NHERI Lehigh Facility User Experience
Seismic Hazard Mitigation with Pressurized Sand Dampers and their Response in Extreme Temperatures

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November 16, 2023

NHERI Lehigh Experimental Facility – Researchers Workshop

SMU-Lehigh-UT Tyler Collaboration

$$\underbrace{\text{Prof. J.M. Ricles} \qquad \text{Prof. N. Makris}}_{\text{PIs}}$$

SMU-Lehigh-UT Tyler Collaboration

Prof. J.M. Ricles   Prof. N. Makris

$\underbrace{\hspace{20em}}$

PIs

Dr. K. Kalfas   Dr. L. Cao

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Researchers

SMU-Lehigh-UT Tyler Collaboration

Prof. J.M. Ricles　　Prof. N. Makris

PIs

Dr. K. Kalfas　　Dr. L. Cao

Researchers

Dr. T. Marullo

IT Expert

SMU-Lehigh-UT Tyler Collaboration

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Researchers

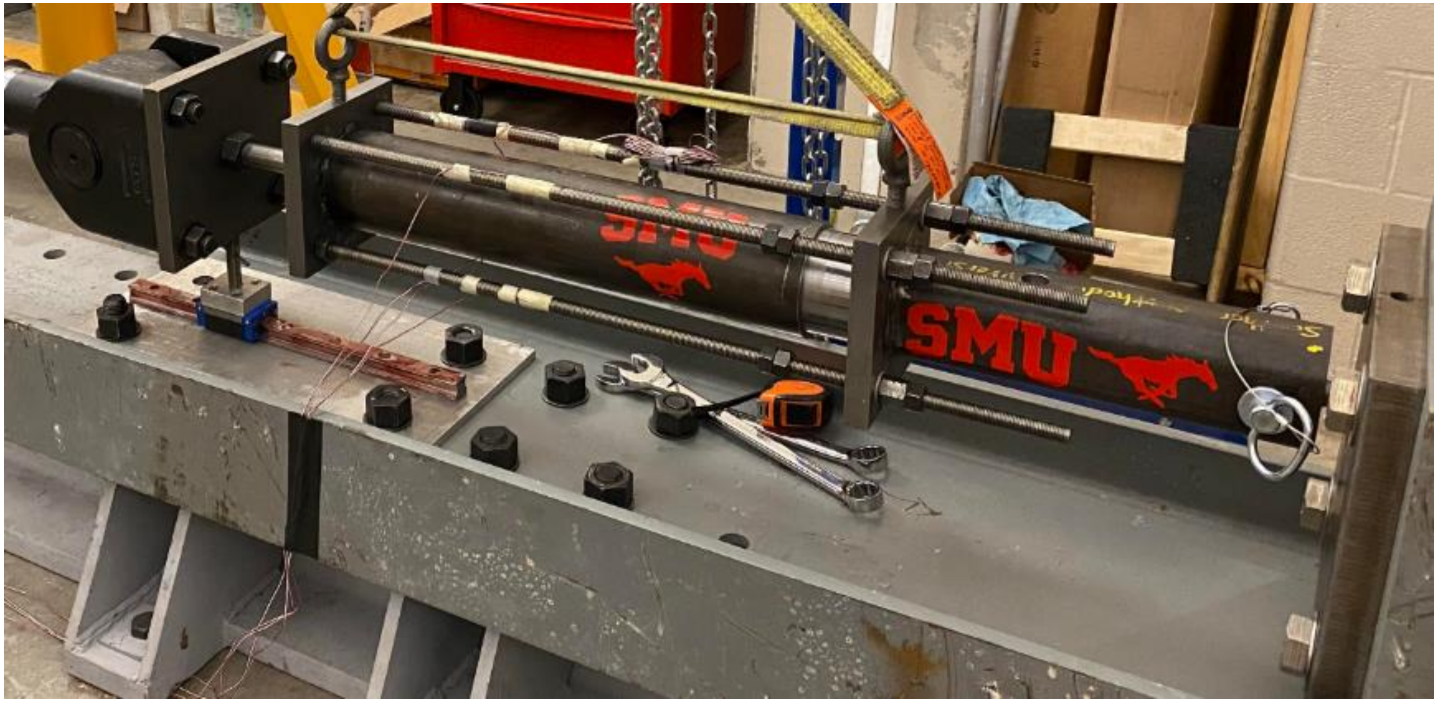
Dr. T. Marullo

IT Expert

SMU & ATLSS Research Center Staff and Technicians

How it started?

Quest for velocity-independent (hysteretic) dissipation



Widely used response-modification devices

Response modification devices to serve sustainable infrastructure

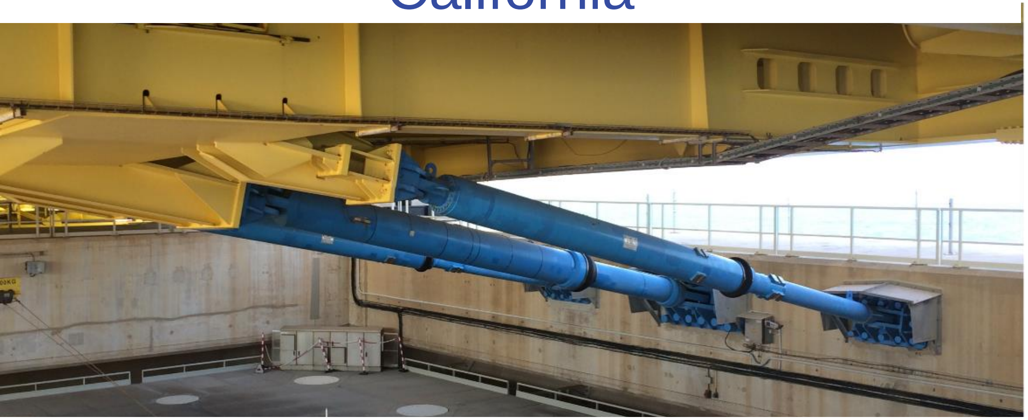
Retrofit of Benicia-Martinez Bridge, California

Seismic Retrofit of Richmond-San Rafael Bridge, California

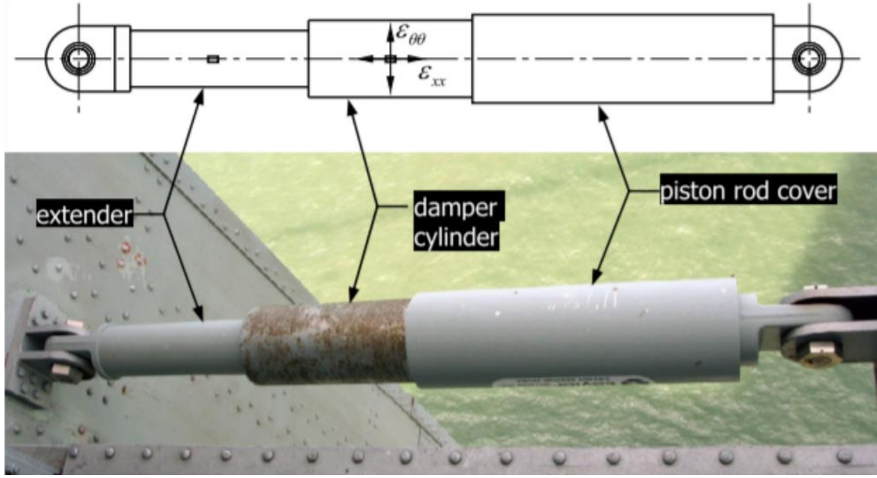
Widely used response-modification devices: Fluid dampers

