A COMPARATIVE SEISMIC SSI STUDY FOR A NUCLEAR ISLAND SITTING ON DIFFERENT BASE-ISOLATION SYSTEMS

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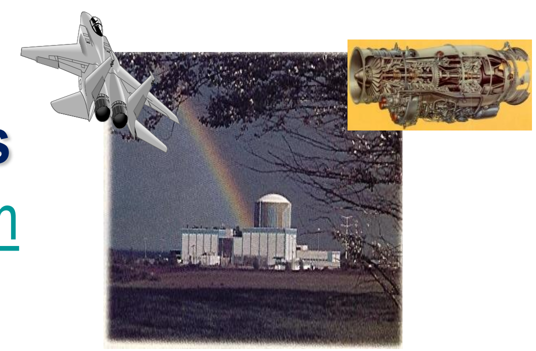


DOE/NRC Natural Phenomena Hazards Meeting

October 20-22, 2020

Purpose of Presentation:

To investigate the effects of base isolation on seismic SSI response of a typical NI complex under *coherent and incoherent* motions using *probabilistic and deterministic SSI* analyses and *different base-isolation systems, LRBs and HVDs*.

The probabilistic and deterministic SSI analyses follow the recommendations of the ASCE 4-16 standard.

Seismic SSI Studies with Base-Isolation

The presentation illustrates key results of a series of studies, done in two project phases, in *2015 (LRBs)* and in *2019 (HVDs)* to investigate

1) Effects of the base-isolation against no base-isolation for *rock sites and soil sites*,

2) Effects of *motion incoherency* on SSI responses

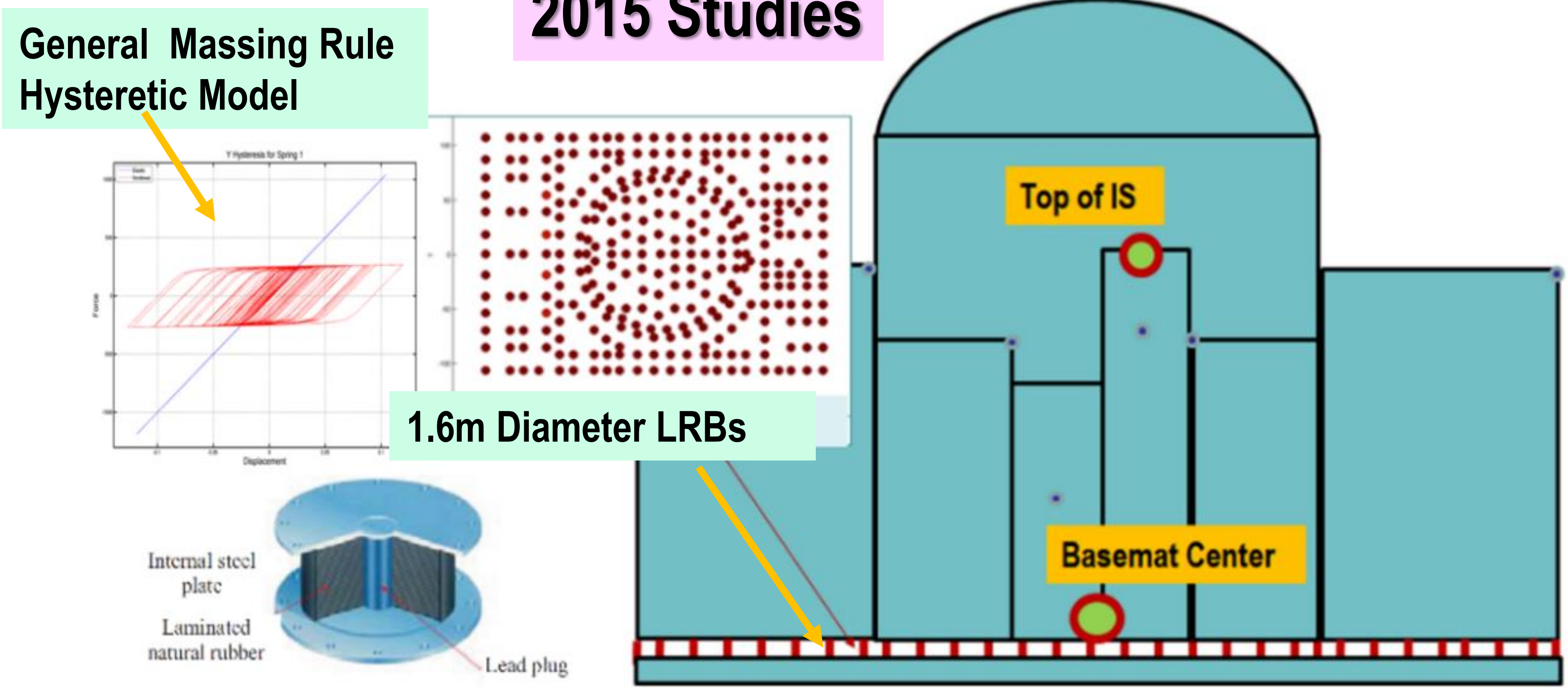
3) *Probabilistic SSI vs. deterministic SSI* analysis

4) Comparison of SSI responses for *3D HVD base-isolators* against the *2D LRB base-isolators*.

5) Concluding remarks

1. Effects of Seismic Base-Isolation on ISRS for Soil and Rock Sites and Coherent Motion

2015 Studies



Soil Layering:
SOIL: Uniform with Vs = 1000 fps
ROCK: Uniform with Vs = 6000 fps

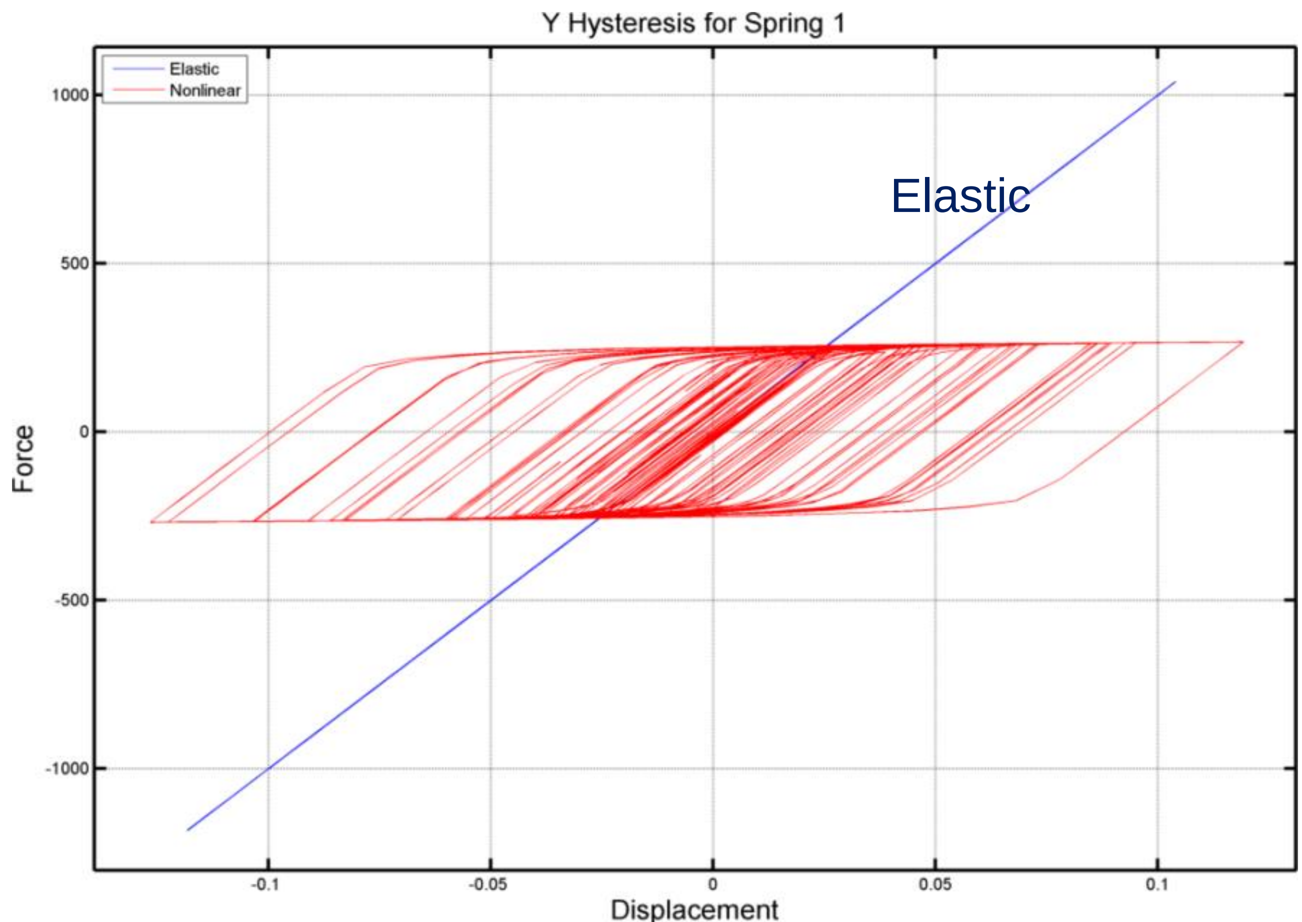
Seismic Input:
RG1.60 Input with 0.30g

Used ACS SASSI software with Option NON (nonlinear springs)

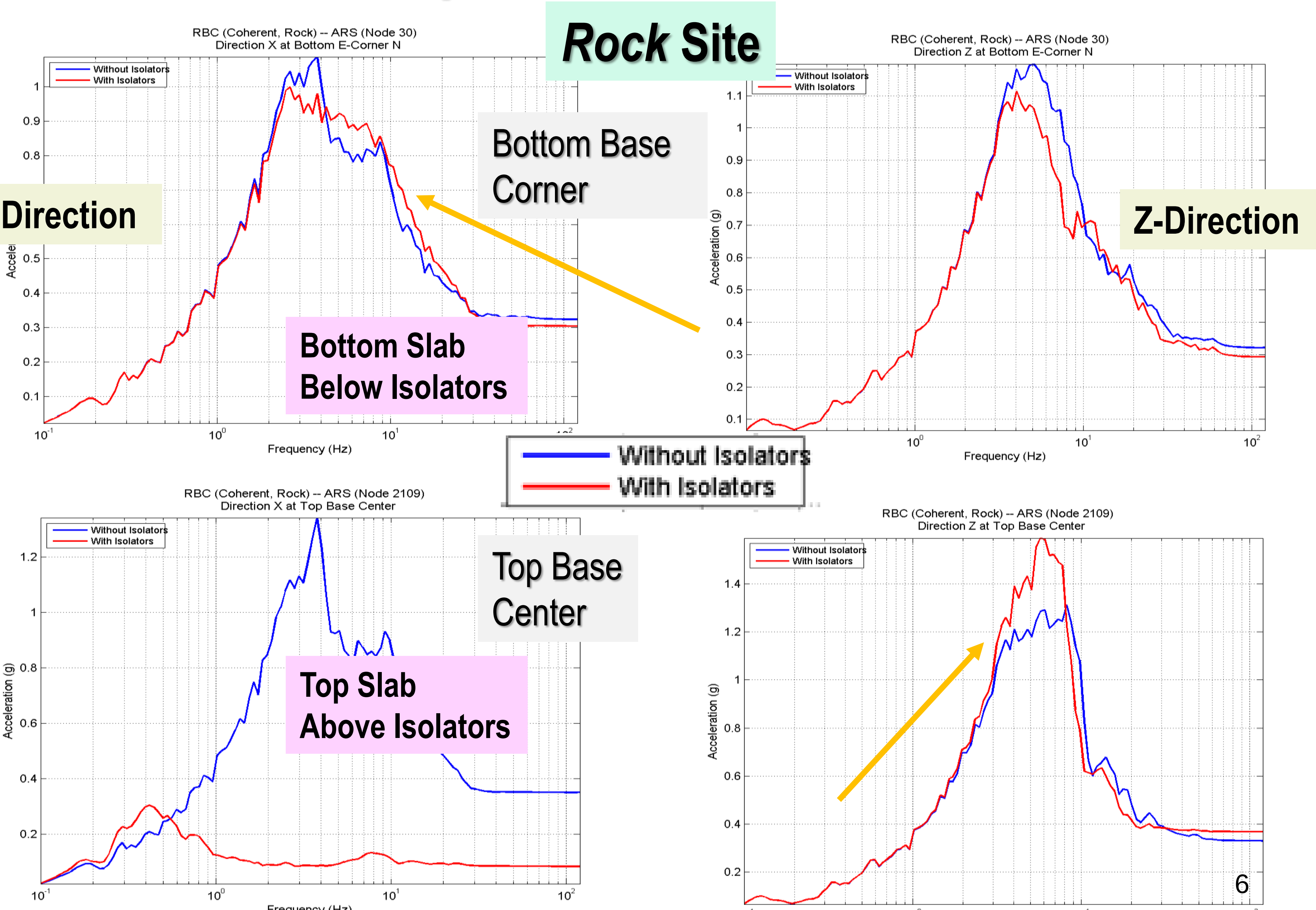
Modelling of the Hysteretic LRB Isolators

By computing *iteratively the SSI response* coupled with an evaluation the *local nonlinear spring behaviour in time domain* for the simultaneous X, Y and Z inputs based on which the equivalent-linear spring is determined.

