Collapse Simulation of Shear-Dominated Reinforced Masonry Wall Systems

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Most Reinforced Masonry Buildings are Low-rise

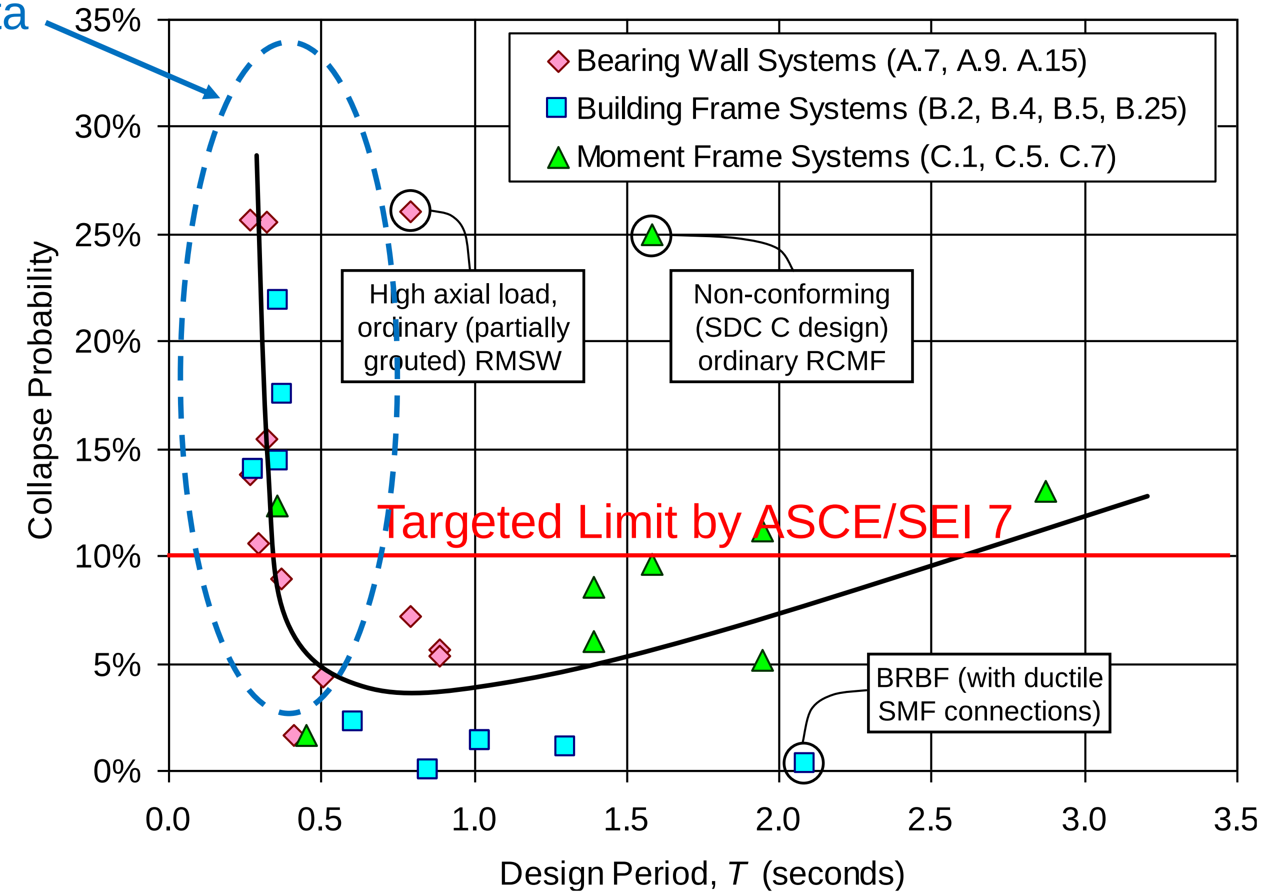
NIST GCR 14-917-31 (NIST 2014)

- Wall elements have low aspect ratios.
- Failure could be dominated by shear even for code-compliant special reinforced masonry shear wall systems.

2011 Christchurch EQ, Ingham & Centeno (2014)

Collapse Probability under MCE

Contradicts field data

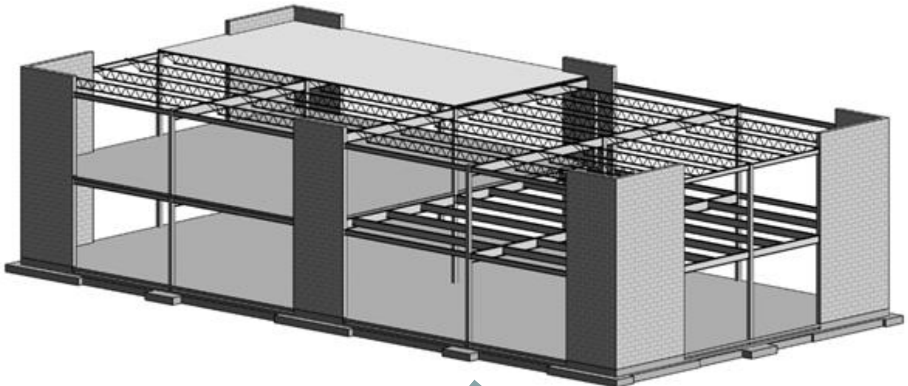


Results based on overly conservative simplified models

NIST GCR 12-917-20, Tentative Framework for Development of Advanced Seismic Design Criteria for New Buildings (2012)

