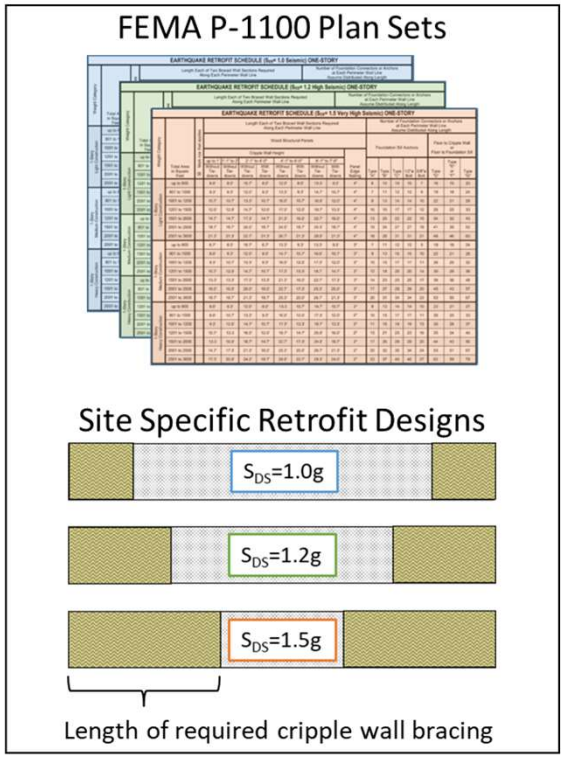
- Wall configuration affects the strength, stiffness, weight and damageable quantities within a home
- ATC-110 configuration collection was used to obtain statistics on interior and exterior wall density



Collaborator: Colin Blaney, ATC-110, PEER-CEA Project Reviewer

How to Analyze?
Selected Building Sites and Ground Motions

- 4 baseline sites adopted ($V_{s,30}$=270m/s)
- Covers seismicity range in FEMA P-1100

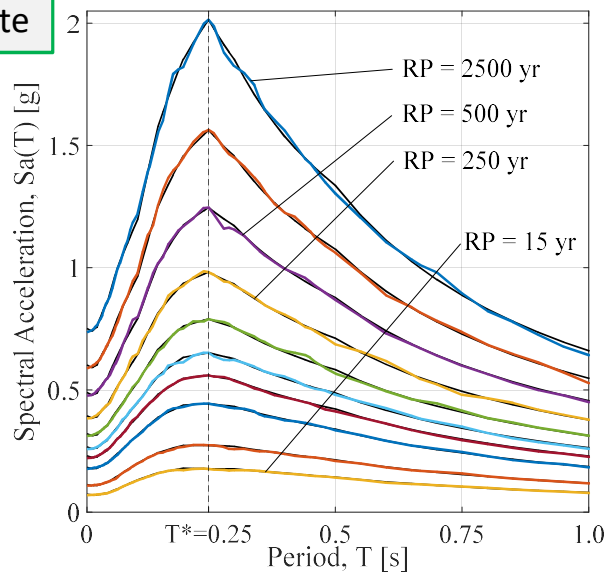


Credit: Silvia Mazzoni and Yousef Bozorgnia, Working Group 3 - Ground Motions (Group leaders)

How to Analyze?
Selected Building Sites and Ground Motions

- 4 baseline sites adopted ($V_{s,30}$=270m/s)
- Covers seismicity range in FEMA P-1100
- 10 intensities per site (RP=15y to 2500y)
- 45 ground motion pairs per intensity selected to match target Conditional Mean Spectrum (T*=0.25s)

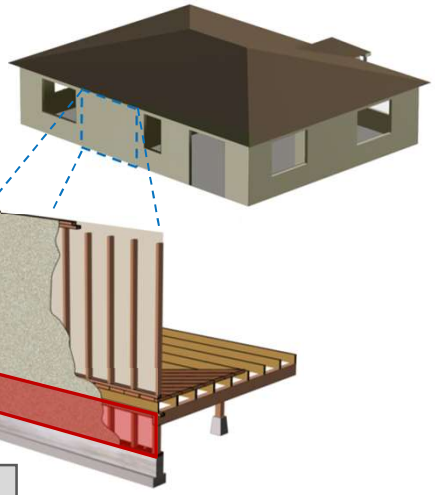
Example CMS:
San Francisco 270 site



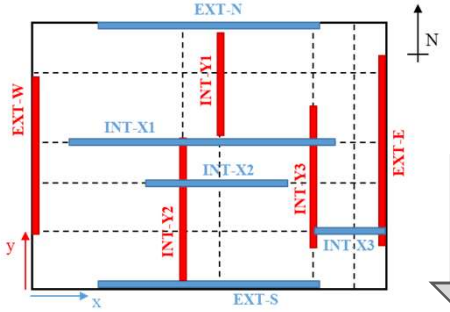
Credit: Silvia Mazzoni and Yousef Bozorgnia, Working Group 3 - Ground Motions (Group leaders)

