Lab Demonstration: Multi-directional Large-Scale Testing of Cross-laminated Wall equipped with Pressurized Sand Damper

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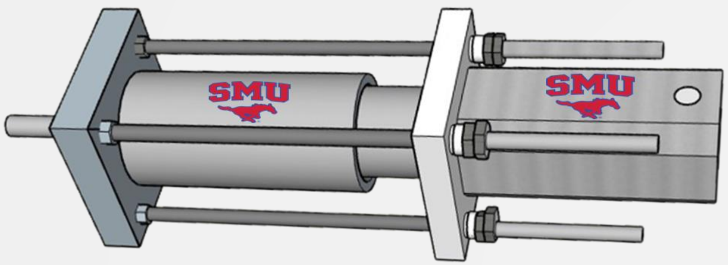
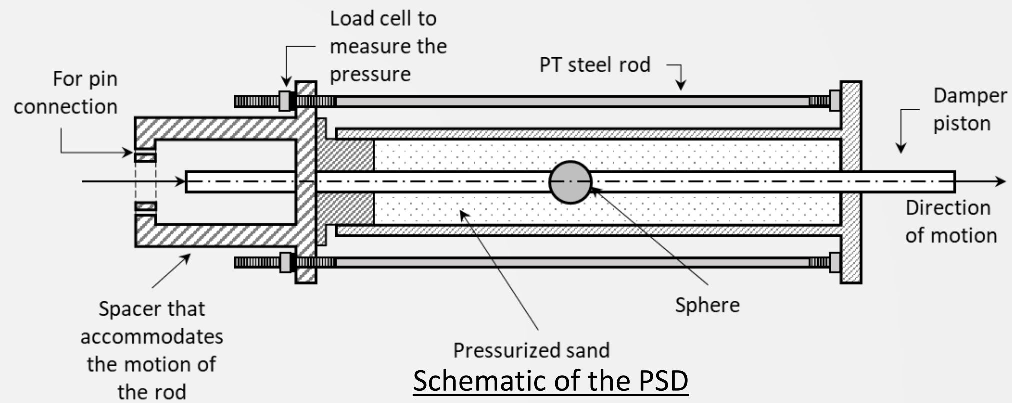
Background of Pressurized Sand Damper

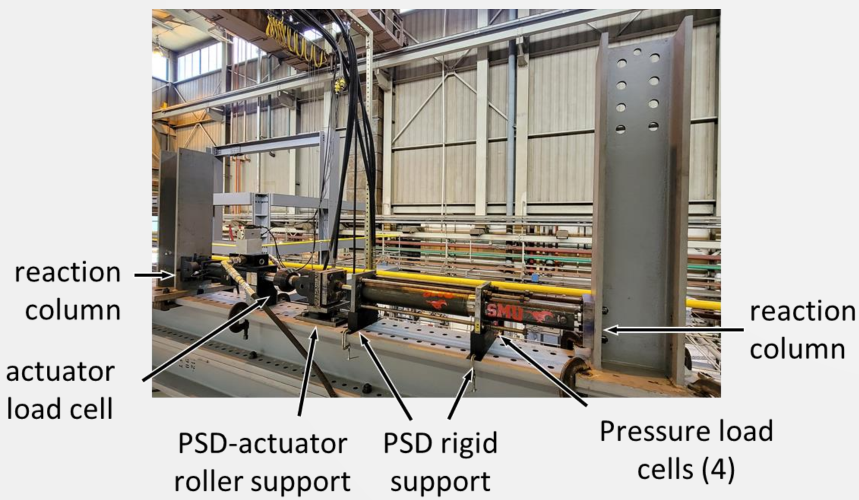
Investigation of a Novel Pressurized Sand Damper for Sustainable Seismic and Wind Protection of Buildings: (CMMI 2036131) **Southern Methodist University (Nicos Makris(PI))**



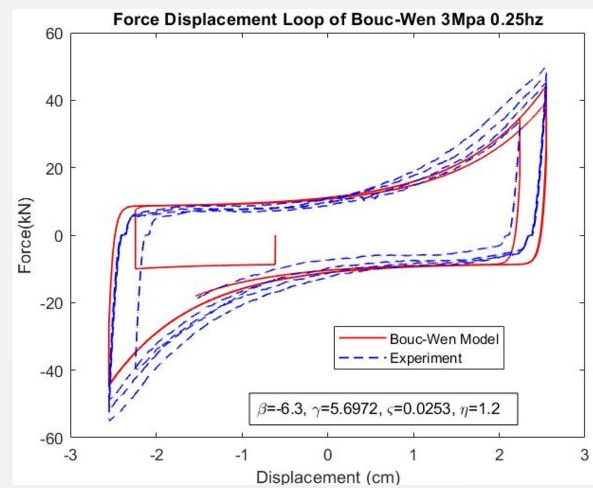
Pressurized Sand Damper (PSD)



Schematic of the PSD



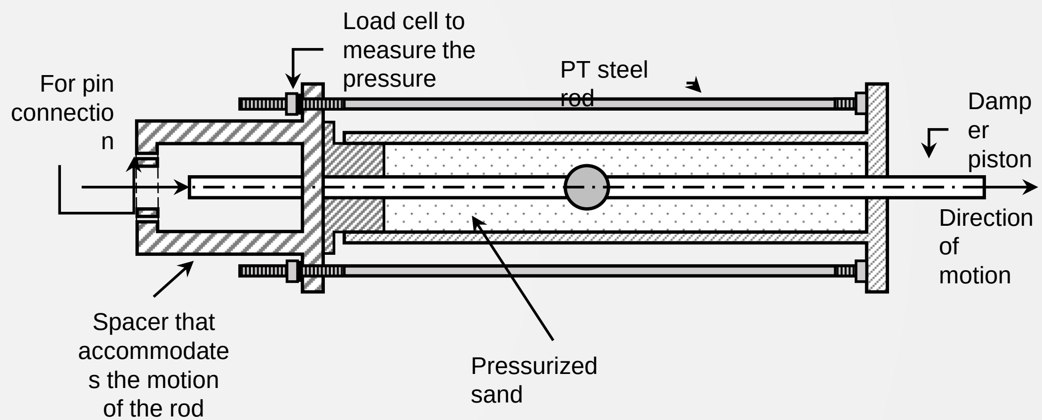
Characterization test setup



Model fitting result (Bouc-Wen Model)

