

Engineering Analysis for Civil Infrastructure

Boris Jeremić

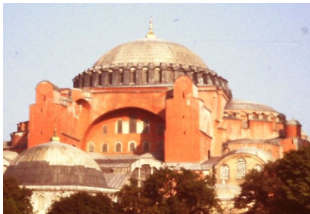
University of California, Davis

ICSRI, NFEES
Tianjin, Jul2026

Motivation

- Safety and economy of infrastructure
- Improve modeling, analysis
- Essential interaction: soil and structure
- Uncertainties: Modeling/Epistemic, Parametric/Aleatory
- Goal is to predict and inform
- Engineer needs to know!

Infrastructure, the Foundation of Modern Society



Progress, Resilient Infrastructure



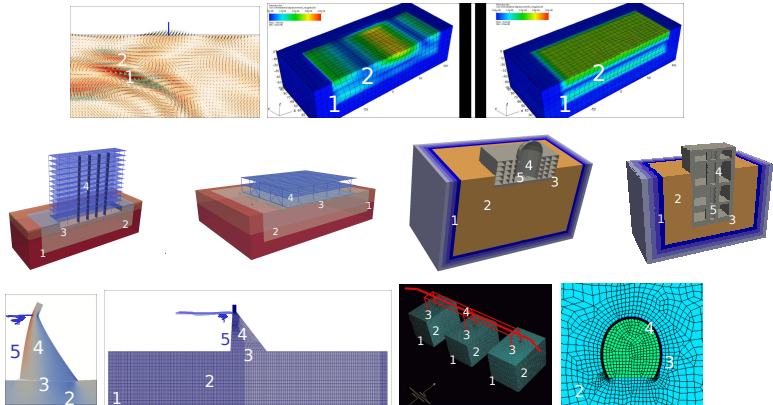
Nov1990



Jul2019



Common Infrastructure Analysis Challenges



Role of Modeling in Civil Engineering

- Physical, experimental Modeling
 - Direct observation of system response
 - Model validation
 - Limitations: expensive, parameter variability...
- Analytical Modeling
 - Clarity and interpretability
 - Model verification, reference solutions
 - Limitations: simple geometry, material behavior...
- Numerical Modeling
 - General method for representing realistic system
 - Complex geometry, advanced material behavior
 - Realistic loads, motions

Full Integration of all Three Domains is Essential

- Analytical modeling: understand and verify
- Experimental modeling: observe and validate
- Numerical modeling: analyze realistic system



Numerical Prediction under Uncertainty

- Modeling, Epistemic Uncertainty

 - Model simplifications

 - Model sophistication level for confidence in results

 - Verification and Validation

 - Choice of sophistication level for confidence in results

- Parametric, Aleatory Uncertainty

- $$M \Delta \ddot{u}_i + C \Delta \dot{u}_i + K^{ep} \Delta u_i = \Delta F(t),$$

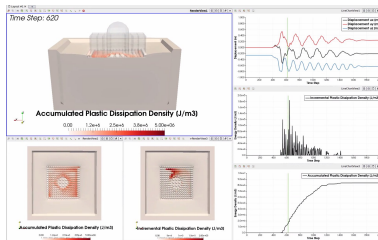
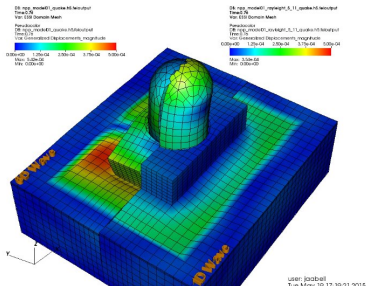
 - Uncertain: mass M , viscous damping C and stiffness K^{ep}

 - Uncertain loads $F(t)$

 - Results are PDFs and CDFs for σ_{ij} , ϵ_{ij} , u_i , $\dot{u}_i$, $\ddot{u}_i$

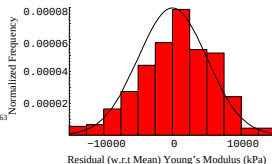
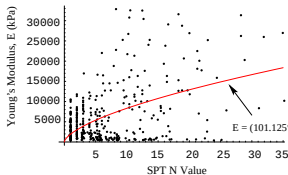
Modeling, Epistemic Uncertainty

