Lab Demonstration: Multi-directional Real-time Hybrid Simulation of Floor Isolation Systems

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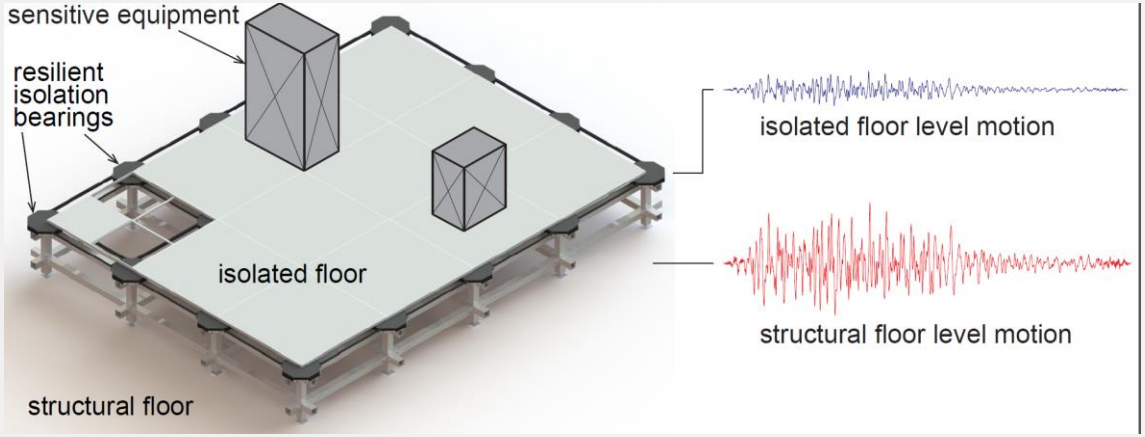
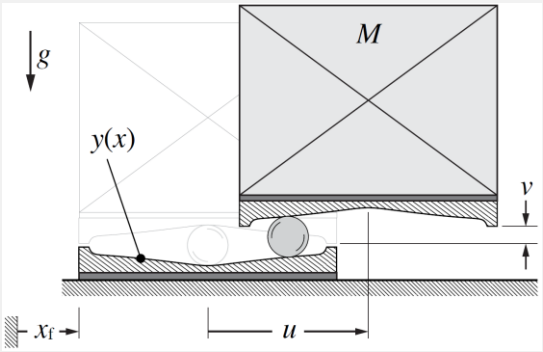
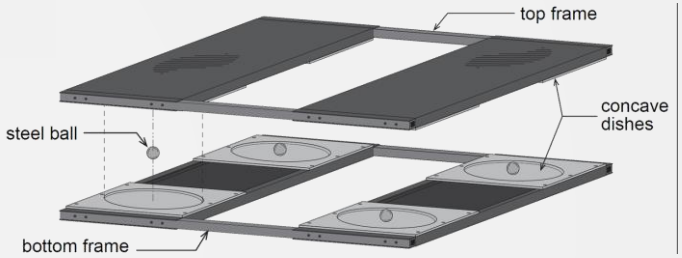
Background of Multi-Functional Floor Isolation Systems

RII Track-4: Quantifying Seismic Resilience of Multi-Functional Floor Isolation Systems through Cyber-Physical Testing **(OIA 1929151) University of Oklahoma (Scott Harvey)**



