An Overview of Research Project:
Quantifying the Performance of Retrofit of Cripple Walls & Sill Anchorage in Single Family Wood-frame Buildings

(Working Group Chairs/Co-Chairs; Alphabetically)

Yousef Bozorgnia (PI), Henry Burton, Kelly Cobeen, Greg Deierlein, Tara Hutchinson, Grace Kang, Bret Lizundia, Sharyl Rabinovici, Evan Reis, Dave Welch, Farzin Zareian

PEER Annual Meeting January 17, 2020

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Acknowledgements

- The project is funded by the CA Earthquake Authority (**CEA**)
- Support and encouragement of **CEA management and staff** are gratefully appreciated
  - **Janiele Maffei, Shawna Ackerman, Badie Rowshandel,…**
- **Project advisory panel** provided important comments and feedback during the life of the project
- Numerous hard-working **researchers and practitioners** who have been working on this high-impact project…**Next Slide…**

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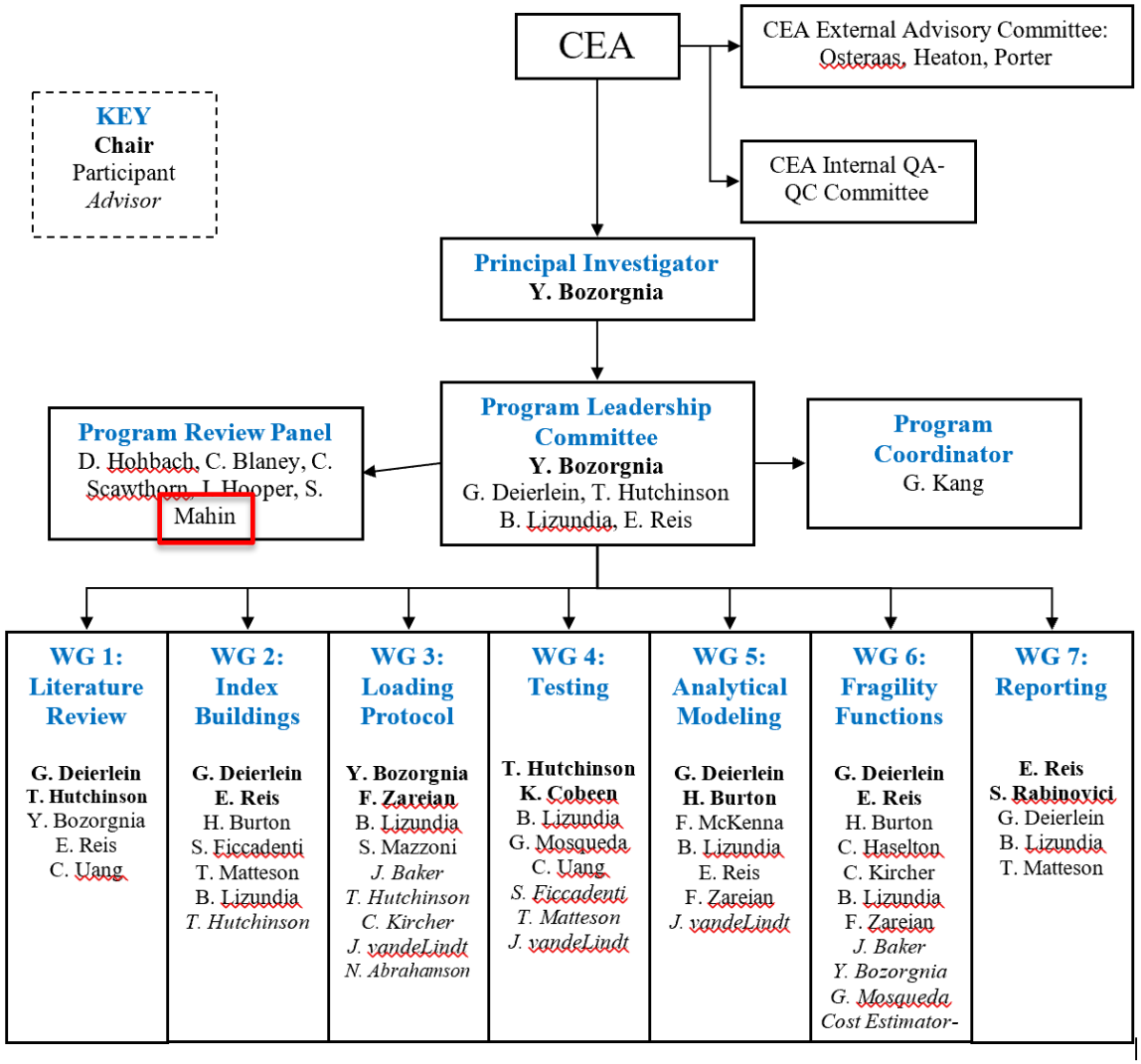

