Validation Experiments for Earthquake Soil Structure Interaction Modeling and Simulation

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Outline

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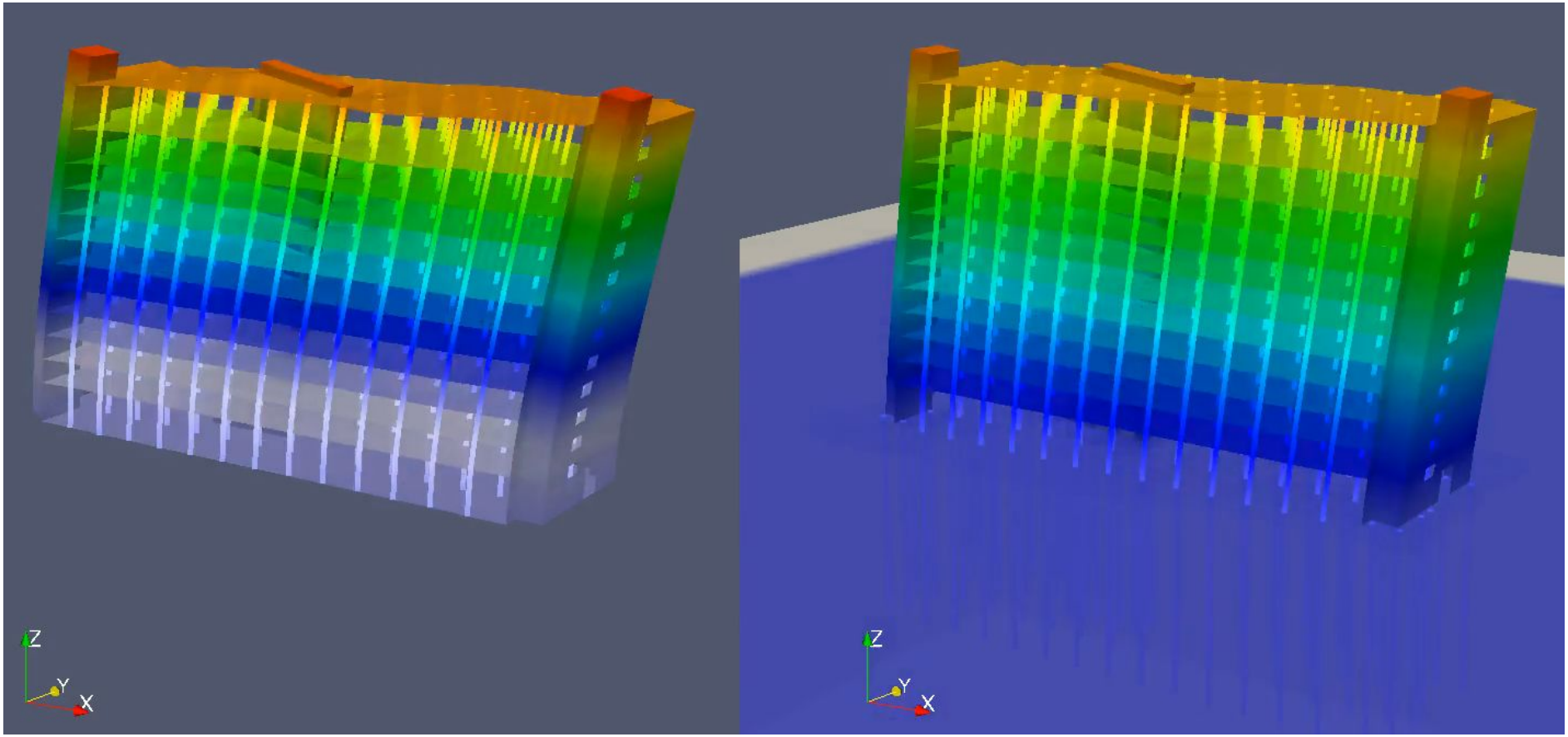
Motivation

- Improve modeling and simulation for infrastructure objects
- Earthquake Soil Structure Interaction – ESSI
- Goal: predict and inform
- Engineer needs to know!
- Expert analysts and expert numerical analysis tool:
  - assess safety
  - improve economy
- Quality assurance: expert numerical analysis tool, SimTool

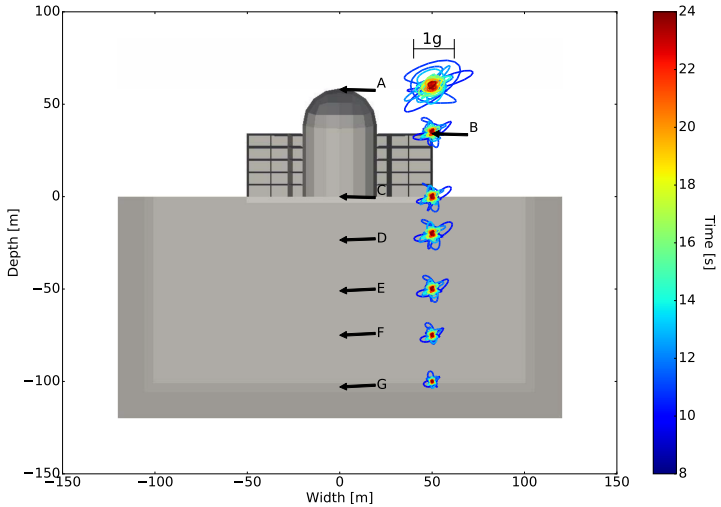
ESSI Analysis is a Must



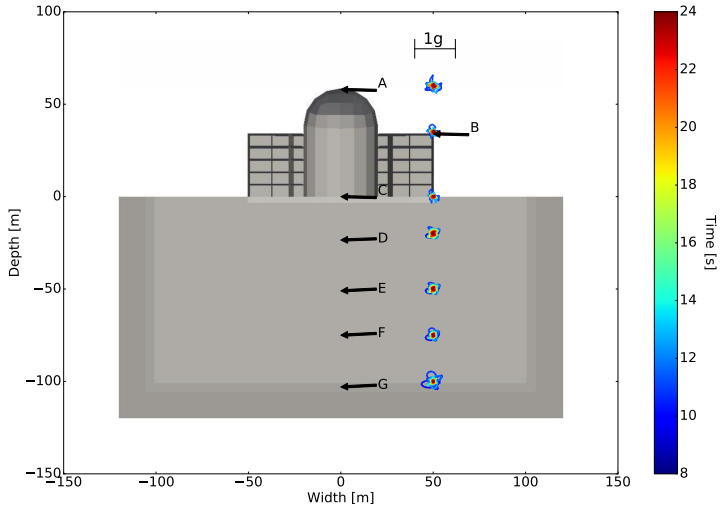
(**MP4**) nonESSI ↑ Ventura Hotel, Northridge eq. ↑ ESSI

Inelastic ESSI, Benefits and Detriments

R. Morita, K. Saito, and A. Yuyama. Development and analysis of seismic experience database of structures, systems and components in nuclear power plants based on investigation reports and maintenance records. Nuc.Eng.&Des., 375:111078, 2021.