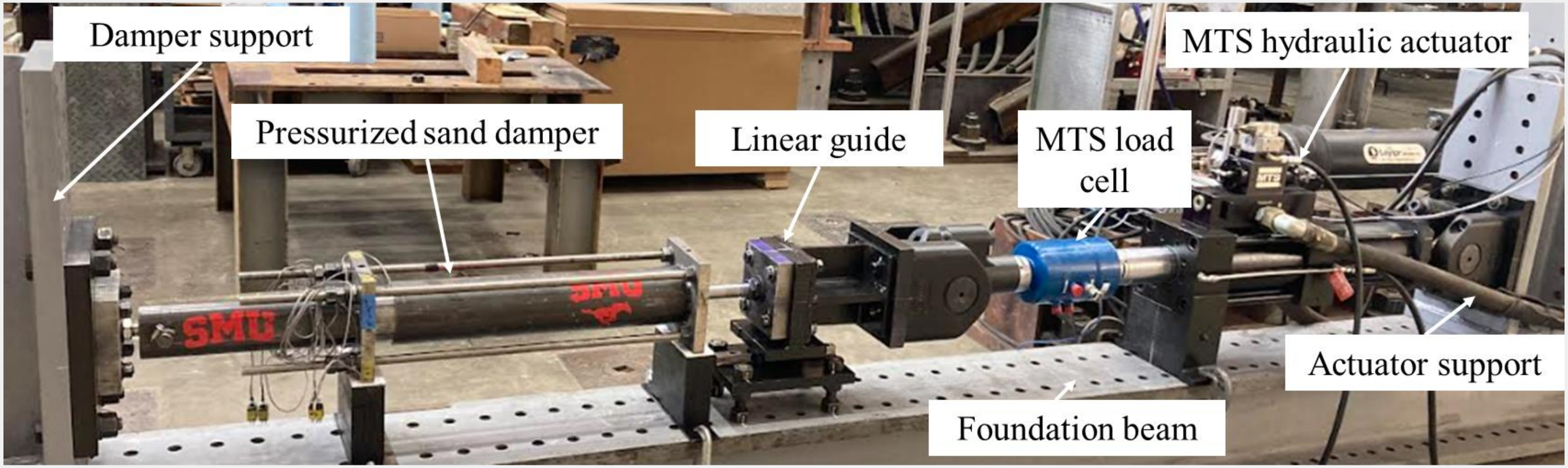
Pressurized Sand Damper (PSD)

Diagram of the PSD

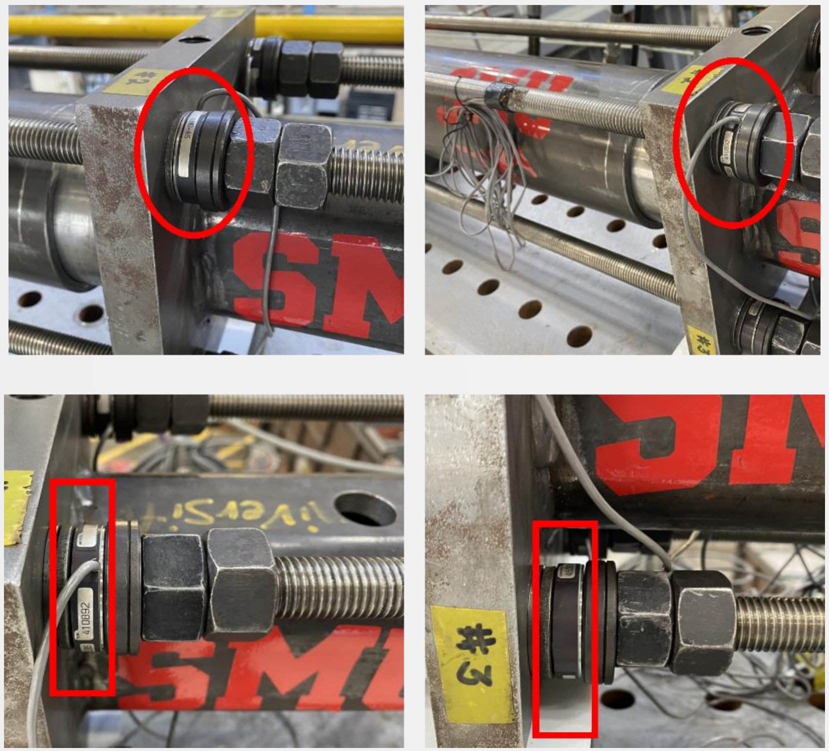


- Moghimi, G., and N. Makris. 2022. “Seismic response of yielding multistory steel buildings equipped with Pressurized Sand Dampers.” J. Struct. Eng. 148 (7): 04022071. https://doi.org/10.1061/(ASCE)ST.1943-541X.0003364.
- Kalfas KN, N Makris, and U El Shamy. 2023. “Assessment of the effect of design parameters of pressurized sand-dampers from component testing.” *ASCE - J Eng Mech* (accepted for publication).

Characterization test setup



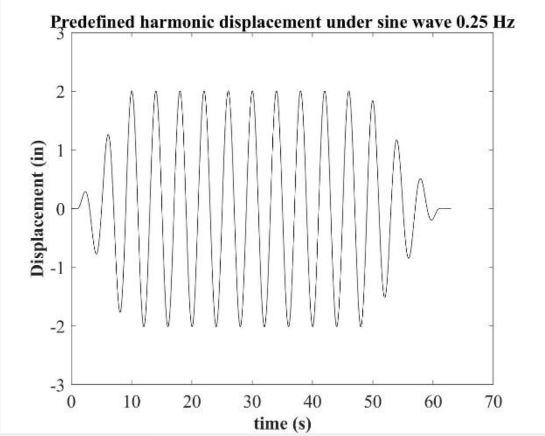
Test Setup: Instrumentation



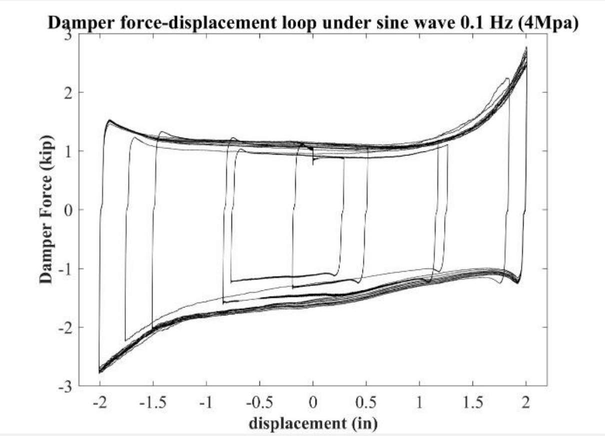
- MTS Load cell and LVDT to measure the damper force and deformation
- Four washer type loadcells on each PT steel rod to measure internal pressure on sand pressure