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Steve Mahin…

- We started the proposal and project together
- We miss him and his vision, leadership, and IDEAS

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The Project

- Objective: To develop fragility modification factors for use by loss modelers for retrofitted and un-retrofitted homes
- Numerical modeling and analytical computations simulate response of homes
- Experimental testing provides validation of numerical modeling and computations
- Project team includes **academic researchers** and **practitioners**

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The Project

- Started: October 17, 2016
- Will end: April 17, 2020
- Consists of seven working groups (tasks), including analytical and experimental investigations

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Working Groups

- WG1: Literature review
- WG2: Index buildings
- WG3: Ground motions and loading protocol
- WG4: Experimental investigations
- WG5: Analytical modeling (simulations)
- WG6: Fragility functions
- WG7: Reporting

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Working Groups

- WG1: Literature review
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Experimental Investigations

- Small scale component tests
  - At UC San Diego
  - **Tara Hutchinson and Brandon Schiller**
- Large-scale component tests
  - At UC Berkeley
  - **Kelly Cobeen and Vahid Mahdavifar**

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UCSD Tests

- A total of 28 specimens have been tested
- With varying sizes and configurations
- Un-retrofitted and retrofitted specimens
- Various boundary conditions

	Specimen	Test No (via date)	Existing or Retrofit	Era	Axial Load	CW Height	Anchorage	Exterior Finish	Top BC	Bottom BC	Loading	Test Date
Phase			(E or R)		(H = 450 plf, L = 150 plf)	(ft)	[WS = wet sill, S = spacing (in)]	(S = stucco only, HS = horizontal siding, HS+Dsh =horizontal siding over diagonal sheathing, S+HSh = stucco over hor. sheathing, S+DSh = stucco over diag. sheathing, T = T1-11 siding)	(A, B, or C)	(a,b,c)	(C = cyclic, M = monotonic)	
1	A-1	4	E	Pre-1945	H	2	S(64")	S+HSh	A	a	C	1/26/2018
1	A-2	3	E	Pre-1945	H	2	S(64")	S+HSh	B	a	C	1/18/2018
1	A-3	6	E	Pre-1945	H	2	S(64")	S+HSh	C	a	C	2/2/2018
1	A-4	1	E	Pre-1945	H	2	S(64")	S+HSh	B	b	C	12/18/2017
1	A-5	5	R	Pre-1945	H	2	S(32")	S+HSh	B	a	C	1/31/2018
1	A-6	2	E	Pre-1945	H	2	WS	S+HSh	B	b	C	12/22/2017
2	A-7	7	E	1945-1955	H	2	S(64")	HS	B	c	C	5/11/2018
2	A-8	8	R	1945-1955	H	2	S(32")	HS	B	c	C	5/22/2018
2	A-9	11	E	1945-1955	H	2	S(64")	HS+DSh	B	c	C	7/19/2018
2	A-10	12	R	1945-1955	H	2	S(32")	HS+DSh	B	c	C	7/26/2018
2	A-11	9	E	1956-1970	H	2	S(64")	T	B	c	C	6/15/2018
2	A-12	10	R	1956-1970	H	2	S(32")	T	B	c	C	6/28/2018
2	A-13	13	E	1945-1955	H	6	S(64")	HS	B	c	C	8/6/2018
2	A-14	14	R	1945-1955	H	6	S(32")	HS	B	c	C	8/30/2018
3	A-15	20	E	Pre-1945	H	2	S(64")	S+DSh	B	c	C	11/20/2018
3	A-16	21	R	Pre-1945	H	2	S(32")	S+DSh	B	c	C	2/5/2019
3	A-17	18	E	Pre-1945	H	2	S(64")	S	B	d	C	11/5/2018
3	A-18	22	R	Pre-1945	H	2	S(32")	S	B	d	C	2/12/2019
3	A-19	19	R	Pre-1945	H	2	S(32")	S+HSh	B	c	C	11/13/2018
3	A-20	15	E	Pre-1945	H	2	S(64")	S+HSh	B	d	C	10/22/2018
3	A-21	17	E	Pre-1945	H	2	WS	S+HSh	B	c	C	10/31/2018
3	A-22	16	E	Pre-1945	H	2	S(64")	S	B	c	C	10/26/2018
4	A-23	23	E	1956-1970	H	6	S(64")	T	B	c	C	9/16/2019
4	A-24	24	R	1956-1970	H	6	S(32")	T	B	c	C	10/3/2019
4	A-25	27	E	Pre-1945	H	6	S(64")	S	B	c	C	10/29/2019
4	A-26	28	R	Pre-1945	H	6	S(32")	S	B	c	C	11/7/2019
4	A-27	26	E	Pre-1945	H	2	S(64")	S+HSh	B	c	M	10/25/2019
4	A-28	25	E	1945-1955	L	2	S(64")	HS+DSh	B	c	C	10/10/2019
Denotes Pre-1945 Tests												
Denotes 1945-1955 Tests			Retrofit		Low axial load	6' tall	Wet Set Sill or Retrofit	Denotes Dry (non-stucco) Finish	Case A, C	Case a,b,d	Monotonic	
Denotes 1956-1970 Tests												

