The Influence of Local Soil Conditions on Seismic Design

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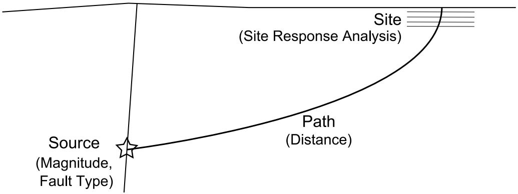
Research Goals

1. Develop tools for random vibration theory based site response simulations
2. Assess accuracy of various site response simulation methods
3. Recommend methods to incorporate variability and uncertainty into site response simulations

Outline

1. Introduction to Site Response
2. Modeling Site Response
3. Real World Complexity
4. Analytical Tools
5. Research Topics
6. Conclusion

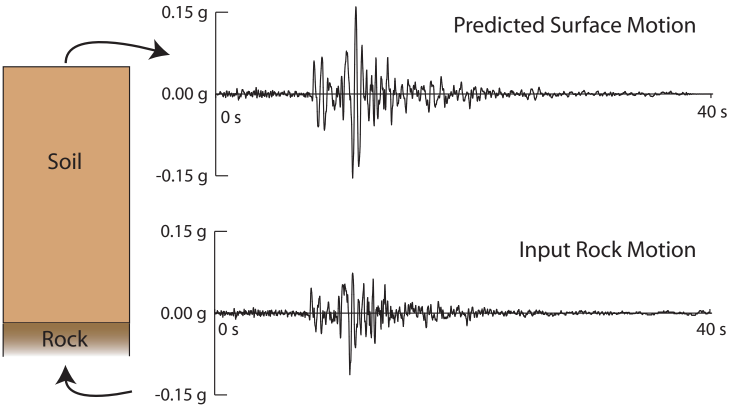
Introduction to Site Response



Ground shaking at the surface of a site is governed by:

1. Source effects (magnitude)
2. Path effects (distance)
3. Site effects (local site conditions)

Site Response Simulations



Modeling Site Response

- Site response simulations:
  - Numerically propagates the motion through a site specific profile
  - Models are typically one dimensional (vertical)
- Soil behavior is nonlinear:
  - Small strains → stiffer and less damping
  - Larger strains → softer and more damping
  - Different techniques for capturing nonlinearity
- Requires site specific information:
  1. Unit weight (or density)
  2. Stiffness (shear-wave velocity, v_s)
  3. Nonlinear change in stiffness with shear strain (G/G_{max})
  4. Nonlinear change in damping with shear strain

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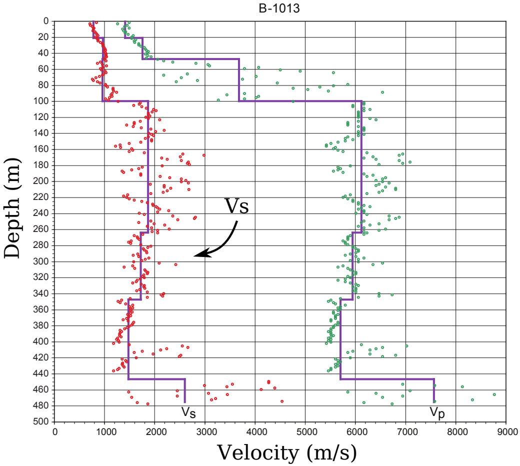
Site Characterization: v_s Profile