Floor isolation of critical building contents



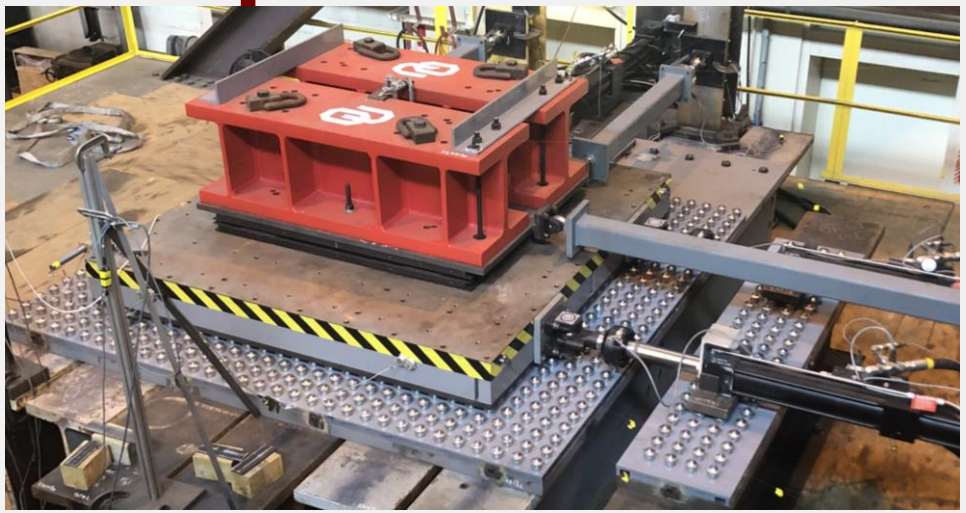


Floor isolation system

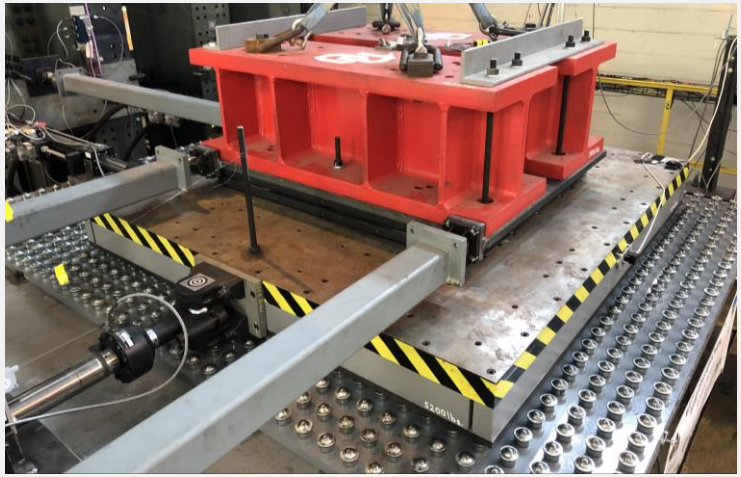
Rolling Pendulum (RP) bearing system

Test set-up

- Single full-scale OCTO-Base™ isolation system (4 RP bearings) from WorkSafe™ Technologies
- Bottom component of the isolation system is attached to the shake table
- Attached atop: assembly composed of I-beams and a transfer plate, which represents the tributary weight of 17.9 kN (3,850 lb)