San Diego Coronado Bridge, California

91/5 overcrossing, southern California



Rion-Antirion cable-stayed bridge, Western Greece



San Francisco-Oakland Bay Bridge, Northern California

Widely used response-modification devices: BRB & ADAS

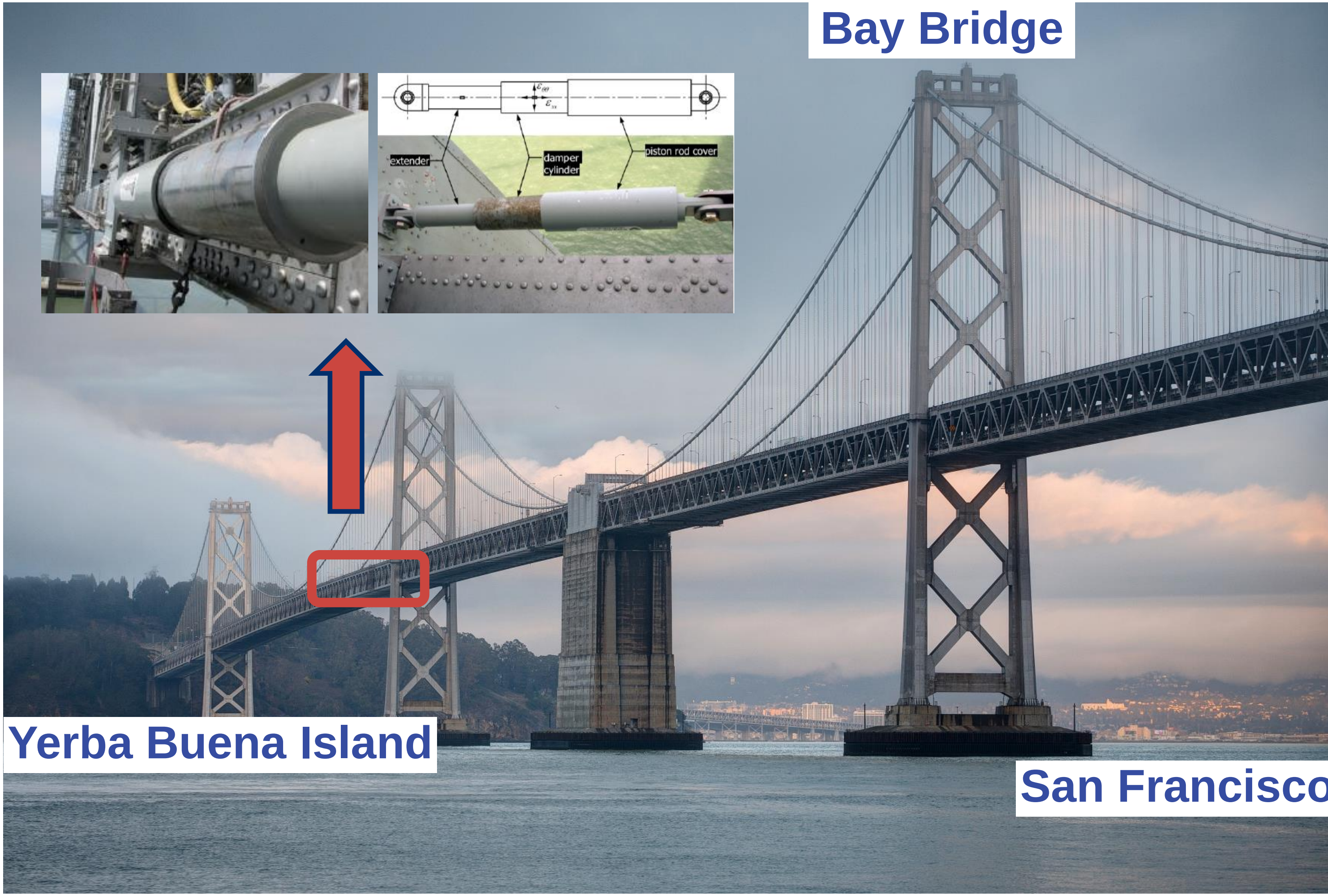
Kaiser Santa Clara Medical, California

Hildebrand Hall -- UC Berkeley, California

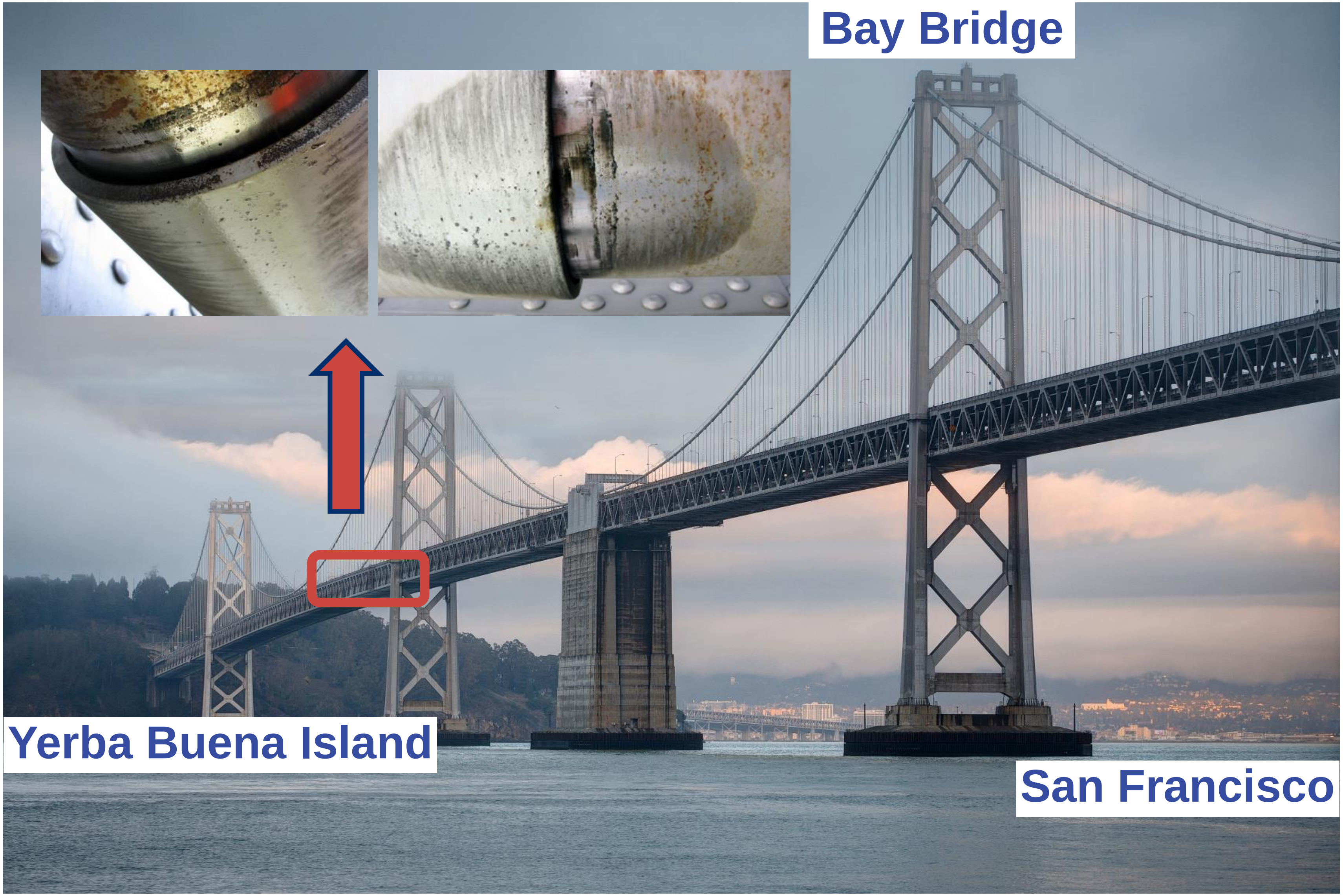
Salt Lake City, Utah

Dalian University of technology, China

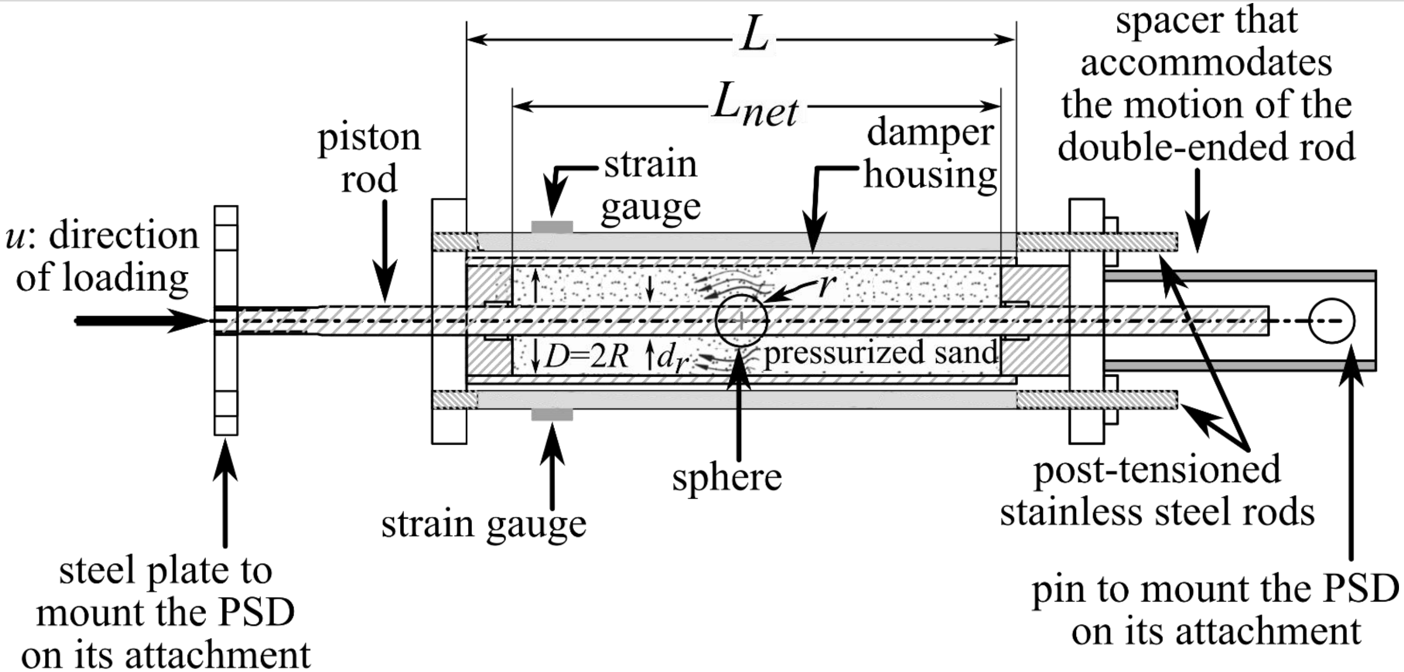
Bay Bridge (San Francisco) retrofitting scheme



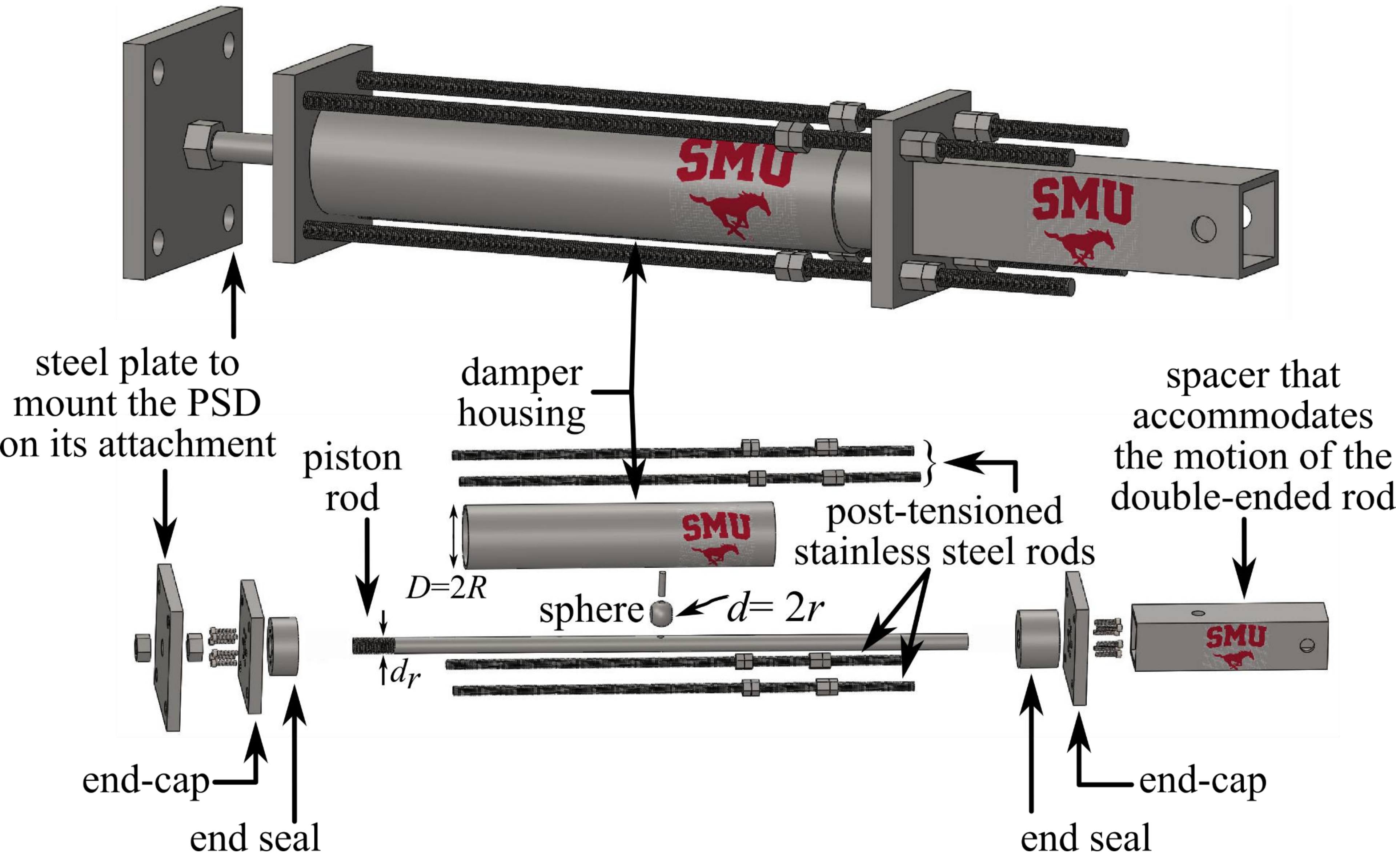
Bay Bridge (San Francisco) retrofitting scheme



Prototype Pressurized Sand Damper



Prototype Pressurized Sand Damper



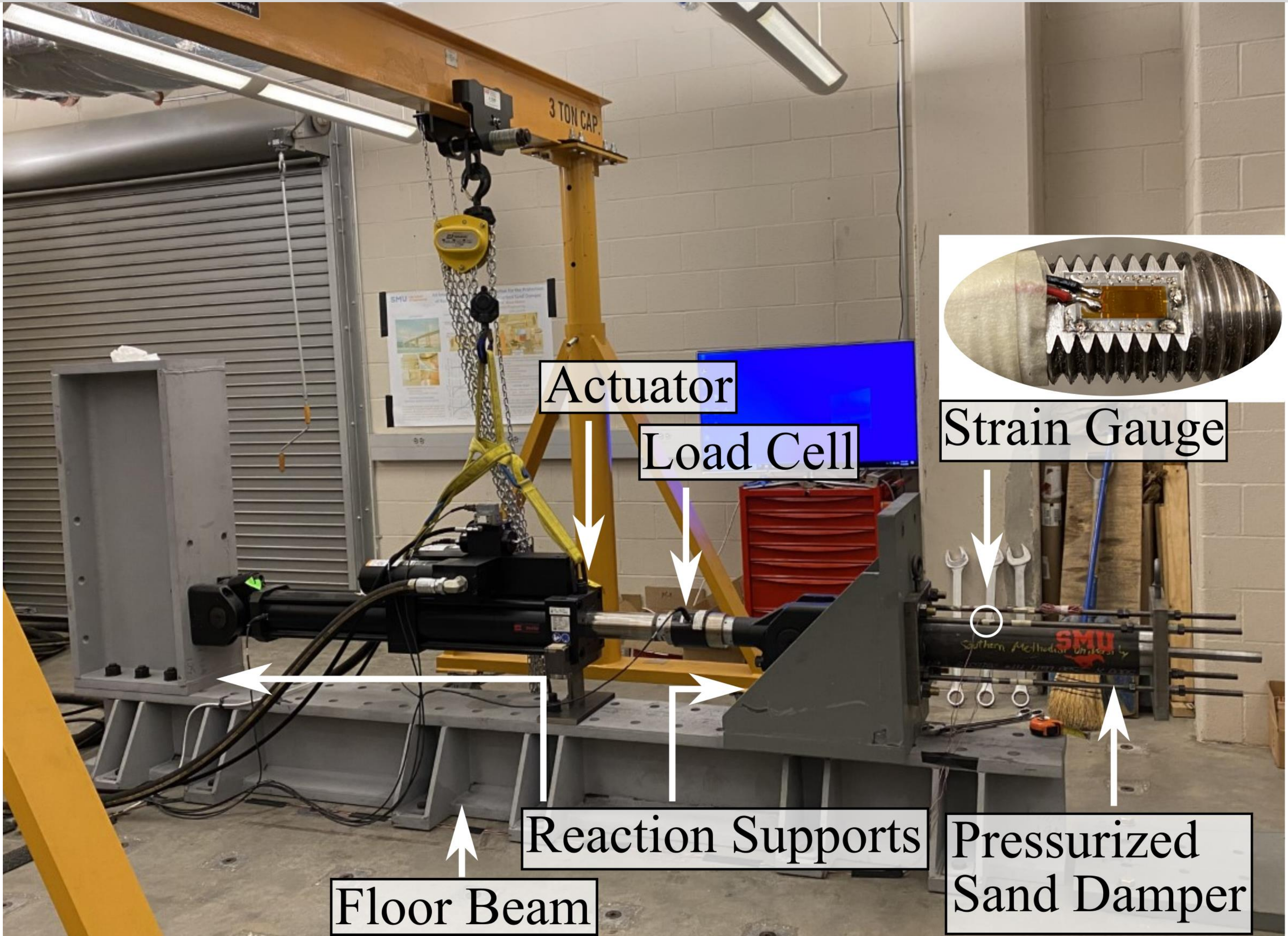
Pressurized Sand Damper — Experimental campaign