ATC 116 Study to Resolve Short-period Building Paradox

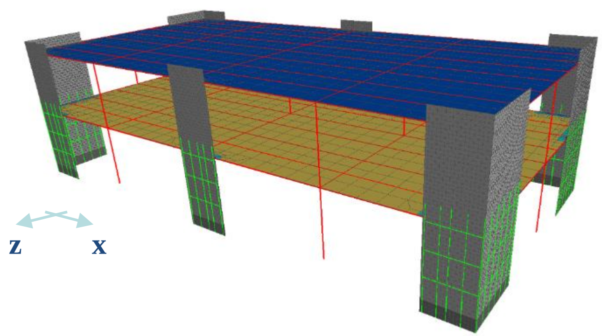
Commercial Reinforced Masonry Building Archetype (6 total)



FEMA P-695

Incremental dynamic analyses to assess collapse probability

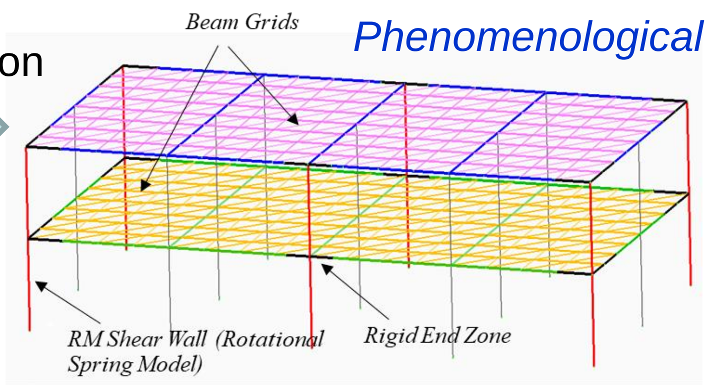
Refined finite element model
(LS-DYNA)



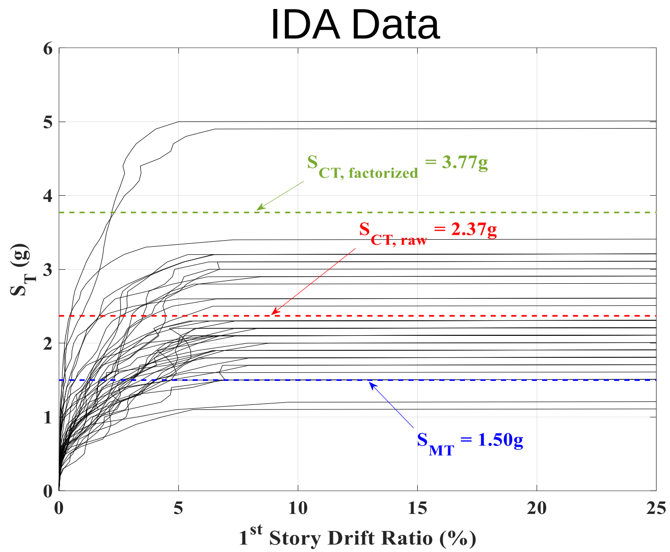
calibration

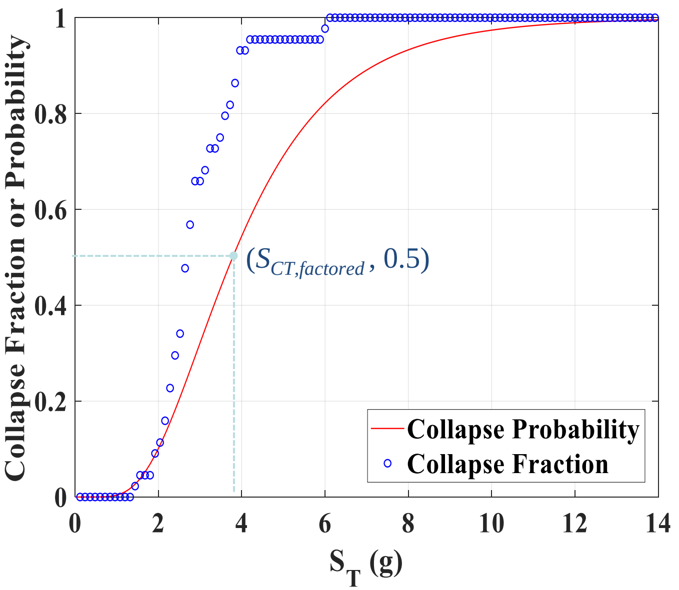
Simplified frame model
(OpenSEES)