How to Analyze?
Structural Modeling (OpenSEES)

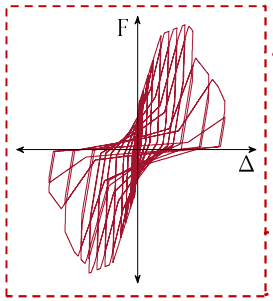
Target Structure

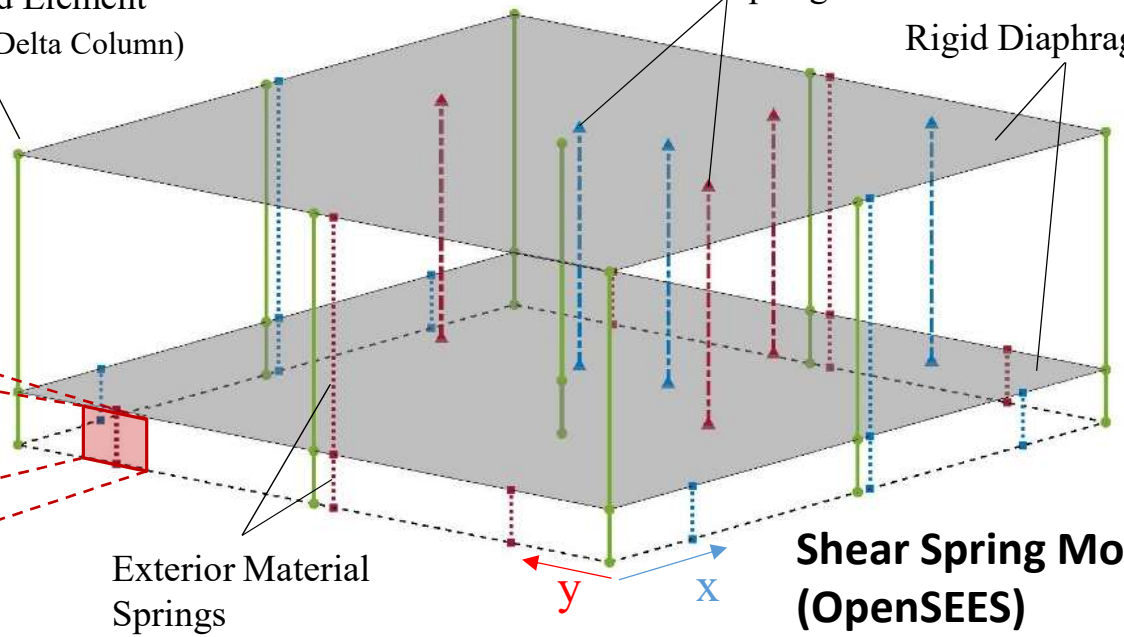


Idealized Floor Plan



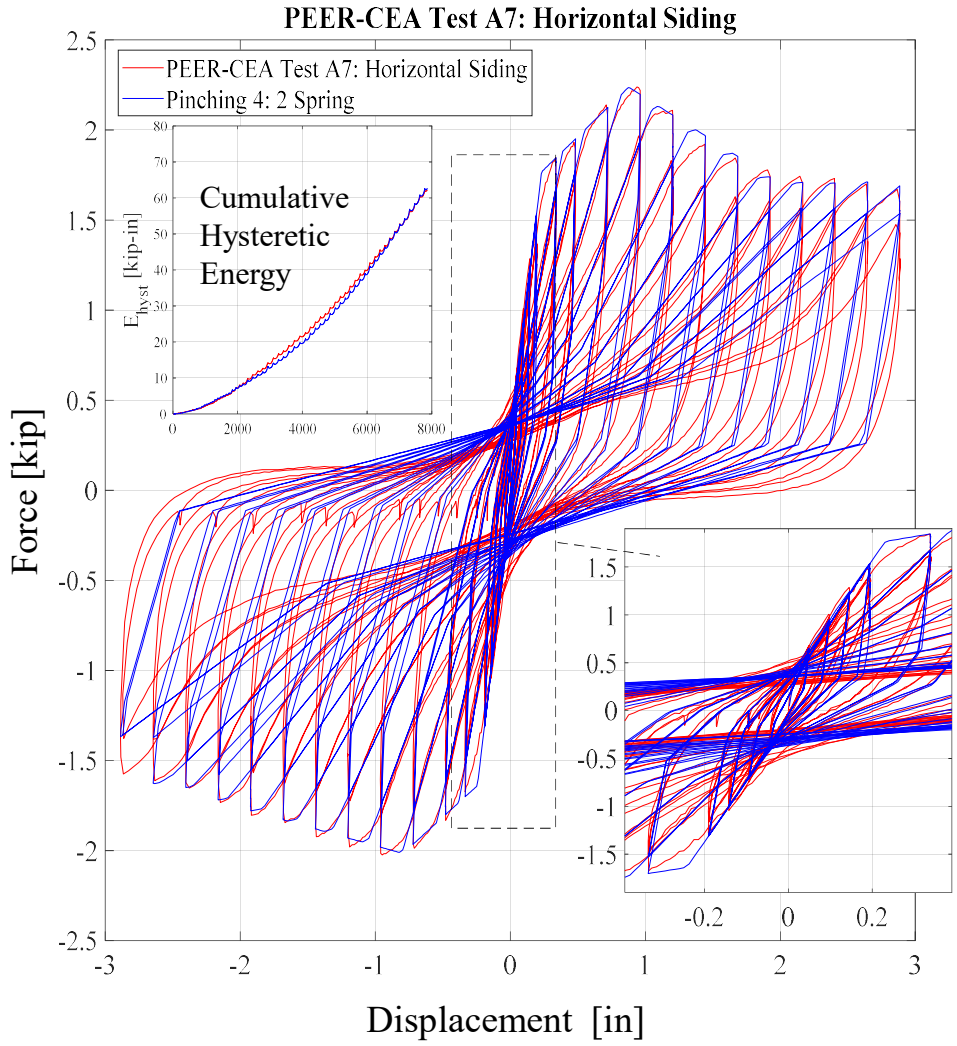
Sub-Assembly Testing





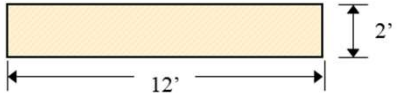
Shear Spring Model (OpenSEES)

How to Analyze?
Hysteretic Modeling of Wall Materials



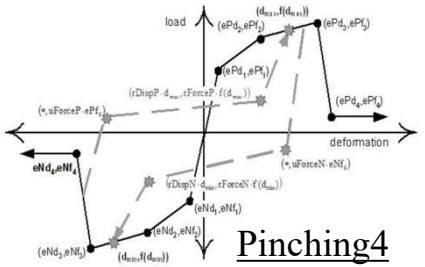