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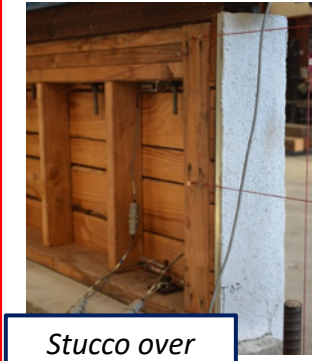
Exterior Finishes and Retrofit

FEMA P-1100 Retrofit

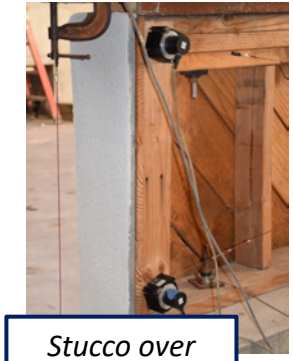
Before WSP installation

After WSP installation

"Wet" Exterior Finishes



Stucco over horizontal sheathing

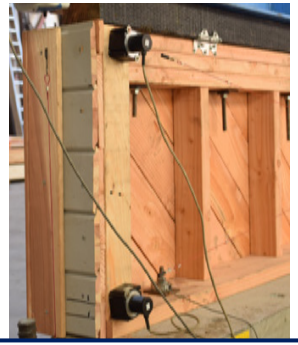


Stucco over diagonal sheathing

Stucco

"Dry" Exterior Finishes

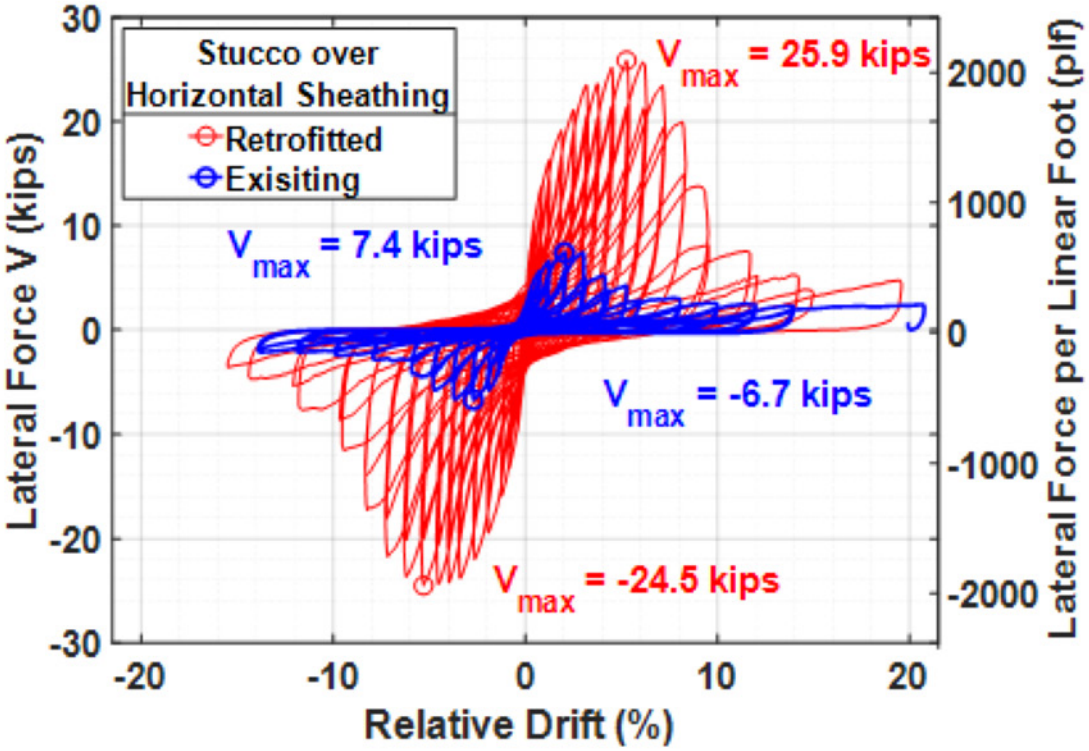
