PRENOLIN
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Questions and Answers

- Definition of the cases to be investigated (information on the input and soil profiles): **it was clear**
- Were the indications on the computations clear for you? **Yes**
- Additional assumptions required by your particular numerical scheme or code that was not included in the initial information ? For example,
  - Did you perform some deconvolution of the input signal? **No (it was forbidden?)**, although we could use a full wave field for a much more analytic seismic input method
  - Did you remove the free surface effect on the given input signal before computing the wave propagation? **No**
  - Did you use pressure dependency for the profile of Non-Linear characteristics ? **Yes**, Pisanò model is a full 3D incremental elastic-plastic material model

Questions and Answers

- Was the number of computations too high or reasonable? **It was reasonable**; Is it possible to reduce them? **No, actually the opposite it true!**; how much time did you spend? **a bit**
- What kind of comparison would you like to see? **full verification and validation (V&V) process.**
- Did the organizers forget something? **This initial effort is good starting point, it could/should be expanded with a hierarchy of more realistic/sophisticated models and their V&V (comparison is not a verification)**
- Something you want to highlight (on your results or anything else...): **There is much more to be done for a full, realistic, analysis of earthquake soil structure interaction (ESSI) for Nuclear Power Plants.**

ESSI Problems: List of Highlights

- Complexity of ground motions (6D, body and surface waves, lack of correlation, etc.)
- Inelastic (elastic-plastic, damage...) behavior of rock, soil, concrete (dry and/or saturated), appropriate modeling (less or more sophisticated material models, etc.)
- Inelastic behavior of foundation – soil/rock zone (gaping, slipping, dry and/or saturated)
- Buoyancy effects (for embedded foundations)
- Timing and location of energy dissipation in ESSI system
- Base isolation effects
- Stochastic/Probabilistic inelastic modeling and simulations using Stochastic Elastic Plastic Finite Element Method
- Verification and Validation processes and procedures

Comments on Models Used

- ESSI Simulator program used (see my my web)
- 3D solid finite elements (27 node bricks) used with appropriate boundary conditions (shear beam)
- Pisanò material model, a 3D incremental elastic plastic bounding surface material model with vanishing elastic region. There was no soil volume change data (which can make a big difference), so we assumed soil does not exhibit a volume change (non-realistic). Unrealistic damping curves (leveling off for higher strains)?
- Finite element size, 1m, so that we can pick up to 30Hz, with 2 quadratic finite elements per wave length, with given stiffness (from G/G_{max} at about 1 %)
- Mesh size effects tested with Ormsby wavelets

Comments on Models Used, cont'd.

- No data on rate effects of G/G_{max} and damping curves
- Three energy dissipation modes (frictional, viscous, numerical)
- For linear elastic models, none of those energy dissipation mechanisms were used! Results are given as undamped (initially excited and then free) vibrations). This is the best way to perform verification.
- For visco-elastic models, a small amount of Rayleigh damping was used. (as requested by PRENOLIN team)
- For nonlinear models, frictional damping (elastic-plastic), with a small amount of viscous damping (within a material model) and a small amount of numerical damping (through Newmark integration algorithm) was used.

Comments on Models Used, cont'd.

- Boundary condition at the bottom: Currently only fixed condition is used. We could have used a full wave field to have a radiation damping (elastic rock beneath in full 3D) but that would have required deconvolution (development of full wave field) and this was specifically forbidden..
- It would be much (!) better to define a complete wave field at the bottom and then use the Domain Reduction Method (DRM) as DRM allows for analytic input of seismic motions in 3D!