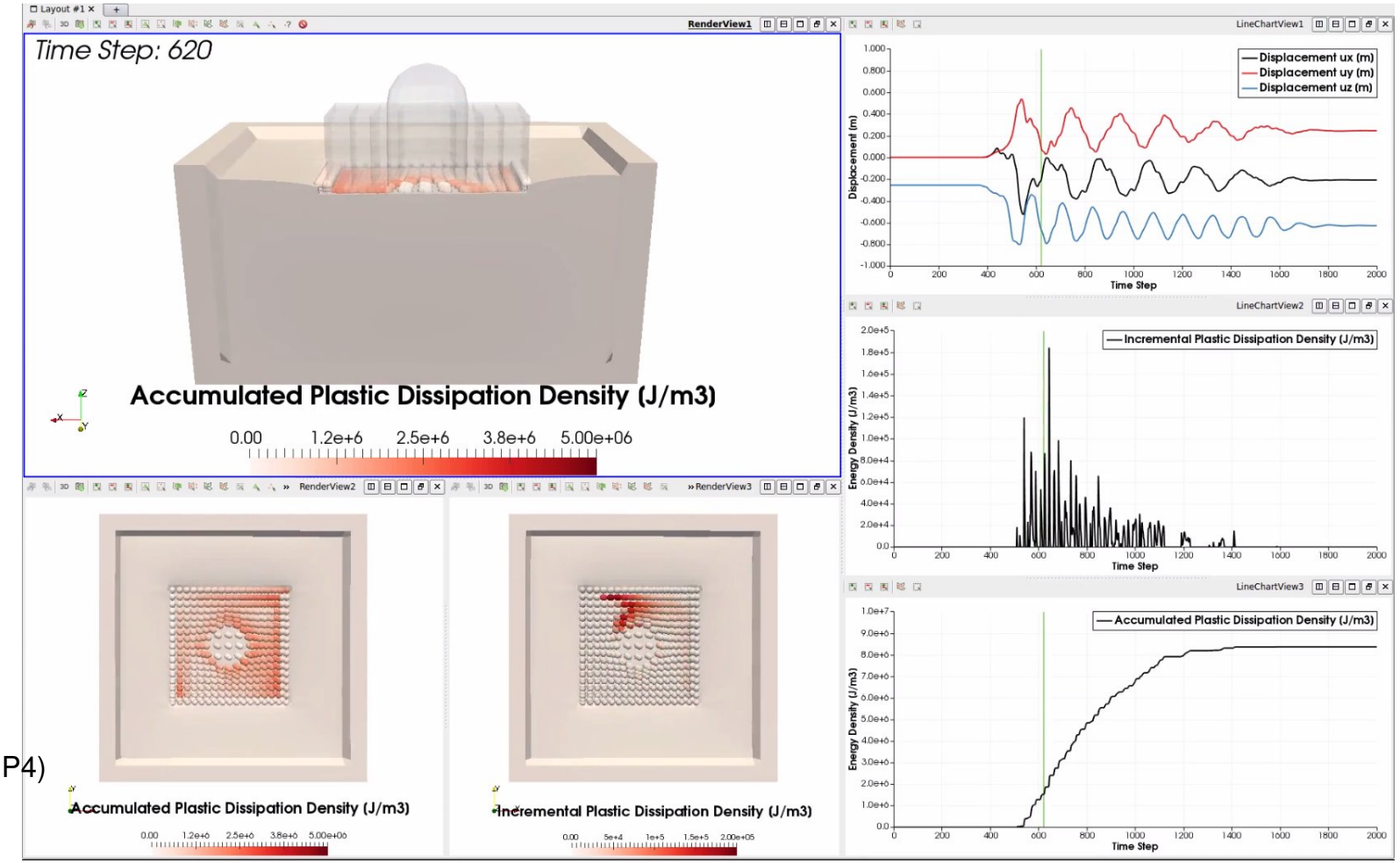


Elastic



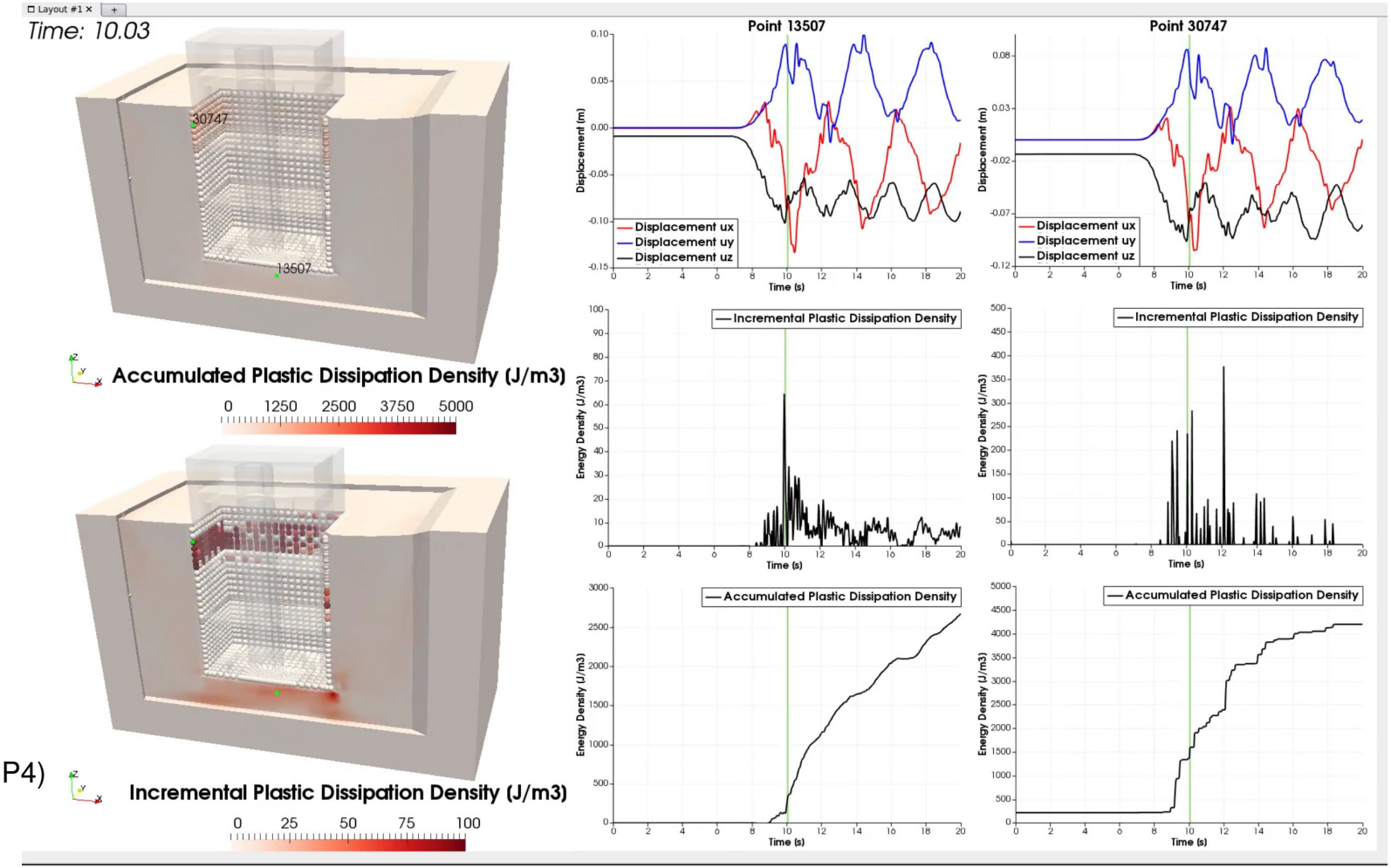
Inelastic

NPP ESSI and Energy Dissipation



(MP4)

SMR ESSI and Energy Dissipation