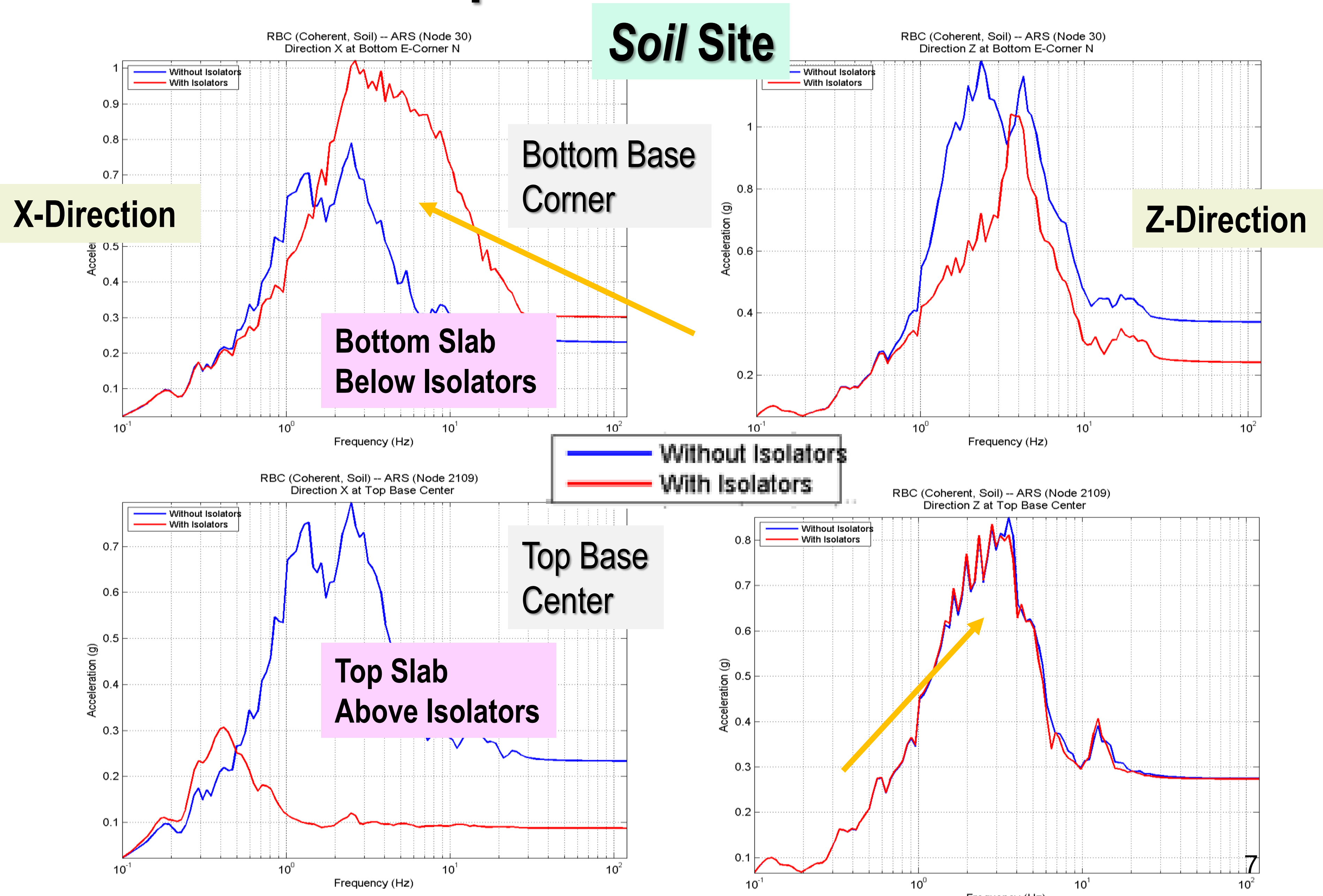
LRB Base-Isolator Hysteresis Loop



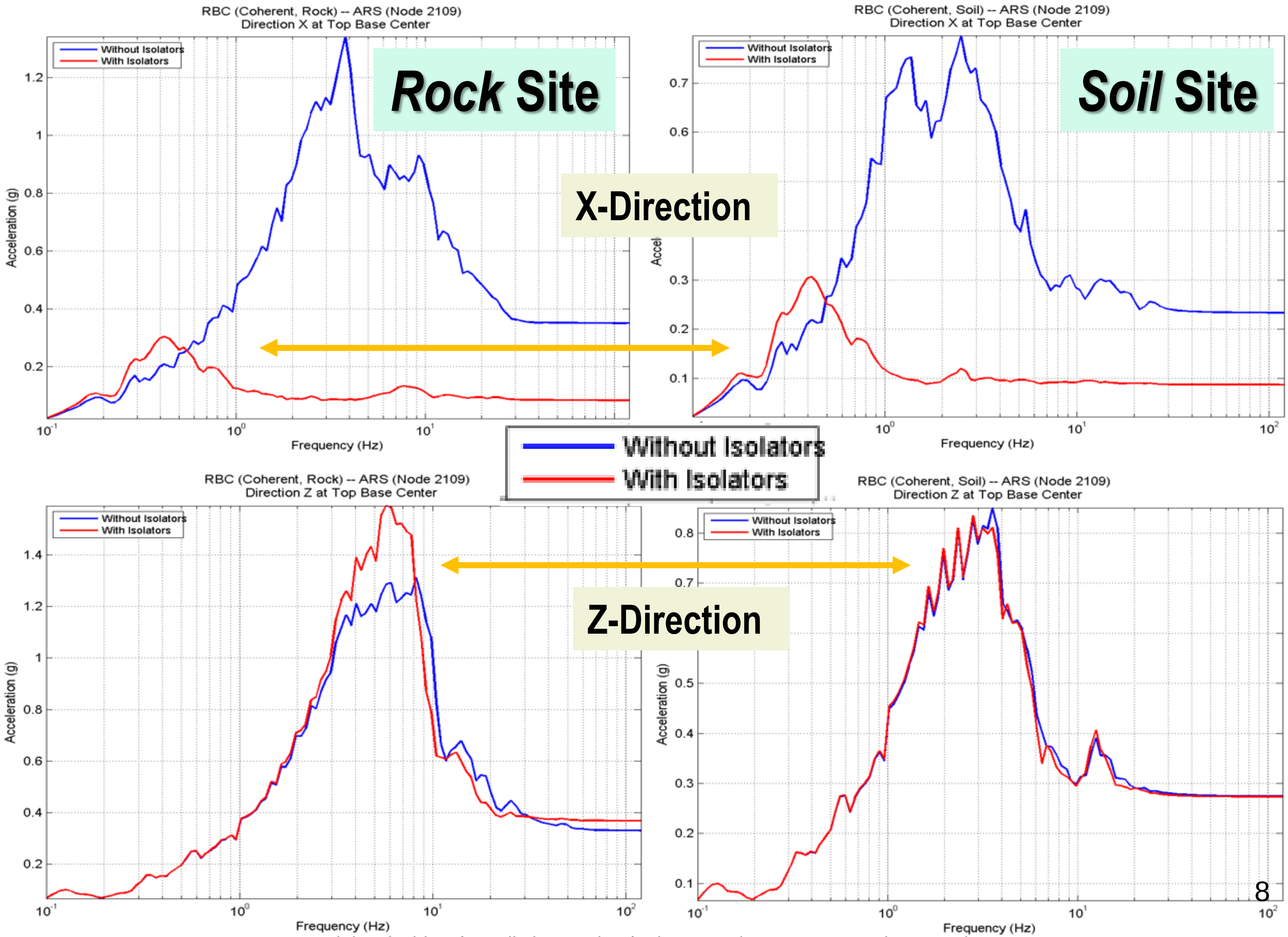
ISRS for NI Complex With and Without Isolators



