Comparative Probabilistic-Deterministic Investigations for Evaluation of Seismic SSI Response

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Purpose of This Presentation:

To present comparative probabilistic vs. deterministic SSI analysis results for nuclear structures.

The applied Probabilistic SSI approaches are those recommended by the new ASCE 04-2013 standard.

Both soil and rock sites are considered.

Comparisons are made in ISRS.

ACS SASSI Option Pro was used for probabilistic SSI analyses

ASCE 04-2013 Probabilistic SSI Analysis

The new ASCE 04-2013 standard states that the purpose of the analytical methods included in the standard is to provide reasonable levels of conservatism to account for uncertainties.

More specifically, in the same section is written that given the seismic design response spectra input, the goal of the standard is based on a set of recommendations to develop seismic *deterministic SSI responses* that correspond approximately to a 80% non-exceedance probability level.

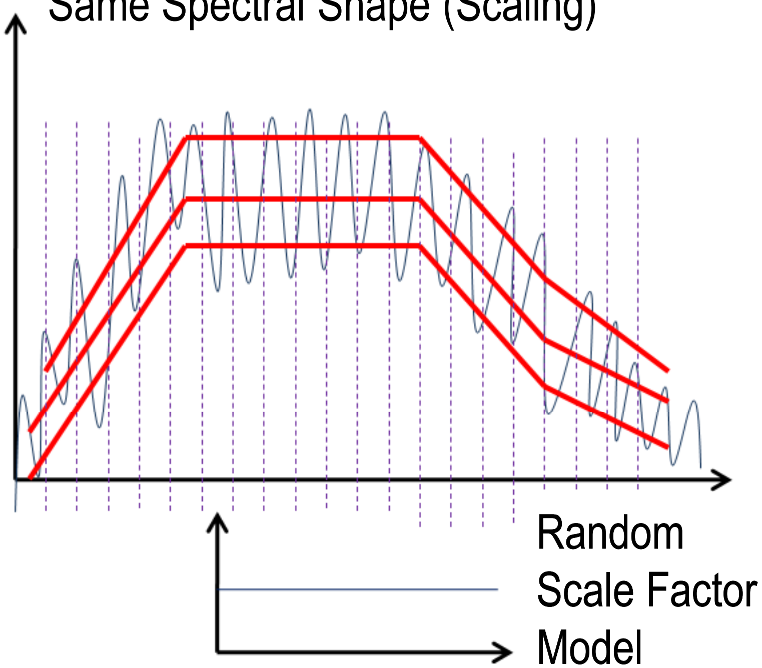
For probabilistic seismic analyses, *probabilistic SSI responses* defined with the 80% non-exceedance probability level are considered adequate.

Section 5.5 of the standard provides guidelines for the acceptable probabilistic SSI approaches. The GRS spectral shape could be considered with variable shape or not (Methods 1 and 2). Soil profiles, Vs and D, should include spatial correlation with depth. Structural stiffness and damping should be also modeled by random variables.

Probabilistic Seismic Input

Method 1

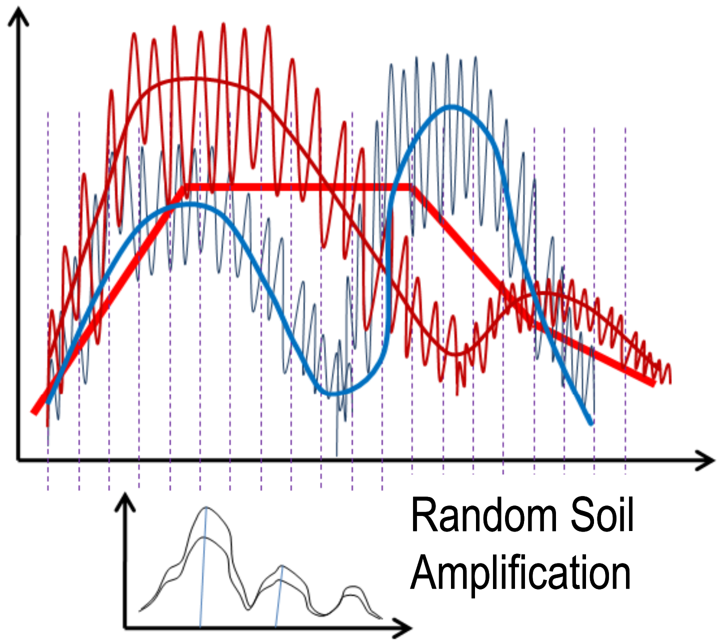
Same Spectral Shape (Scaling)

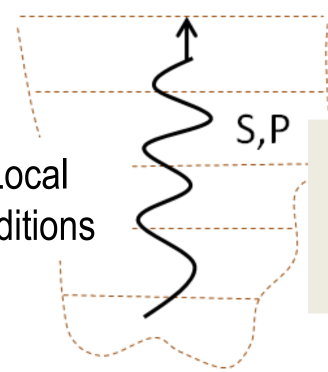


Full Correlation in Frequency….
Simpler...
Less information required….

Method 2

Random Spectral Shape



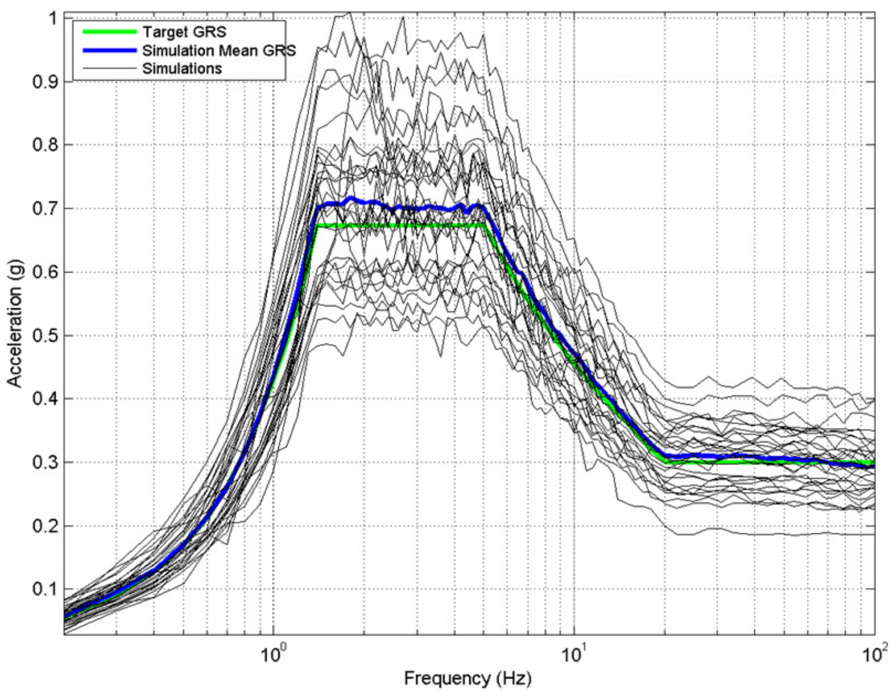


Include Local
Soil Conditions

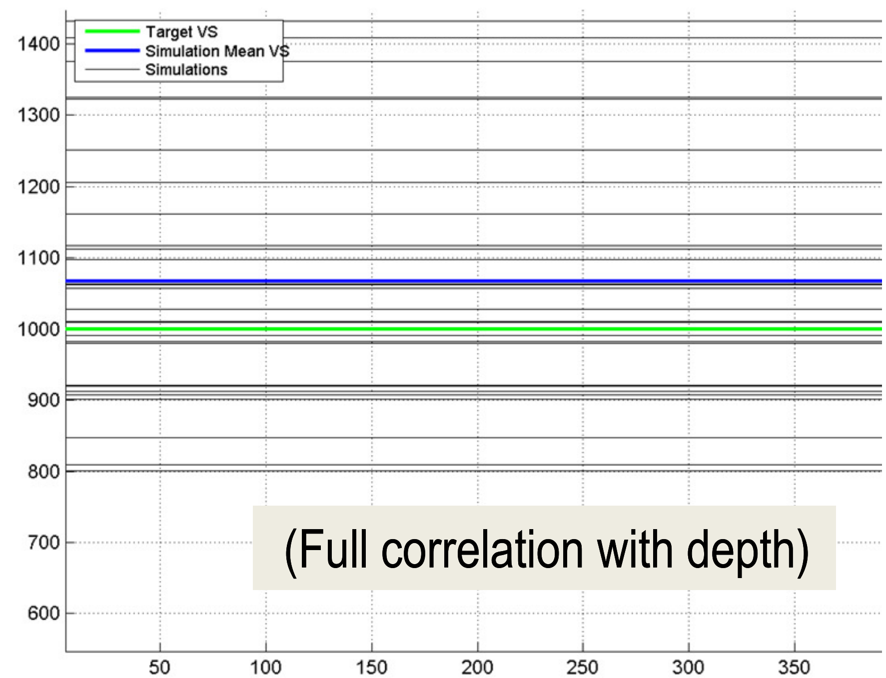
Correlation in Frequency….
More physics-based…
More information required….