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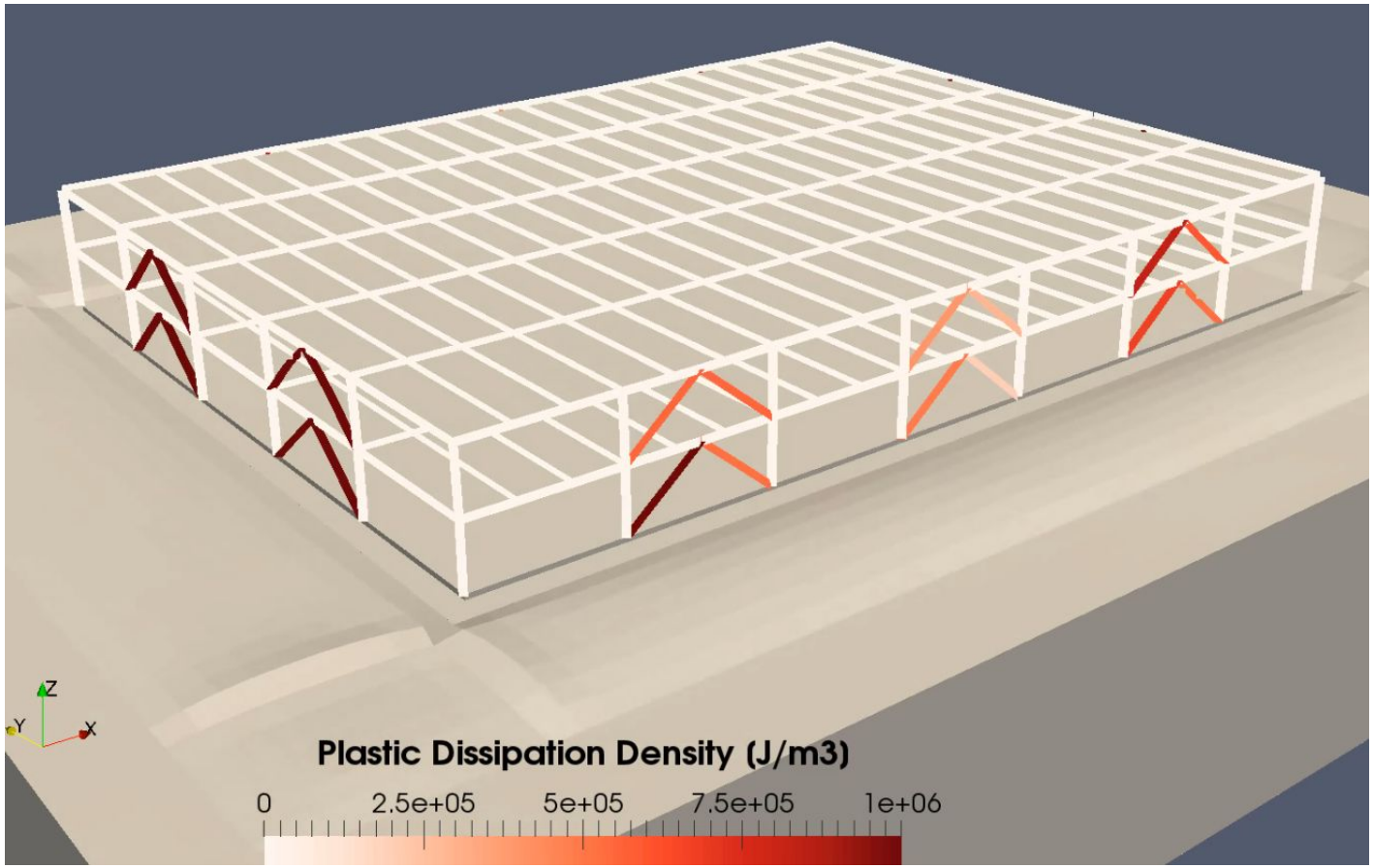
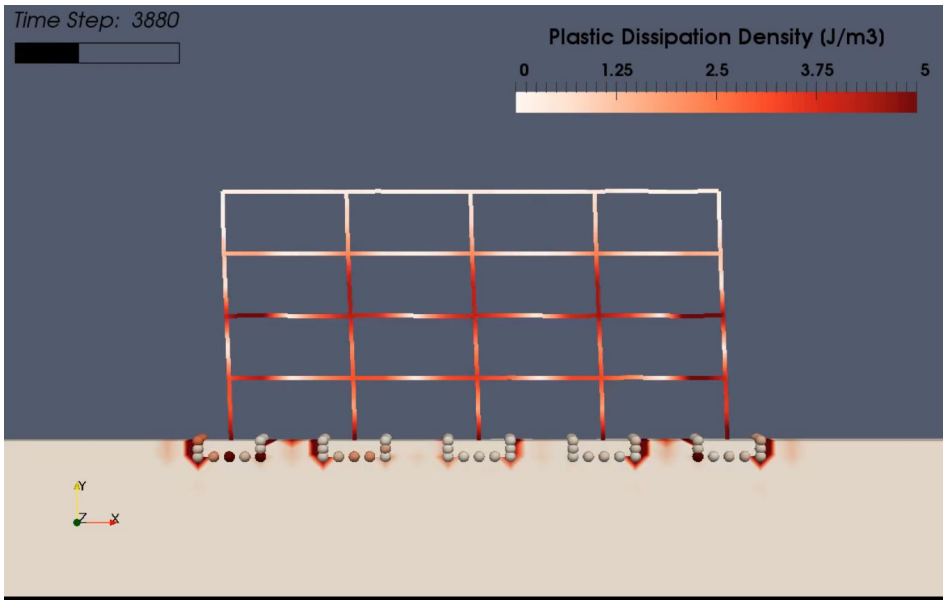
Base Slab Averaging vs Inelasticity