$$d = 2r = 2''; d = 2r = 2\,{}^{1}/_{4}''$$

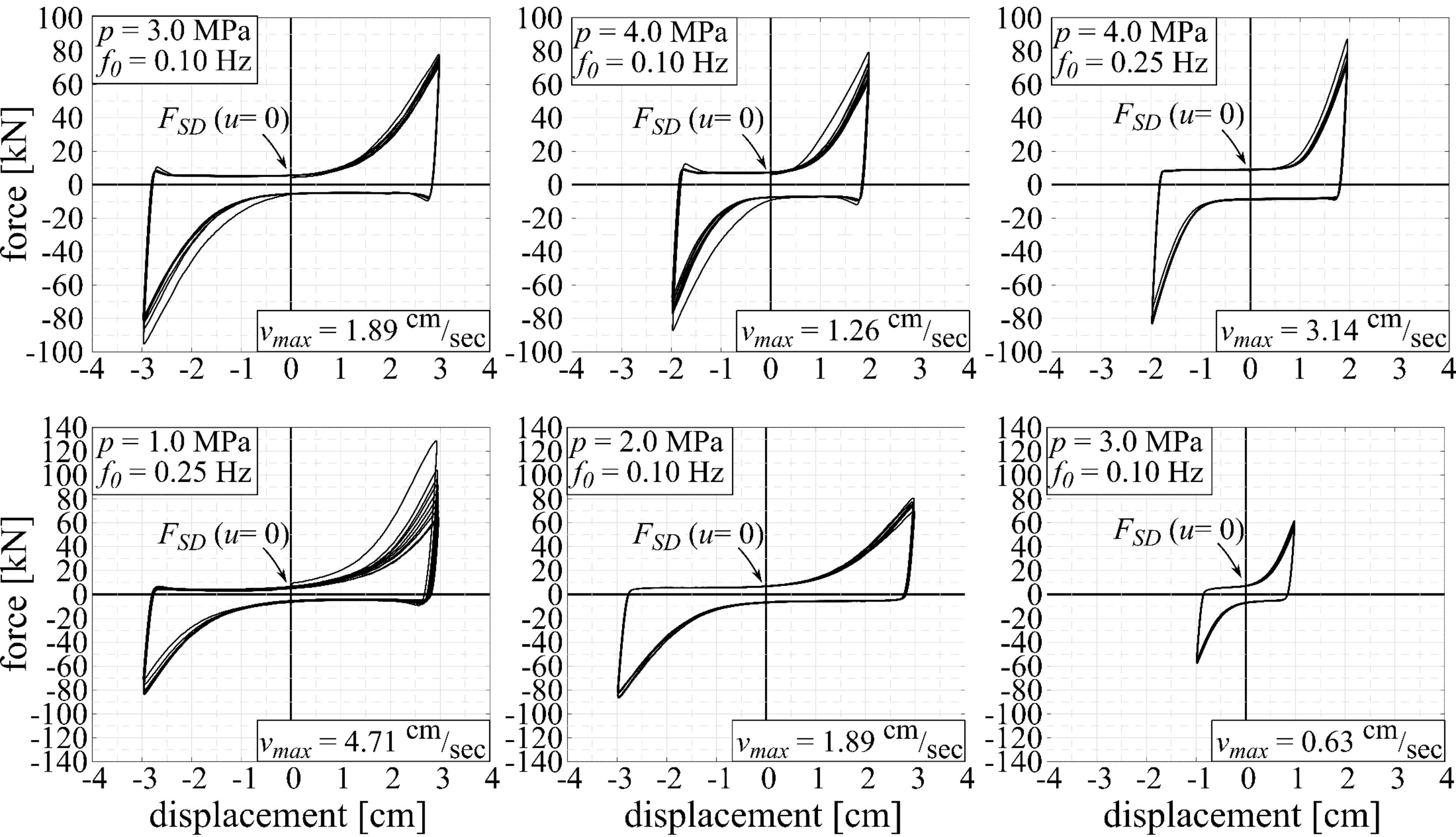
$$d_r = 1\,{}^{1}/_{4}''$$

- Tubes with different diameters and lengths
- Spheres with different diameters
- Subjected to different stroke amplitudes, pressure levels, cyclic frequencies

Pressurized Sand Damper — Experimental set up

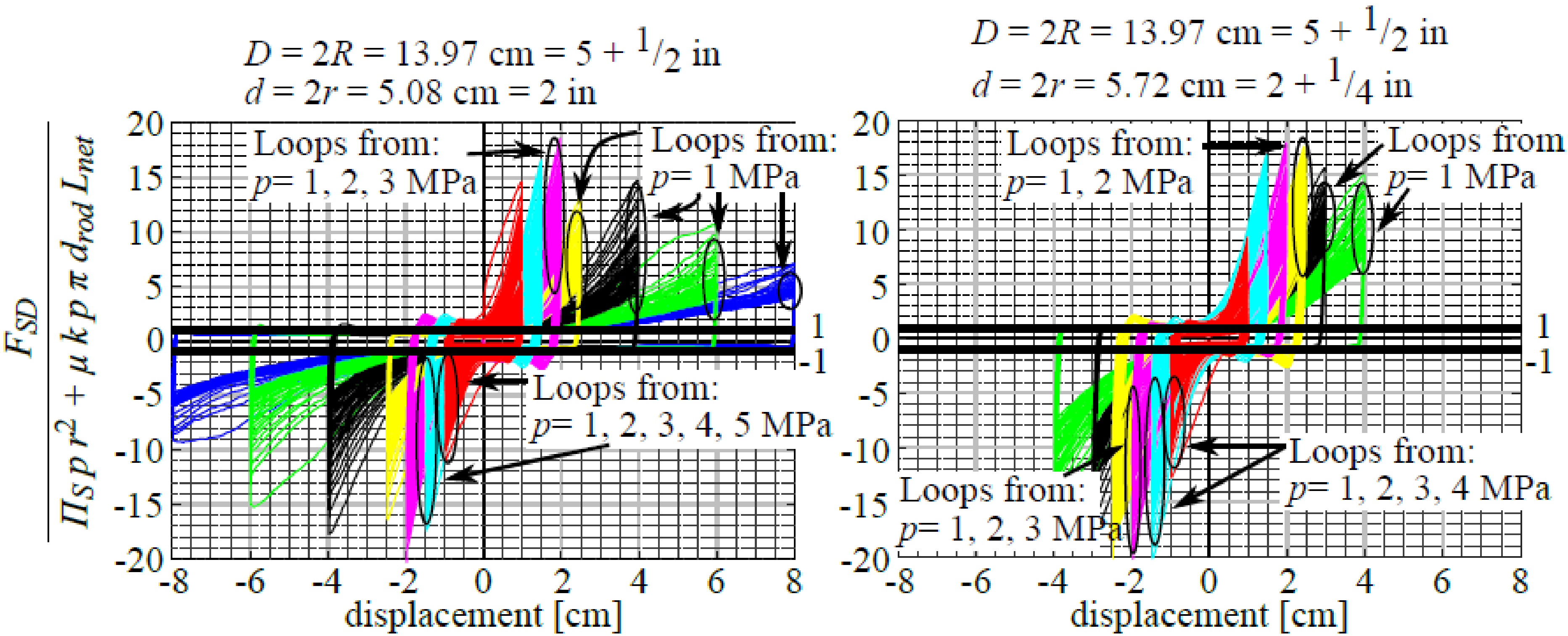


Behavior of the PSD



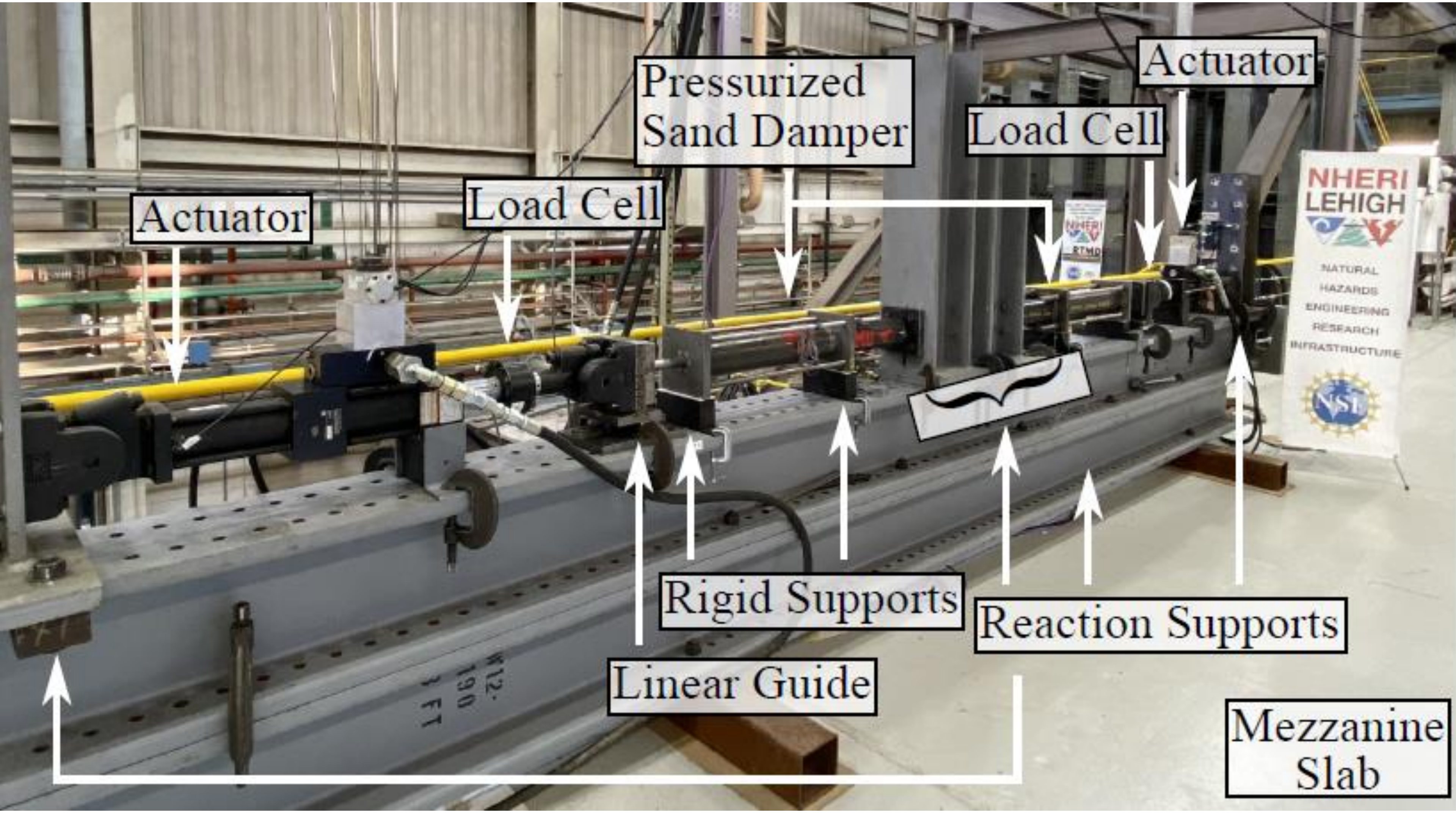
Normalized loops to the strength of the PSD, $F_{SD}(u=0) = \Pi_S p r^2 + \mu k p \pi d_{rod} L_{net}$

