3D vs 1D vs 3x1D Ground Motions and the Earthquake Soil Structure Interaction

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Outline

Introduction

Seismic Ground Motions

Summary

Motivation

- ▸ Improve seismic modeling and simulation for infrastructure objects

- ▸ Use of high fidelity numerical models to analyze seismic behavior of soil structure nuclear facilities system

- ▸ Reduction of modeling uncertainty, ability to perform high(er) level of sophistication modeling and simulation

- ▸ Accurately follow the flow of seismic energy in a soil structure system

- ▸ What seismic motions to use (3D, or 3×1D or 1D)?

Earthquake Ground Motions

- ▶ Body, P and S waves
- ▶ Surface waves (Rayleigh waves, Love waves, etc.)
- ▶ Inclined waves
- ▶ 3D/6D waves

3D (6D) Seismic Motions

- ▶ All (most) measured motions are full 3D (6D)
- ▶ One example of an almost 2D motion (LSST07, LSST12)
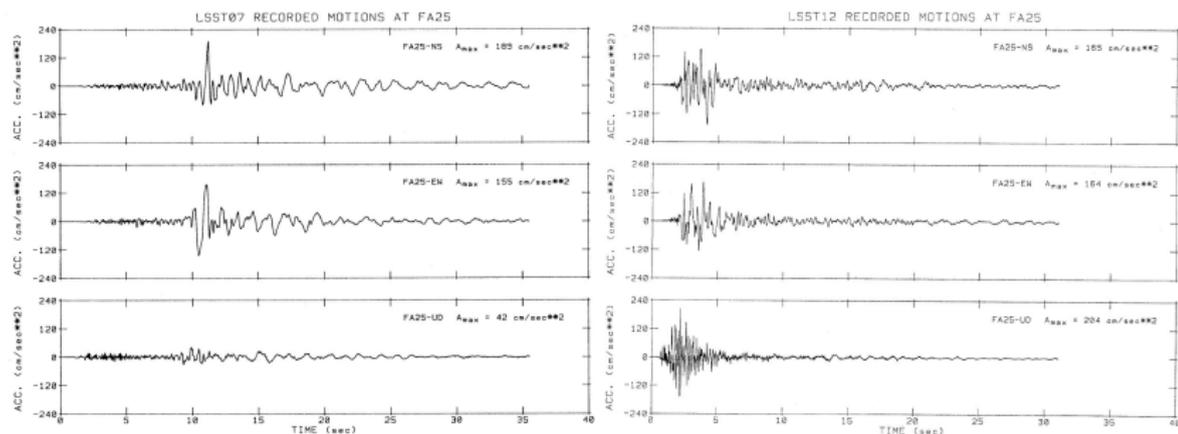
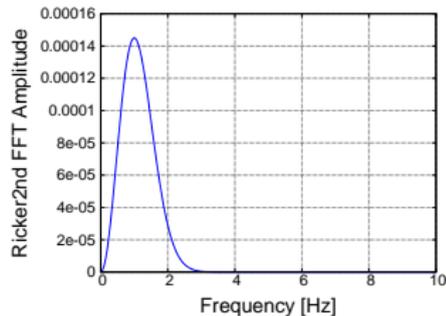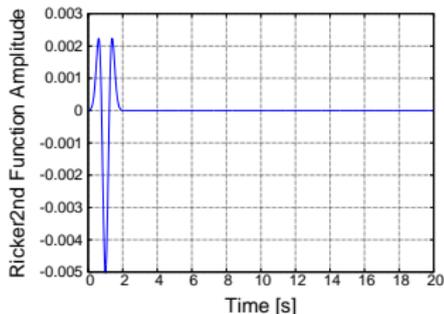- ▶ 1D (?): M 6.9 San Pablo, Guatemala EQ, 14Jun2017