Characterization test

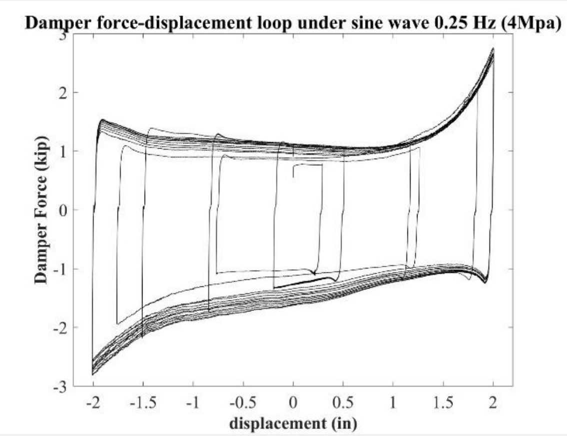
Displacement input



Damper force displacement plot under Harmonic test with pressured sand of 4 Mpa



0.1 Hz



0.25 Hz

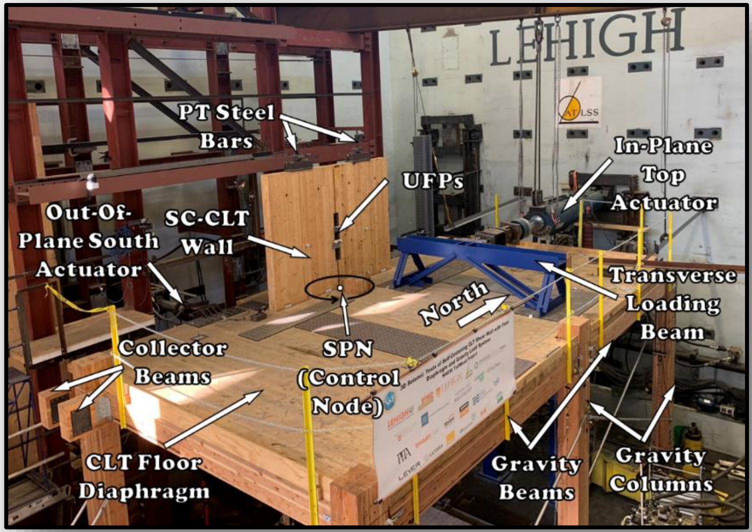
Background of the SC-CLT Shear Wall

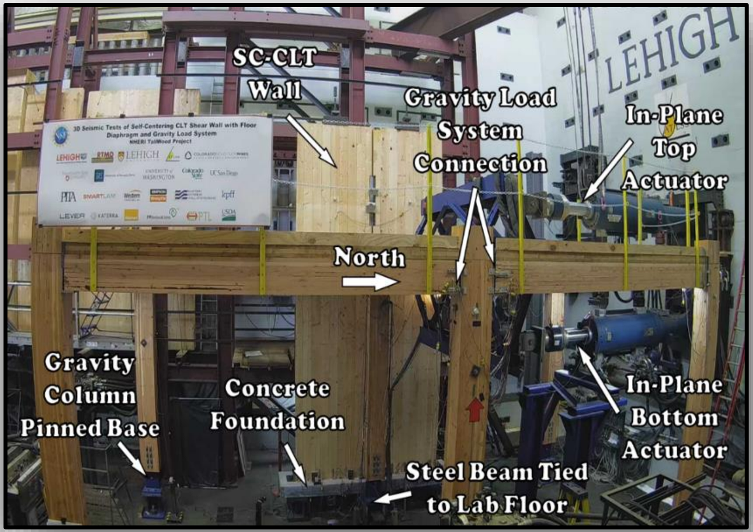
Collaborative Research: Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings

(CMMI 1636164) Colorado School Mines (Shiling Pei), (CMMI 1635156) Washington State (James Dolan), (CMMI 1635227) Lehigh University (James Ricles)

- Overview
  - ➢ Design and construct a low-damage, resilient 3-D CLT building sub-assembly
  - ➢ Investigate the lateral-load response and damage of SC-CLT walls under multidirectional loading
  - ➢ Investigate the associated response of the CLT floor diaphragm, collector beams, and gravity load system within this 3-D sub-assembly under multidirectional loading

<u>Isometric and long-side view of 0.625-scale test sub-assembly</u>





Amer, A., Sause, R., and Ricles, J. (2023) “Experimental Response and Damage of SC-CLT Shear Walls under Multidirectional Cyclic Lateral Loading.” Journal of Structural Engineering. 10.1061/JSENDH/STENG-12576.

