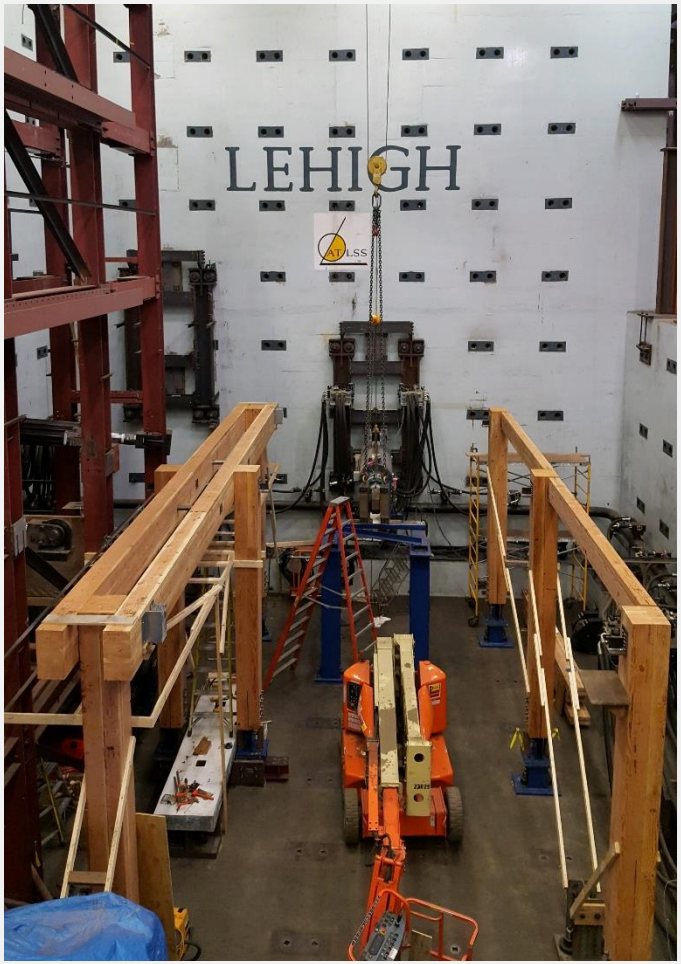
NHERI Lehigh Project Portfolio

Richard Sause
NHERI Lehigh EF

NHERI Lehigh EF 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 Displacement (Quasi-Static or Dynamic) Testing
- Dynamic Testing

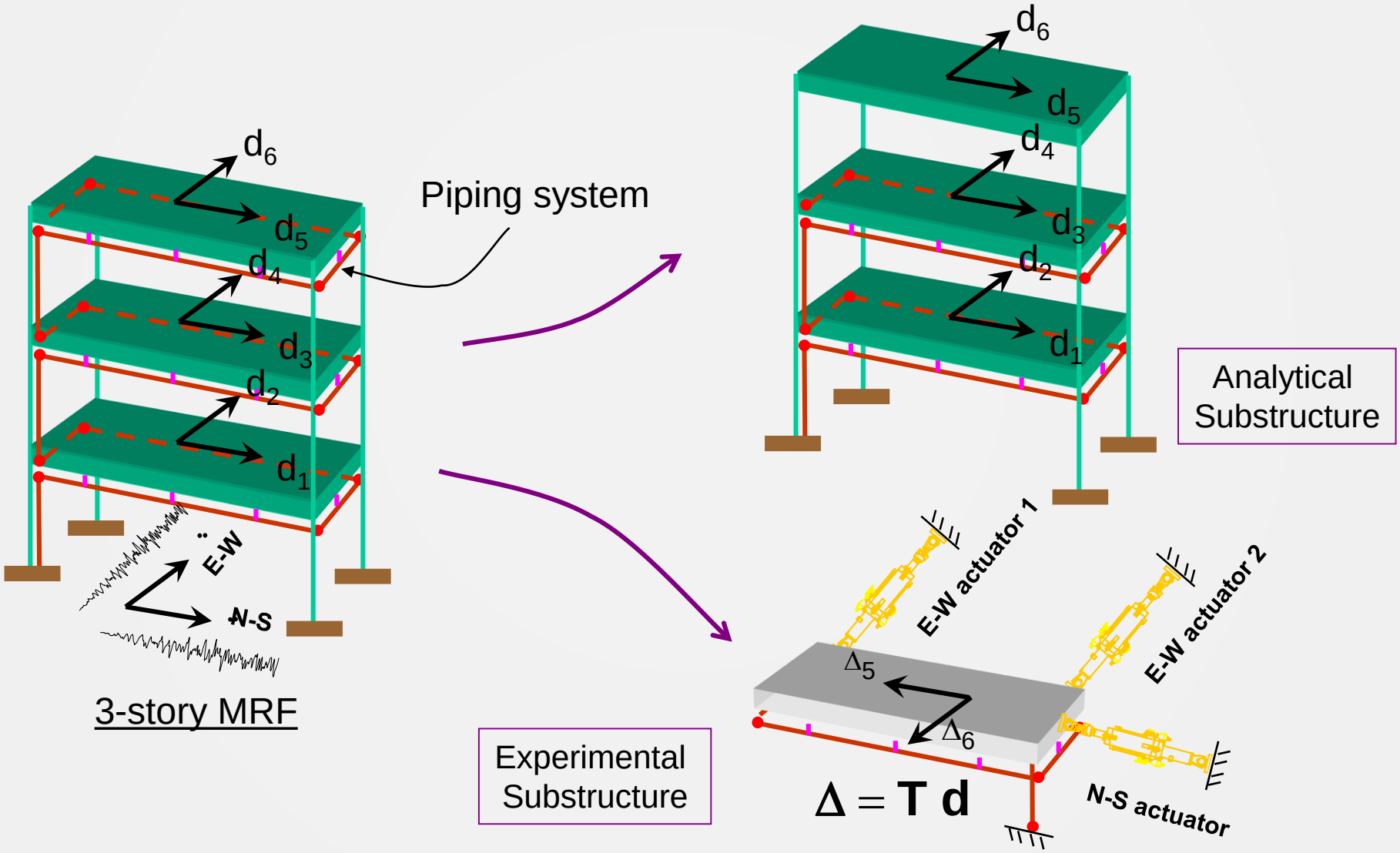


Example Past Projects

Experiment	Capability
3-story building with piping system	Multi-directional real-time hybrid simulation
Self-centering moment-resisting frame (SC-MRF)	Large-scale hybrid simulation
Self-centering concentrically-braced frame (SC-CBF)	Large-scale hybrid simulation
Real-time testing of structures with dampers	Large-scale real-time hybrid simulation with multiple experimental substructures
Seismic hazard mitigation using passive damper systems	Predefined displacement dynamic testing (for characterization)
Seismic hazard mitigation using passive damper systems (steel MRF building with passive dampers)	Large-scale real-time hybrid simulations
Tsunami-driven debris	Dynamic testing (impact loading)
Post-tensioned coupled shear wall system	Complex large-scale multi-directional predefined force and displacement quasi-static testing
Inertial force-limiting floor anchorage systems for buildings	Predefined displacement dynamic testing (for characterization)