Observations

Stress Testing SSI Systems

- ► Excite SSI system with a suite of seismic motions
- ► Simple sources, variation in strike and dip, P and S waves, surface waves (Rayleigh, Love, etc.)
- ► Stress test soil-structure system
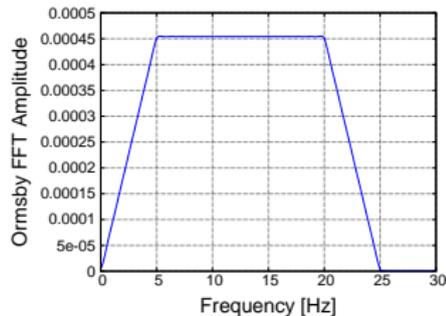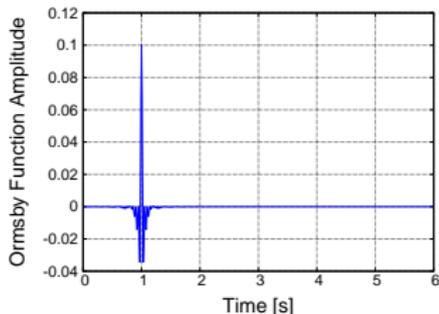- ► Try to "break" the system, shake-out strong and weak links
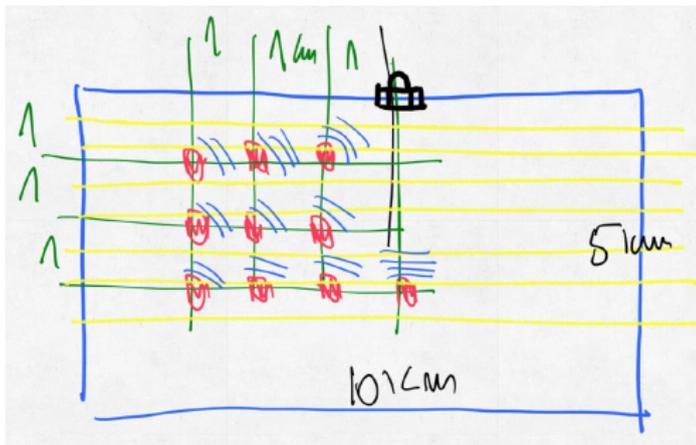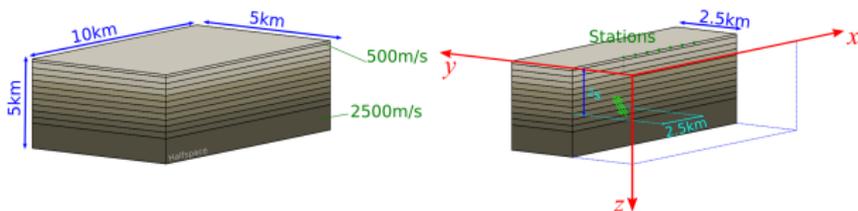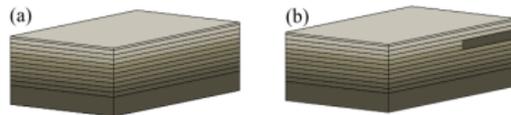
Stress Test Source Signals

► Ricker

► Ormsby

Layered and Dyke/Sill Models

- ▶ (a) Horizontal layers
- ▶ (b) Dyke/Sill intrusion

- ▶ Source locations matrix (point sources)
- ▶ Source strike and dip variation
- ▶ Magnitude variations
- ▶ Range of frequencies

Layered System, Displacement Traces

- ▶ Epicenter is 2500m away from the location of interest
- ▶ Source depth 850m (left) and 2500m (right)
- ▶ Different wave propagation path to the point of interest
- ▶ Surface waves quite pronounced
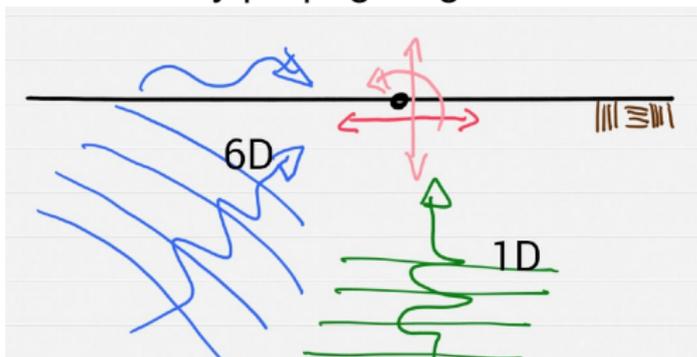- ▶ Layered geology did not filter out surface waves