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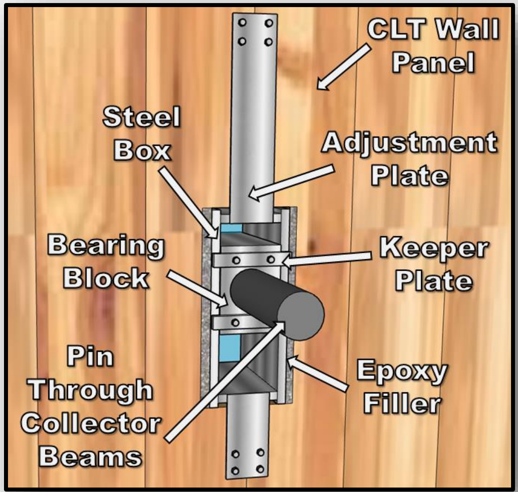
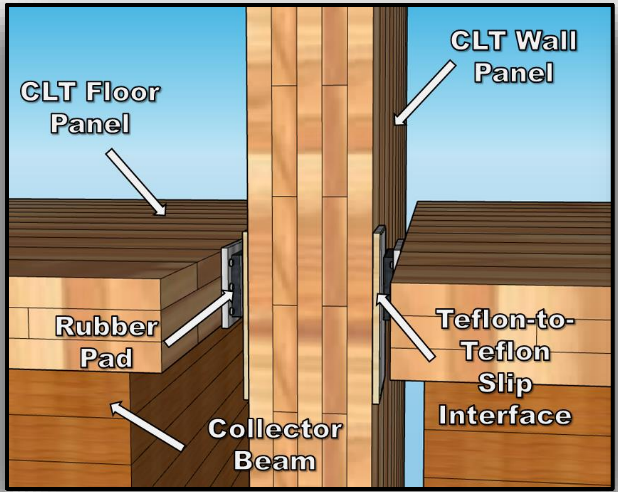
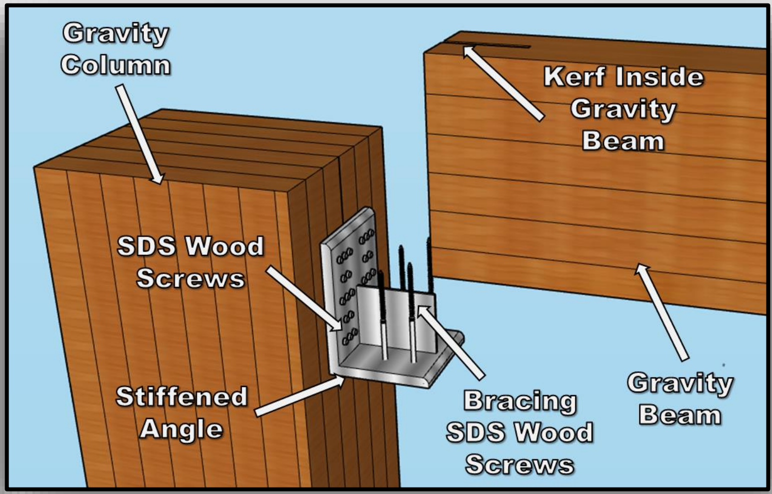
- Test Sub-Assembly Components and Connection Details
  - ➢ Design considering force and/or deformation demands expected during the multidirectional lateral-load tests
  - ➢ 3.0% story-drift as performance objective for damage initiation to sub-assembly components and connection details



Collector-beam-to-SC-CLT-wall connection details



CLT-floor-diaphragm-to-SC-CLT-wall connection details



Gravity-beam-to-gravity-column connection details

Amer, A. (2023) "Multidirectional Experimental Performance of a Seismically Resilient Self-Centering Cross-Laminated Timber Shear Wall System." PhD Dissertation, Lehigh University, Bethlehem, PA.

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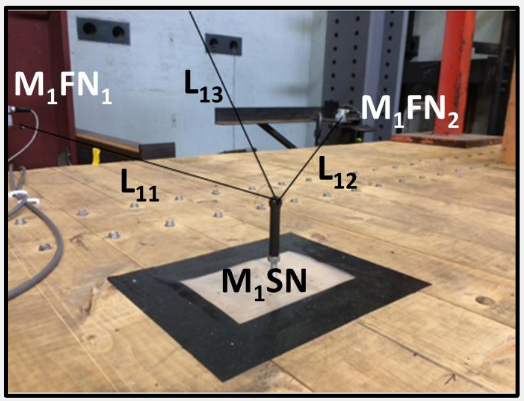
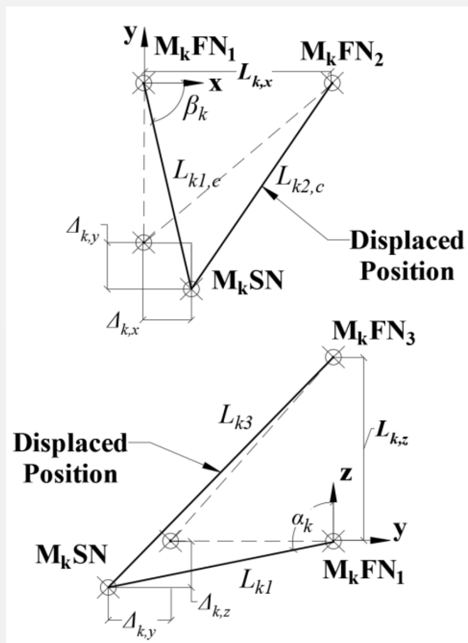
- Multidirectional Displacement Control Scheme
  - ➢ In-plane and out-of-plane story-drifts and vertical motion of the test sub-assembly
  - ➢ Control algorithm for 3-D large-scale lateral-load testing with flexible diaphragms
  - ➢ Kinematic relationship between the control node, feedback displacement sensors, and actuator command displacements