- Important (?!) features are simplified
 - 3C/6C vs 1C seismic motions
 - Elastic vs inelastic behavior
- Modeling simplifications are justifiable if one or two level higher sophistication model demonstrates that behavior being simplified out is not important

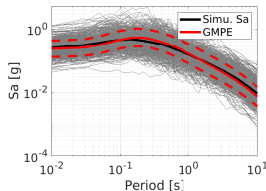
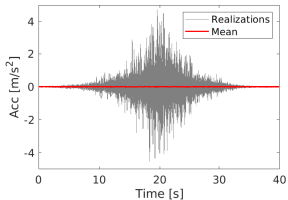


Parametric, Aleatory Uncertainty

Need to be fully documented and accounted for!

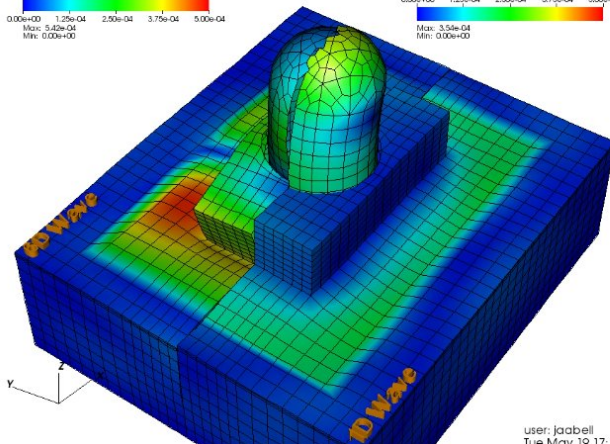
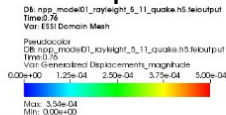
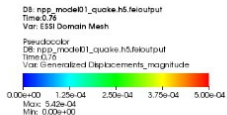


(cf. Phoon and Kulhawy (1999B))



(cf. Wang et al. (2019))

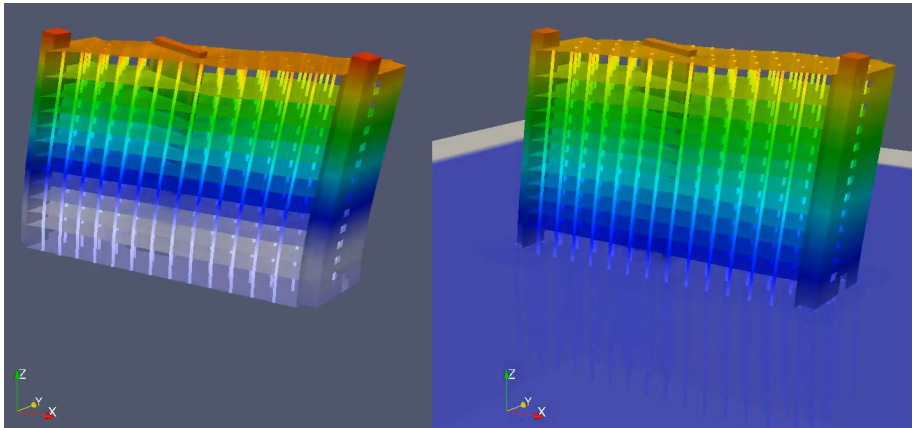
6C vs 1C NPP ESSI Response Comparison



(MP4)