Horizontal Siding



Horizontal siding over diagonal sheathing

T1-11 wood structural panels

An example of results



"Baseline" specimen (ie. 2'-foot-tall cripple wall, with stucco over horizontal sheathing finish (retrofit vs unretrofit)

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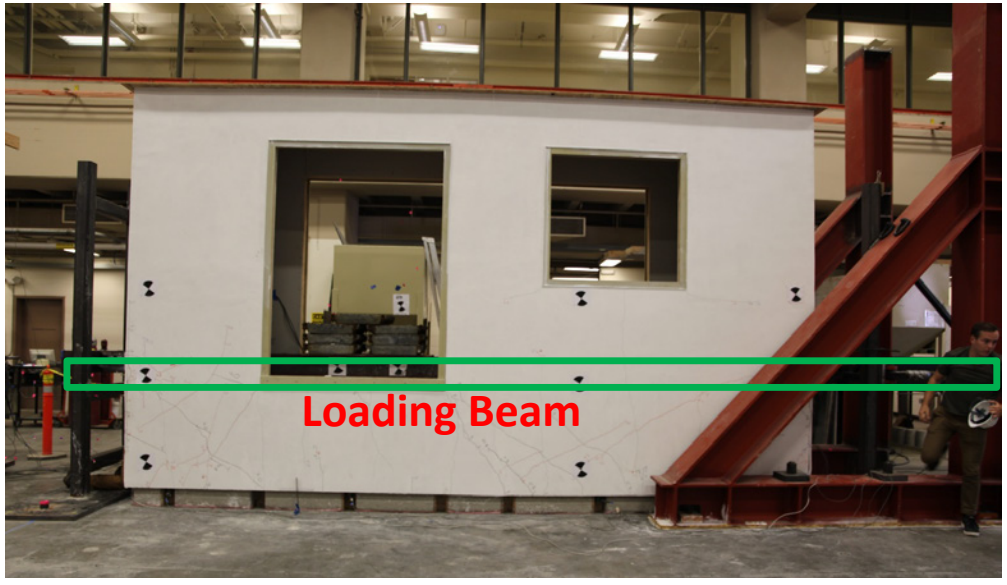
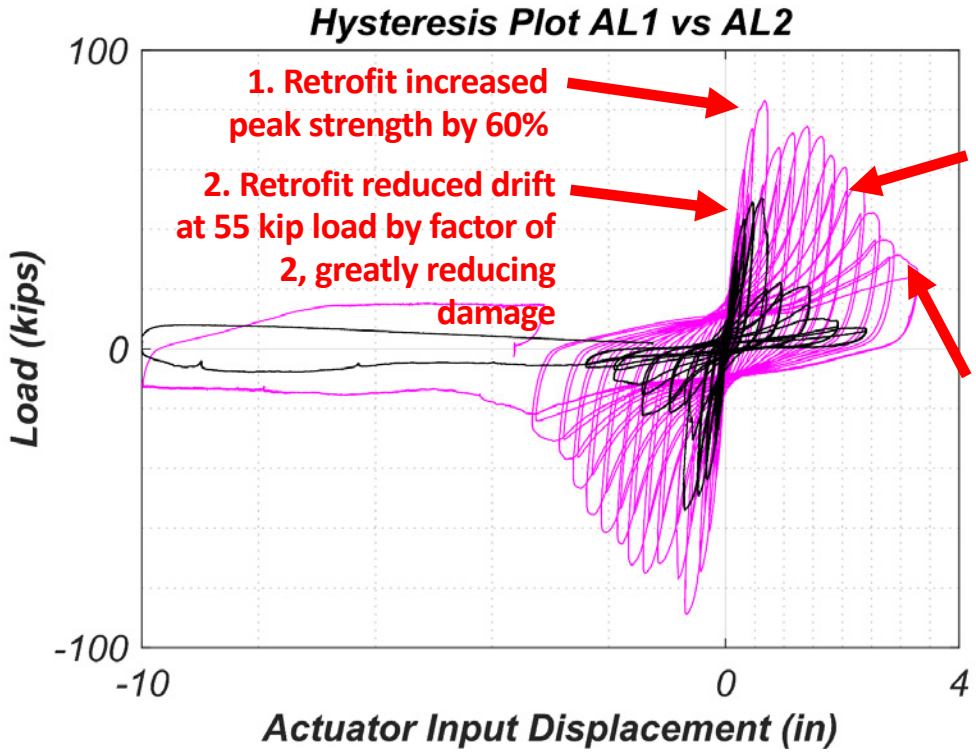
UCB – Cripple Wall Large Component