Master Curves



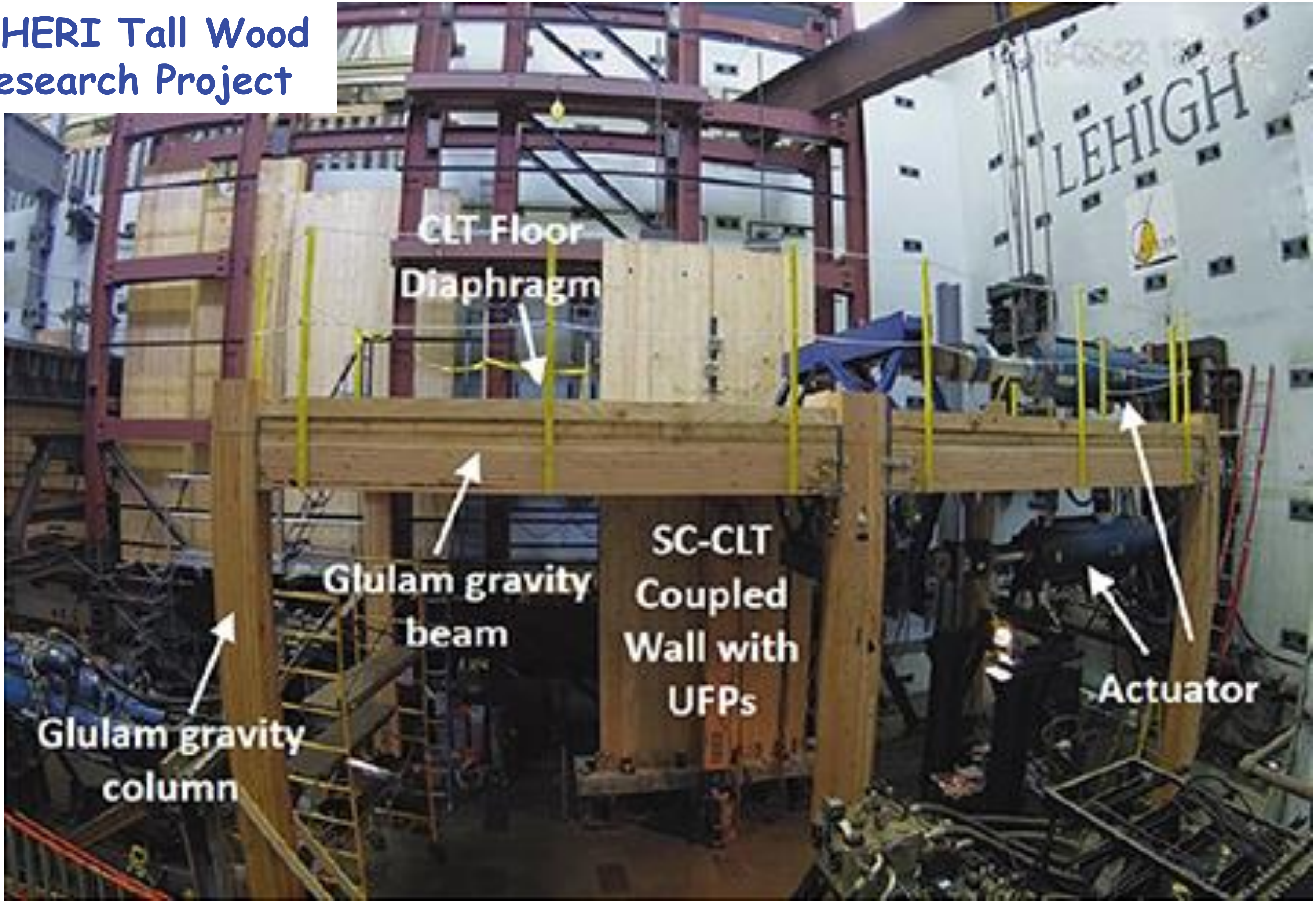
*Kalfas KN, N Makris, and U El Shamy. 2023. "Assessment of the effect of design parameters of pressurized sand-dampers from component testing." *ASCE - J Eng Mech*, **149**(**10**), pp: 04023072

Nonlinear real-time hybrid simulations of structural systems with pressurized sand dampers

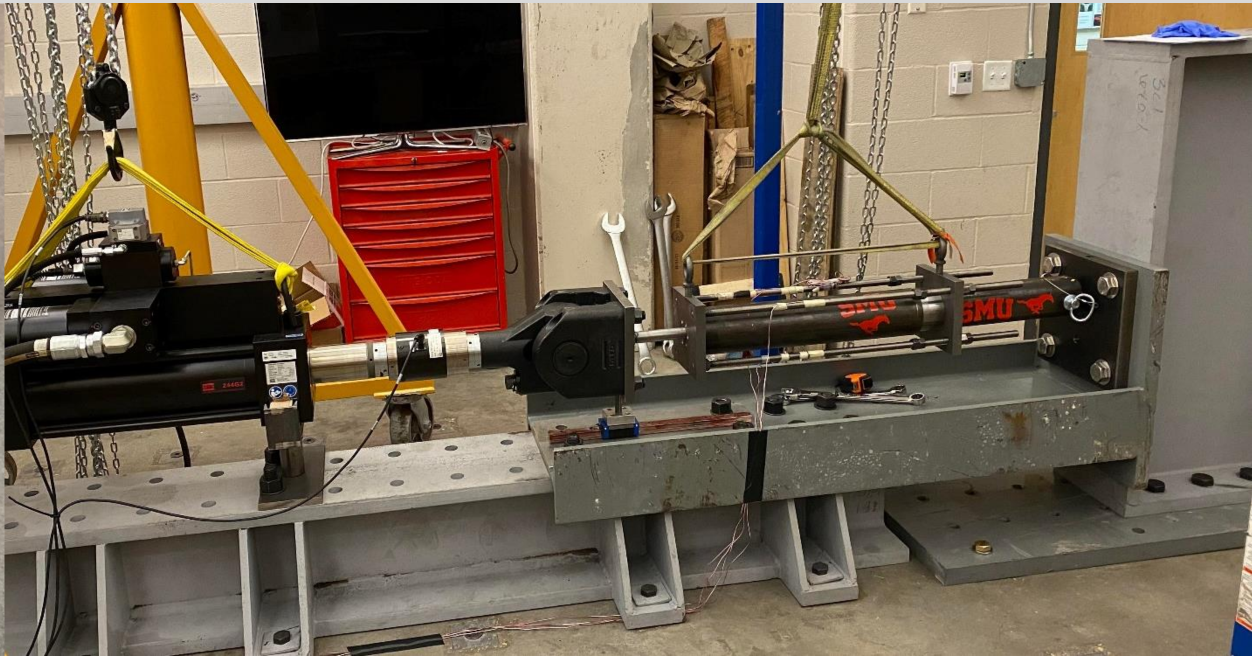


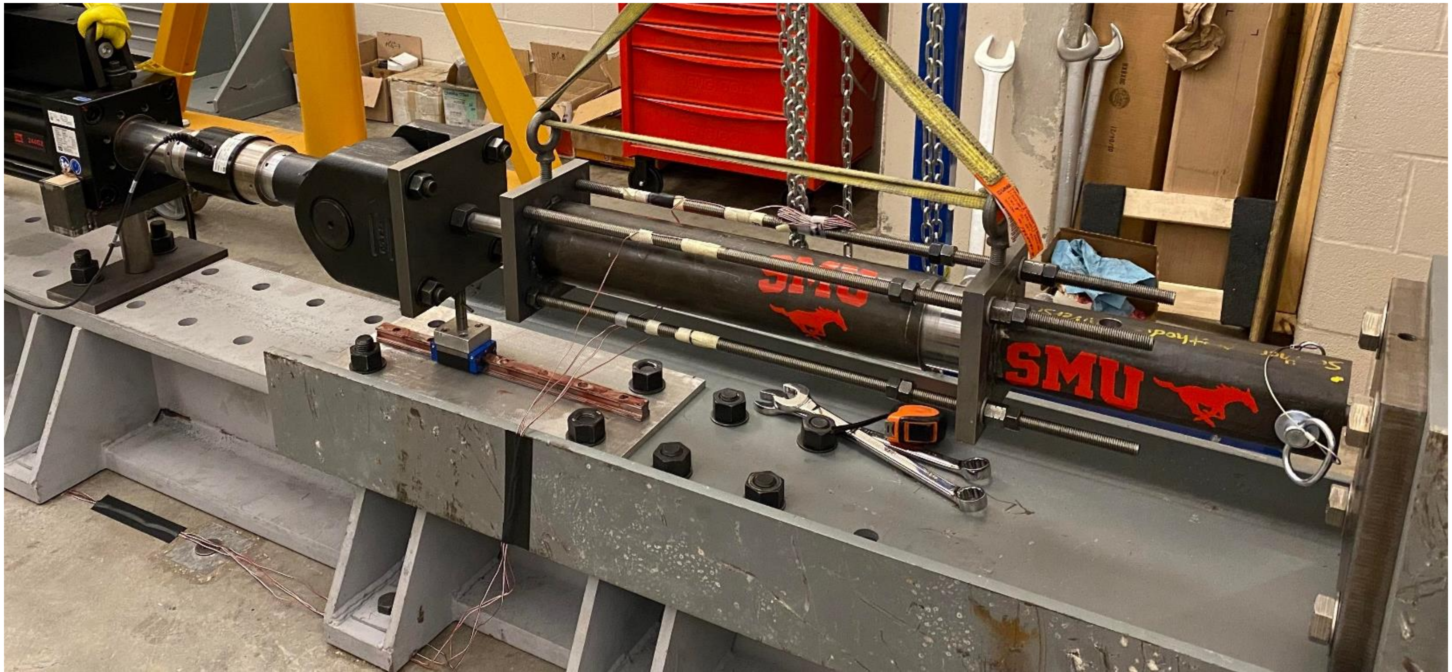
Nonlinear real-time hybrid simulations of structural systems with pressurized sand dampers

