ASCE 4-16 STANDARD-BASED PROBABILISTIC SEISMIC SSI ANALYSIS; PART 1 APPLICATION FOR DESIGN-BASIS LEVEL (DBE)

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DOE/NRC Natural Phenomena Hazards Meeting

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Purpose of This Presentation:

To show the application of the ASCE 4-16 based probabilistic SSI analysis for *Design-level (DBE) applications.*

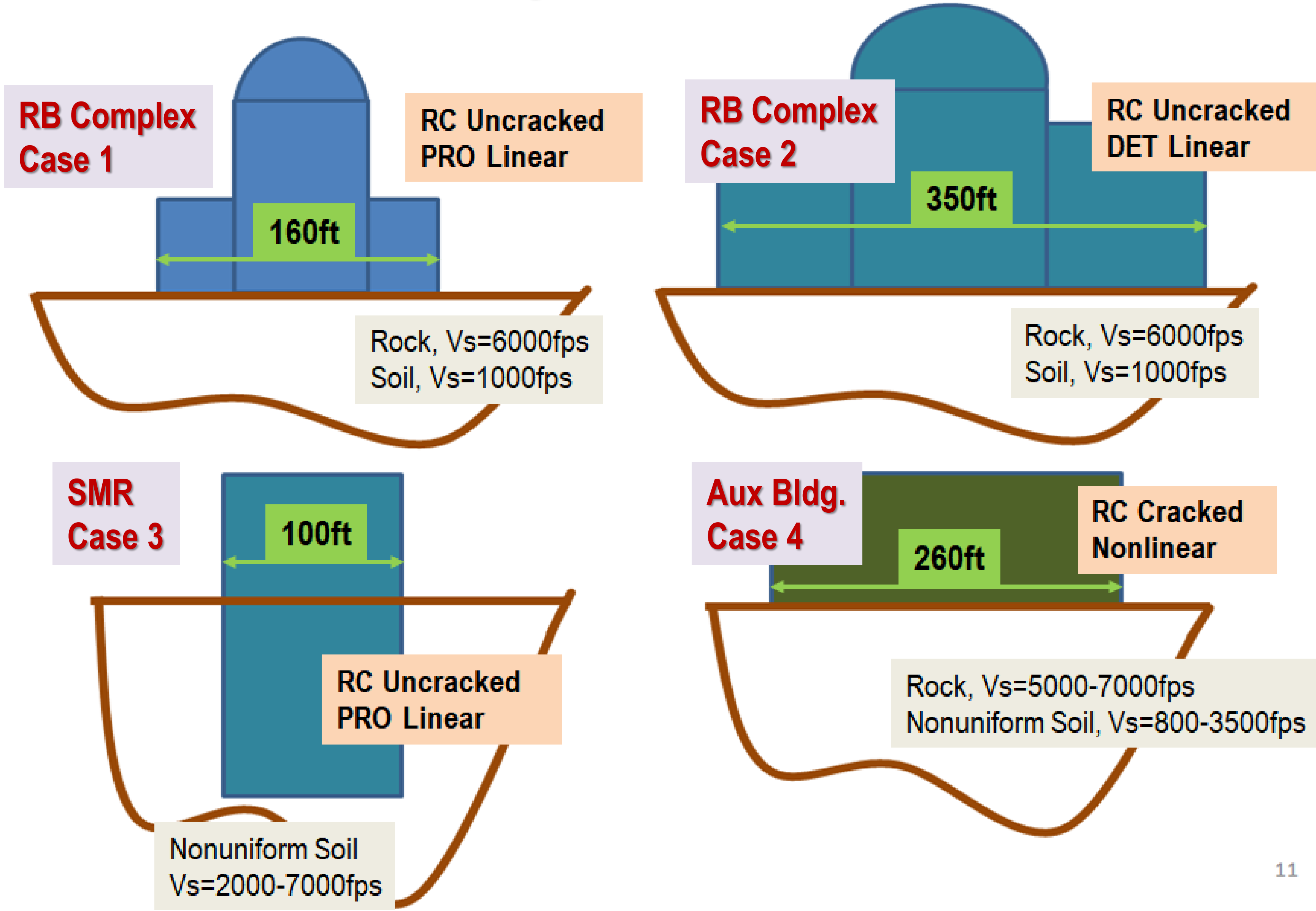
To answer to a question:

Is the ASCE 4-16 probabilistic SSI responses with 80% NEP more conservative or less conservative than the ASCE 4-16 deterministic SSI responses for the *design-level* analyses?

To be able to answer to this question, we investigated a number of case studies. Herein, we show few representative results from four SSI case studies including surface and deeply embedded structures on rock and soil sites.

ACS SASSI V3 with Options PRO and NON was used.

ASCE 4-16 Based Probabilistic vs. Deterministic SSI Analysis Case Studies



ASCE 4-16 Probabilistic Site Response Analysis (PSRA) and Probabilistic SSI Analysis (PSSIA)

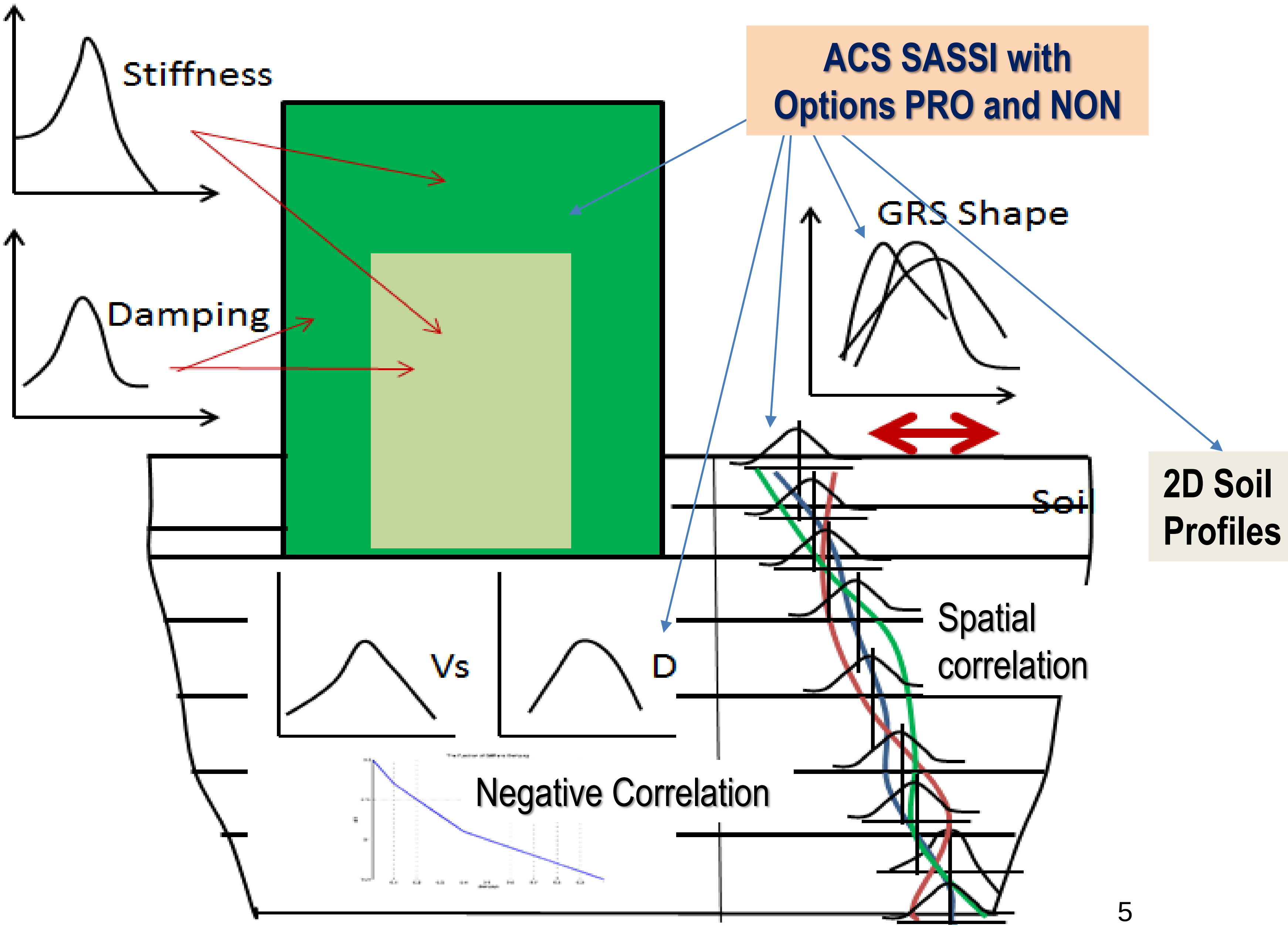
Based on the new ASCE 04-2016 recommendations:

- *Probabilistic SSI analyses should be performed using at least 30 LHS randomized simulations*

- For the ***design-level applications***, *probabilistic SSI responses should defined for the 80% non-exceedance probability (NEP)*.

- Probabilistic modeling should minimally include:
    - SEISMIC INPUT: GMRS/UHRS amplitude assumed to randomly varying (Methods 1 and 2).
    - SOIL PROFILE: Vs and D soil profiles
    - STRUCTURE: Effective stiffness and damping, as functions of stress/strain level in different parts of structure.

ASCE 4-16 Probabilistic SSI Simulation Concept



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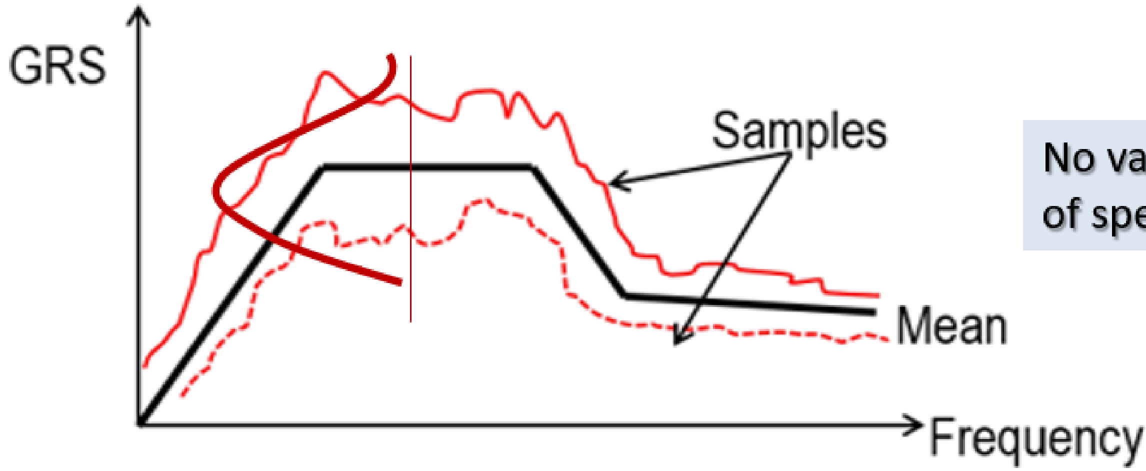
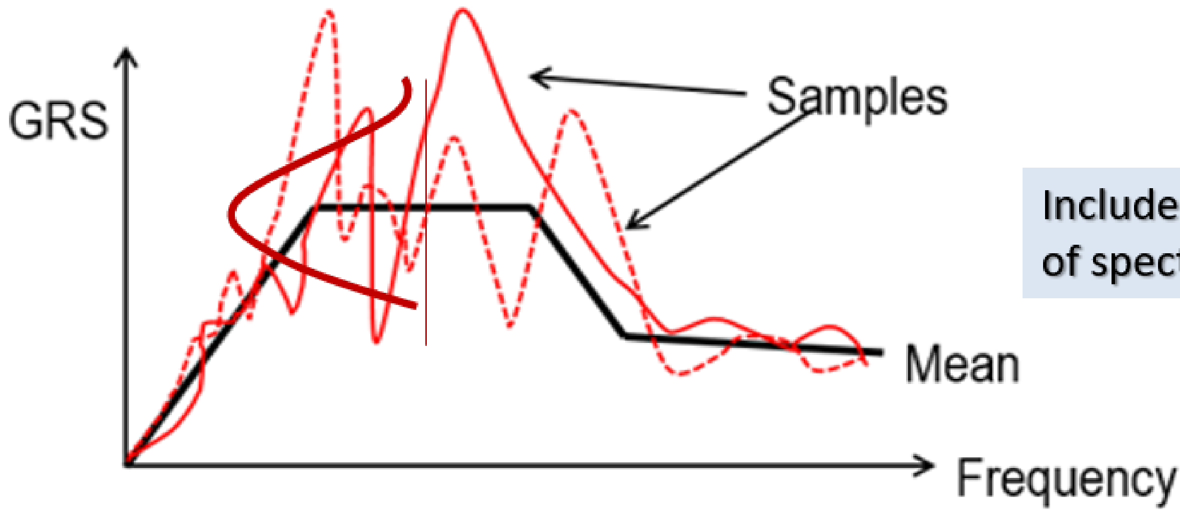
Probabilistic Seismic Input Models