Jeremić et al.
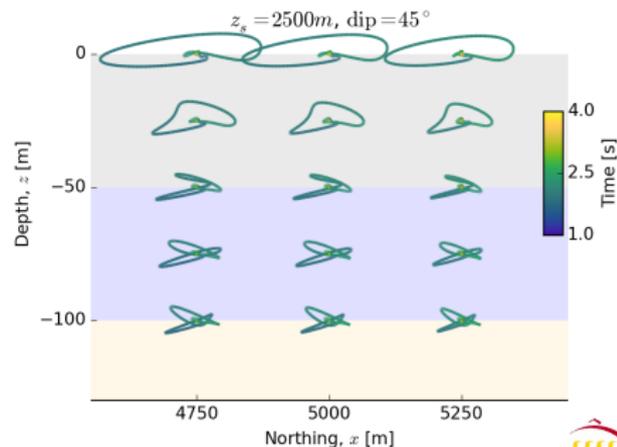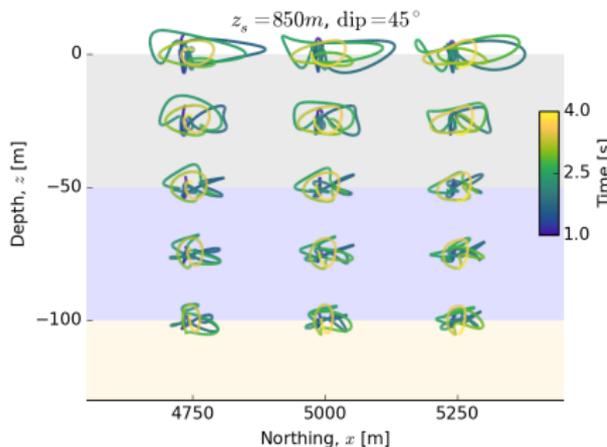
Layered System, Variable Source Depth
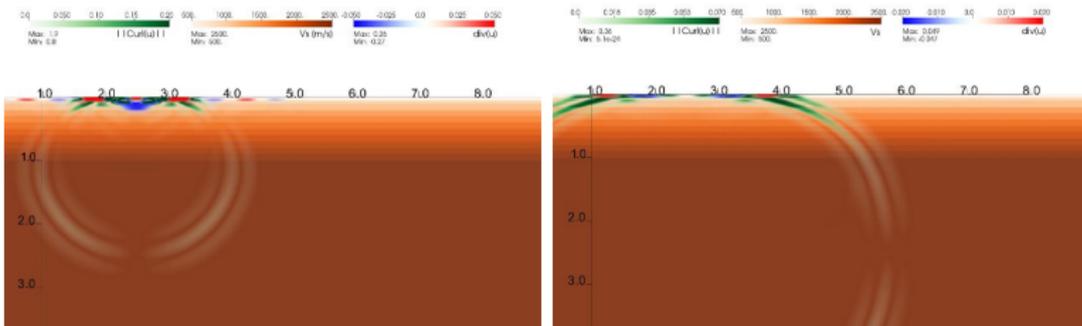
3D or 1D or 3×1D Seismic Motions