- ○ Field measurement
- – Best estimate profile

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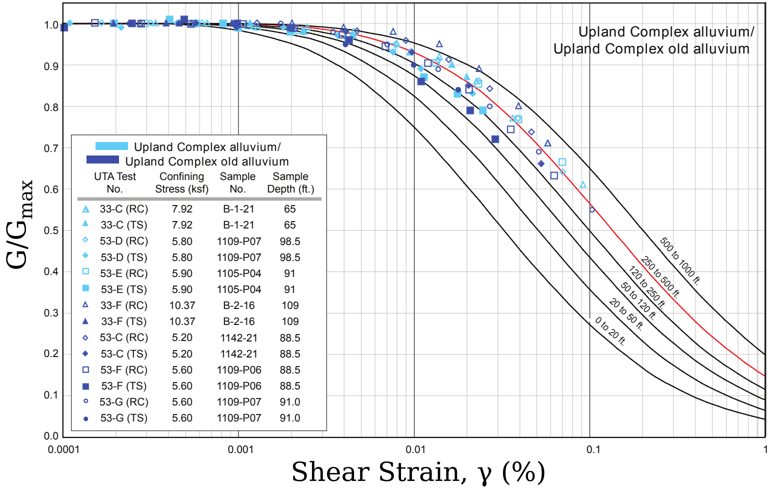
Site Characterization: Nonlinear change in stiffness



UTA Test No.	Confining Stress (ksf)	Sample No.	Sample Depth (ft.)
33-C (RC)	7.92	B-1-21	65
33-C (TS)	7.92	B-1-21	65
53-D (RC)	5.80	1109-P07	98.5
53-D (TS)	5.80	1109-P07	98.5
53-E (RC)	5.90	1105-P04	91
53-E (TS)	5.90	1105-P04	91
33-F (RC)	10.37	B-2-16	109
33-F (TS)	10.37	B-2-16	109
53-C (RC)	5.20	1142-21	88.5
53-C (TS)	5.20	1142-21	88.5
53-F (RC)	5.60	1109-P06	88.5
53-F (TS)	5.60	1109-P06	88.5
53-G (RC)	5.60	1109-P07	91.0
53-G (TS)	5.60	1109-P07	91.0

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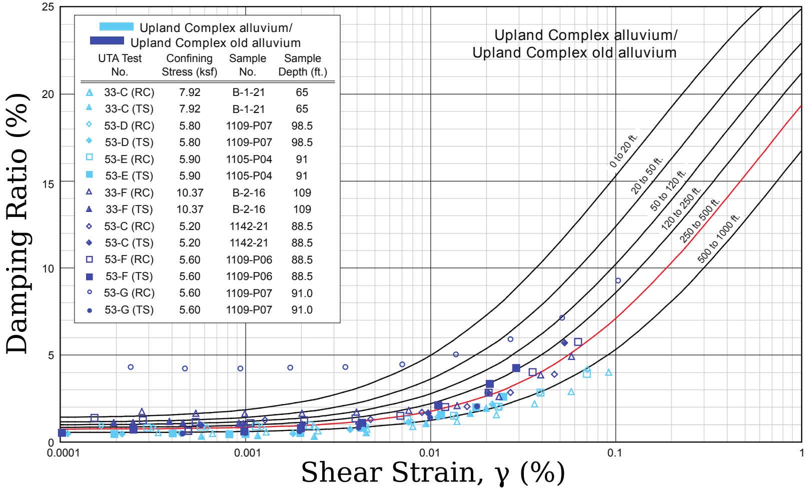
Site Characterization: Nonlinear change in damping



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Variability and Uncertainty

Previous plots show significant scatter in the data from:

1. Spatial variability
   - Soil and rock properties are variable in nature
   - Variability can be quantified through collection of an abundance of data
2. Parametric uncertainty
   - Sample volume is a tiny fraction of the total volume under a site
   - Sampling disturbance influences the measured properties in laboratory tests
   - Laboratory tests tend to sample more competent material
   - Uncertainty can be reduced through more tests

Engineers are forced to balance the reduction in uncertainty with the cost of acquiring more data.