NHERI Tall Wood Research Project

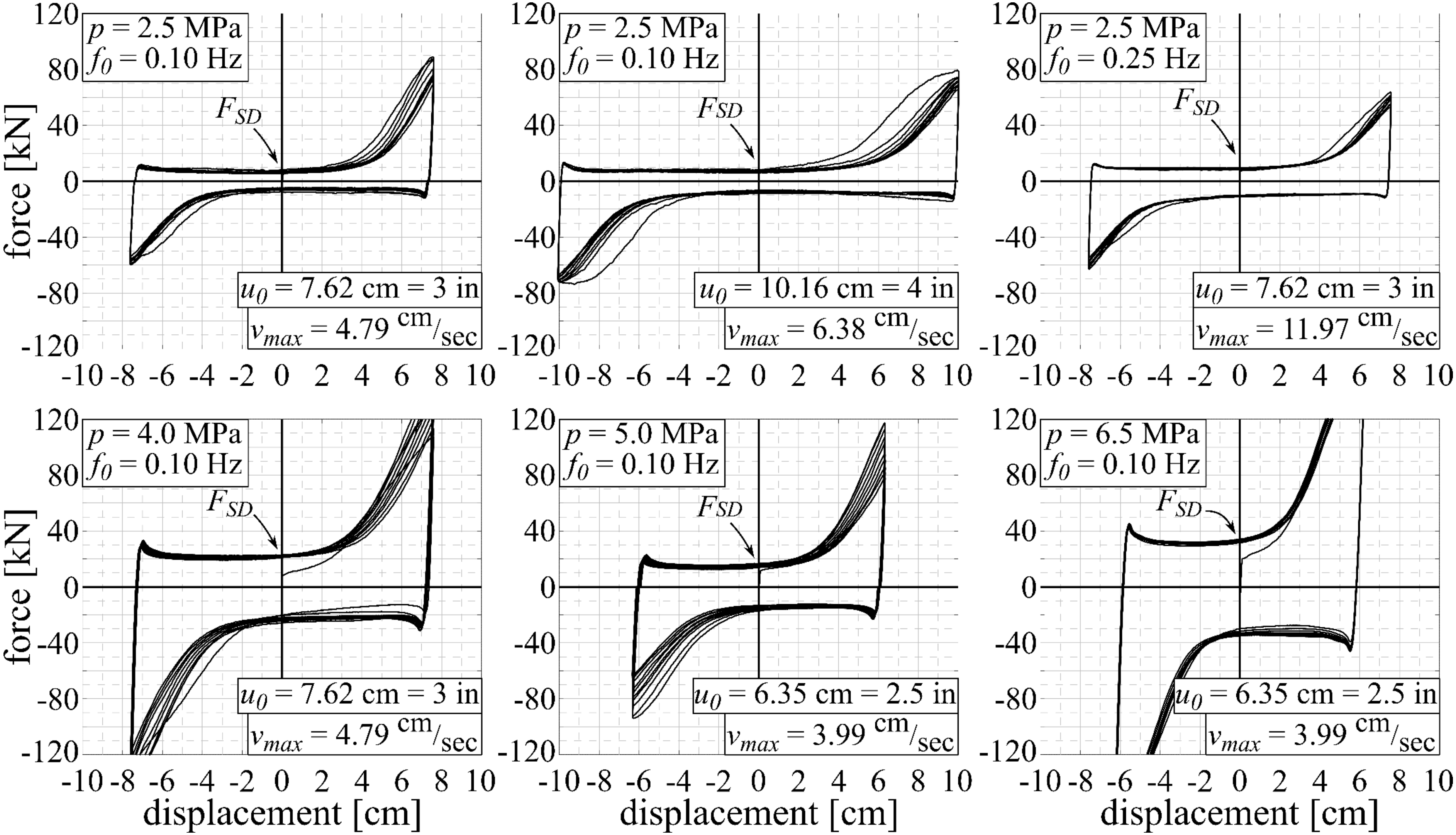


Double-ended sand damper to be mounted on the CLT rocking wall





Double-ended sand damper to be mounted on the CLT rocking wall



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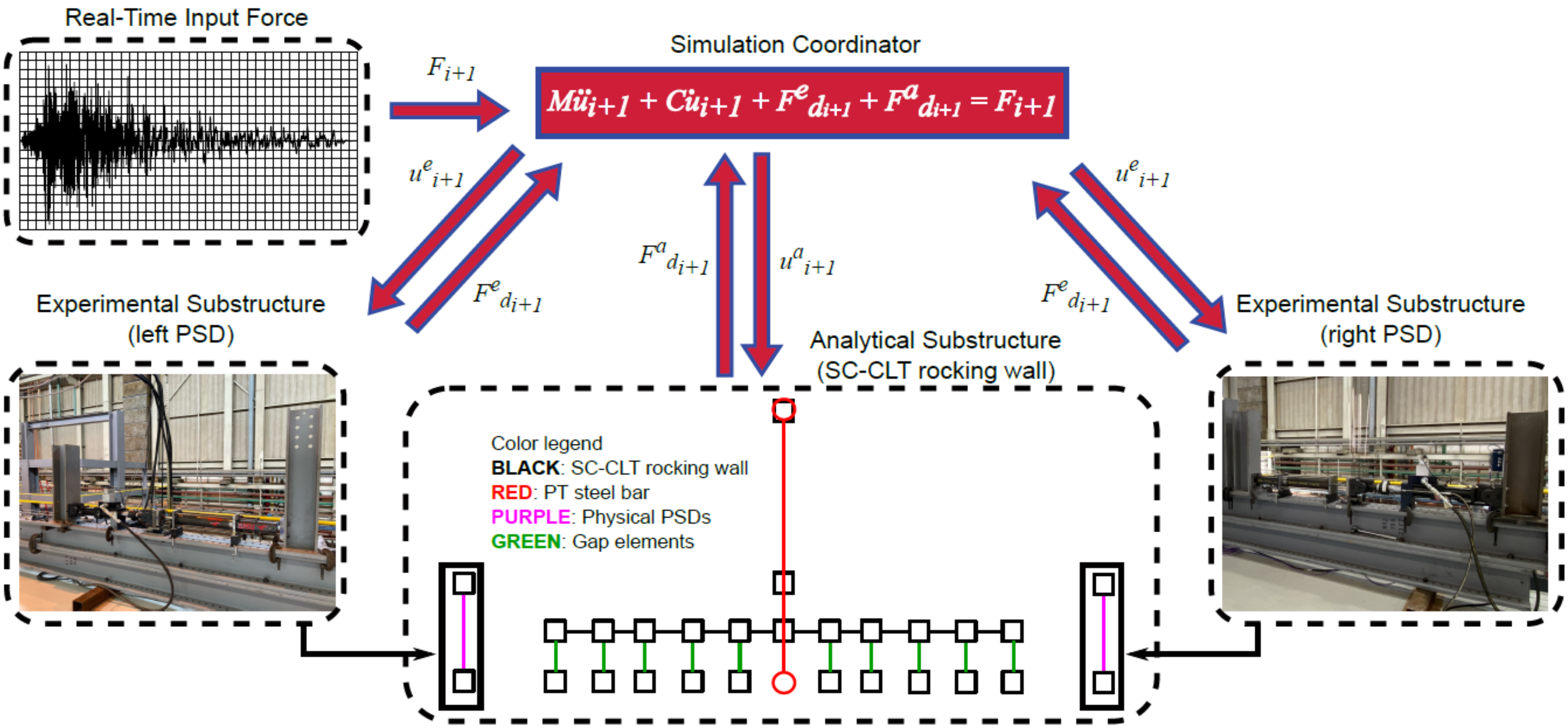
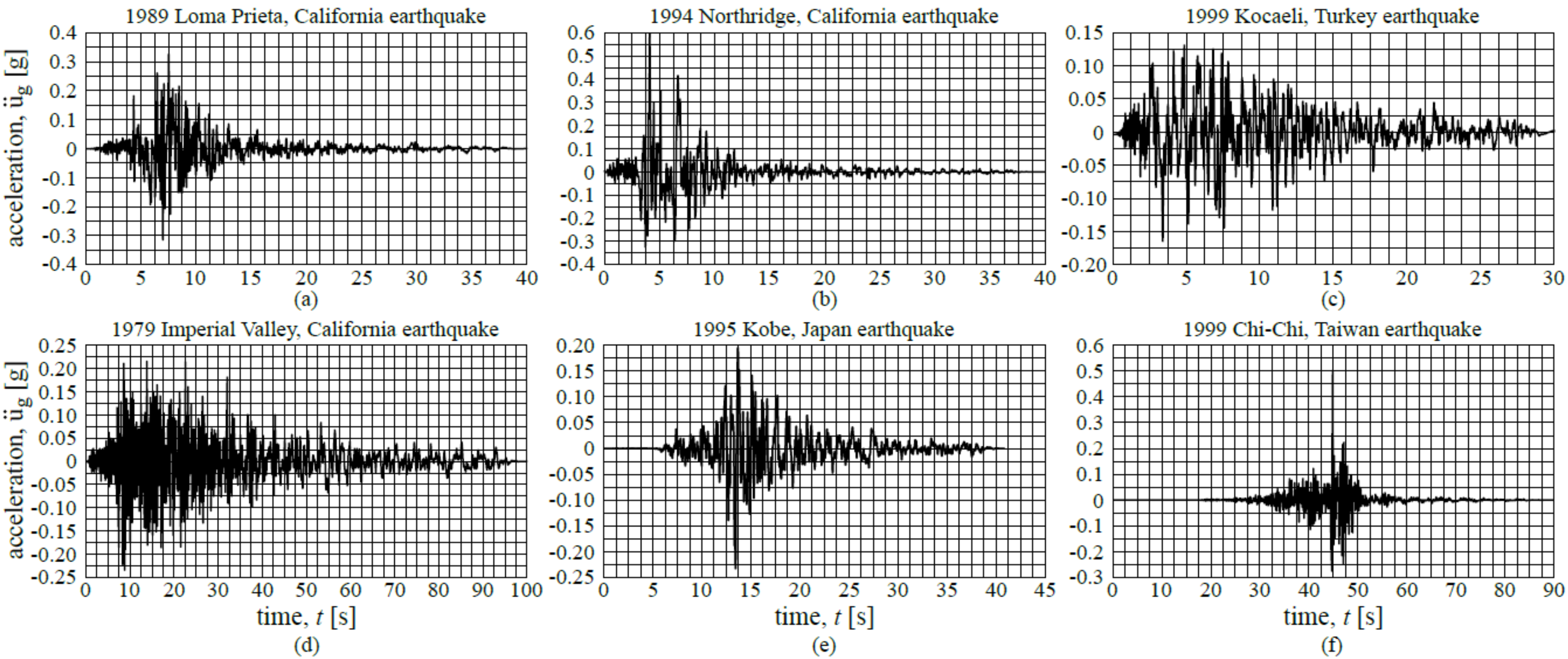
Kalfas KN, L Cao, JM Ricles, and N Makris. 2024. "Seismic response of CLT rocking structures equipped with pressurized sand dampers through real-time hybrid simulations." *ASCE - J Eng Mech* (under preparation)

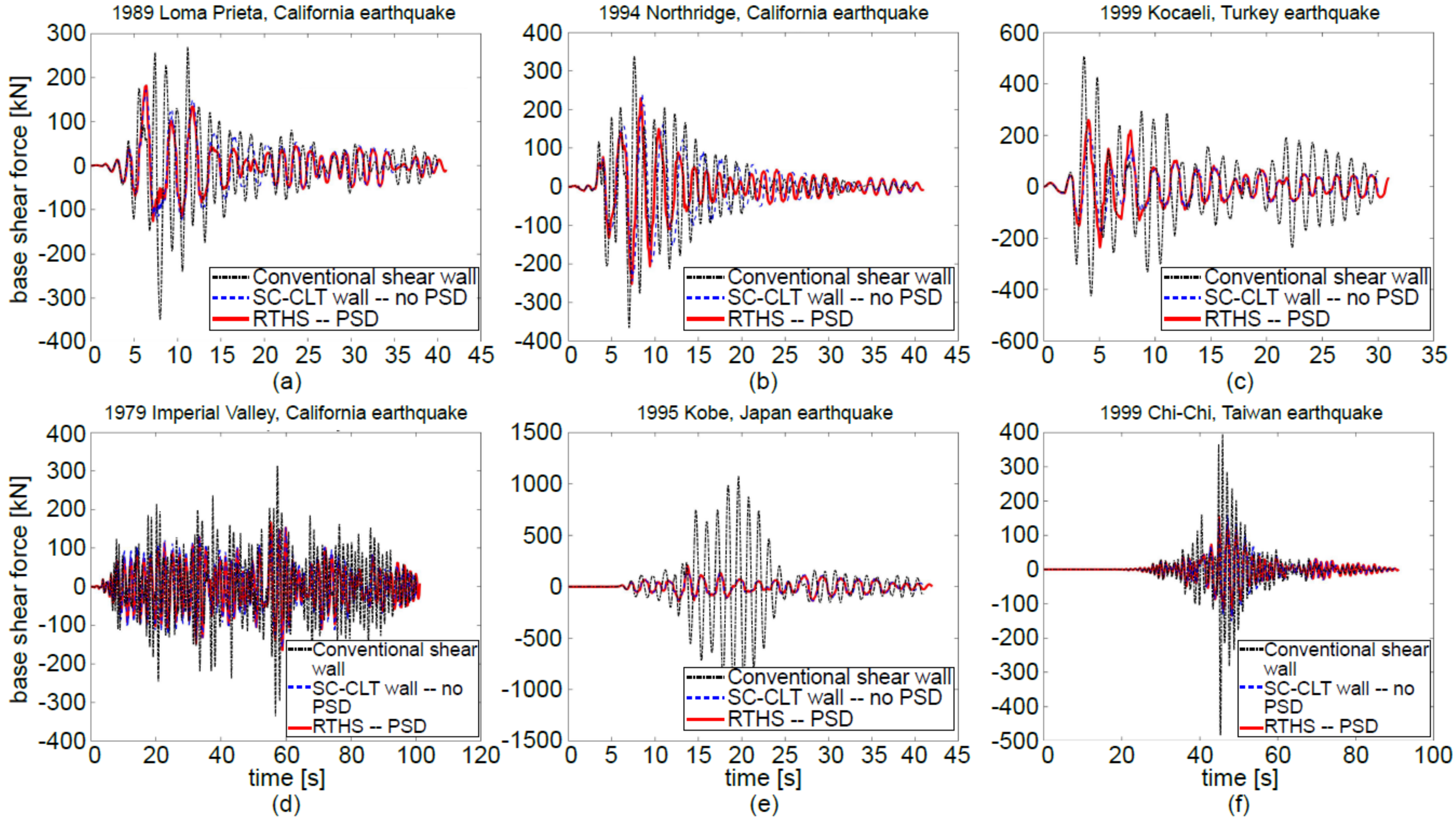
Nonlinear RTHS of rocking systems with PSDs



