NHERI Lehigh Experimental Facility with Large-Scale Multi-Directional Hybrid Simulation Testing Capabilities

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NHERI LEHIGH Real-Time Multi-Directional Testing Facility

FACILITY DESCRIPTION

The NHERI Lehigh Experimental Facility, originally established in 2004 under the NSF-sponsored NEES program, is an open-access facility associated with the NSF-funded Natural Hazards Engineering Research Infrastructure (NHERI) program. The facility, known as the **Real-Time Multi-Directional Facility** (**RTMD**), enables unique research to be performed to promote multi-natural hazard resiliency of civil infrastructure. The unique strengths of the facility include:

- Portfolio of state-of-the-art equipment, instrumentation, infrastructure, testbeds, and experimental simulation control protocols for **Large-scale Multi-directional Testing** including **cyber-physical systems simulation** referred to as **Real-time Hybrid Simulation (RTHS)**
- Concurrent multiple large-scale experiments
- Operated by experienced staff

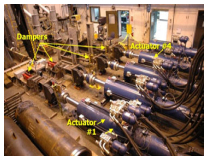
EXAMPLE TESTBEDS

1. Lateral Force Resisting System Testbed

- Test large-scale systems of up to **13.7 m** in height, **11 m** in width
- Applicable to **large scale dynamic tests**, including RTHS of large-scale structural systems

2. Full-Scale Damper Testbed

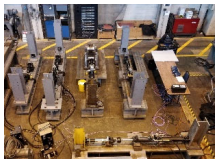
- **Five** servo-hydraulic actuators
- Maximum force of **2300-kN**, **1.143 m/s** velocity, and **1 m** stroke range
- Applicable to **damper characterization tests** and **real-time hybrid simulations**



EXAMPLE TESTBEDS

3. NHERI Lehigh Real-time Cyber-Physical Structural Systems (RCPSS) Testing Laboratory: Testbeds

- **Five** servo-hydraulic actuators
- Maximum force of **98-kN**, **1.295 m/s** velocity, and **0.736 m** stroke range
- Four small scale **30-kN** capacity **nonlinear viscous dampers**
- One **45-kN** capacity **rotary friction damper**

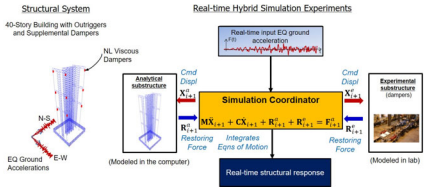


4. NHERI Lehigh Real-time Cyber-Physical Structural Systems (RCPSS) Testing Laboratory: Multi-directional Shake Table

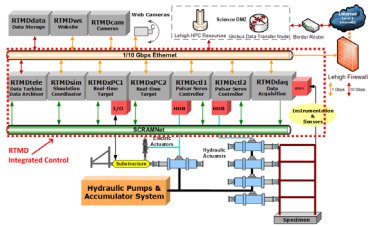
- **Three degrees of freedom**: Bidirectional in-plane translations and rotation normal to platen.
- **1.83 m** by **1.83 m** platen.
- **45-kN** payload at 1 g.
- **Stroke: ± 2.54 m** NS, **± 1.77 m** EW directions
- Maximum velocity of **0.737 m/s**
- Applicable to **real-time hybrid shake table simulation**, **traditional shake table testing**, and **quasi-static** or **dynamic testing.**

REAL-TIME HYBRID SIMULATION

Overall Concept of RTHS: Structural System Subject To Seismic Natural Hazards



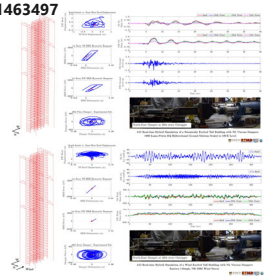
NHERI Lehigh EF Real-time Integrated Control System



EXAMPLE PROJECTS

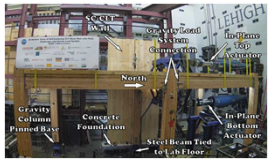
1. 3D RTHS of Tall Buildings Equipped With Non-linear Viscous Dampers Subject to Multi-Natural Hazards – PI: James Ricles, Lehigh University, CMMI-1463497