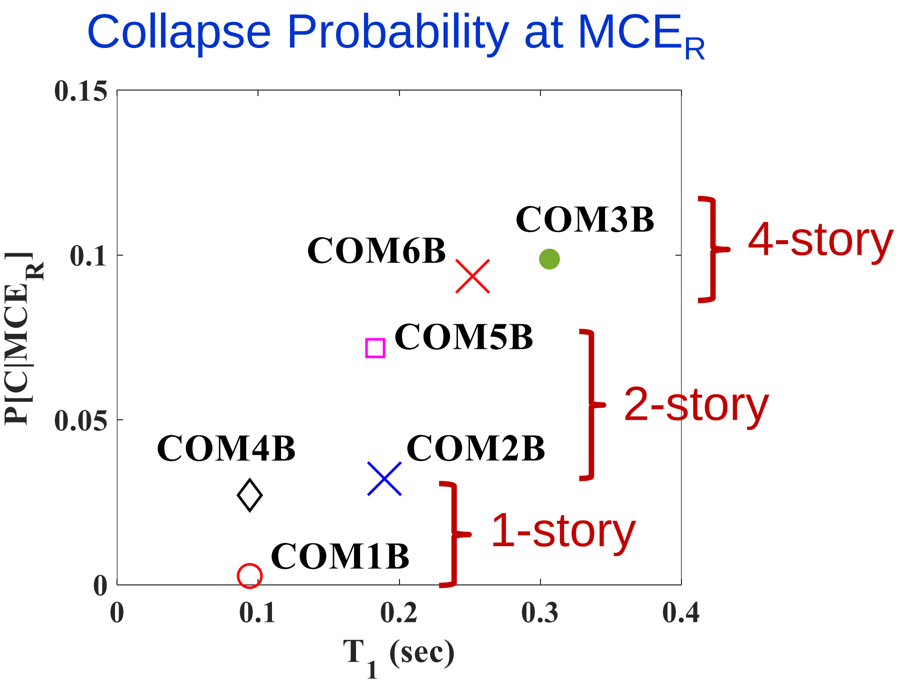
Phenomenological



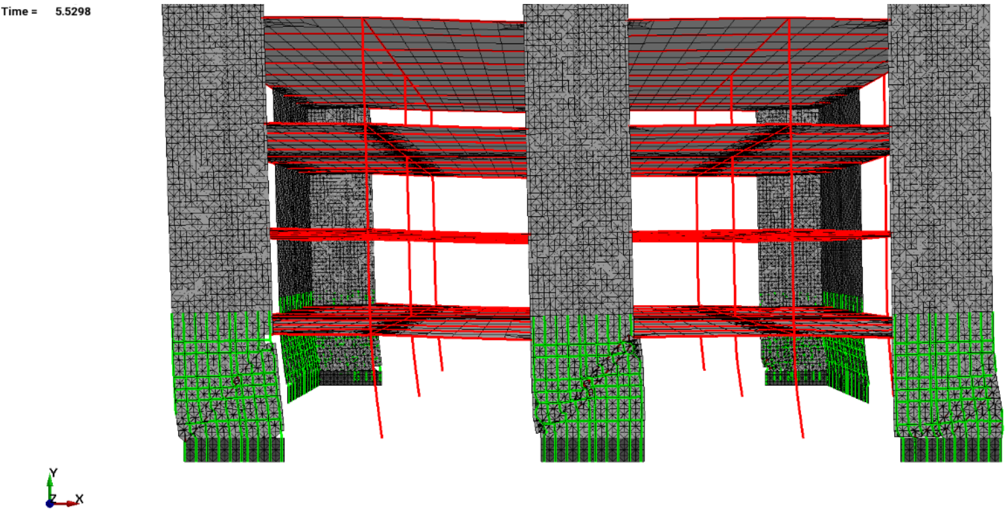
ATC 116 Study to Resolve Short-period Building Paradox

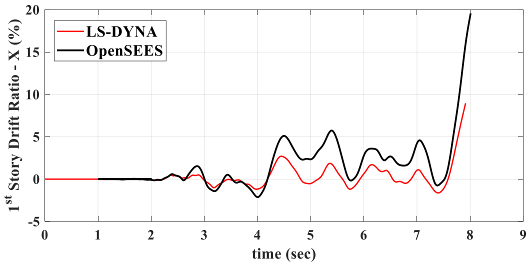


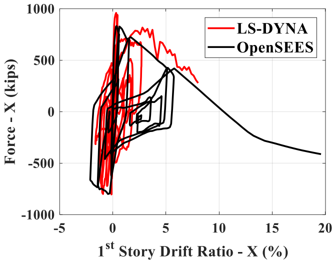




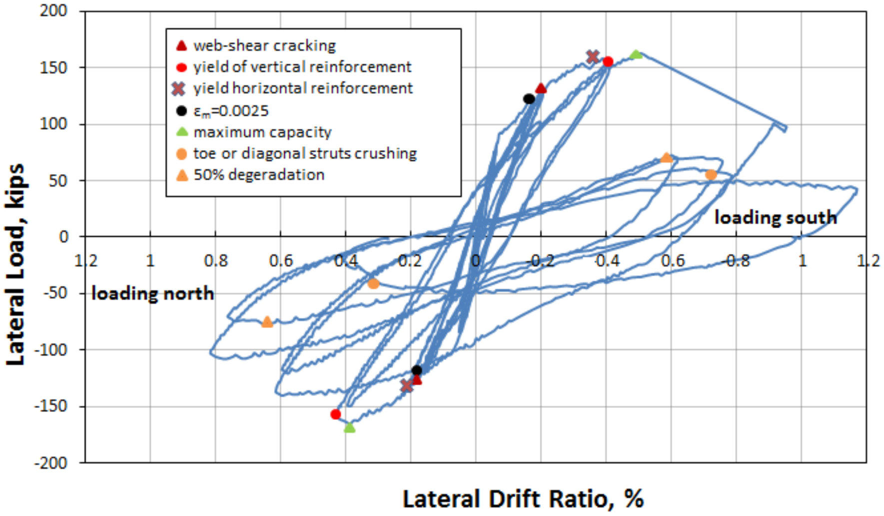
Are the results trustworthy?







