The Nonlinear Time-Domain Modeling of Earthquake Soil Structure Interaction for Nuclear Power Plants: Nonlinear Contact Between Foundation and Rock

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Outline

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Introduction

- High fidelity modeling and simulation of earthquake soil/rock structure interaction behavior of NPPs
- Reduction of modeling uncertainty
- Focus in this study are nonlinear material effects at the foundation – soil/rock interface
- Thanks to Dr. Godoy and Dr. Kennedy for pointing out to this issue/problem
- One of the case studies for the NRC ESSI Simulator System

Outline

Foundation – Soil/Rock Interface

- The case of nonlinear, elastic-plastic zone between a concrete slab and a foundation soil/rock.
- Layers of plastic waterproof sheets in the zone
- Reduction of capacity for horizontal shear a the foundation-rock contact
- Possible gaping, opening and closing (hard or soft)

Beneficial and/or Detrimental ?

- Benefits of nonlinear contact between the foundation slab and the soil/rock
  - Dissipation (significant) of seismic energy (shear)
  - Change of seismic motions characteristics (frequency reduction)
  - "Passive" base isolation
- Detriments of nonlinear contact between the foundation slab and the soil/rock
  - Gap opening with hard gap closing (high frequency load)
  - Change of seismic motions

Contact Element

- Node to node contact element
- General, 3D element
- Gap opening/closing in normal direction
- Frictional contact in shear direction
- Viscous and/or non-viscous gap opening/closing

Verification and Validation

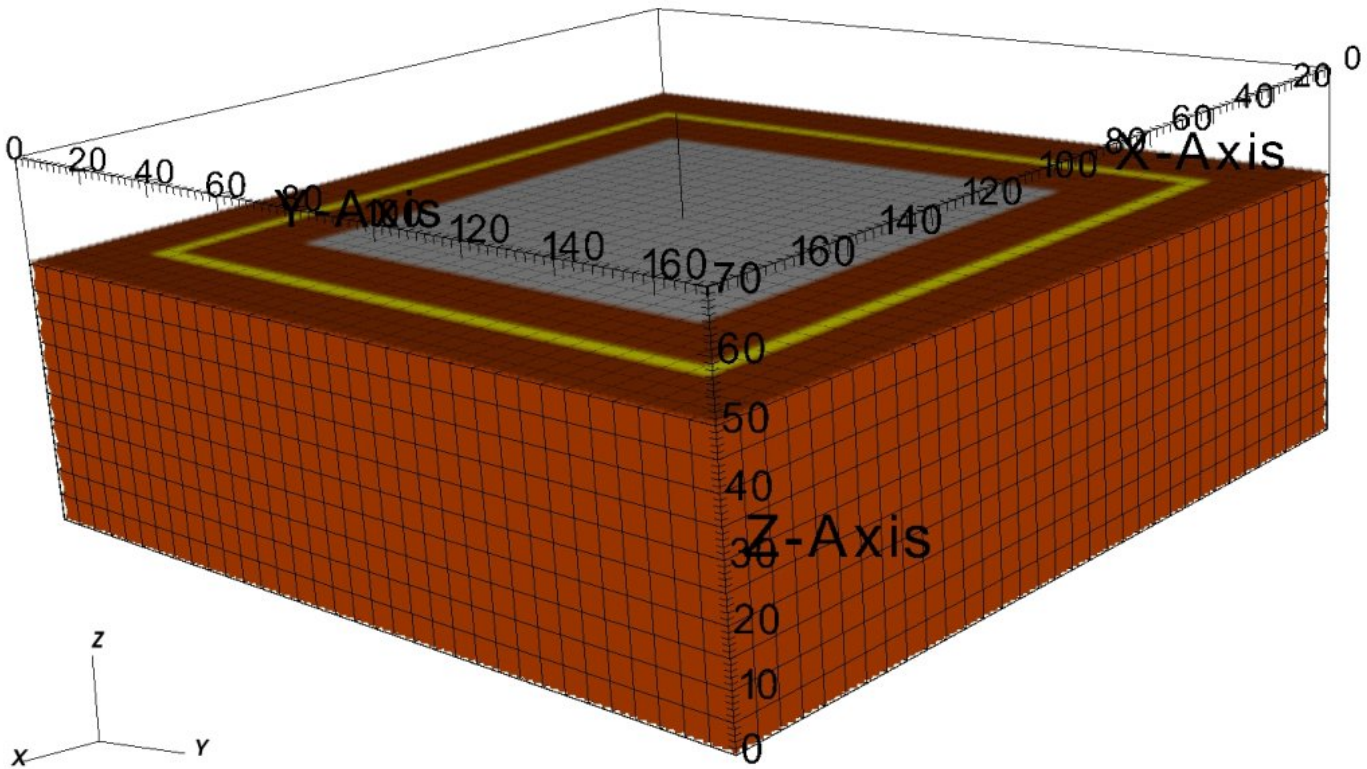
Verification provides evidence that the model is solved correctly.