ASCE 04 Method 1



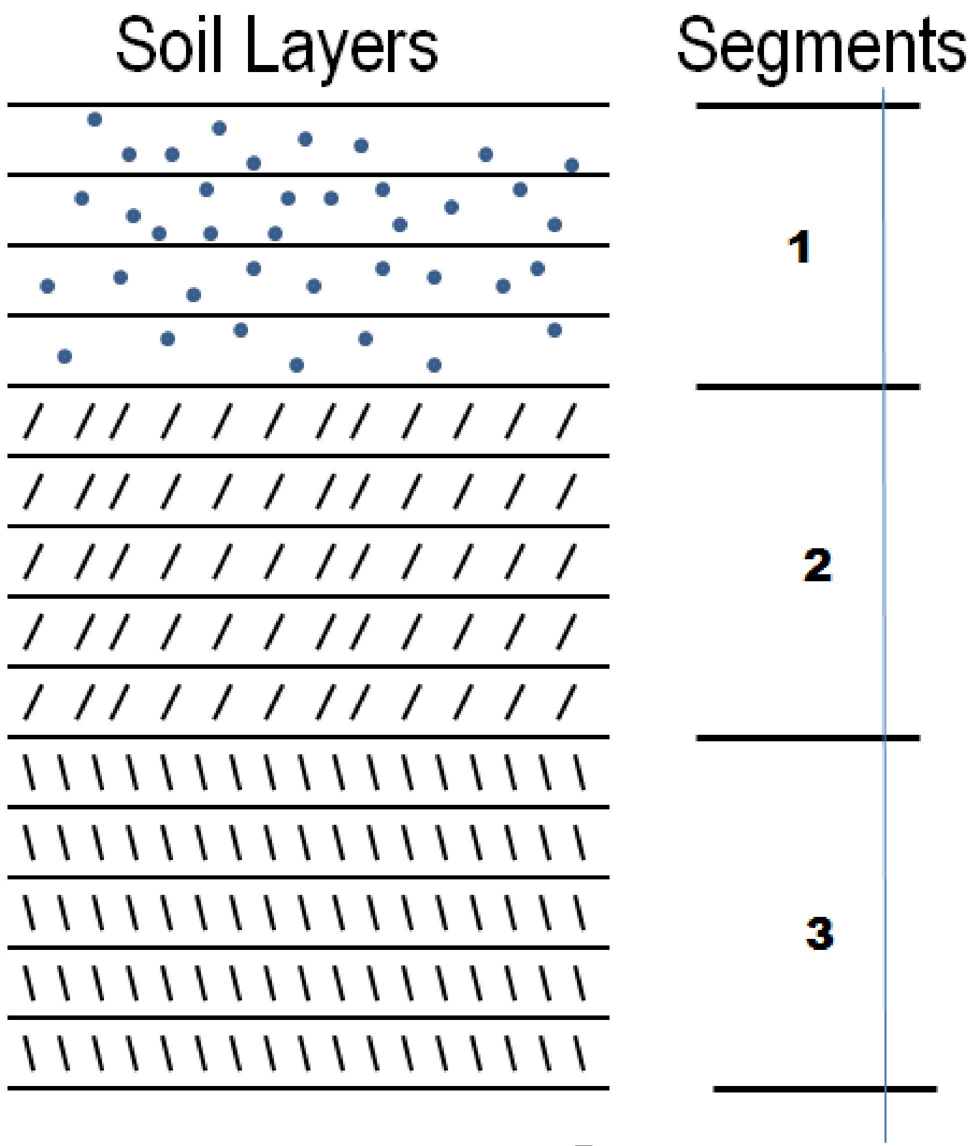
No variation
of spectral shape

ASCE 04 Method 2



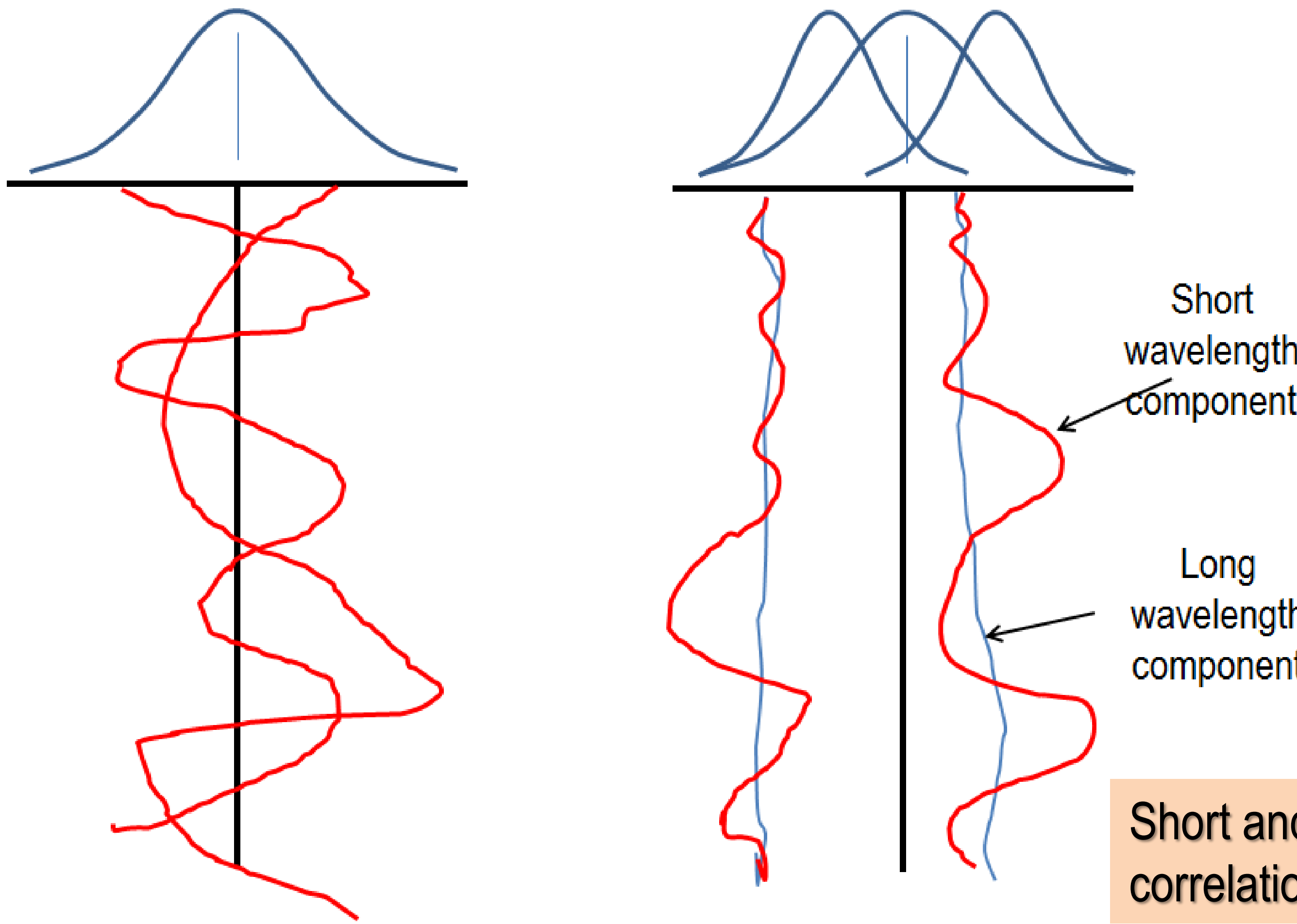
Include variation
of spectral shape

Vs and D Soil Profile Probabilistic Models Using Multiple Segments Split



Different statistical properties for different soil profile segments in depth

Vs and D Soil Profile Probabilistic Models. Two Variation Scale Models Based on Field Data



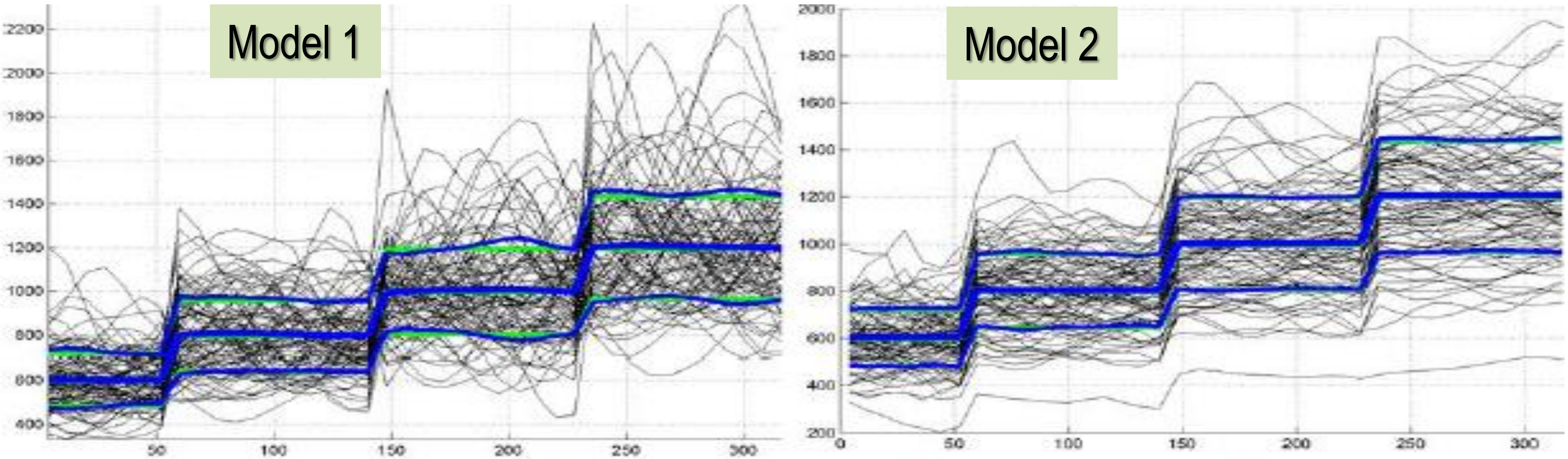
Short and large correlation lengths

Model 1 (Simple)

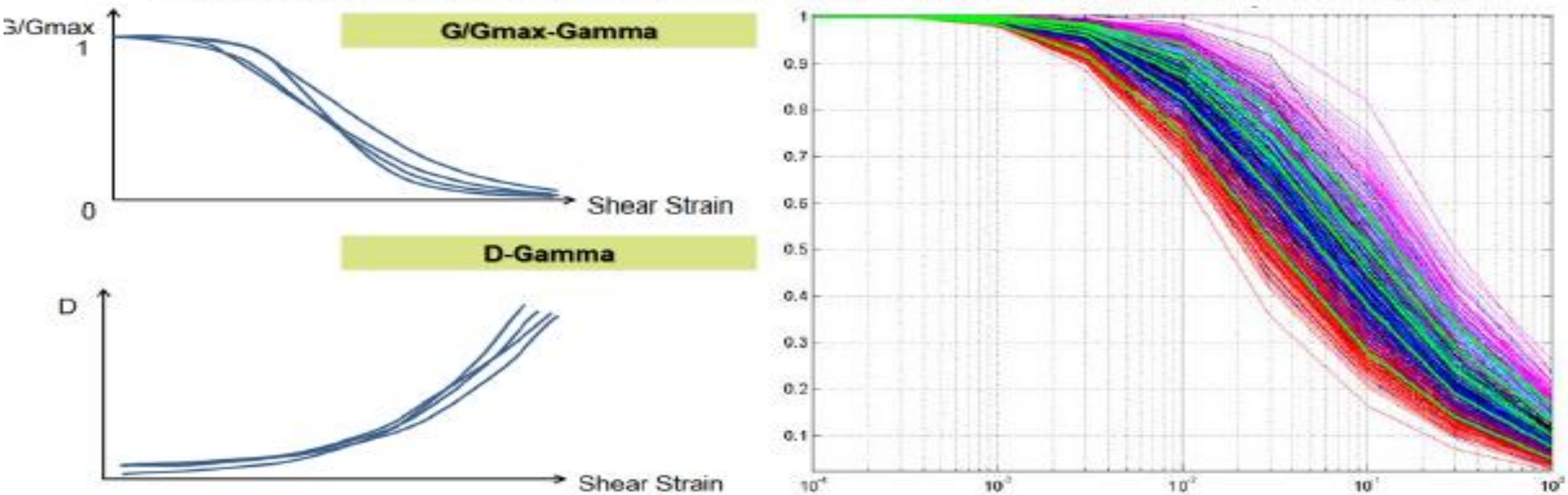
Model 2 (Composite)

(Popescu, 1996)

Probabilistic Simulations of Soil Profiles & Curves



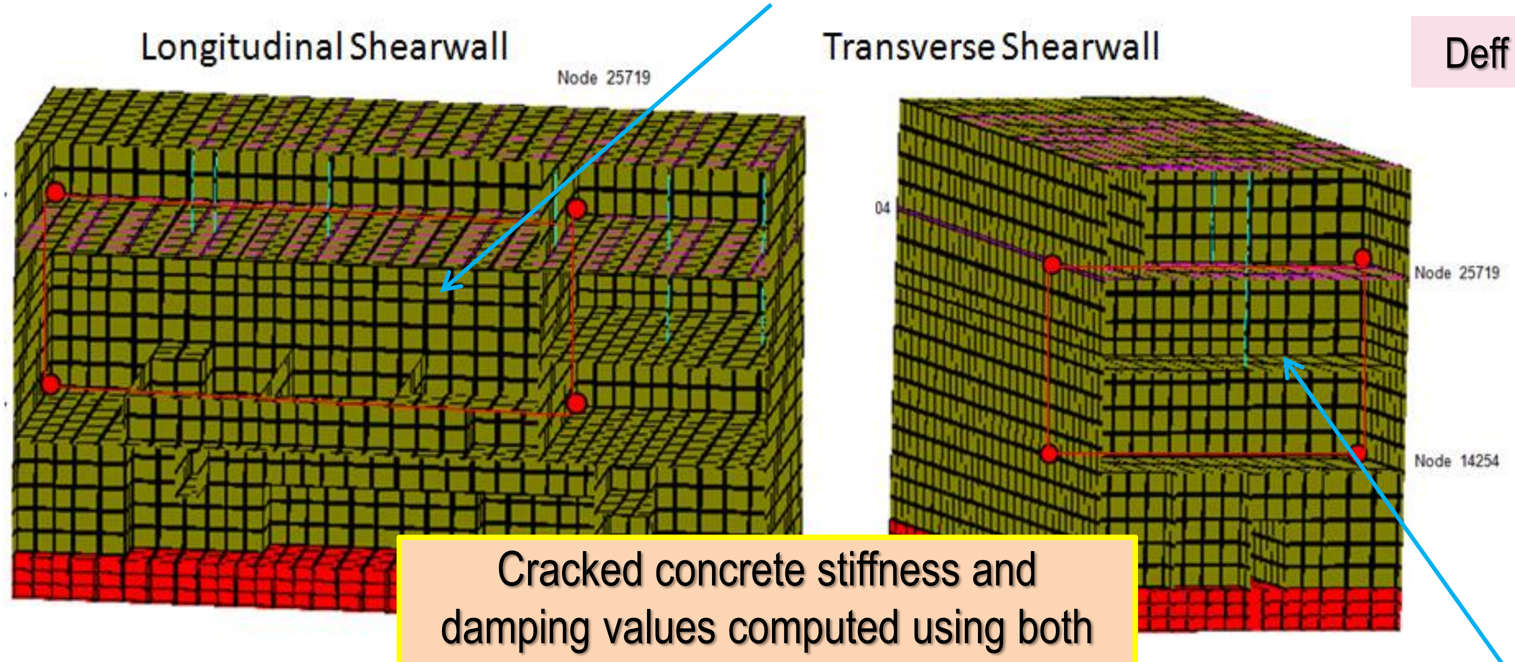
Simulated vs. Target Soil Vs Profiles Using Method 1 (left) and Method 2 (right)



Soil G/Gmax and D Curve Random Variations (left); Simulated G/Gmax for 4 Soil Curves (right). The Mean Values of 4 Soil Curves Are Plotted with Green Lines.

Probabilistic Linear Structural Models; Effective Stiffness and Damping *Depend on Wall Strain Levels*

- Keff/Kel and Deff variables should defined by user *for each element group.*
- Effective stiffness ratio Keff/Kelastic and damping ratio, Deff, should be modeled as *statistically dependent* random variables. They can be considered *negatively correlated*, or Deff defined as a *response function* of Keff/Kelastic based on experimental tests.

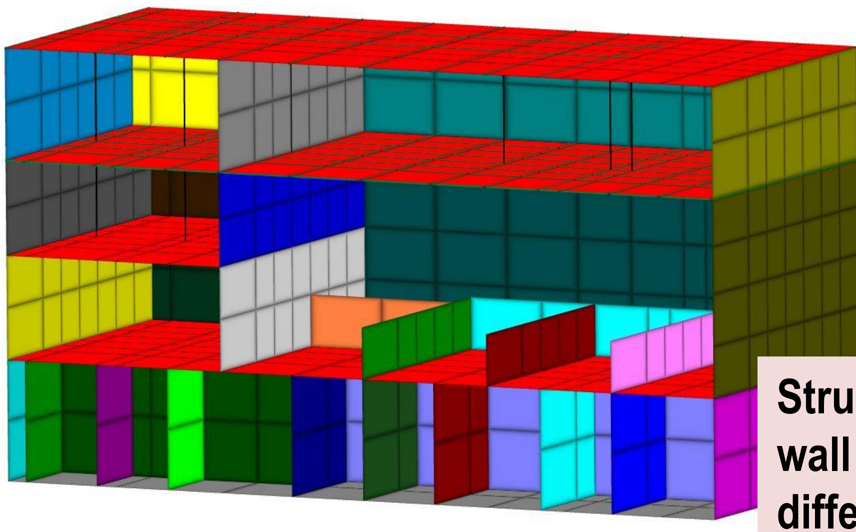


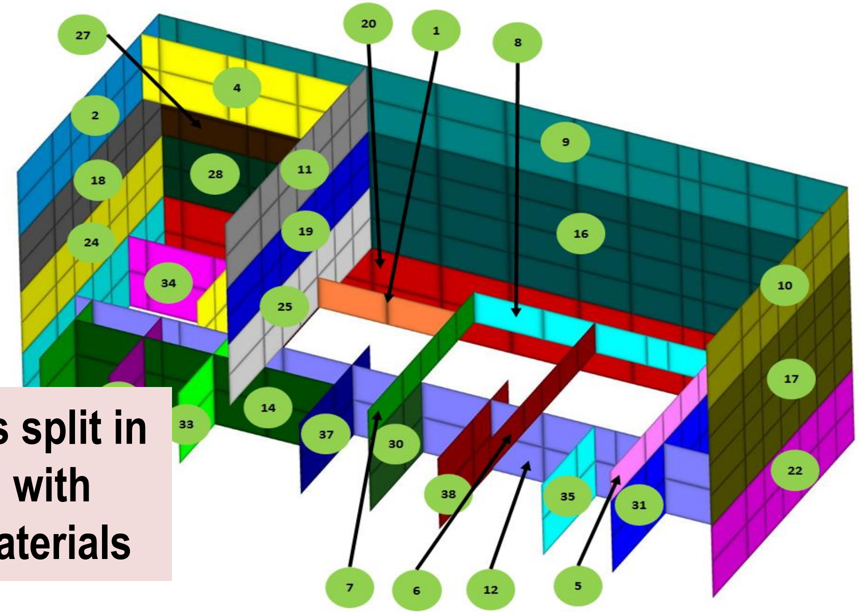
Cracked concrete stiffness and damping values computed using both Option PRO and NON capabilities.