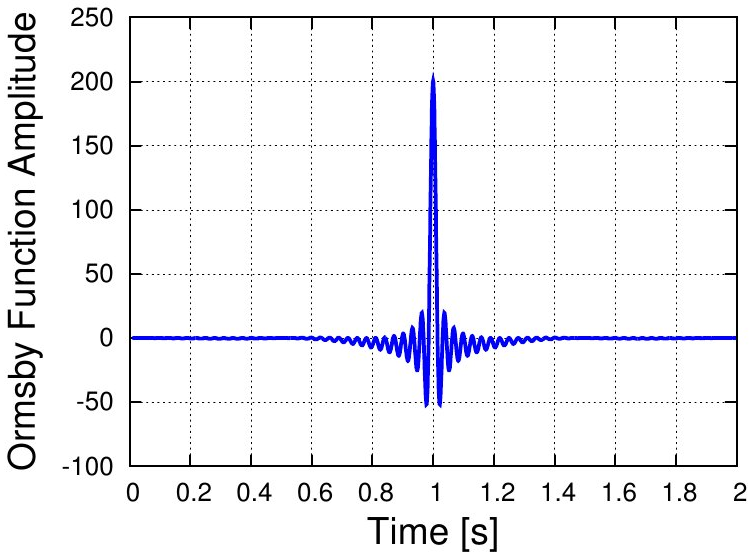
Numerical Modeling and Simulation of ESSI

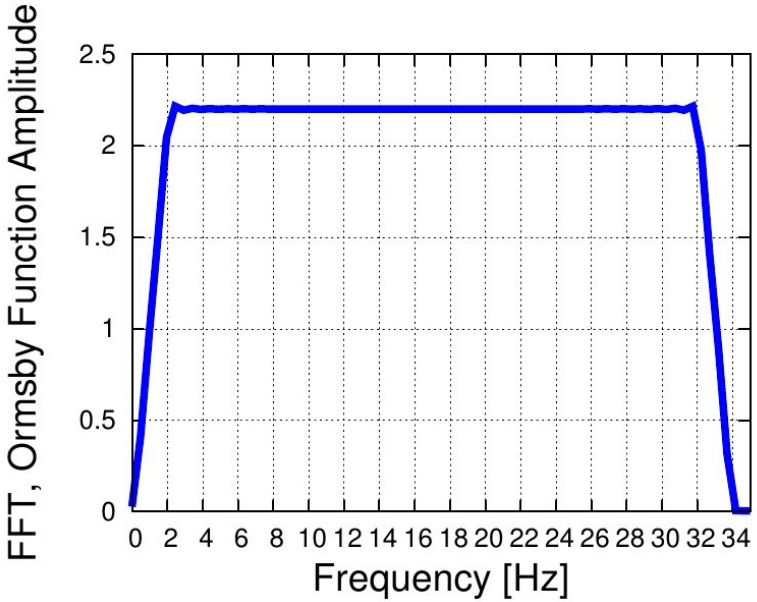
- **Hypothesis:** Interplay of Earthquake, Soil/Rock and Structure. in time and space, plays major role in successes and failures.
- **High fidelity** numerical models for accurate following of the flow of seismic energy within the soil/rock structure interaction system
- **Verification** provides evidence 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.
- **Low Kolmogorov Complexity** predictive capabilities

Uncertainty in Modeling

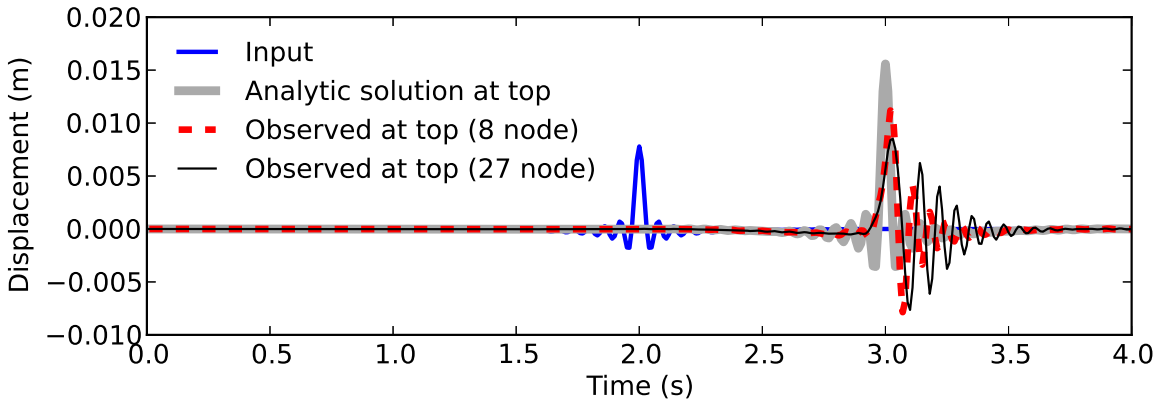
- Simplified (or inadequate/wrong) modeling: important features are missed (seismic ground motions, uncertainty in material modeling etc.)
- Introduction of uncertainty and (unknown) lack of accuracy in results due to use of un-verified simulation tools (software quality, numerics artifacts, etc.)
- Introduction of uncertainty and (unknown) lack of accuracy in results due to use of un-validated models (lack of validation experiments)
- Example:
  - Complexity of and uncertainty in ground motions
  - Complexity of and uncertainty in material modeling (spatial variability, testing errors, transformation errors)

