

# On Modeling Uncertainty in Earthquake Soil Structure Interaction Analysis

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# Outline

Motivation

ESSI Illustrations

Summary

# Long Term Motivation

- ▶ High fidelity seismic modeling and simulation for infrastructure objects
- ▶ Development of an expert numerical modeling and simulation tool
- ▶ Use of expert tool and high fidelity numerical models to analyze seismic behavior of soil structure systems
- ▶ Predict and inform rather than (force) fit

# ESSI Hypothesis

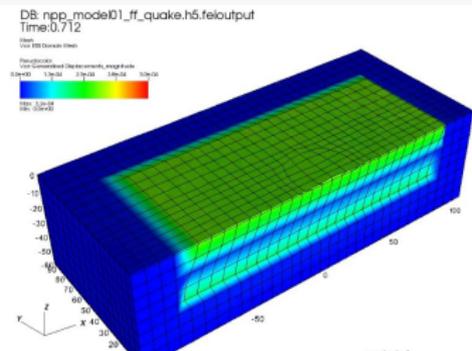
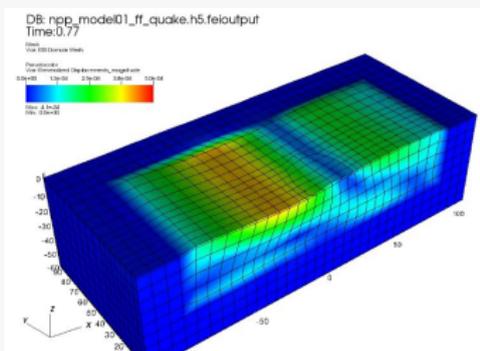
- ▶ Nonlinear interplay of the Earthquake, Soil and Structure plays a decisive role in successes and failures
- ▶ Timing and spatial location of energy dissipation determines location and amount of damage
- ▶ When we control and direct timing and spatial location of energy dissipation, we optimize soil structure system for
  - ▶ Safety and
  - ▶ Economy

# High Fidelity Predictive Capabilities

- ▶ Verification provides evidence that the model is solved correctly. Mathematics issue.
- ▶ Validation provides evidence that the correct model is solved. Physics issue.
- ▶ Prediction: use of computational model to foretell the state of a physical system under consideration under conditions for which the computational model has not been validated.
- ▶ Prediction under uncertainty:
  - ▶ Modeling uncertainty
  - ▶ Parametric uncertainty
- ▶ Predictive capabilities with low Kolmogorov Complexity

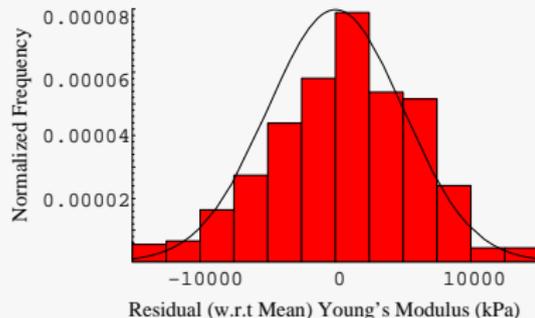
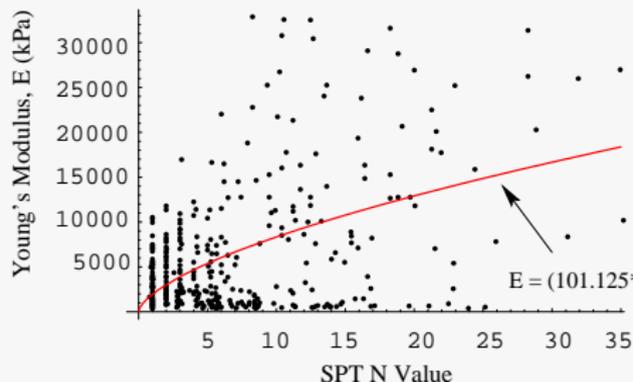
# Modeling Uncertainty: Simplified Models

- ▶ Simplified modeling: Features (important ?) are neglected (6D ground motions, inelasticity)
- ▶ Modeling Uncertainty: unrealistic and unnecessary modeling simplifications
- ▶ Modeling simplifications: justifiable iff higher level sophistication model shows that simplified features are not important



## Parametric Uncertainty: Material and Loads

- ▶ Significant uncertainty in material and loads
- ▶ Need to propagate uncertainty through simulation, to give regulators and engineers information for design, licensing...