Simulated Probabilistic Seismic GRS (Method 1) and Soil Profile (Vs and D) Using Random Variables

Simulated GRS Inputs



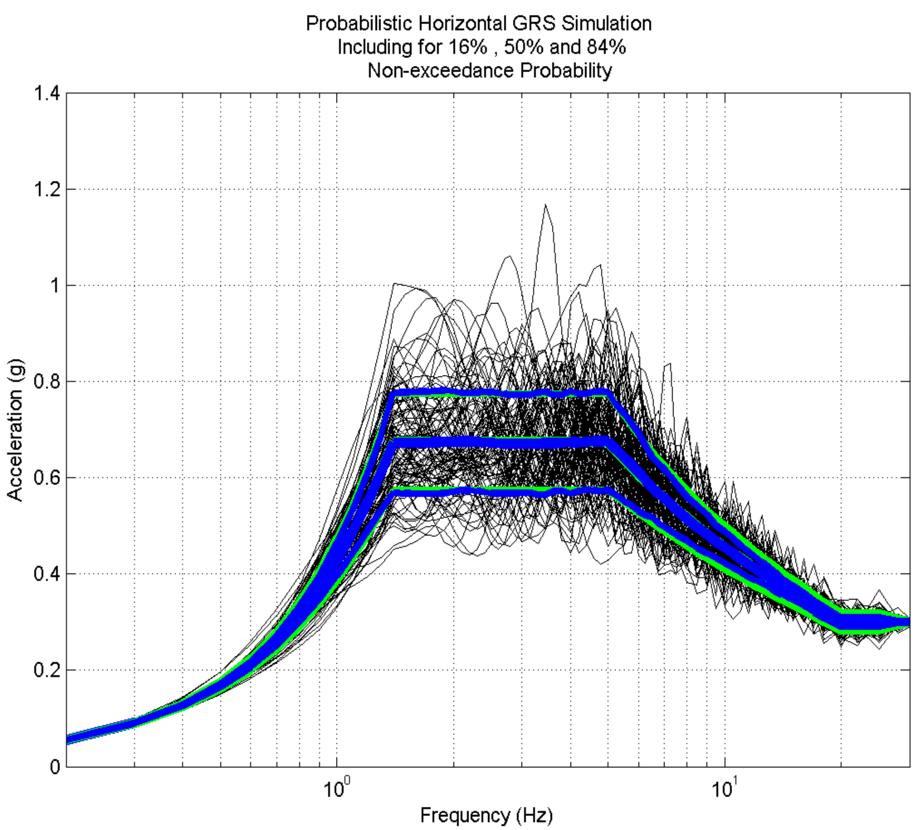
Simulated Soil Profiles



Note: Only 30 LSH simulations were used

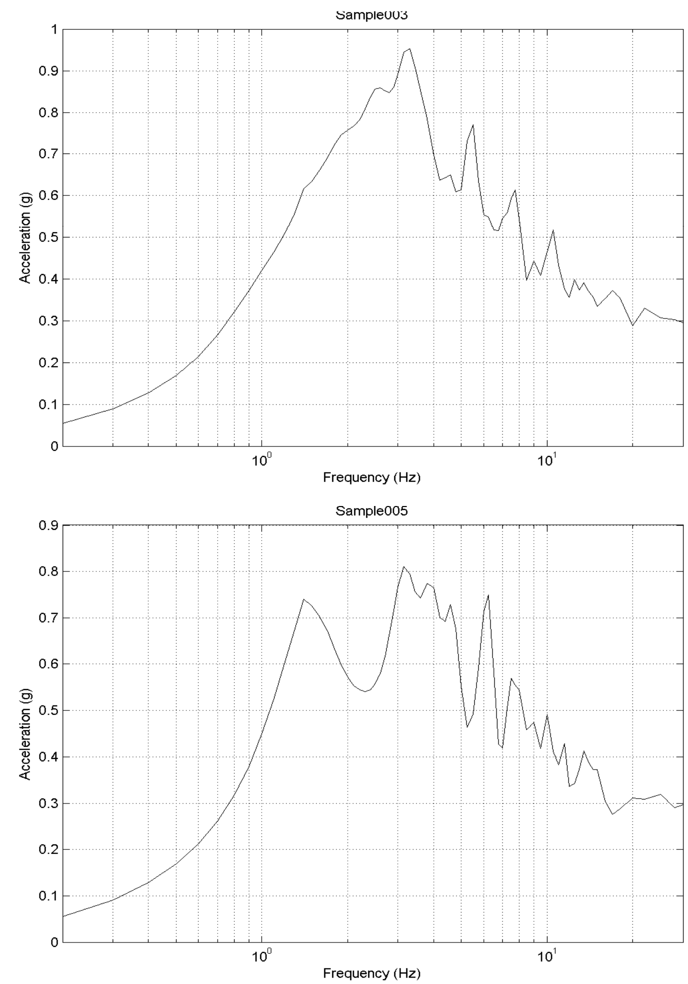
Simulated Probabilistic Seismic GRS (Method 2)

Probabilistic UHRS Input
0.30 ZPGA



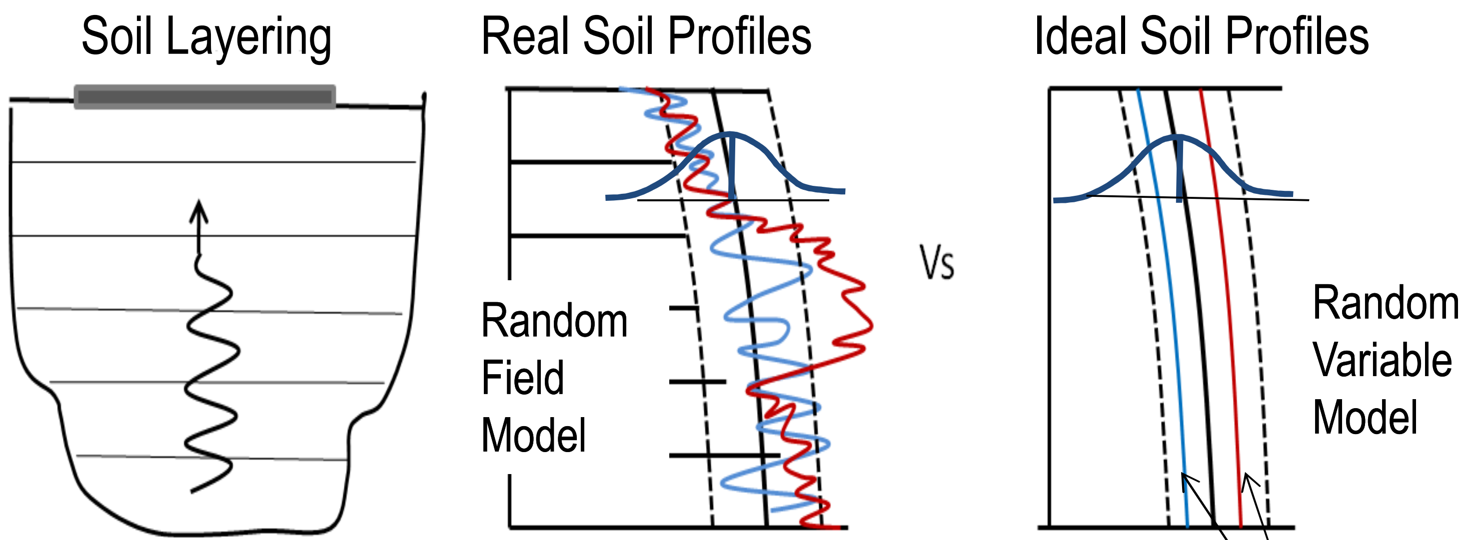
c.o.v. = 15%; Correl. Length = 1 Hz

Simulated GRS

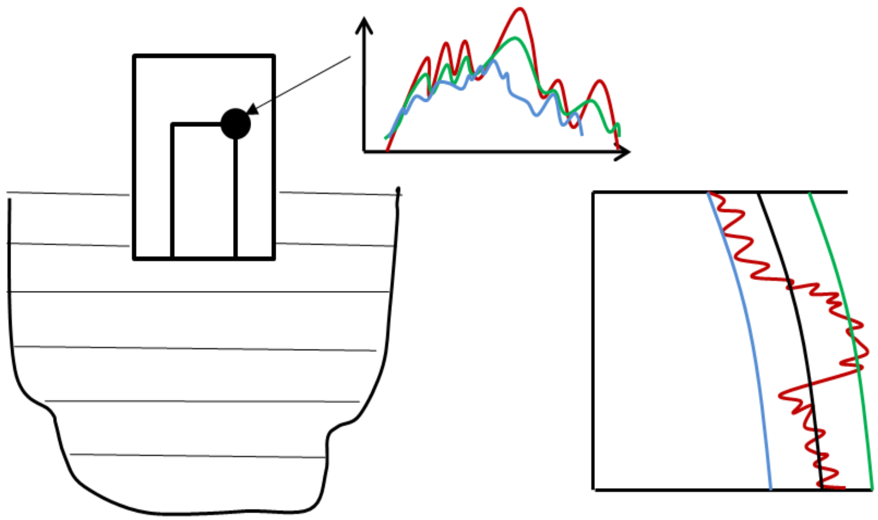


Random Samples

Probabilistic Soil Profiles (at Low Shear Strains)