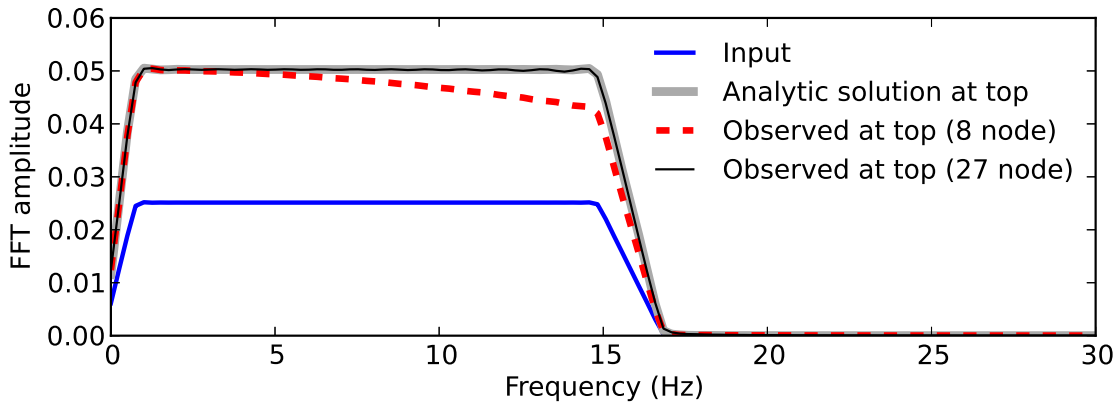
Stress Test Ground Motions: Ormsby Wavelet