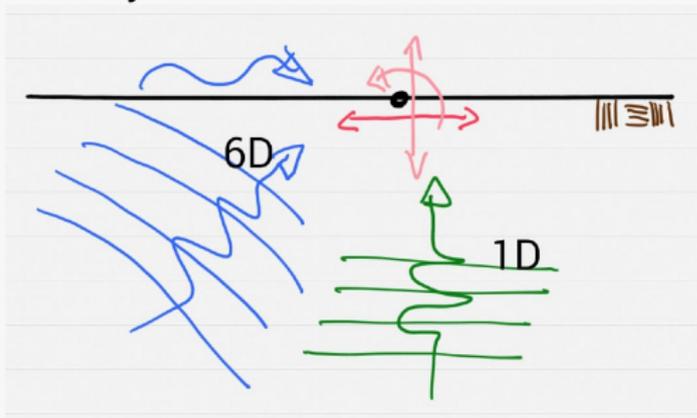
Transformation of SPT  $N$ -value: 1-D Young's modulus,  $E$  (cf. Phoon and Kulhawy (1999B))

# Real ESSI Simulator System

- ▶ **The Real ESSI Program** is a 3D, nonlinear, time domain, parallel finite element program specifically developed for Hi-Fi modeling and simulation of Earthquake Soil Structure Interaction problems for infrastructure objects
- ▶ **The Real ESSI Computers** are distributed memory parallel computers, clusters of clusters with multiple performance processors and networks
- ▶ **The Real ESSI Notes** are a hypertext documentation system (Theory and Formulation, Software and Hardware, Verification and Validation, Examples, and Applications) detailing modeling and simulation of ESSI problems

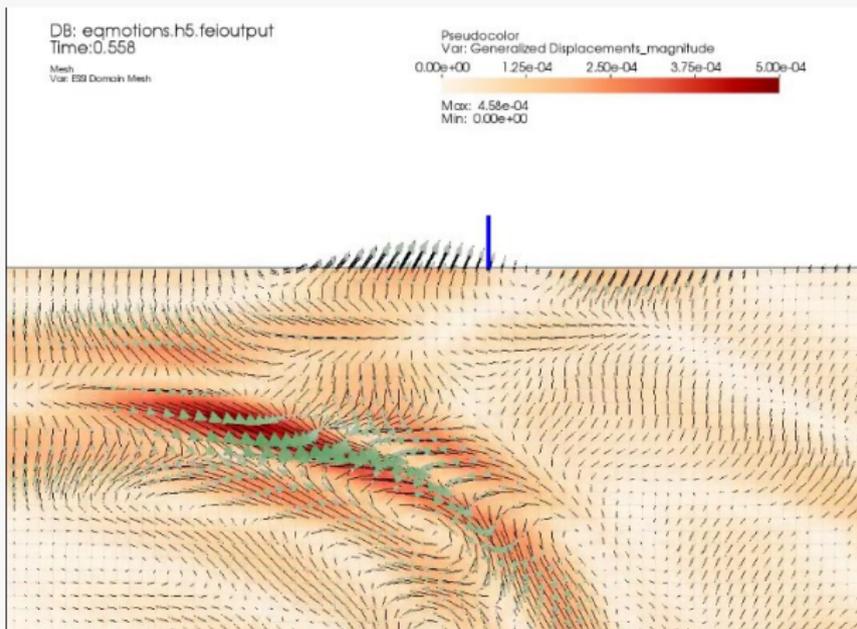
## Nuclear Power Plants: 6D or 1D Seismic Motions

- ▶ Assume that a full 6D (3D) motions at the surface are only recorded in one horizontal direction
- ▶ From such recorded motions one can develop a vertically propagating shear wave in 1D
- ▶ Apply such vertically propagating shear wave to the same soil-structure system