(MP4)

FEMA/ASCE-7

ESSI and Energy Dissipation for Design



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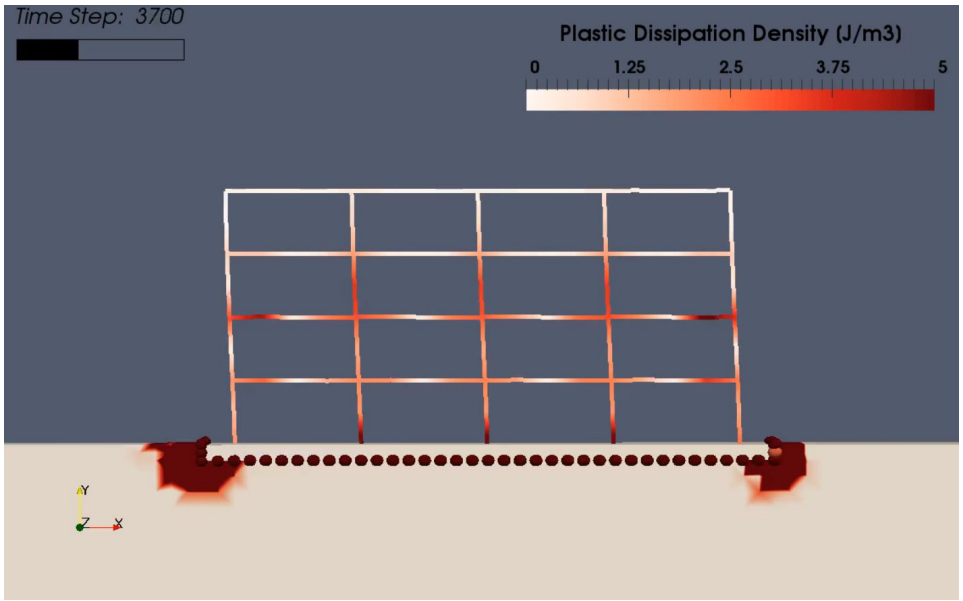
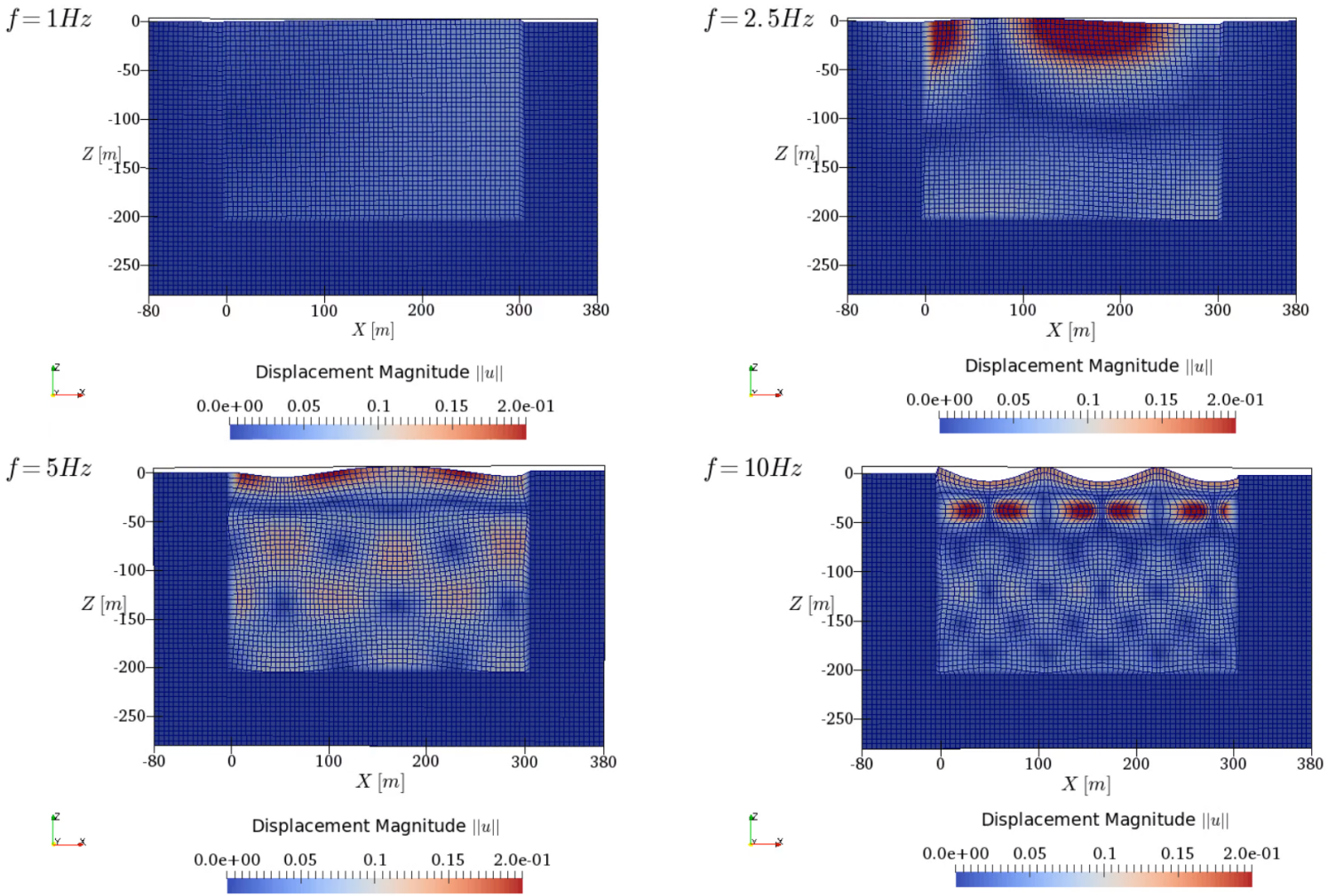