Potential Situations that are not covered by Deterministic SSI…

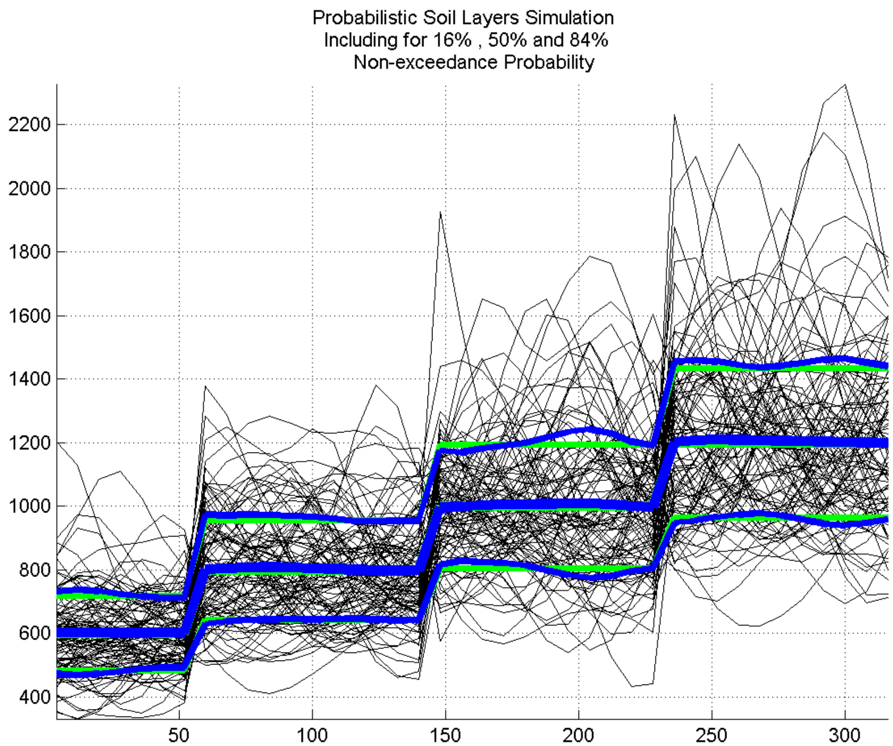


Perfect Correlation with depth looses physics…

No Correlation with depth looses physics…

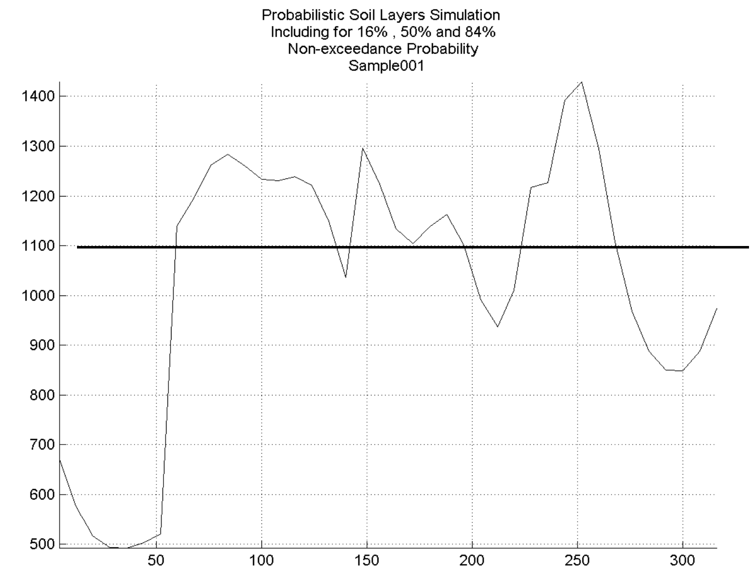
Simulated Probabilistic Soil Layer Profiles

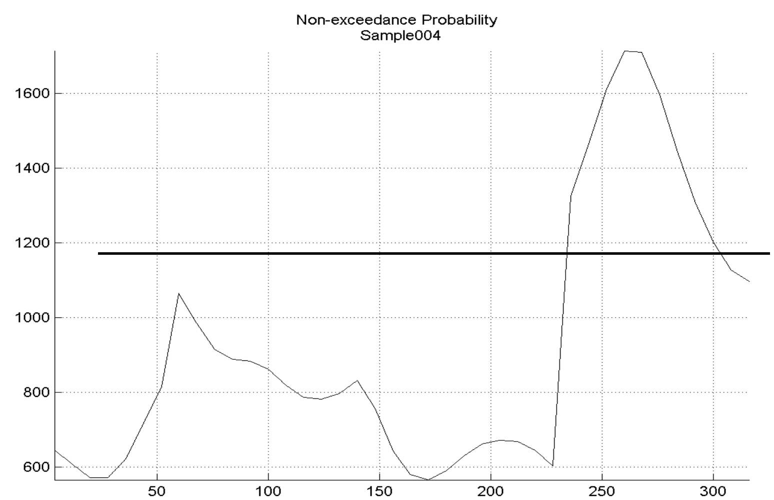
Probabilistic Soil Profile



c.o.v. = 20%; Correl. Length = 20 ft

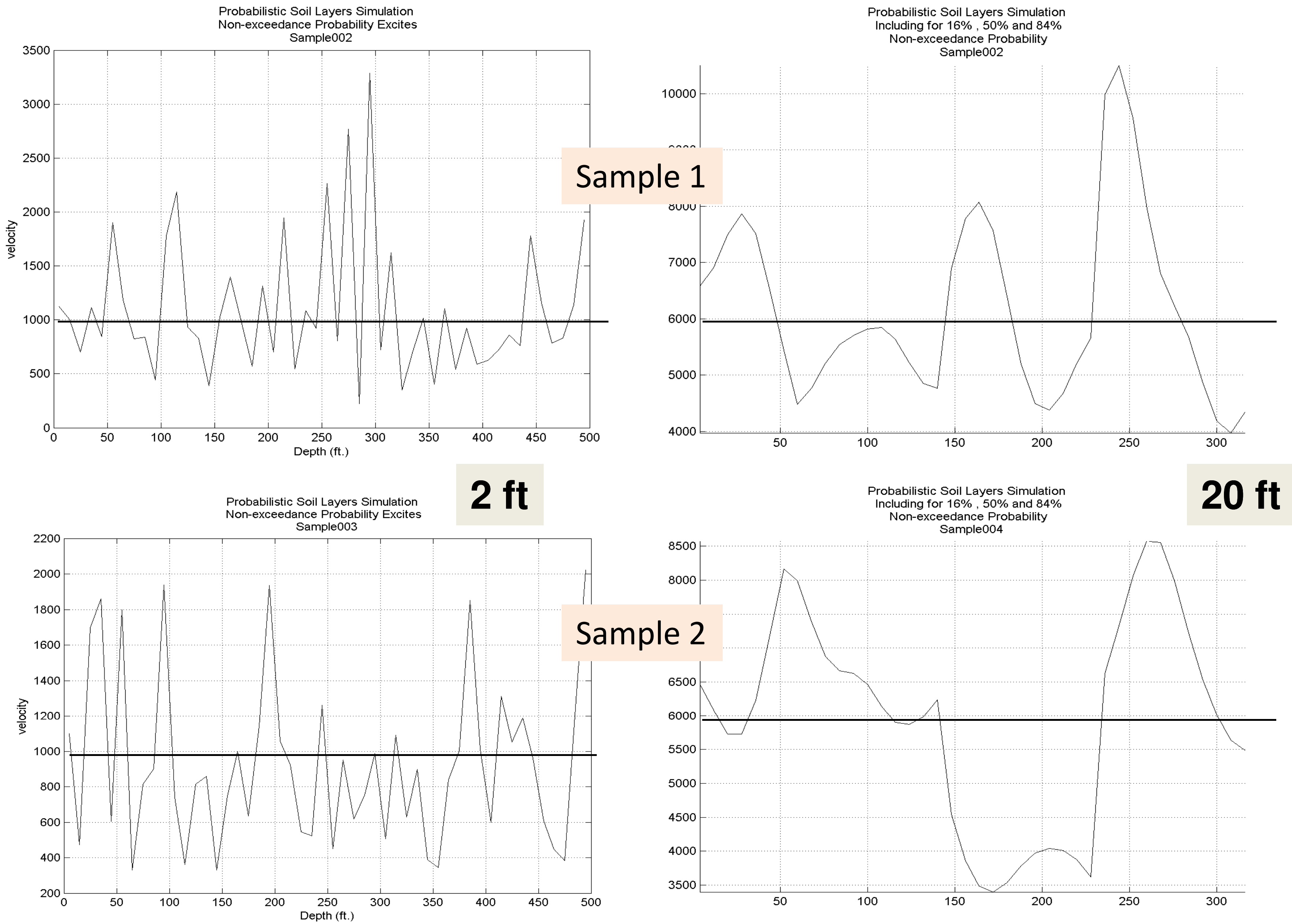
Simulated Soil Profiles





Random Samples

Effect of Spatial Correlation Length on Simulated Soil Profiles

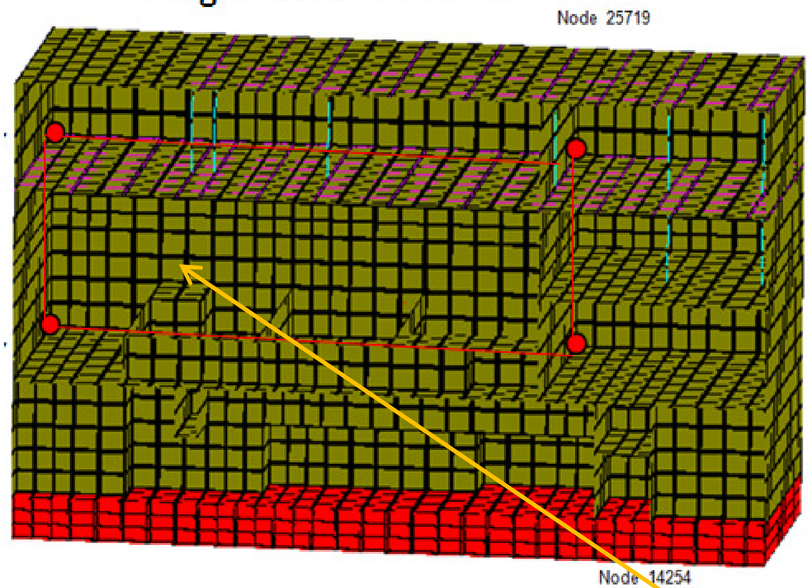


Probabilistic Structural Modeling (Stiffness & Damping)

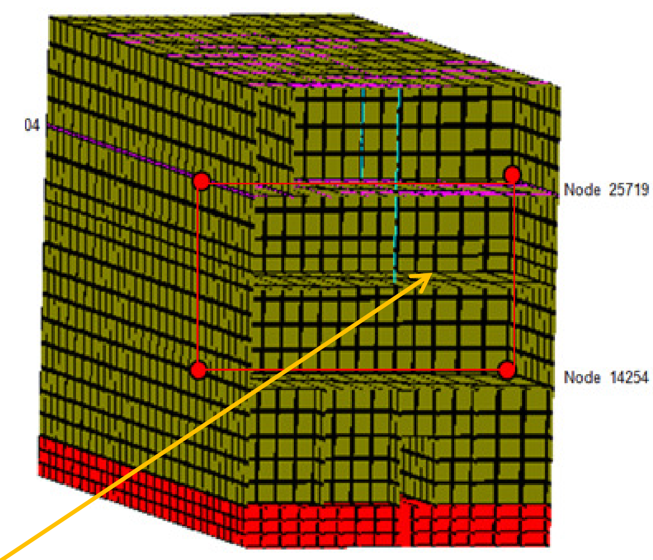
- Effective stiffness ratio Keff/Kelastic and damping ratio, Deff, are modeled as statistically dependent random variables.