ISRS for NI Complex *With* and *Without Isolators*

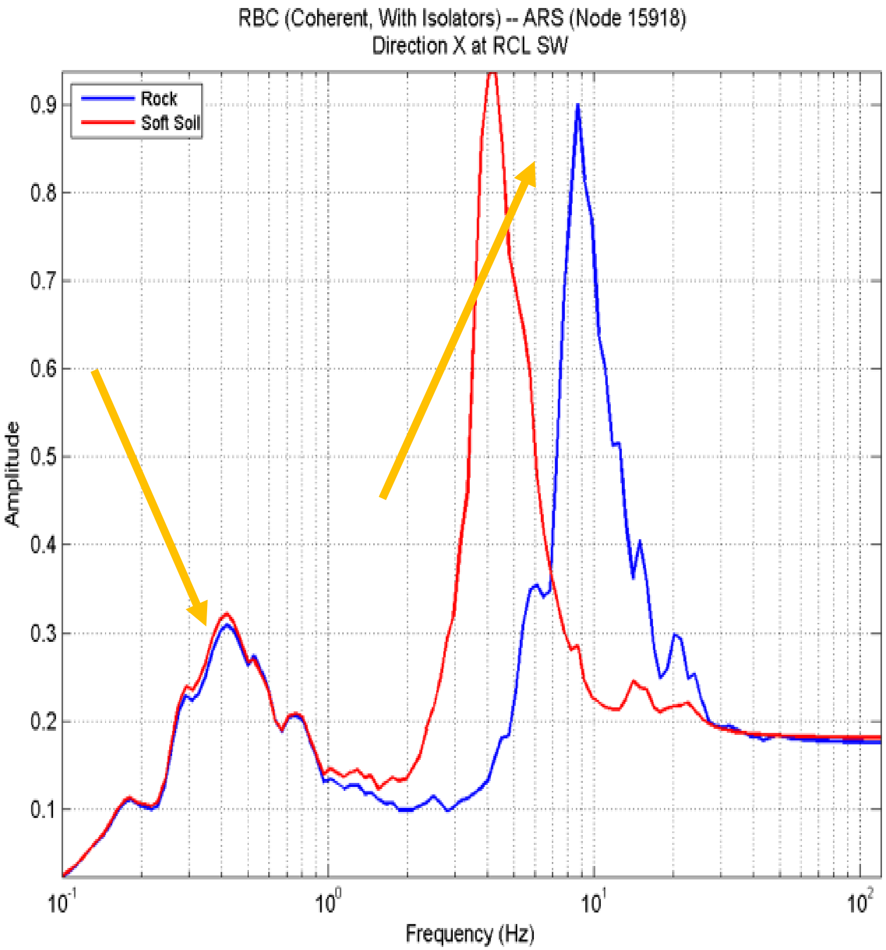


Top Basemat ISRS *With* and *Without Isolators*

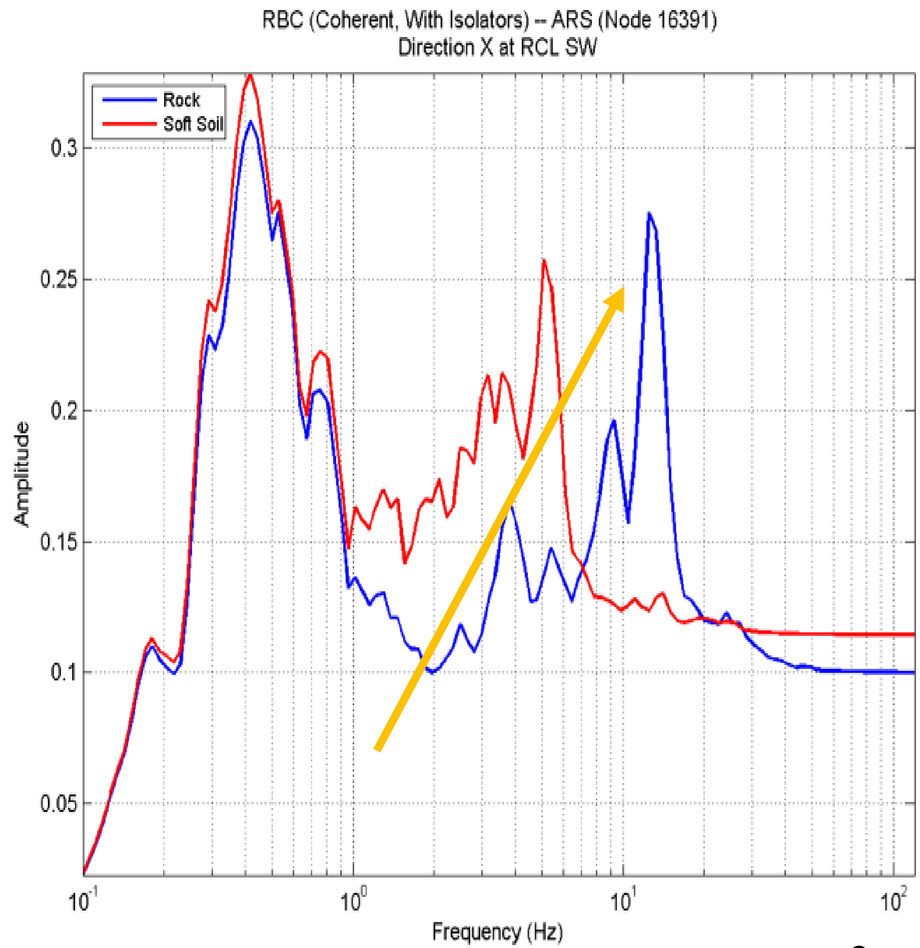


High-Elevation Horizontal ISRS *With Isolators* for Rock and Soil Sites

Location 1



Location 2



2. Effects of Motion Incoherency on ISRS

Incoherent Seismic Input:

- For the comparative coherent vs. incoherent deterministic SSI analysis study, a uniform soil deposit with a Vs of 2,000 fps was considered.

- The incoherent motion was defined based on the Abrahamson coherence function for soil sites (Abrahamson, 2007).

- Additionally, an apparent traveling wave velocity of 6,000 fps was included to simulate wave passage effects in X-longitudinal direction.

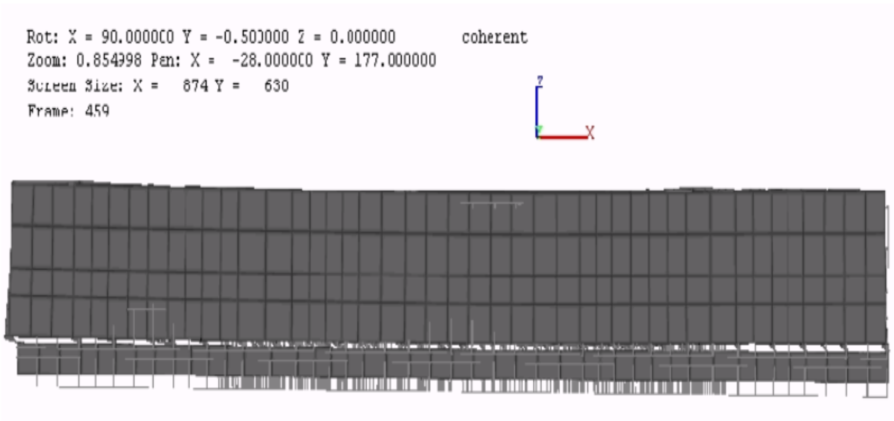
- For the incoherent SSI analysis, the rigorous stochastic simulation approach (with no phase adjustment) based on an accurate Monte Carlo soil motion wavefield simulations was used.

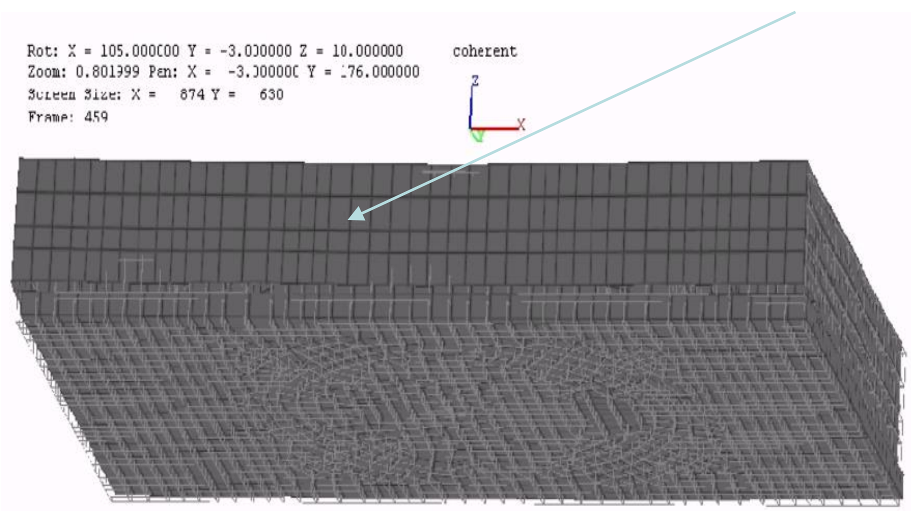
- Several incoherent seismic wavefields were simulated.

Extreme Incoherency conditions were used.