(MP4)

Seismic Motions, Horizontal vs Vertical



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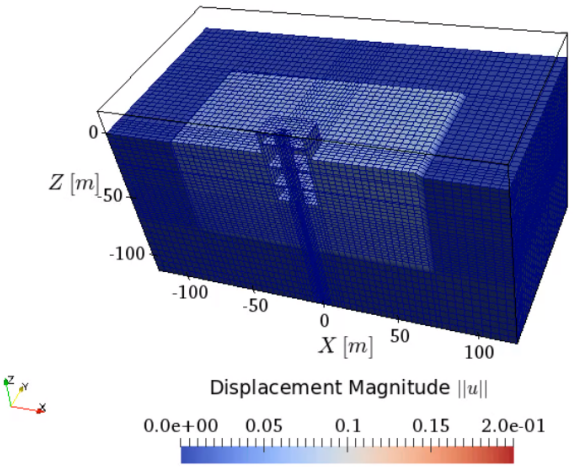
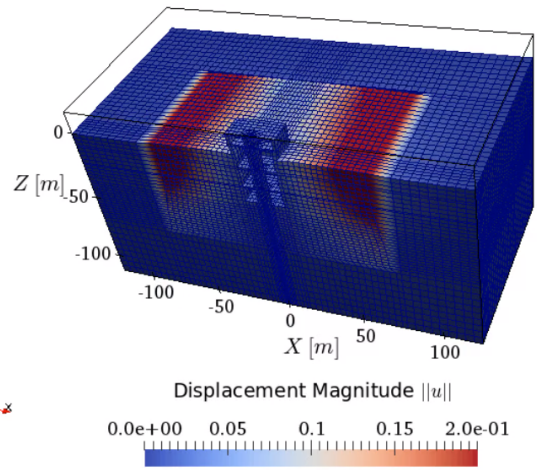
SMR ESSI