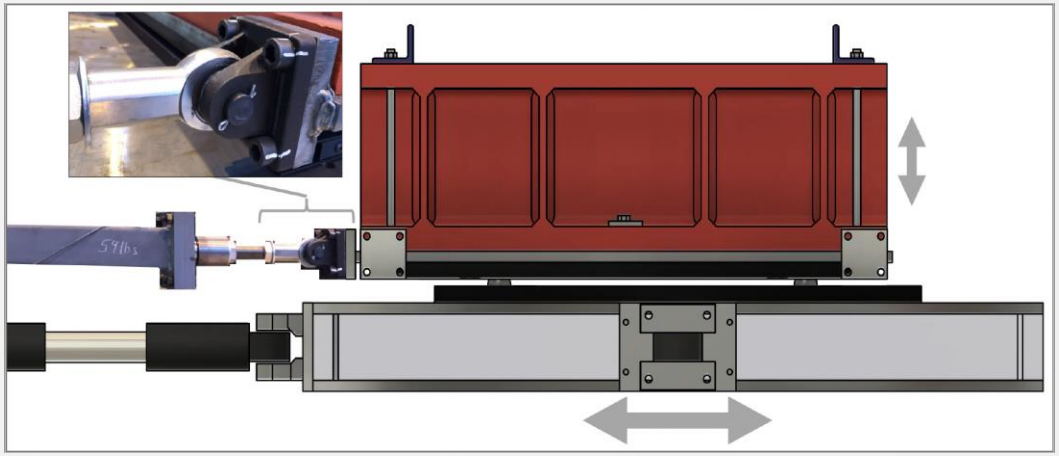
South-West top general view



North-East view

Test set-up

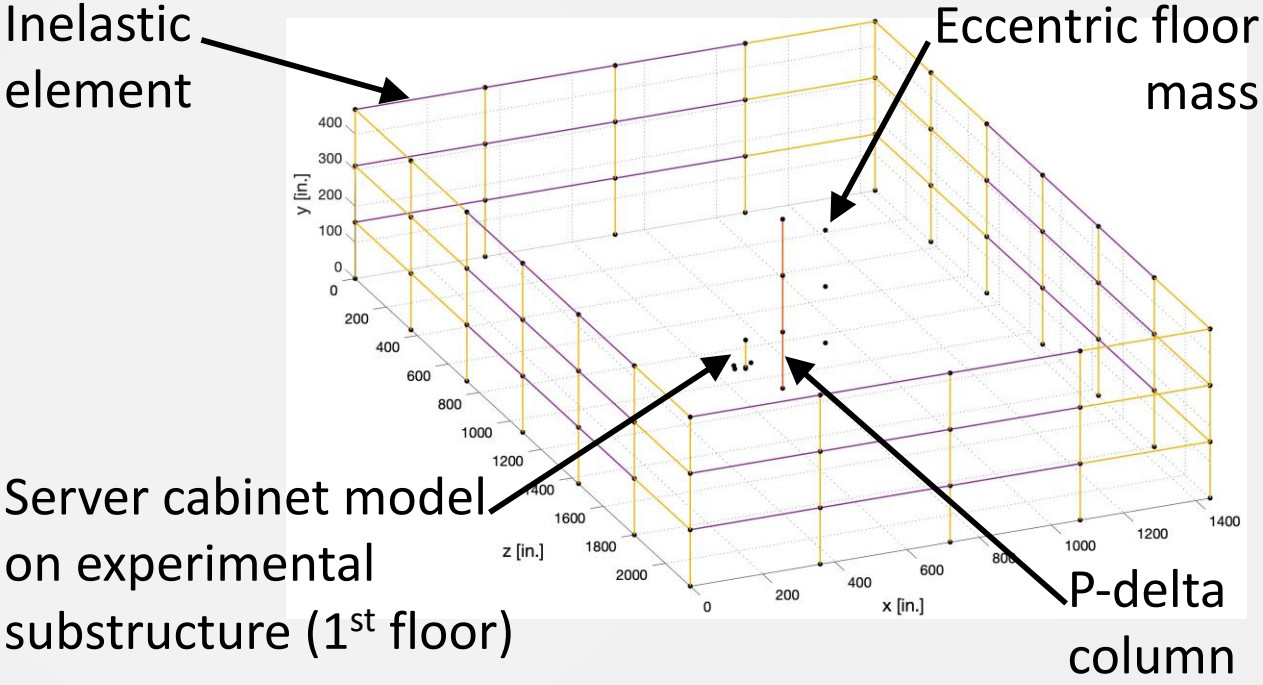
- Top component is restricted from any horizontal movement or rotation by means of 3 restraints attached to the transfer plate
- Restraints pinned at both ends
- Uniaxial load cells located at the restraints to obtain directly the experimental restoring force



