NHERI Lehigh Facility Project Portfolio

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NHERI Lehigh EF Testing Capabilities for Natural Hazards Engineering Research

- Large-Scale Hybrid Simulation
- Large-Scale Real-time Hybrid Simulation
- Large-Scale Real-time Hybrid Simulation with Multiple Experimental Substructures
- Geographically Distributed Hybrid Simulation
- Geographically Distributed Real-time Hybrid Simulation
- Predefined load or displacements (Quasi-static testing or characterization testing)
- Dynamic testing

Multi-directional Dynamic Testing of Pipe Couplers

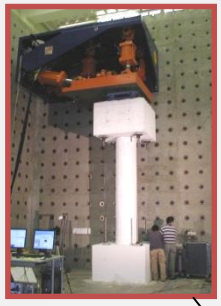
Example Project & Testing Types

Test Specimen	Mode of Testing
R/C bridge-soil-foundation	Distributed hybrid simulations
Building with piping system	Multi-directional real-time hybrid simulations
Self-centering beam-to-column moment connections	Characterization tests
Self-centering frame systems	Characterization, hybrid simulations
R/C bridge with MR dampers	Real-time hybrid simulations
Passive and semi-active dampers	Characterization, hybrid and real-time hybrid simulations
Steel frame building with MR dampers	Real-time hybrid simulations with single and multiple experimental substructures, real-time distributed hybrid simulations
Tsunami-driven debris	Dynamic impact loading
Post-tensioned coupled shear wall systems	Characterization testing, multi-mode dynamic testing
Laterally and axially loaded SSI pile tests	Characterization testing, quasi-static testing

Pre-NEESR MISST: Multi-Site Soil-Structure-Foundation Interaction EQ Simulation Test – UIUC, RPI, Lehigh

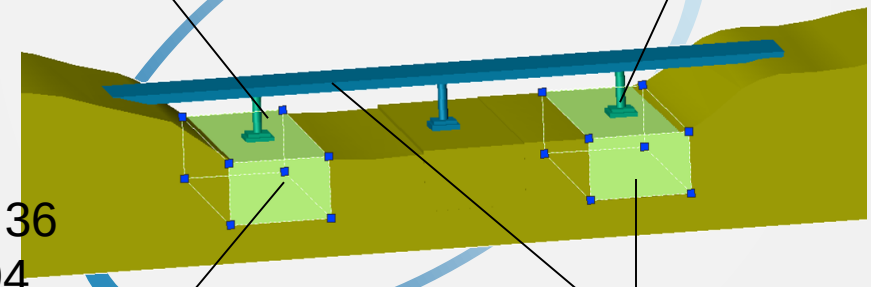
Distributed Hybrid Simulation Test Setup

UIUC
Pier test subassembly



UI-SIMCOR

Lehigh University
Pier test subassembly



I-10 Collector-Distributor 36

- Damaged during 1994 Northridge EQ

RPI
Soil test subassembly

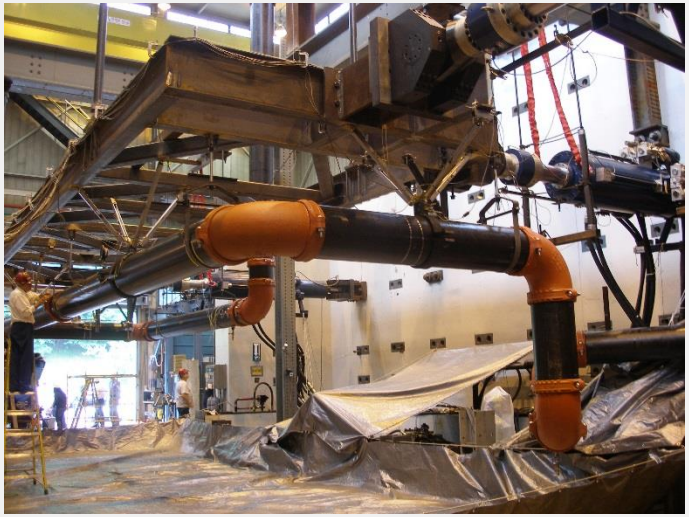
NCSA
Remaining soil, superstructure analytical subassembly

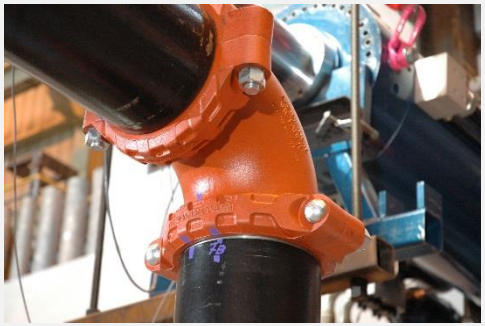
Schematic Courtesy of UIUC

Multi-directional Large-Scale Real-time Hybrid Simulation of 3-story Building with Piping System – Lehigh

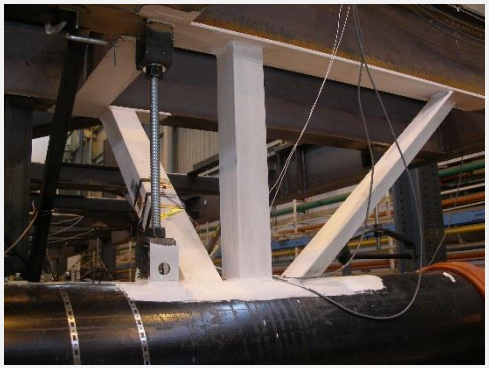
Objectives

- Evaluate seismic performance of Victaulic grooved couplers for building piping systems
- Evaluate seismic performance of alternative pipe bracing details