- Code verification
- Finite elements
- Constitutive simulations
- Static and dynamic solution advancement algorithms
- Solvers
- Wave propagation
- Model/mesh verification

Validation provides evidence that the correct model is solved.

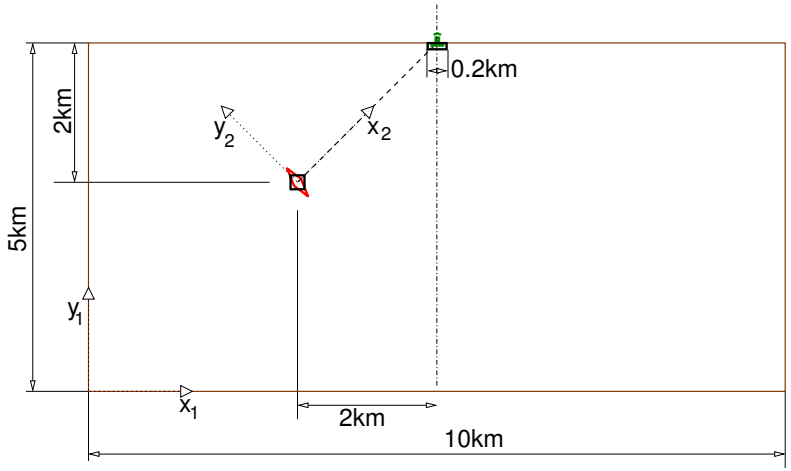
- Validate components, unit tests
- Validate the system (limited data, recent ea[illegible]al)

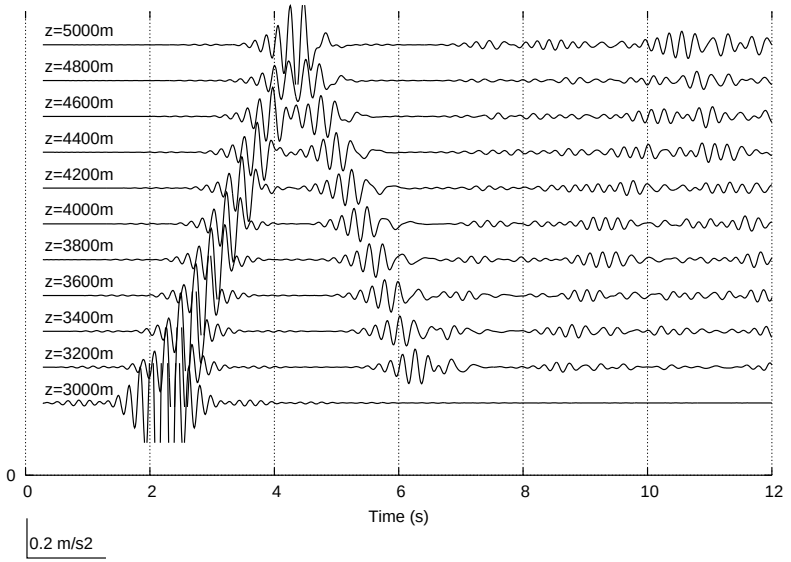
ESSI Model, with/without Interface



Model Verification

- Verification: finite element mesh, wave propagation
- Synthetic motions: Ricker, Ormsby wavelets
- Verify propagation of **Body** (P, SV and SH) and **Surface** (Rayleigh, Love) waves