East schematic view of restraints

3D Real-time Hybrid Simulation (RTHS) Analytical Substructure: SMRF Model

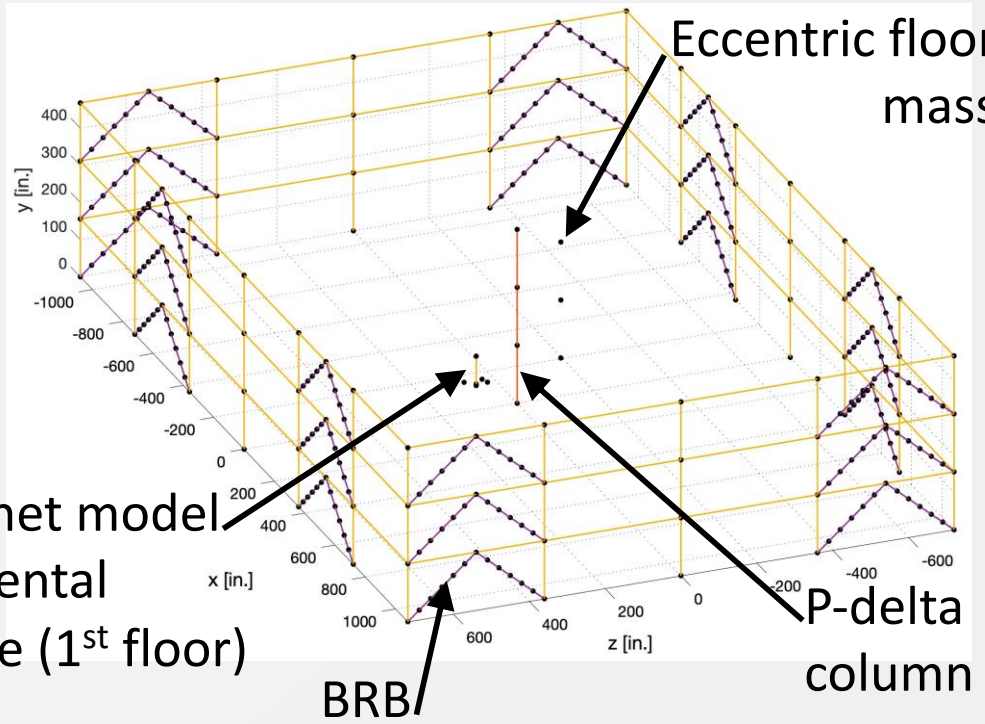
- Steel 3-story (LA3) special moment resisting frame (SMRF)
- Inelastic force-based fiber beam-column elements for SMRF's girders
- Elastic elements for remaining structural components
- Modeled in 3D, including P-Δ effects, using HyCOM-3D



LA3 SMRF model

3D Real-time Hybrid Simulation (RTHS) Analytical Substructure: BRBF Model

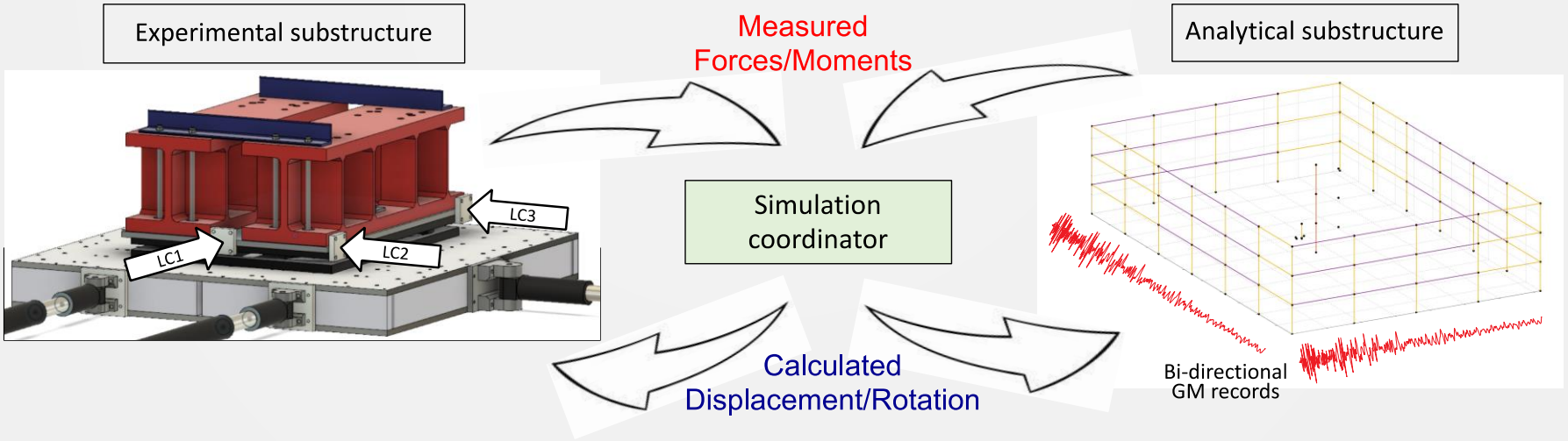
- Steel 3-story (3vb) buckling-restrained brace frame (BRBF)
- 3D inelastic truss elements for the BRBs
- Elastic elements for remaining structural components
- Modeled in 3D, including P-Δ effects, using HyCOM-3D