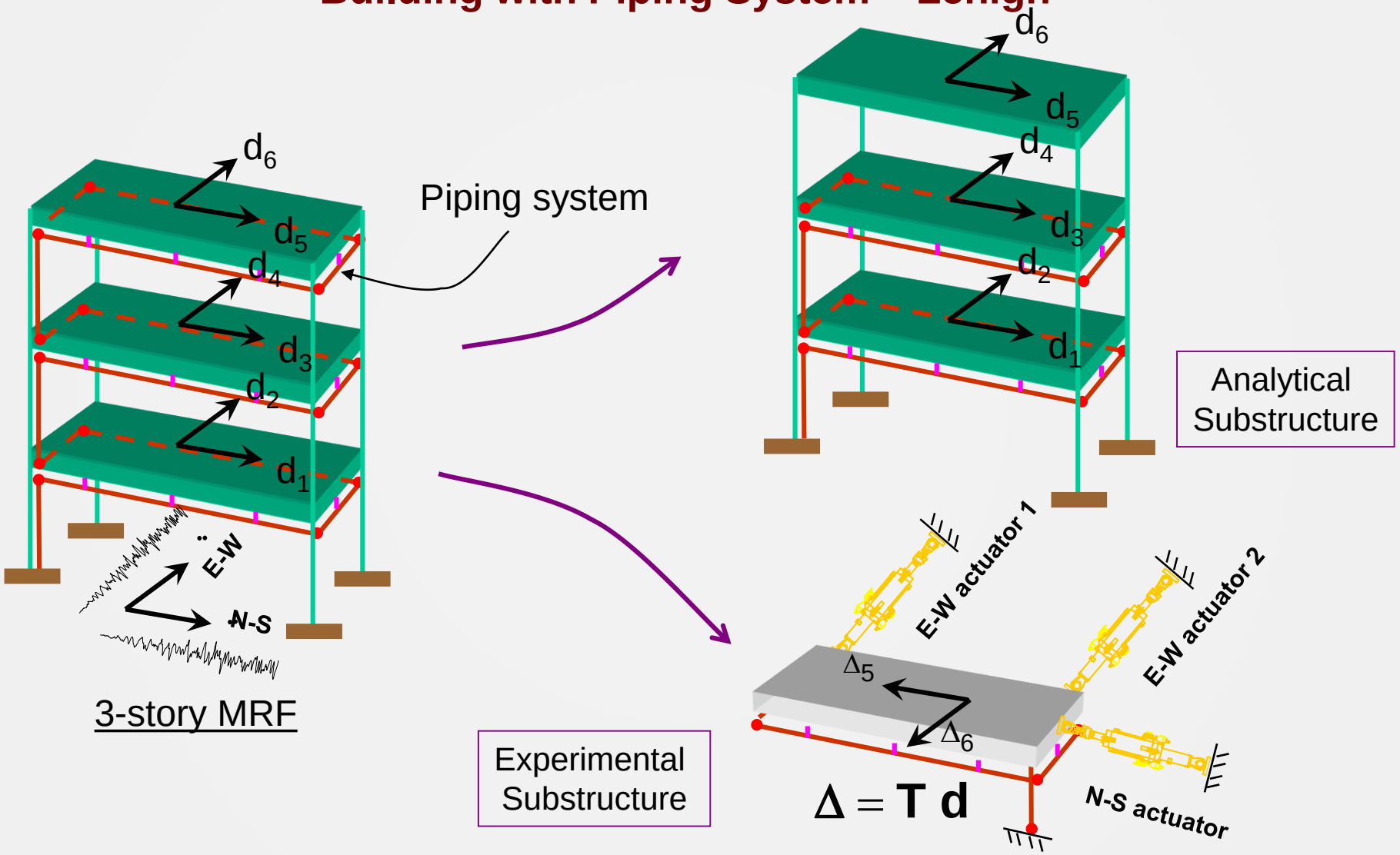
Grooved coupler



Rigid bracing

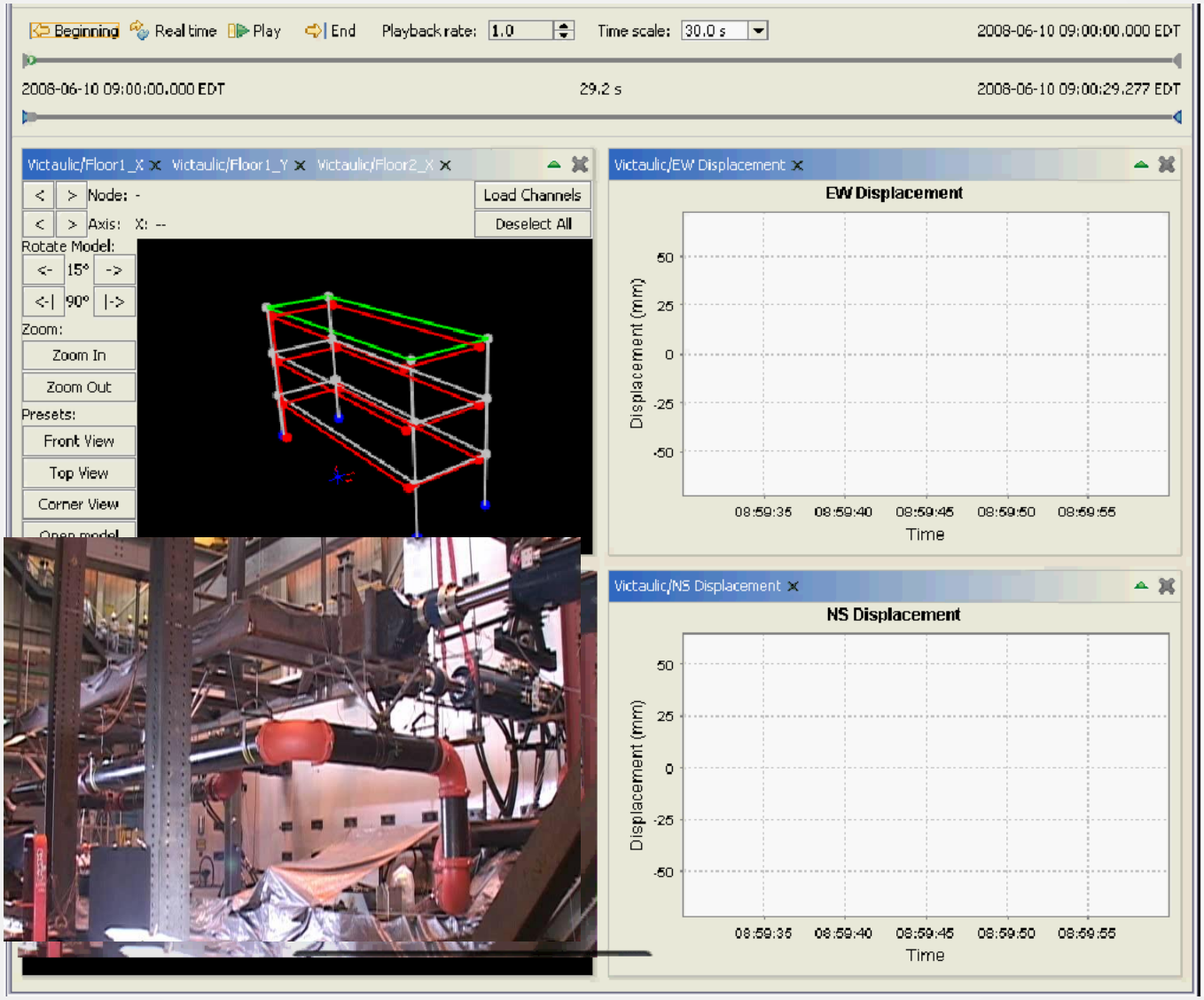
Flexible bracing

Multi-directional Large-Scale Real-time Hybrid Simulation of 3-story Building with Piping System – Lehigh



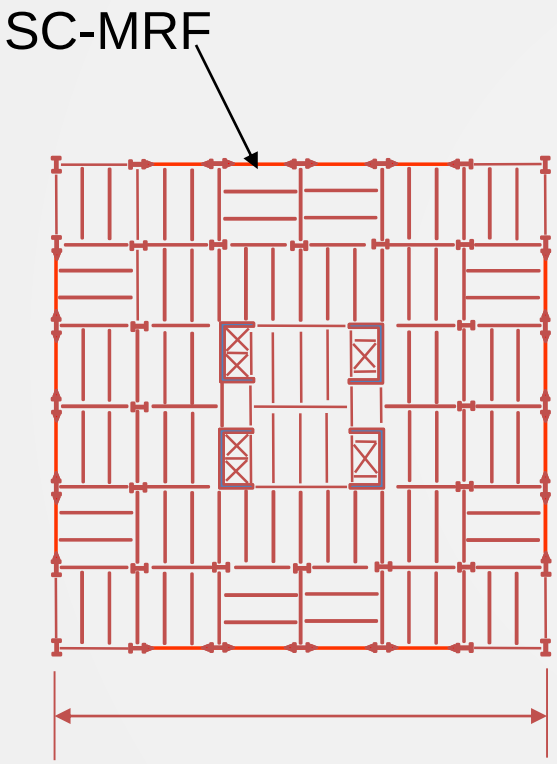
Multi-directional Large-Scale Real-time Hybrid Simulation of 3-story Building with Piping System – Lehigh

RTHS: 1994 Northridge EQ, Canogo Park (MCE)



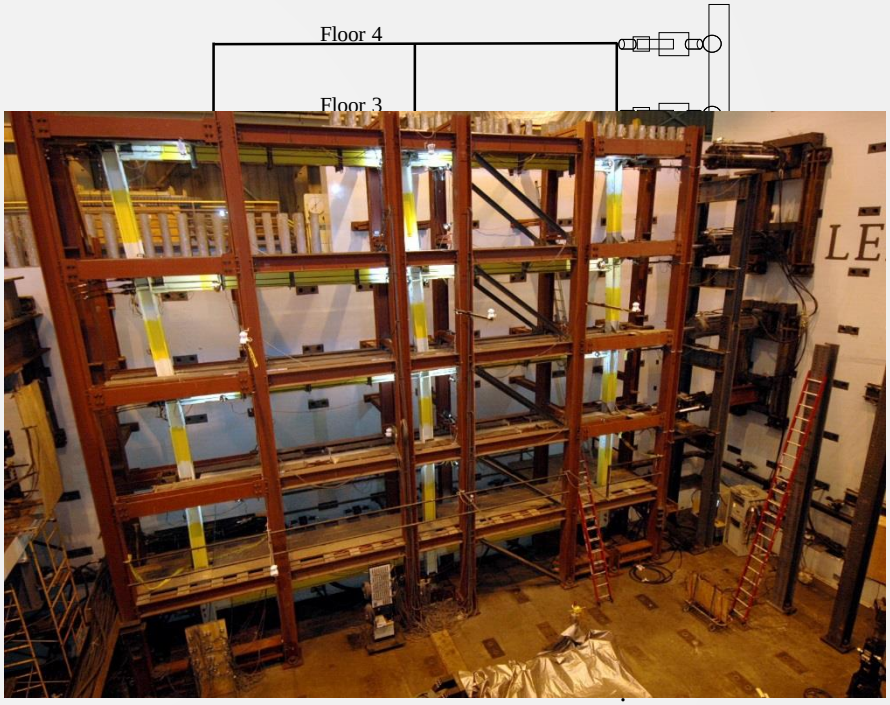
NEESR-SG Self Centering Damage-Free Seismic Resistant Steel Frame Systems – Princeton, Purdue, Lehigh, MCEER

Large-Scale Hybrid Simulation



6-story : 6 bays @ 30 ft = 180 ft

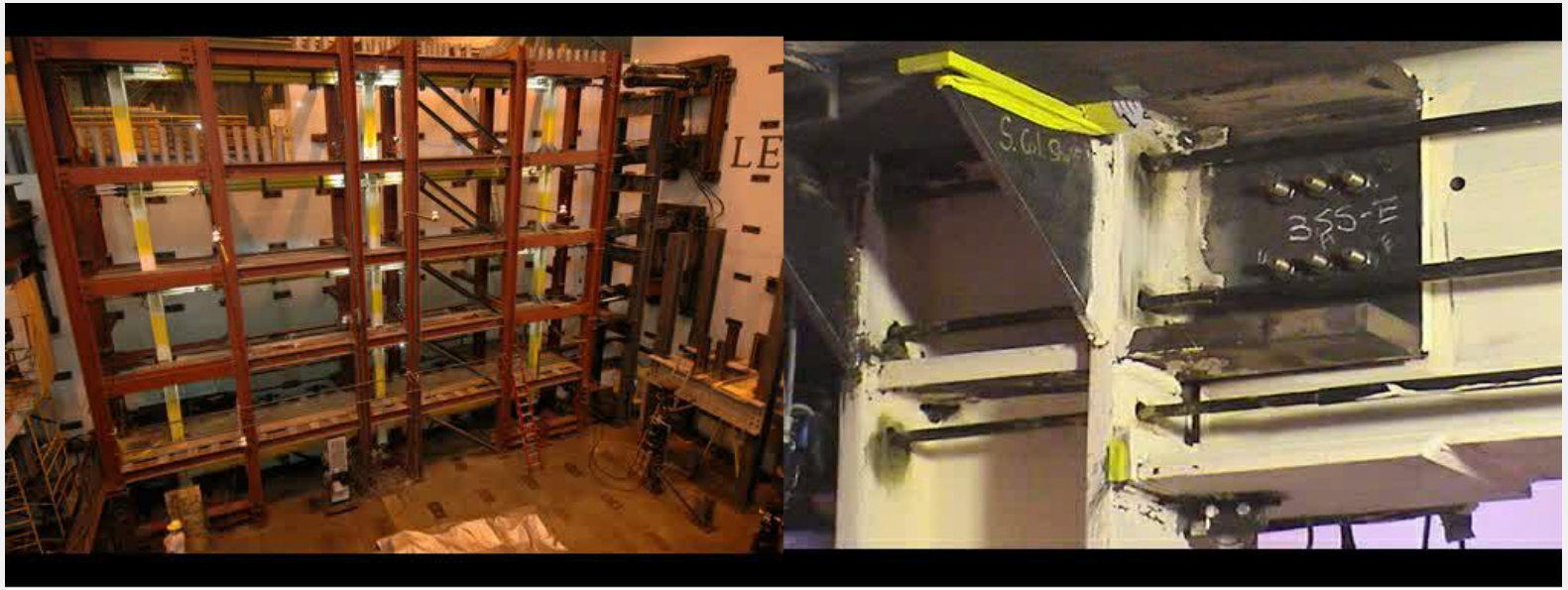
Plan of Prototype Building

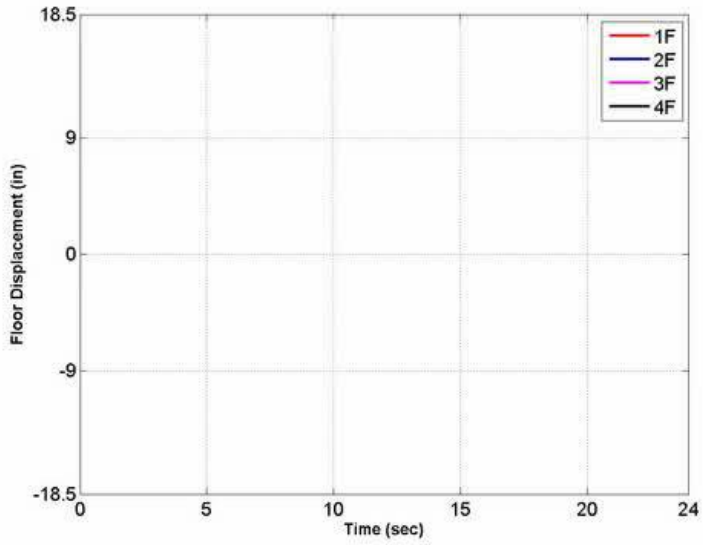


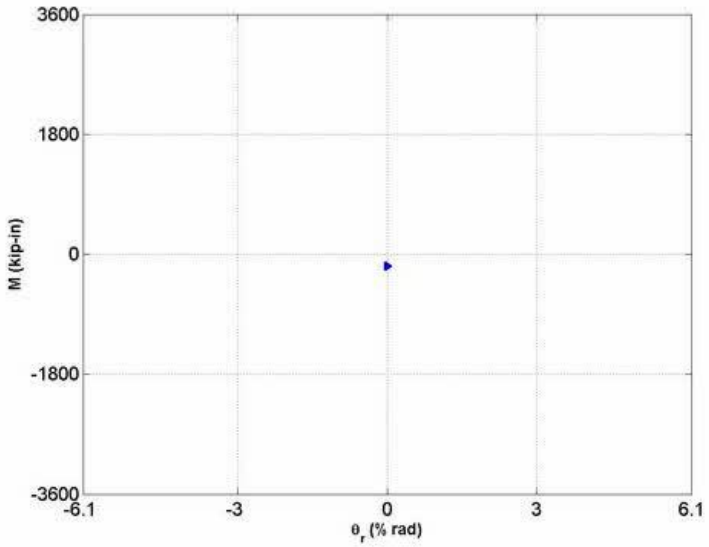
Schematic of SC-MRF Exper. Substructure (Diaphragm and Gravity Systems Analytically Defined)