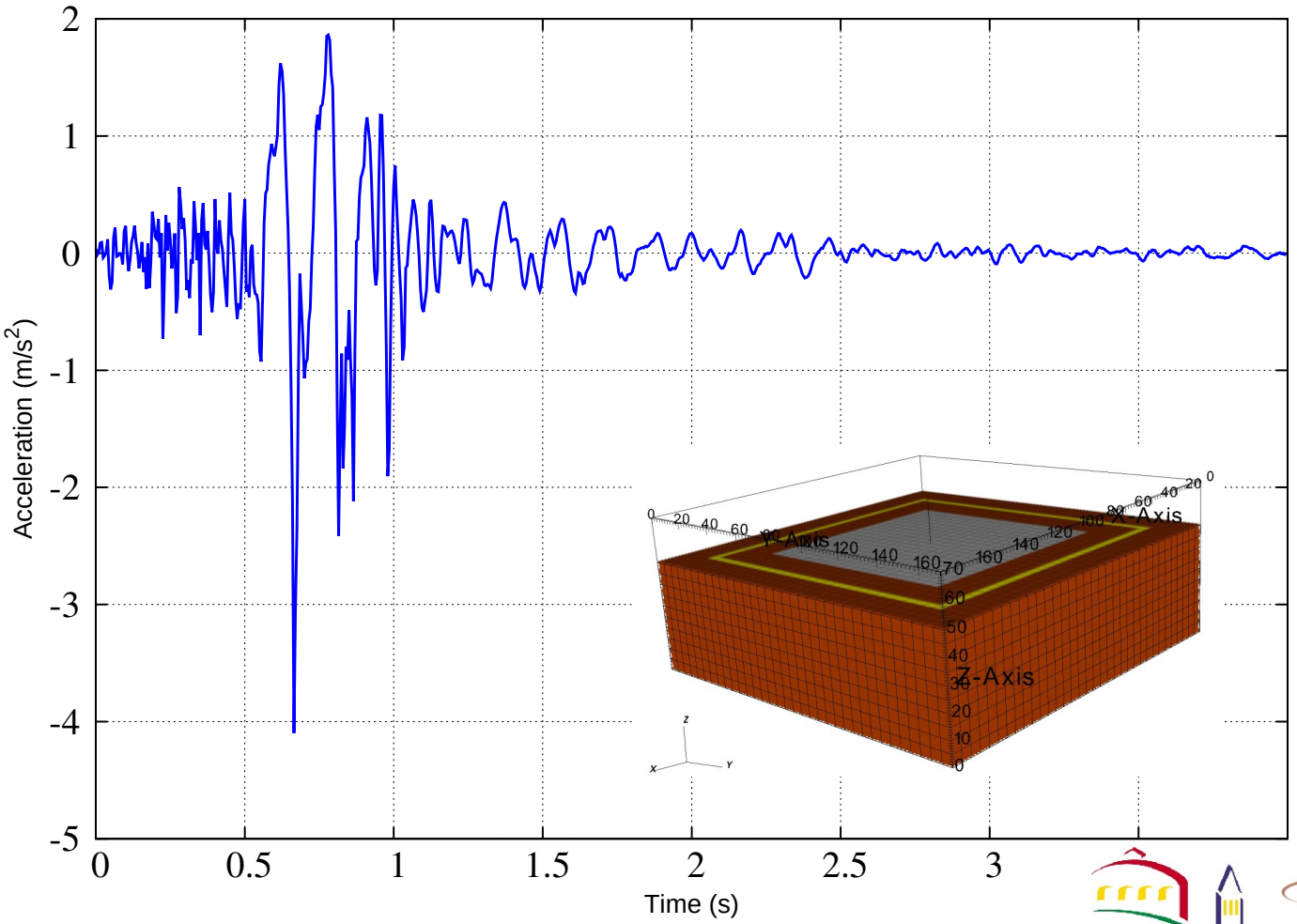


Outline

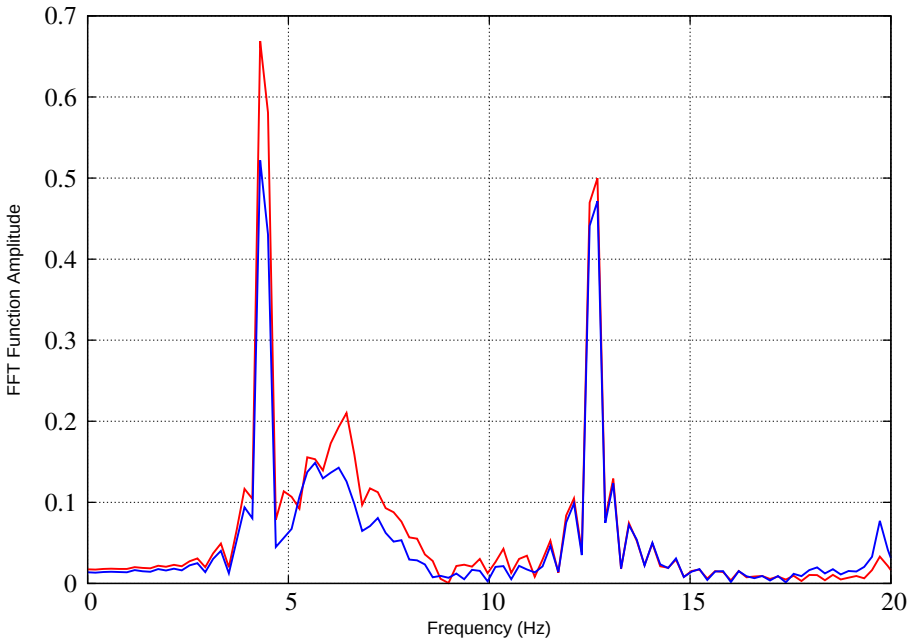
Influence of Inelastic Foundation-Soil/Rock Contact on the NPP Response

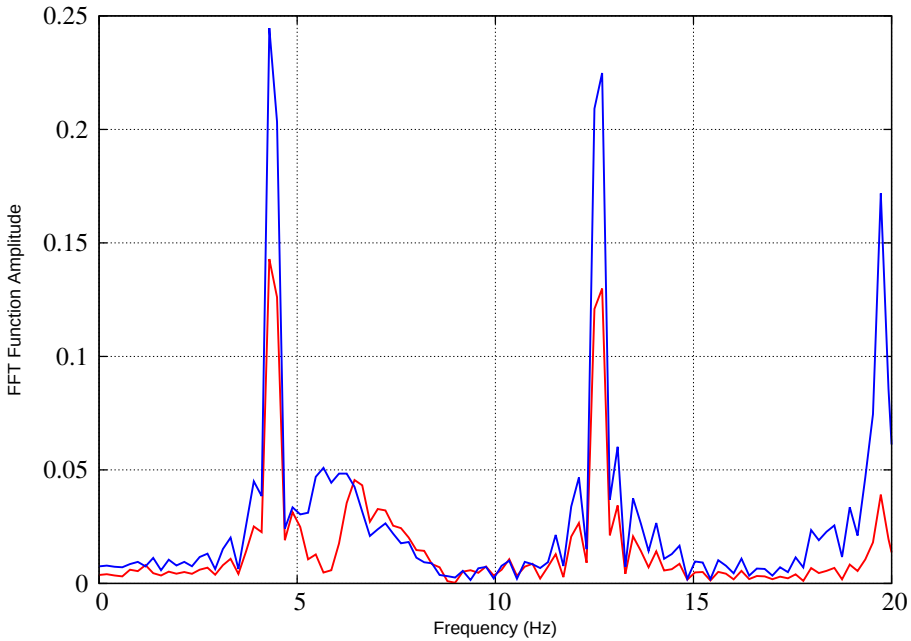
- Soil/rock – foundation interface slip behavior
- Changes in Earthquake Soil/Rock Structure Interaction (reduction/increase in demand)
- Dissipation of seismic energy in the slip plane
- Passive (and active) base isolation
- Two examples, 1D seismic wave and 3D synthetic Ricker wavelet