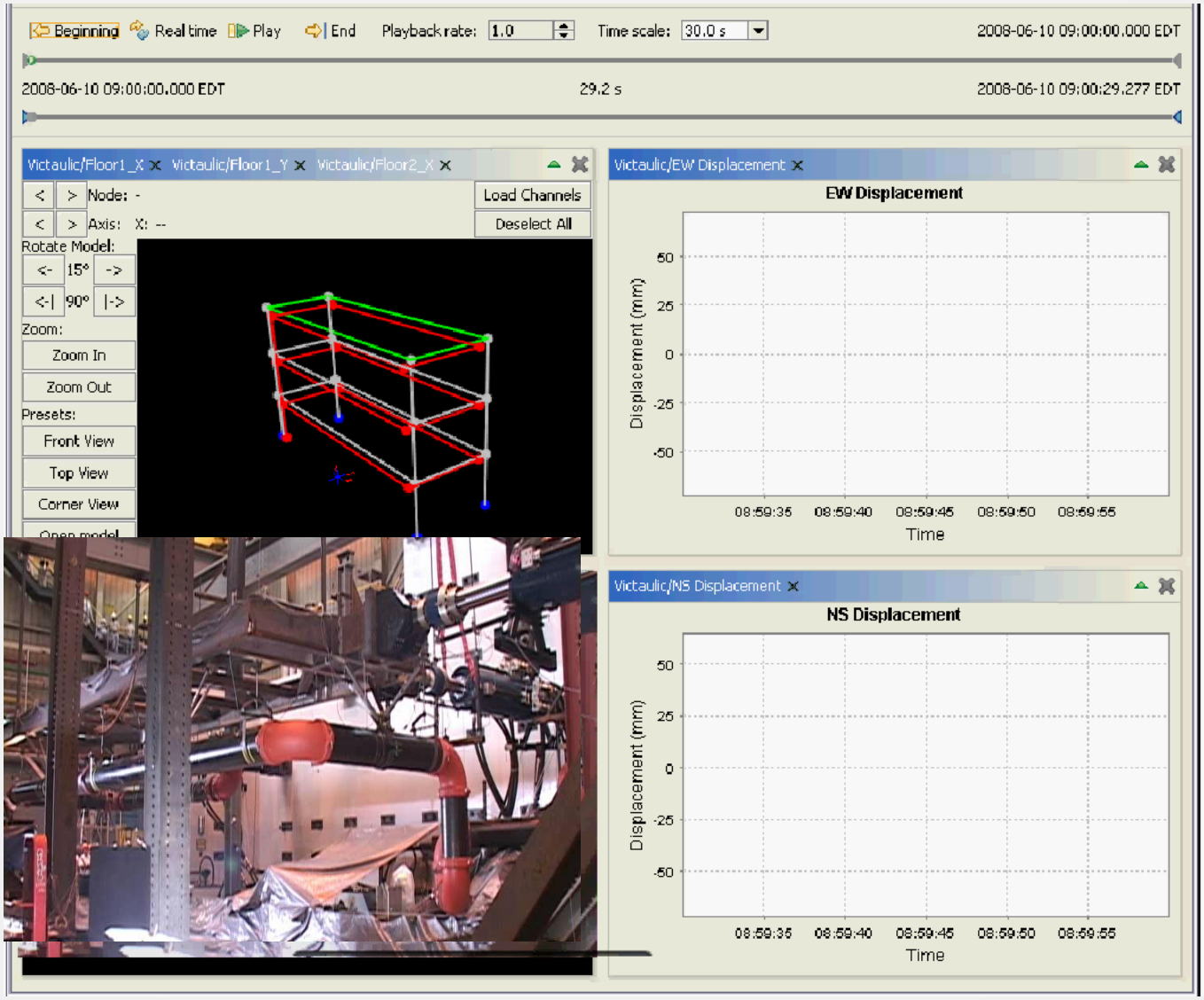
Multi-Directional Large-Scale Real-Time Hybrid Simulation of 3-story Building with Piping System

Multi-Directional Large-Scale Real-Time Hybrid Simulation



Multi-Directional Large-Scale Real-Time Hybrid Simulation of 3-story Building with Piping System

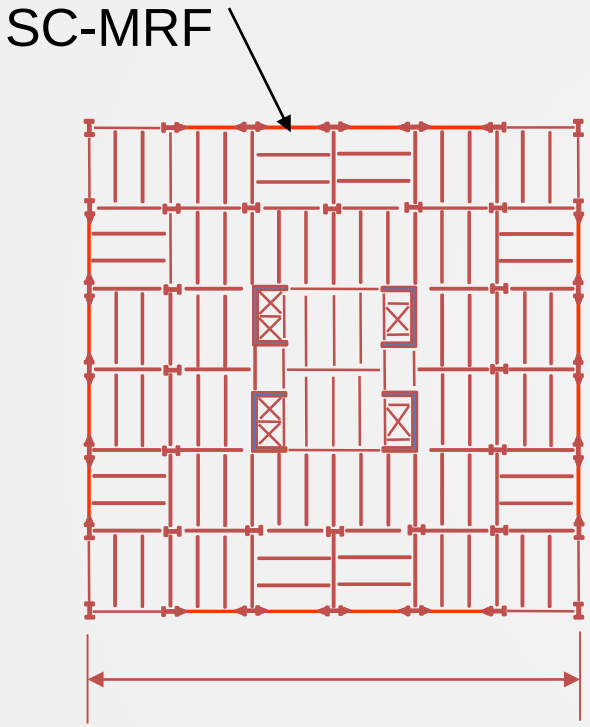
RTHS: 1994 Northridge EQ, Canogo Park (MCE)



NEES

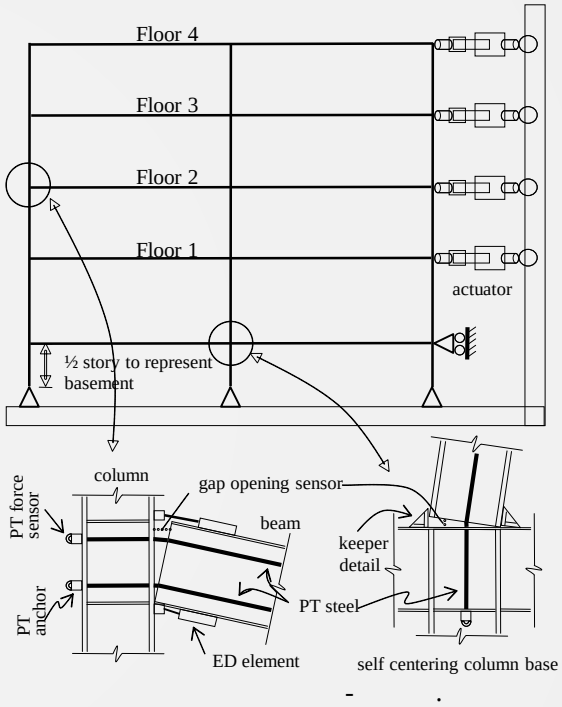
Self Centering Steel Moment-Resisting Frame (SC-MRF) Systems
Princeton, Purdue, Lehigh, NCREE