NEESR-SG Self Centering Damage-Free Seismic Resistant Steel Frame Systems – MCE (2500 yr Return Period EQ) Hybrid Simulation Results

MCE (2500 yr Return Period EQ) Hybrid Simulation Results

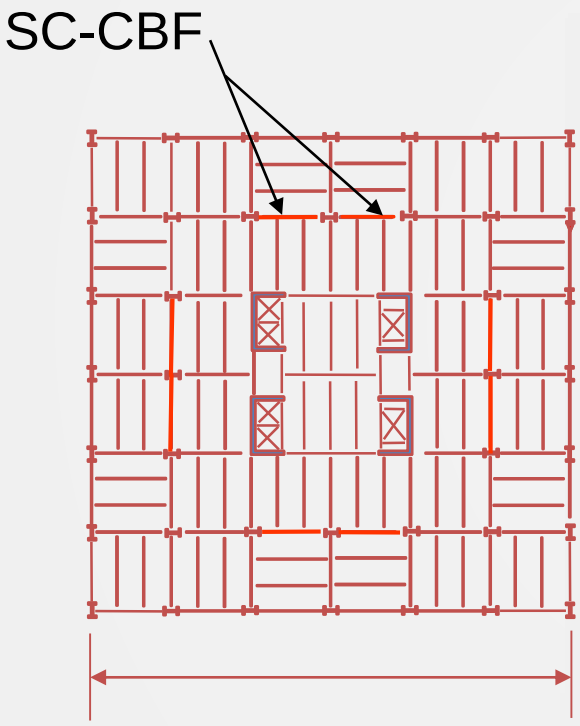






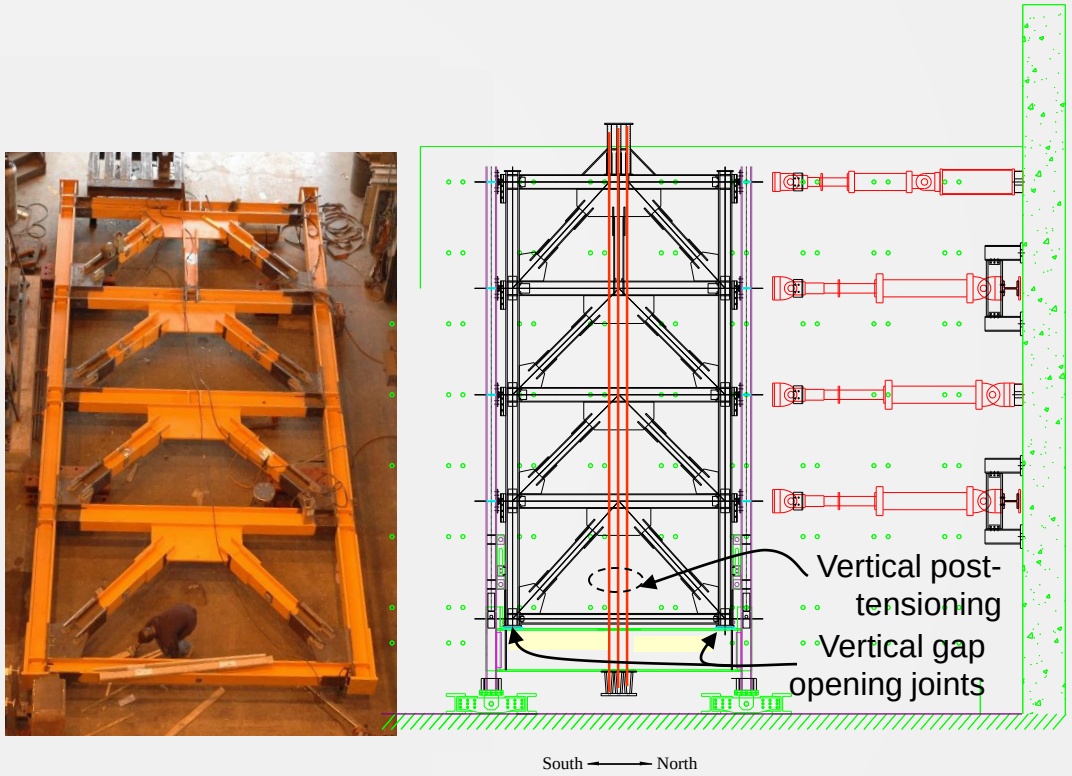
NEESR-SG Self Centering Damage-Free Seismic Resistant Steel Frame Systems - Princeton, Purdue, Lehigh, MCEER

Large-Scale Hybrid Simulations



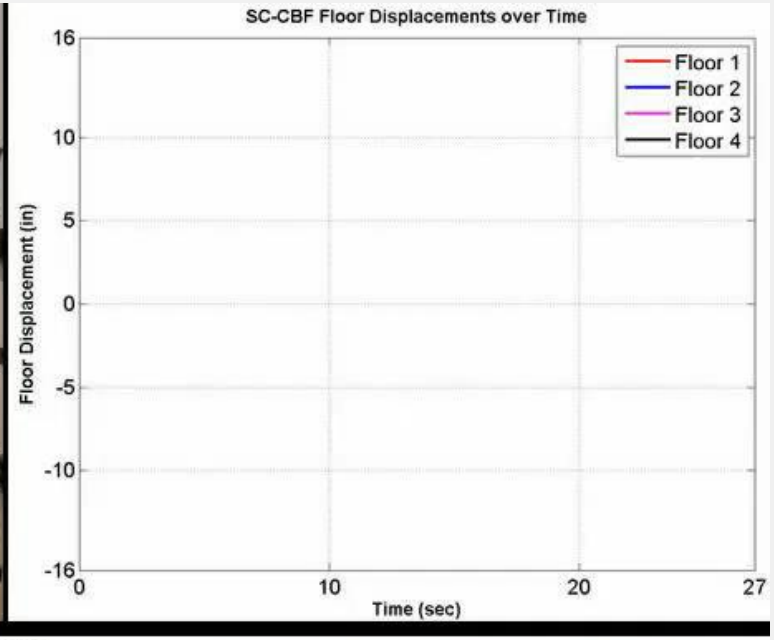
6-story : 6 bays @ 30 ft = 180 ft

Plan of Prototype Building



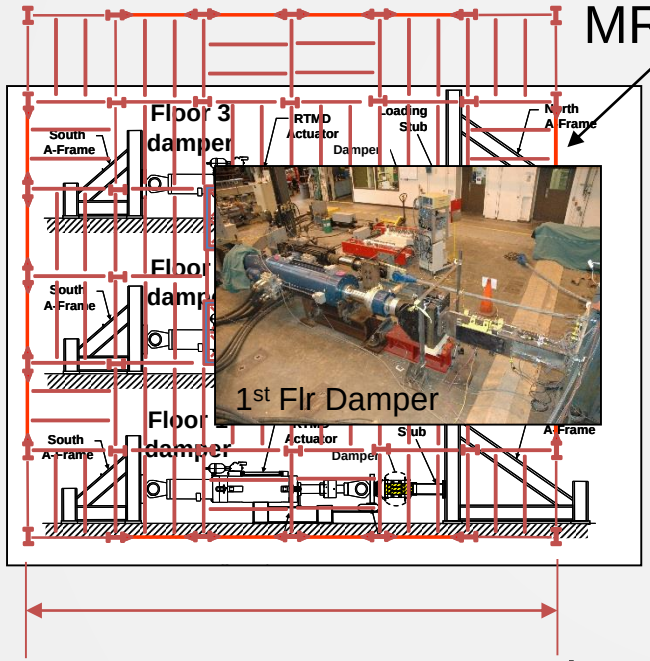
SC-CBF Exper. Substructure (Diaphragm and Gravity Systems Analytically Defined)

1995 Takitori, Japan EQ ($\mu_{MCE} + 3\sigma$) Simulation Results



Development Of Advanced Servo-Hydraulic Control and Test Bed For Real-Time Testing Of Damped Structures Subjected To Earthquakes - Lehigh

Real-time Hybrid Simulation



Elevation of MRF with Passive Dampers

Close up view of damper

6-story : 6 bays @ 30 ft = 180 ft

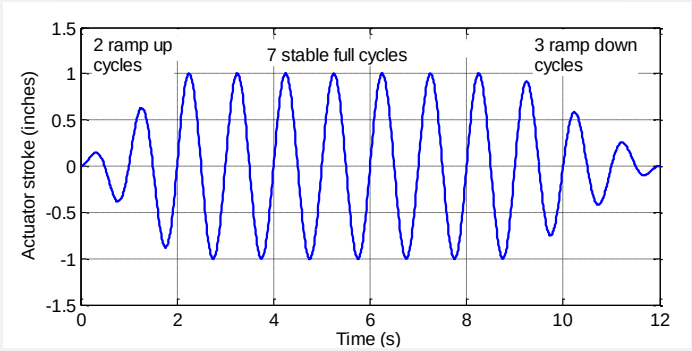
Plan of Prototype Building

Experimental Substructures (MRFs, Diaphragm and Gravity Systems Analytically Defined)