Deff = f (Keff/Kelastic)

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

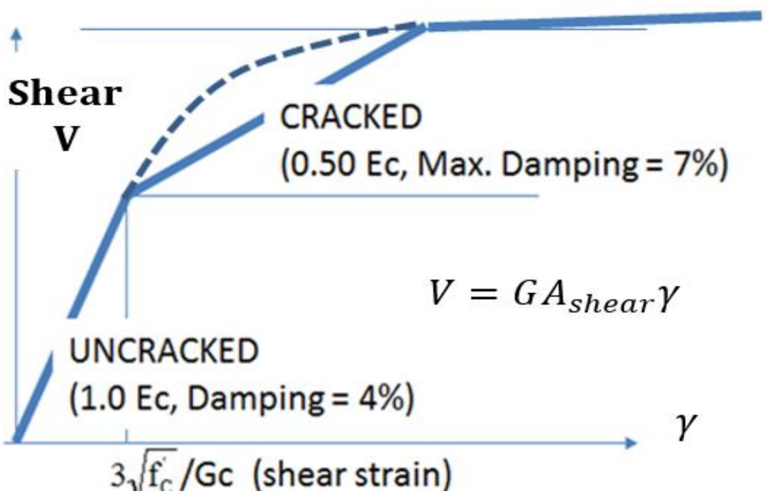
Probabilistic Nonlinear Concrete Structural Models Based on *Wall (Panel) Strain Levels*



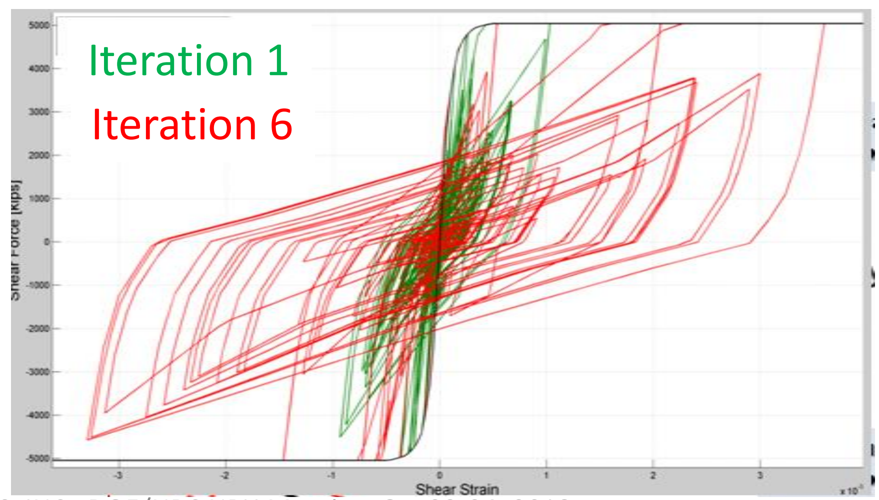


Structure is split in wall panels with different materials

Backbone Curves Automatically Generated



Iterative SSI Fast Analyses Until Convergence



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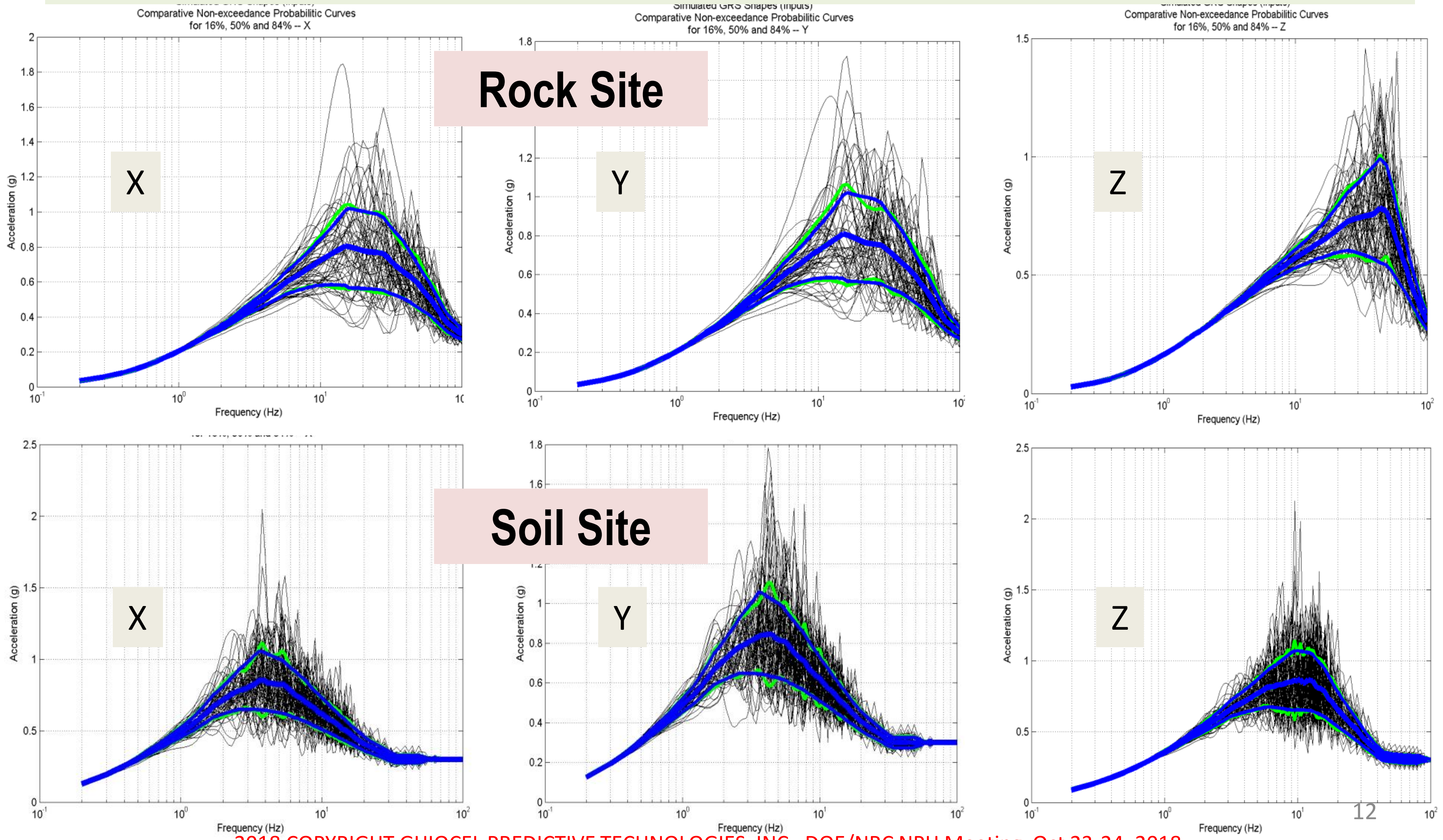
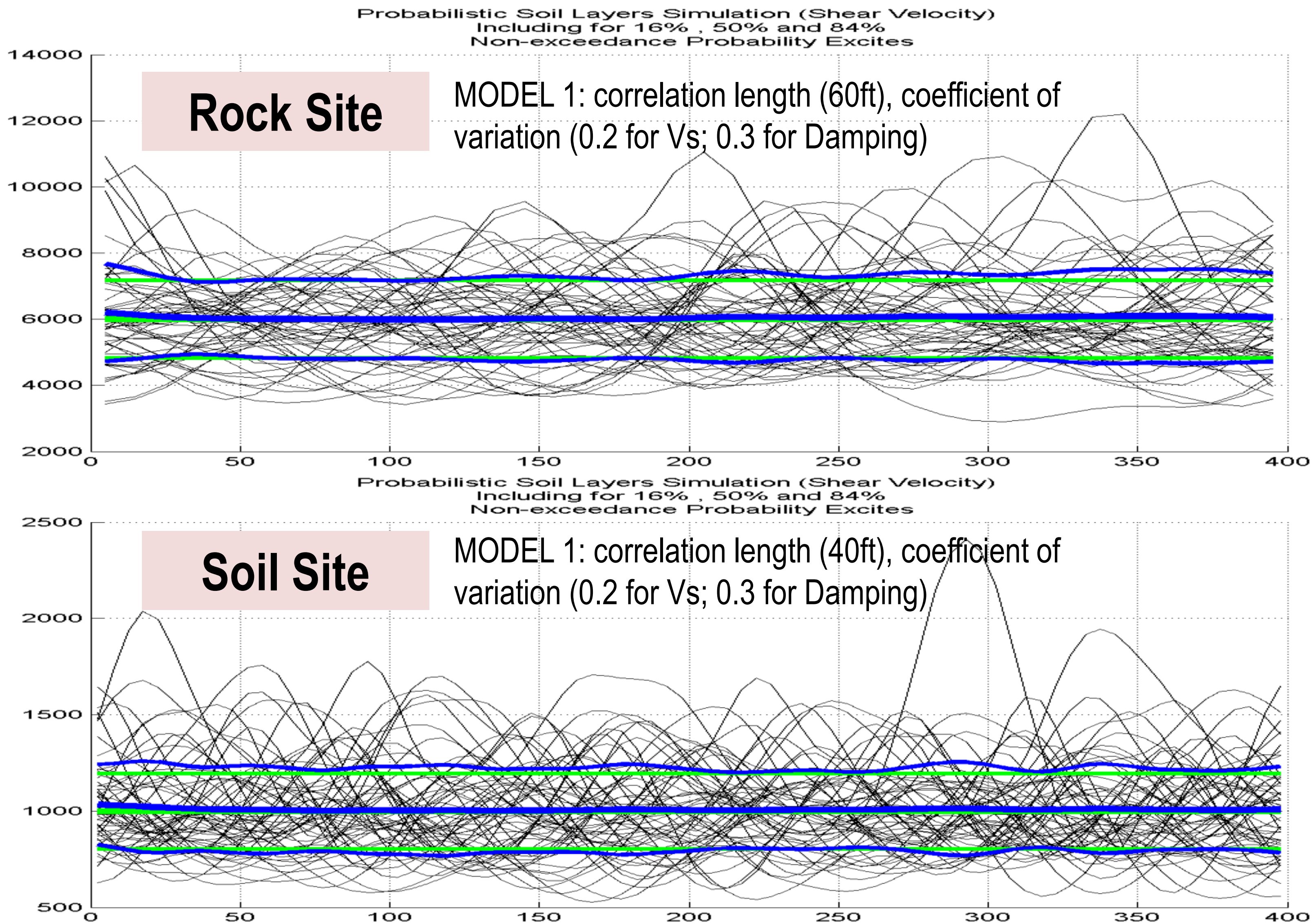
Case Study No. 1: Surface RB Complex with 160ft Foundation Size on Rock and Soil Sites

60 Probabilistic GRS Input Simulations (ASCE 4-16, Method 2)



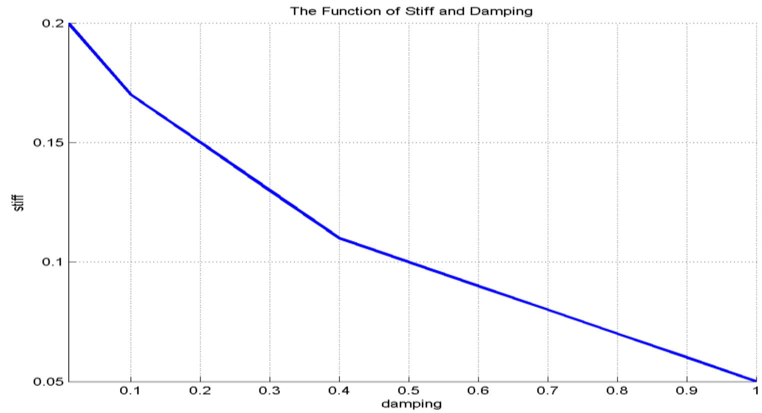
60 Probabilistic Soil Layer Simulations

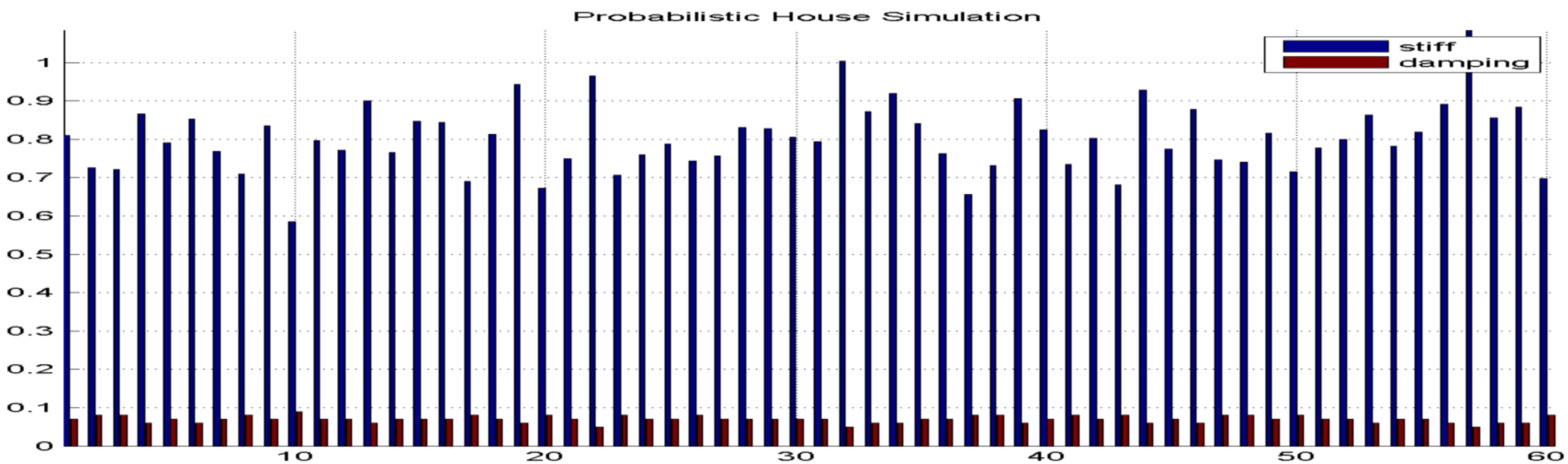


60 Probabilistic Structure Simulations

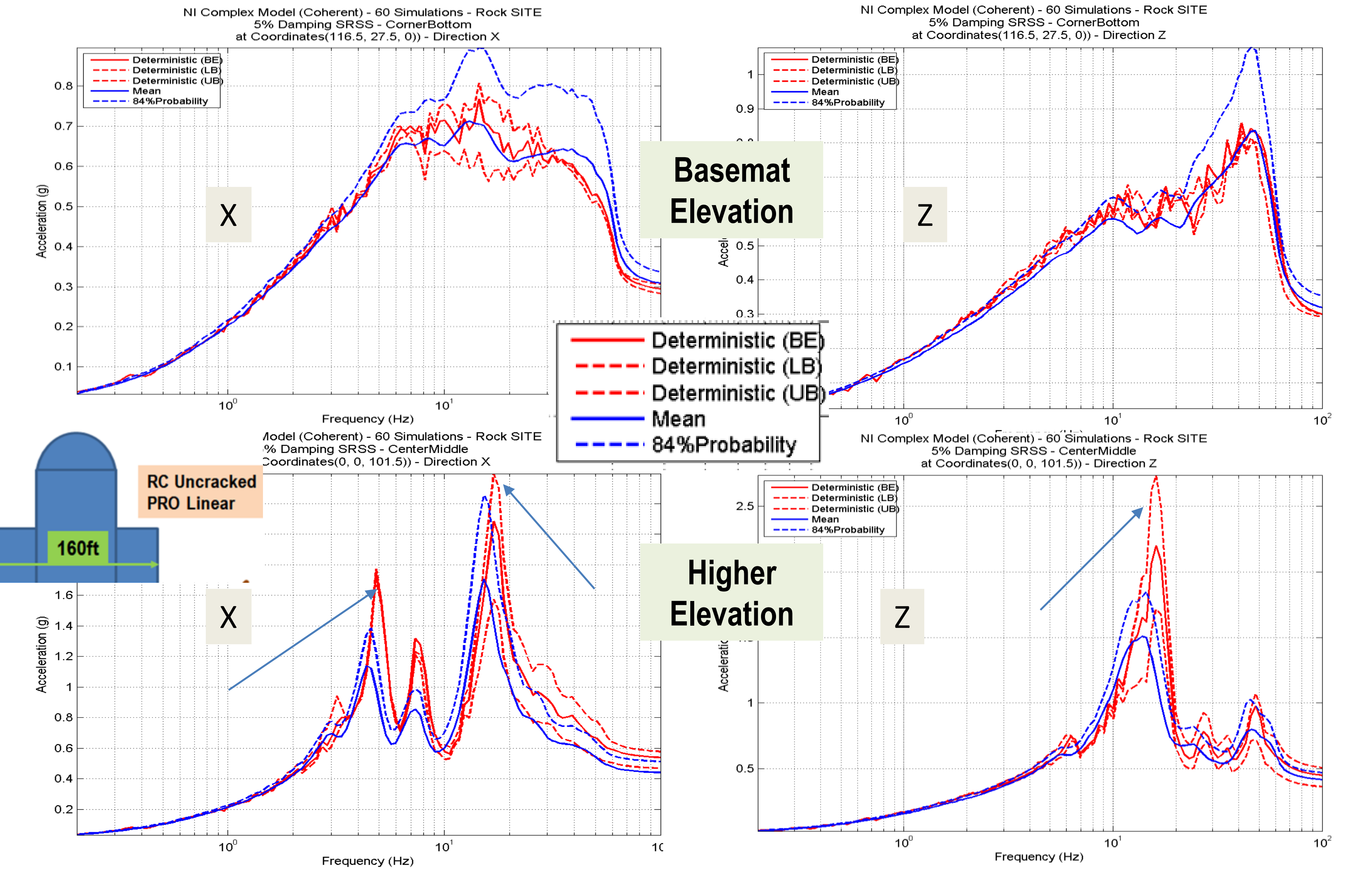
- Simulate 87 material types: Group 1 Solid (4); Group 2 Beam (27); Group 3 Shell (56)
- Mean of Stiffness: 0.8; Coefficient of Variation: 0.1
- Correlation Matrix: without correlation
- Damping Computation: Using a response function shown below:

0.01	0.2
0.10	0.17
0.20	0.15
0.30	0.13
0.40	0.11
0.50	0.1
0.60	0.09
0.70	0.08
0.80	0.07
0.90	0.06
1.00	0.05

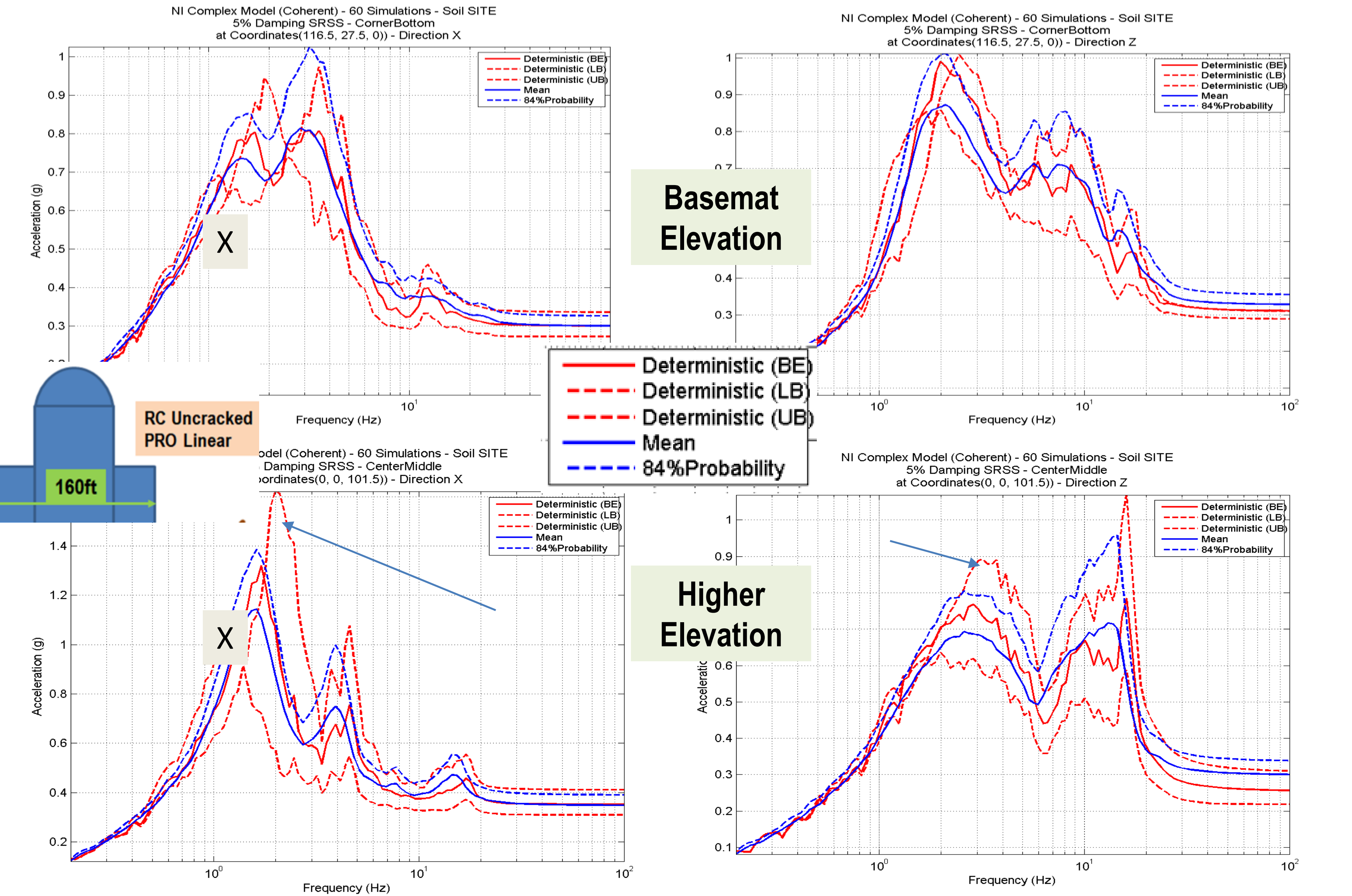




ISRS for Surface RB Complex (160ft size) on Rock



ISRS for Surface RB Complex (160ft size) on Soil



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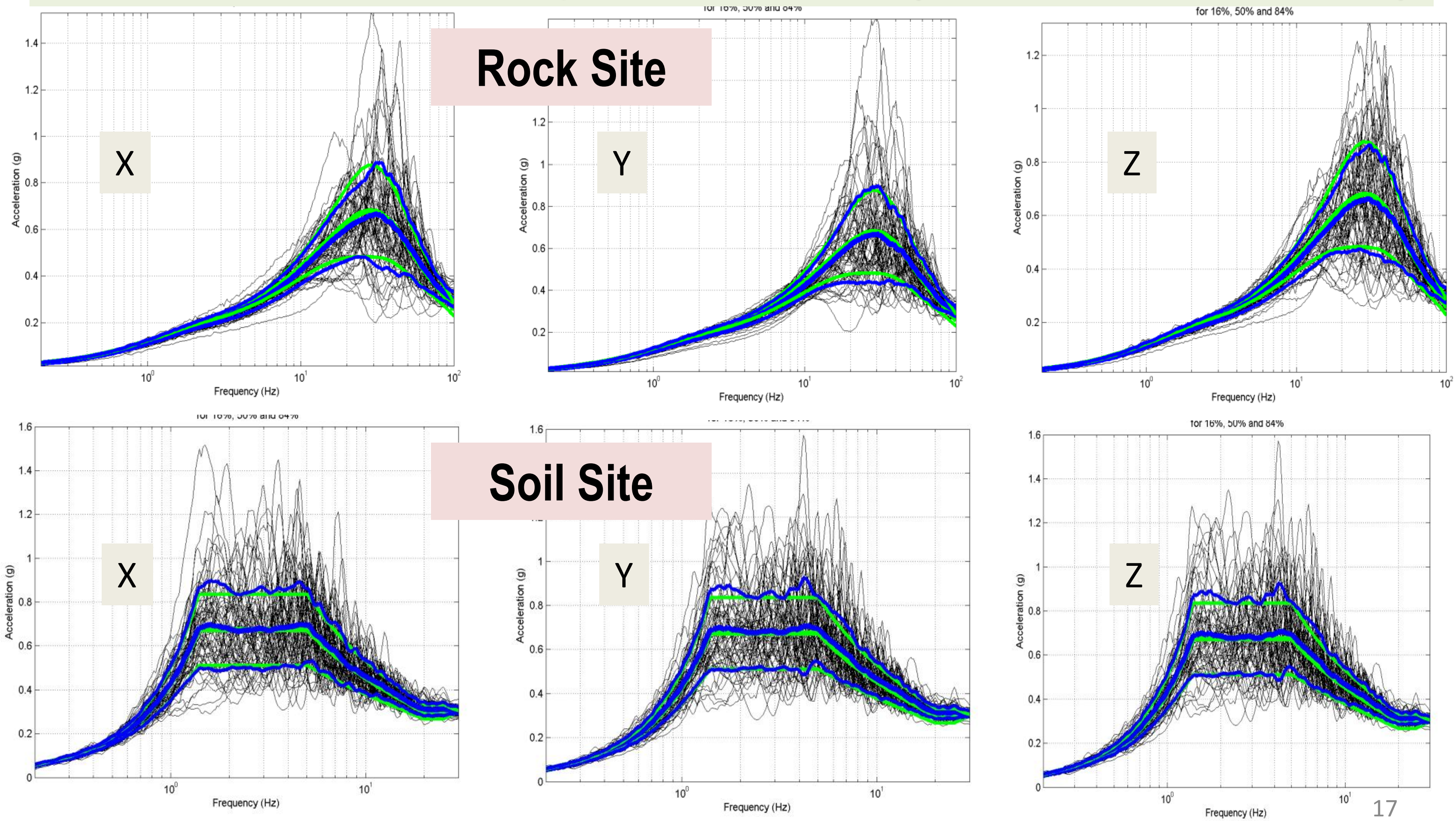
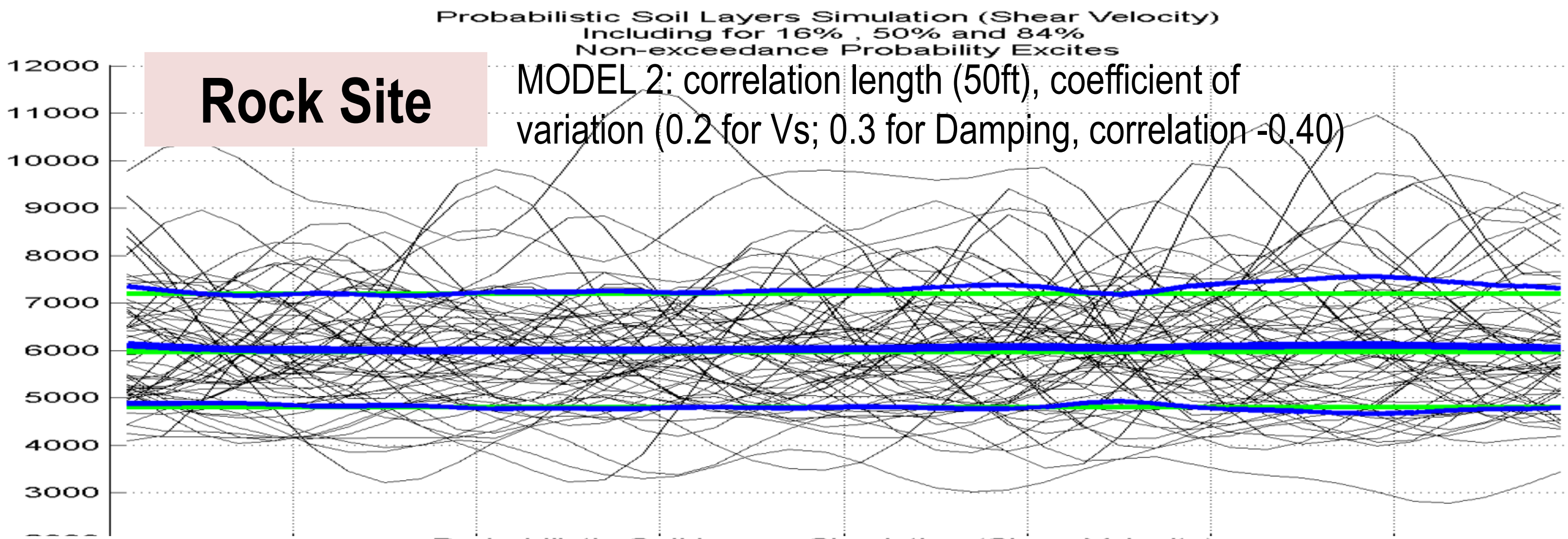
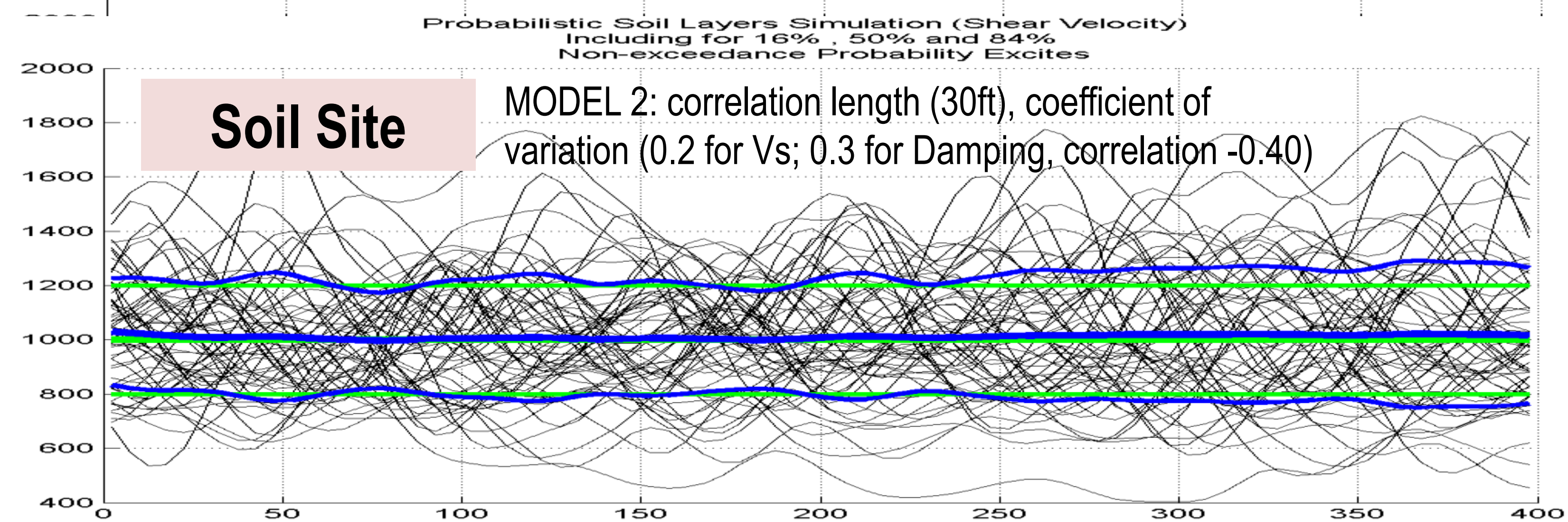
Case Study No. 2: Surface RB Complex with 360ft Foundation Size on Rock and Soil Sites