<u>Instrumentation layout for 3-D displacement feedback</u>



<u>3-D motion of test sub-assembly</u>

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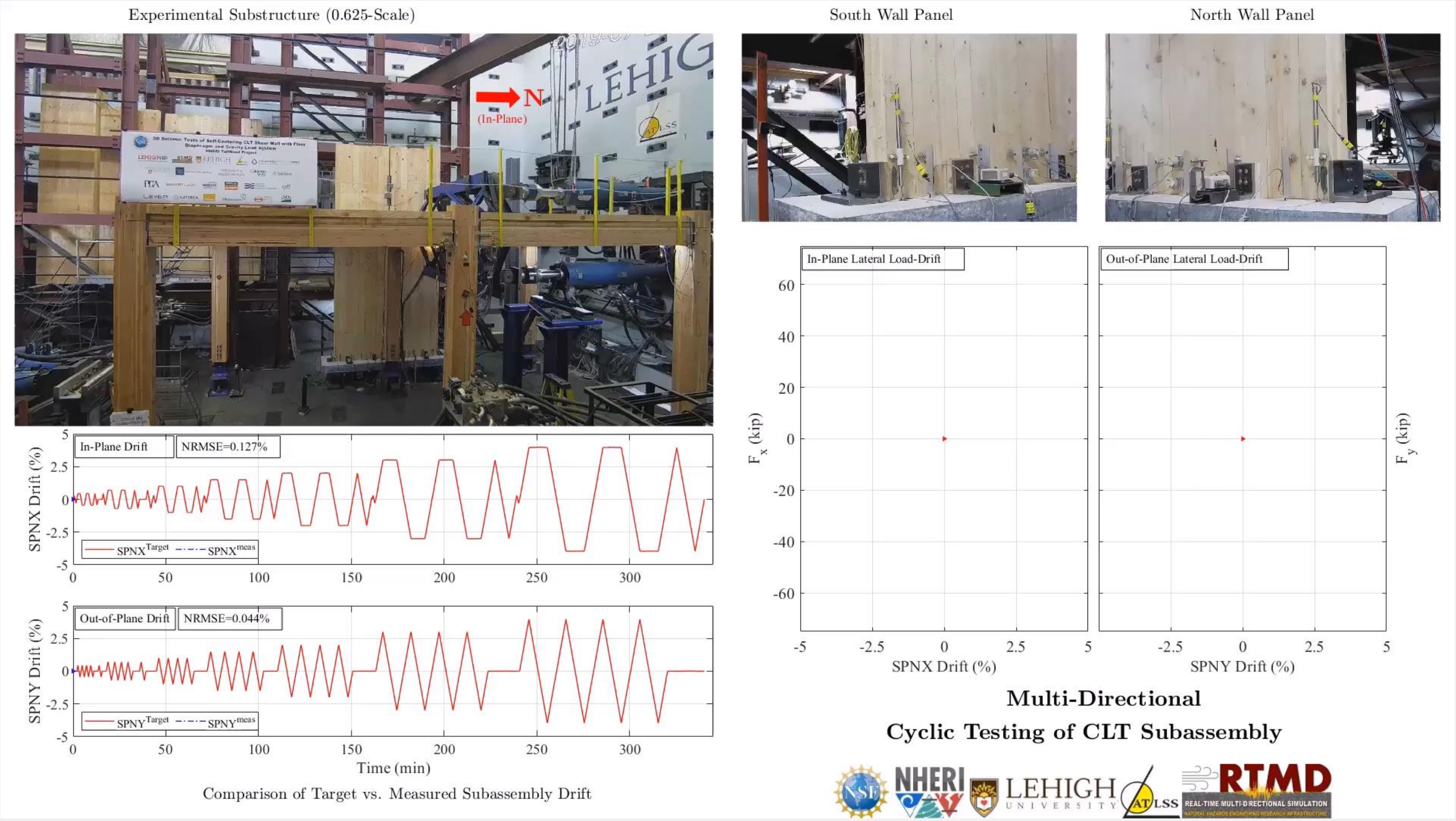
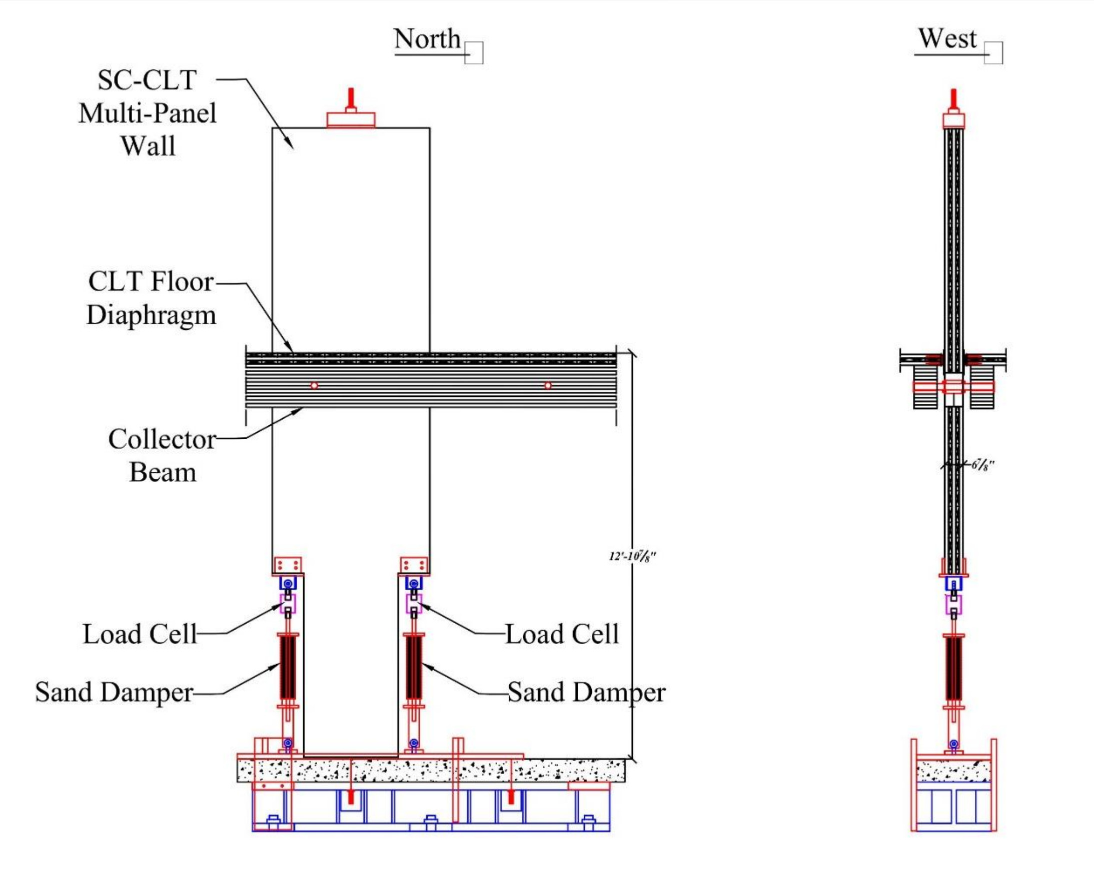


Application of PSDs on the SC-CLT Shear Wall

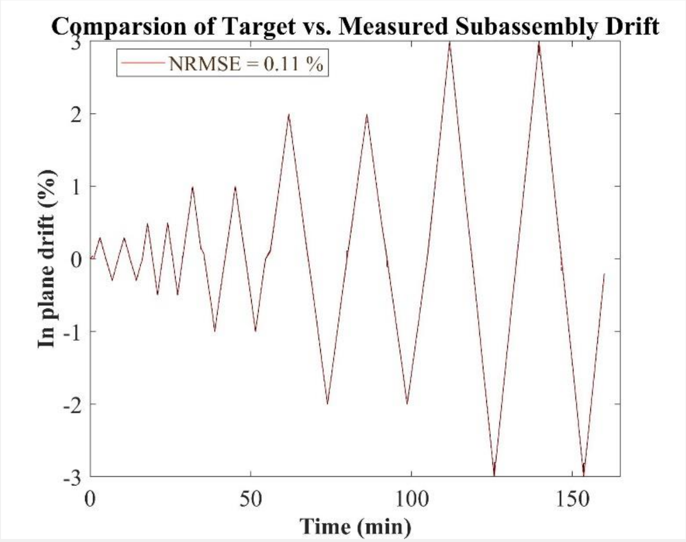


Test Matrix

Test	Objective
Unidirectional cyclic	Investigate experimental response of SC-CLT wall with PSD under unidirectional cyclic loading
Multi-directional cyclic	Investigate experimental response of SC-CLT wall with PSD under multidirectional cyclic loading
Predefined earthquake	Investigate seismic performance of SC-CLT wall with PSD under predefined earthquake