3vb BRBF model

3D RTHS Configuration

- Use of:
  - Explicit MKR-α Integration Algorithm
  - Explicit Force-based Nonlinear Fiber Element – Analytical Substructure
  - Adaptive Time Series Compensator for Actuator Control
  - Uniaxial load cells from restraints measures real-time experimental restoring forces



3D RTHS Configuration

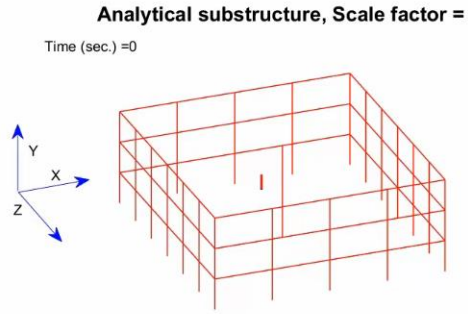
- Use of:
  - Explicit MKR-α Integration Algorithm
  - Explicit Force-based Nonlinear Fiber Element – Analytical Substructure
  - Adaptive Time Series Compensator for Actuator Control
  - Restraints are equipped with uniaxial load cells to obtain directly and in real-time the experimental restoring forces

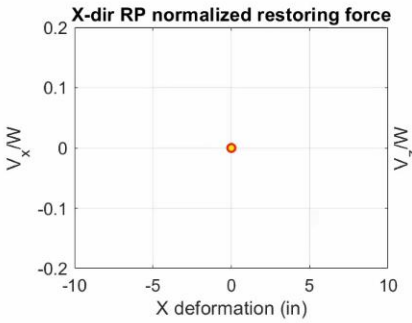
MKR-α parameter and Adaptive Servo-Control ATS Coefficients

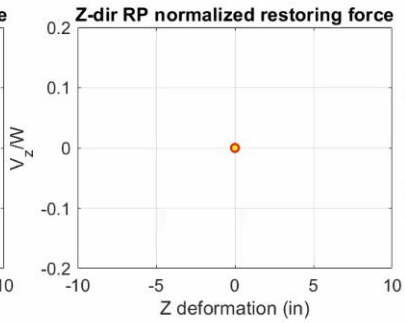
Time Step, Δt (sec)	ρ_∞	ATS Coefficients		
		a_{0k}	a_{1k}	a_{2k}
$\frac{2}{1024}$	0.5	Adaptive	Adaptive	Adaptive

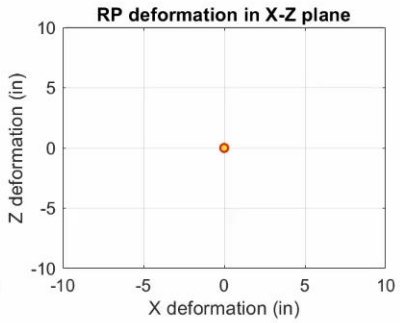
3-D Real-time Hybrid Simulation

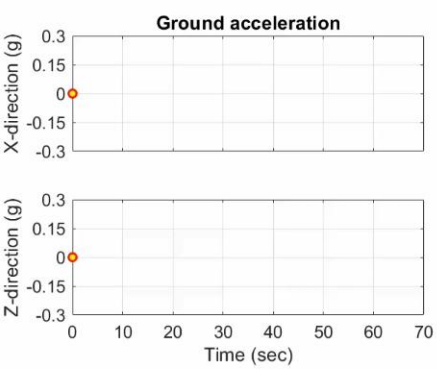
SMRF with RP Isolation System (FIS) @ 2nd Floor, Coalinga EQ Scaled to SLE