2ft X 12ft cripple wall with **horizontal wood siding** (PEER-CEA Test A7)

Experimental



Test Data:
Schiller & Hutchinson, UCSD

Numerical



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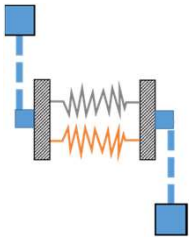
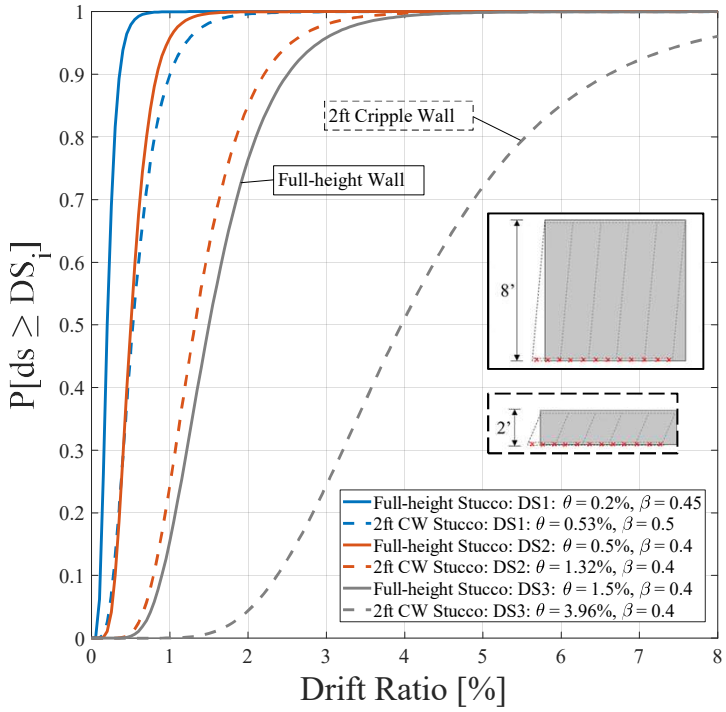


2 Spring Material

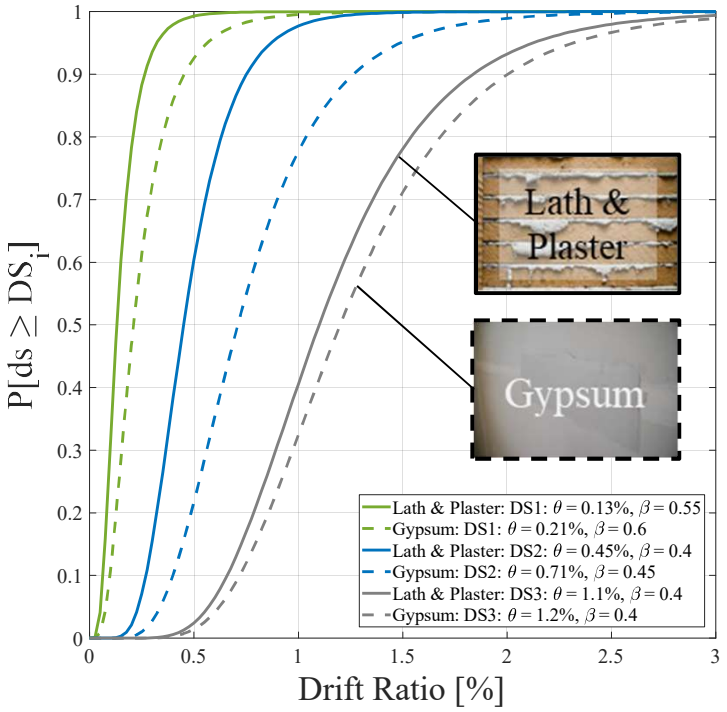
How to Analyze?
Damage Analysis of Older Wood-frame