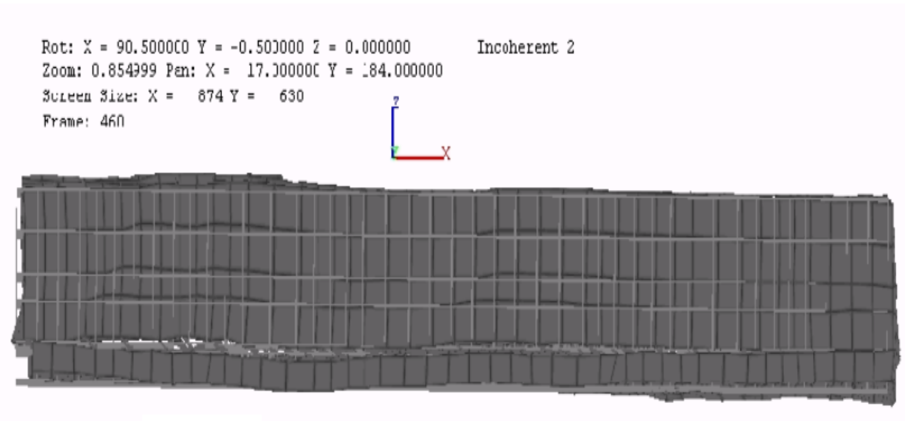
Coherent and Incoherent SSI Responses

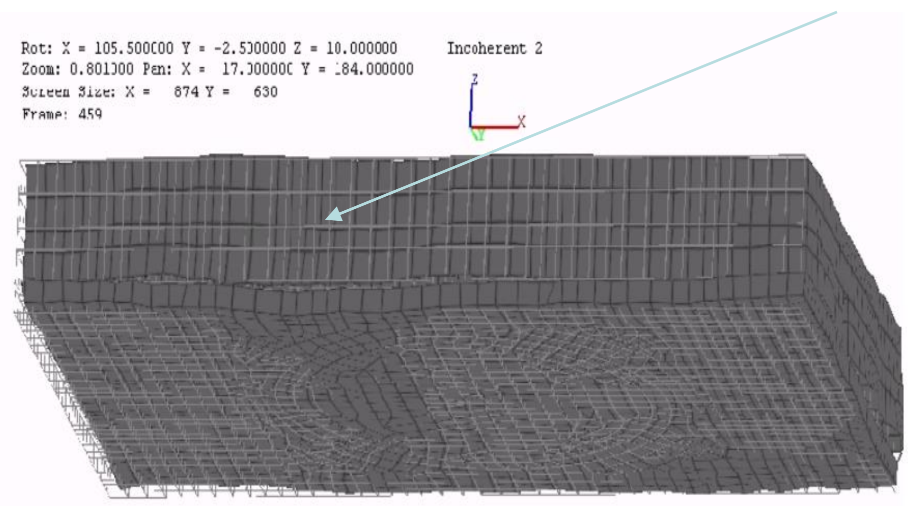
Coherent Accelerations





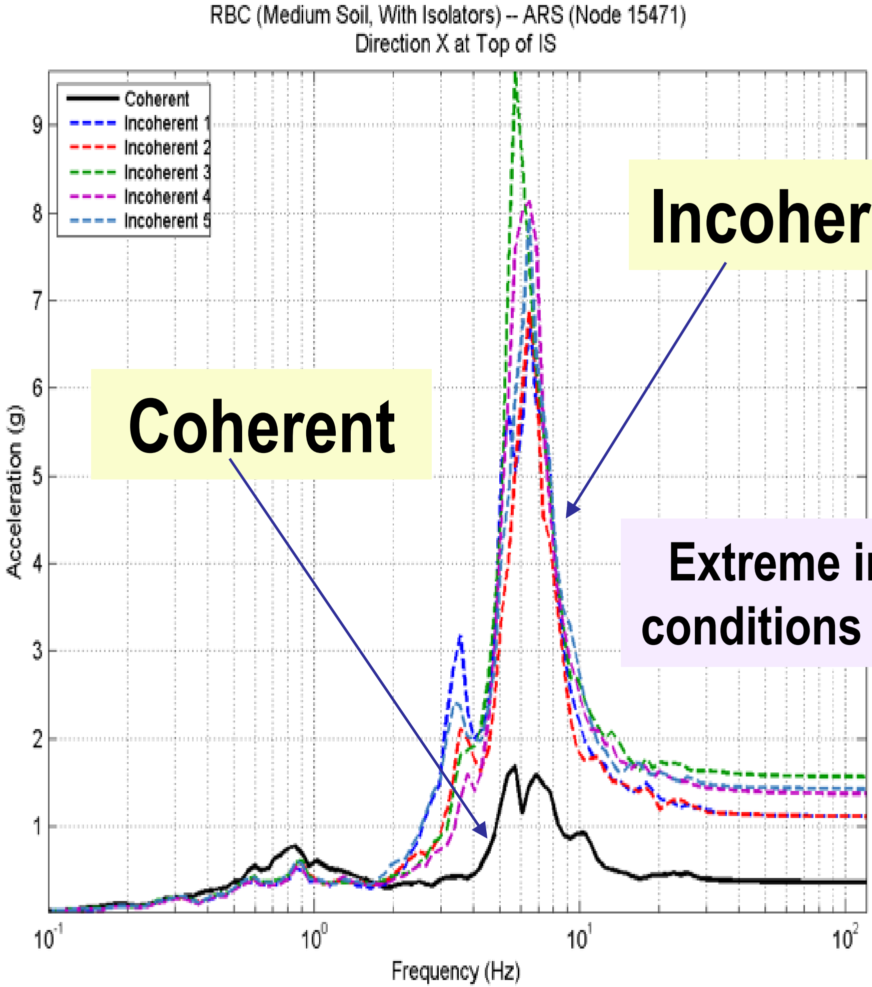
Incoherent Accelerations





Horizontal and Vertical ISRS at Top of IS

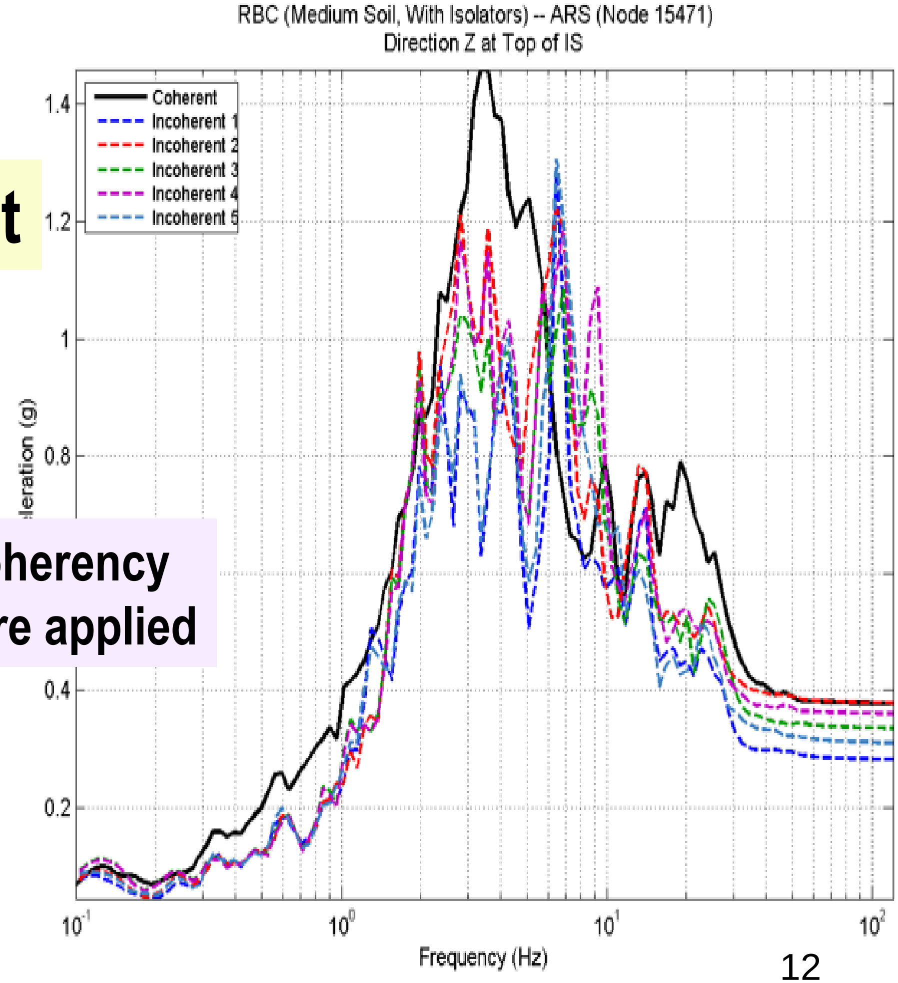
Horizontal



Coherent

Incoherent

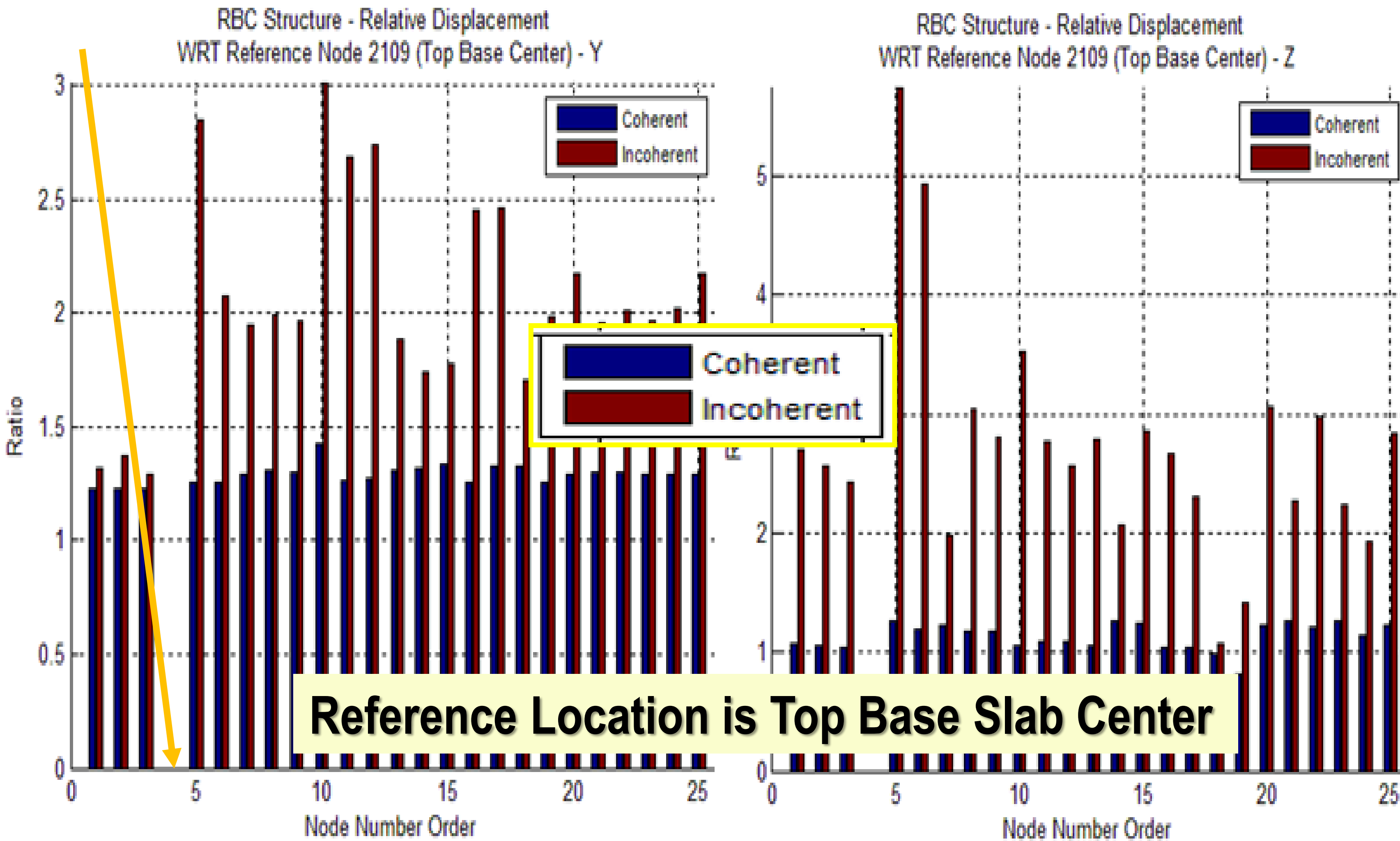
Vertical



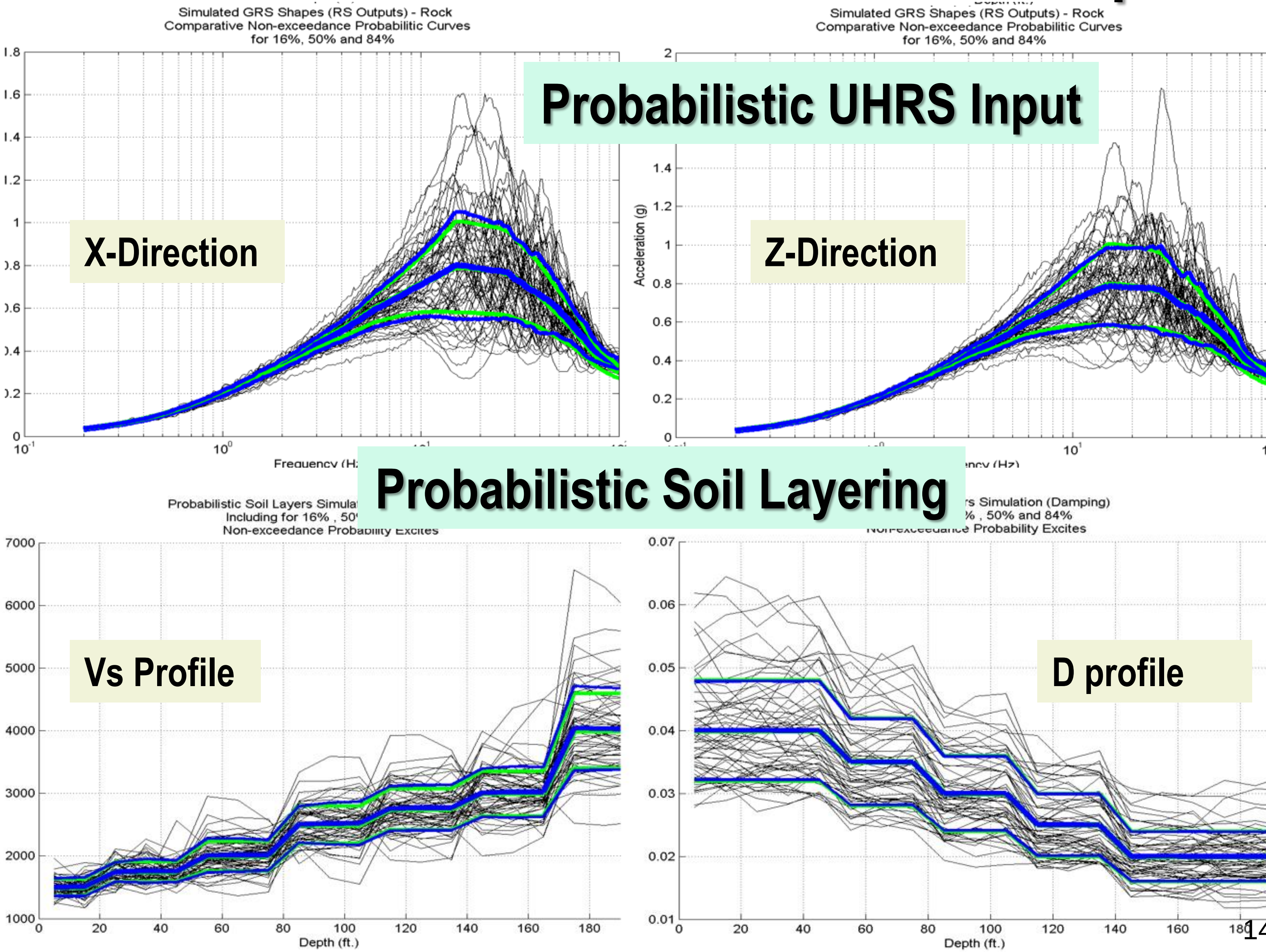
Extreme incoherency conditions were applied

Effects of Motion Incoherency on Relative Displacements at NI Complex Critical Locations