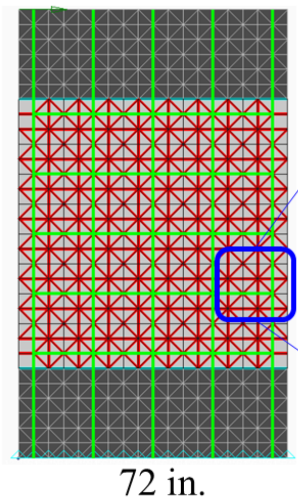
Quasi-static Test by Ahmadi, Ph.D. Dissertation, UT-Austin (2012)

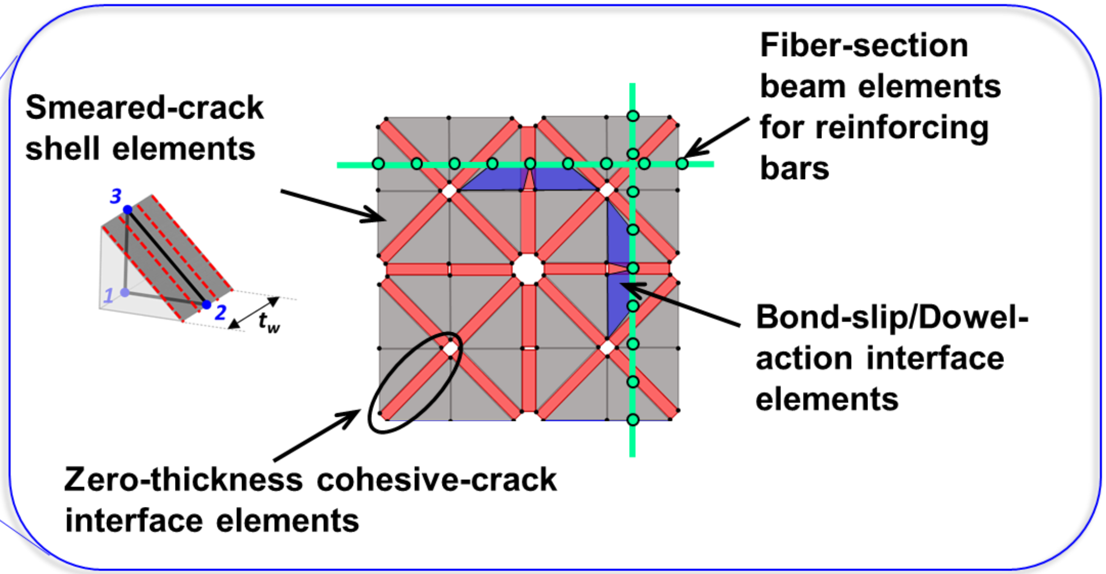


Detailed FE Models

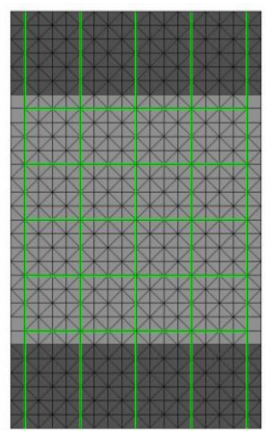
Koutras, Ph.D. Dissertation, UC San Diego (2019)

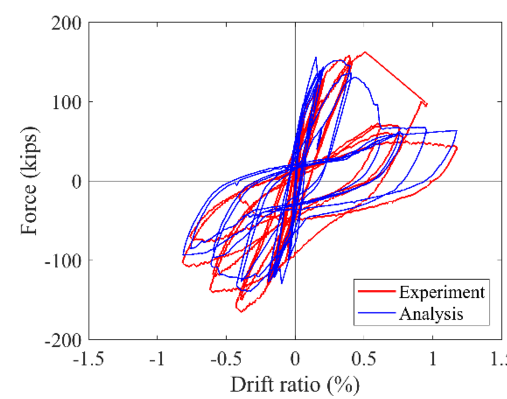
FE discretization of a RM wall





Only validated by experimental data with limited drift levels





Goals of NHERI Project

Motivation of the Study:

- Lack of experimental data on RM walls tested to collapse.
- Lack of experimental data on shear behavior of flanged RM walls.
- Lack of experimental data on behavior of wall systems at incipient collapse.
- Lack of reliable simplified numerical models to simulate behavior of shear-dominated wall systems.

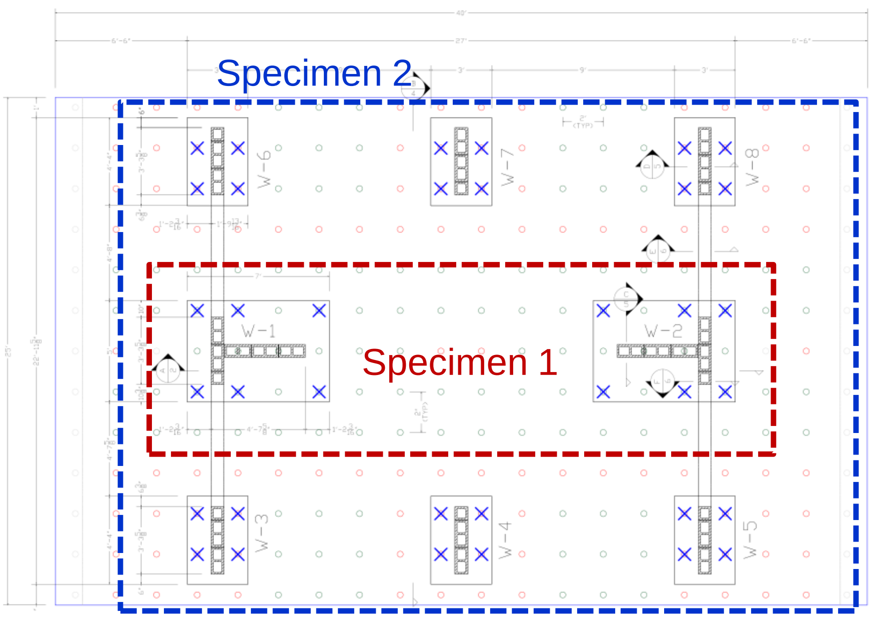
Main Objectives:

- Validation of computational models for collapse simulation.
- Development of computationally efficient simplified numerical models to analyze shear-dominated wall systems.

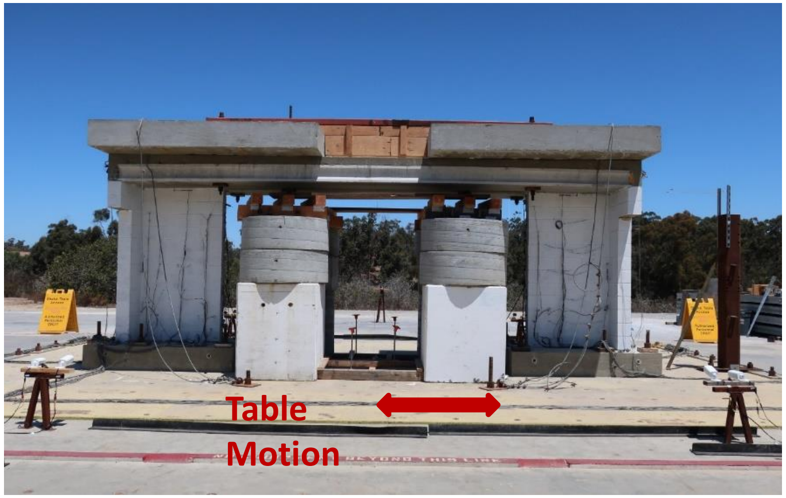
Additional Goals and Scope

Additional Goals:

- Quantify the contribution of wall flanges to the shear strength and ductility of walls.
- Quantify the influence of horizontal diaphragms.
- Quantify the influence of orthogonal walls.



Wall Specimen 1



Wall Specimen 2

Design Considerations

- The two wall specimens were to be tested to near collapse.
- They satisfied the prescriptive design requirements of TMS 402-16 for special RM walls.
- The T-walls in the two specimens had the same design and carried the same gravity load.
- Specimen 1 had the same seismic weight as Specimen 2 but a lower roof weight to have the same gravity load.

Dynamic Similitude

Specimen 1	
Roof Weight (W_1)	55 kips
Time Scale Factor ($\sqrt{W_{1E}/W_{2E}}$)	0.65
Acceleration Scale Factor (W_{2E}/W_{1E})	2.36

Specimen 2	
Roof Weight (W_2)	135 kips
Time Scale Factor	1
Acceleration Scale Factor	1

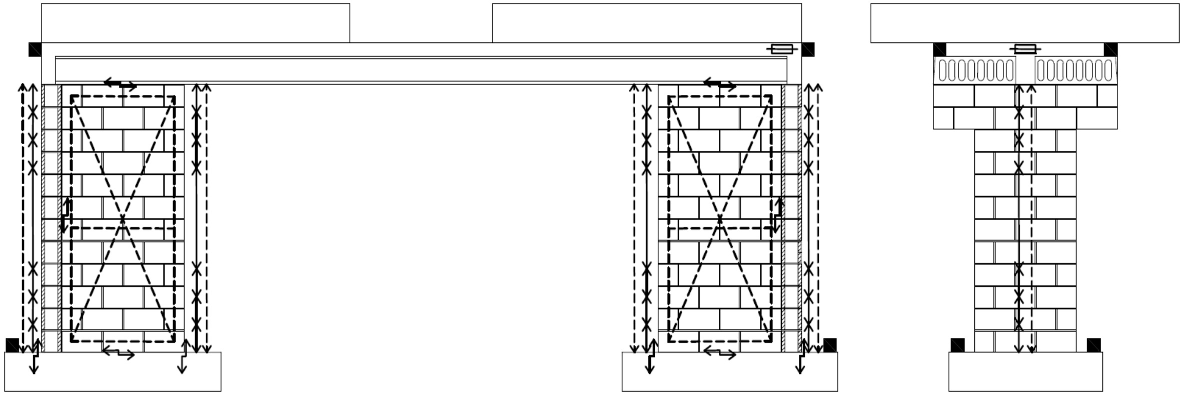
W_{1E} and W_{2E}: expected roof weights