- Review and Modification of FEMA P-58 Database
- Updating Existing Component Fragilities (based on testing)

Median Drift Adjustment
for Shorter Stucco Walls

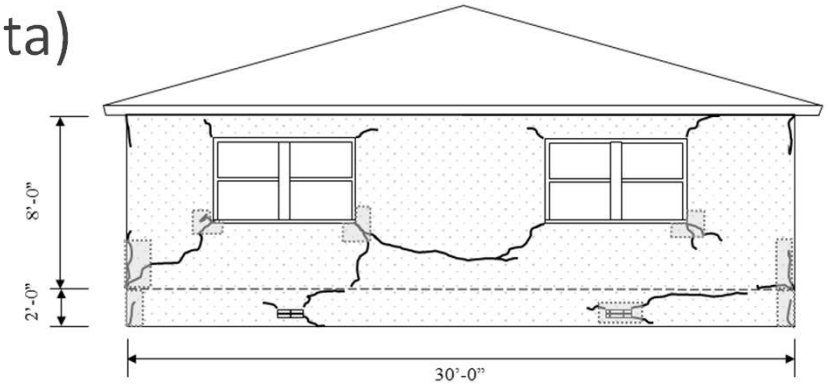


Gypsum vs. Lath and Plaster Fragility



How to Analyze?
Consequence Modeling of Older Wood-frame

- **Claims Adjustor Damage Workshop** (February/March 2019)
  - Obtained **repair cost estimates** from practicing claims adjustors with earthquake damage experience
  - **Slight Damage to Complete Replacement**
  - Damage states in line FEMA P-58 where applicable (Comparison to existing P-58 information)
  - Case studies **target materials with large knowledge gaps** in terms of repair costs (Expand Applicability)
  - Survey questions (Experience data)

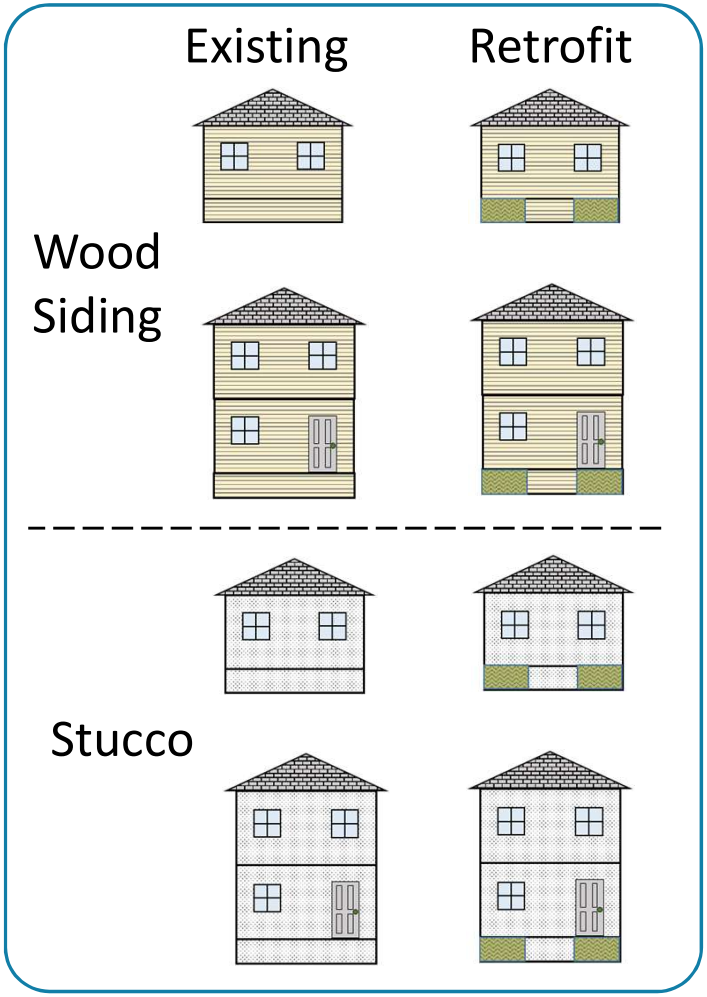


Credit: Bret Lizundia, Workshop Organizer

Example Results and Trends

Consider four variants:

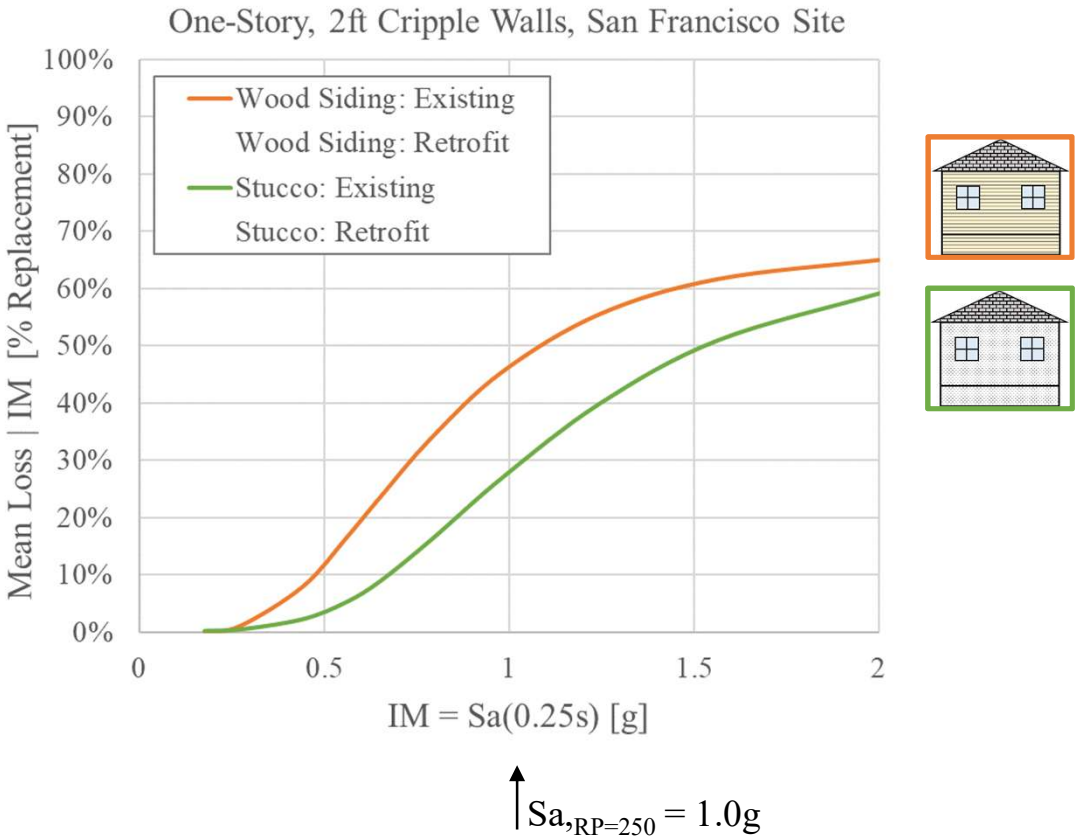
- One- and Two-Story
- Wood Siding and Stucco Exterior
- Post-1955 era (Gypsum Interior)
- 2-foot Level Cripple Walls
- Located in San Francisco



Key Performance Results:

- Mean Loss vs. Intensity Curve
- Expected Annual Loss
- Mean Loss at 250yr Hazard Intensity