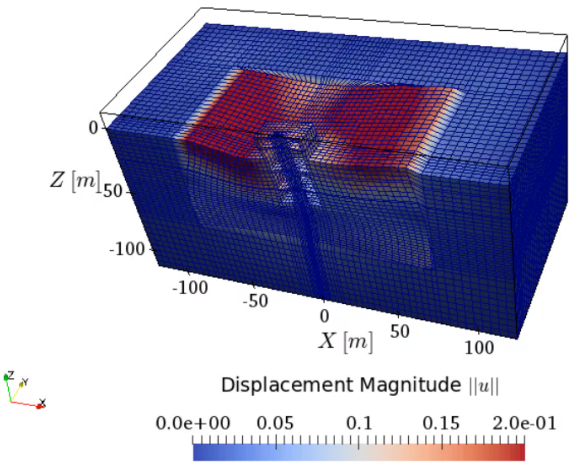
$f = 1Hz$



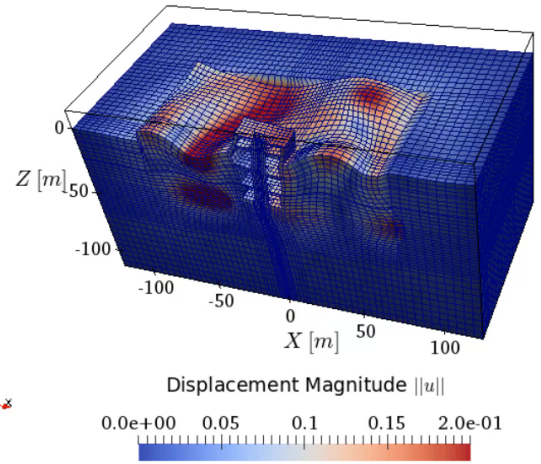
$f = 2.5Hz$



$f = 5Hz$



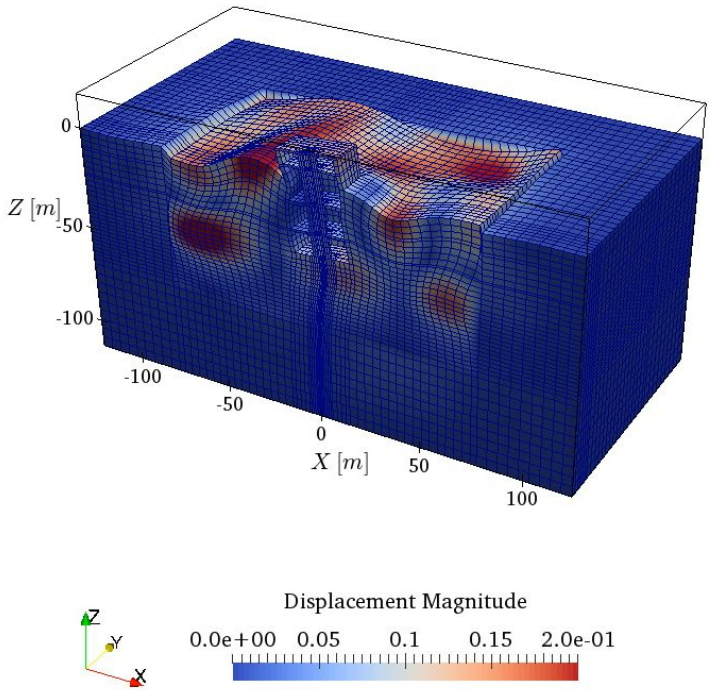
$f = 10Hz$



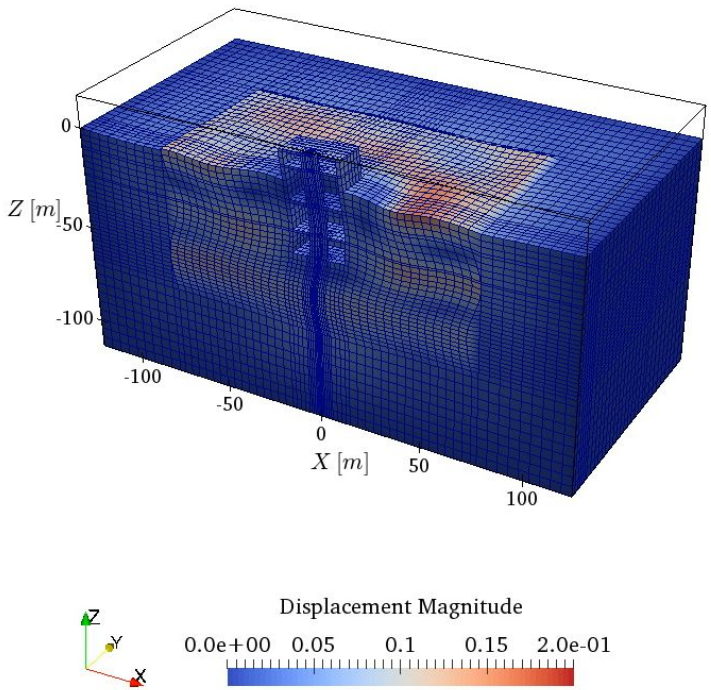
(MP4)

SMR ESSI, 3C vs 3×1C

$3C$

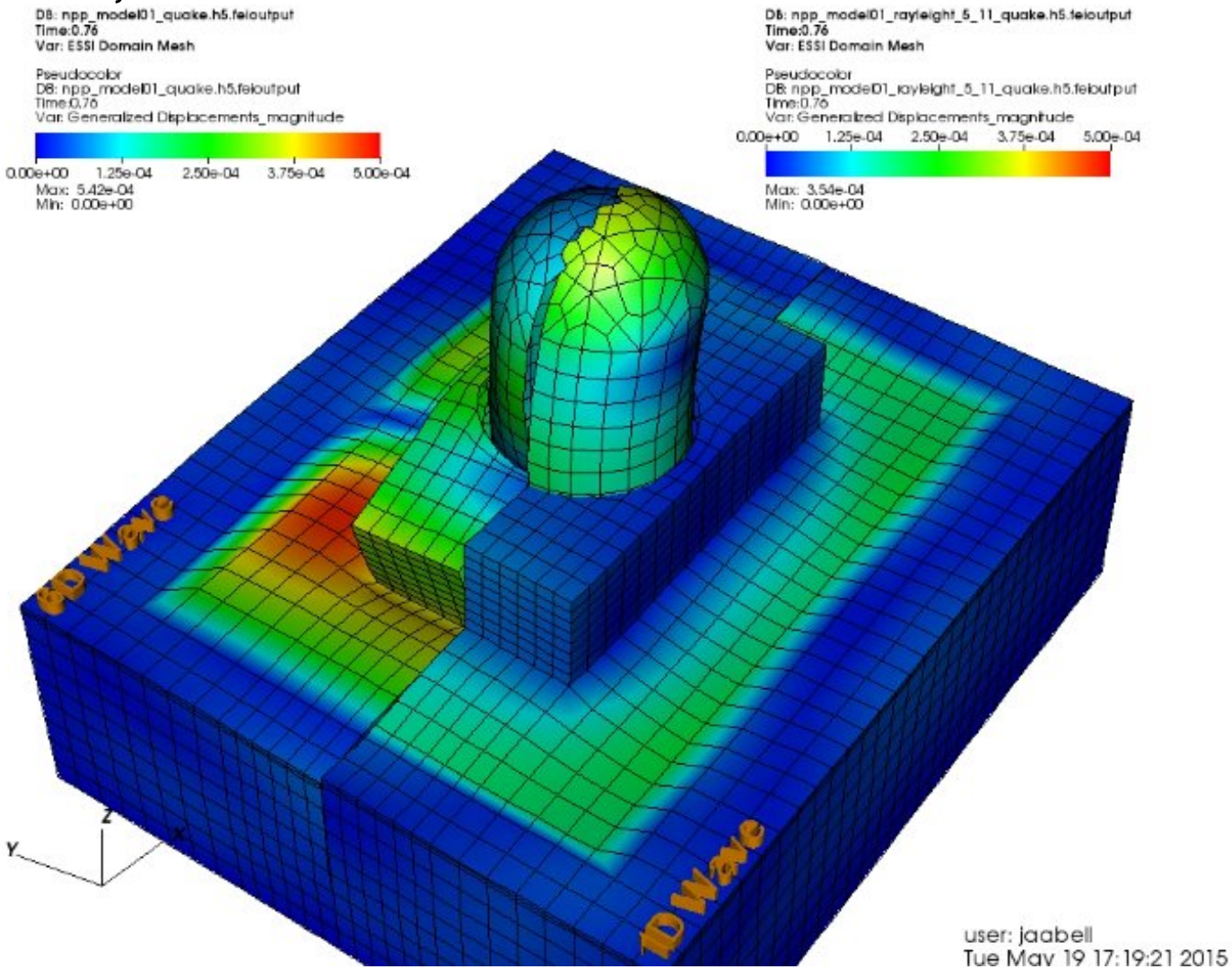


$3 \times 1C$



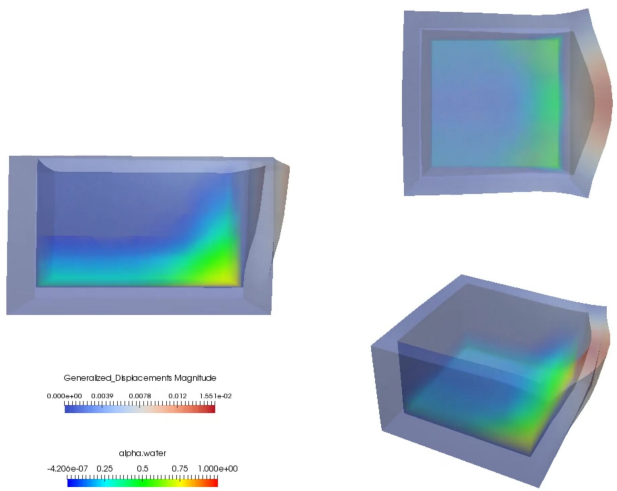
(OGV)