60 Probabilistic GRS Input Simulations (ASCE 4-16, Method 2)

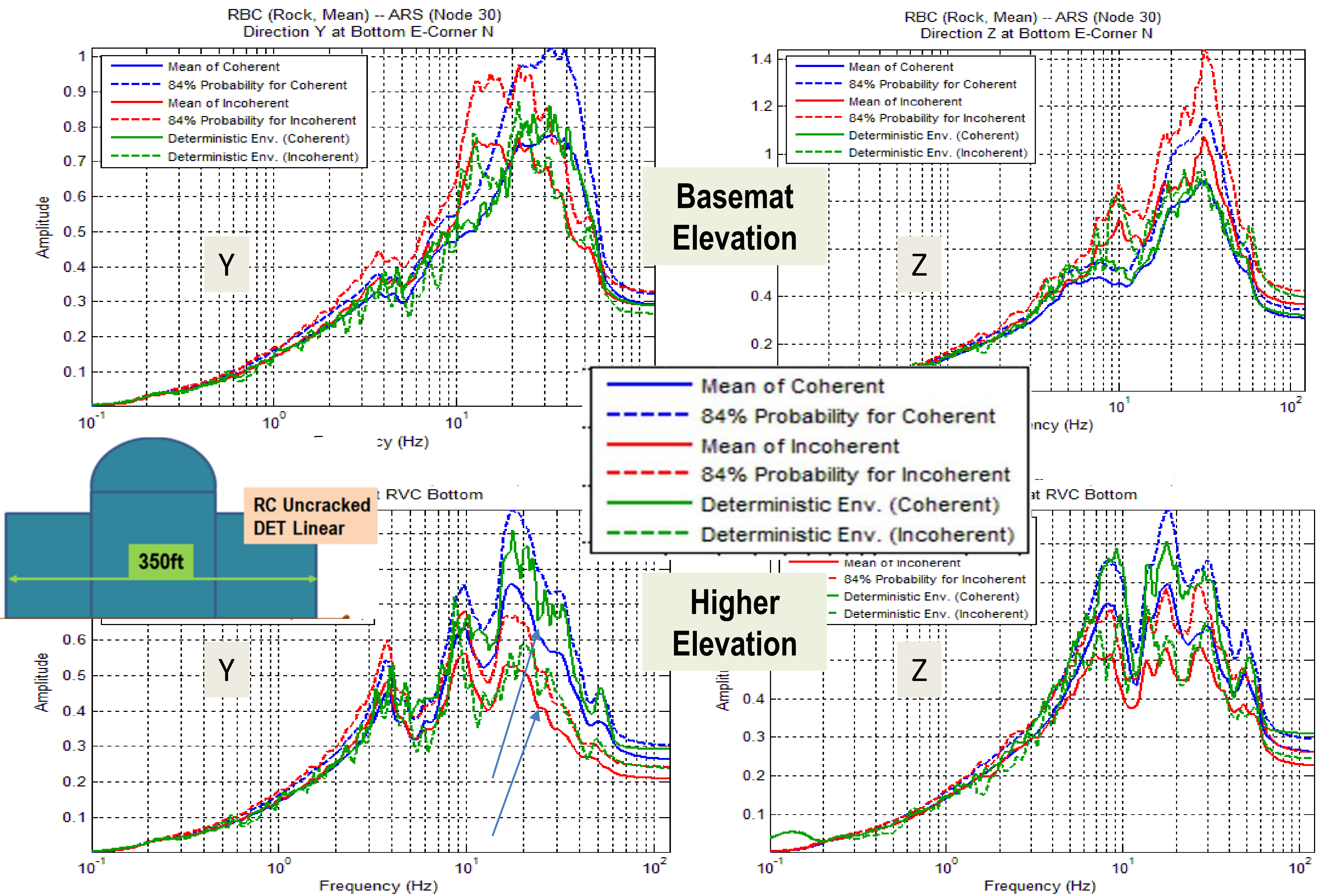


60 Probabilistic Soil Layer Simulations





ISRS for Surface RB Complex (360ft size) on Rock



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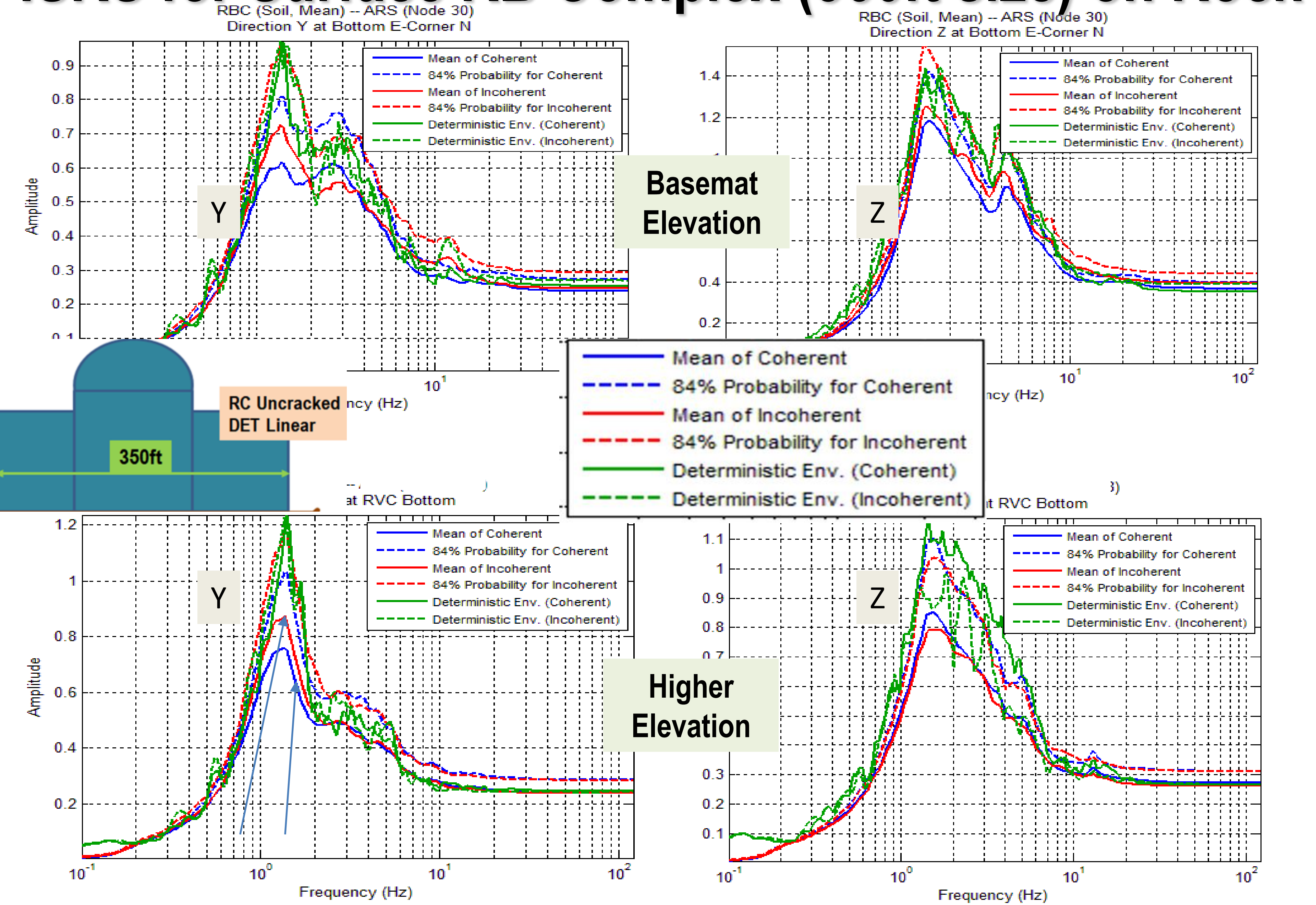
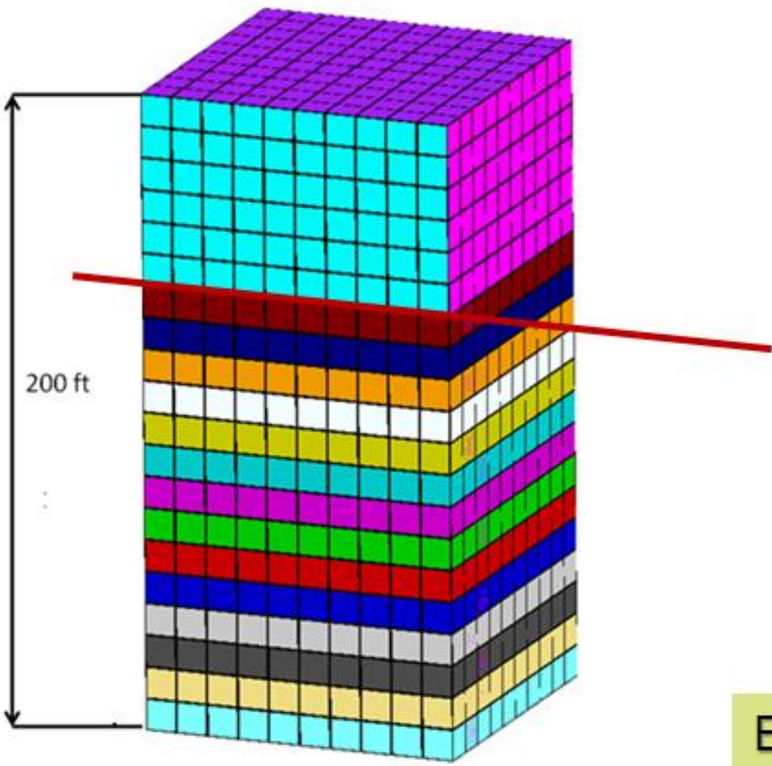
ISRS for Surface RB Complex (360ft size) on Rock

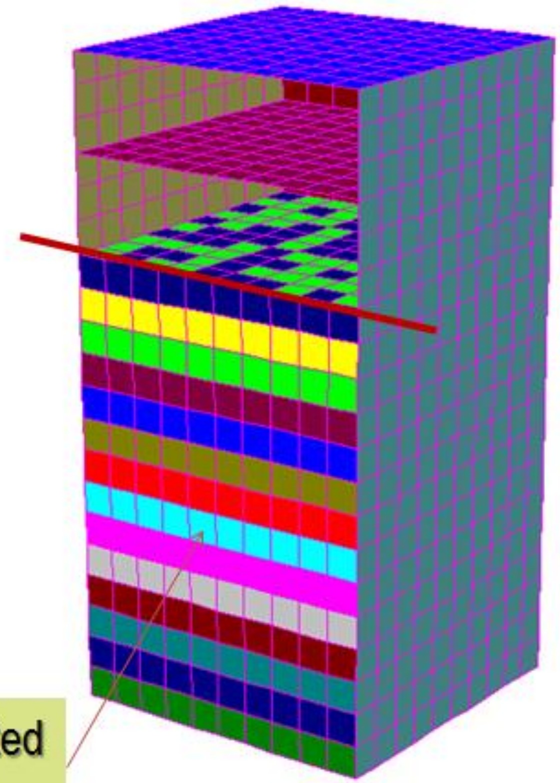


Case No. 3: Probabilistic vs. Deterministic SSI For Deeply Embedded SMR Structure



Generic SMR Structure

SMR size: 100 ft x 100 ft X 200 ft
Embedment: 140 ft
Mesh size: 10 ft X 10 ft X 10 ft
Number of Nodes: 2,580
Interaction Nodes: 1,815



Excavated Soil

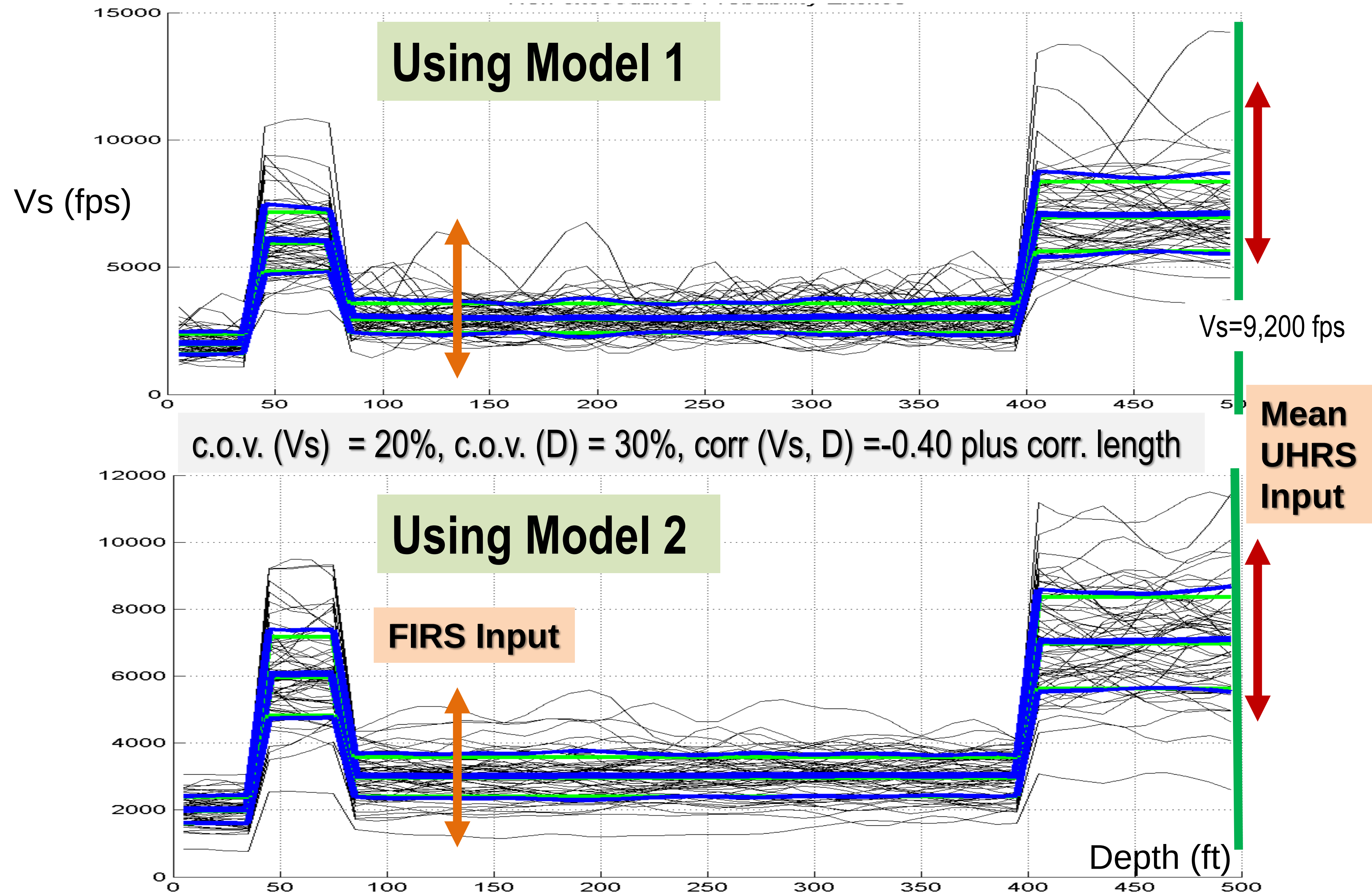
140 ft Embedment SMR SSI Model (use FV method)

STIFFNESS and DAMPING:

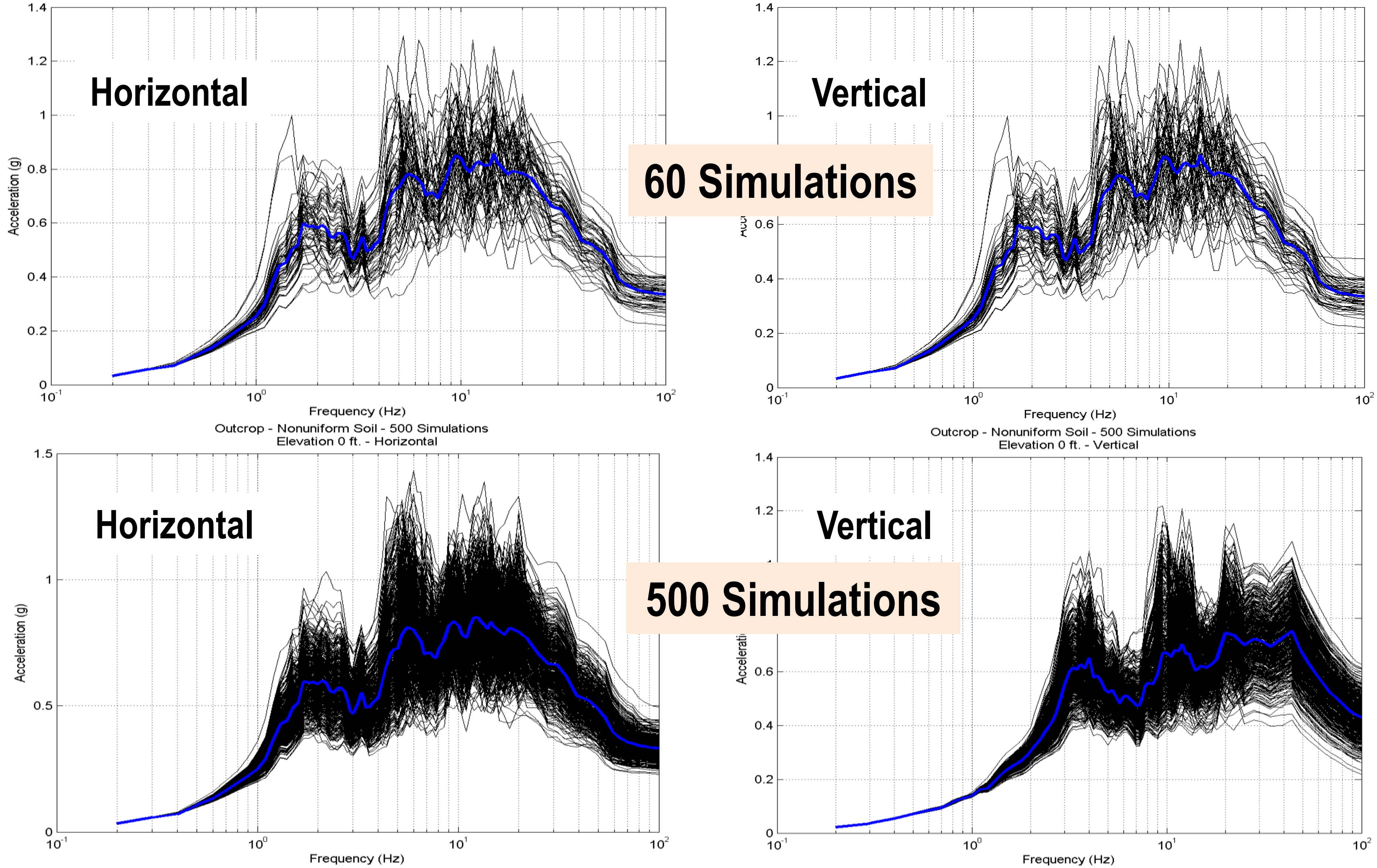
Prob Keff/Kel
Mean = 0.80;
C.O.V. = 10%
Prob Dmean = 6%;
C.O.V. = 30%
Keff/Kel and D correlation -0.8