Nonlinear RTHS of rocking systems with PSDs: Input motions

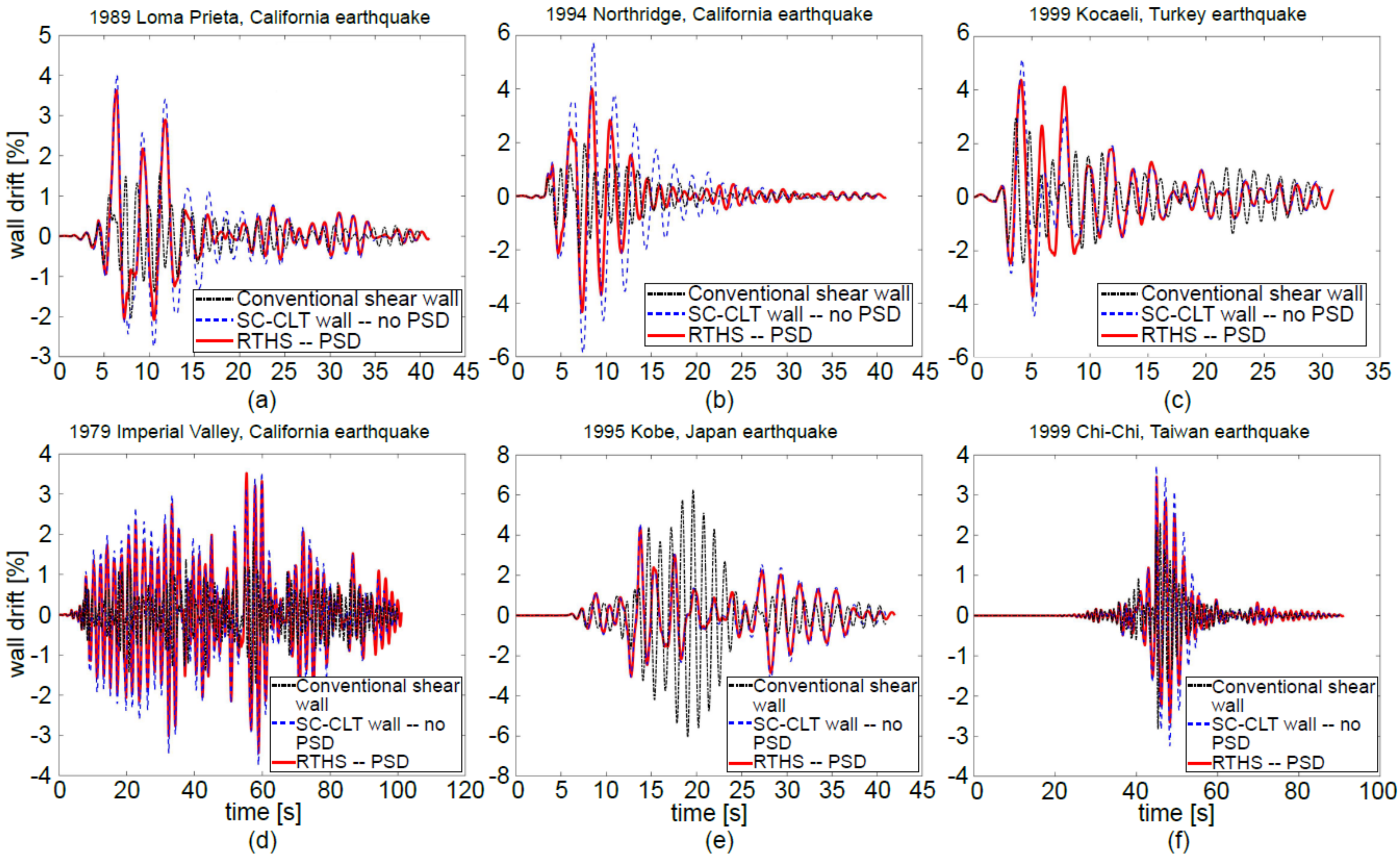


Nonlinear RTHS of rocking systems with PSDs

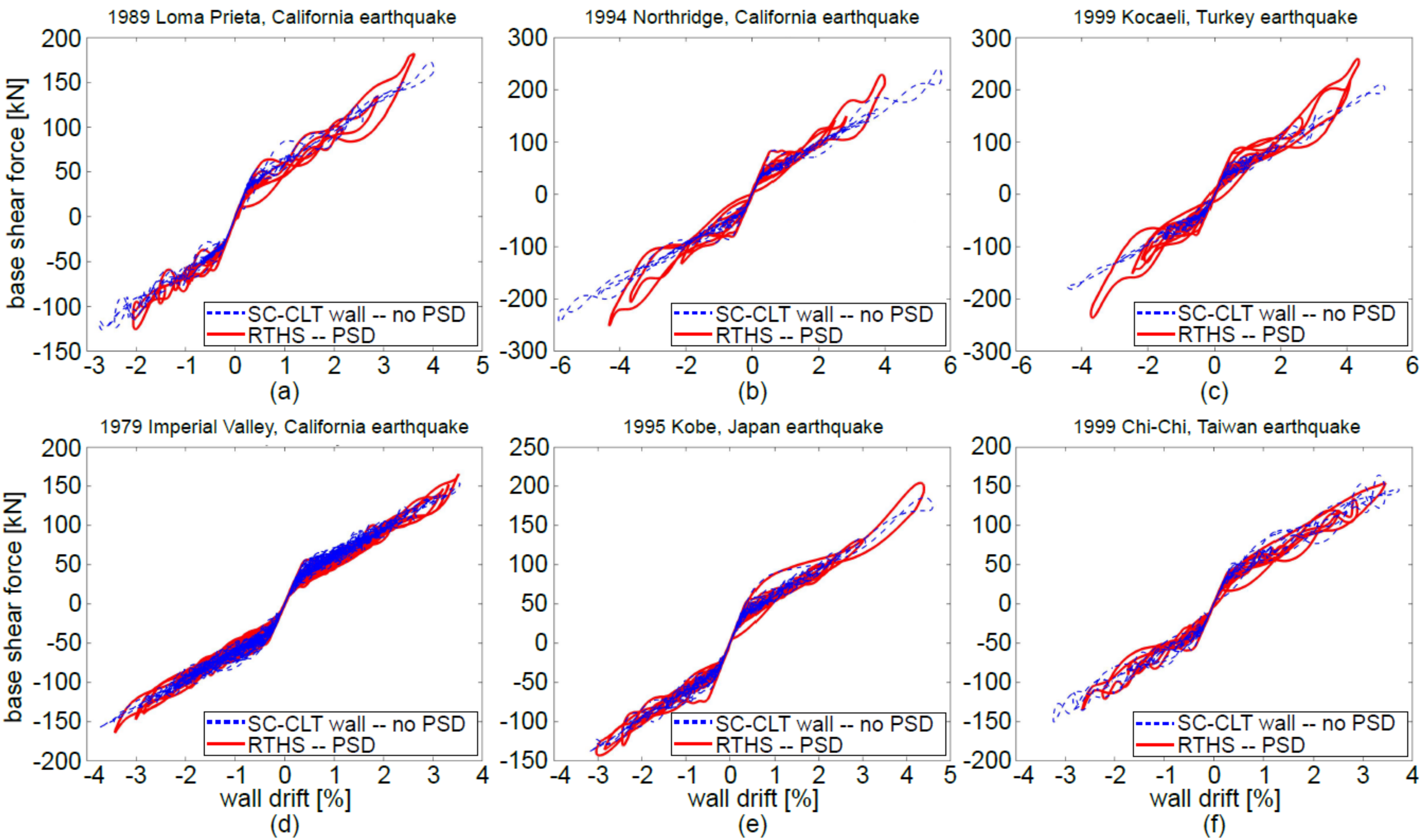


		Base shear reduction (%)				Acceleration reduction (%)			
		Max		RMS		Max		RMS	
Earthquake name		W/o PSDs	With PSDs	W/o PSDs	With PSDs	W/o PSDs	With PSDs	W/o PSDs	With PSDs
Near Field (NF)	Loma Prieta	50.66	47.91	29.77	40.53	10.39	9.53	17.58	22.83
	Northridge	33.01	31.13	13.48	29.72	-1.97	-2.23	8.51	21.83
	Kocaeli	58.74	48.89	55.60	49.56	25.13	25.19	32.20	29.95
Far Field (FF)	Imperial Valley	52.97	50.67	23.12	32.08	-0.65	0.63	11.87	16.89
	Kobe	82.73	80.99	79.36	80.95	40.05	38.62	62.68	63.82
	Chi-Chi	66.04	68.09	42.02	50.82	17.56	16.61	30.45	33.46

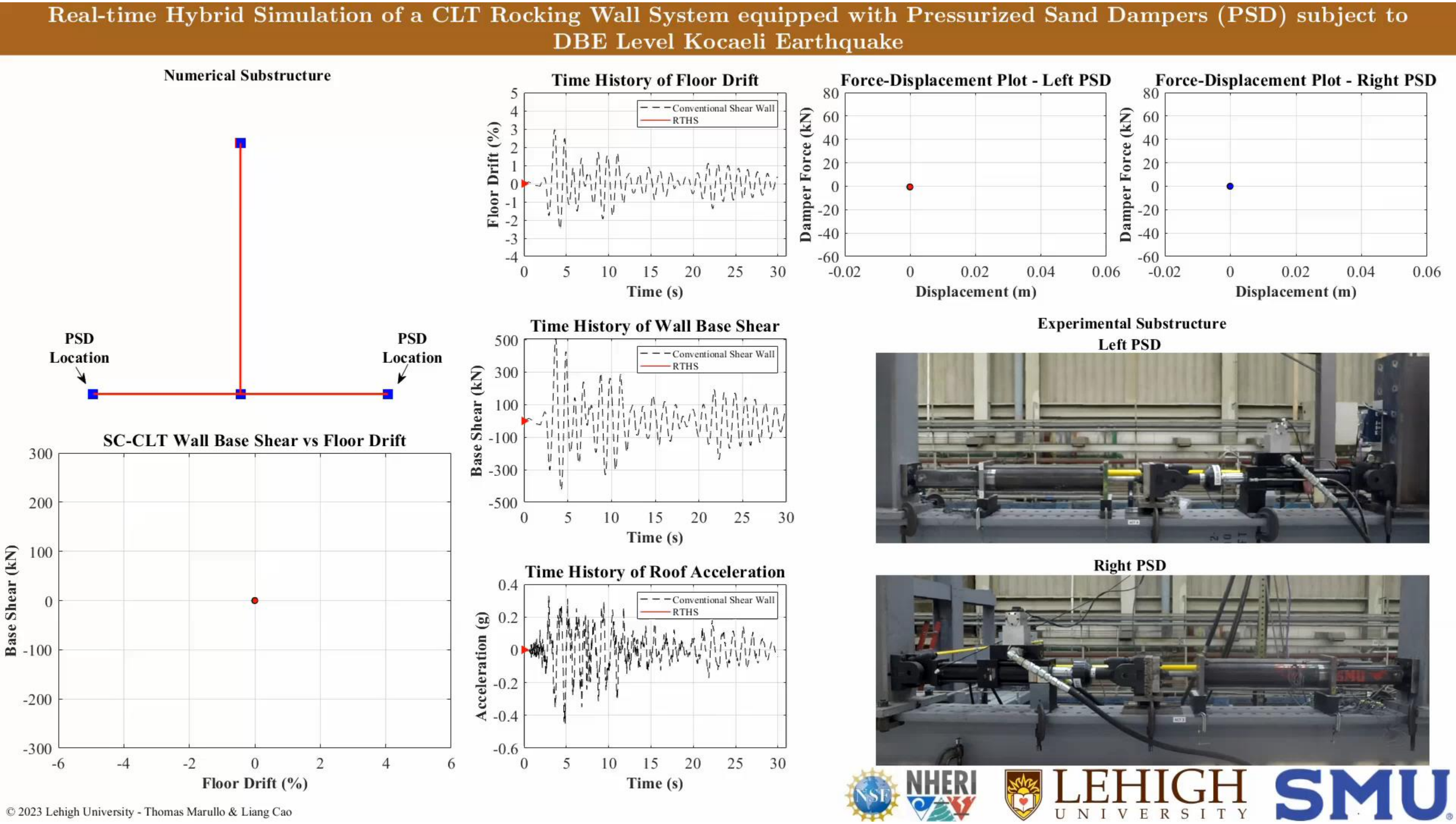
Nonlinear RTHS of rocking systems with PSDs