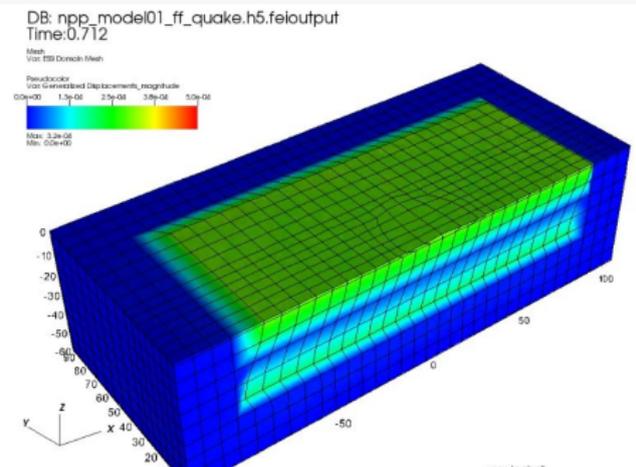
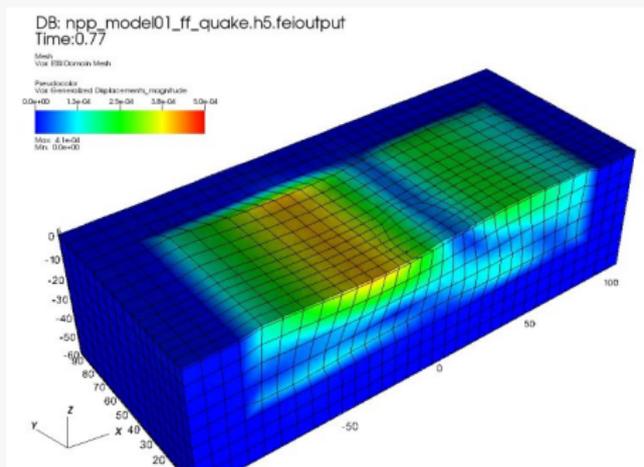
# Development of Realistic Motions

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

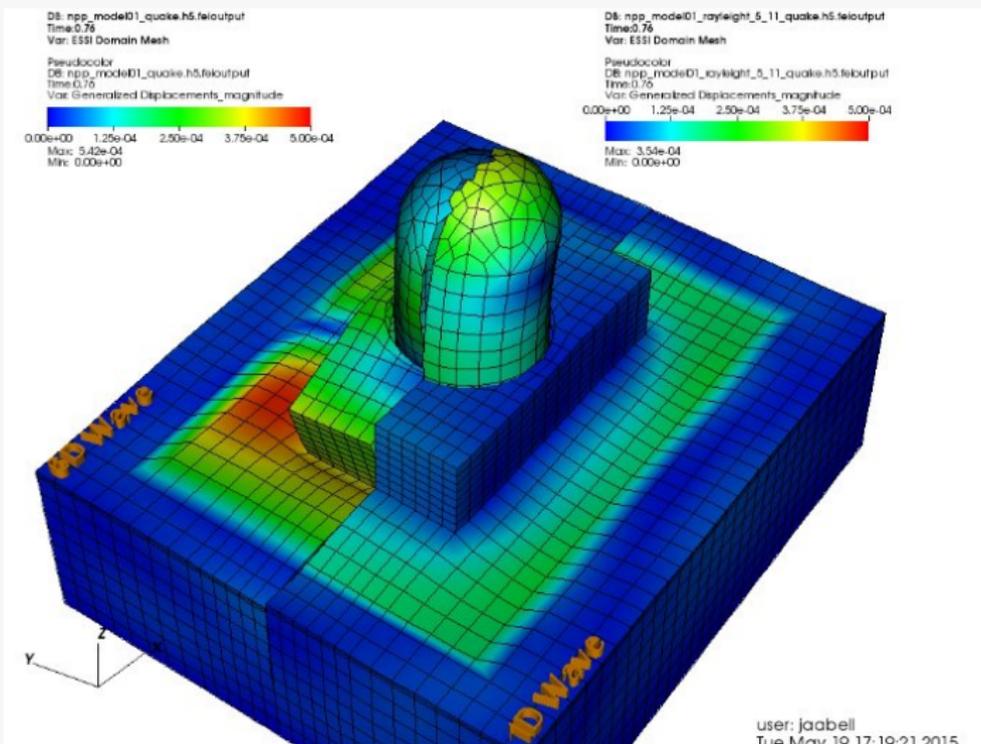


# Realistic Earthquake Motions, 6D vs 1D

- ▶ Danger of picking one component of motions (1D) from 3D
- ▶ Excellent (forced) fit, but not a prediction, information is lost



# 6D vs 1D NPP ESSI Response Comparison



user: jaabell  
Tue May 19 17:19:21 2015



# Summary

- ▶ Reduction of modeling uncertainty
- ▶ Development and expert use of high fidelity modeling and simulation numerical tools: Real ESSI Simulator System
- ▶ Education and training of users (researchers, designers, regulators, owners) will prove essential
- ▶ Collaborators: Yang, Cheng, Jie, Sett, Taiebat, Tafazzoli, Karapiperis, Abell, Pisanò, Luo, Feng, Sinha, Lacour, Yang, Behbehani, Wang, Petrone, Wong, McKenna, McCallen
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