Det Keff/Kel = 1
Det D = 4%

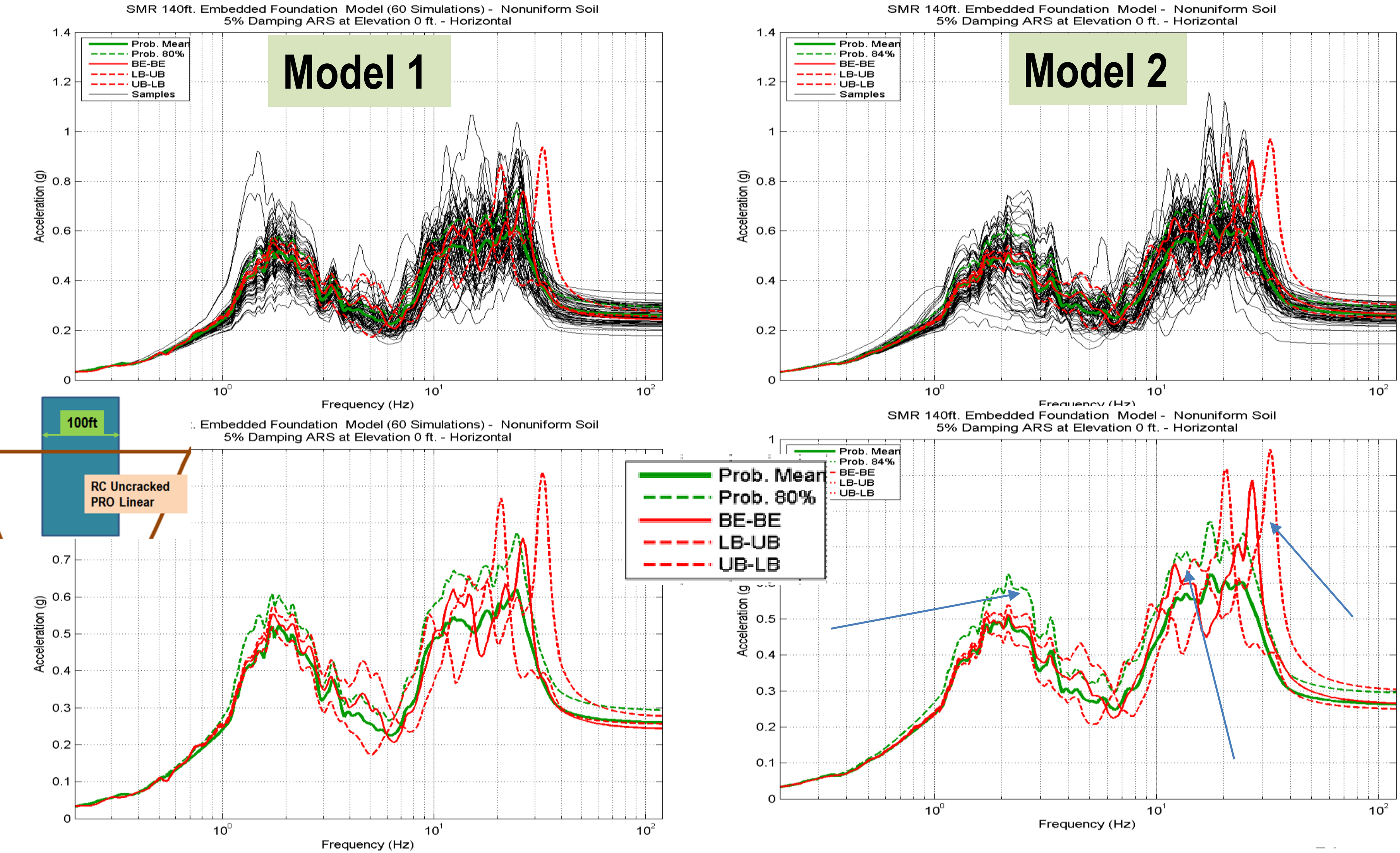
Probabilistic and Deterministic Soil Profiles



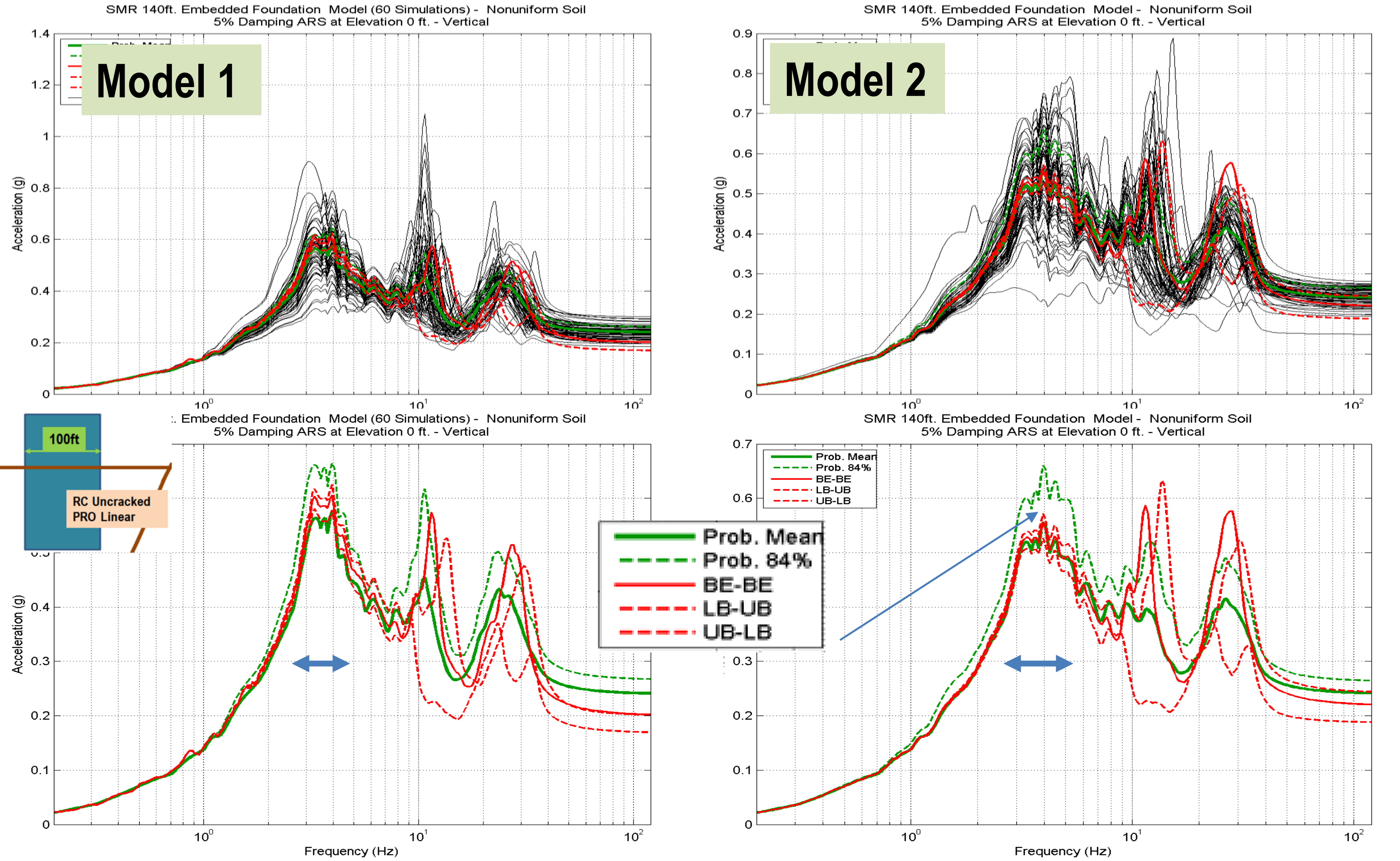
60 and 500 Probabilistic Simulations for Outcrop FIRS in Horizontal and Vertical Directions



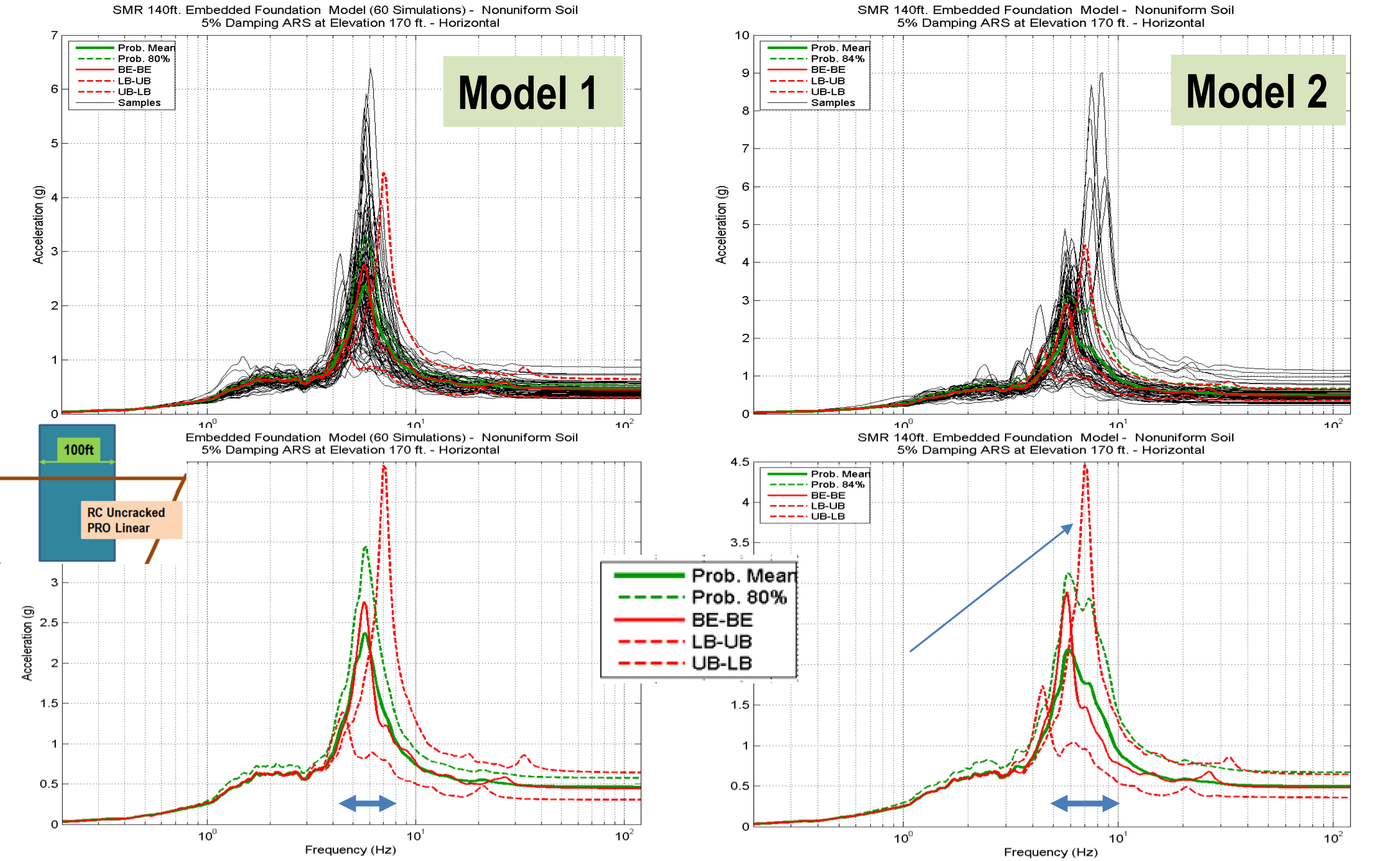
Probabilistic *Horizontal* ISRS (Mean and 80% NEP) vs. Deterministic (LB, BE, UB) at Elev. 0 ft (Foundation Level)



Probabilistic *Vertical* ISRS (Mean and 84% NEP) vs. Deterministic (LB, BE, UB) at Elev. 0 ft (Foundation Level)



Probabilistic *Horizontal* ISRS (Mean and 80% NEP) vs. Deterministic (LB, BE, UB) at El. 170ft (30ft above ground)



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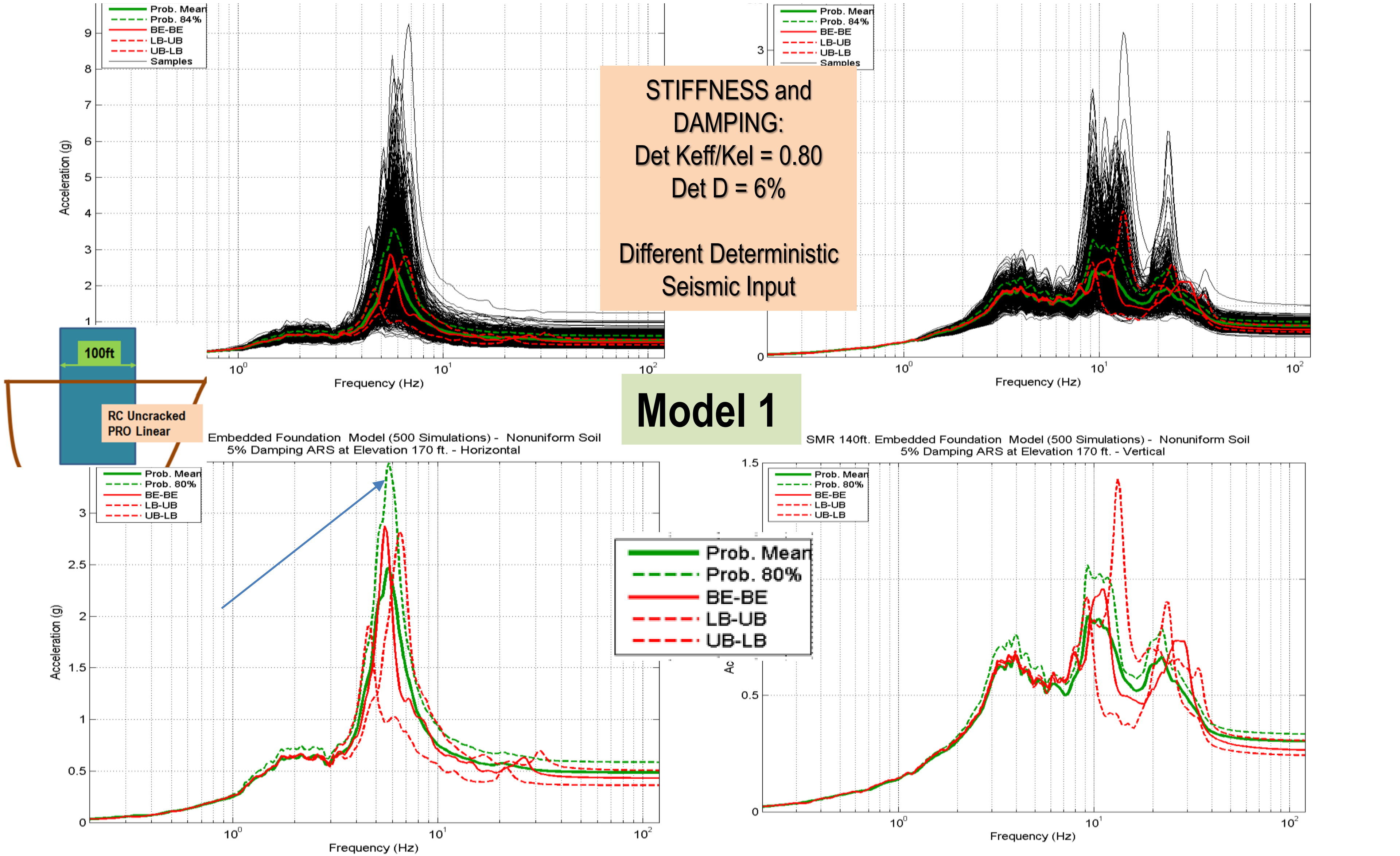
Probabilistic *Horizontal* ISRS (Mean and 80% NEP) vs. Deterministic (LB, BE, UB) at El. 170ft (30ft above ground)