Large-Scale Hybrid Simulation



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

Plan of Prototype Building

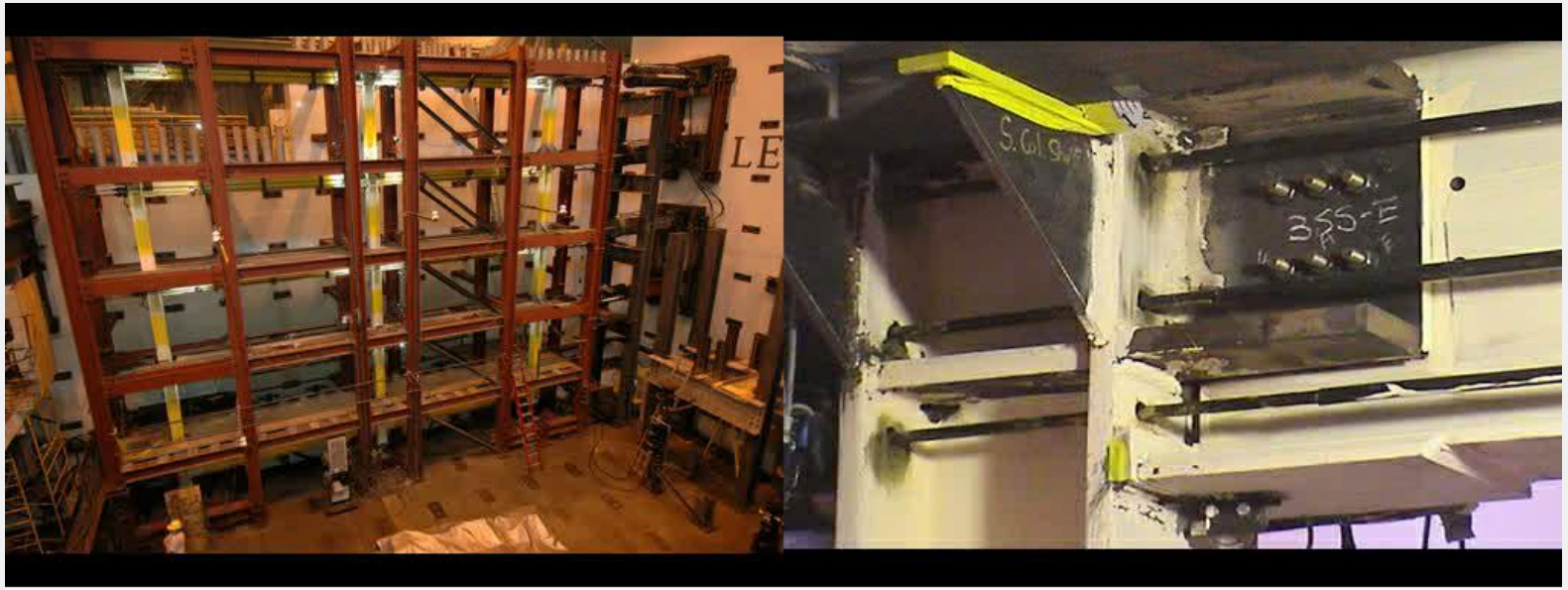


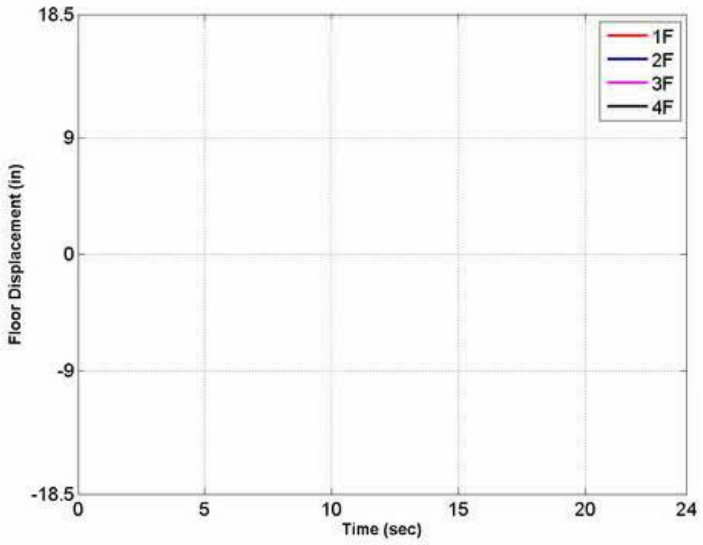
SC-MRF Experimental Substructure
(Floor Diaphragm and Gravity System in Analytical Substructure)

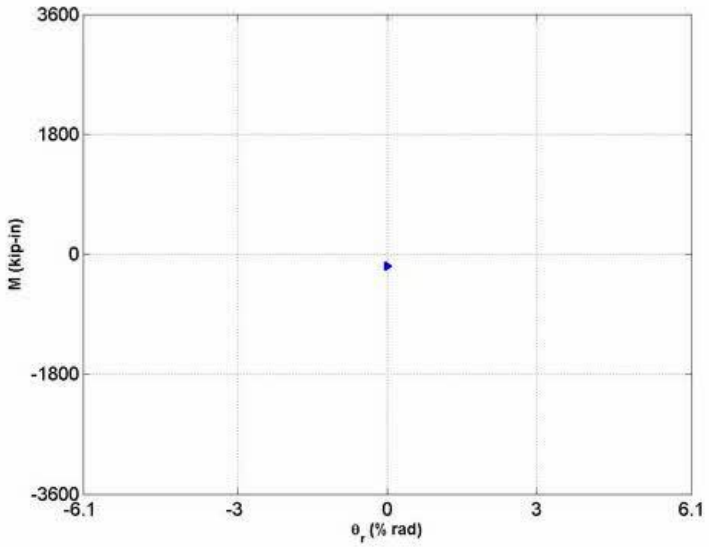
NEES

Self Centering Steel Moment-Resisting Frame (SC-MRF) Systems
Princeton, Purdue, Lehigh, NCREE

Large-Scale Hybrid Simulation (SC-MRF)

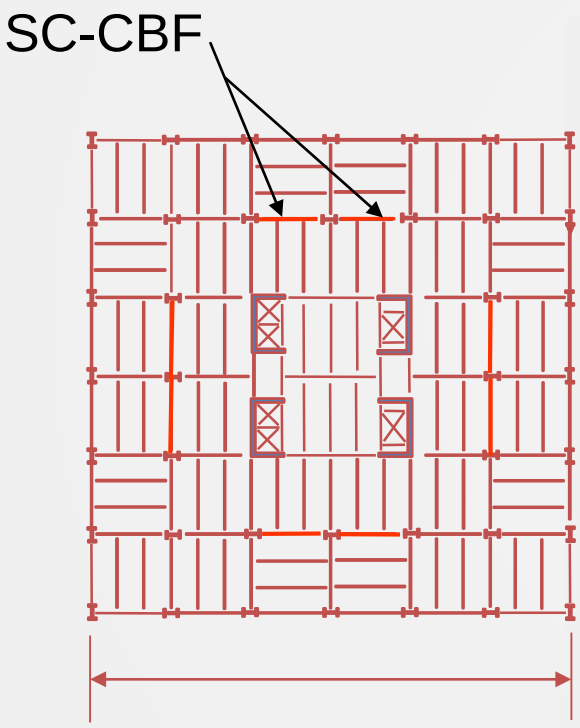






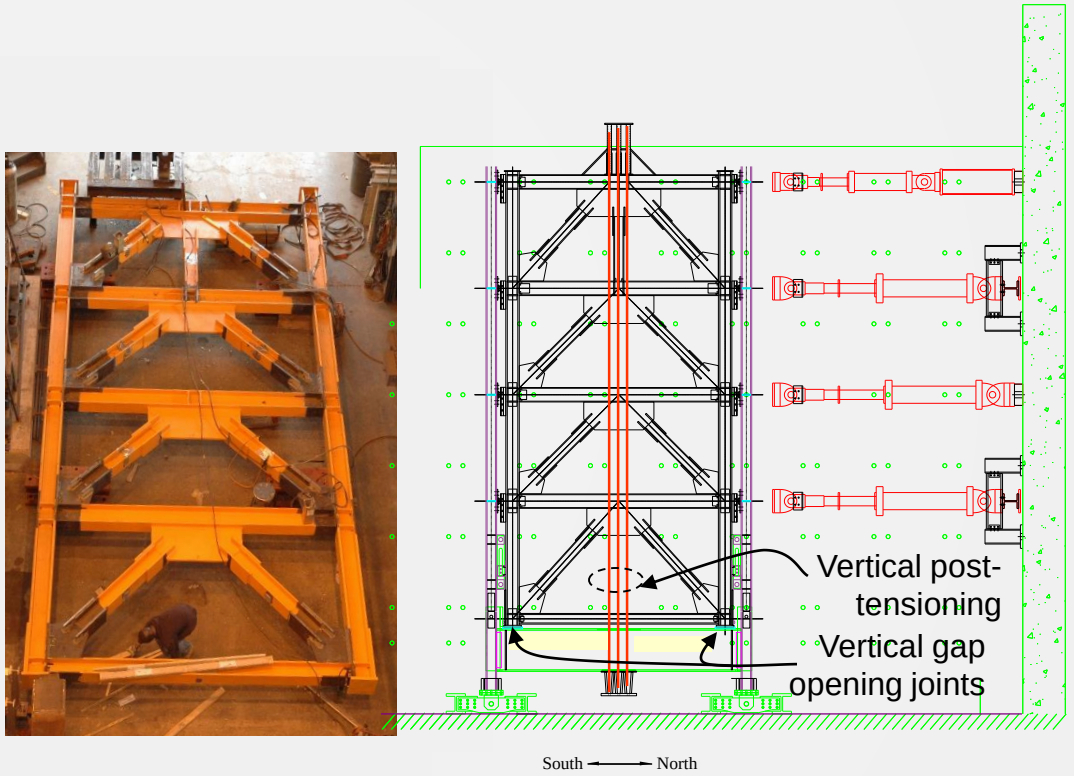
Self Centering Steel Concentrically-Braced Frame (SC-CBF) Systems
Princeton, Purdue, Lehigh, NCREE