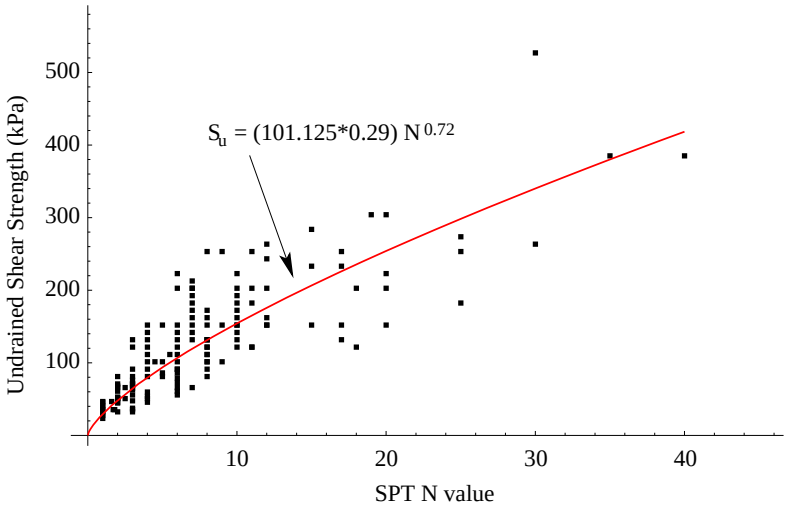
Mesh Size Effects Analysis Results

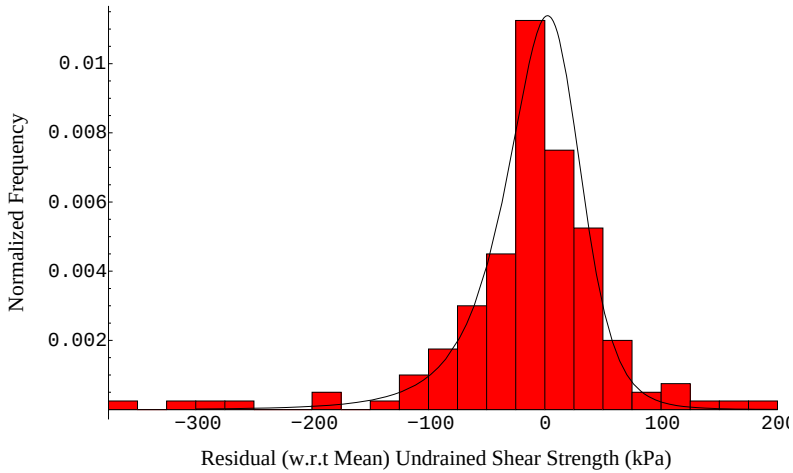




(Case 1, Vs = 1000 m/s, Cutoff Fq. = 15 Hz, E. Size = 10 m)

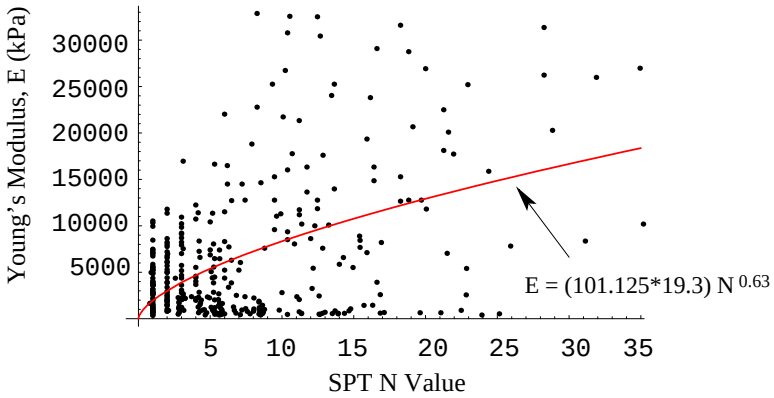
SPT Based Determination of Shear Strength

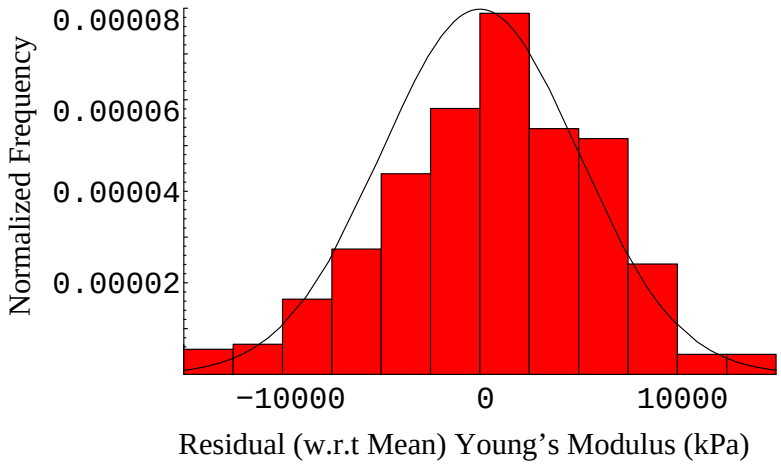




Transformation of SPT *N*-value $\rightarrow$ un-drained shear strength, s_u (cf. Phoon and Kulhawy (1999B)
Histogram of the residual (w.r.t the deterministic transformation equation) un-drained strength, along with fitted probability density function (Pearson IV)