- ► Assume that a full 3D motions are recorded/available
- ► Assume that ESSI is performed using
  - ► 3D
  - ► 3×1D
  - ► 1D
- ► For 1D and 3×1D, develop a vertically propagating S and P waves in 1D
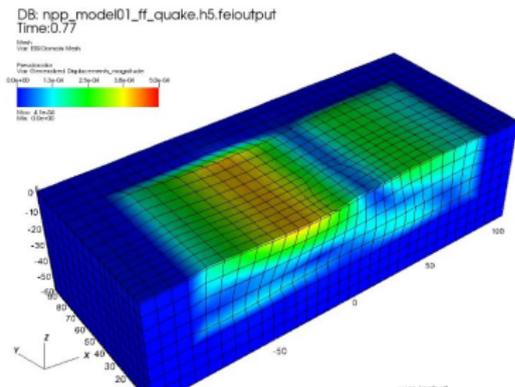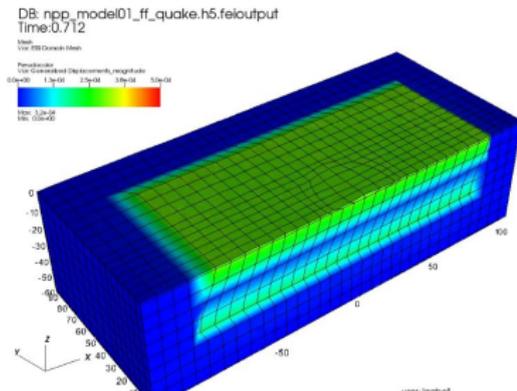- ► Apply such vertically propagating waves

Development of Realistic Motions

- ► Free field seismic motion models
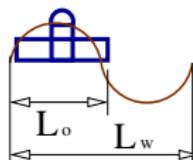- ► Sources will send both P and S waves

Introduction · Seismic Ground Motions · Summary
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Observations
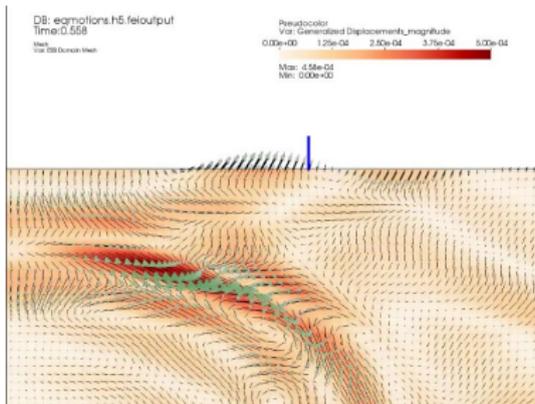
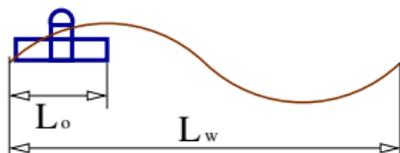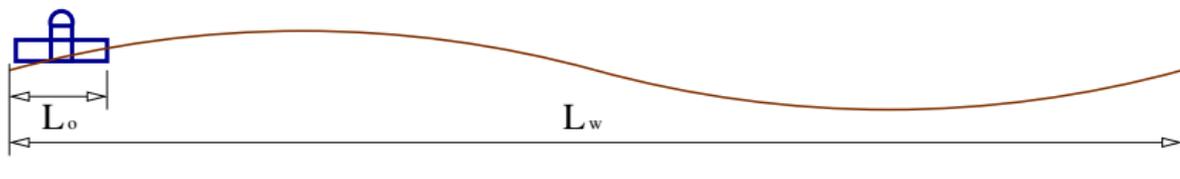# 3D vs 1D
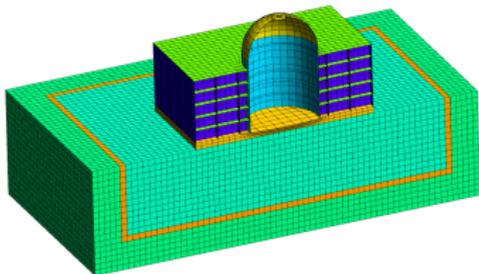
- ▶ in 1D (or 3×1D), seismic energy delivered at once
- ▶ Incoherent motions (wave passage effects)