Construction of Specimen 2

Masonry Walls Built by Apprentice Masons

Instrumentation

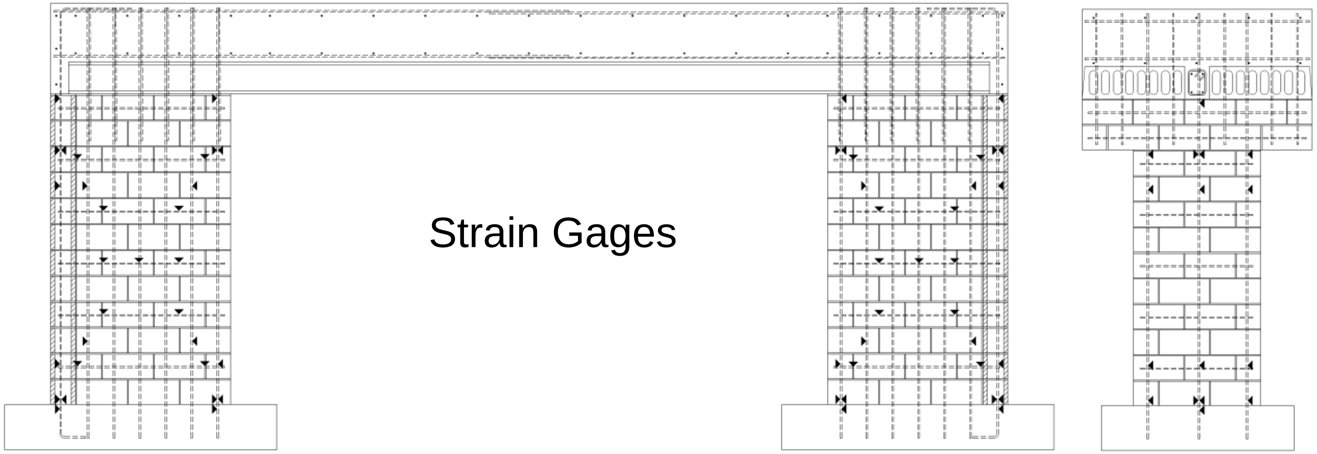
Wall Specimen 1



(a) (b)

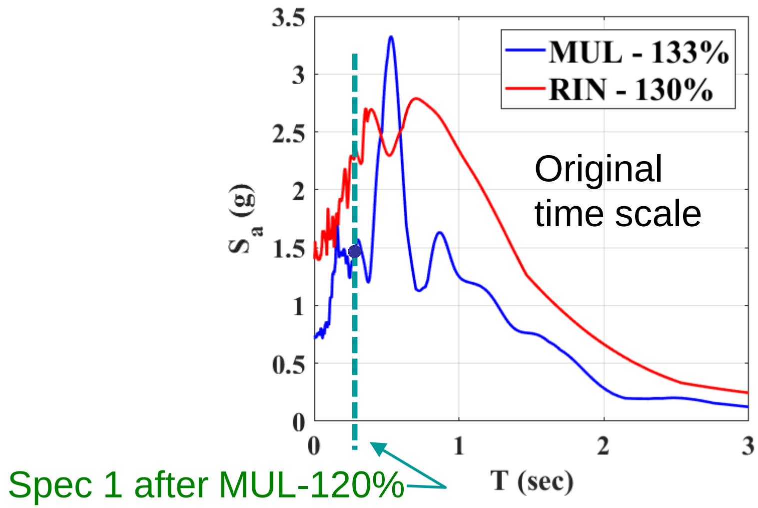
■ Accelerometer ↔ ---- Linear Pot and Stringpot ↔ Linear Pot for Uplift and Sliding

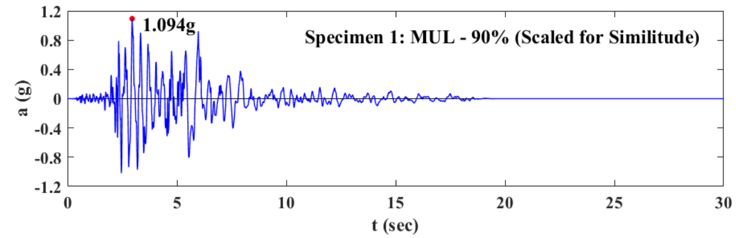
Stringpot measuring horizontal displacement of the roof with respect to the shake-table platen