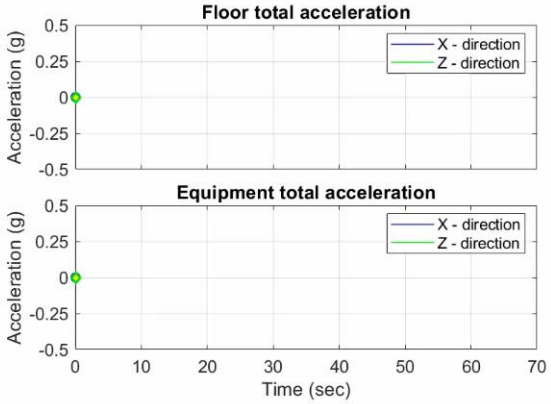


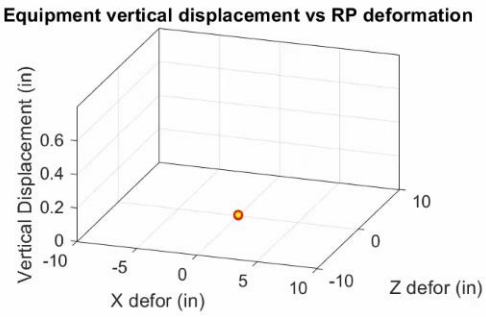












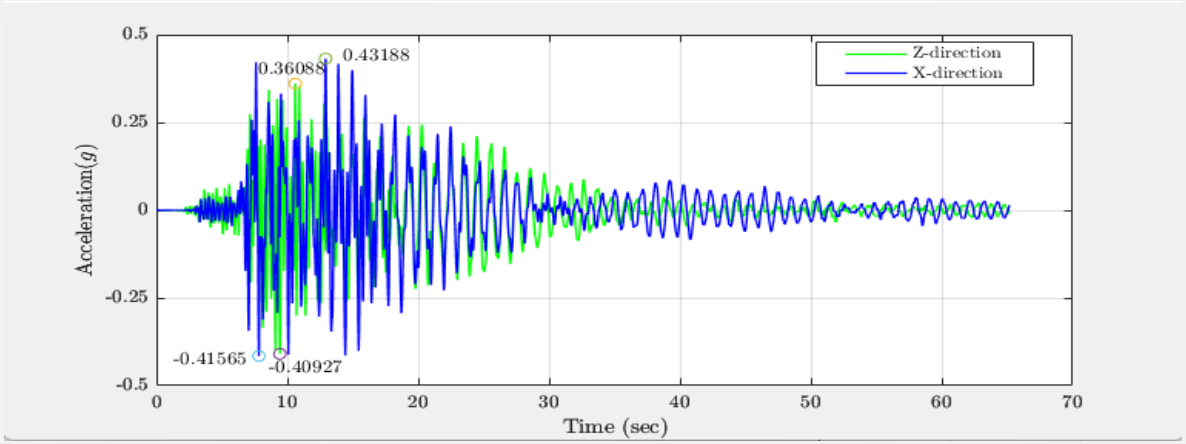
X-direction = 270 component, Z-direction = 360 component

3-D Real-time Hybrid Simulation of a 3-Story SMRF with 2nd Floor Rolling Pendulum Equipment Isolation System: 1983 Coalinga EQ Bidirectional Ground Motions Recorded at Cantua Creek School and Scaled to SLE Hazard Level.

3D RTHS Results: Equipment Acceleration

Reduction in Equipment Total Acceleration	
X-Direction	Z-Direction
81.3%	68.9%

SMRF 2nd Floor Total Acceleration



Equipment Total Acceleration