When to use 3D and/or 3×1D

Observations
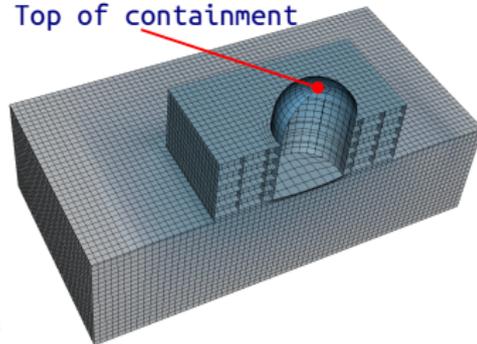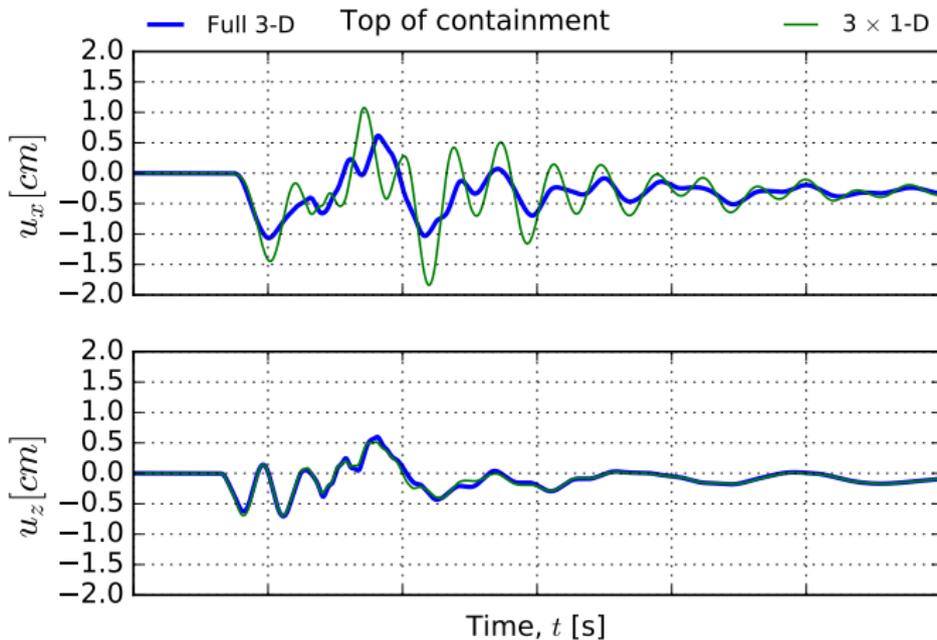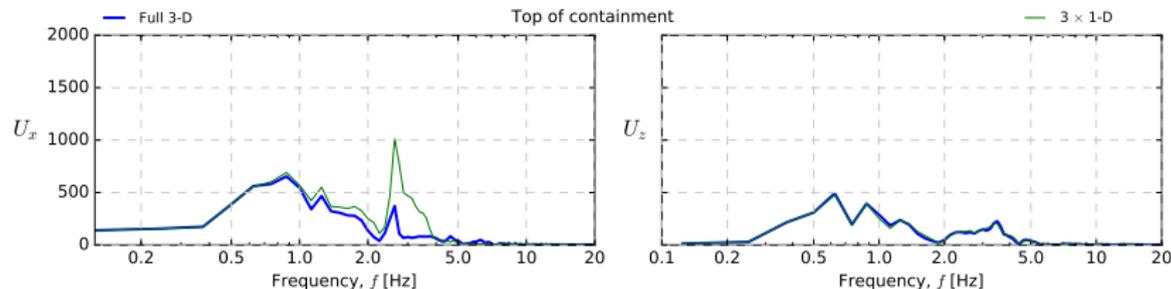
NPP Model

Top of containment

Acc. 3D vs 3×1D

FFT, 3D vs 3×1D

- ▸ Difference in horizontal response, for 3×1D all the energy delivered at once, NPP oscillates
- ▸ Vertical similar for all long waves

Summary

- ▶ Use of full 3D motions is important
- ▶ Use of 3×1D motions is possible for low frequencies
- ▶ The Real ESSI Simulator system used for all the model development, modeling/simulations and post-processing
- ▶ The Real ESSI Simulator system documentation and information about different availability/use options is at http://real-essi.info
- ▶ Nonlinear/Inelastic Earthquake Soil Structure Interaction (ESSI) short course offered this fall in San Francisco, more info at http://real-essi.info
- ▶ Funding from and collaboration with the US-DOE, US-NRC, US-NSF, CNSC-CCSN, UN-IAEA, and Shimizu Corp. is greatly appreciated,