Large-Scale Hybrid Simulation



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

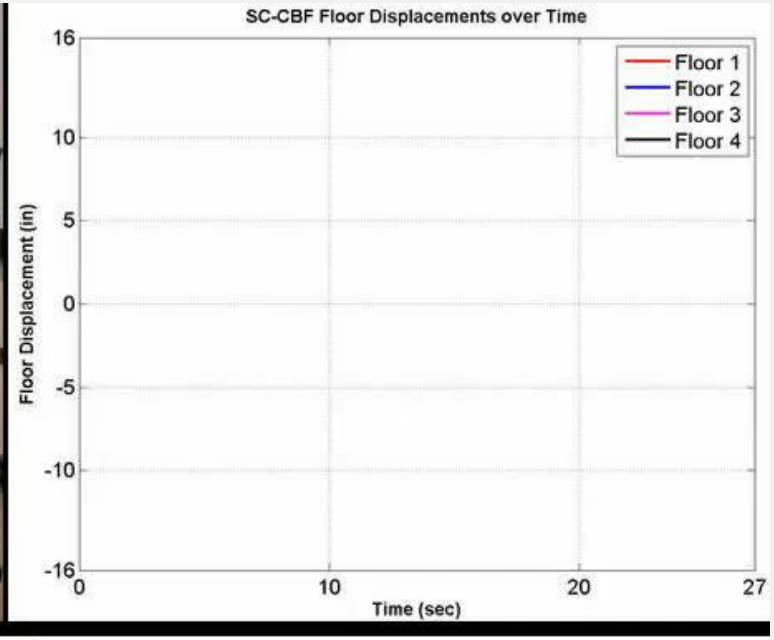
Plan of Prototype Building



SC-CBF Experimental Substructure
(Floor Diaphragm and Gravity System in Analytical Substructure)

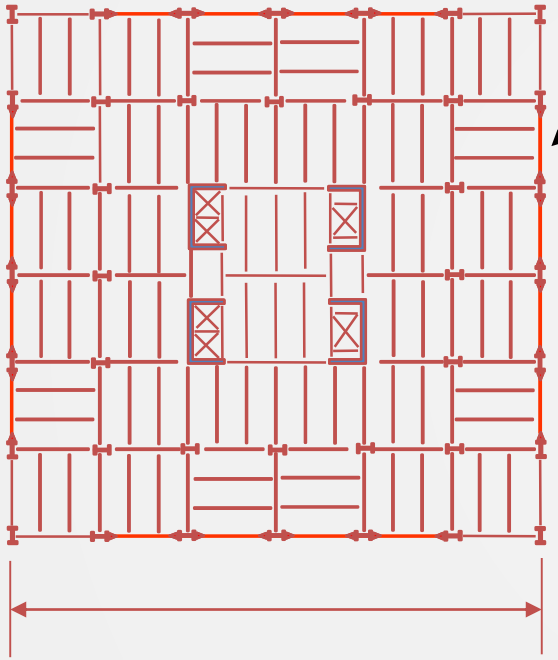
NEES

Large-Scale Hybrid Simulation (SC-CBF)



Test Bed For Real-Time Testing of Structures with Dampers

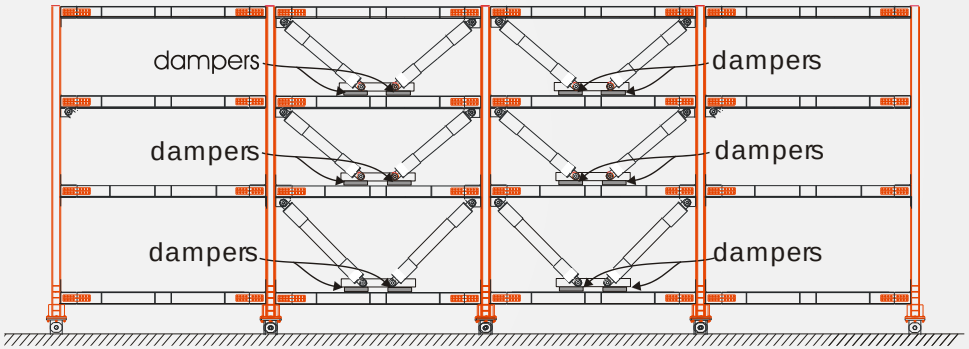
Large-Scale Real-Time Hybrid Simulation, Multiple Experimental Substructures



Steel MRF with Passive Dampers

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

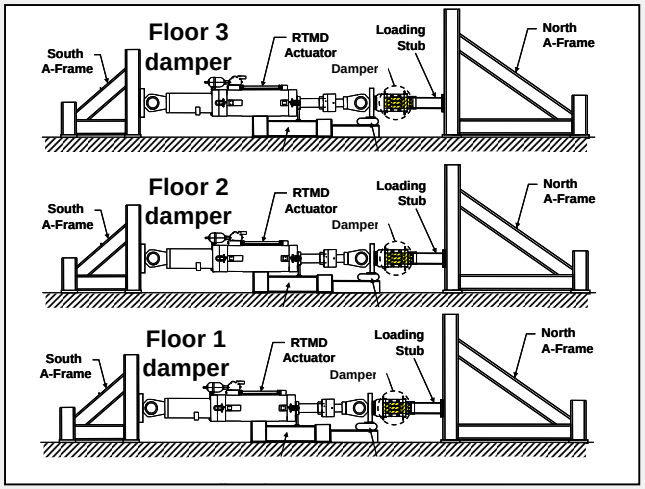
Plan of Prototype Building

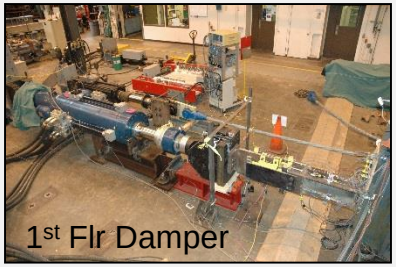


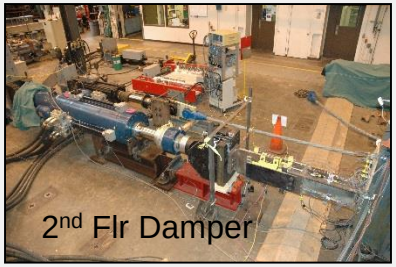
Elevation of MRF with Passive Dampers

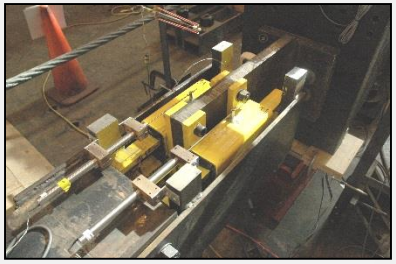
Test Bed For Real-Time Testing of Structures with Dampers

Large-Scale Real-Time Hybrid Simulation, Multiple Experimental Substructures









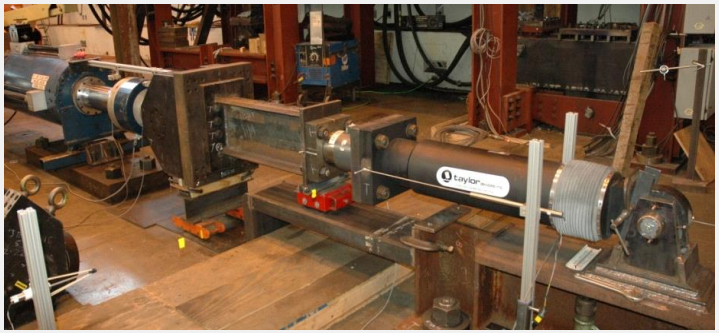
Experimental Substructures
(MRF, Floor Diaphragm and Gravity System in Analytical Substructure)

Close up view of damper

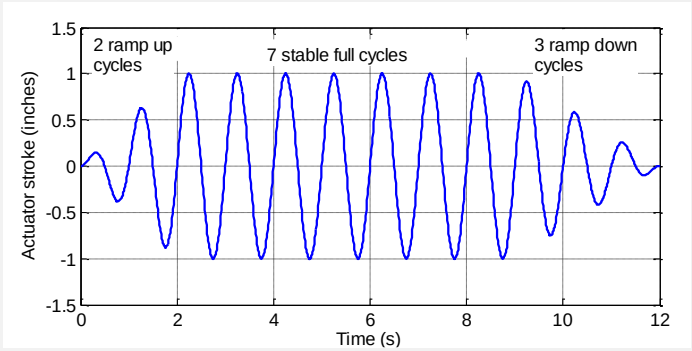
NEES

Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems
Cal State Pomona, Cal State Northridge, Lehigh