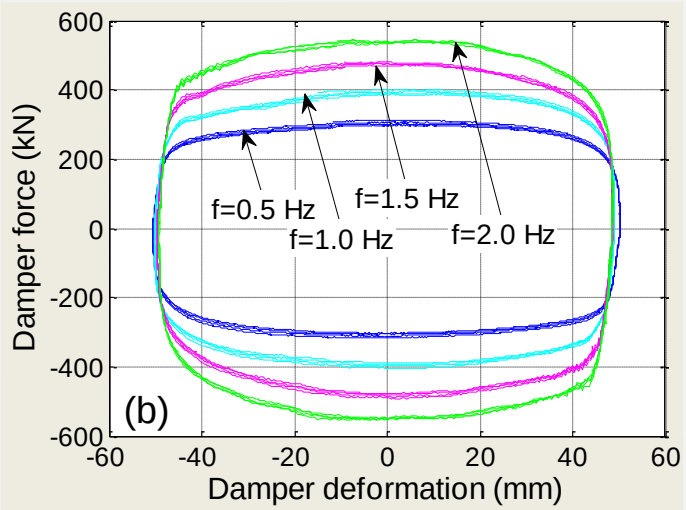
Full-Scale Nonlinear Viscous Dampers

Characterization testing

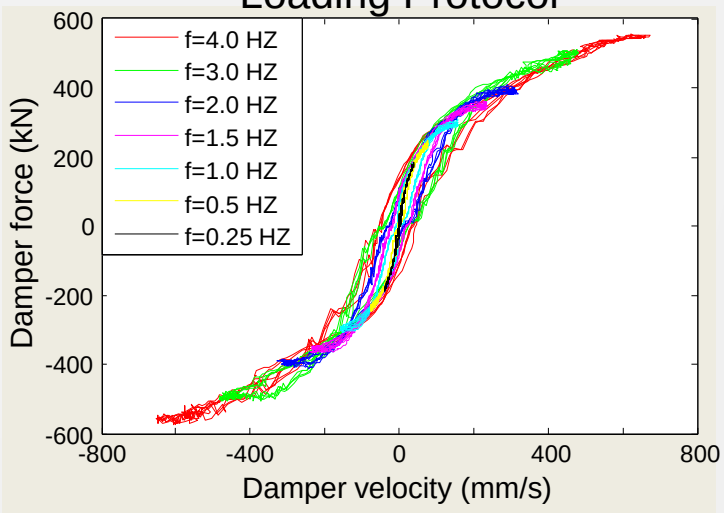
Damper testbed



Loading Protocol

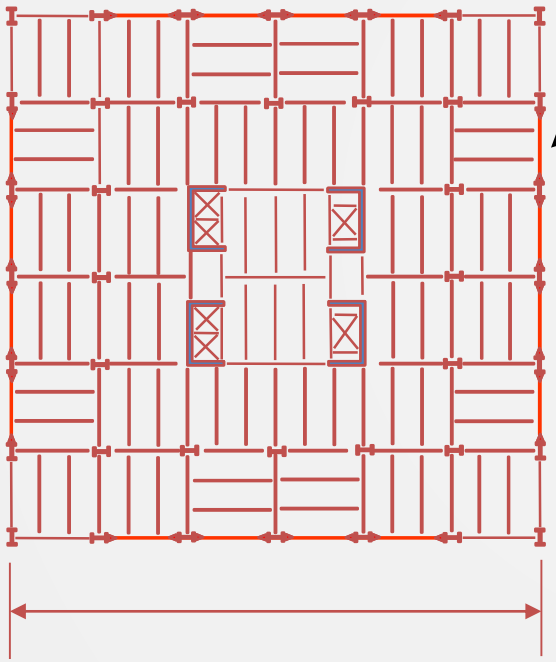


Damper force - deformation



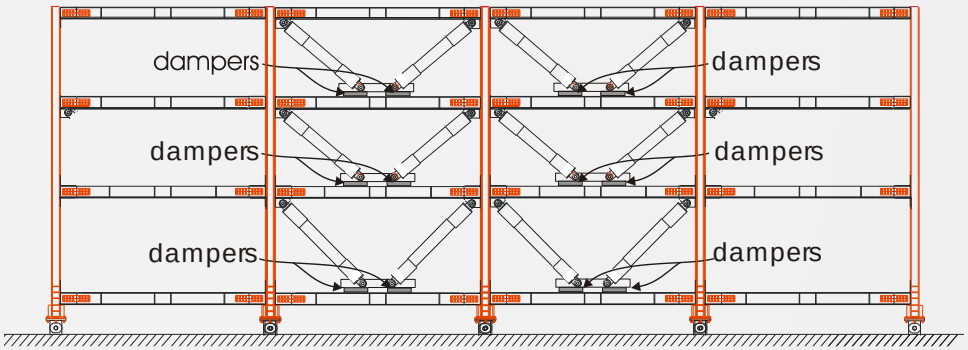
Damper force - velocity

NEESR-CR: Performance-Based Design for Cost-Effective Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems - Cal St. Pomona, Cal St. Northridge, Lehigh



6-story : 6 bays @ 30 ft = 180 ft

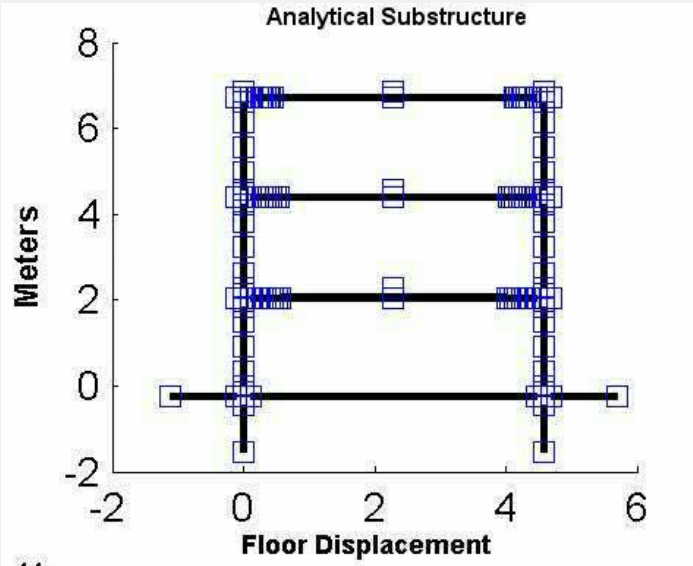
Plan of Prototype Building

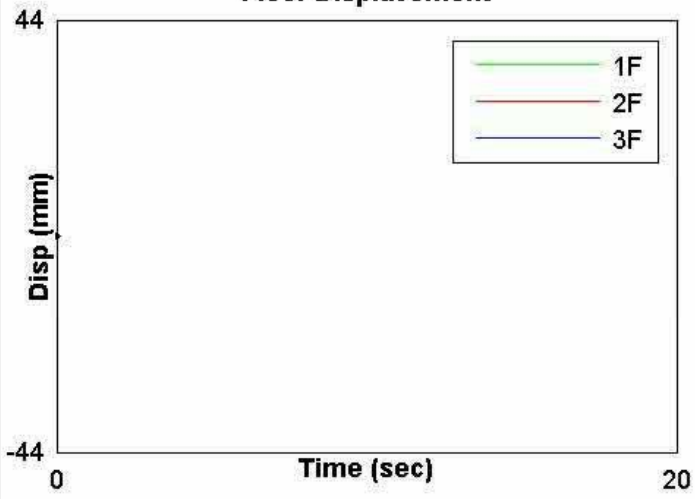


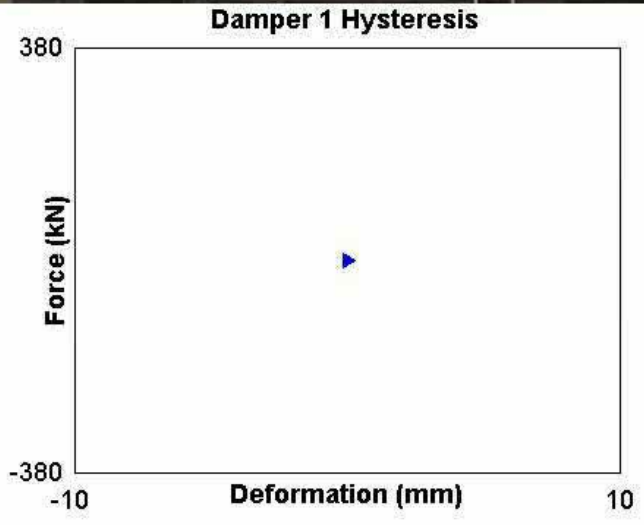
Elevation of MRF with Passive Dampers

NEESR-CR: Performance-Based Design for Cost-Effective Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems

Real-time Hybrid Simulation – MRF, Gravity Frames Anl Sub





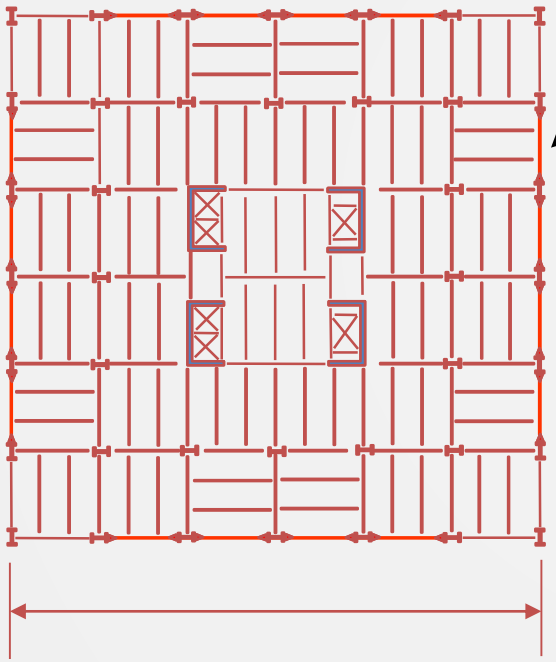


RTHS Phase-2: MCE level 1994 Northridge Earthquake RRS318 component

Real-time Hybrid Simulation: MRF + Braced Frame Exp Sub.

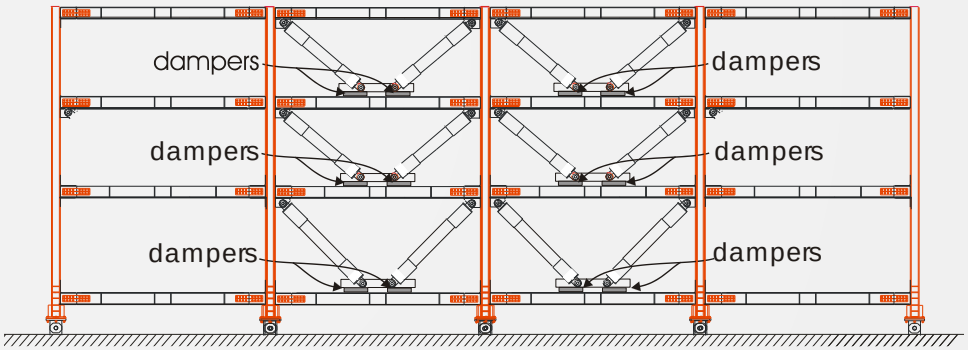
NEESR-SG Performance-Based Design and Real-time Large-scale Testing to Enable Implementation of Advanced Damping Systems – Purdue, UIUC, CUNY, UConn, Lehigh