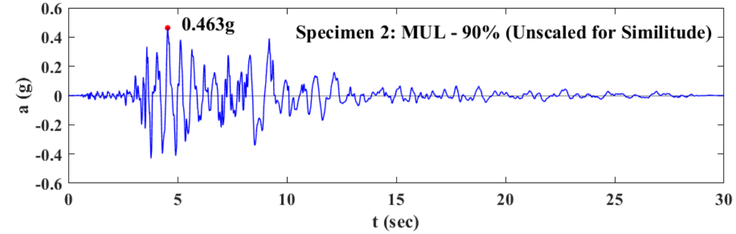


Ground Motion Records

Mulholland and Rinaldi Records, 1994 Northridge Earthquake





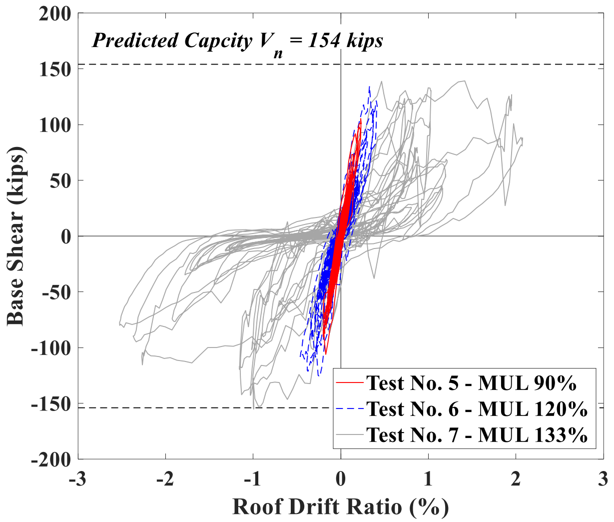


Scaling Determined by Pretest FE Analyses

Specimen 1			Specimen 2		
Test ID	Input Motion	Period After Test (sec)	Test ID	Input Motion	Period After Test (sec)
	N/A	0.072		N/A	0.090
1	MUL-45%	0.072	1	MUL-45%	0.090
2	MUL-45%	0.074	2	MUL-90%	0.097
3	MUL-90%	0.090	3	MUL-120%	0.121
4	MUL-90%	0.095	4	MUL-90%	0.123
5	MUL-90%	0.107	5	MUL-133%	0.164
6	MUL-120%	0.166	6	MUL-160%	0.328
7	MUL-133%	0.751	7	RIN-130%	-