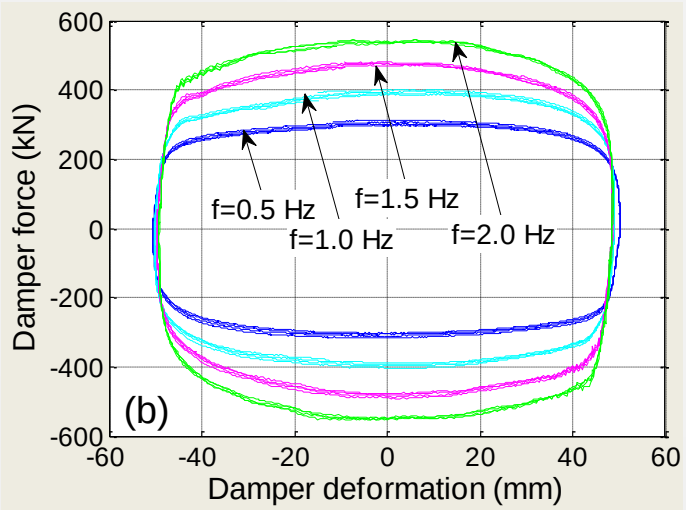
Predefined Displacement Dynamic Testing for Characterization



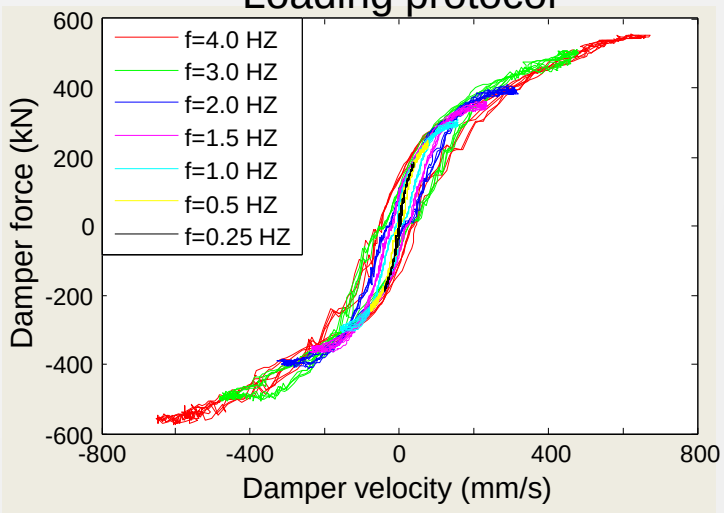
Damper testbed



Loading protocol



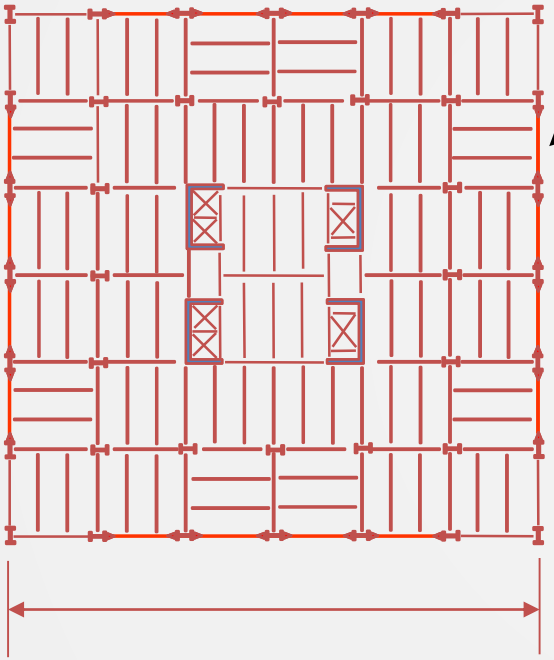
Damper force - deformation



Damper force - velocity

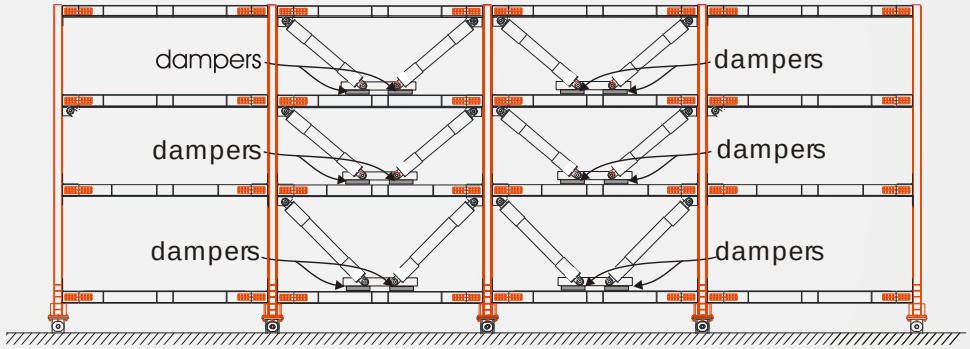
Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems
Cal State Pomona, Cal State Northridge, Lehigh

Large-Scale Real-Time Hybrid Simulation



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

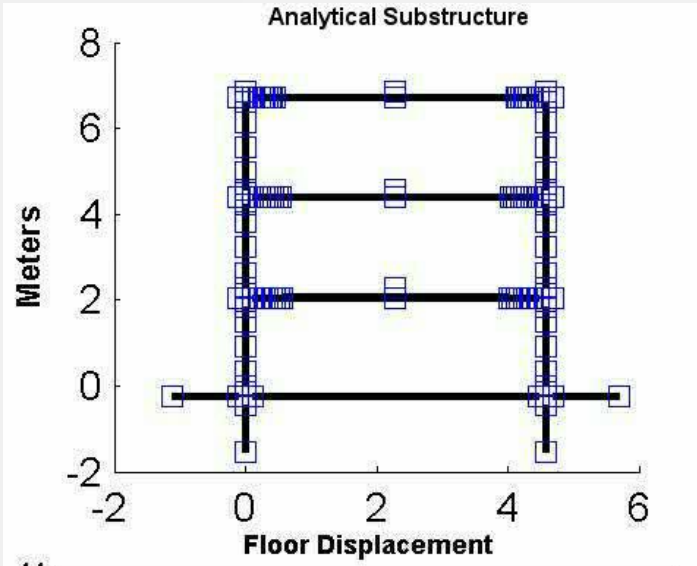
Plan of Prototype Building

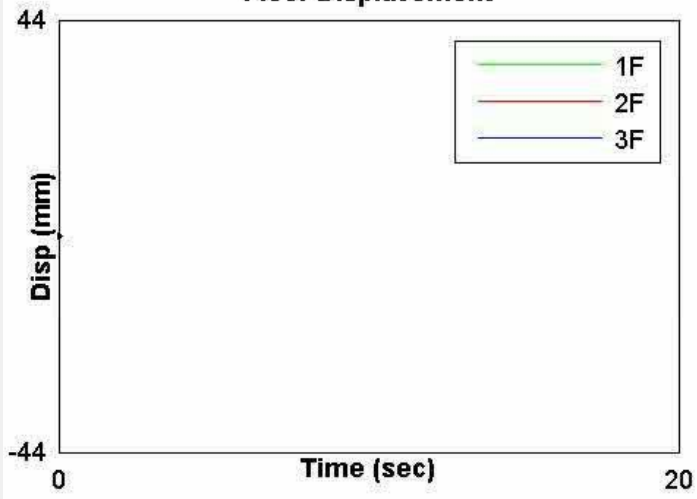


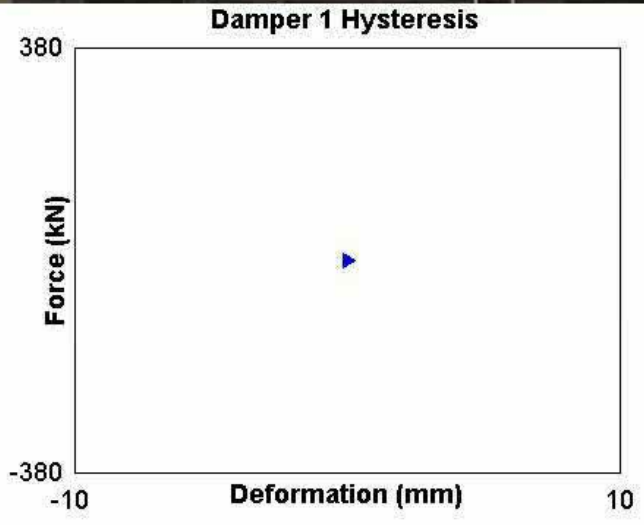
Elevation of MRF with Passive Dampers

Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems
Cal State Pomona, Cal State Northridge, Lehigh