Unidirectional Quasi-static Cyclic Test

Stage	Wall Drift at Floor Level % (in)	Cycles	Loading Rate (in/min)
A	±0.3 (±0.46)	2	0.3
B	±0.5 (±0.77)	2	0.6
C	±1.0(±1.54)	2	0.6
D	±2.0 (±3.08)	2	0.6
E	±3.0 (±4.62)	2	0.8



Example Unidirectional Cyclic Test (up to 3%)

Unidirectional Quasi-static Cyclic Test

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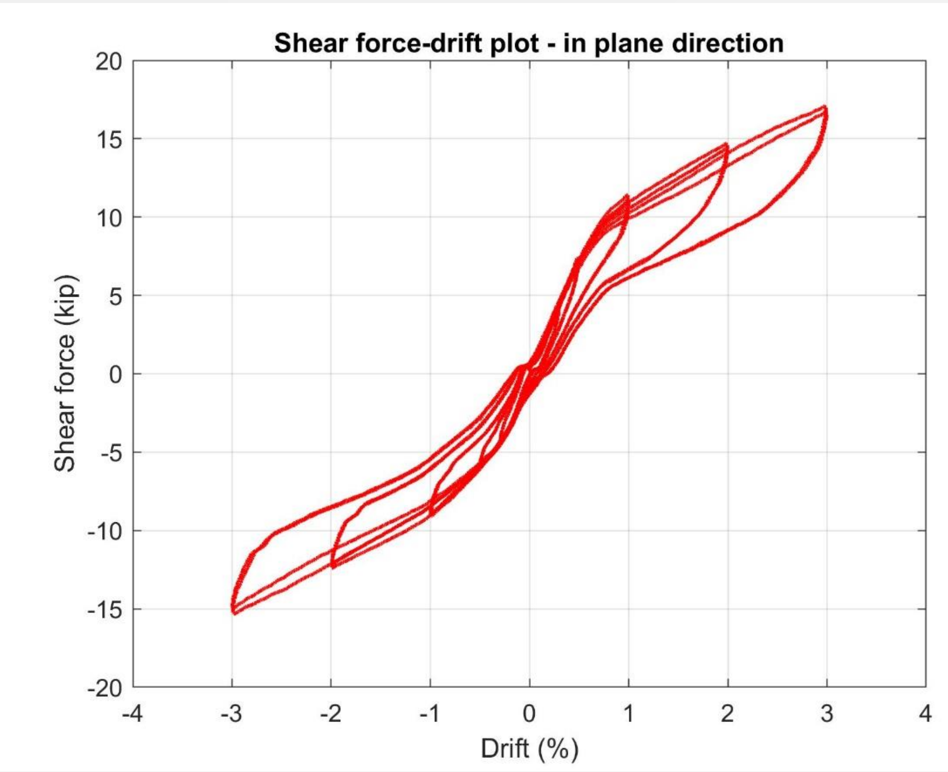
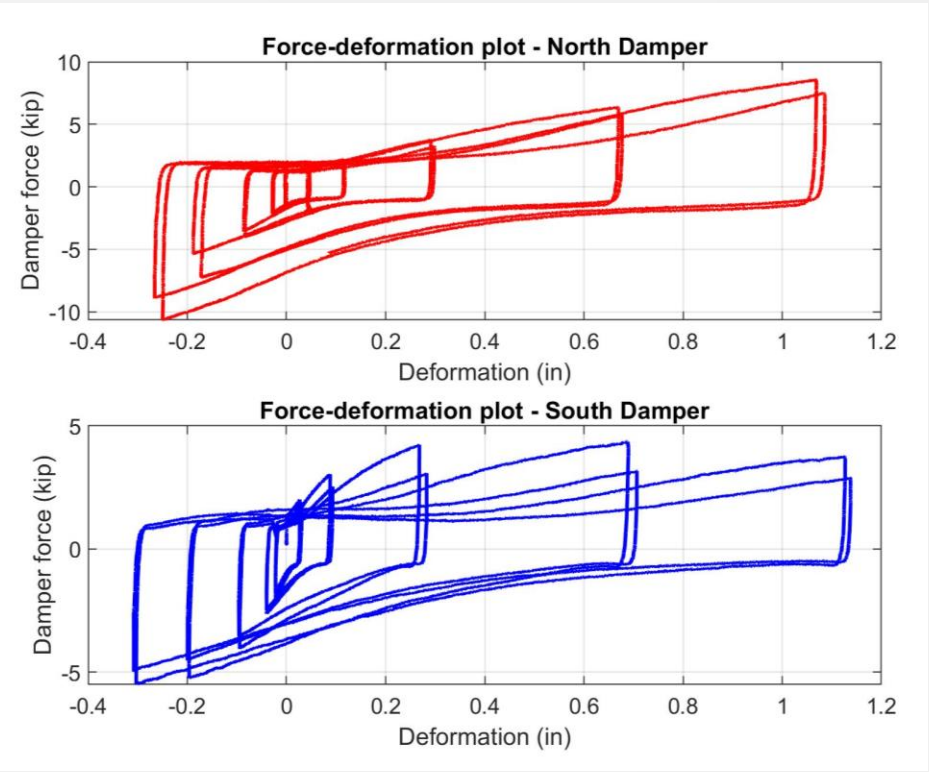
Unidirectional Quasi-static Cyclic Test