Example Results and Trends

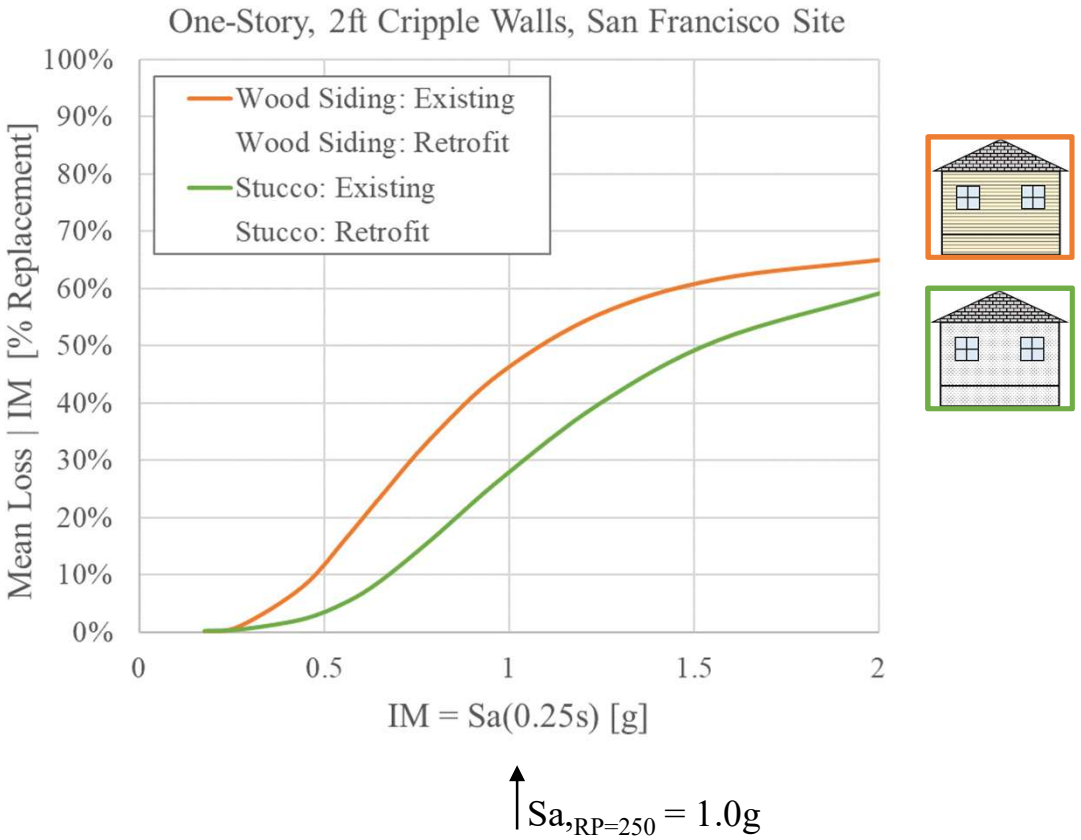


Loss versus Intensity (SF Site)

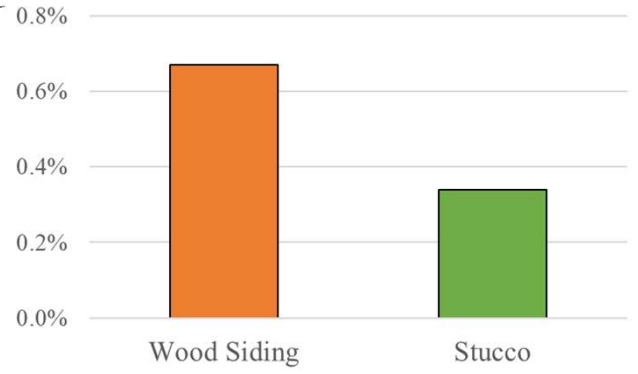
Expected Annual Loss

Loss at 250yr Hazard Intensity

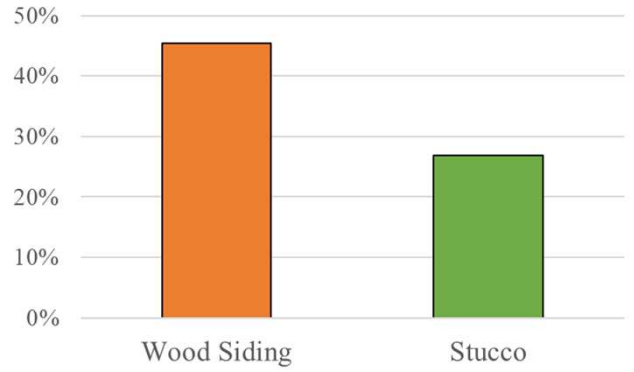
Example Results and Trends



Loss versus Intensity (SF Site)