Large-Scale Real-Time Hybrid Simulation
(MRF, Floor Diaphragm, Gravity System in Analytical Substructure)







Seismic Hazard Mitigation in New Buildings Using Supplemental Passive Damper Systems
Cal State Pomona, Cal State Northridge, Lehigh

Large-Scale Real-Time Hybrid Simulation
(Floor Diaphragm, Gravity System in Analytical Substructure)

Impact Forces from Tsunami-Driven Debris
University of Hawaii, Oregon State University, Lehigh

Dynamic Testing (Impact Loading)

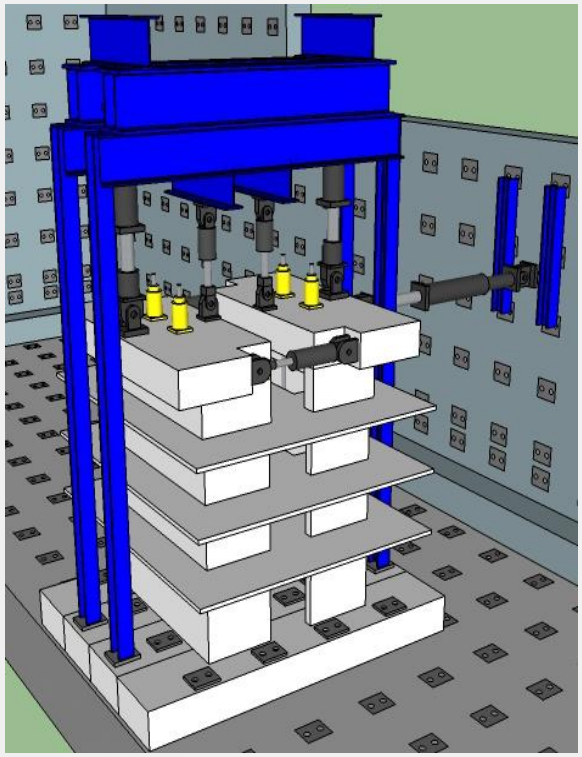
Test Setup with Cargo Shipping Container Debris

High Speed Video of Impact of Cargo Shipping Container on Structure

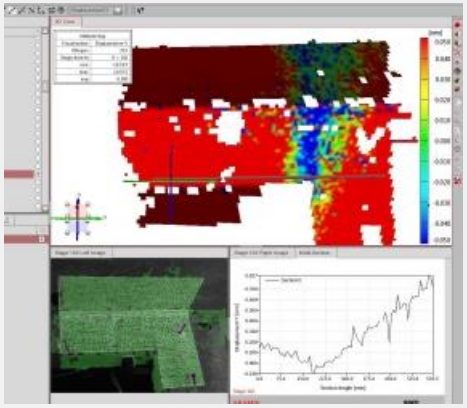
NEES

Post-Tensioned Coupled Shear Wall System
Notre Dame, University of Texas at Tyler

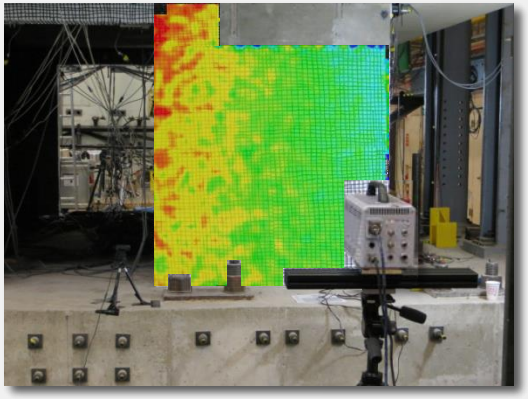
Complex Large-Scale Predefined Multi-Directional Force & Displacement (Quasi-Static) Testing



RC coupled shear wall test specimen with multi-directional loading. Upper 5 stories of 8-story building simulated with vertical force-controlled actuators. 1 displacement-controlled and 10 force-controlled (11 total) used for test.



Joint strains measured by DIC (S. Pakzad)



RC coupled shear wall pier vertical deformation measured by Digital Image Correlation (DIC) (M. McGinnis)

NEES

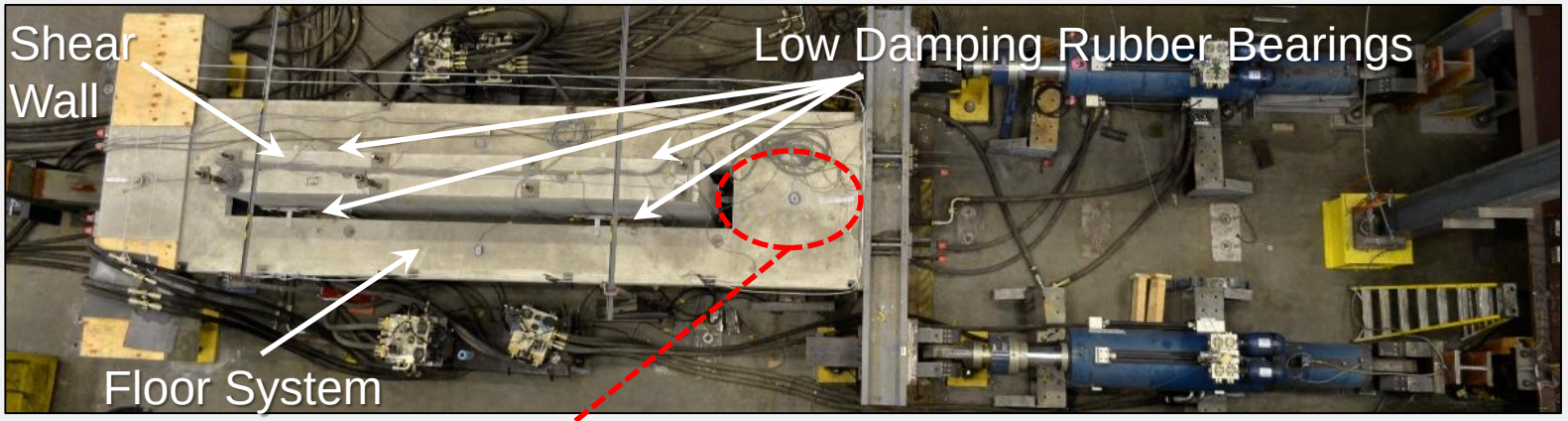
Post-Tensioned Coupled Shear Wall System
Notre Dame, University of Texas at Tyler

Complex Large-Scale Predefined Multi-Directional Force & Displacement (Quasi-Static) Testing

NEES

Inertial Force Limiting Floor Anchorage Systems for Buildings
University of Arizona, UCSD, Lehigh

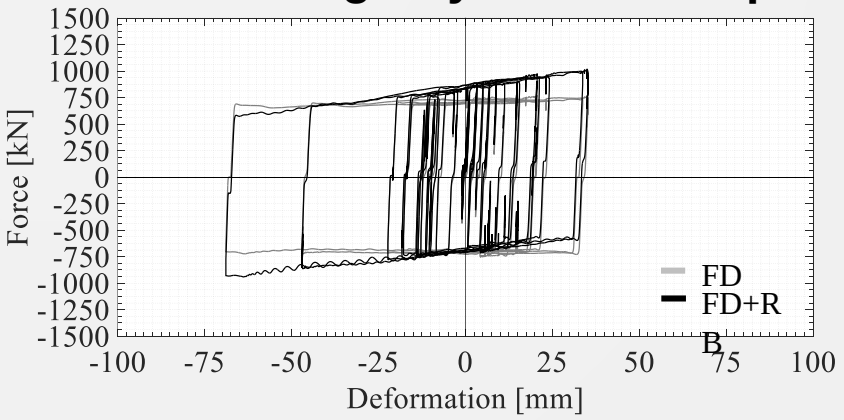
Predefined Displacement Dynamic Testing for Characterization