SC-CLT Wall Shear Force vs Drift



PSD force vs deformation



Multidirectional Quasi-static Cyclic Test

Stage	Wall Drift at Floor Level % (in)		Cycles	Loading Rate (in/min)
	X	Y		
A	±0.3 (±0.46)	-	1	0.6
B	±0.5 (±0.77)	±0.5 (±0.77)	2	0.8
C	±1.0 (±1.54)	±1.0 (±1.54)	2	0.8
D	±2.0 (±3.08)	±2.0 (±3.08)	2	0.8
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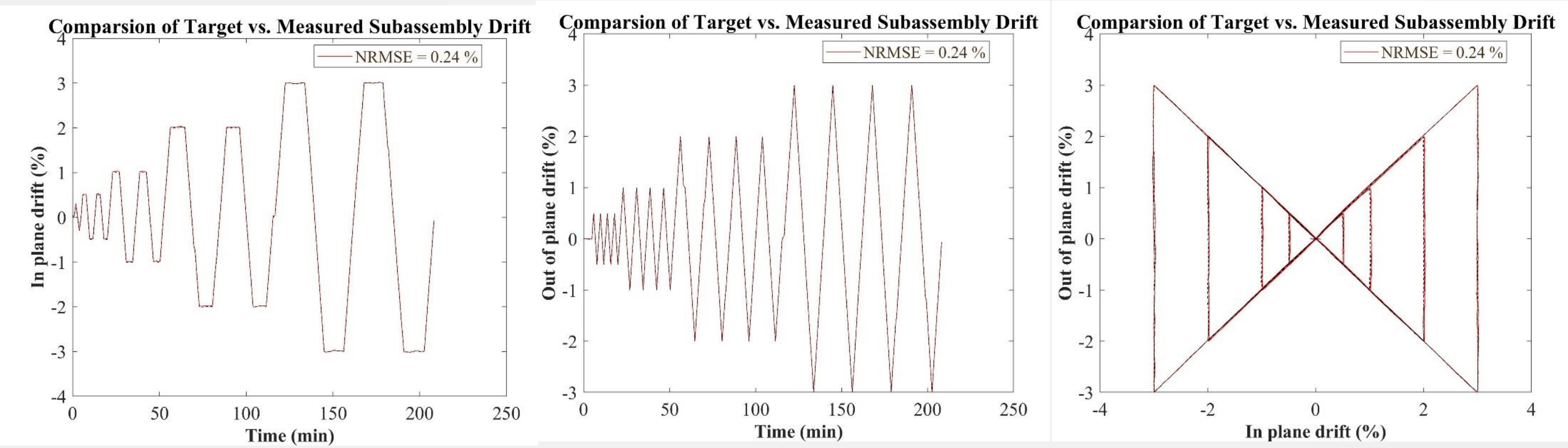

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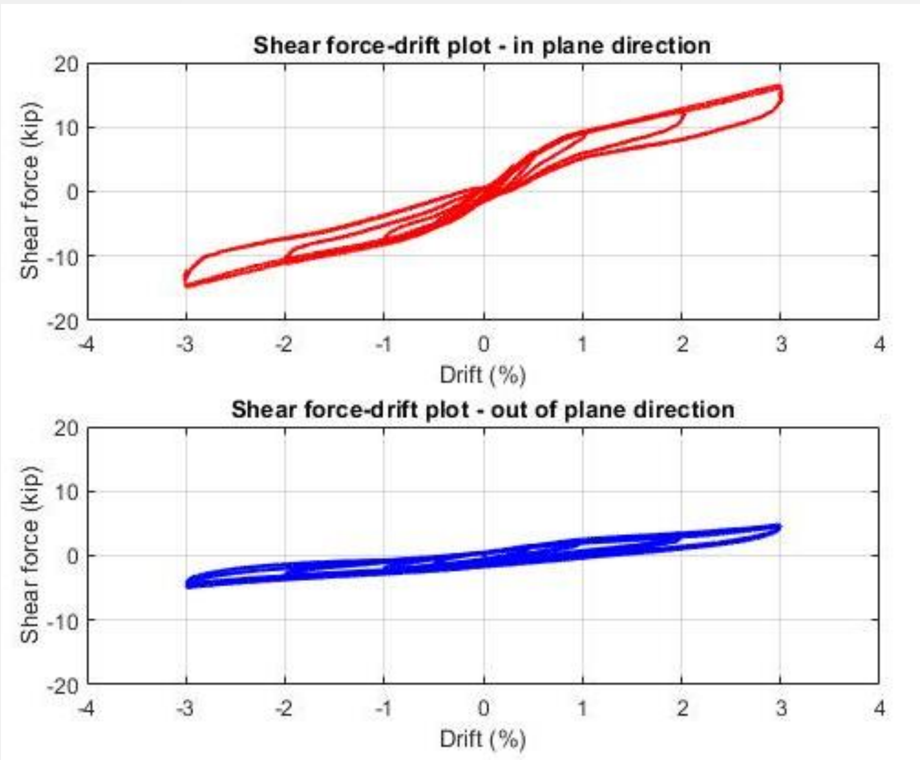
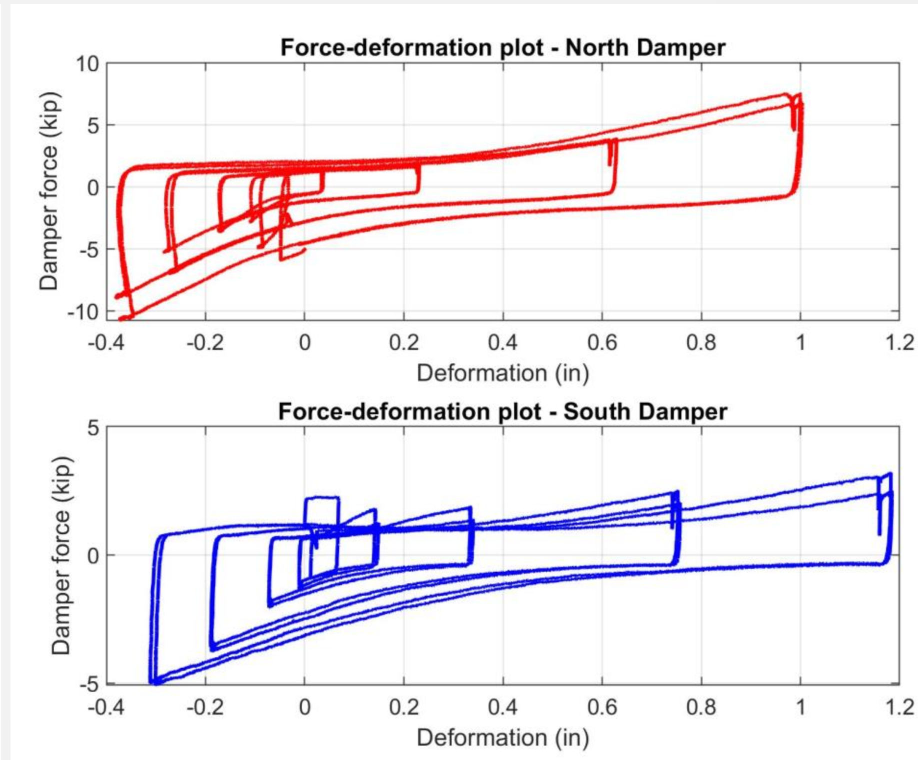
Multidirectional Quasi-static Cyclic Test