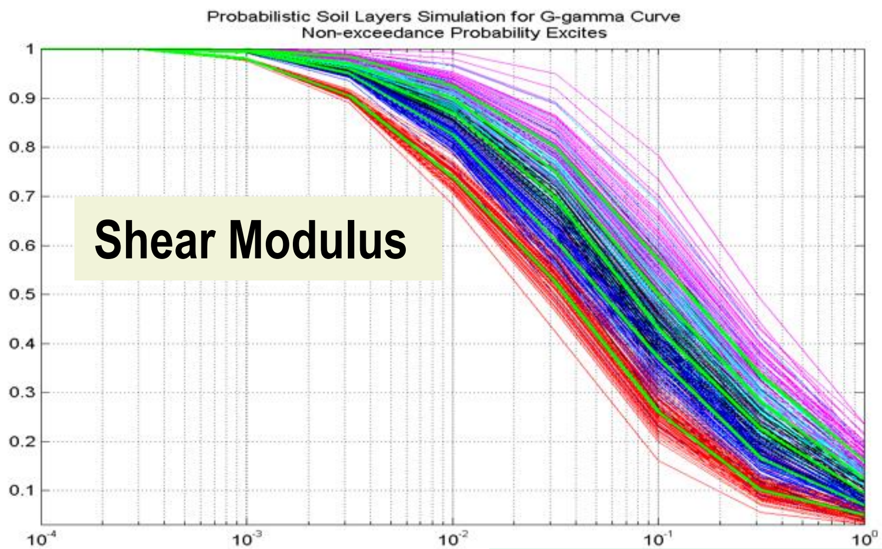
Horizontal **Vertical**

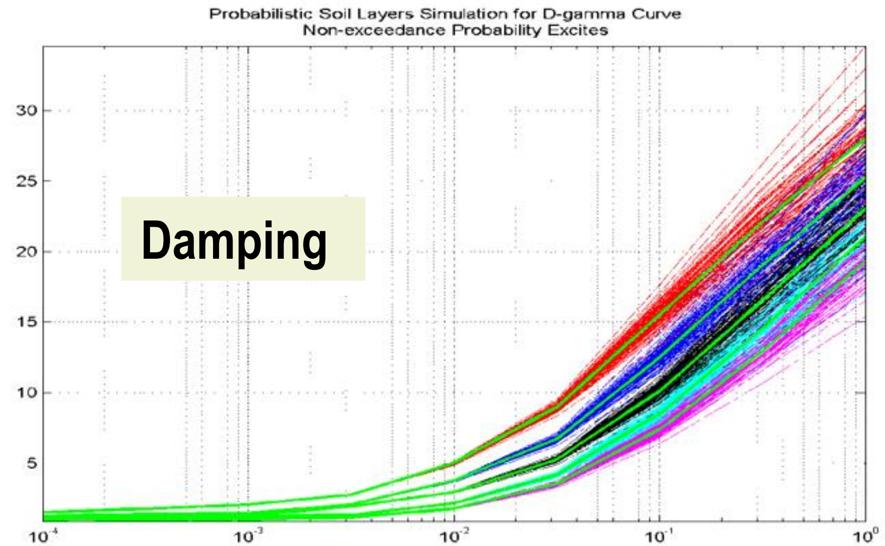


3. Probabilistic vs. Deterministic SSI Responses

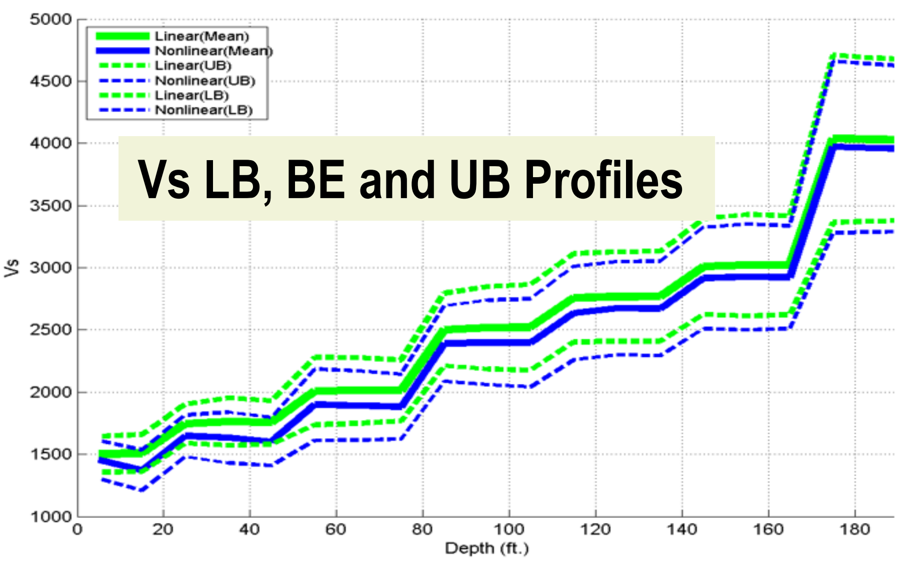


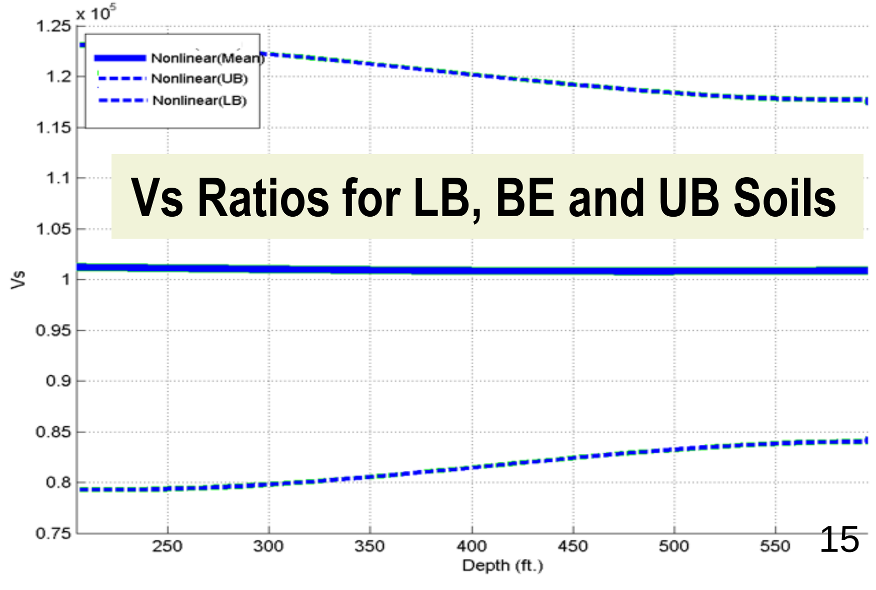
Probabilistic Soil Material Curves



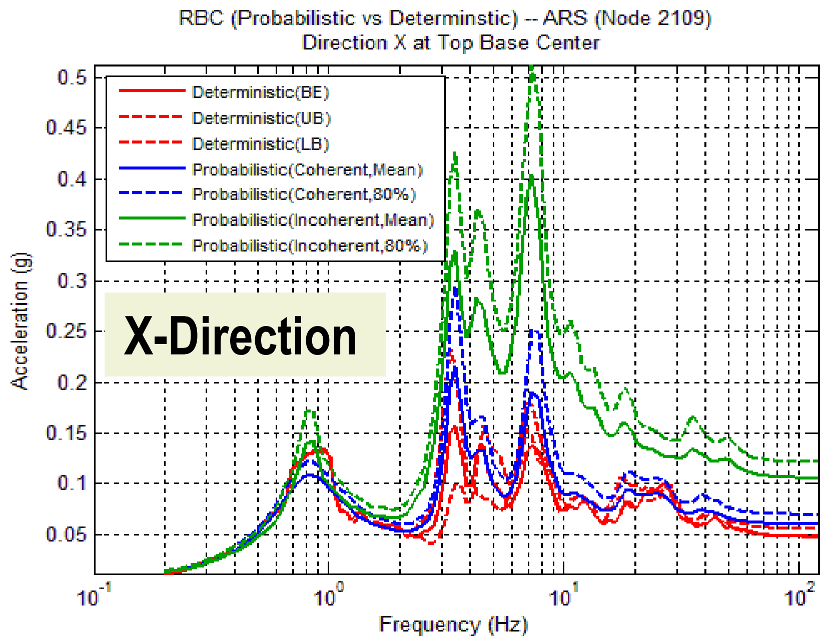


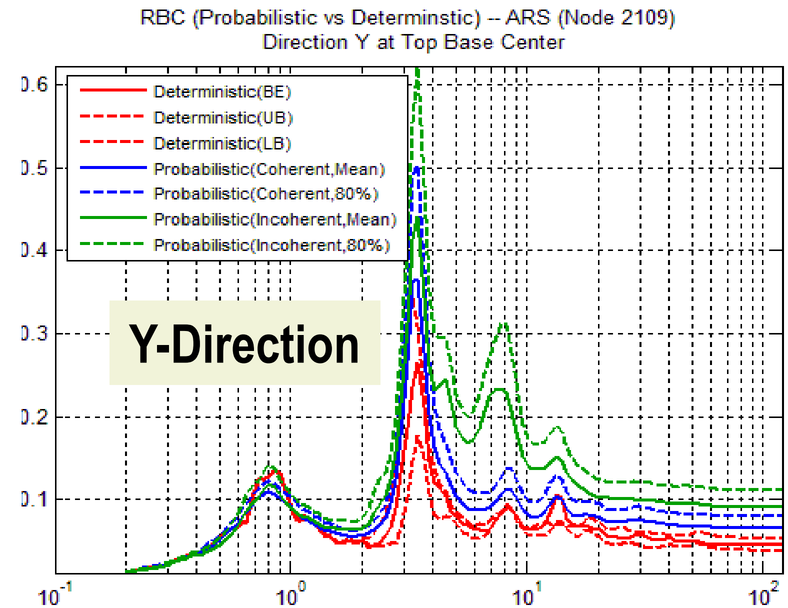
Deterministic Soil Profiles



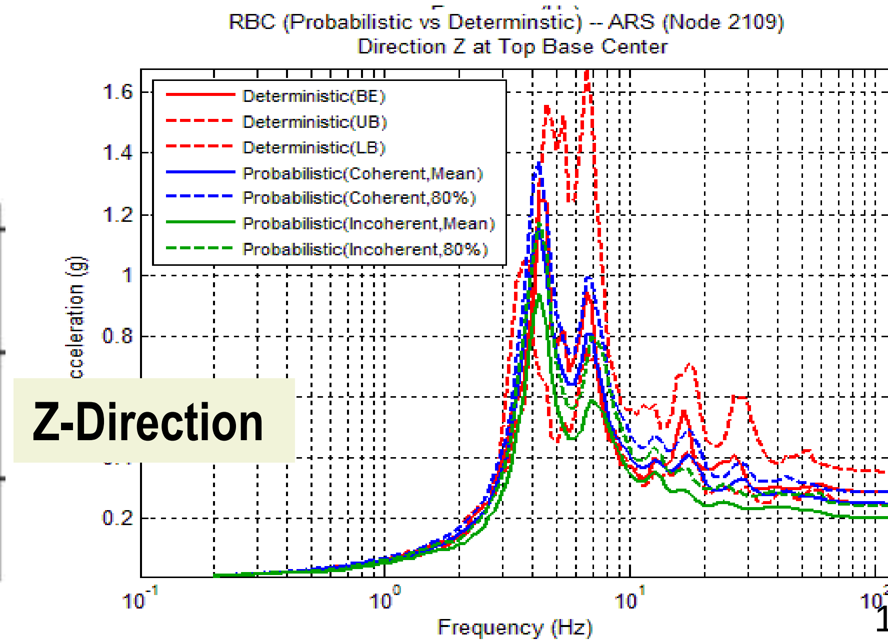


Probabilistic-Deterministic ISRS for NI Complex

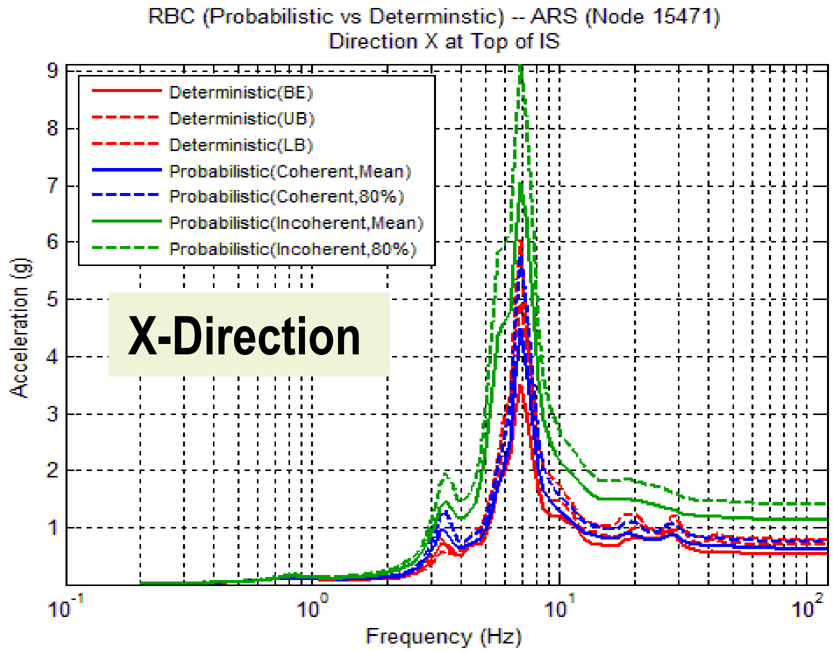


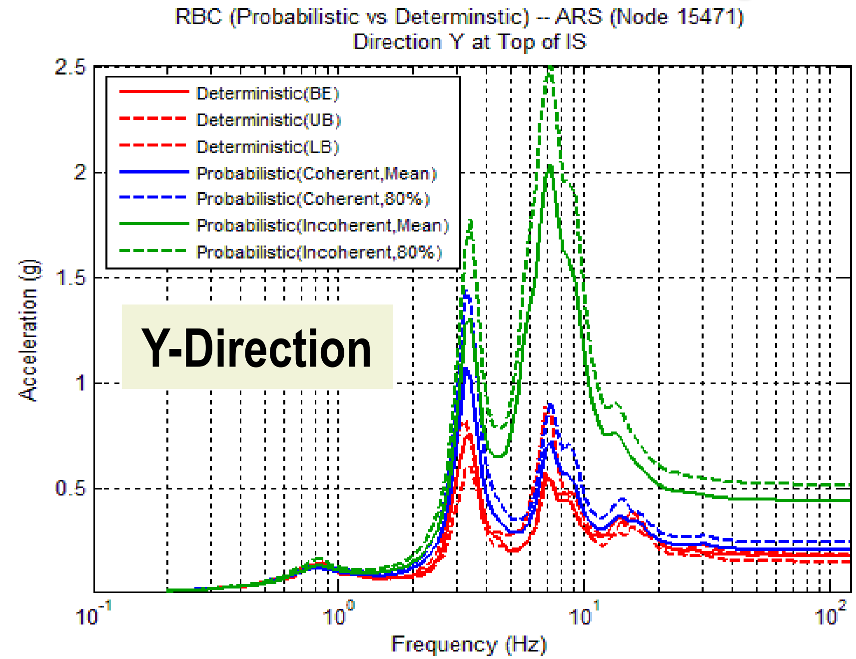


Top Base Center

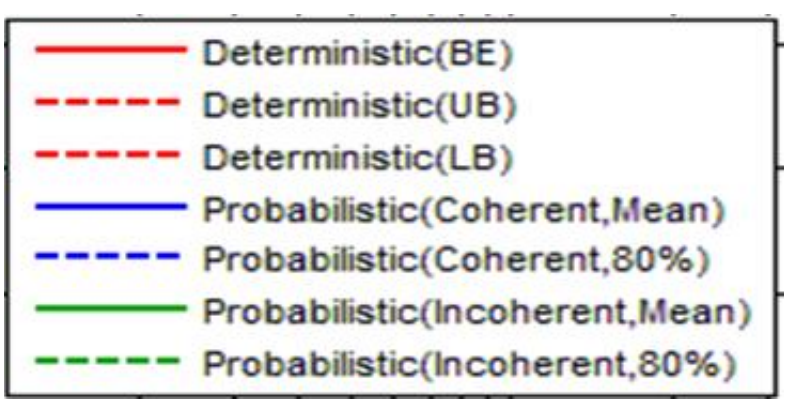


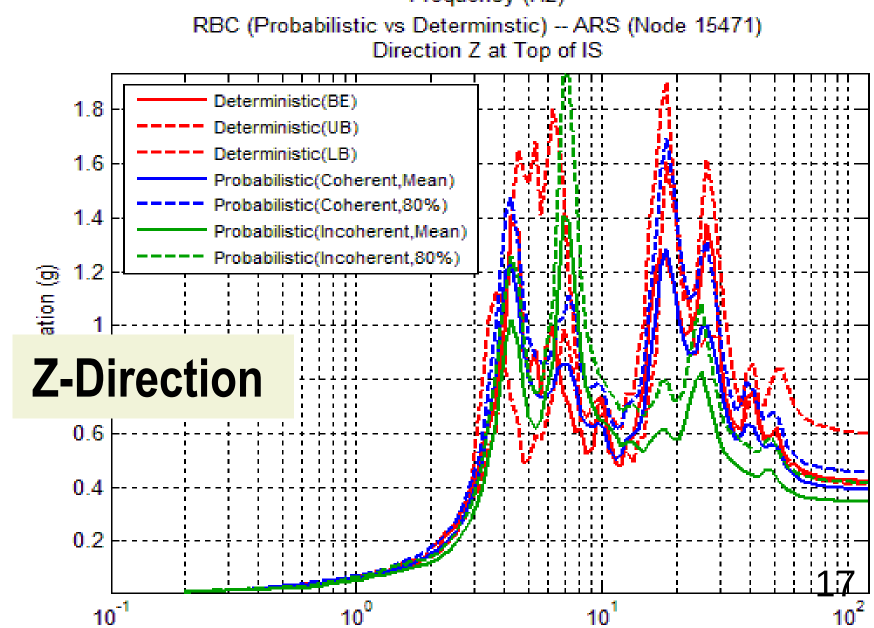
Probabilistic-Deterministic ISRS for NI Complex





Top of IS





Some Remarks from 2015 Studies:

- Probabilistic SSI analysis results are larger than Deterministic SSI analysis results for the coherent inputs.