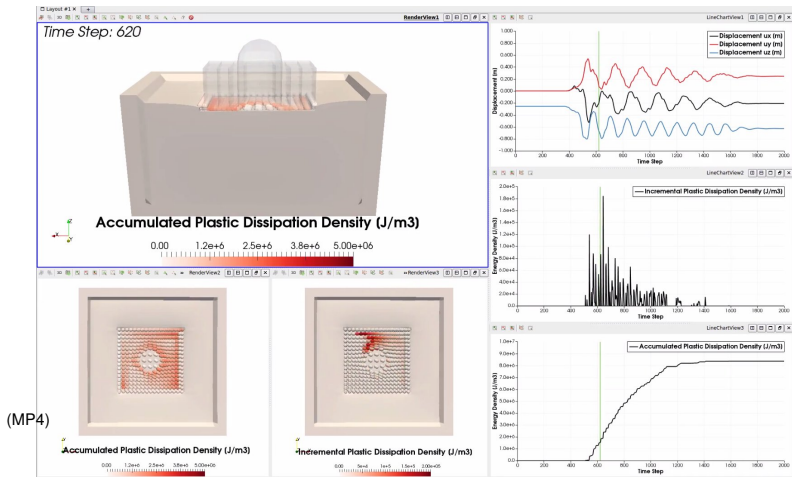
user: jaabell
Tue May 19 17:19:21 2015

Ventura Hotel, Northridge Earthquake, nonSSI vs SSI

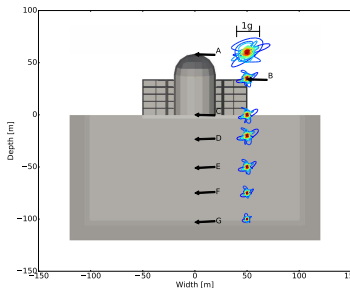


(MP4)

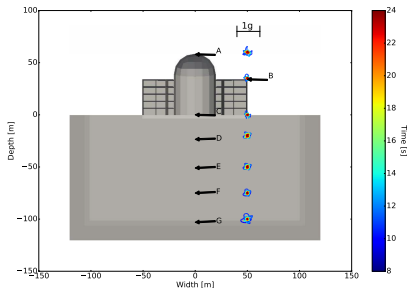
NPP Seismic Reponse, Energy Dissipation



Acceleration Traces, Elastic vs Inelastic

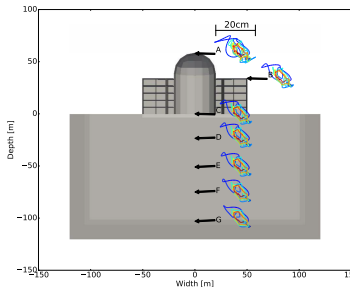


Elastic

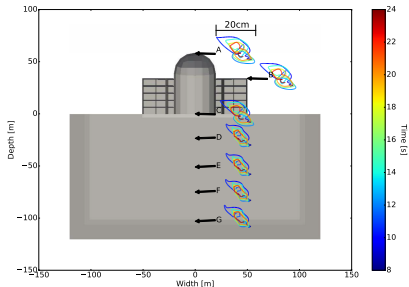


Inelastic

Displacement Traces, Elastic vs Inelastic

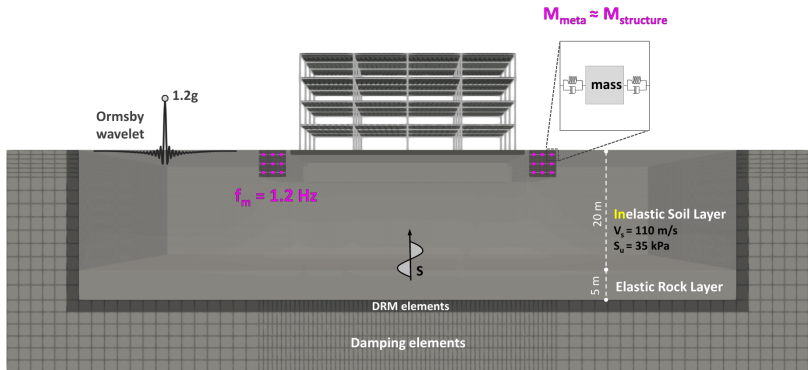


Elastic



Inelastic

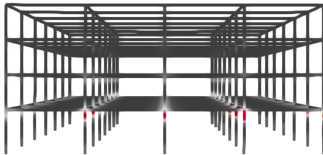
Metadevice/Metamaterial Seismic Shielding



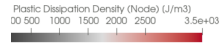
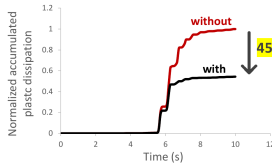
[Kanellopoulos et al., ETH]

Metadevice/Metamaterial Shielding

without metamaterials



with metamaterials



Summary

- Engineering analysis to **predict** and **inform**
- Engineer needs to **know**
- Analysis uncertainties
 - Modeling, Epistemic
 - Parametric, Aleatory
- **Education** and **Training** is the Key
- `http://real-essi.us`