- Keff/Kelastic and Deff can be considered negatively correlated, or having a complementary probability relationship, or Deff be a response function of Keff/Kelastic based on experiments

Longitudinal Shearwall



Transverse Shearwall



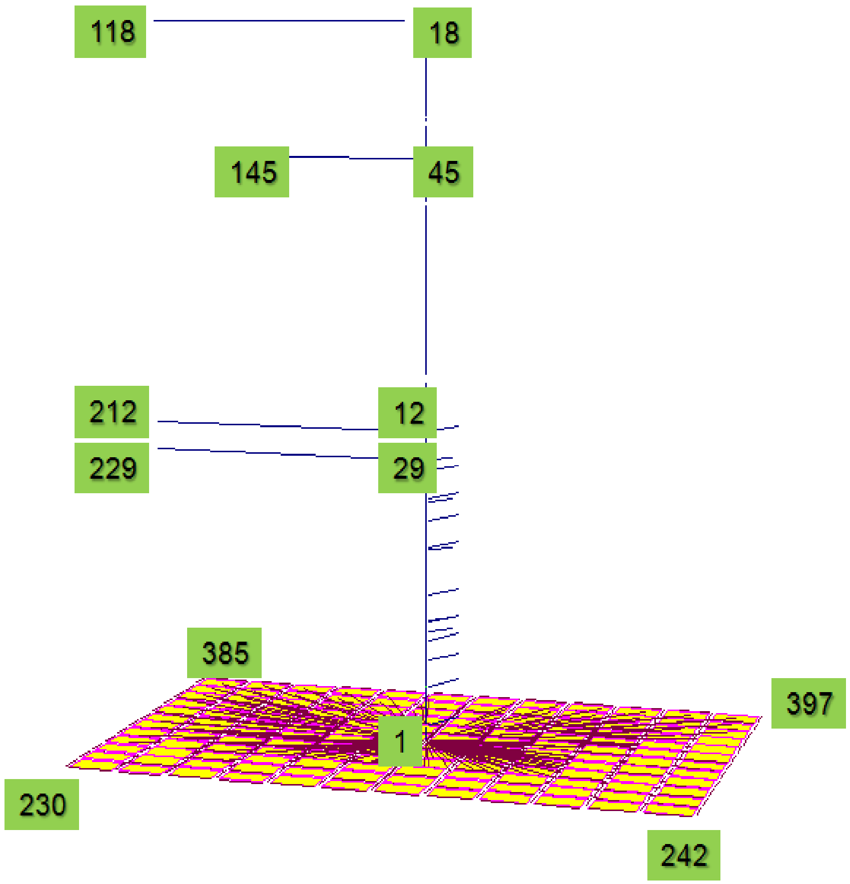
Deff = f (Keff/Elastic)

Stiff	Damp
0.01	0.20
0.10	0.17
0.20	0.15
0.30	0.13
0.40	0.11
0.50	0.10
0.60	0.09
0.70	0.08
0.80	0.07
0.90	0.06
1.00	0.05

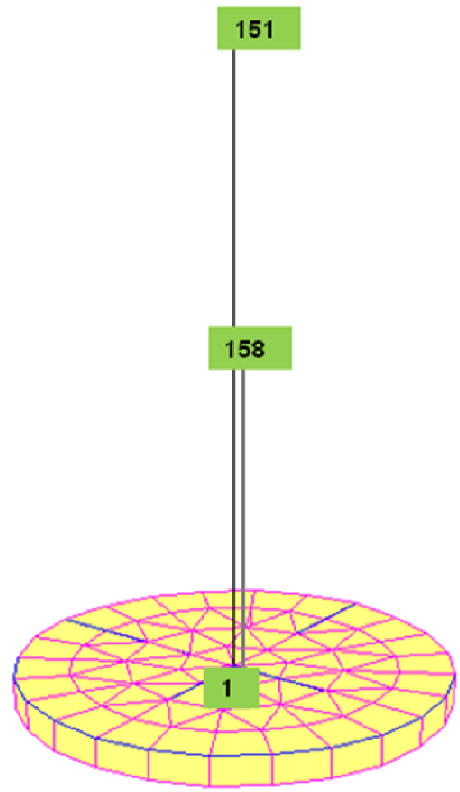
- Keff and Deff are defined separately for each element group. Statistical correlation between different group Keff variables can be included.

Case Studies: 1) EPRI AP1000 NI & 2) PWR RB Sticks

EPRI AP1000 NI Stick Model



PWR RB Stick Model



Deff = f (Keff)

Stiff	Damp
0.01	0.20
0.10	0.17
0.20	0.15
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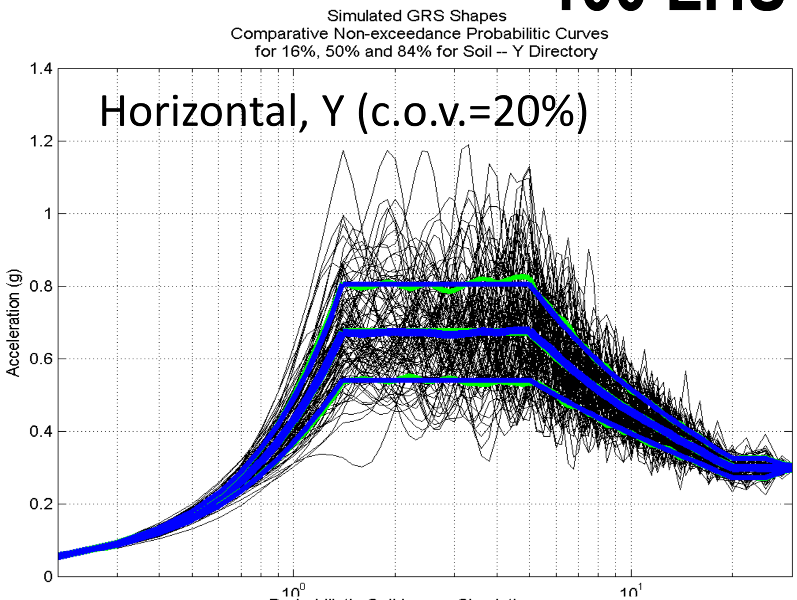
0.50	0.10
0.60	0.09
0.70	0.08
0.80	0.07
$\boxed{0.90 \quad 0.06}$	
1.00	0.05

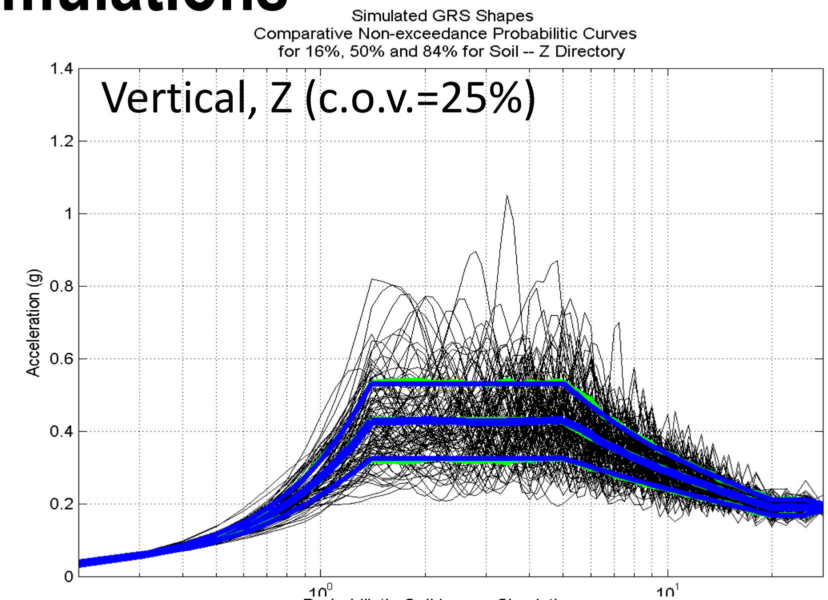
Mean Values

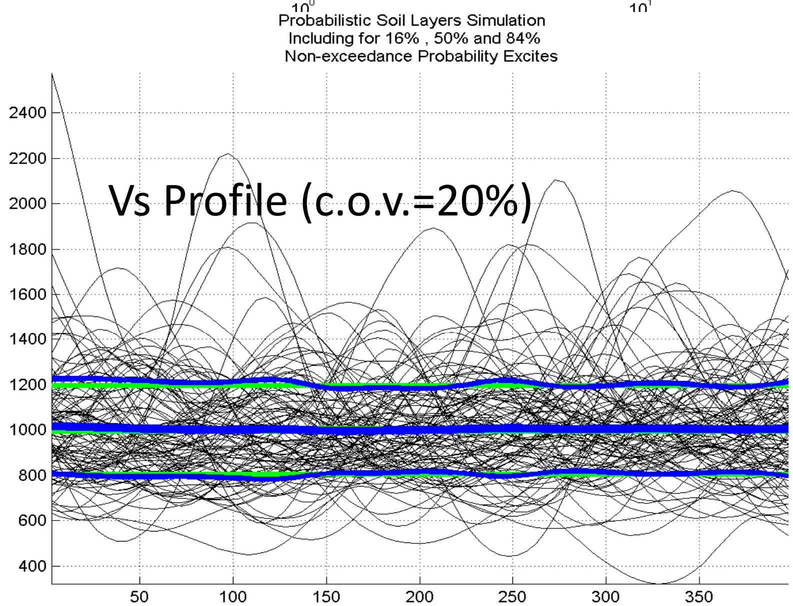
Case 1: Soil Site, Vs = 1,000 fps
Case 2: Rock Site, Vs = 6,000 fps

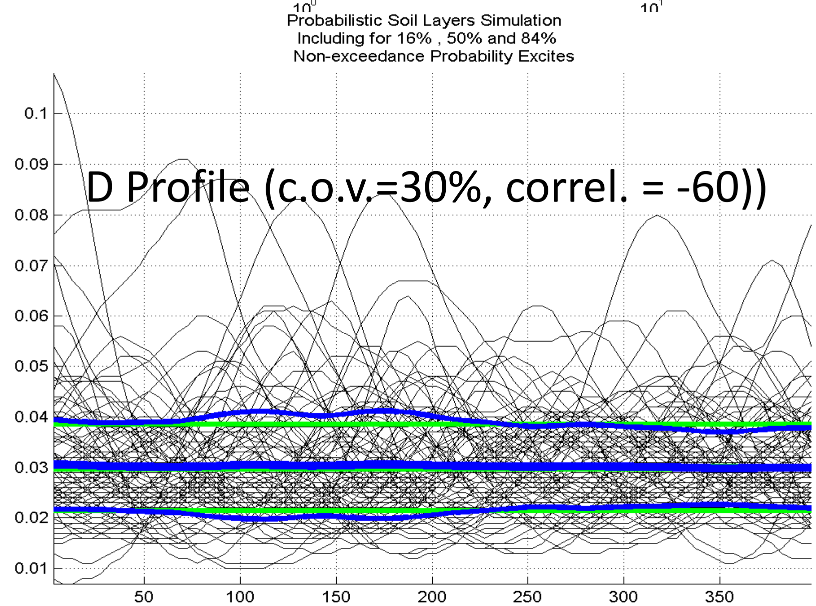
Seismic GRS (Method 2) and Soil Profiles for Soil Site