- Probabilistic SSI analysis produces significantly larger ISRS amplifications for the higher frequency modes.
- Motion incoherency increases significantly the ISRS and the relative displacements within the NI complex.

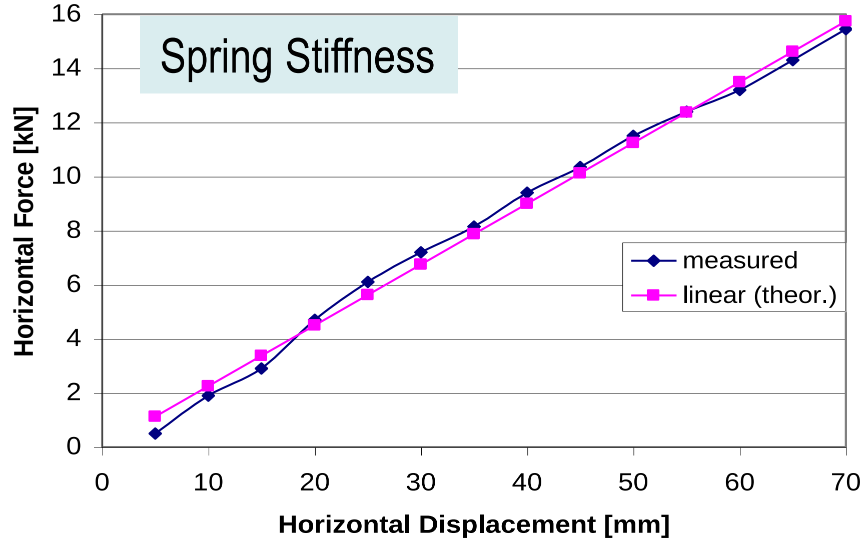
For the coherent-incoherent comparisons, extreme incoherency and wave passage, to evaluate the upper bound effects due to the motion spatial variation.

4. Frequency-Dependent 3D HVD isolators

GERB 3D BCS

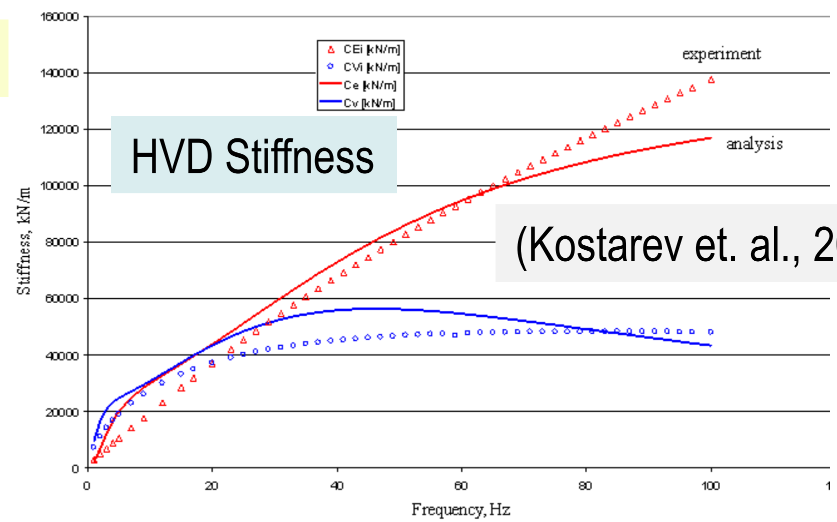
2019 Studies

3D Springs



(Nawrotzki et al., 2018)

3D HV Dampers



(Kostarev et. al., 2018)

3D HVD is a new ACS SASSI element

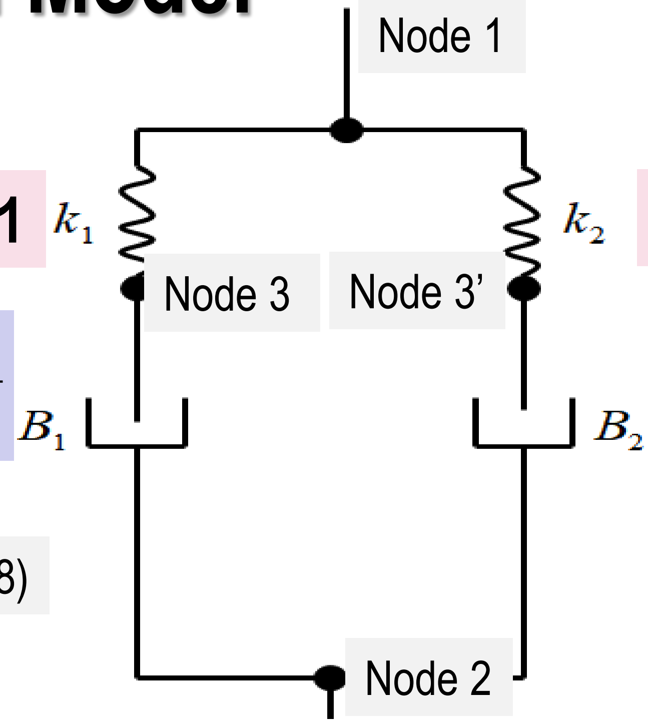
3-Node HVD Element is Based on 4-Parameter Maxwell Model

3D HVD

(Nawrotzki, Kostarev et al, 2018)