Real-time Hybrid Simulation



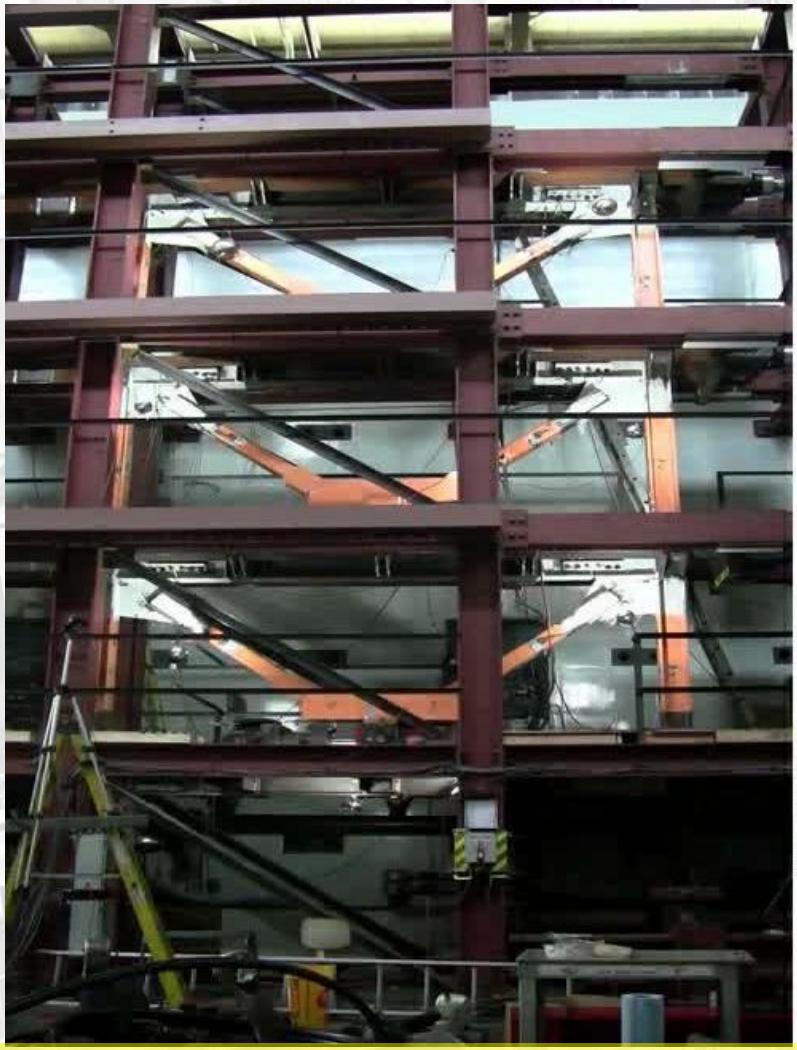
6-story : 6 bays @ 30 ft = 180 ft

Plan of Prototype Building

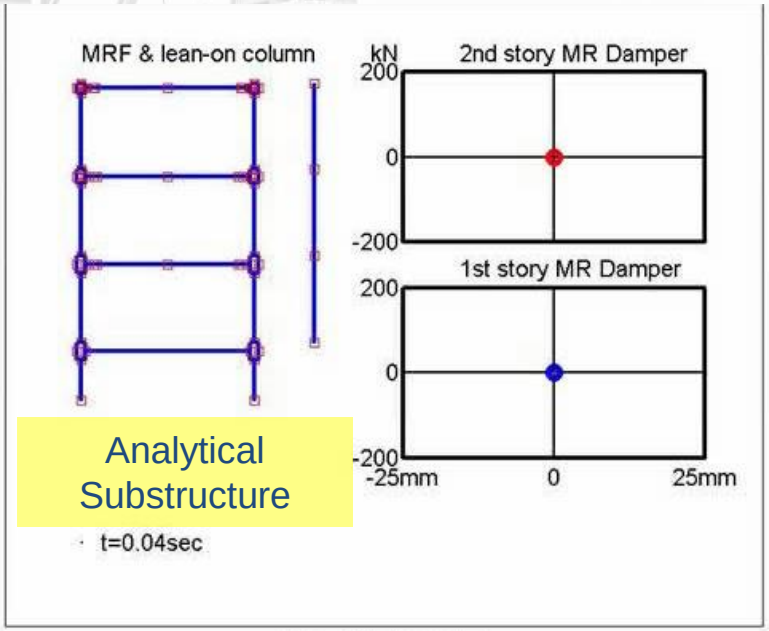


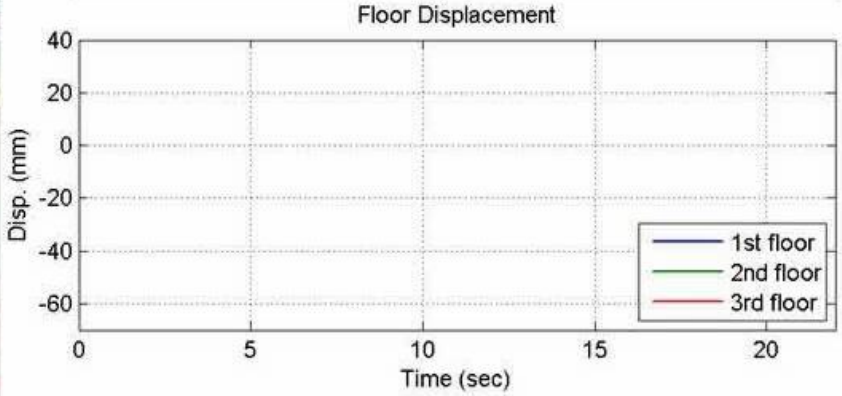
Elevation of MRF with MR Dampers

NEESR-SG PBD and Real-time Large-scale Testing to Enable Implementation of Advanced Damping Systems – Purdue, UIUC, CUNY, UConn, Lehigh RTHS: 1994 Northridge EQ (0.80*DBE), Semi-active MR



Experimental Substructure – CBF with MR Dampers





NEESR-CR Impact Forces from Tsunami-driven Debris Dynamic Impact Loading – Univ Hawaii, Oregon St., Lehigh

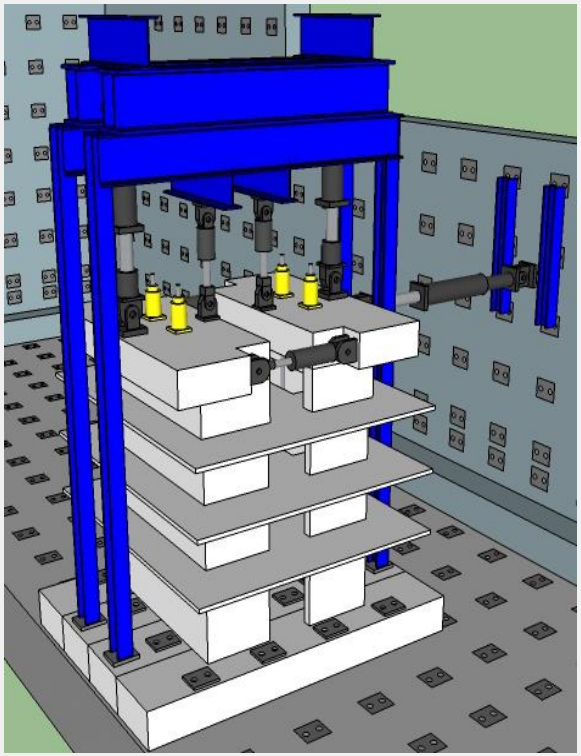
Dynamic Impact Loading

Test Setup Cargo Shipping Container Debris

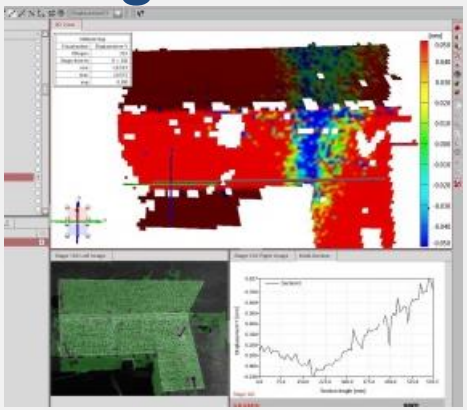
High Speed Video of Impact of Cargo Shipping Container with Structure

NEESR-CR Post-Tensioned Coupled Shear Wall Systems – Notre Dame, University of Texas @ Tyler

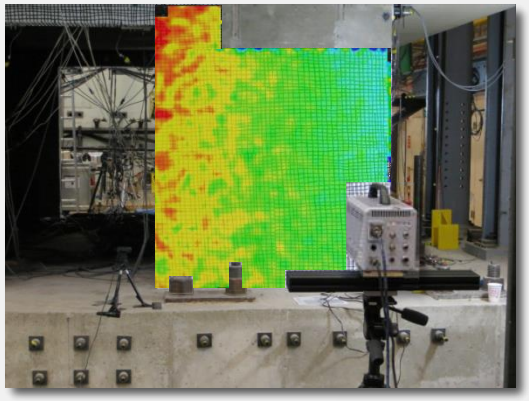
Mixed Mode Hybrid Simulation Testing



NEES@Lehigh Coupled Shear Wall Test Specimen with Multi-Directional Loading (Upper 5 floors analytically modeled)



Joint Strains Measured by DIC System (Pakzad)

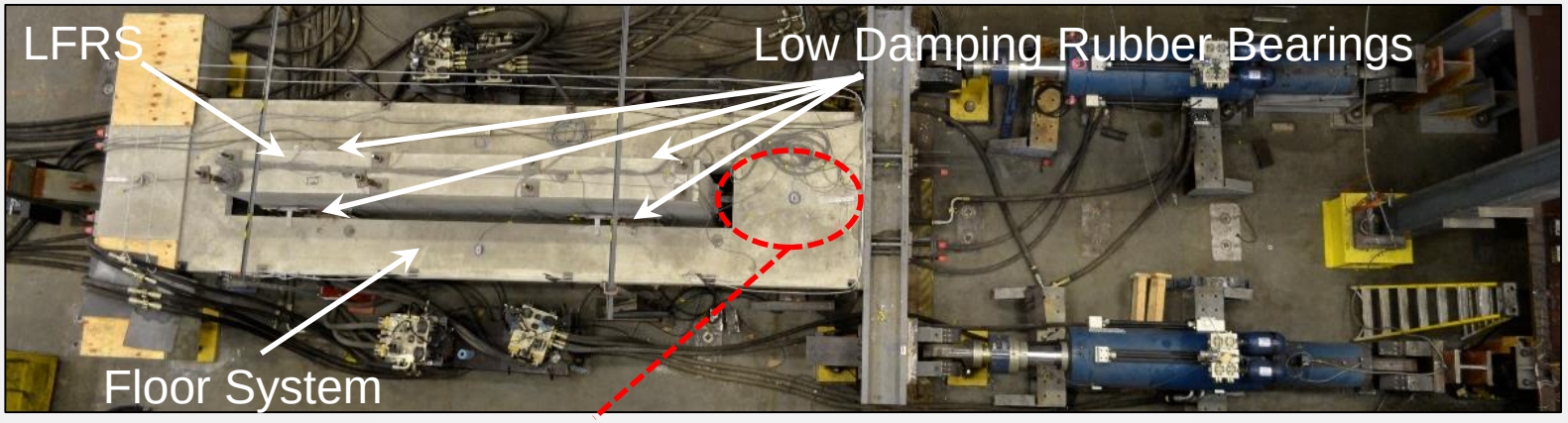


Digital Imaging Correlation System: reinforced concrete coupled-shear wall test specimen measured pier vertical displacements (courtesy M. McGinnis)

NEESR-CR: Inertial Force Limiting Floor Anchorage Systems for Seismic-Resistant Building Structures – Univ. Arizona, UCSD, Lehigh