SC-CLT Wall Shear Force vs Drift

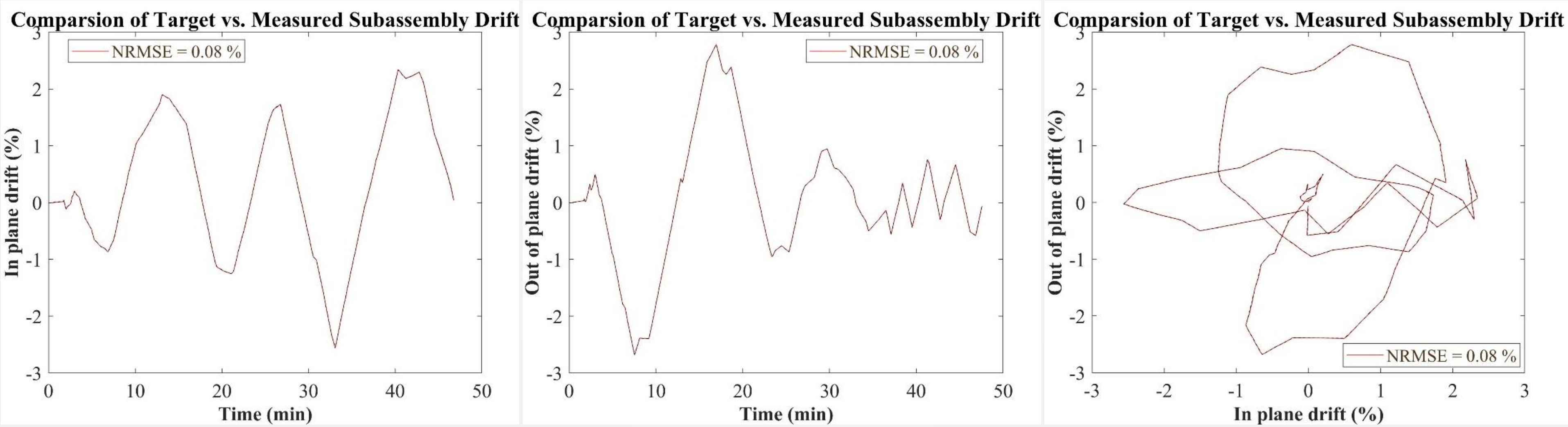


PSD force vs deformation



Predefined Quasi-static Earthquake Test

Earthquake name	Year	Station Name	Clipped time (s)	Loading Rate (in/min)
KOCAELI	1999	Izmit	0 to 8	0.8



Example Multi-directional DBE Level Kocaeli Earthquake

Predefined Quasi-static Earthquake Test

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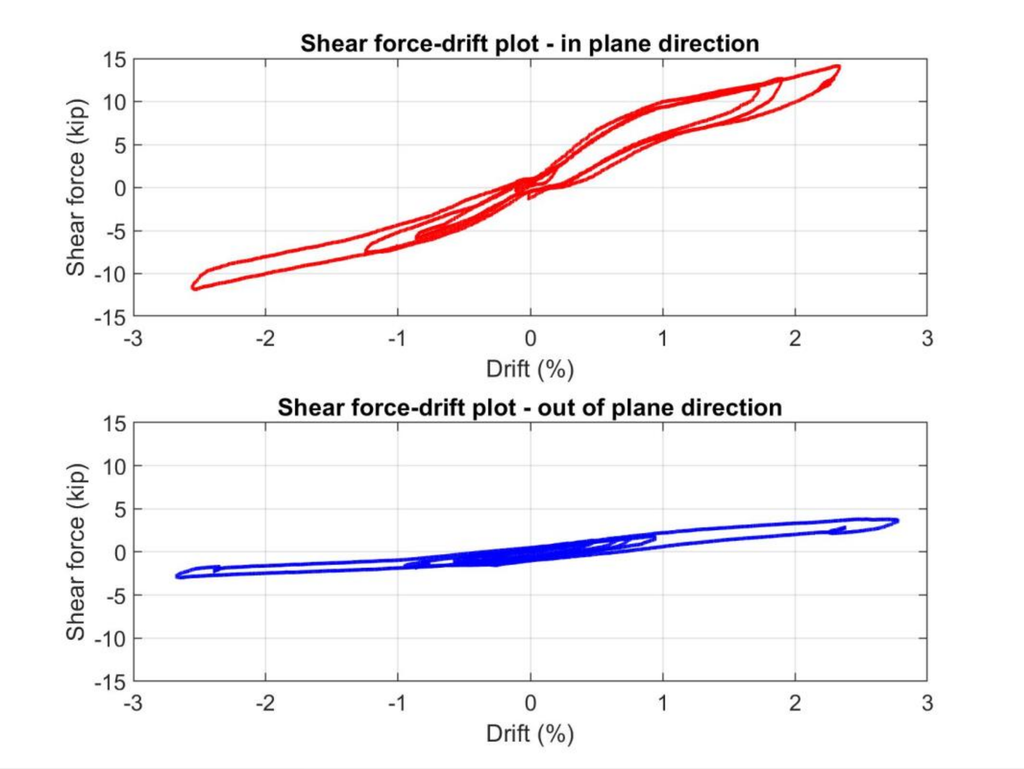
KOCAELI	1999	Izmit	0 to 8	0.8

<u>Example Multi-directional DBE Level Kocaeli Earthquake</u>

Predefined Quasi-static KOCAELI Earthquake Test

SC-CLT Wall Shear Force vs Drift



PSD force vs deformation