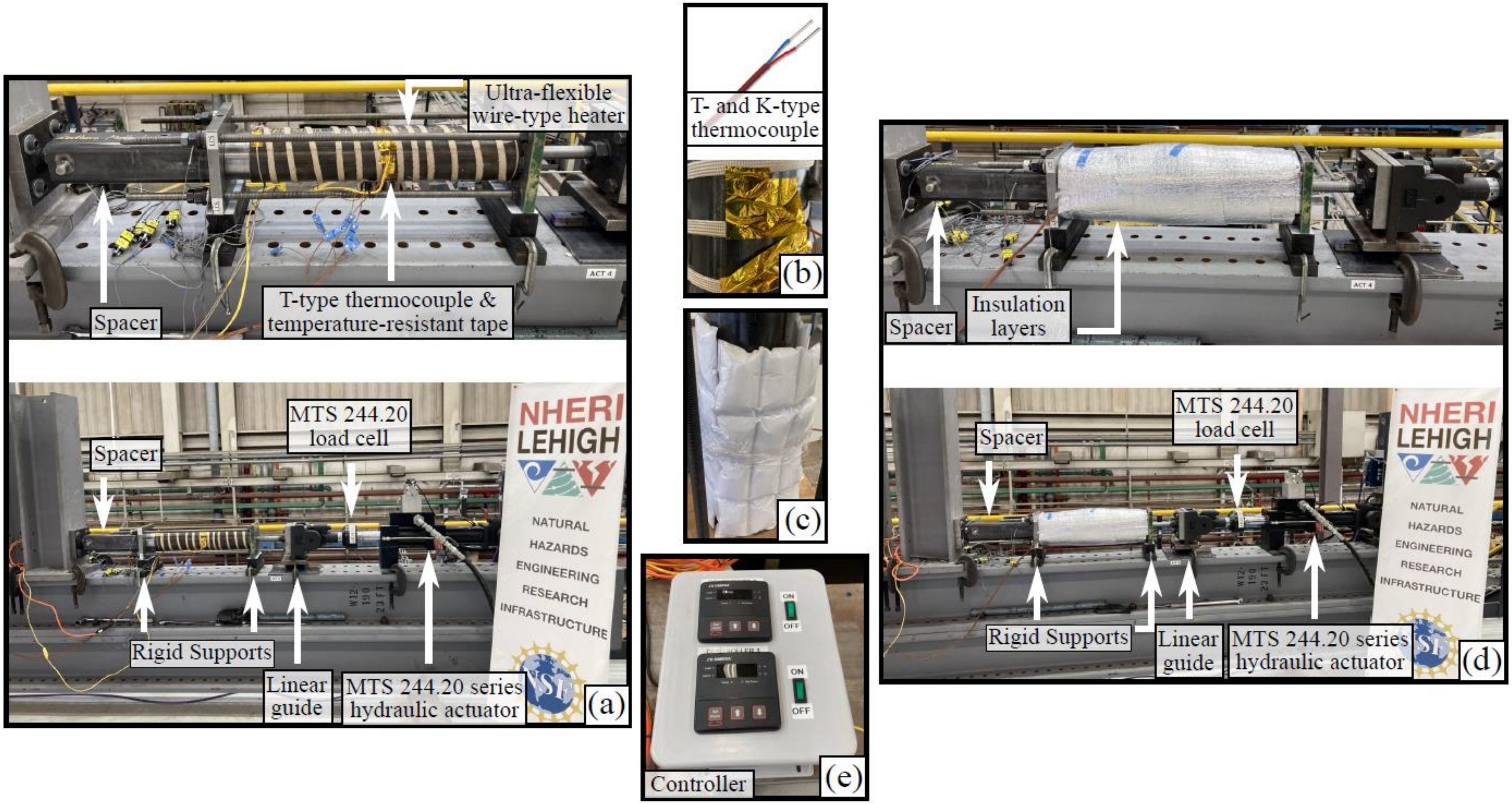
Nonlinear RTHS of rocking systems with PSDs



Nonlinear RTHS of rocking systems with PSDs



Temperature effect on the response of PSDs

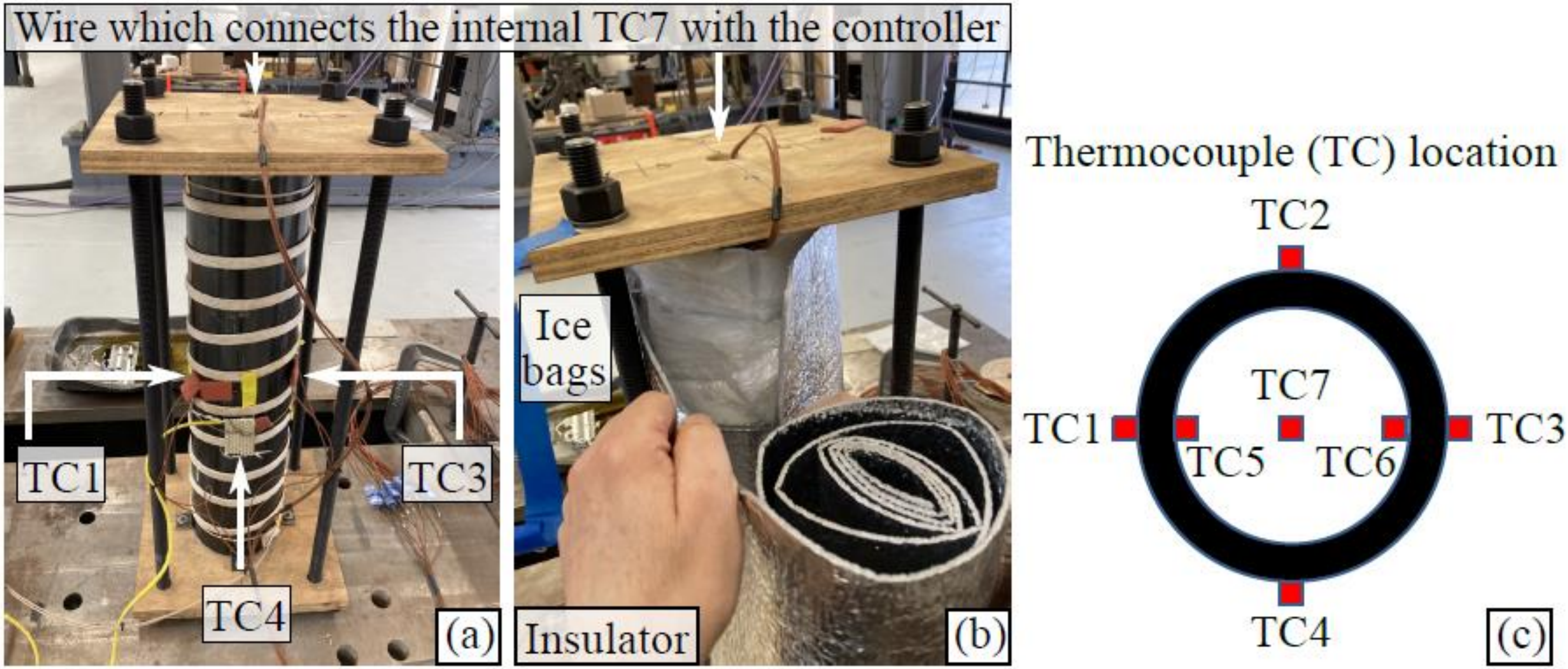


Temperature effect on the response of PSDs

6 ^oC = 43 ^oF: reached after approximately 5 hours

40 ^oC = 104 ^oF: reached after approximately 1 hour and 42 minutes

60 ^oC = 140 ^oF: reached after approximately 2 hours and 20 minutes



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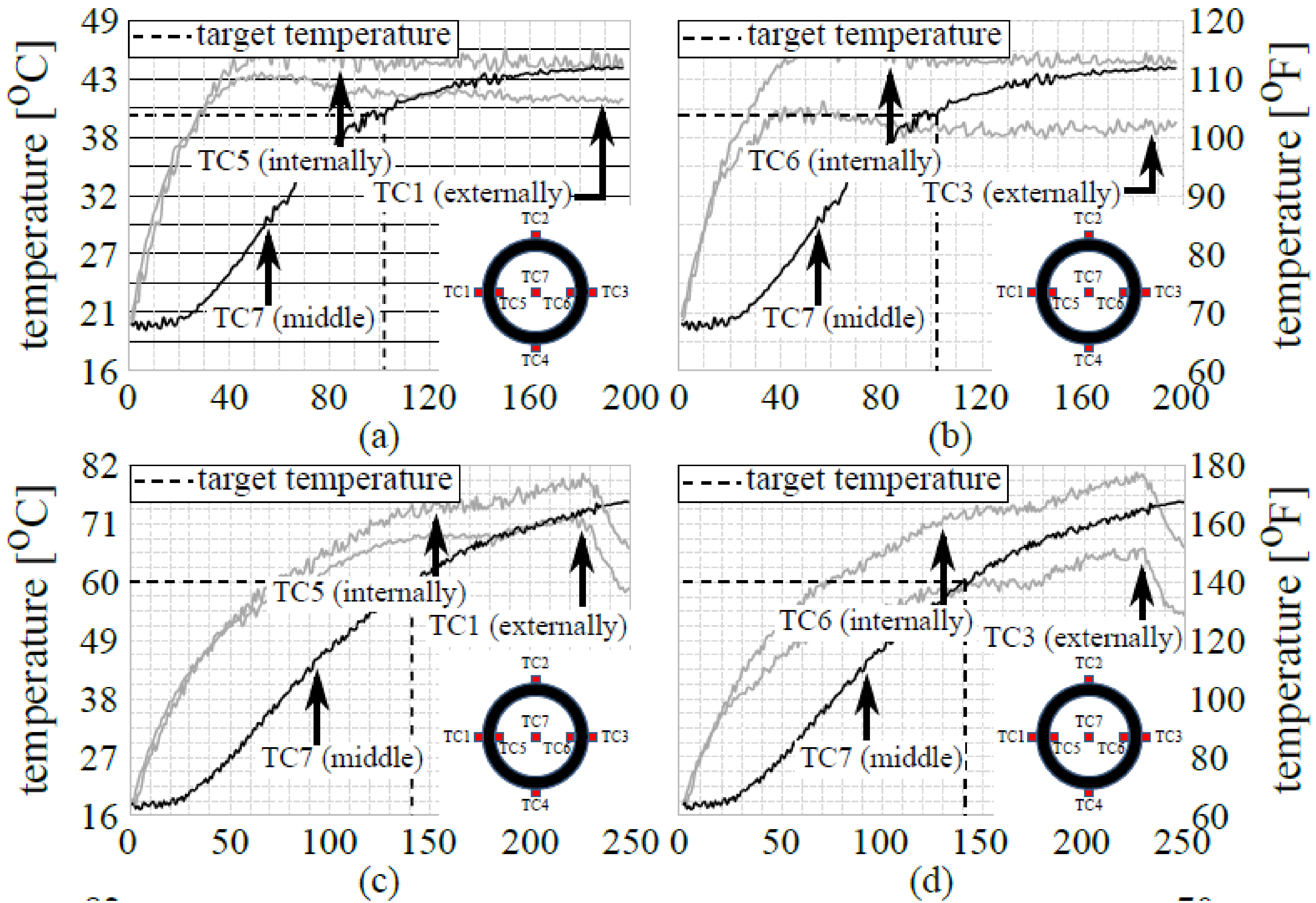