NPP ESSI, 6C vs 1C



(MP4)

ESSI with External/Pool and Internal/Pore Fluid



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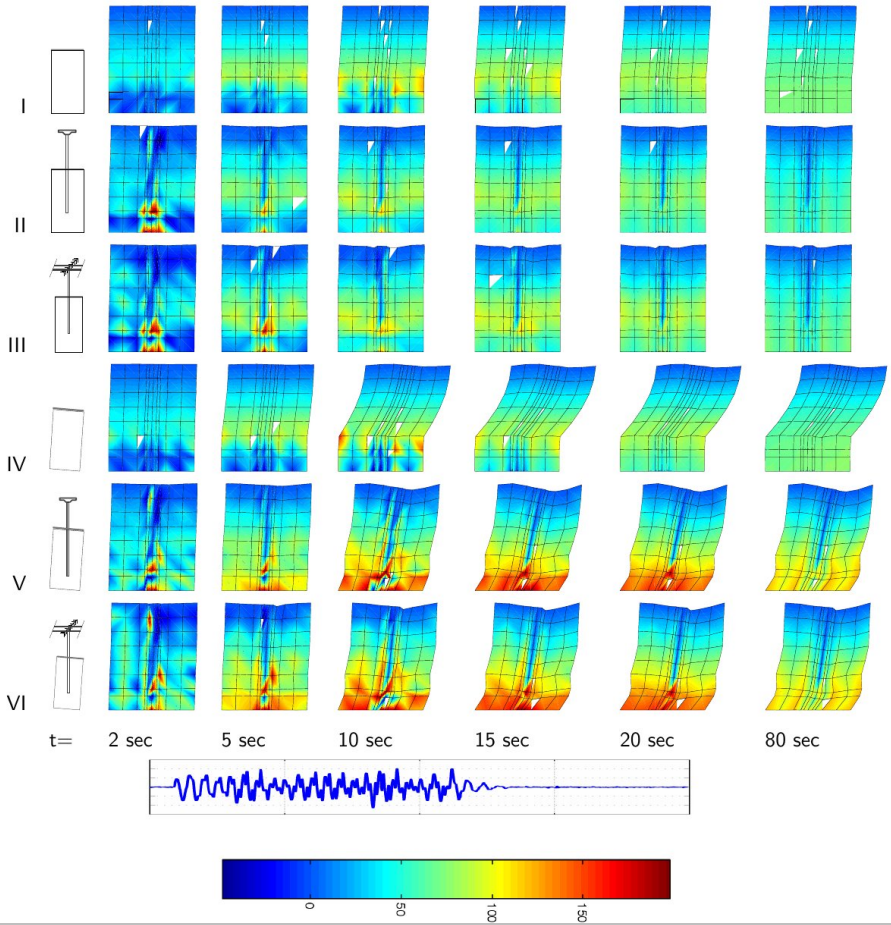
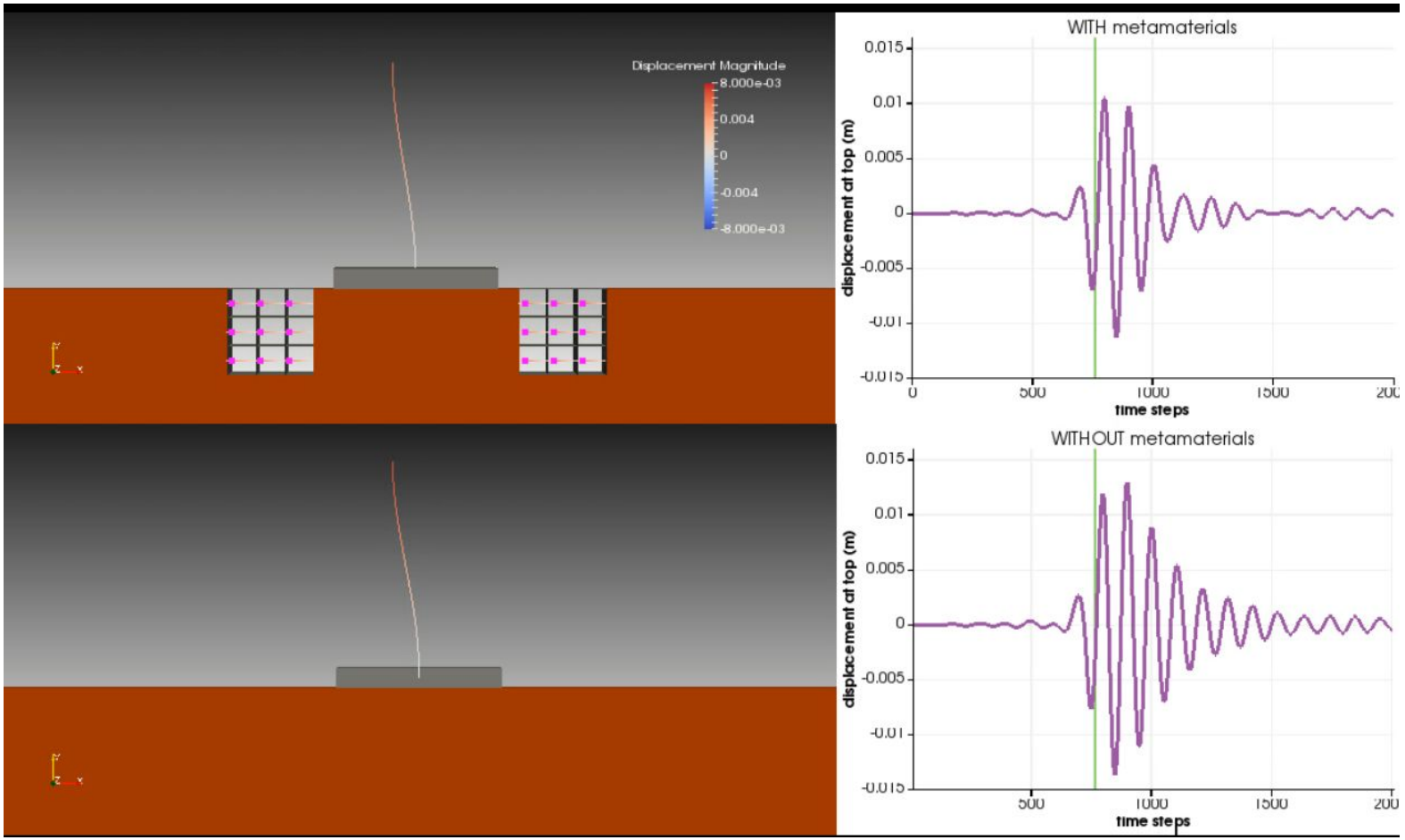