Chain 1

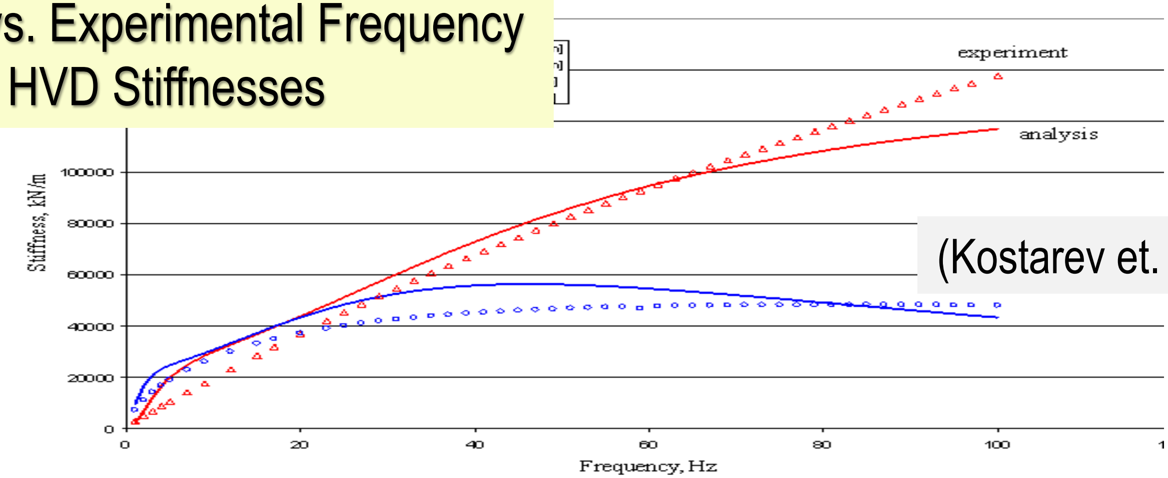
$$\omega_1 = \frac{k_1}{B_1}$$



Chain 2

$$\omega_2 = \frac{k_2}{B_2}$$

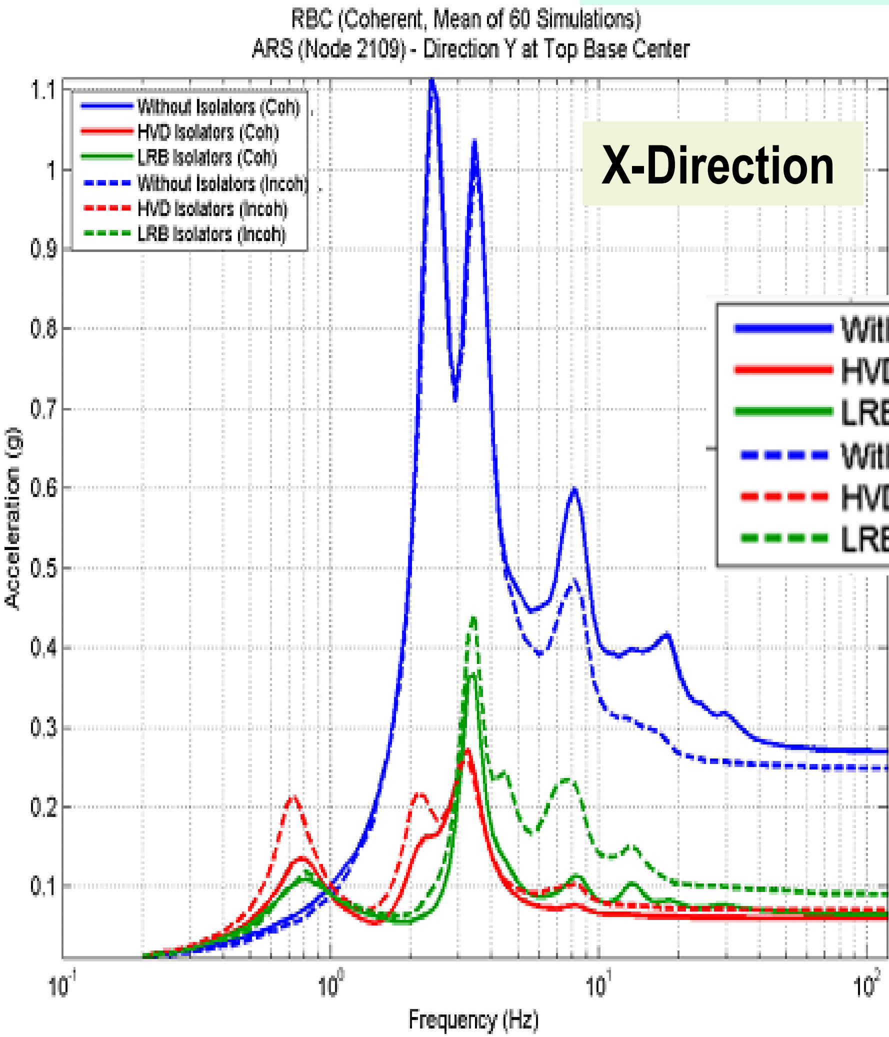
Analytical vs. Experimental Frequency Dependent HVD Stiffnesses

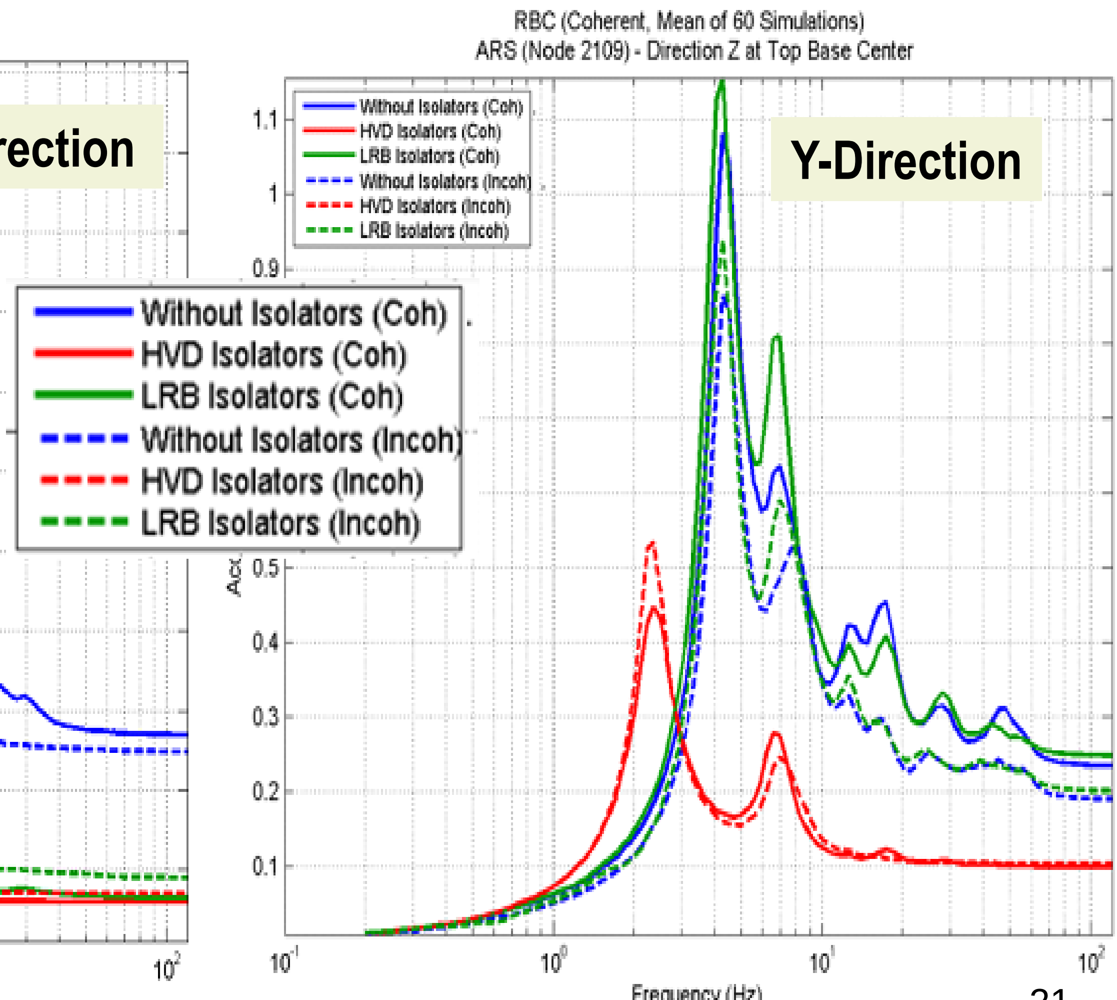


(Kostarev et. al., 2018)

Comparative Coherent vs. Incoherent ISRS for No Isolators vs. HVD and LRB Isolators

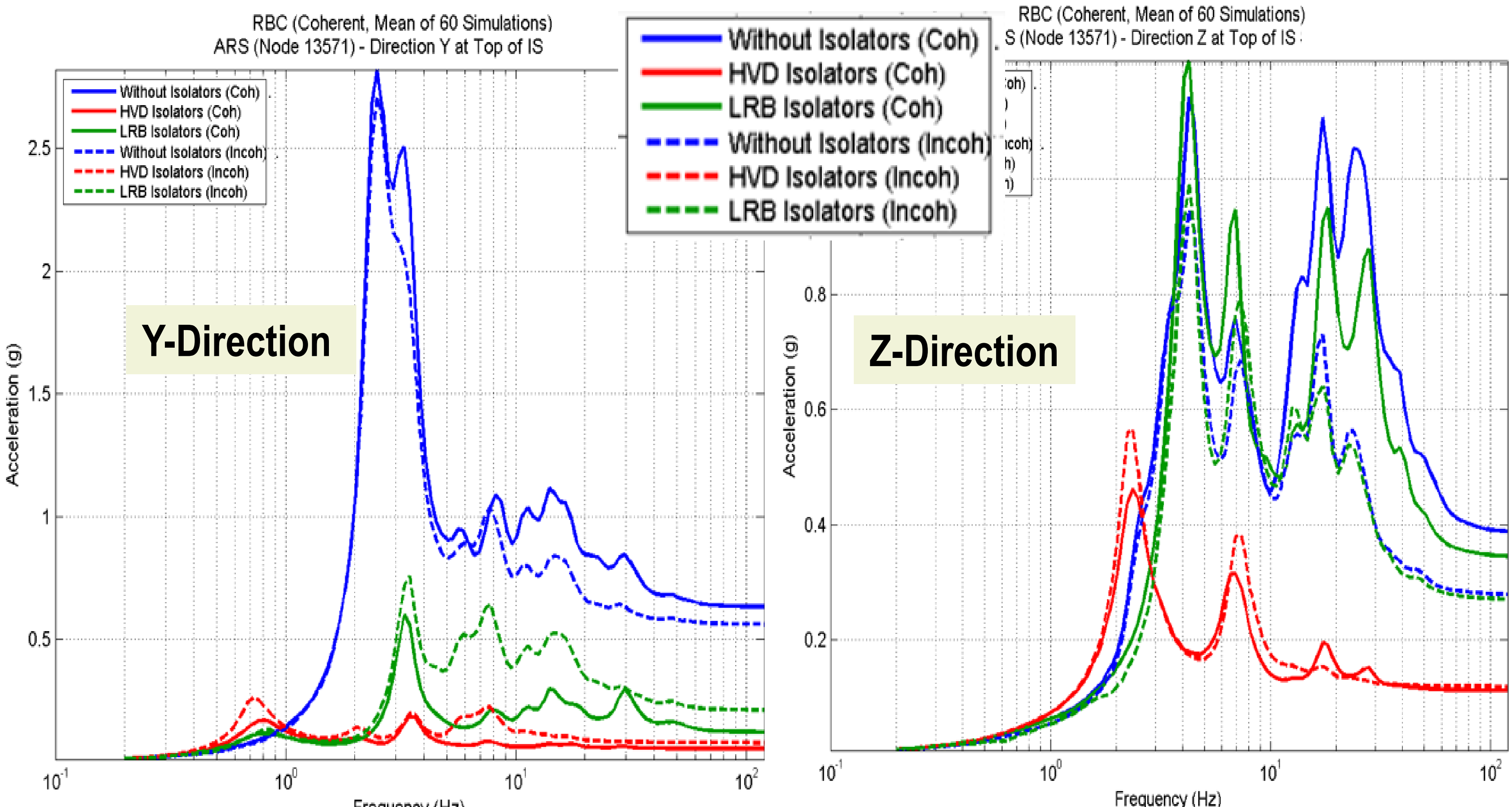
Top Base Slab Center





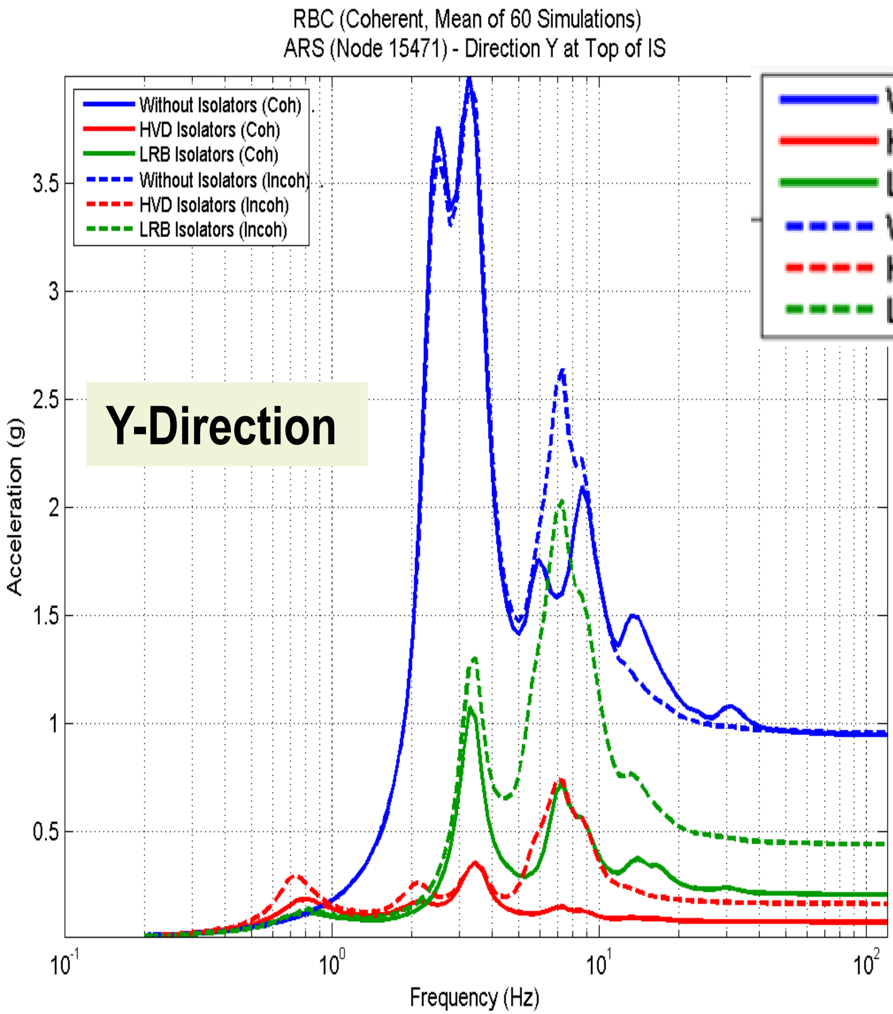
Comparative Coherent vs. Incoherent Mean ISRS for No Isolators vs. HVD and LRB Isolators