100 LHS Simulations



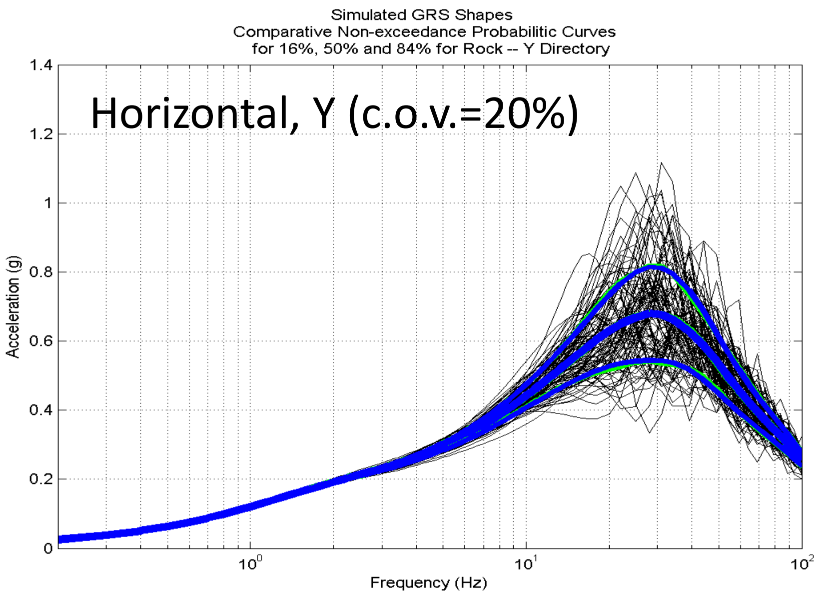


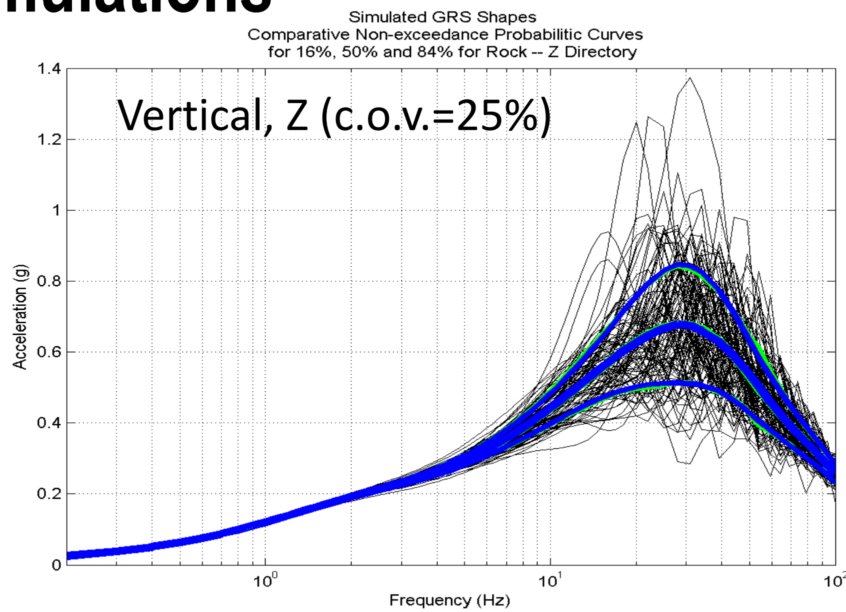


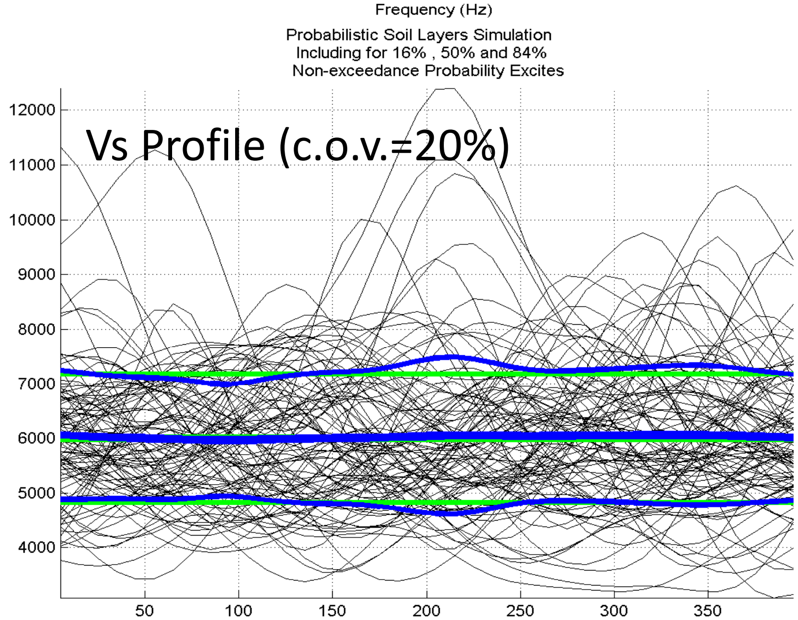


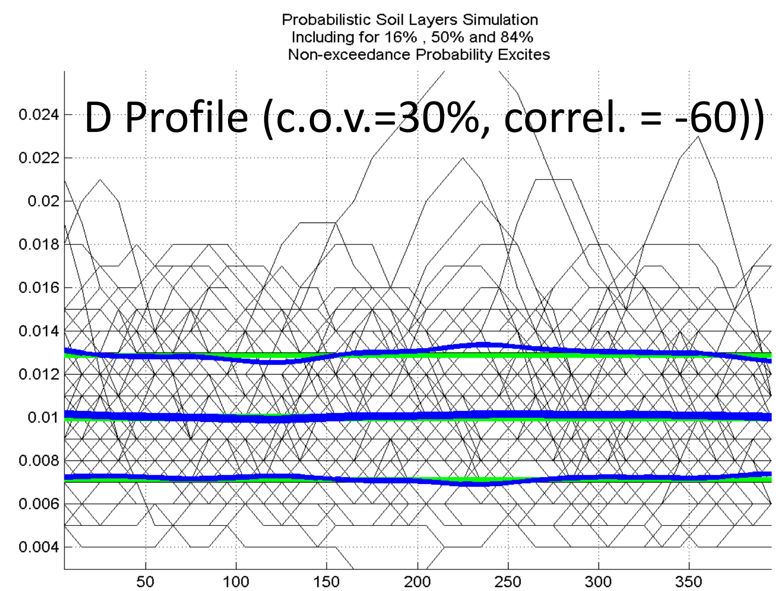
Seismic GRS (Method 2) and Soil Profiles for Rock Site

100 LHS Simulations





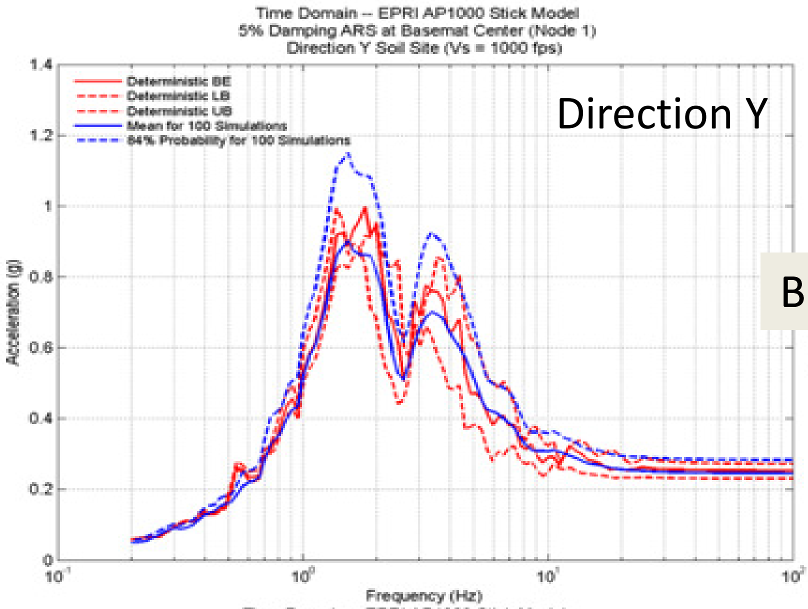


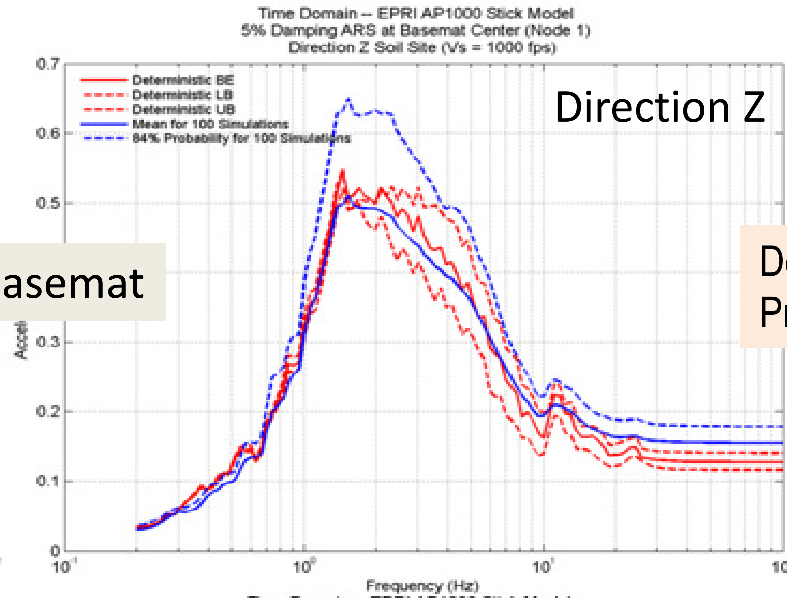


Deterministic vs. Probabilistic SSI Analysis for Soil Site

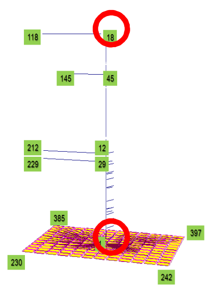
CASE A: Deterministic Mean (Mean GRS, Soil LB, BE,UB, and Struct Mean Keff=0.90 and Deff=6%)