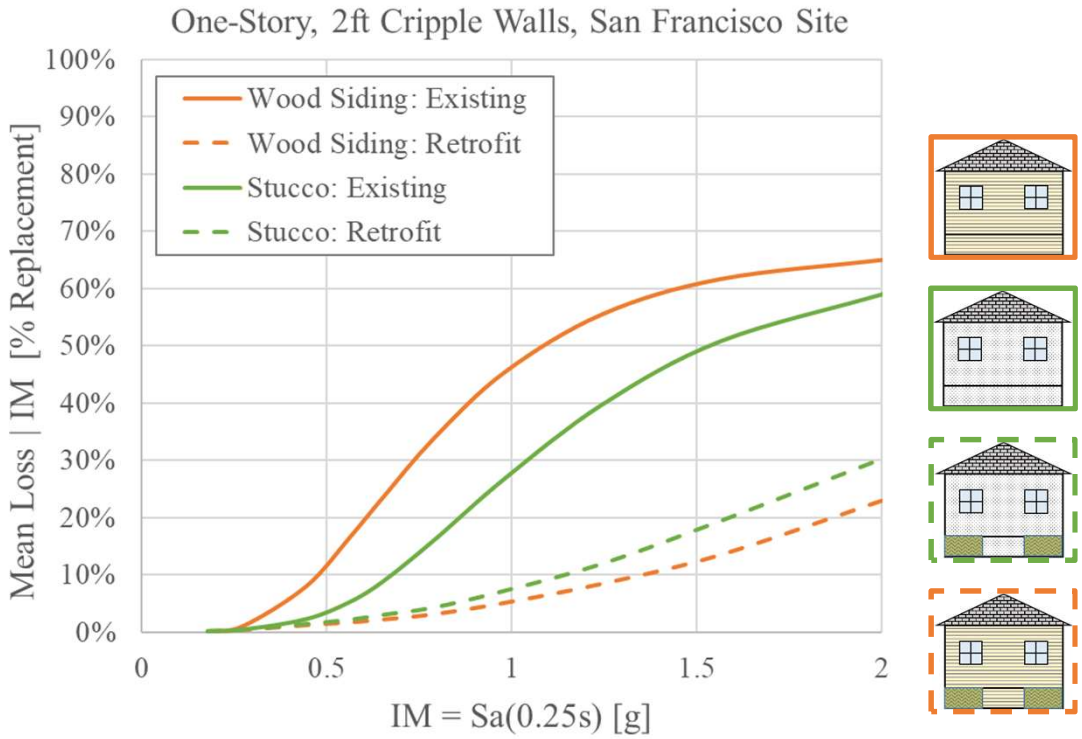


Expected Annual Loss

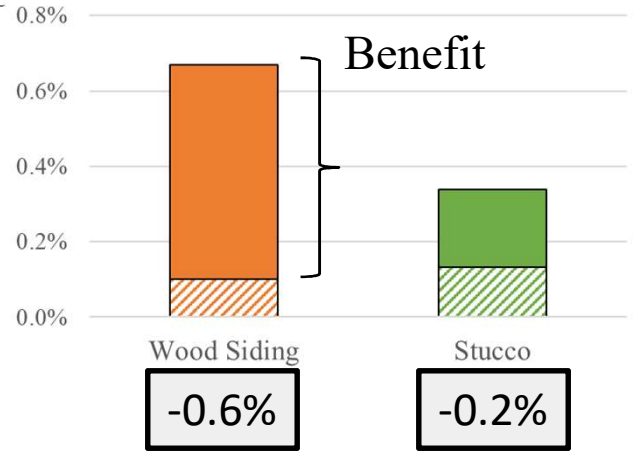


Loss at 250yr Hazard Intensity

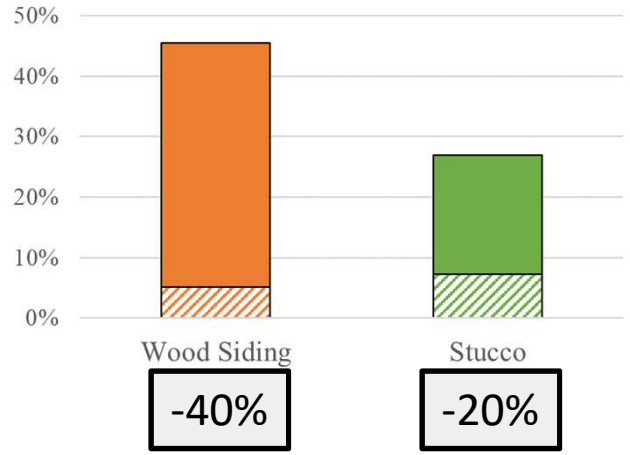
Example Results and Trends



Loss versus Intensity (SF Site)