Incident Earthquake SV Wave



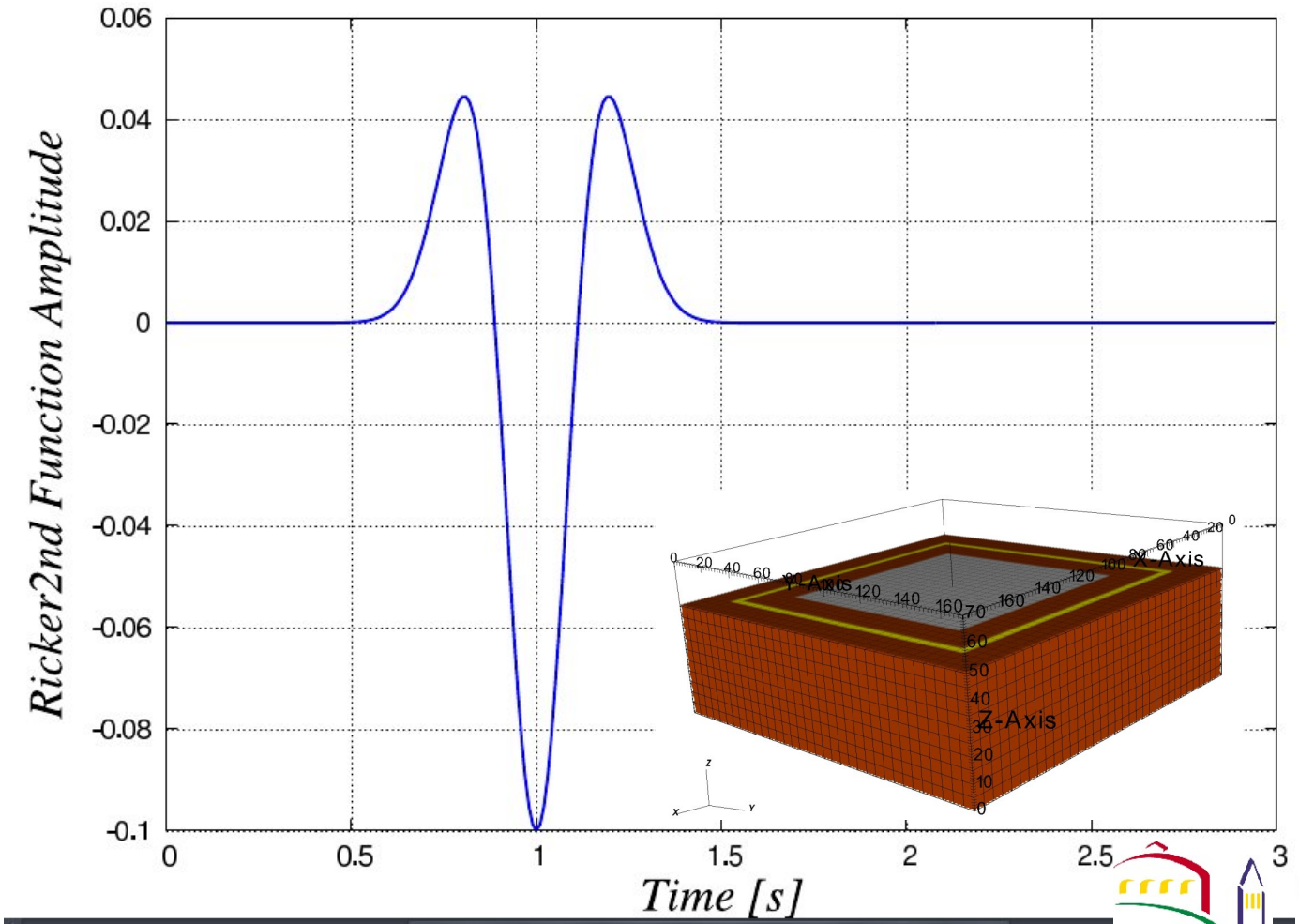
Base and Top of the Containment



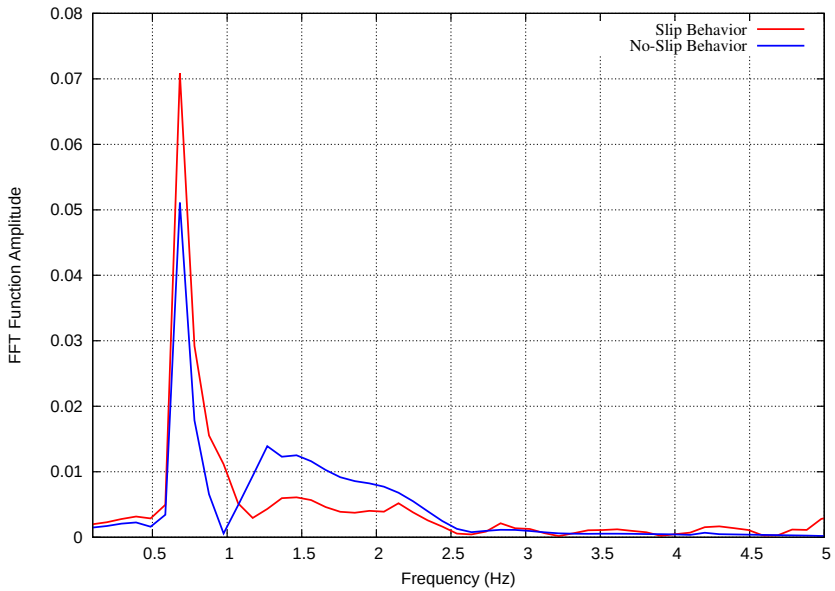


—slip —noslip

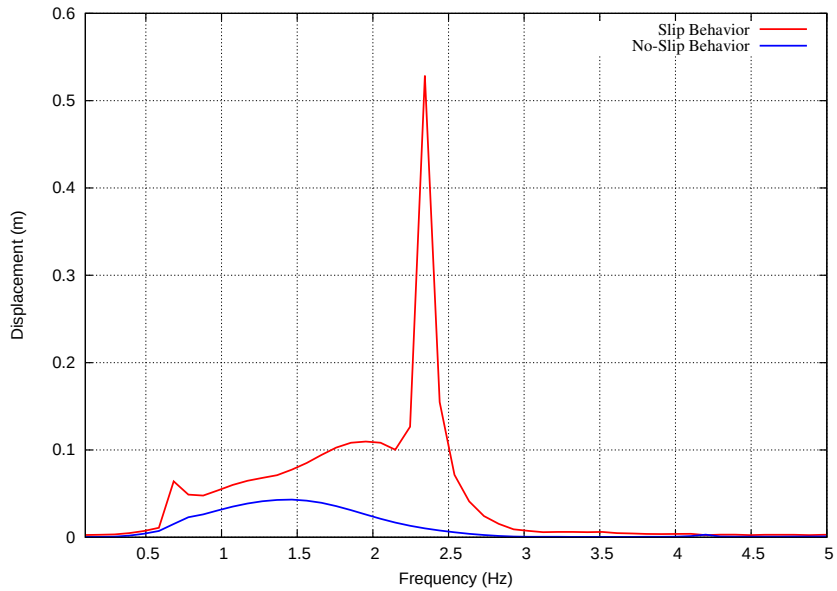
Incident Ricker Wavelet at 45^o



ESSI with Slip, Base, Accelerations FFT

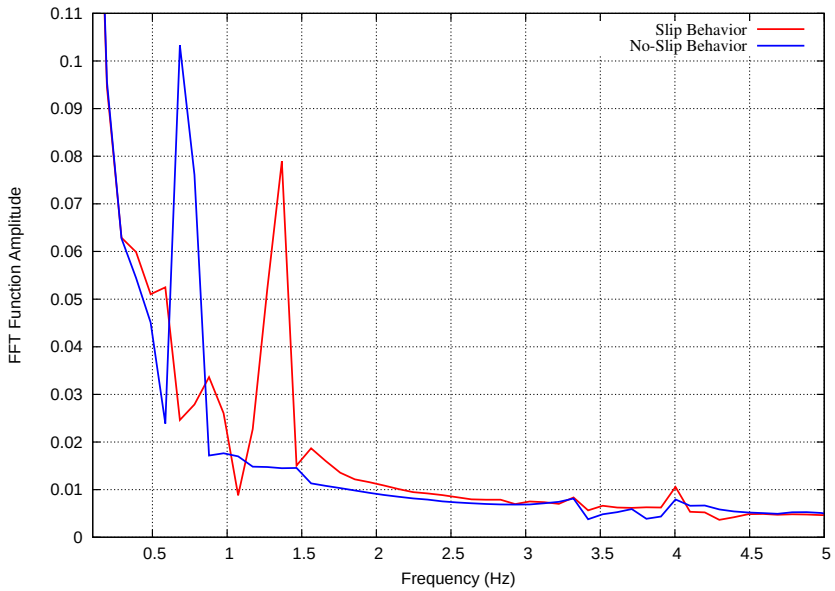