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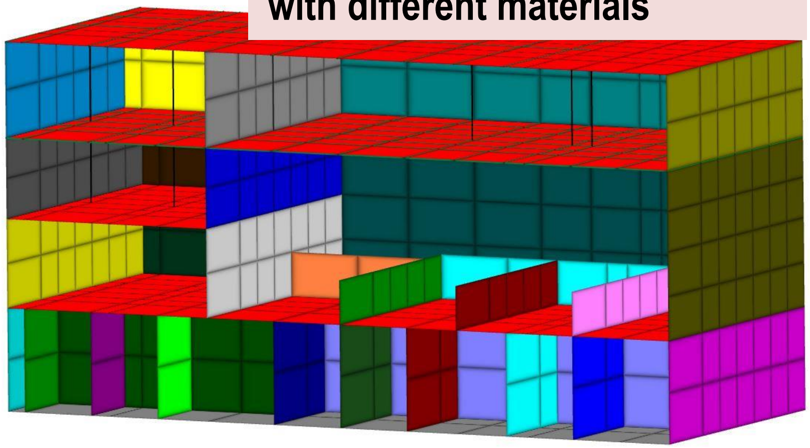
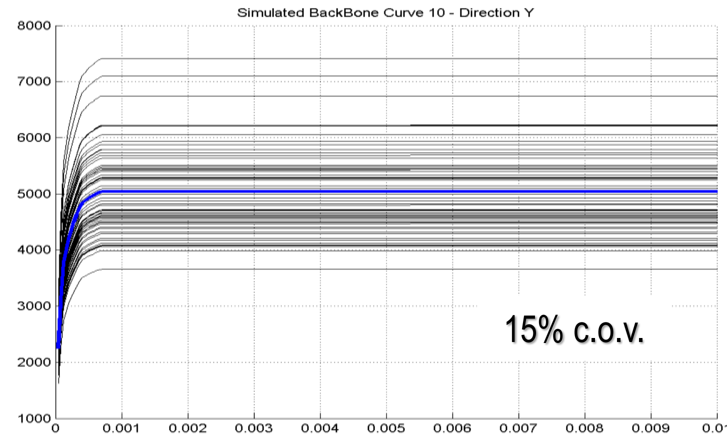
Case No. 4: Probabilistic vs. Deterministic SSI Surface Concrete Structure (Nonlinear Analysis)

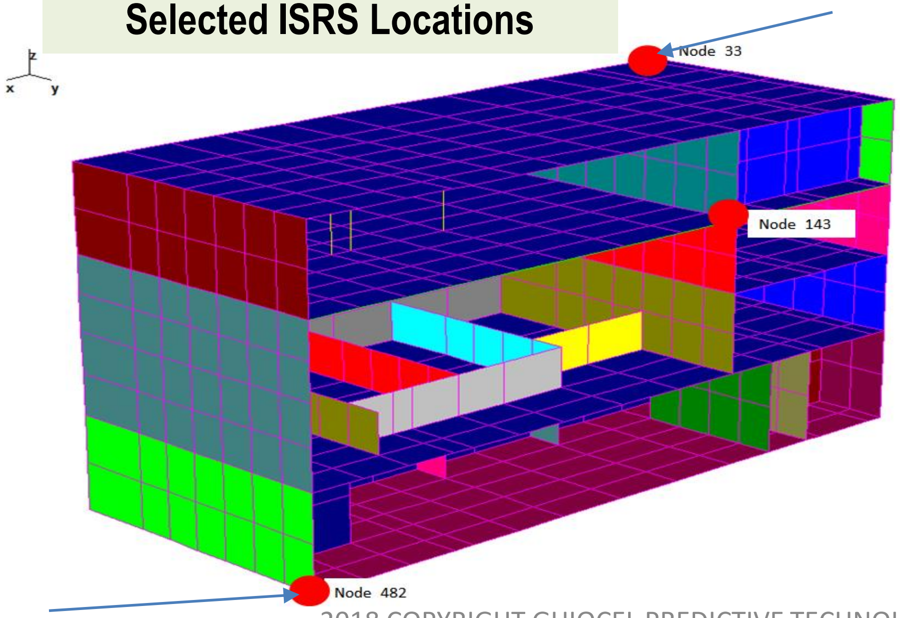
Structure is split in wall panels with different materials



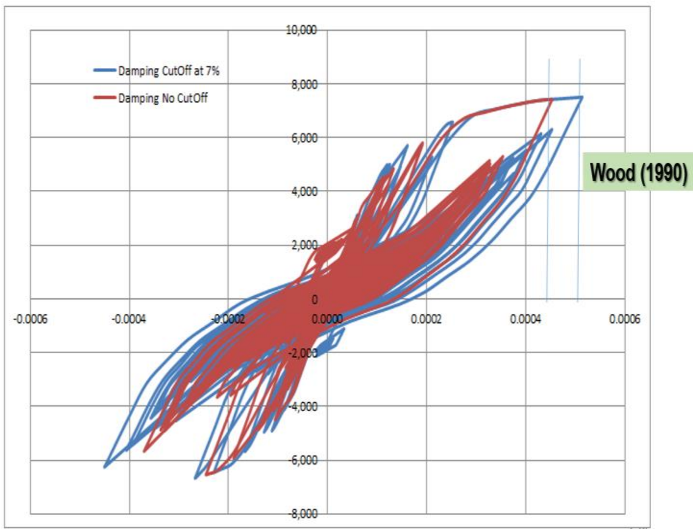
60 Probabilistic Backbone Curve Simulations



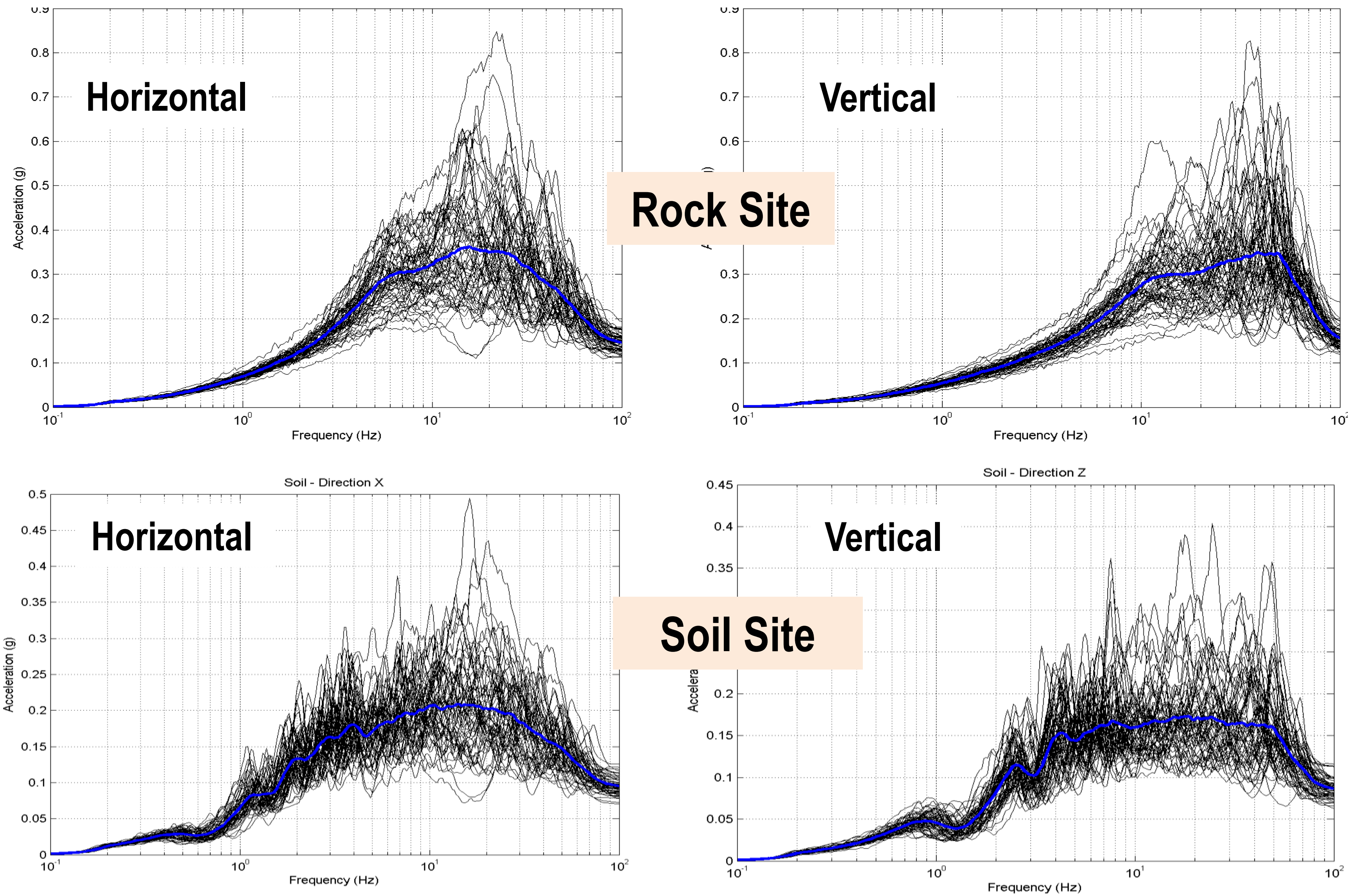
Selected ISRS Locations



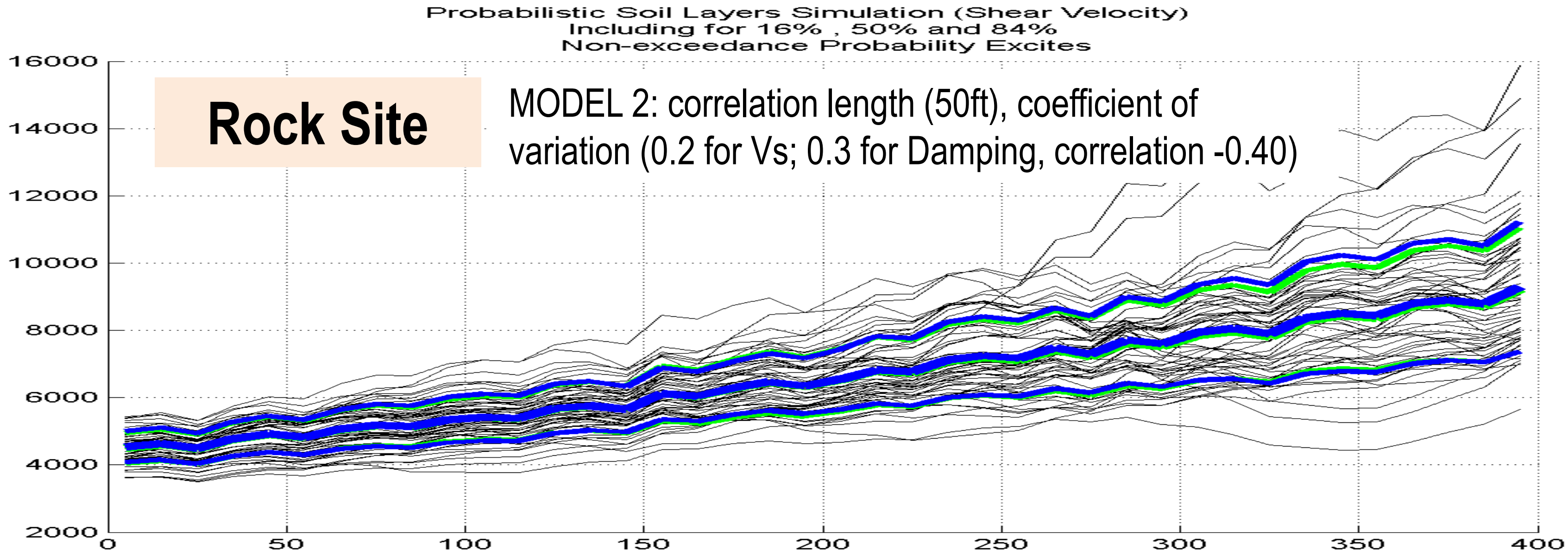
Iterative SSI with 7% Deterministic Damping Cut-off