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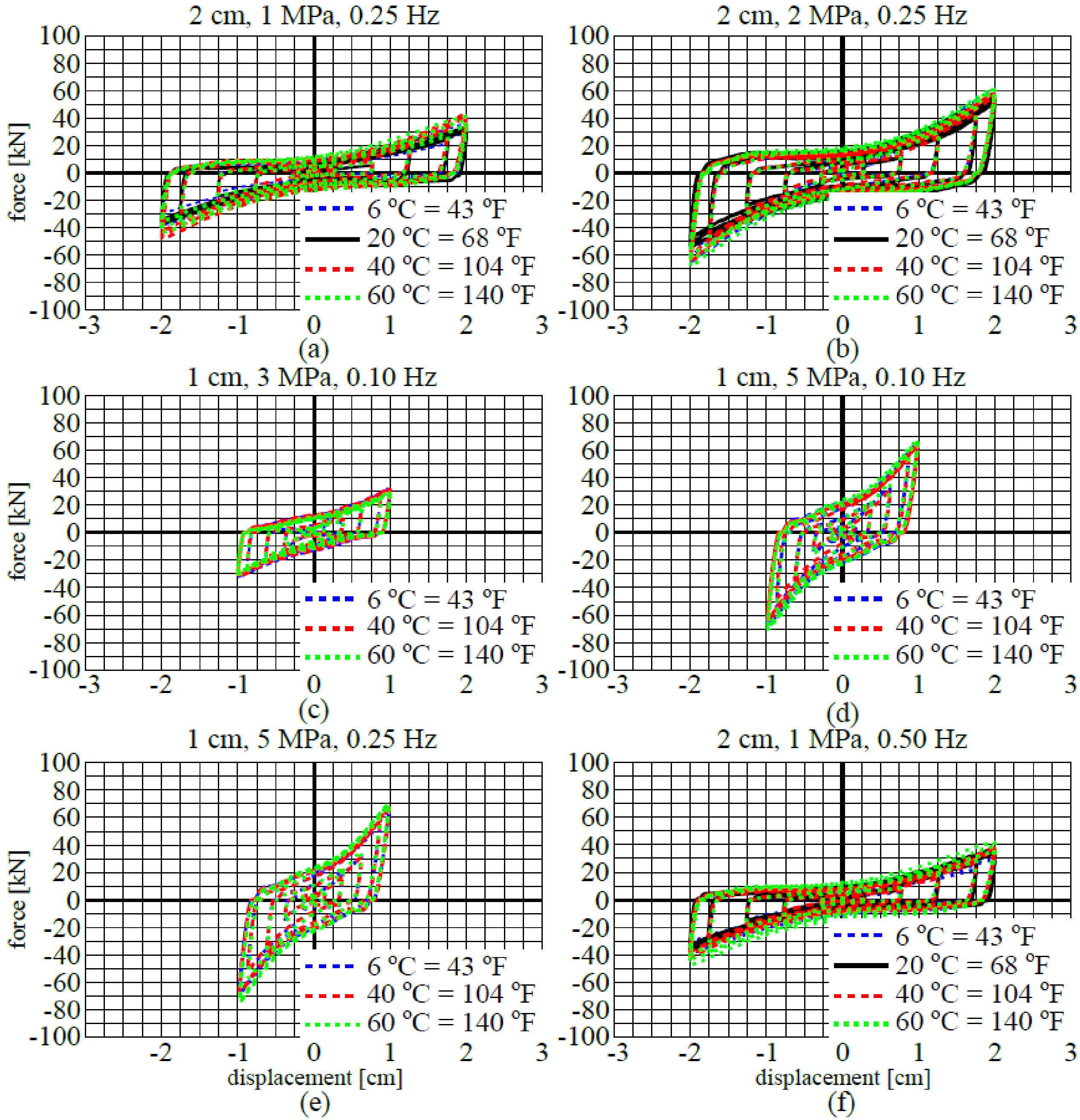


REU Experience

Future Steps – CLT rocking wall with supplemental damping

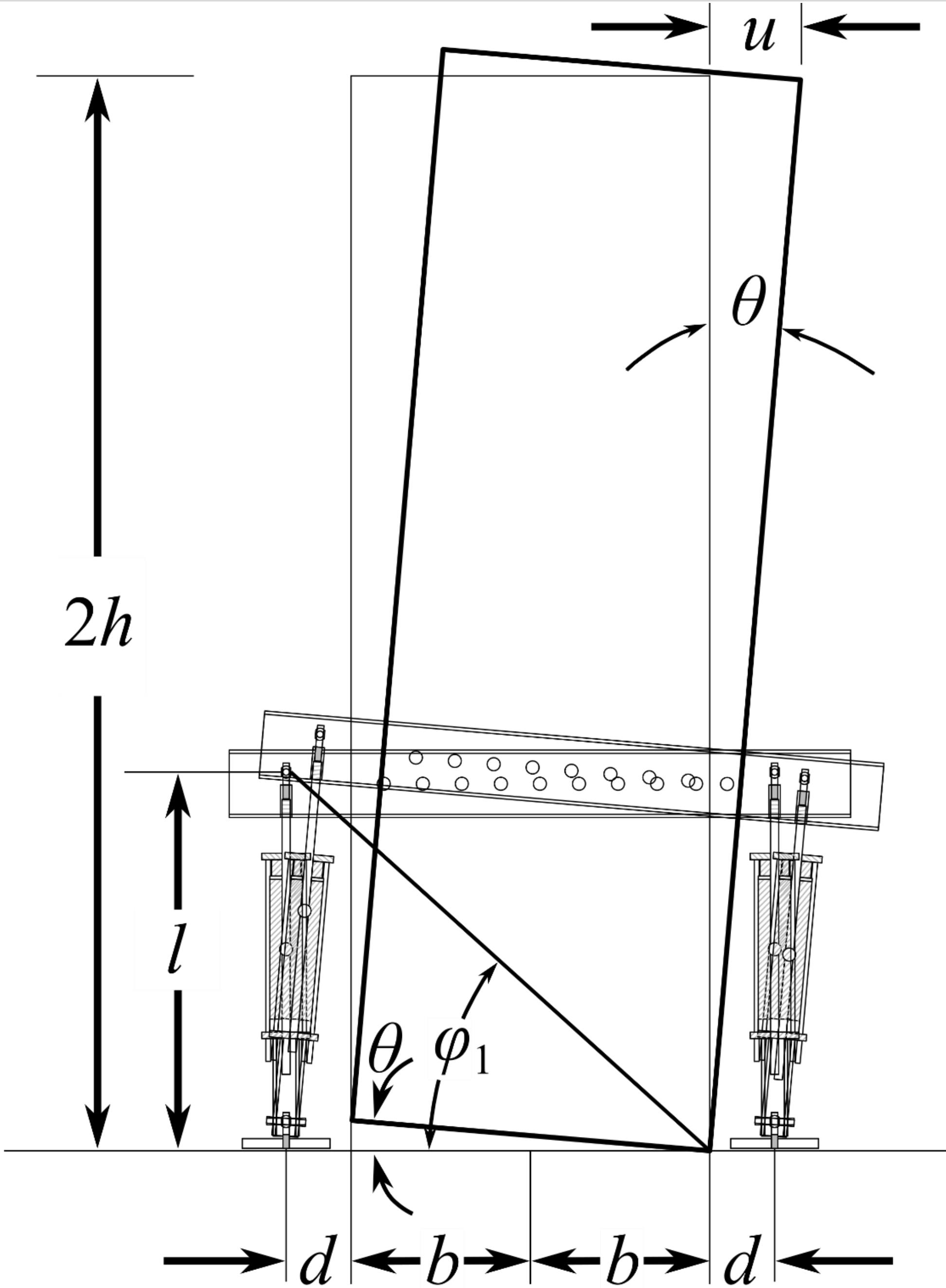
- 5/8-scale cross-laminated timber (CLT) rocking wall

- Allow for a drift ratio, ${}^{u}/_{2h}$, of 3% ⇒ rocking wall maximum rotation:

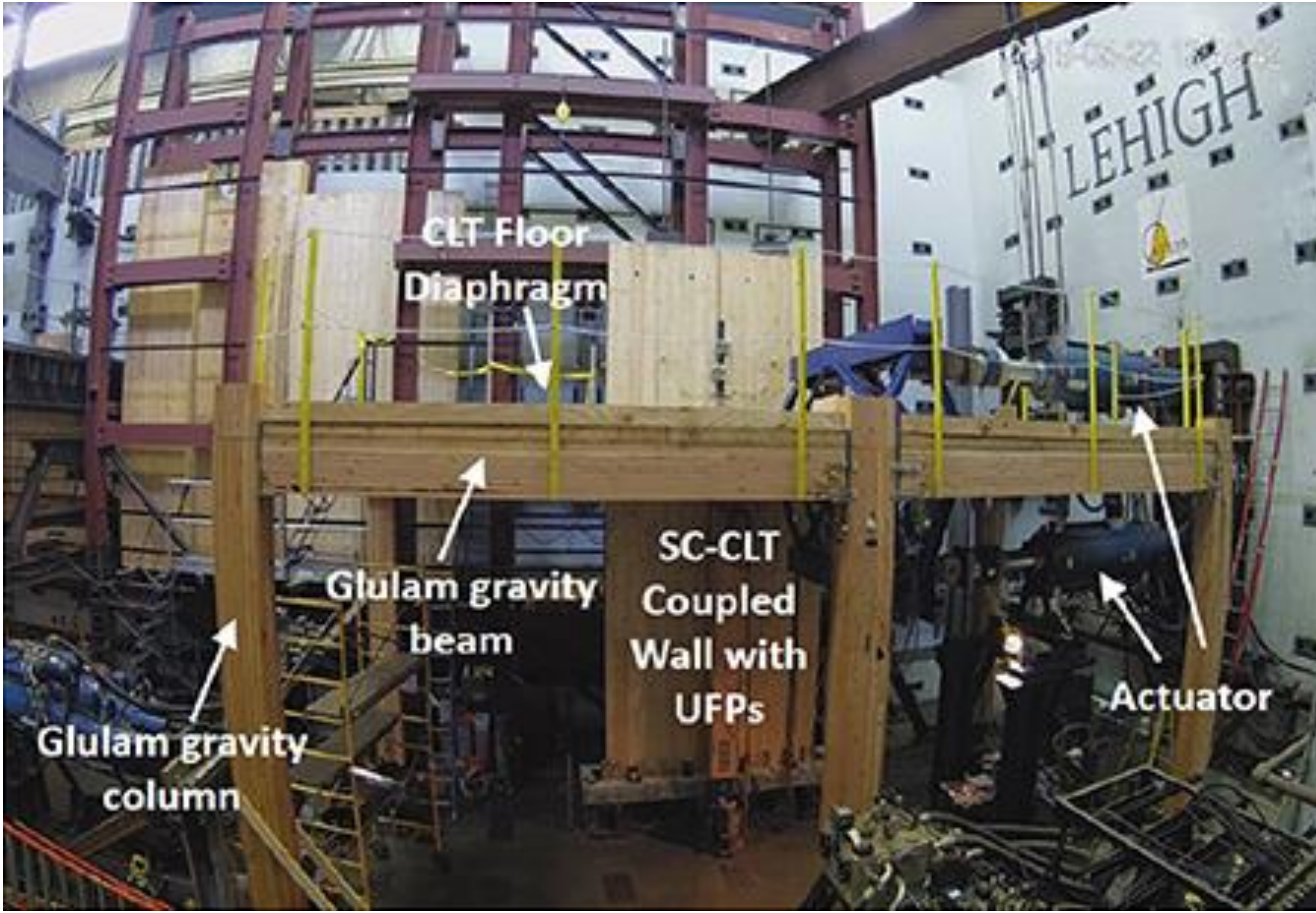
$$\theta_{max} \approx \tan\theta_{max} = {}^{u}/_{2h} = 0.03\,rad$$

- Maximum damper elongation:

$$e_{1,max} = (2b + d)\tan\theta_{max} \approx 2\text{ in}$$



Future Steps ─ CLT rocking wall with supplemental damping



Acknowledgements

The pressurized sand damper project has been funded by the National Science Foundation under grant No. CMMI - 2036131.

The SMU – Lehigh collaboration has been funded by the NSF under grant No. CMMI – 2037771.

We would like to thank the machinist of SMU, Ken Sangston, as well as the ATLSS Engineering Research Center staff and technicians.

Thank you for your attention!

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