horizontal Acc. FFT



vertical acc. FFT

ESSI with Slip, Top, Accelerations FFT



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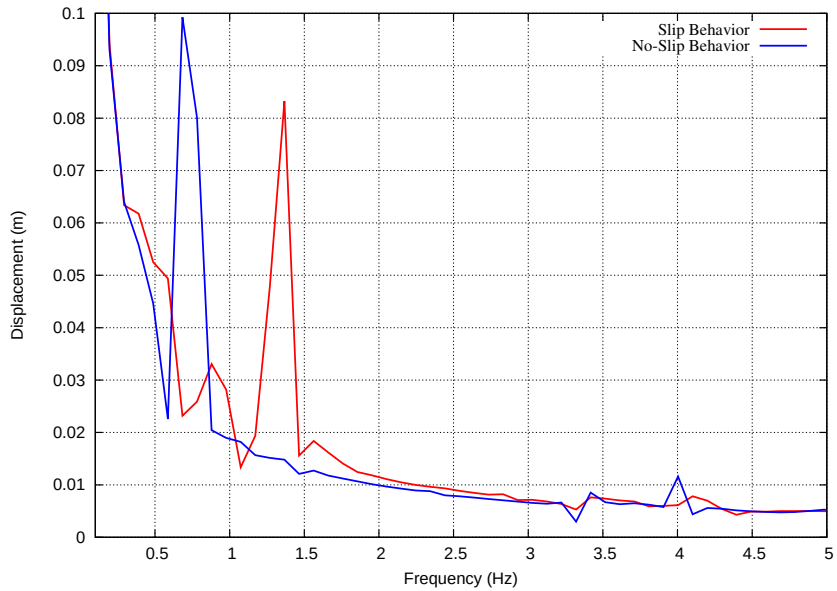

vertical acc. FFT

Outline

Summary

- Nonlinear behavior of the foundation – soil/rock interface zone can have beneficial and detrimental effects on the seismic response of NPPs
- Beneficial or Detrimental, such nonlinear interface does exists and has to be properly modeled
- High fidelity numerical prediction relies heavily on proper verification and validation
- Information Portal: **`http://nrc-essi-simulator.info`**
- Funding by and Collaboration with the U.S.-NRC is gratefully acknowledged