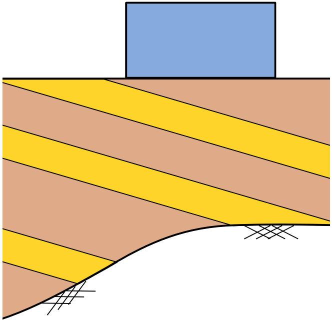
Modeling Real World Complexity

Selection of simulation technique:

- Equivalent-linear (EQL)
- EQL with frequency dependent properties
- Fully nonlinear (NL)
- Importance of 2D/3D effects

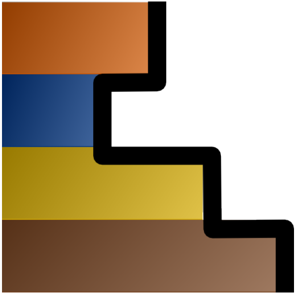
Engineers must:

- Balance the complexity of the numerical model with increased computation time and increased number of input parameters.
- Incorporate parametric uncertainty and spatial variability in site response simulations.



Strata: Program for Site Response Simulations

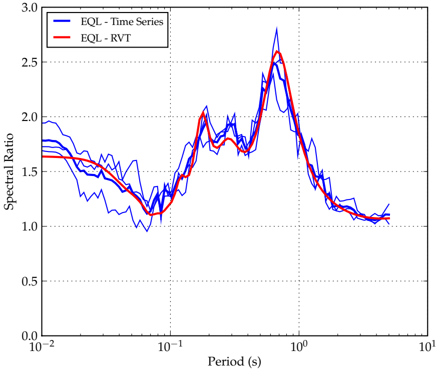
- EQL site response simulations
- Response can be computed by:
  - Time series method
  - Random vibration theory method
- Uncertainties in site properties can be modeled:
  - G/G_{max} and damping curves
  - Shear-wave velocity profile
  - Depth to bedrock
- Free and open-source



Continued development funded by the NRC to enhance available features.

- Time series simulations require multiple input motions (3-10)
- RVT simulations require one input motion
  - Removes motion selection (scaling/matching)
  - Reduces calculation time

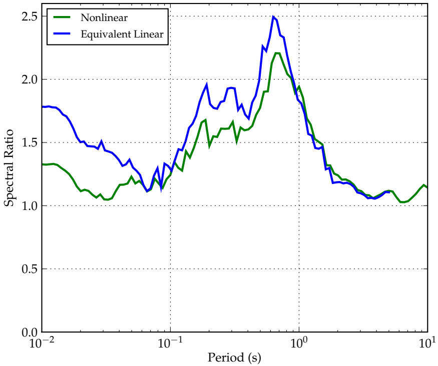
Current research work involves making RVT more accessible to engineers.



Effect of Simulation Method

- Nonlinear site response more fully models the nonlinear stress-strain relationship of the soil
- Nonlinear simulations are more complex:
  - Defining the input parameters
  - Increased calculation time
- EQL and NL techniques often provide different results

Future research will investigate the accuracy of the methods with respect to ground motion recordings.

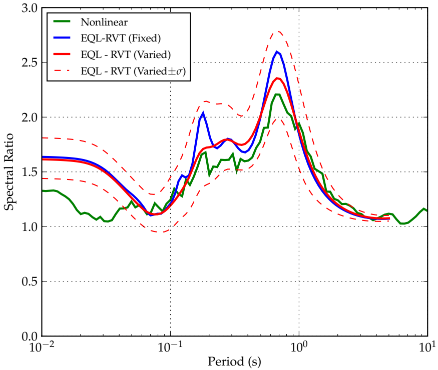


Modeling Site Uncertainty and Variability

Use multiple possible site realizations to model soil property uncertainty and variability (Monte Carlo simulations)

- Models the uncertainty and natural variability of soil properties
- Reduces differences between NL and EQL

Research is clarifying the role of Monte Carlo simulations in seismic hazard assessment.



Conclusion

- Modeling real world complexity with site response simulations is a challenge:
  - Spatial variability
  - Parametric uncertainty
  - Nonlinear soil response
- Research aims to:
  - Develop tools for RVT based site response simulations
  - Assess accuracy of various simulation methods
  - Recommend methods to incorporate variability and uncertainty into site response simulations