Test of Specimen 1

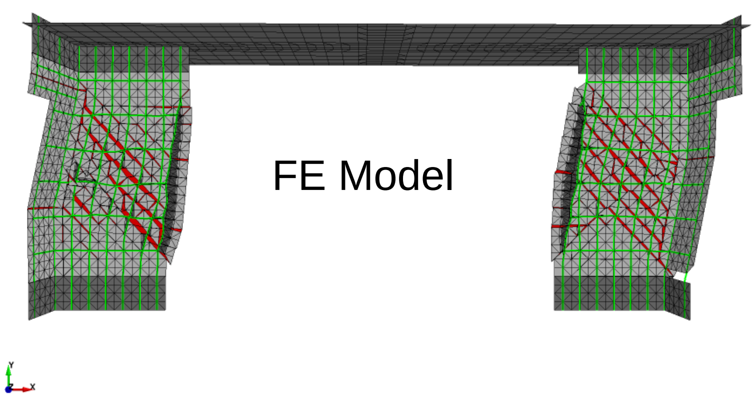
MUL 133%



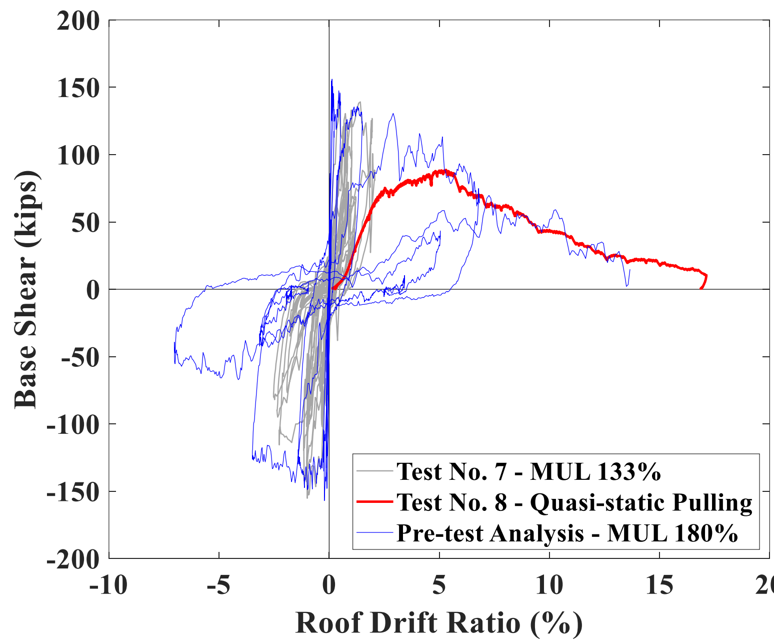
After MUL 133%

Test of Specimen 1

Quasi-static Pull Test

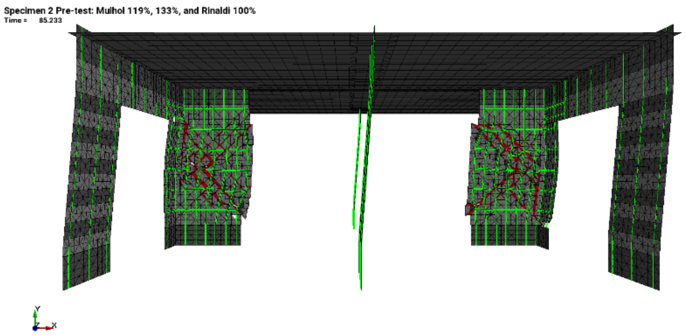


Comparison w/ Pretest Analysis

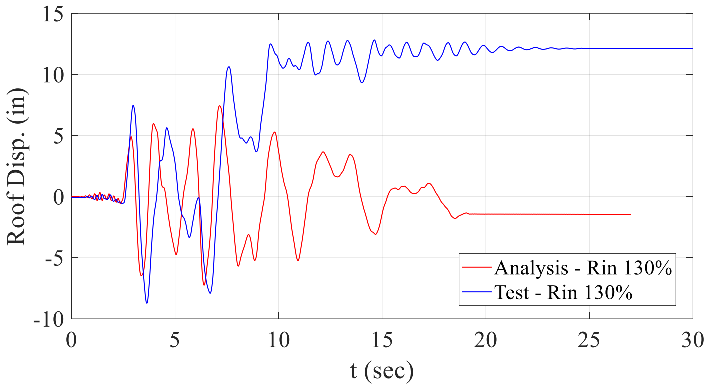


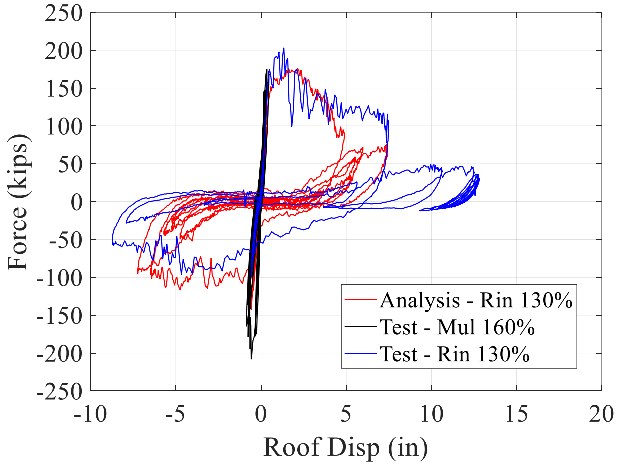
Test of Specimen 2

Rinaldi 130%

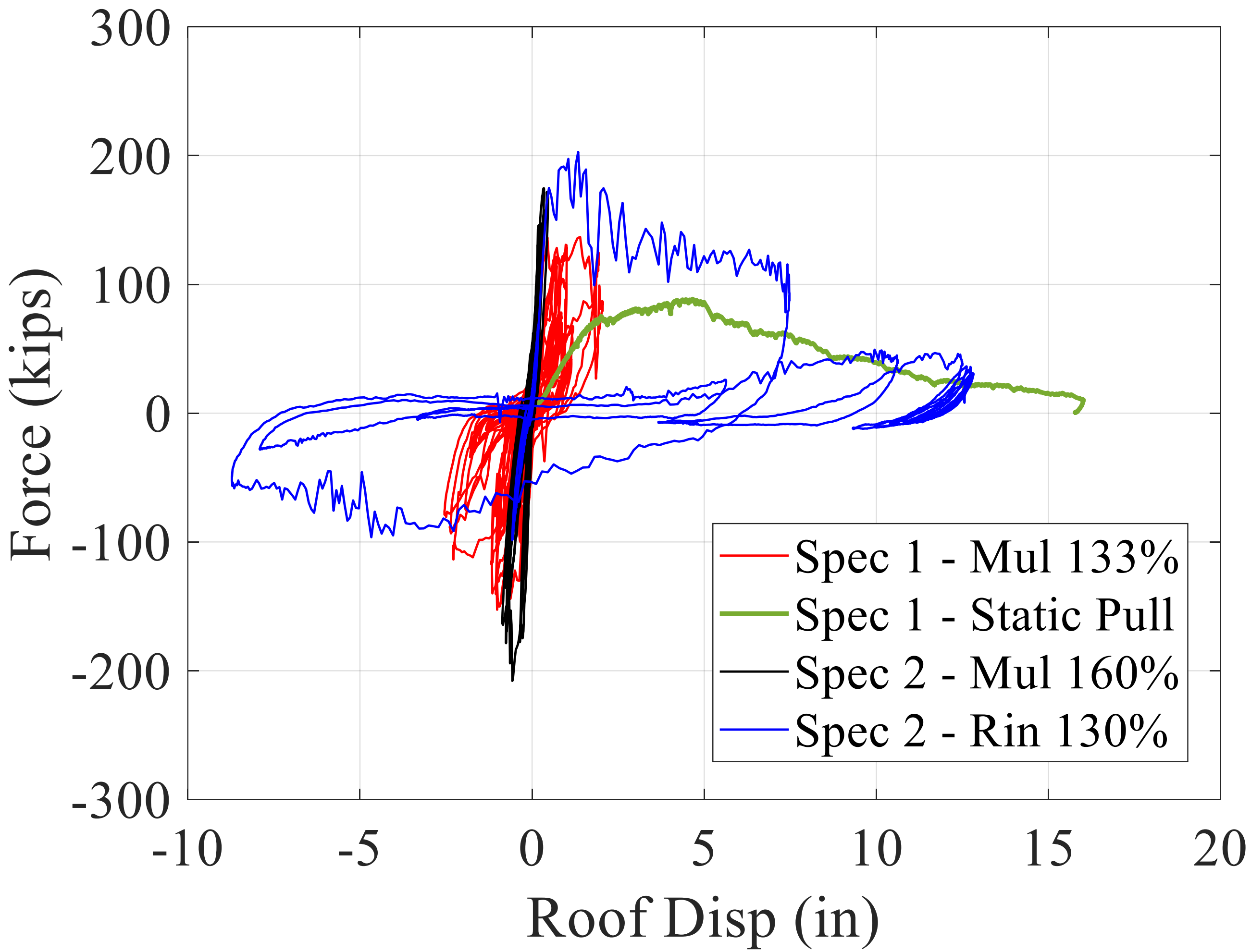


Comparison w/ Pretest Analysis





Comparison of Two Specimens



Additional Work

- Development of more physics-based simplified numerical models to simulate nonlinear shear as well as flexural critical wall behavior.
- Additional numerical studies with detailed FE models to investigate the influence of wall flanges on the shear strength and ductility.

Thank you!