A

UCB - With and Without Cripple Wall Retrofit; Example result



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Computer Simulations

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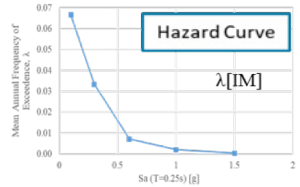
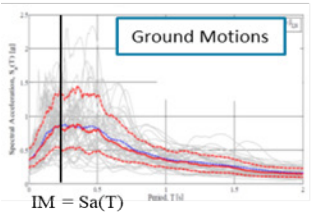
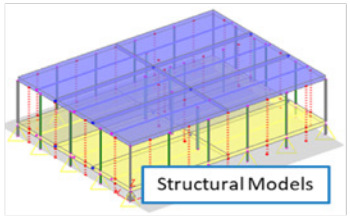
Numerical Studies

Building Variants

Existing Retrofit



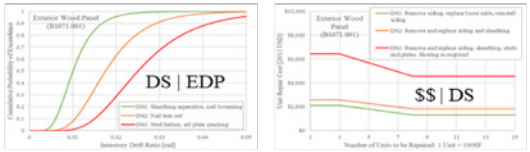




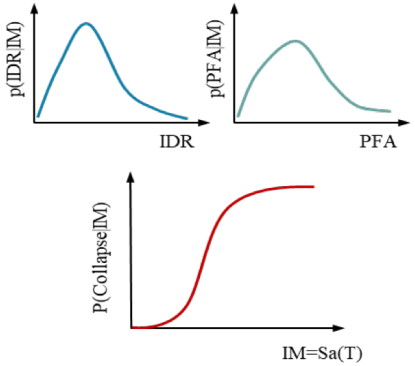
Define Damageable Inventory

- Exterior wall material
- Interior wall material
- Number of interior walls

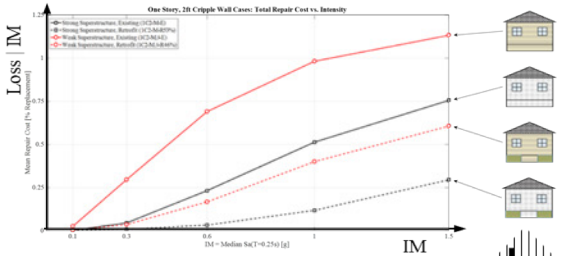
Assign Damage Fragilities and Consequence Functions