- 40-story (+4 basement) BRBF building in Los Angeles was modeled
- Improve performance using nonlinear fluid viscous dampers with outriggers
- Assess performance of structure under multi-hazards using RTHS



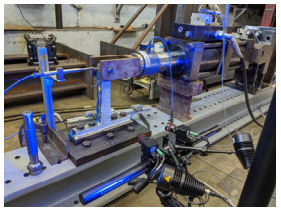
2. Multi-Directional Testing of Cross-Laminated Timber Self-Centering Walls-Floor Diaphragm-Gravity System - PI: Shiling Pei, Colorado School of Mines, CMMI-1636164

- Study **self-centering rocking cross-laminated timber (SC-CLT) wall** with floor diaphragm and gravity load system
- Conduct **large-scale** tests of subassemblies under **multi-directional loading** (& associated vertical motion)



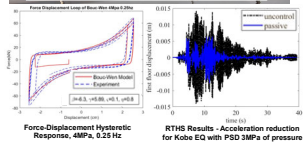
3. Frame-Spine System with Force-Limiting Connections (FLC) for Low-Damage Seismic-Resilient Buildings- PI: Larry Fahnestock, Univ of Illinois Urbana-Champaign, CMMI- 1928906

- Study **benefits** of system on **reducing floor accelerations**, **improving drift performance** and **reducing risk** of critical story mechanisms
- Conduct quasi-static unidirectional tests on FLC yielding components at full scale, generate strain data via digital image correlation (DIC)



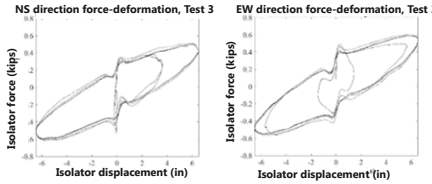
4. Investigation of a Novel Pressurized Sand Damper for Sustainable Seismic and Wind Protection of Buildings-PI: Nicos Makris, Southern Methodist University, CMMI- 2036131

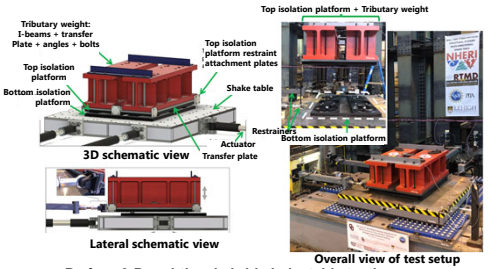
- Develop and validation of an innovative, low-cost, long-stroke, environmentally friendly, Pressured Sand Damper that **meets the criteria for sustainable engineering** without suffering from the challenge of viscous heating
- **Validate** experimentally **using 3D real-time hybrid simulation**



EXAMPLE PROJECTS

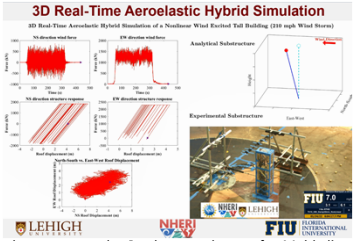
5. 3D RTHS of Multi-Functional Floor Isolation Systems in Buildings Subject to Seismic Hazards - PI: Scott Harvey, University of Oklahoma, OIA-1929151





- Perform **3-D real-time hybrid shake table testing**
- Evaluate performance of **floor isolation systems** under various hazard levels of **multi-directional** earthquake motions

6. 3D Real-Time Aeroelastic Hybrid Simulation of a Tall Building – NHERI FIU and NHERI Lehigh Collaboration, PI: James Ricles, Lehigh Univ; Arindam Chowdhury, FIU, CMMI-2037771 and CMMI-2037899



- Development and Implementation of Multi-directional Nonlinear Real-time Aeroelastic Hybrid Simulation (RTAHS)
- Assess **aeroelastic** response of structural systems to effects of **multi-directional wind loading** using **real-time hybrid simulation**

ACKNOWLEDGEMENTS

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