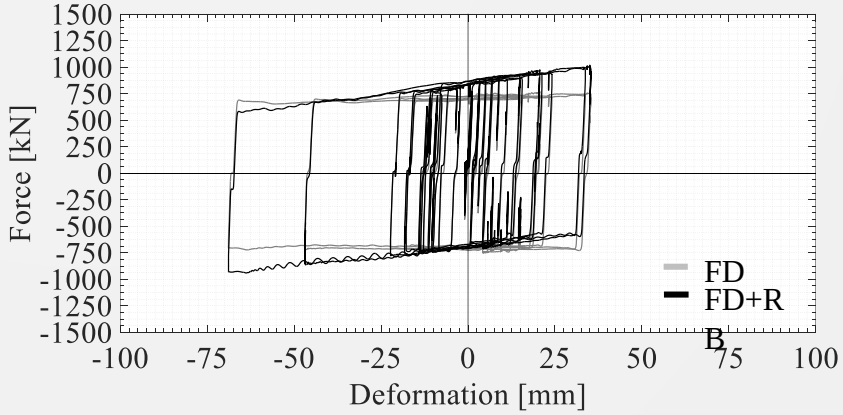
Cyclic Quasi Static and Dynamic Load Testing

Experimental Setup Up



Friction Device

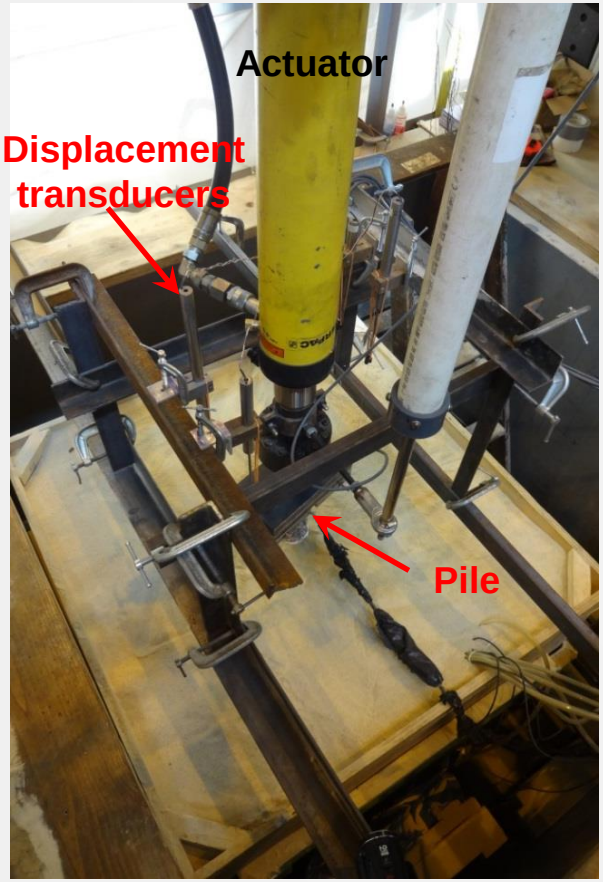
Floor Anchorage Hysteretic Response

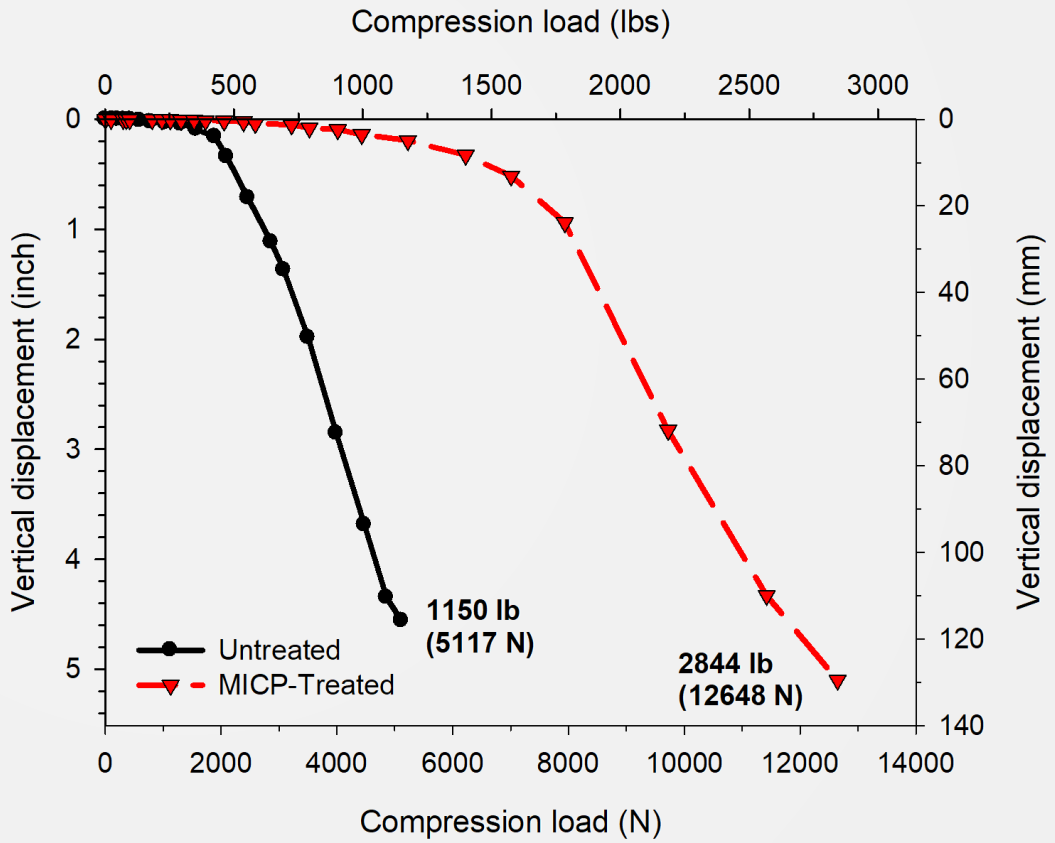


NSF-CMMI: Enhancement of Vertical Element for Foundation Supported by Ureolytic Carbonate Precipitation

Lehigh, Arizona State

Vertical Tests on Biomodified Soil-Pervious Pile Systems





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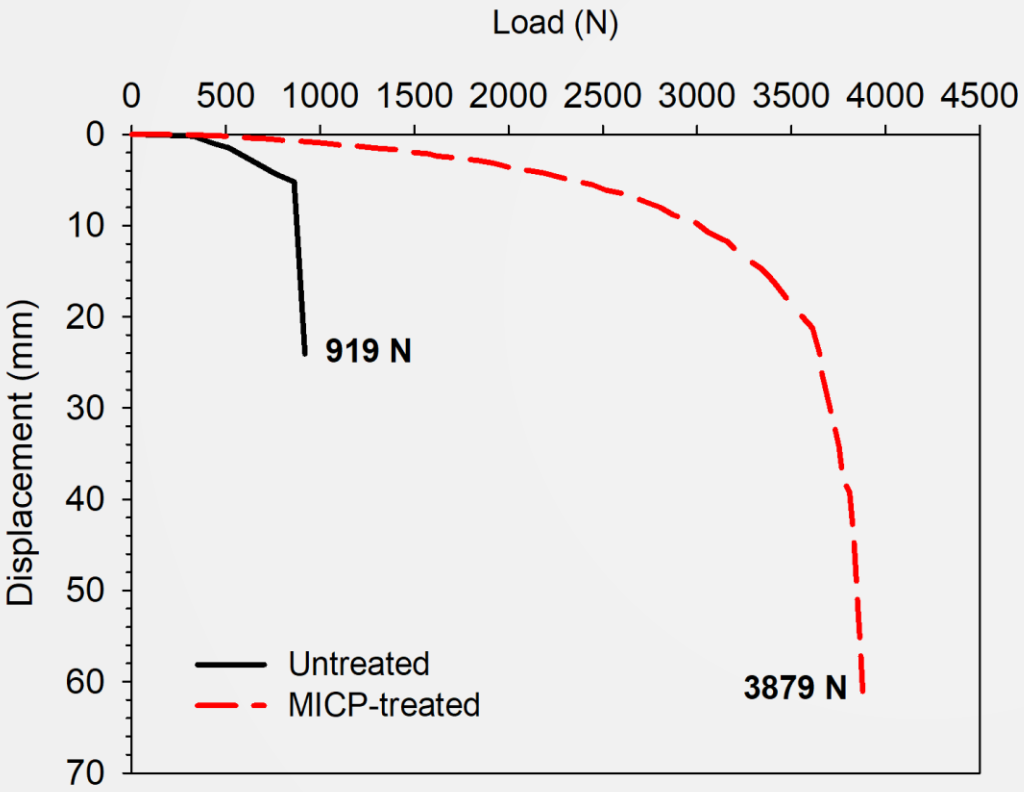
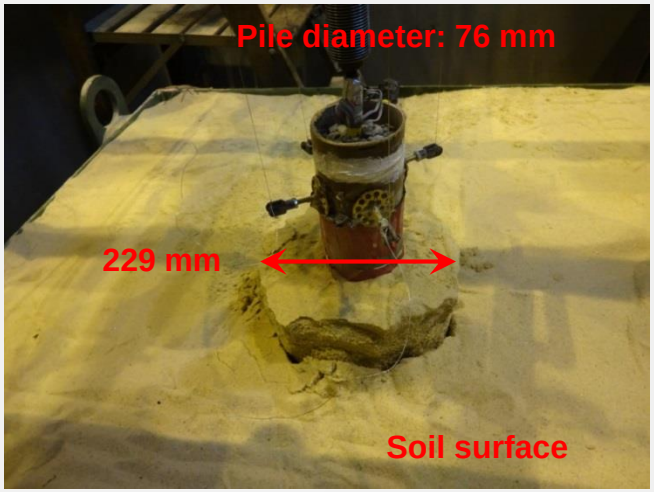
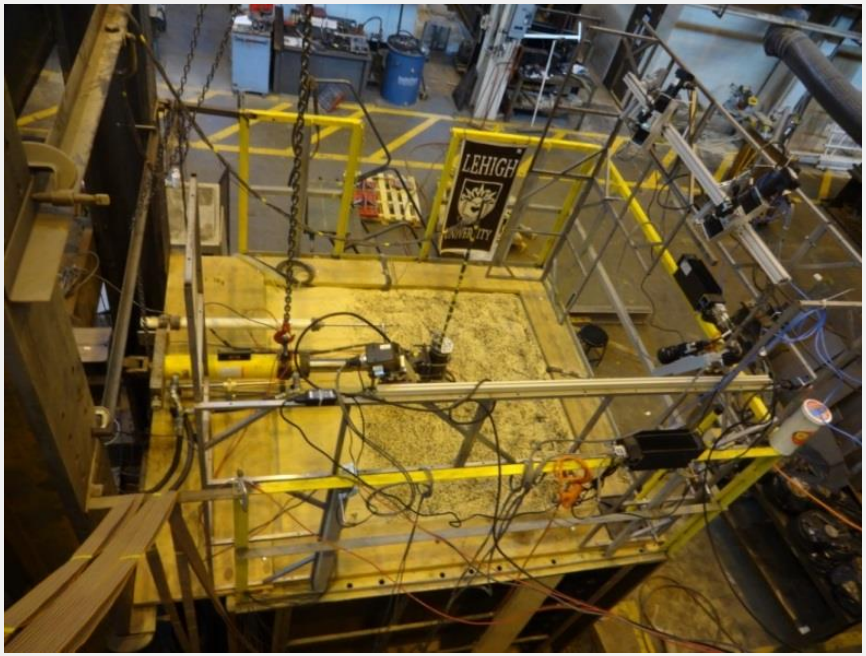