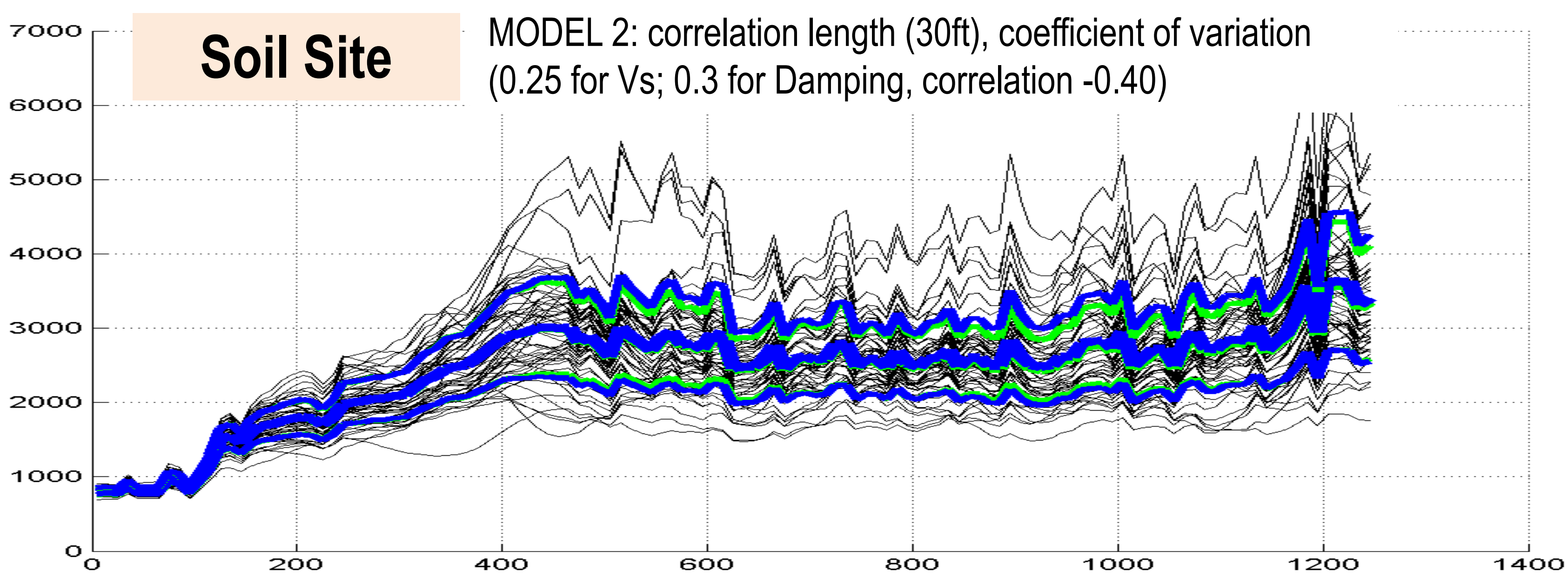


60 Probabilistic Simulations for Surface GRS in Horizontal and Vertical Directions

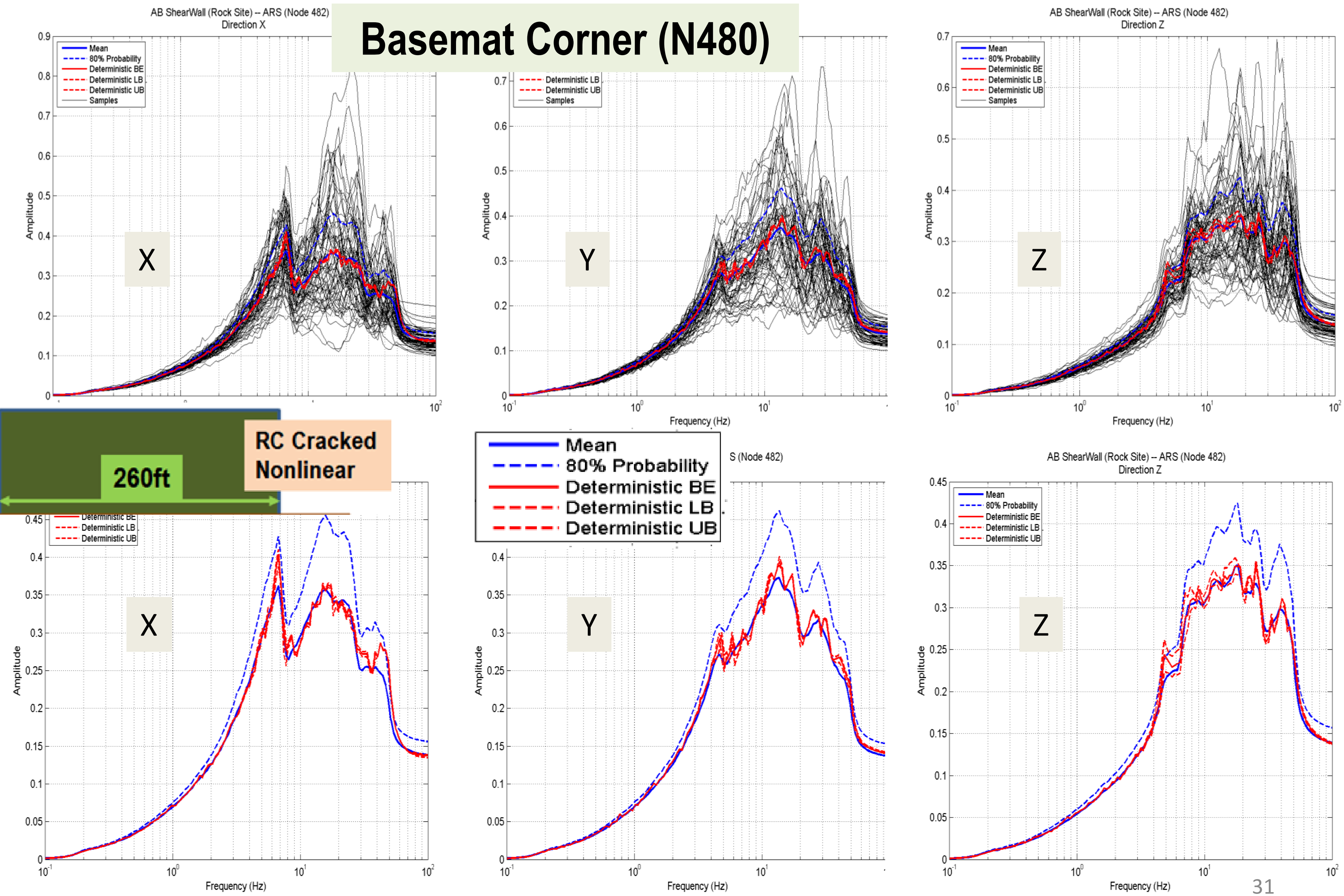


Probabilistic and Deterministic Soil Profiles

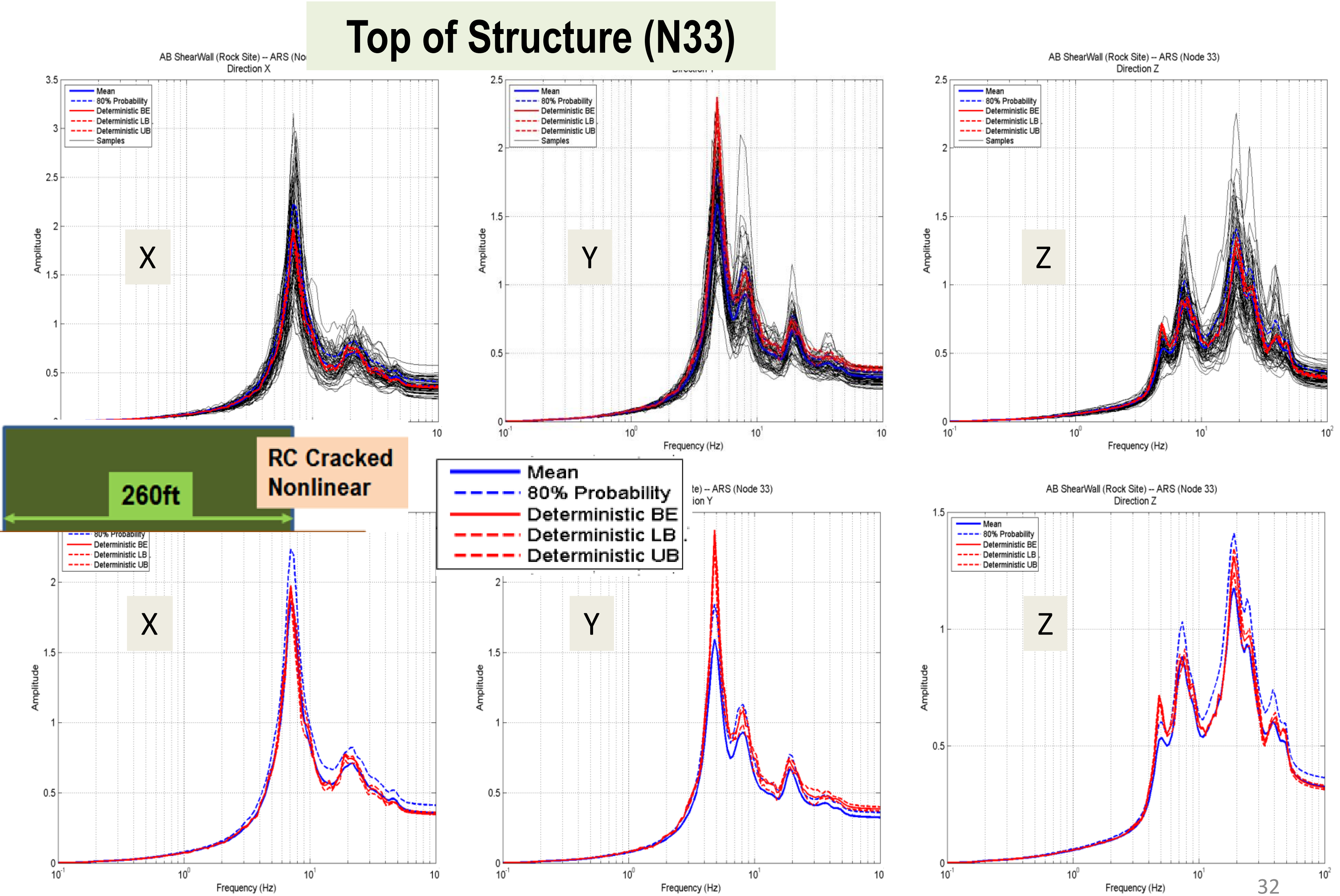




ISRS for Surface Shearwall Structure on Rock



ISRS for Surface Shearwall Structure on Rock



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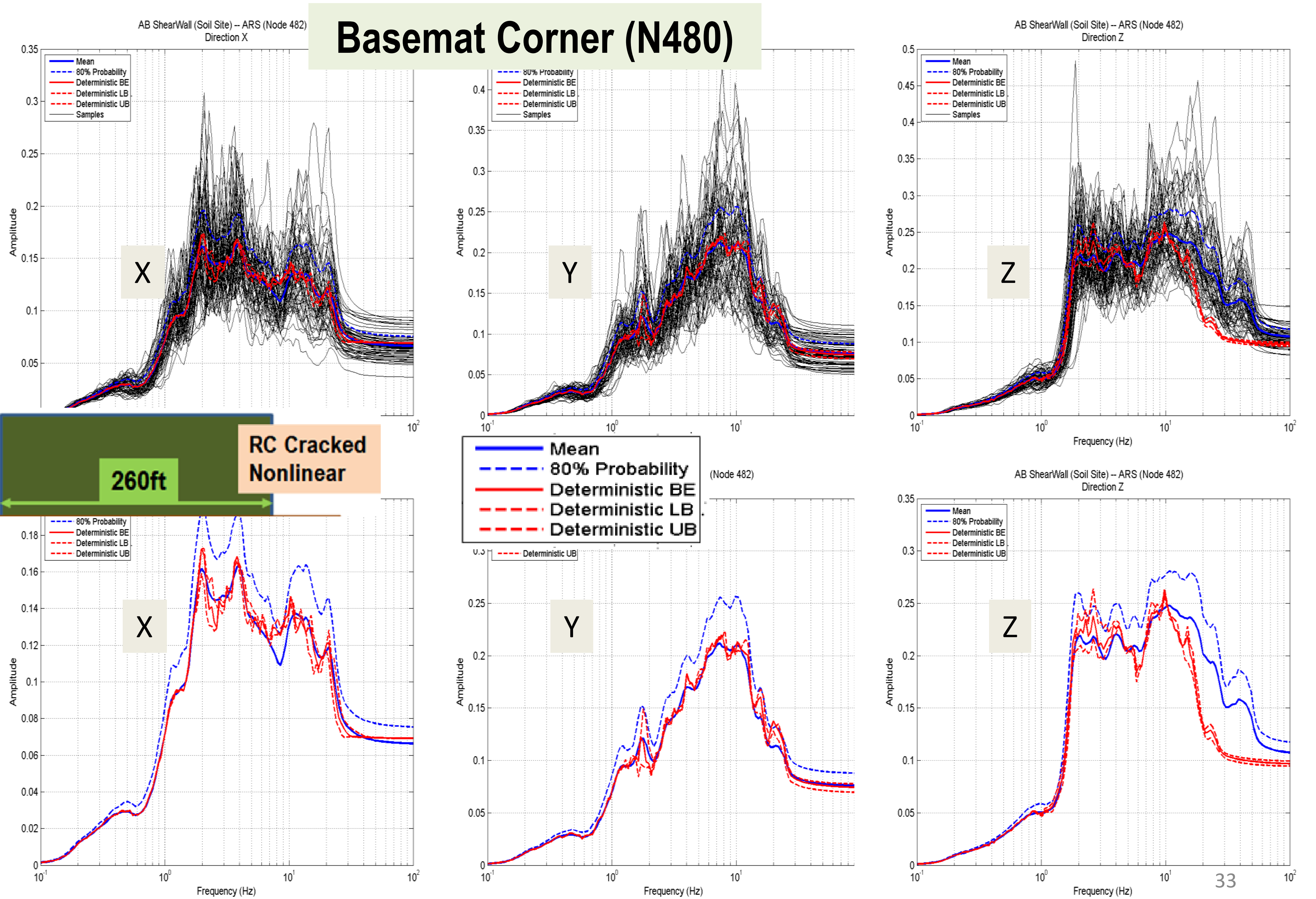
ISRS for Surface Shearwall Structure on Soil



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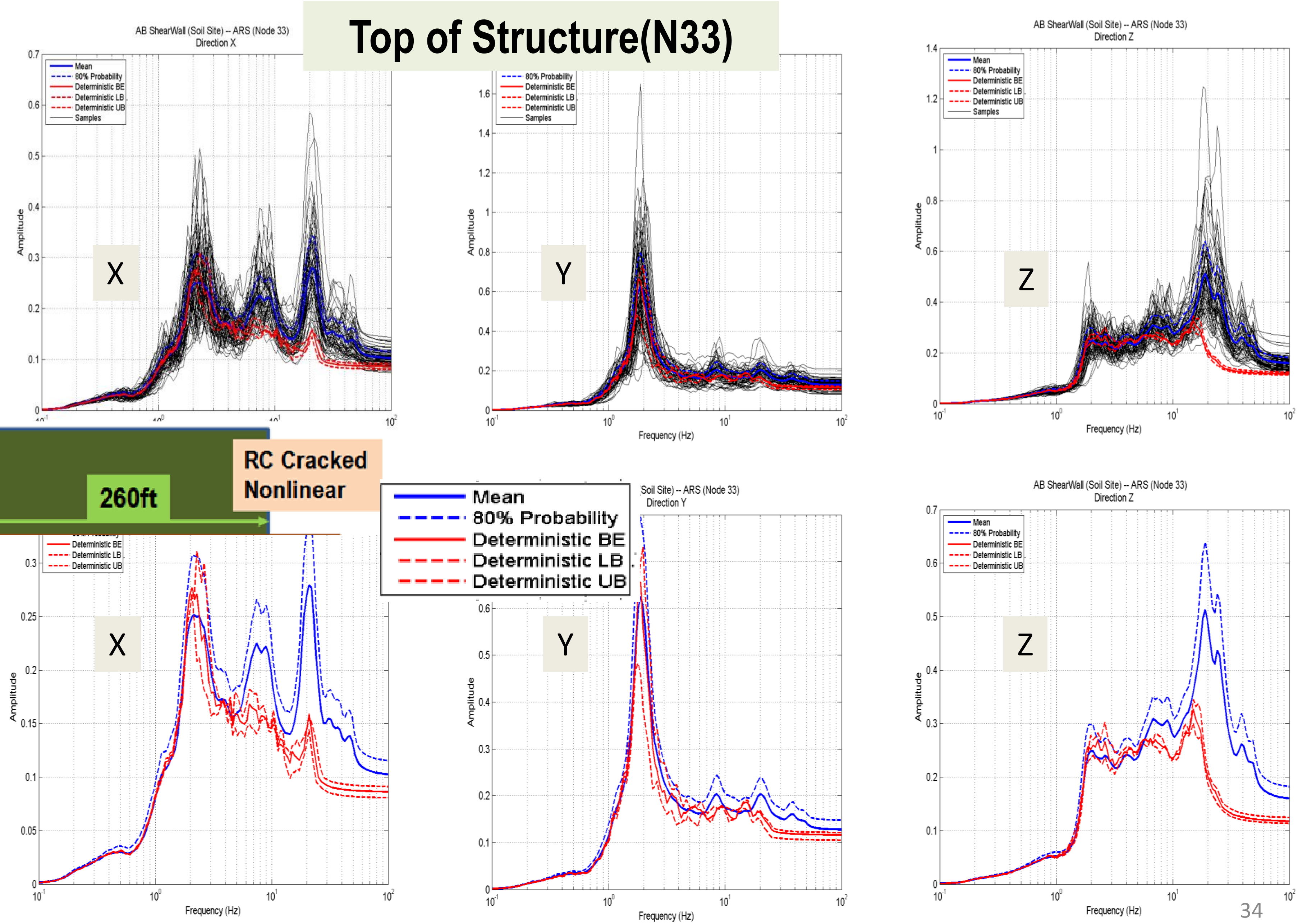
ISRS for Surface Shearwall Structure on Soil



Conclusions

Design-Level:

PSSIA and DSSIA were compared for the same seismic (mean) GRS input:

At Basemat & Lower Elevations:

- The 80% NEP Probabilistic ISRS responses appear to be slightly larger than Deterministic ISRS responses, especially for the rock sites.

At Higher Elevations:

- Deterministic ISRS responses are significantly larger than 80% NEP Probabilistic ISRS if lower damping values for uncracked concrete are included in the DSSIA. If the cracked concrete is included for both PSSIA and DSSIA, then, differences are reduced.

Special attention is required for poor structural designs with significant mass eccentricities (Case 4 for Soil Site) which are much more sensitive to the seismic input random variations, and for which PSSIA can provide much larger ISRS responses than DSSIA.