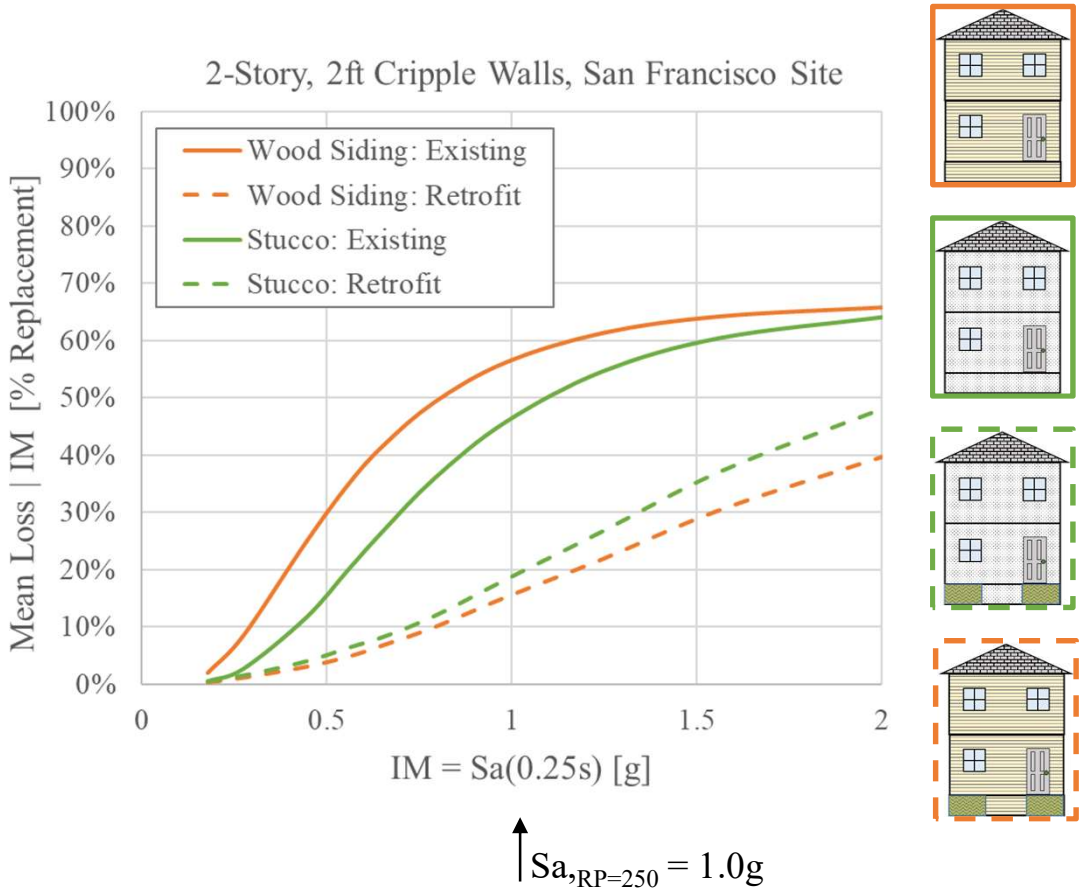


Expected Annual Loss



Loss at 250yr Hazard Intensity

Example Results and Trends



Loss versus Intensity (SF Site)

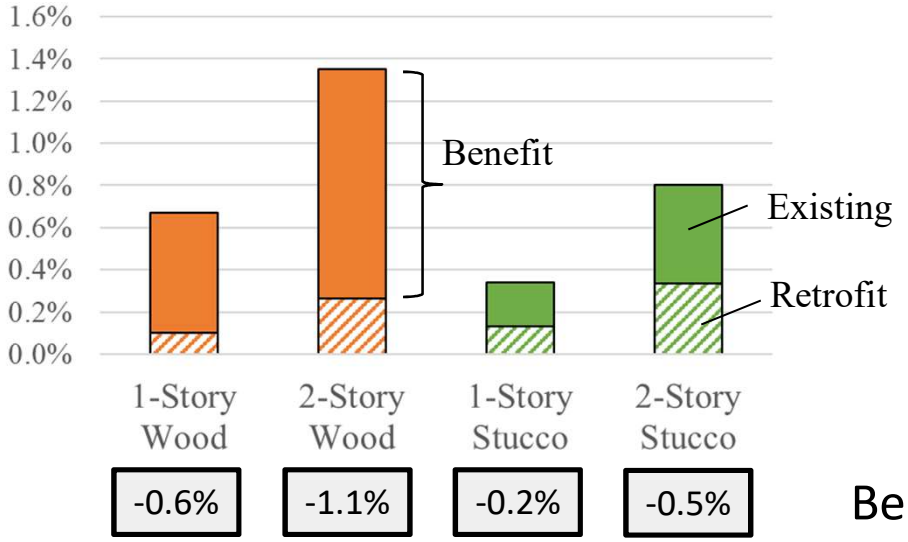
Expected Annual Loss

Loss at 250yr Hazard Intensity

Example Results and Trends

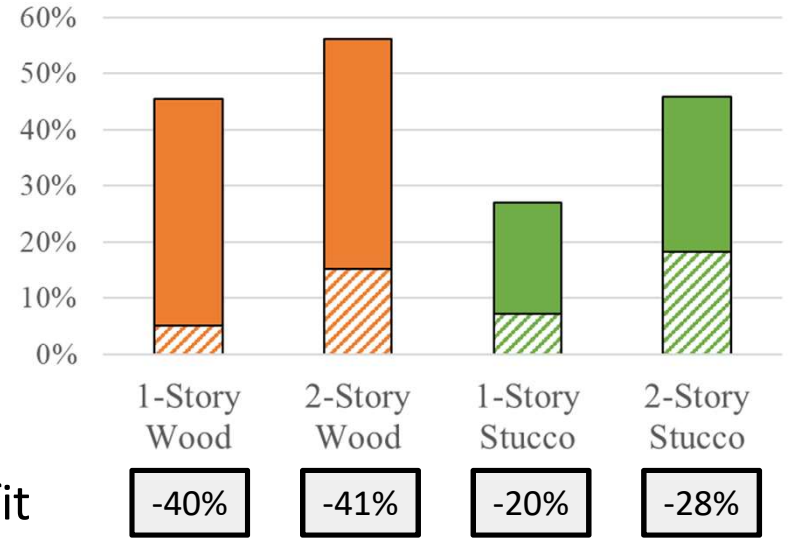
- Lower cripple wall strength increases observed retrofit benefit
- Two-story perform worse than one-story (existing and retrofit)
- Observed benefits due to retrofitting vary significantly depending on building variant and loss metric

Expected Annual Loss (SF Site)



Benefit	1-Story Wood	2-Story Wood	1-Story Stucco	2-Story Stucco
	-0.6%	-1.1%	-0.2%	-0.5%

Loss at 250yr Hazard Intensity (SF Site)



	1-Story Wood	2-Story Wood	1-Story Stucco	2-Story Stucco
	-40%	-41%	-20%	-28%

Thank you for your attention!