NSF-CMMI: SSI of Active and Passive Laterally Loaded Piles – Lehigh, Lafayette College

Static Lateral Load Pile Tests



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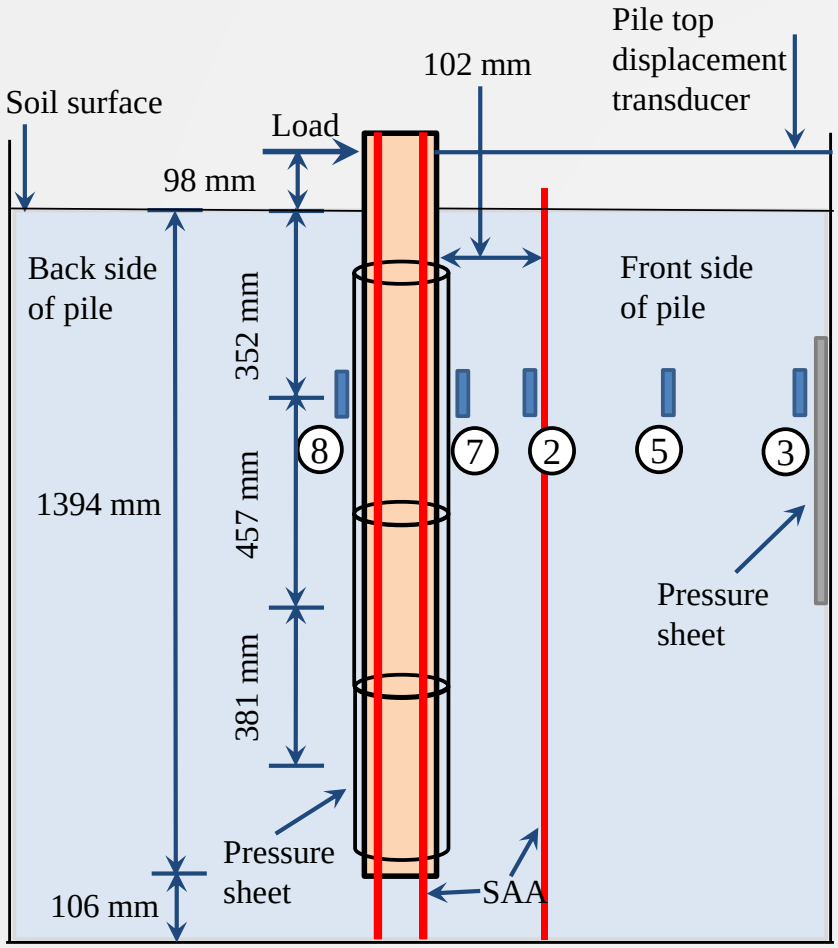
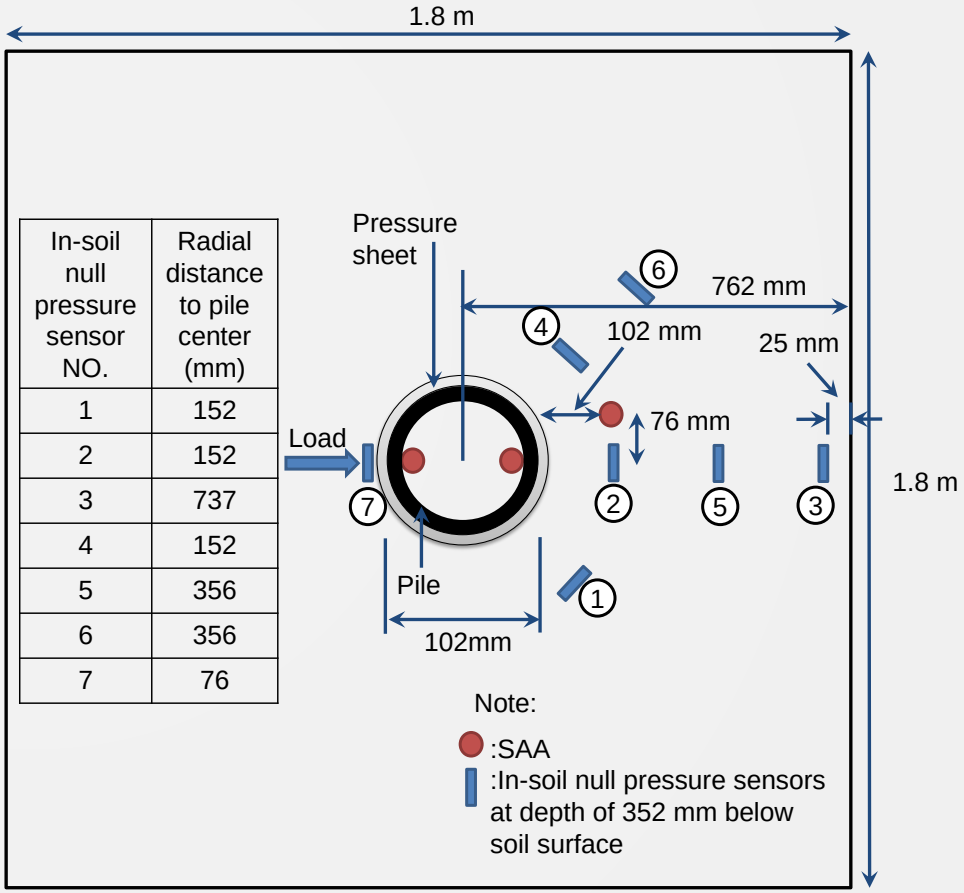
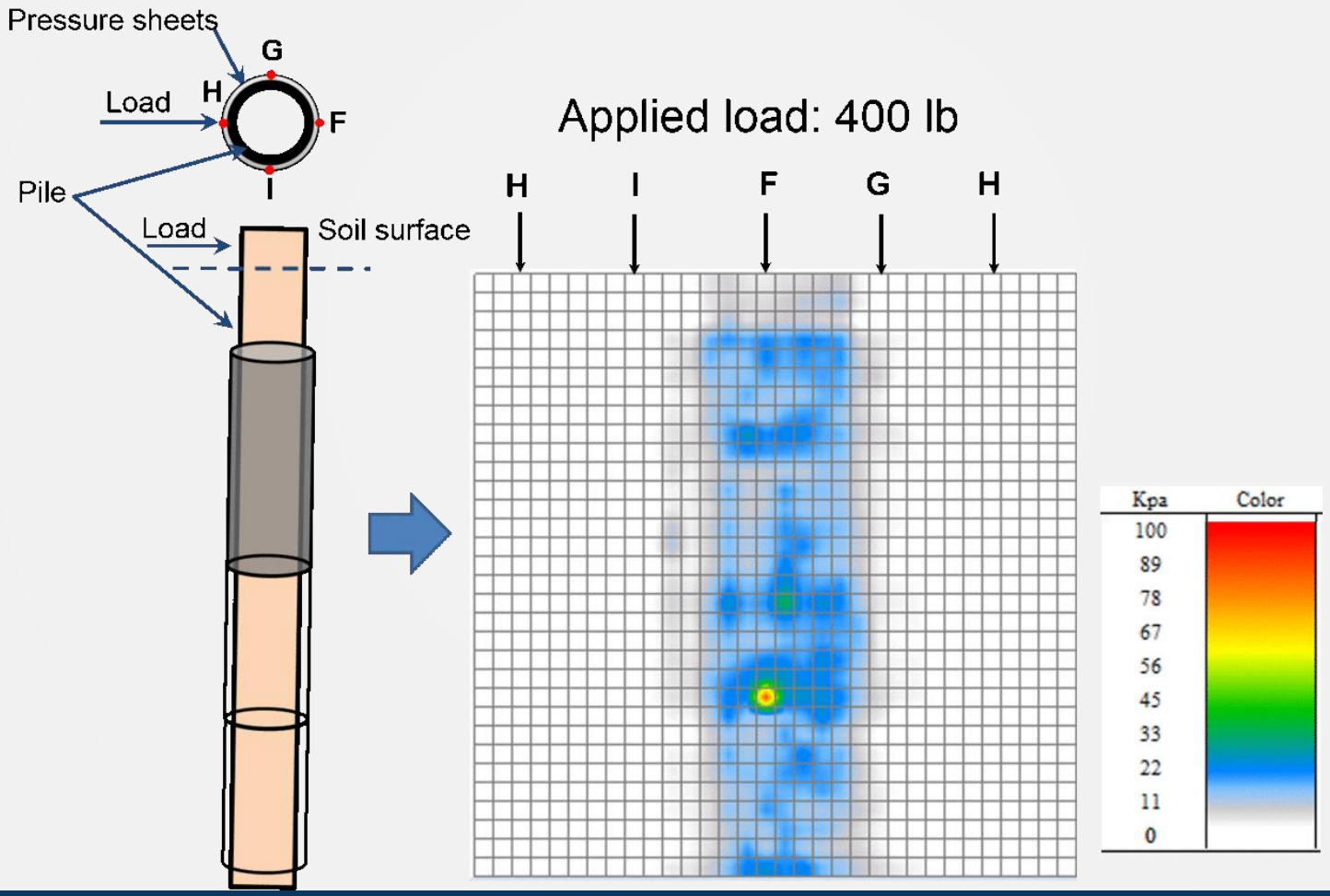




In-soil null pressure sensor NO.	Radial distance to pile center (mm)
1	152
2	152
3	737
4	152
5	356
6	356
7	76

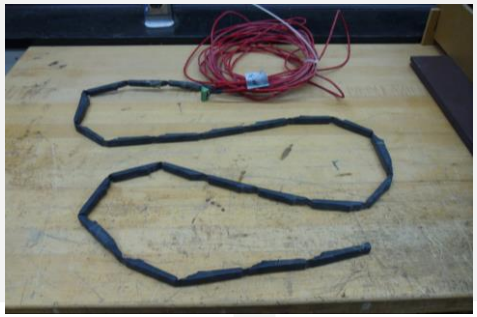
NSF-CMMI: SSI of Active and Passive Laterally Loaded Piles – Lehigh, Lafayette College