Seismic Shielding, Meta-Materials, ETHZ-UCD



Outline

Verification and Validation

- US-DOE/Sandia NL work, over last 40+ years
- Verification: provides evidence that the model is solved correctly. Mathematics issue.
- Validation: provides evidence that the correct model is solved. Physics issue.
- V&V procedures are the primary means of assessing accuracy in modeling and computational simulations
- V&V procedures used to build confidence and credibility in modeling and computational simulations
- Prediction under Uncertainty: use of computational model to predict the state of SSI system under conditions for which the computational model has not been validated.

V&V: Important References

- W. L. OBERKAMPF, T. G. TRUCANO, AND C. HIRSCH. Verification, Validation and Predictive Capability in Computational Engineering and Physics. In Proc. of the Foundations for V&V in the 21st Century Workshop, 2002, Johns Hopkins Univ.
- W. L. OBERKAMPF, Short Course on V&V in Computational Mechanics, US-DOE – SNL, 2003, Albuquerque, NM.
- I. Babuška and J.T. Oden. Verification and Validation in Computational Engineering and Science: Basic Concepts. Comp. Meth. in App. Mech. and Eng., 193(36-38):4057-4066, 2004.
- W. L. Oberkampf and C. J. Roy. Verification and Validation in Scientific Computing. Cambridge Univ. Press, 2010.

Physical Experiments

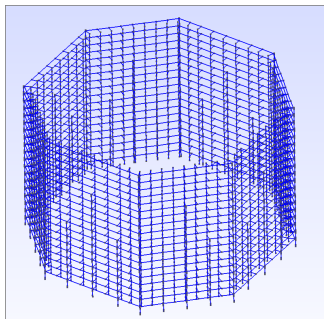
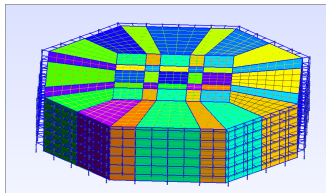
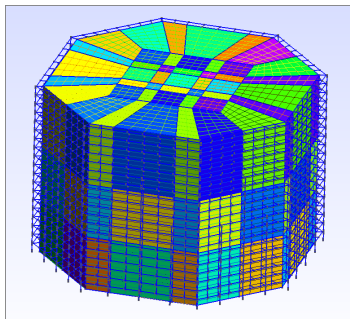
- Traditional Experiments
  - Improve the fundamental understanding of physics involved
  - Improve the mathematical models for physical phenomena
  - Assess component performance
- Validation Experiments
  - Model validation experiments
  - Designed and executed to quantitatively estimate model's ability to simulate well defined physical behavior
  - The simulation tool, SimTool, is the customer!

Validation Experiments

- A validation experiment is jointly designed and executed by experimentalist and computationalist
- A validation experiment is designed to capture the relevant physics
- Validation experiments on unit level problems and progressing up the hierarchy of increasing computational difficulty
- Experimental uncertainty analysis should be developed

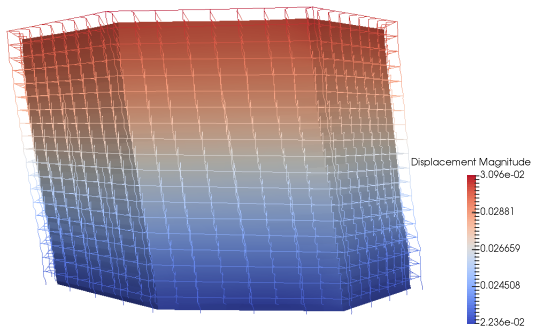
Great Need for Validation Experiments

- Inelastic response, energy dissipation of interfaces
- Base slab averaging vs inelastic interface/contact response
- Deeply embedded SMRs, near surface interface, deep soil
- Energy balance, input and dissipation
- Seismic shielding, meta-materials, seismic trenches
- 6C seismic motions, NPP and SMR response
- ESSI with internal/pore and external/pool fluids

Initial Validation Experiments

- Base slab averaging vs inelastic interface/contact response: use unique box capabilities, apply Love waves and a combination of Love and SV waves, with variable soil profiles and variable surface soil layers to validate/investigate effects of incoherent motions on SSI
- Deeply embedded structure, SMR: validate/investigate inelastic behavior of near surface interface, and inelastic behavior of deep soil



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Acknowledgment

- Collaborators: Feng, Yang, Behbehani, Sinha, Wang, Karapiperis, Wang, Lacoure, Pisanó, Abell, Tafazzoli, Jie, Preisig, Tasiopoulou, Watanabe, Cheng, Yang.

- Funding from and collaboration with the US-DOE, US-FEMA/ATC, US-NRC, US-NSF, CNSC-CCSN, UN-IAEA, ENSI-CH-B&H, Shimizu Corp and UC is greatly appreciated,

Summary

Quality assurance, V&V, for ESSI analysis

Great need for validation experiments for ESSI

Numerical modeling to predict and inform

Engineer needs to know!

`http://real-essi.us/`