Friction Device for Floor Anchorage

BRB was also Studied

Floor Anchorage Hysteretic Response



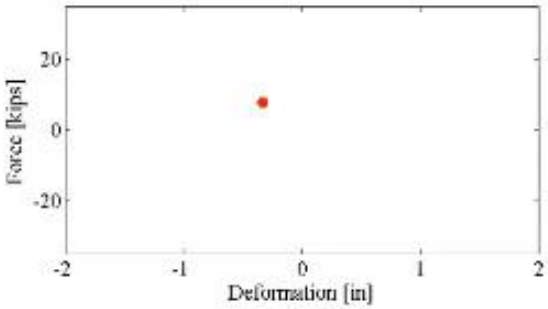
Inertial Force Limiting Floor Anchorage Systems Buildings University of Arizona, UCSD, Lehigh

Predefined Displacement Dynamic Testing for Characterization

Inertial Force Limiting Floor Anchorage Systems Buildings University of Arizona, UCSD, Lehigh

Complimentary Shake Table Tests at NHERI UCSD

EQ 14: Berkeley MCE - Floor 4



THE UNIVERSITY OF ARIZONA UCSanDiego LEHIGH UNIVERSITY

Current Projects at NHERI Lehigh EF

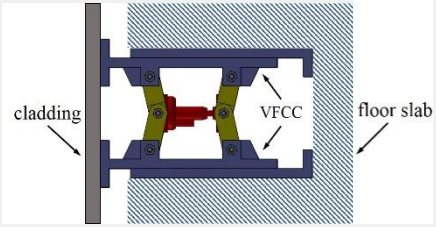
Project	Capability
Semi-Active Controlled Panel Cladding to Improve the Performance of Buildings under Multiple Hazards (*Semi-Active Device*): Iowa State University (S. Laflamme)	Real-time hybrid simulation
Semi-Active Controlled Panel Cladding to Improve the Performance of Buildings under Multiple Hazards (*Passive Device*): Lehigh University (J. Ricles, S. Quiel)	Real-time hybrid simulation
Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings (*Non-Structural System*): University of Nevada, Reno (Keri Ryan)	Complex predefined multi-directional displacement quasi-static testing
Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings (*Structural System*): Lehigh University (J. Ricles, R. Sause)	Complex predefined multi-directional displacement quasi-static testing
Advancing Knowledge on the Performance of Seismic Collectors in Steel Building Structures: University of Arizona (R. Fleischman (PI) with C.-M. Uang (UCSD), J. Ricles, R. Sause (Lehigh University))	Complex large-scale predefined force and displacement quasi-static testing

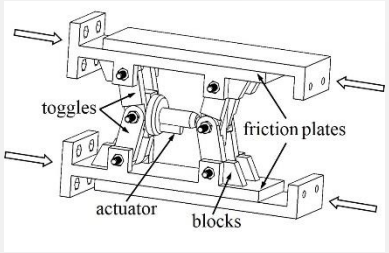
Current Projects at NHERI Lehigh EF

Collaborative Research: Semi-Active Controlled Panel Cladding to Improve the Performance of Buildings under Multiple Hazards: (CMMI 1463252) **Iowa State University (Simon Laflamme)**

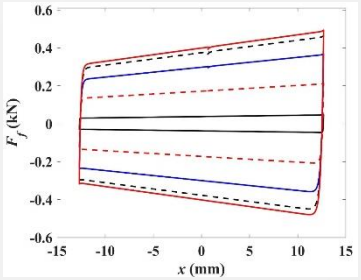
Features Using NHERI Lehigh Underlined

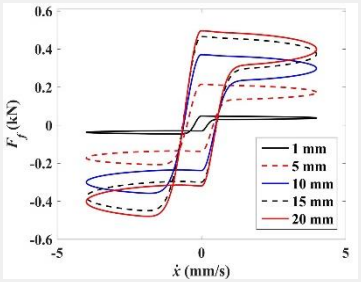
- Project Overview
  - Improve performance of buildings for multiple hazards using semi-active controlled variable friction cladding panel connectors
  - Hazards: Earthquake, Wind (NHERI UF), Blast Loading
- Project Scope
  - Design cladding connectors and control laws
  - Construct prototype connector, perform characterization testing
  - Perform large-scale RTHS to validate numerical models and results (300 data sets from RTHS uploaded to DesignSafe to date)





Semi-Active Controlled Variable Friction Cladding Connector





Dynamic Numerical Models

Current Projects at NHERI Lehigh EF

Collaborative Research: Semi-Active Controlled Panel Cladding to Improve the Performance of Buildings under Multiple Hazards: (CMMI 1463497) **Lehigh University (James Ricles, Spencer Quiel)**

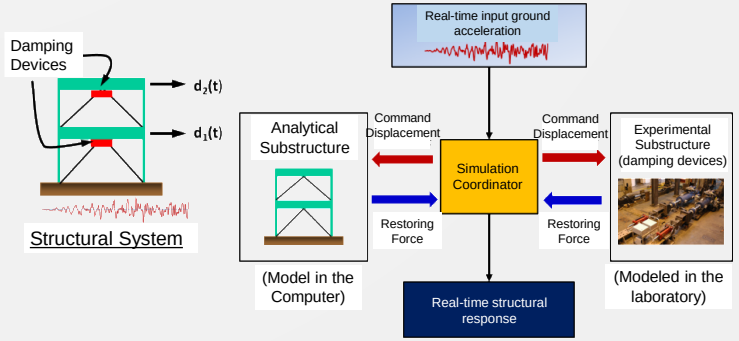
Features Using NHERI Lehigh Underlined

- Project Overview
  - Improve performance of buildings under multiple hazards using passive energy dissipating cladding panel connectors
  - Hazards: Earthquake, Wind (NHERI UF), Blast Loading
- Project Scope
  - Design prototype buildings of various heights
  - Perform nonlinear time history analysis to assess performance
  - Perform large-scale RTHS to validate numerical models and results (300 data sets from RTHS uploaded to DesignSafe to date)

Test Matrix: Passive Control Connectors

HAZARD	METHODOLOGY	HAZARD LEVEL
WIND	Real Time Hybrid Simulation	700- and 1700- years return period per wind speeds & hurricane
SEISMIC	Real Time Hybrid Simulation	DBE and MCE ground motions
BLAST	Shock Tube	GSA Medium and High Design basis blast threat

Seismic Hybrid Simulation Experiments

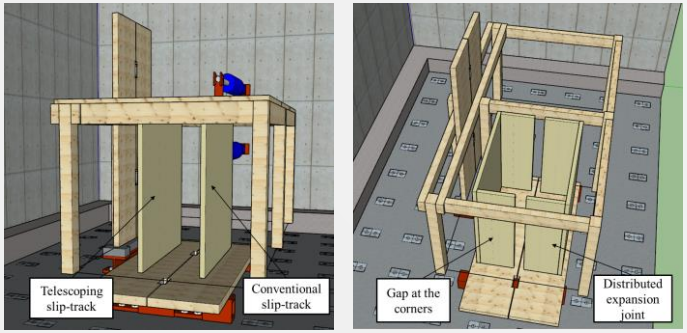


Current Projects at NHERI Lehigh EF

Collaborative Research: Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings: (CMMI 1635363)
University of Nevada, Reno (Keri Ryan)

Features Using NHERI Lehigh Underlined

- Project Overview
  - Develop seismic design methodology for tall wood buildings with high-performance structural and non-structural systems
  - Determine partition wall configurations for large lateral drift with minimized partition damage
- Project Scope
  - Conduct large-scale tests of partition wall systems under in-plane & out-of-plane (bi-directional) loading (& associated vertical motion)
  - Consider different partition slip track and other details to minimize damage



Test setup for partition wall testing

Test Phases	Objectives
Phase I.1-NS	Two independent flat partition walls tested to characterize slip behavior of different slip track details and measure forces in walls under bidirectional loading
Phase I.2-NS	Two independent C-shaped partition walls tested to characterize deformability with different details and measure forces in walls under bidirectional loading
Phase III-NS	Partition walls with dense layout tested under bidirectional loading

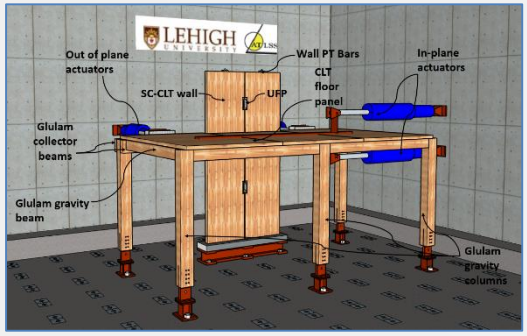
Test plan for partition wall testing

Current Projects at NHERI Lehigh EF

Collaborative Research: Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings: (CMMI 1635227) **Lehigh University (James Ricles, Richard Sause)**

