Coupled Earthquake Engineering Simulations

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Overview

• Three ongoing threads of coupled-physics interactions
• SPUR Integration Effort
  – NSF-funded basin/building inventory model
  – Soil-structure coupling using grid technology
  – Principals: Bielak (CMU), Fenves (Berkeley)
• LLNL Morrow Point Dam Analysis
  – Excellent solid-fluid interaction example
  – Foundation-dam-reservoir coupling via interoperability
  – Principals: Noble, McCallen, Loomis (LLNL)
• Terascale Framework
  – Prototype computational subsystem for NEES
  – Soil-structure liquefaction multiphysics by design
  – Principals: Taylor (Terascale), Muraleetharan (OU)
Characteristics of Physics Interactions

• Three forms of mathematical interactions

One-way coupling

Loose coupling

Full coupling
SPUR: Integration by Grid

• One-way coupled basin-structure analysis
  – Precomputed basin results imposed on structural models via subgrid resolution sampling to determine foundation motions

• Ambitious attempt to use NSF-funded middleware technology
  – Harvest basin results at remote site
  – Analyze building inventory at other sites
  – Visualize by gathering all results and rendering
SPUR Results

- Schematic of Basin with ground-motions

Basin/Fault Geometry

Computed Ground Motion
LLNL Morrow Point Dam Analysis

- **Complex coupling problem**
  - Initial states computed using NIKE3D
  - Dam-reservoir interaction computed using DYNA3D hydrodynamics code
  - Assumption of vertically propagated shear waves for application of earthquake loads
  - Analysis included complex grouted shear key details in concrete dam

- **Validated using empirical reservoir results**
Morrow Point Geography

- Dam is about 200 miles SW of Denver

USGS 1983 Topographic Map

Generated IGES Surface for Mesh Generation
Analysis of Site, Dam, and Reservoir

• Interoperability: NIKE3D/DYNA3D data
Morrow Point Finite-Element Mesh

• Analyze foundation, dam, and fluid in lake
Terascale Multiphysics Simulations

• Full or loose coupling within framework
  – Framework: general-purpose computer science infrastructure to facilitate sharing of element technology, data, transient algorithms
  – Hides computer science details (e.g., scalability) from physics methods development

• Goals on NEES MRE
  – Provide scalable platform for FE computation
  – Demonstrate interdisciplinary capabilities
Terascale Results

- Sample Saturated/Unsaturated Dynamics

![Diagram showing sample saturated/unsaturated dynamics]

Pore Pressure Sample Results
Summary

• Interdisciplinary research commonly results in physically coupled problems
• There are many ways to model the physical interactions of coupled problems
• There are many ways to design the computational infrastructure to handle the coupled physics
• Tsunami simulations may likely involve difficult physics, but simpler coupling