SPT Based Determination of Young's Modulus

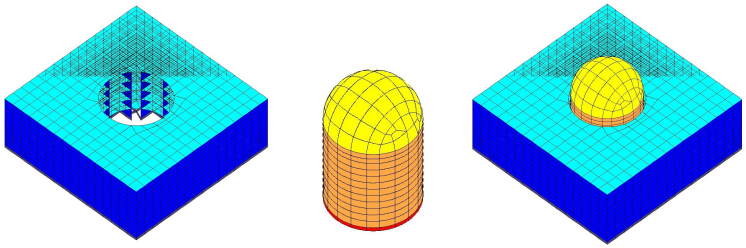


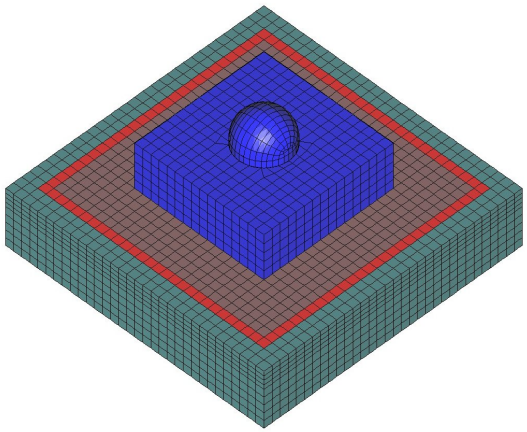


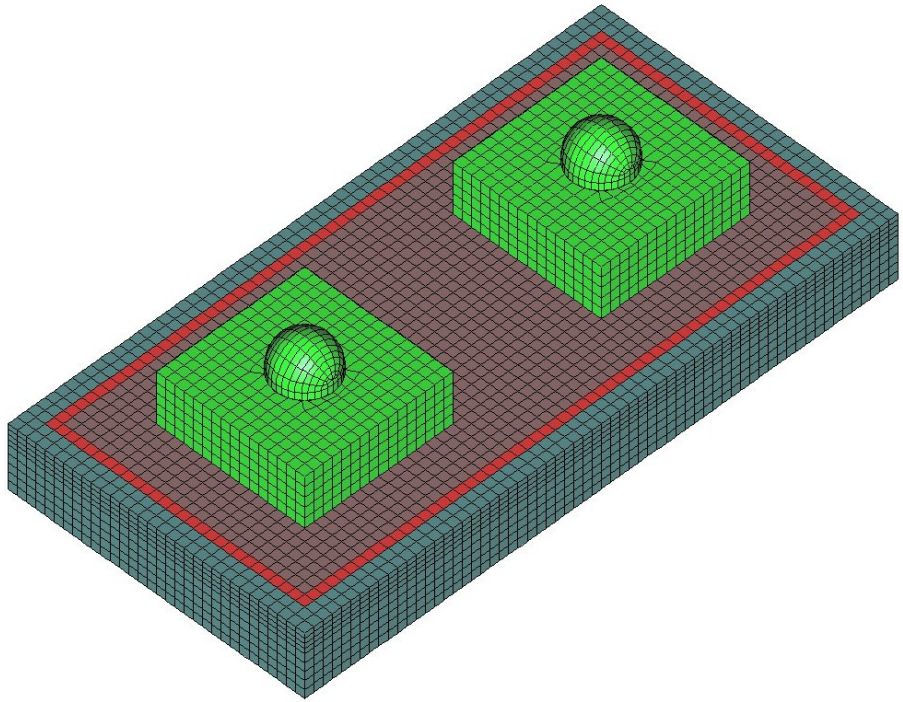
Transformation of SPT N-value $\rightarrow$ 1-D Young's modulus, E (cf. Phoon and Kulhawy (1999B))

Histogram of the residual (w.r.t the deterministic transformation equation) Young's modulus, along with fitted probability density function

Final Goal?







UCD/LBNL Team

- Federico Pisanò (development and calibration of elastic-plastic G/G_{max} Pisanò model),
- Chang-Gyun Jeong (development of elastic FEM models and pre- and post-processing scripts),
- Kohei Watanabe (development of elastic-plastic FEM models),
- Nima Tafazzoli (Pisano model implementation review and improvements),
- Jose Antonio Abell Mena (review),
- Boris Jeremić (system and model development, lead/guidance, compilation, review, documentation)