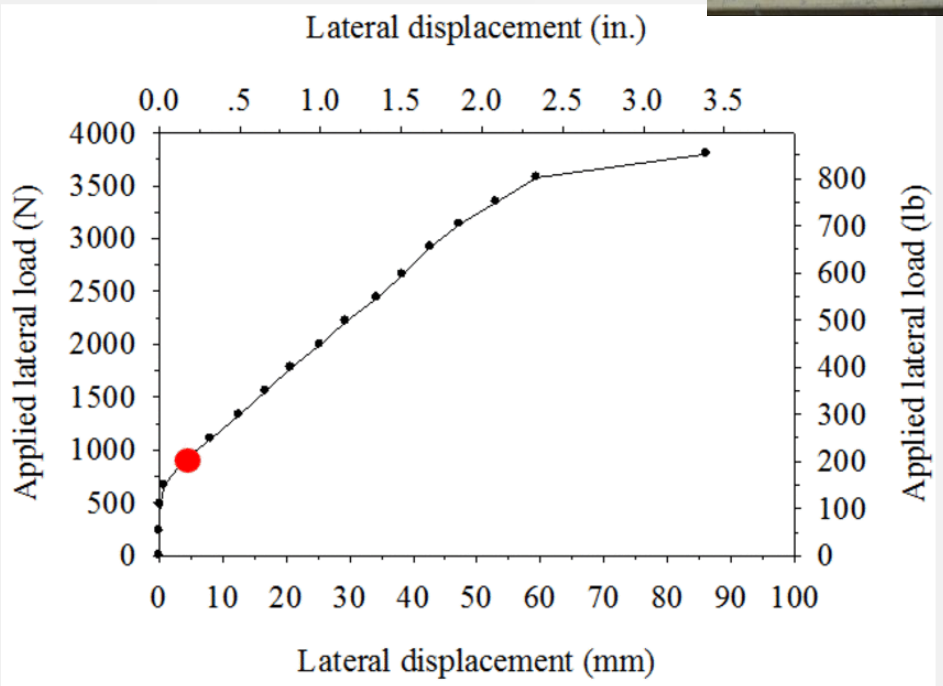
Static Lateral Load Pile Tests

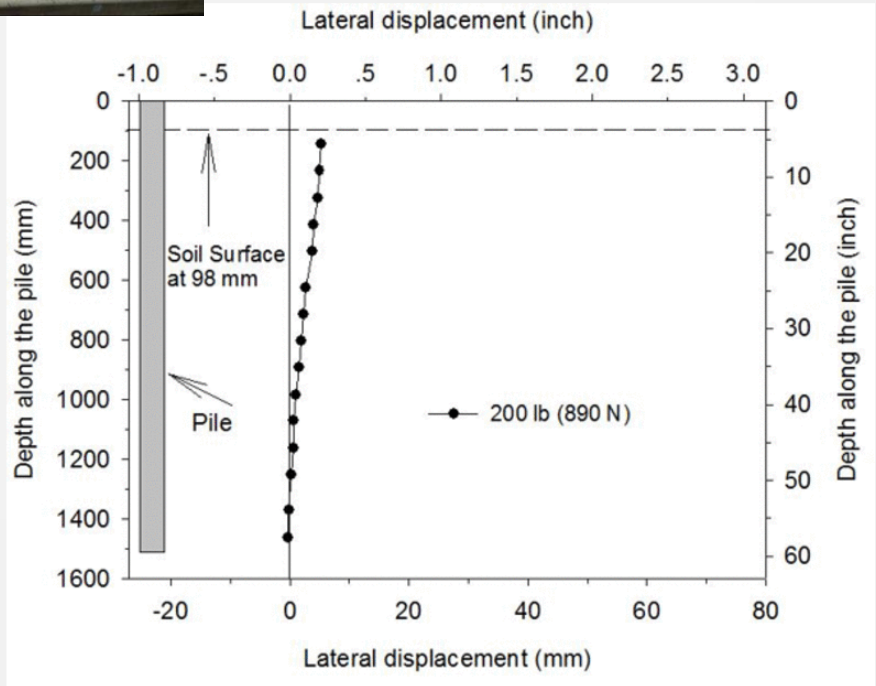


NSF-CMMI: SSI of Active and Passive Laterally Loaded Piles – Lehigh, Lafayette College

Static Lateral Load Pile Tests

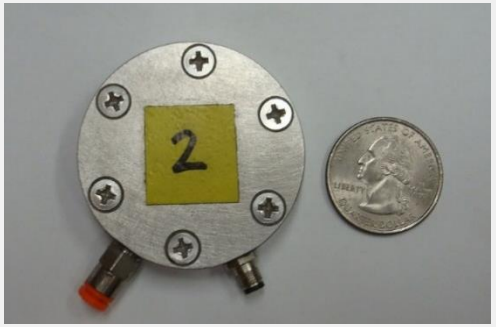


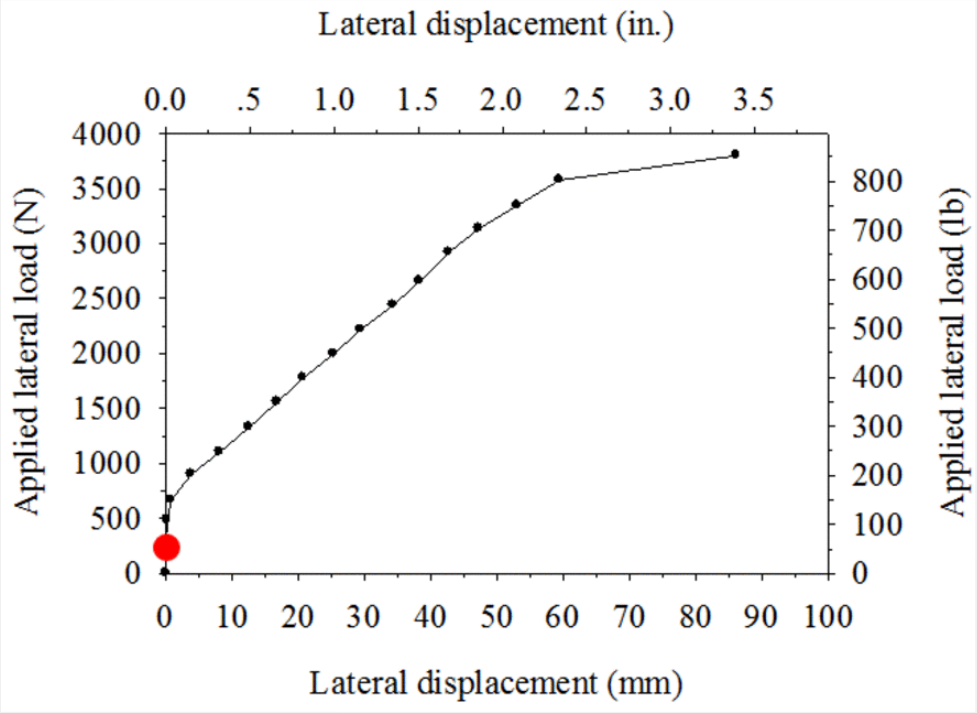


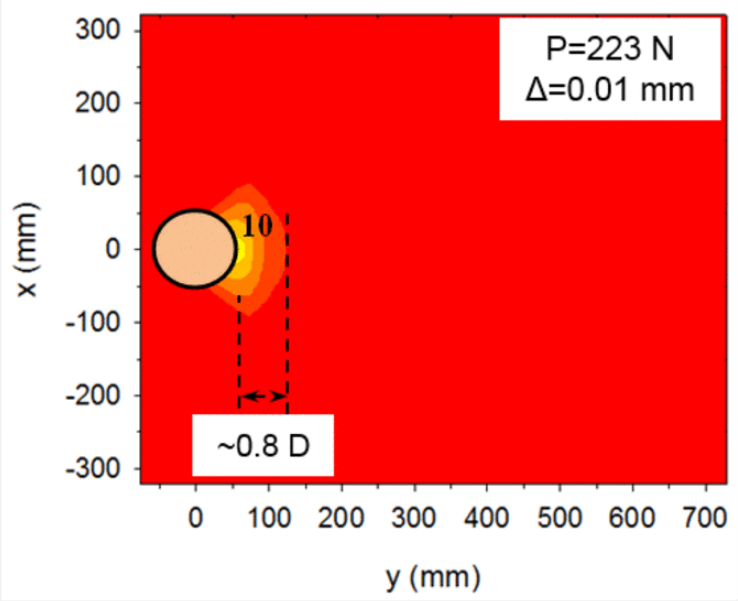


NSF-CMMI: SSI of Active and Passive Laterally Loaded Piles – Lehigh, Lafayette College

Static Lateral Load Pile Tests

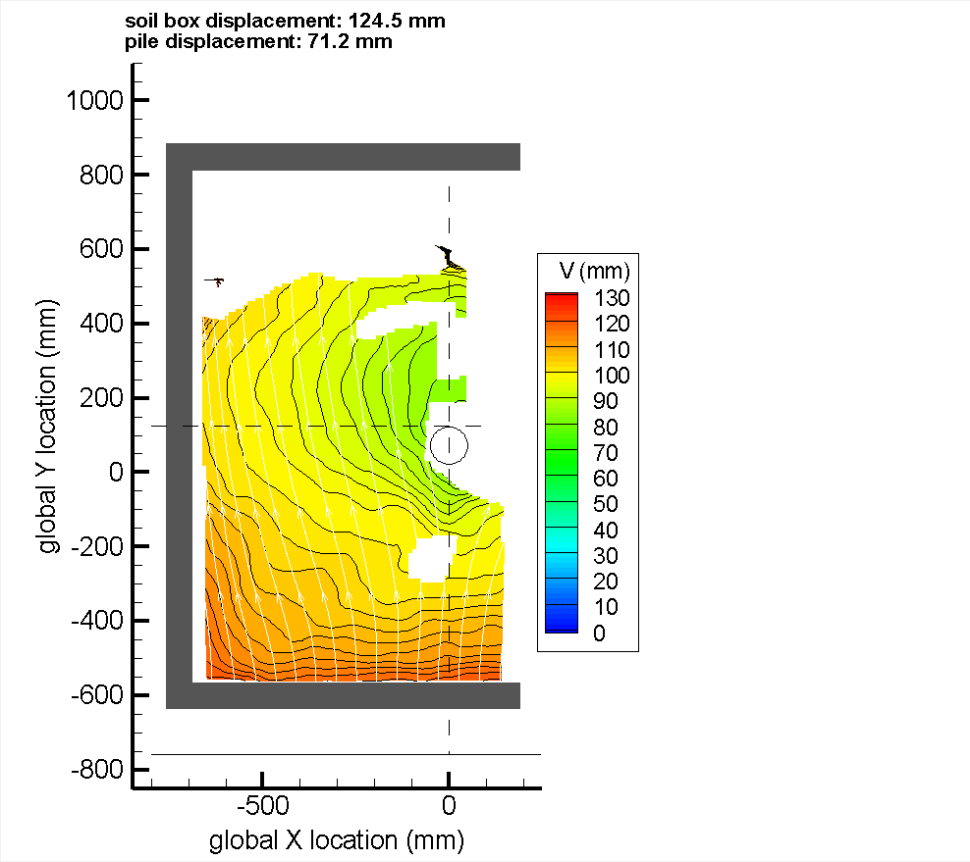






NSF-CMMI: SSI of Active and Passive Laterally Loaded Piles – Lehigh, Lafayette College

Static Lateral Load Pile Tests



Thank You