Basemat

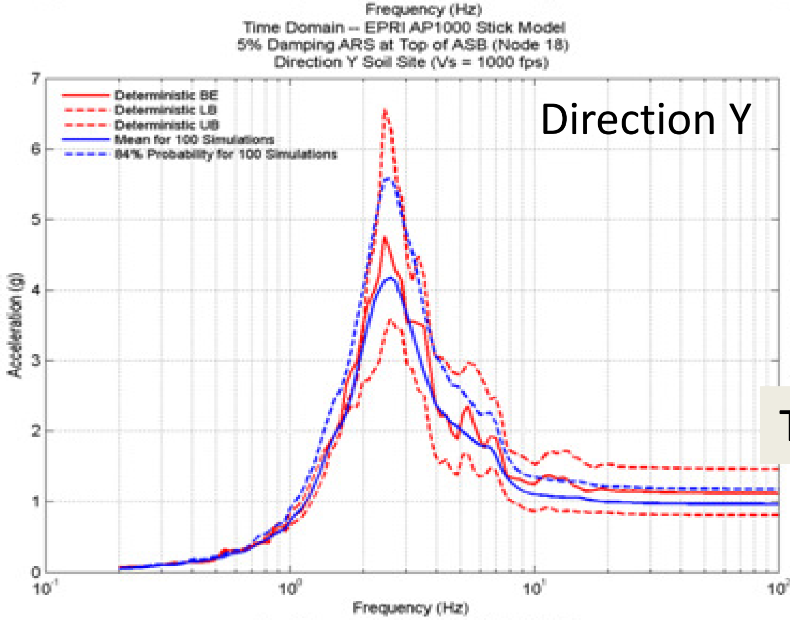


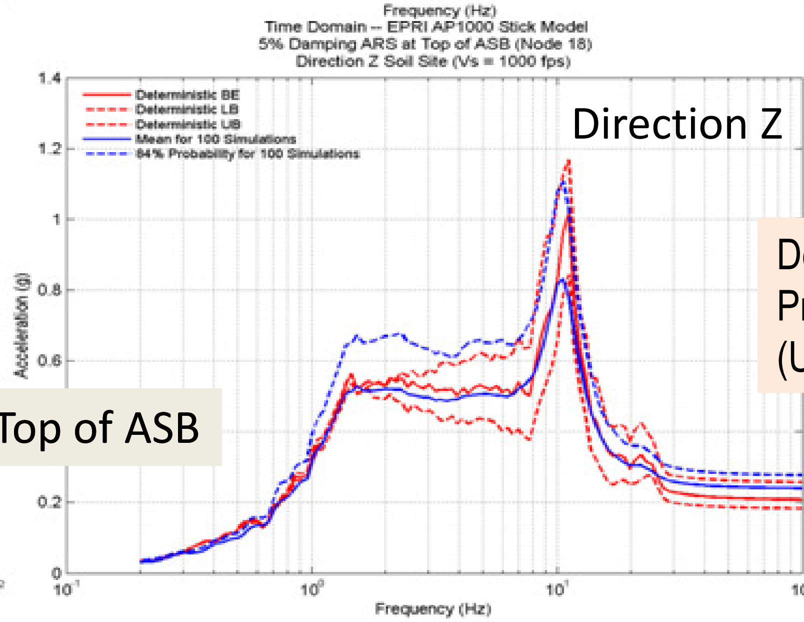


Det ranges
Prob 60%-80%



Top of ASB

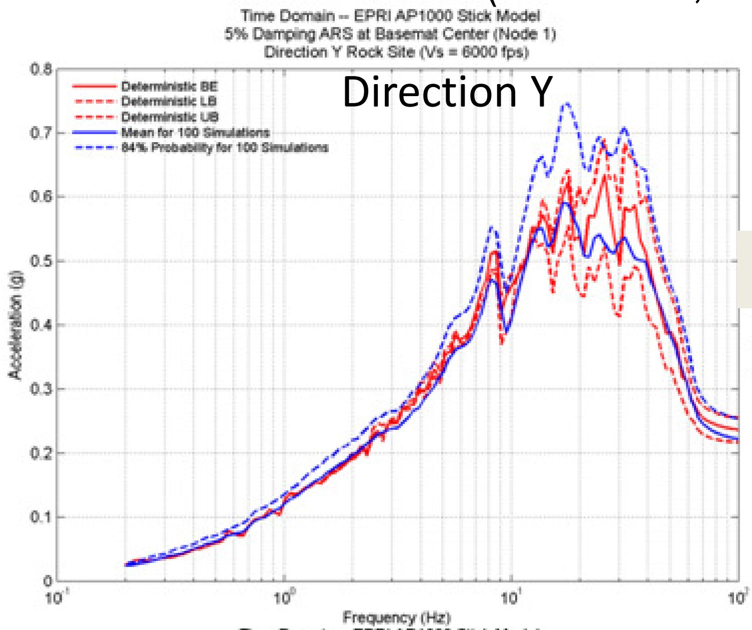


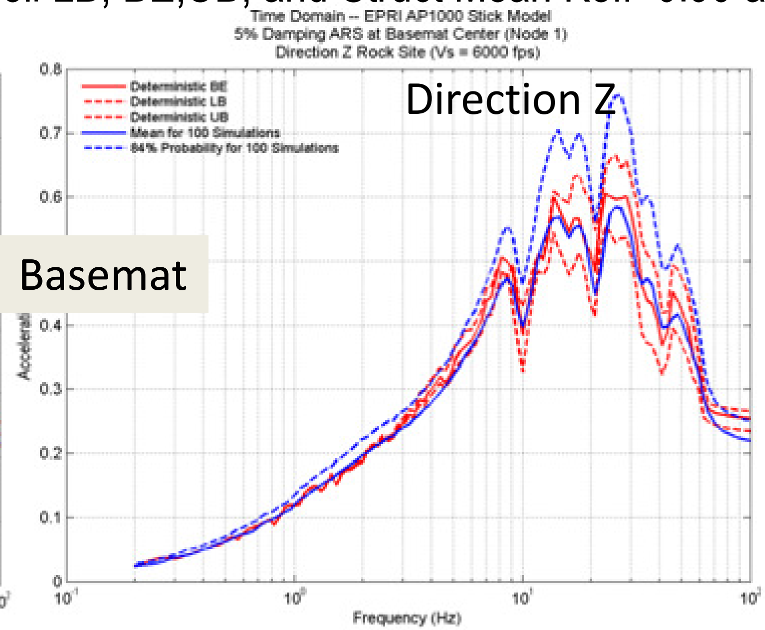


Det ranges
Prob 85%-95%
(UB role)

Deterministic vs. Probabilistic SSI Analysis for Rock Site

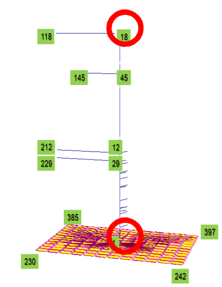
CASE A: Deterministic Mean (Mean GRS, Soil LB, BE,UB, and Struct Mean Keff=0.90 and Deff=6%)