Features Using NHERI Lehigh Underlined

- Project Overview
  - Develop seismic design methodology for tall wood buildings with high-performance structural and non-structural systems
  - Study self-centering rocking cross-laminated timber (SC-CLT) wall with diaphragm and gravity load system
- Project Scope
  - Conduct large-scale tests of subassemblies under in-plane & out-of-plane (bi-directional) loading (& associated vertical motion)
  - Project is supporting work to model tall CLT buildings and shake table tests (CSM, S. Pei) at NHERI UCSD EF



Test setup for subassembly testing

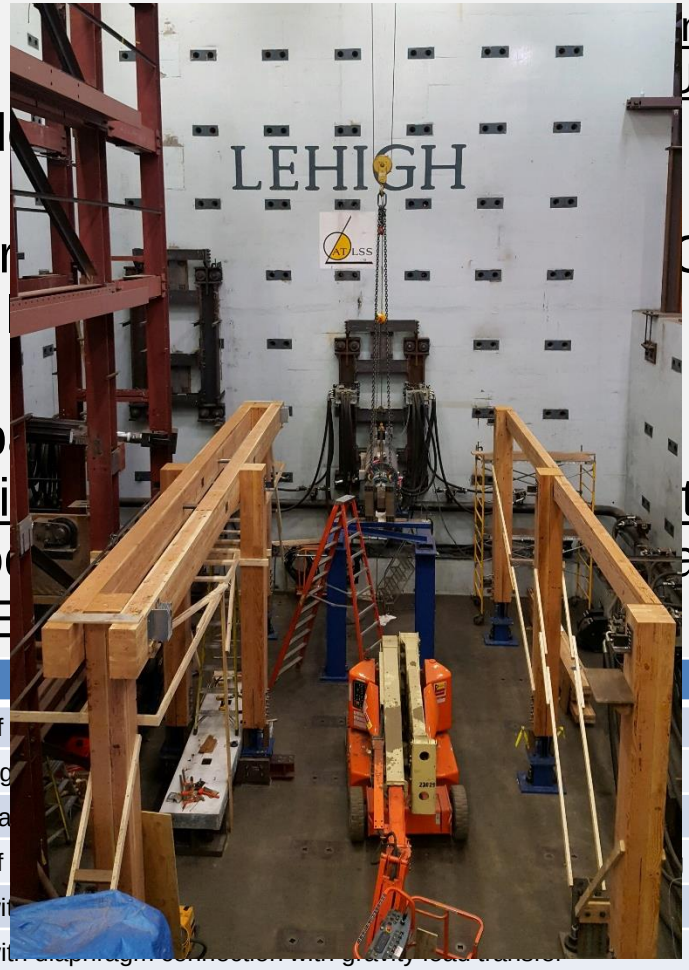
Test Phase	Objectives
Phase I	Investigation of limit states of SC-CLT walls with diaphragms
Phase I.1-S	In-plane loading up to failure (up to 10% lateral drift)
Phase I.2-S	Out of plane loading up to failure (up to 10% lateral drift)
Phase II	Investigation of SC-CLT walls and gravity system under bidirectional loading
Phase II.1-S	SC-CLT wall with diaphragm connection without gravity load transfer
Phase II.2-S	SC-CLT wall with diaphragm connection with gravity load transfer
Phase III	SC-CLT wall with partition walls with dense layout tested under bidirectional loading

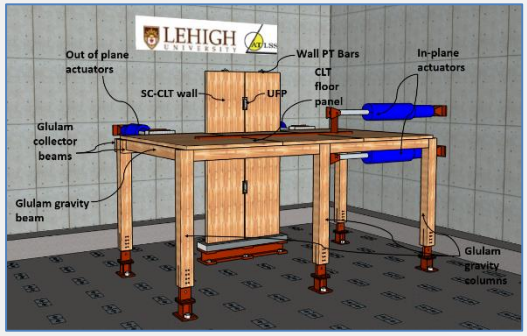
Test plan for subassembly testing

Current Projects at NHERI Lehigh EF

Collaborative Research: Development and Validation of Resilience-Based Seismic Design Methodology for Tall Wood Buildings: (CMMI 1635227) **Lehigh University (James Ricles, Richard Sause)**

- Project Overview
  - Develop seismic design method[ng NHERI Underlined with high-performance structural and
  - Study self-centering rocking cr[CLT) wall with diaphragm and gravity
- Project Scope
  - Conduct large-scale tests of sub[out-of-plane (bi-directional) loadi[tion)
  - Project is supporting work to mo[ake table tests (CSM, S. Pei) at NHE





Test setup for subassembly testing

Test Phase	
Phase I	Investigation of
Phase I.1-S	In-plane loading
Phase I.2-S	Out of plane loa
Phase II	Investigation of
Phase II.1-S	SC-CLT wall wi
Phase II.2-S	SC-CLT wall wi
Phase III	SC-CLT wall with partition walls with dense layout tested under bidirectional loading

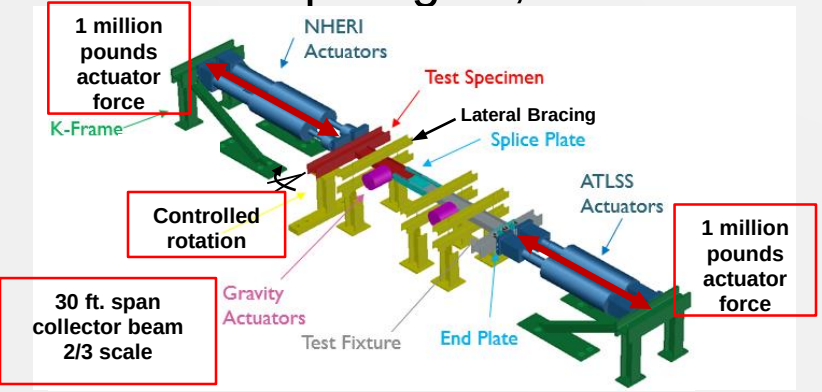
Test plan for subassembly testing

Current Projects at NHERI Lehigh EF

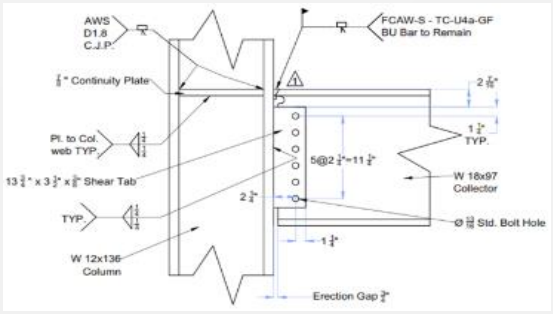
Advancing Knowledge on the Performance of Seismic Collectors in Steel Building Structures: (**CMMI 1662816) University of Arizona (Robert Fleischman (PI), Chia-Ming Uang, James Ricles, Richard Sause)**

Features Using NHERI Lehigh Underlined

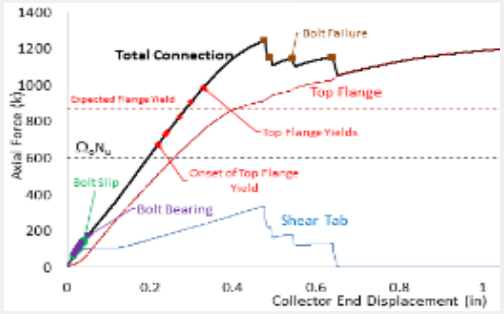
- Project Overview
  - Investigate failure-critical yet poorly understood component of steel seismic force resisting system, the seismic collector
  - FE analyses, large-scale tests and shake-table tests of floor diaphragms and collectors
- Project Scope
  - Conduct large-scale (1000k axial force plus simulated drift) tests on collector connections (tension/compr.) and members (compr.)
  - Project is supporting FE models and studies of collectors and floor diaphragms, and shake table tests at NHERI UCSD EF



Test setup for collector connection testing



Collector connection details



FE analyses

Thank You