EDP Response and Collapse Fragility



Estimate Seismic Performance



FEMA P-58 Process

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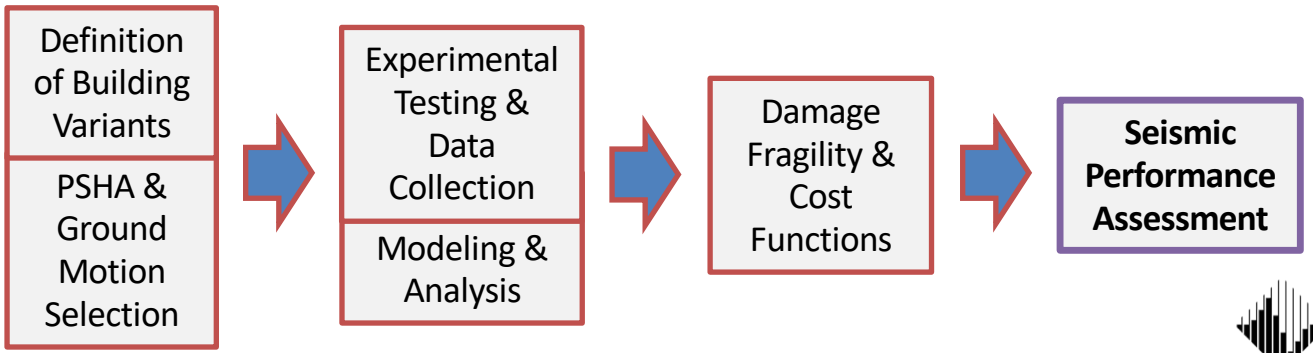
Numerical Studies

- 128 variant and site combinations analyzed (so far)
- ~92,000 nonlinear response (time) history analyses
- ~3.8M simulations of damage and loss
- Parallel processing on HPC cluster reduced run time to 4.5 weeks (vs. 4 years on single CPU)



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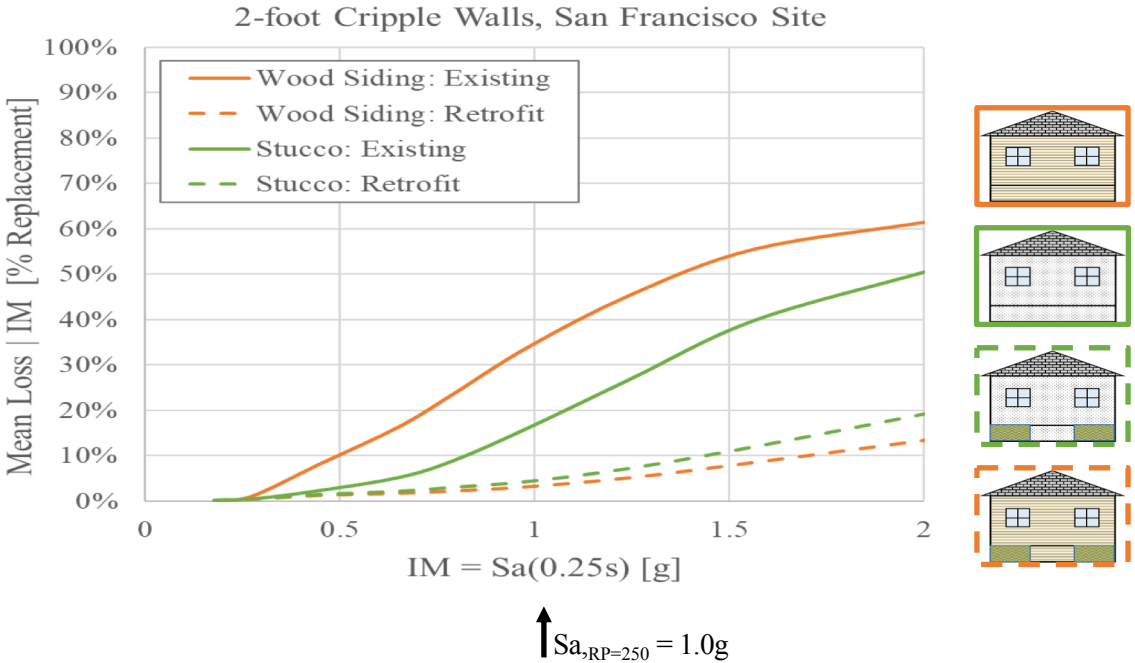
Numerical Studies: An Example



Loss versus Intensity (San Francisco Site)

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Summary

- Project is progressing very well
- Multiple PEER reports are being drafted
- All reports will be published by April 17, 2020
- Two specific “final” reports will also be published
  - Technical final report summarizing technical findings of the project
  - A shorter report for non-technical and non-research audience
- A web site for the project is being developed to post all data, reports, backup documents
- And the summary in few words…

Retrofit is very effective!

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Thank You!


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