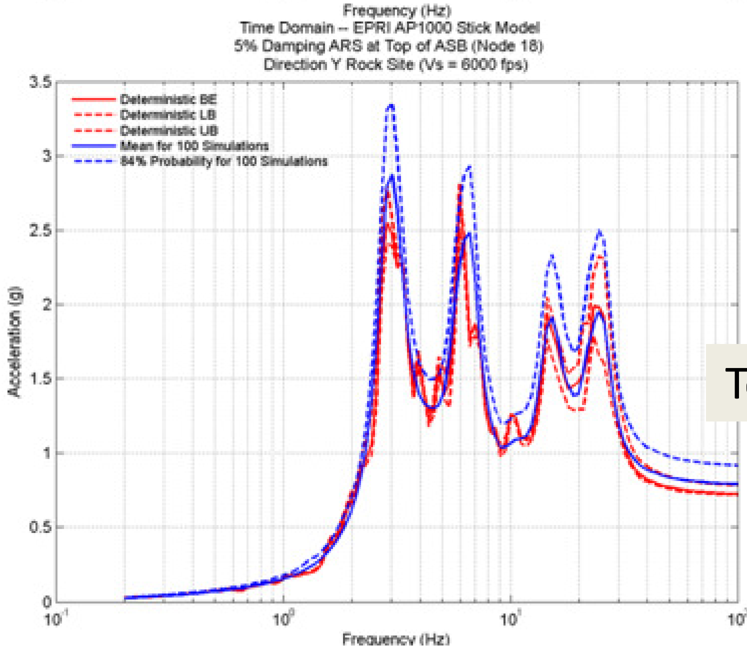


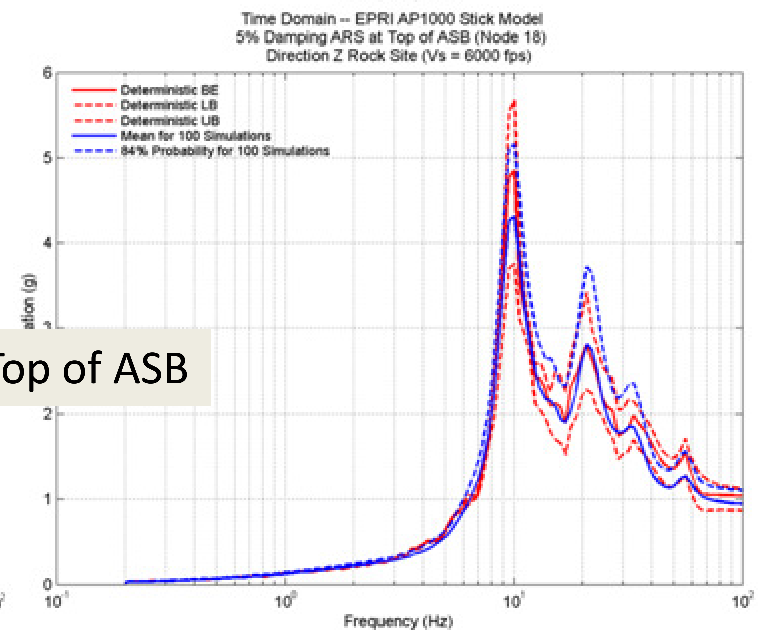


Basemat

Det ranges
Prob 65%-80%





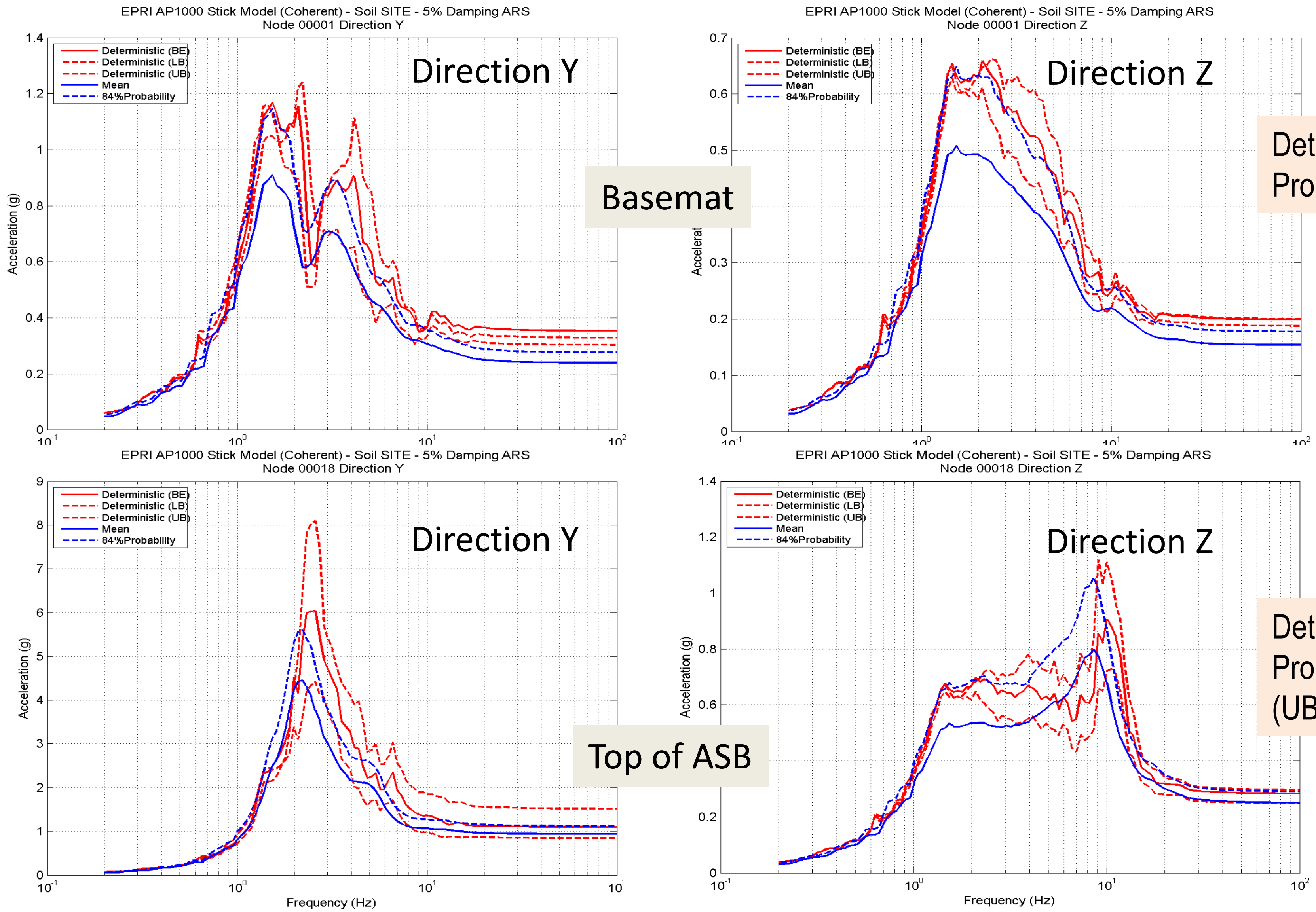


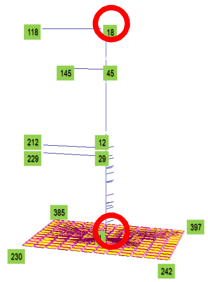
Top of ASB

Det ranges
Prob 65%-95%
(UB role)

Deterministic vs. Probabilistic SSI Analysis for Soil Site

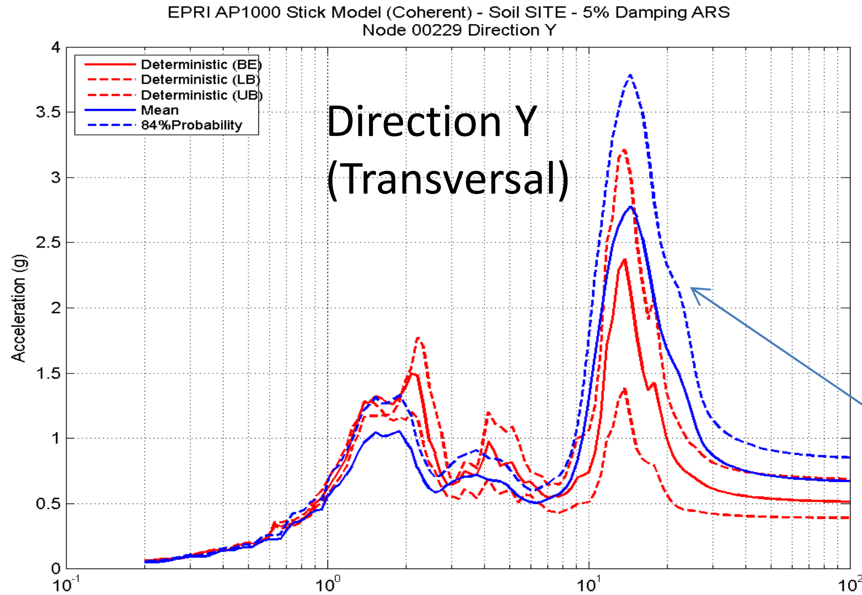
CASE B: Deterministic ASCE (Mean GRS, Soil LB, BE,UB, and Struct Code Keff=1.00 and Deff=4%)

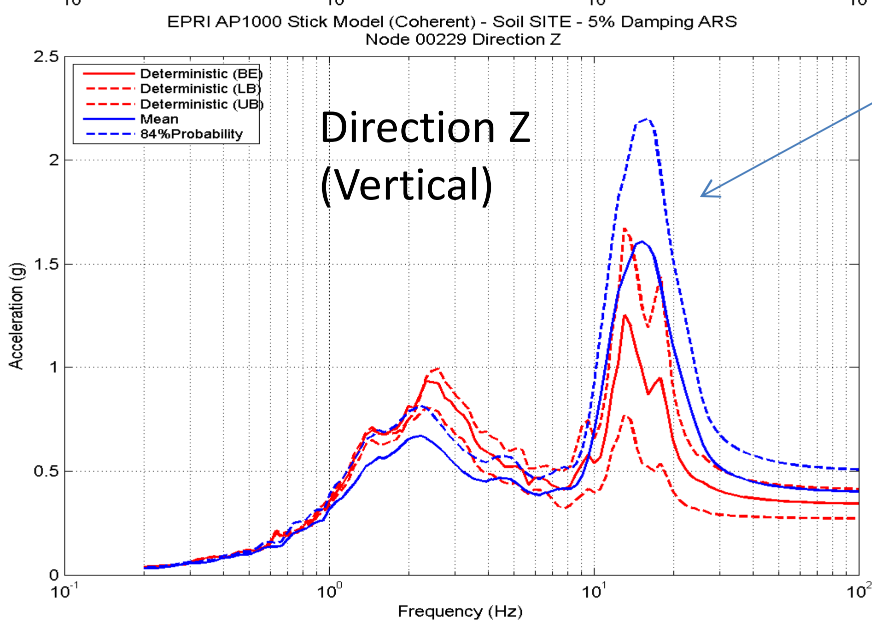




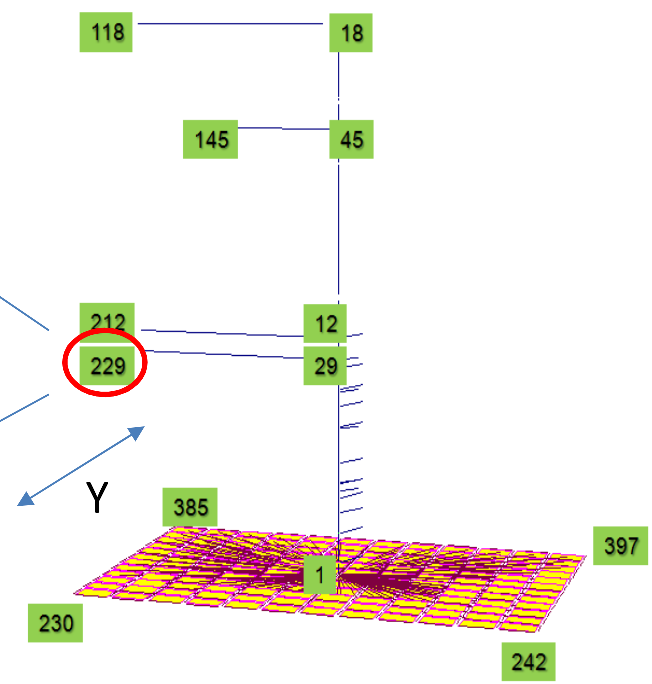
Deterministic vs. Probabilistic SSI Analysis for Rock Site

CASE B: Deterministic ASCE (Mean GRS, Soil LB, BE,UB, and Struct Code Keff=1.00 and Deff=4%)





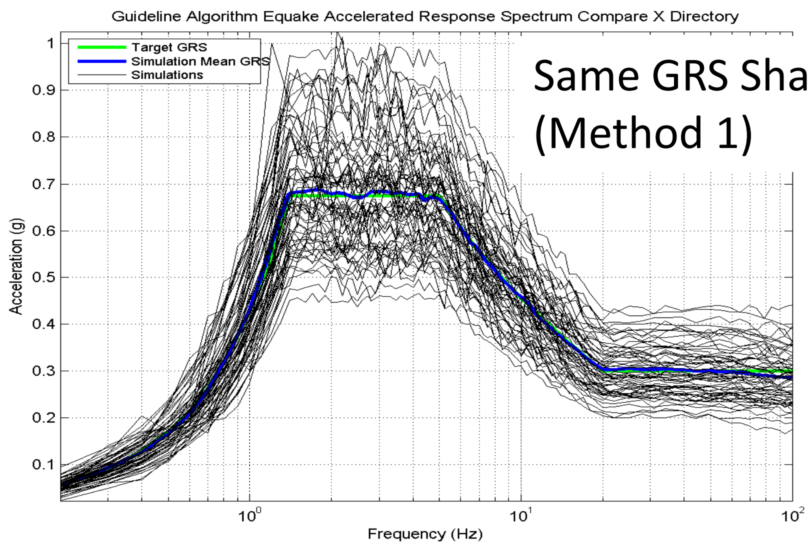
EPRI AP1000 Stick Model

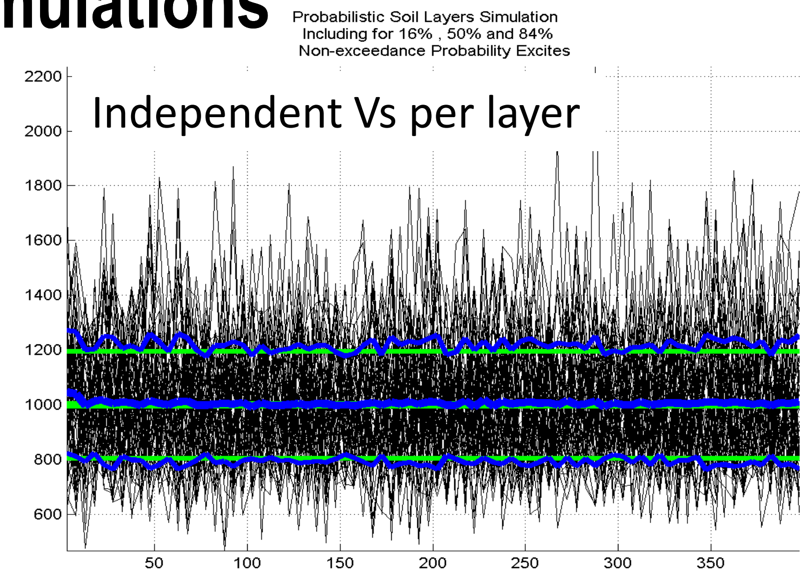


NOTE: 229 node location sensitive to torsional and rocking motion components

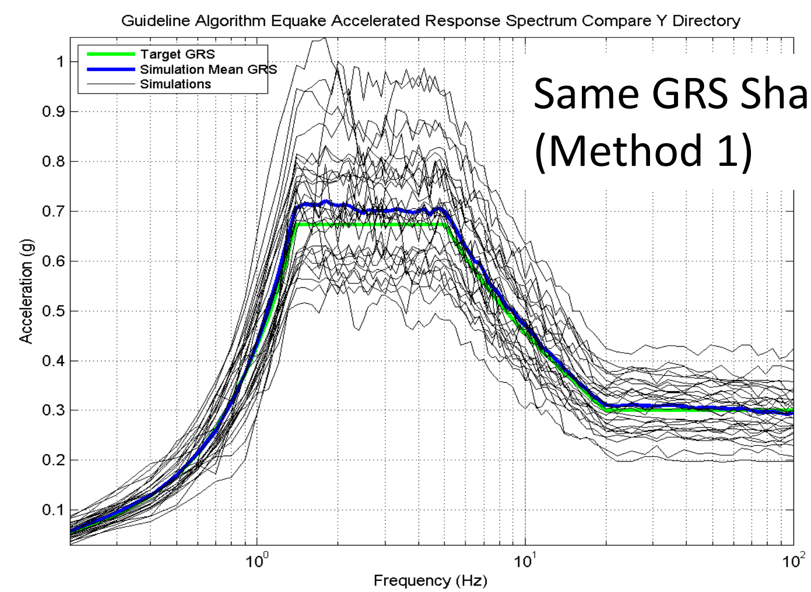
Probabilistic SSI Using Alternate Simulation Approaches

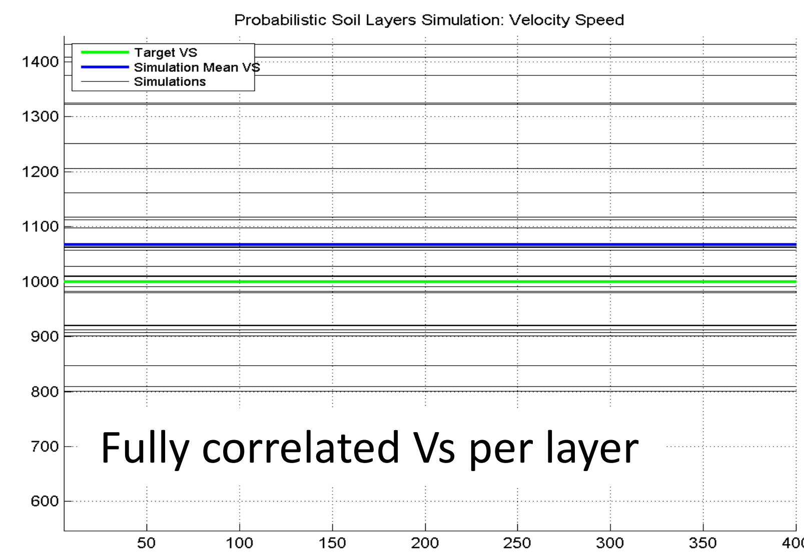
60 LHS Simulations



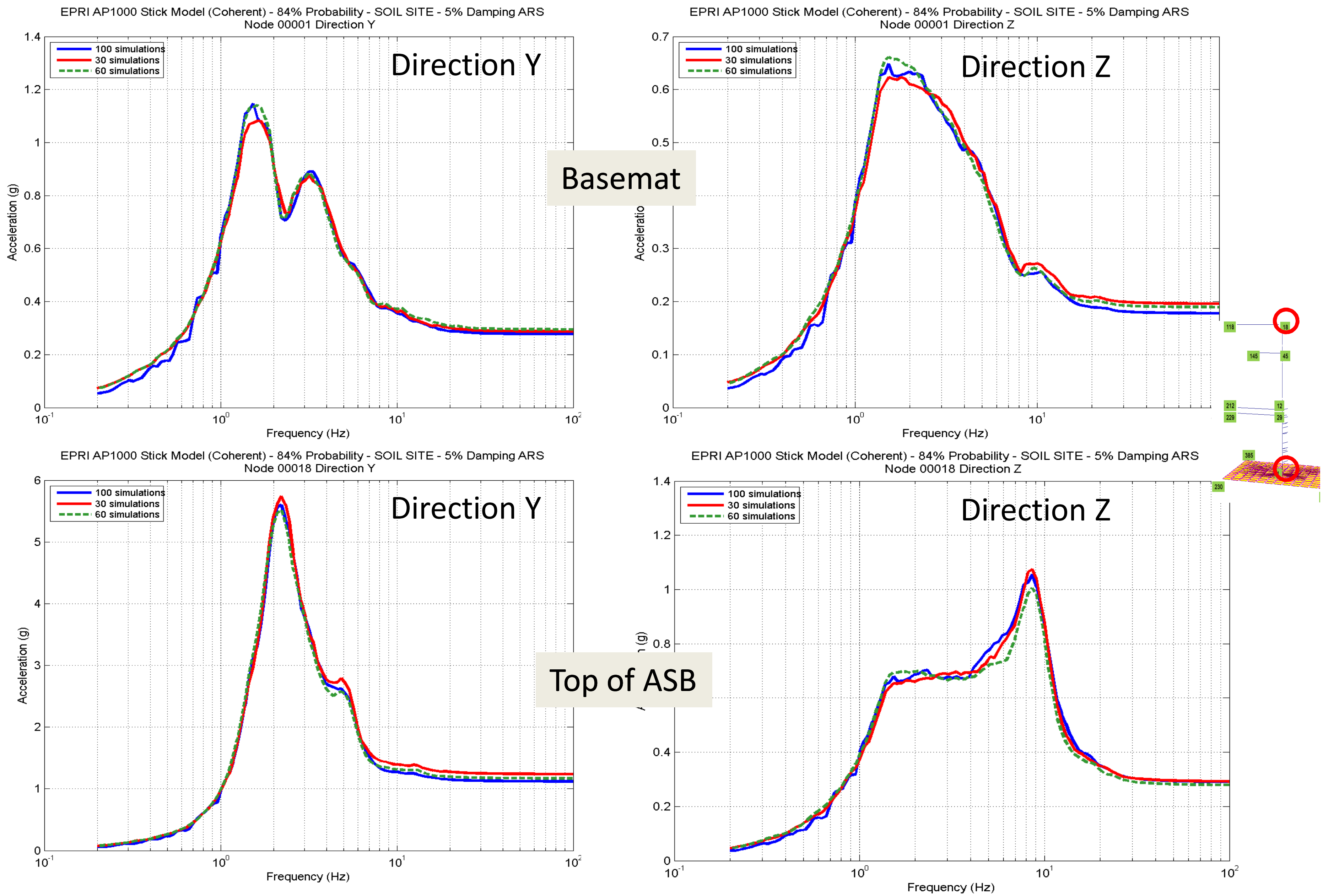


30 LHS Simulations





Comparative Results for Probabilistic SSI Approaches



Conclusions

- The ASCE 04-2013 standard goal, that Deterministic SSI produces SSI responses that correspond to approximately 80% NEP, is accomplished in an overall, average sense.

- Exceptions appear to corresponds to particular cases of large mass eccentricity structures that are more sensitive to rotational motions, including torsional and rocking motions. More investigations are needed, and currently underway.

- Using lower damping in structure in Deterministic SSI analysis impacts larger for the rock sites for which radiation damping is much lower. More investigations are needed, and currently underway.