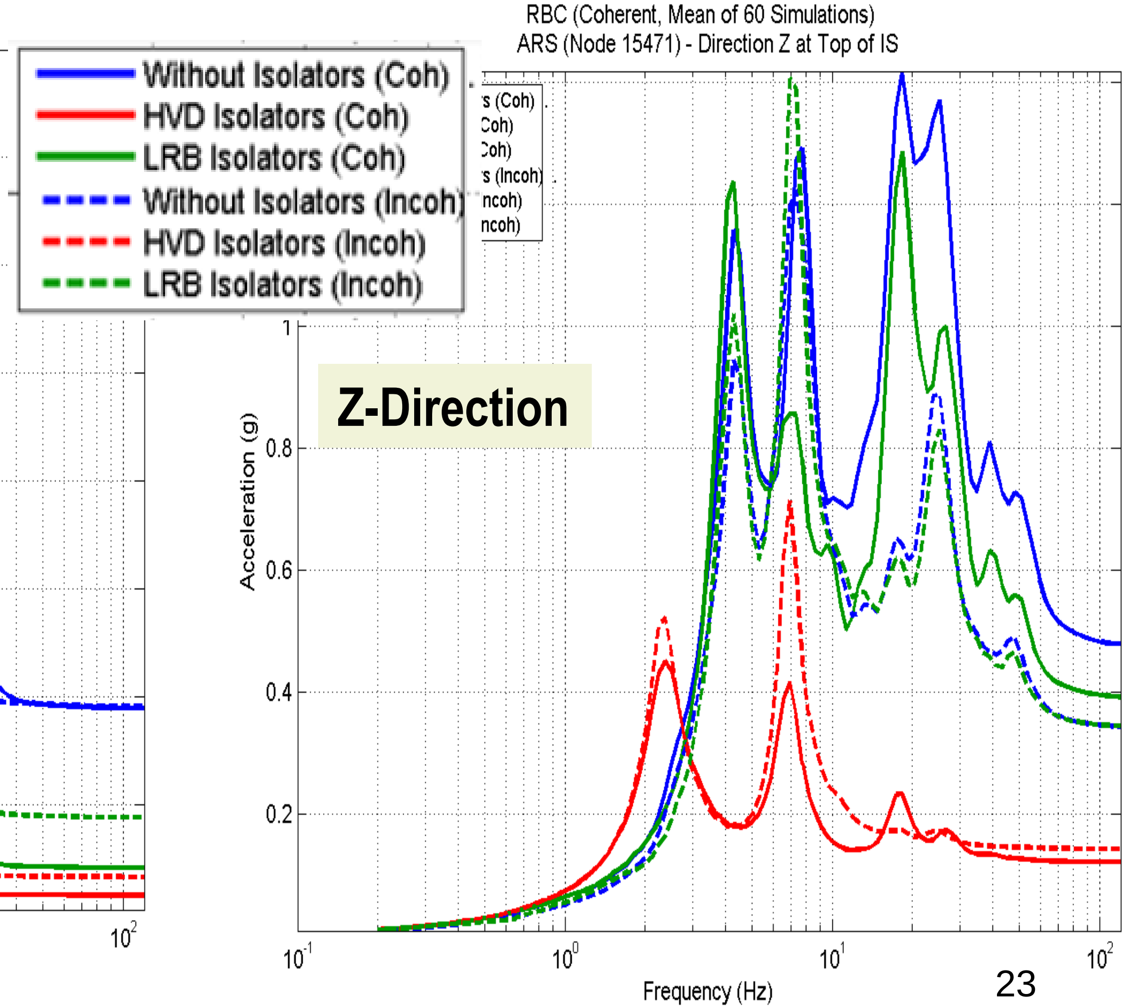
Top of IS near Center



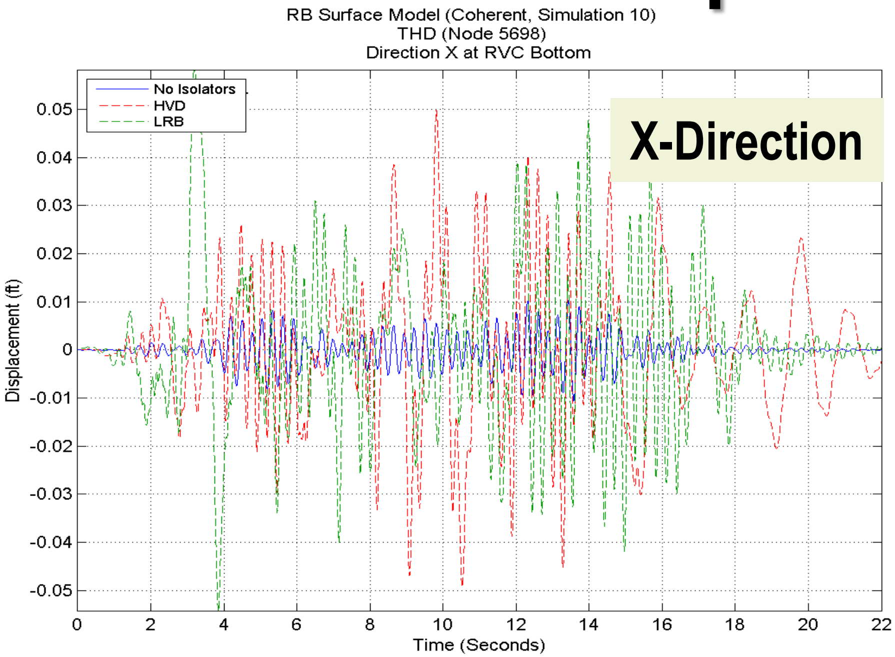
Comparative Coherent vs. Incoherent Mean ISRS for No Isolators vs. HVD and LRB Isolators

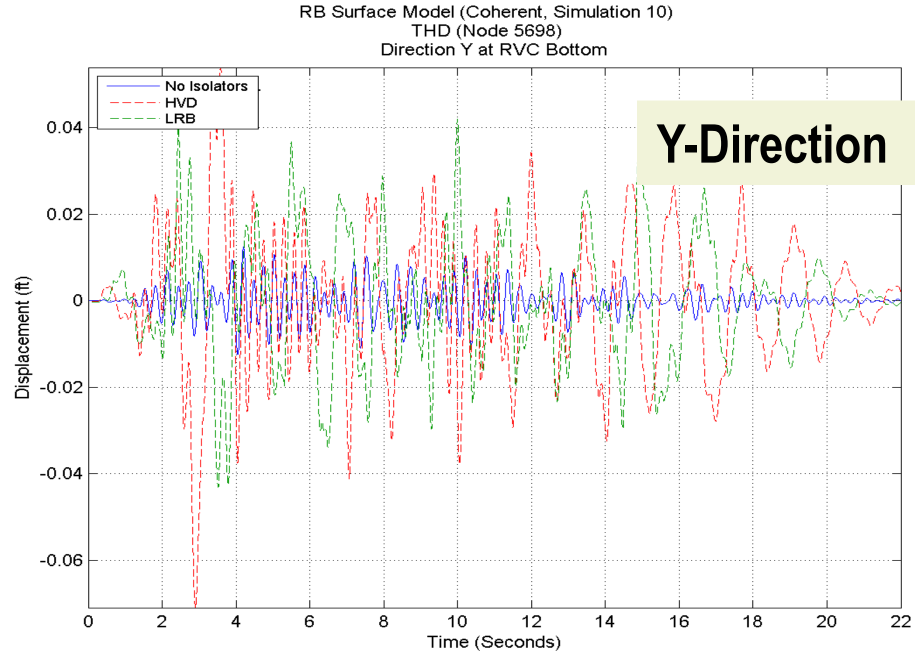
Top of IS near Edge



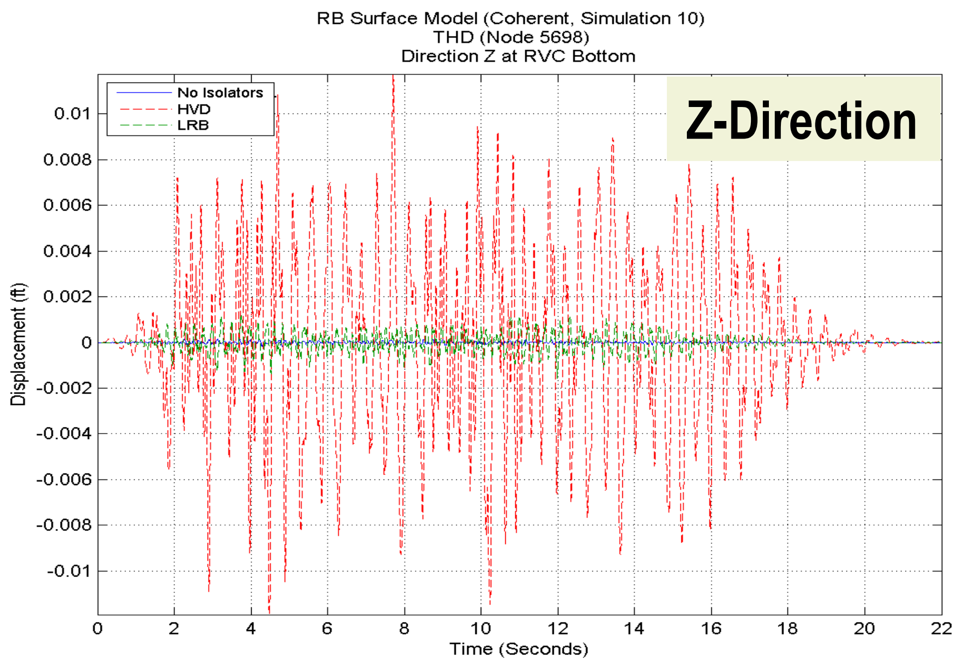


Coherent Rel. Displacements wrt to *Bottom Slab*



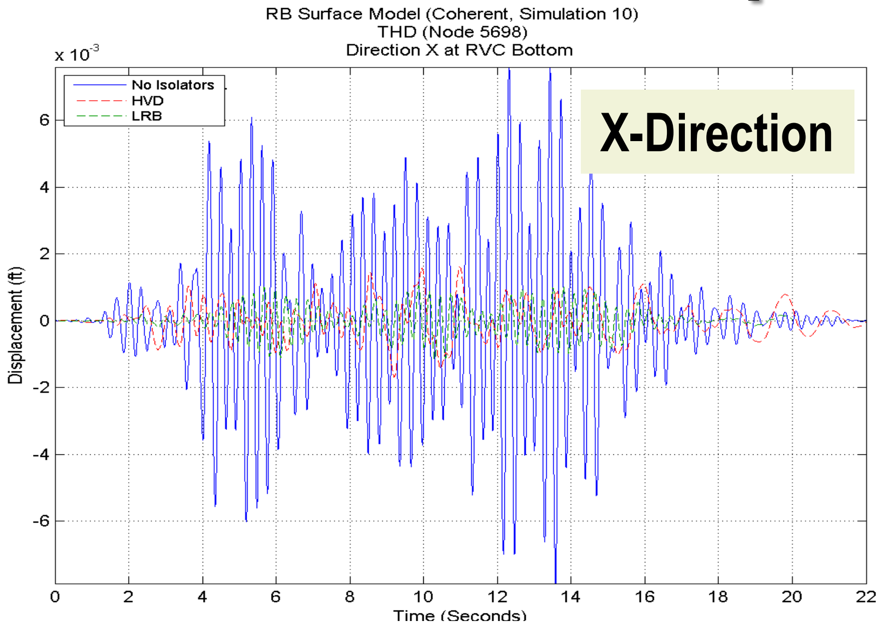


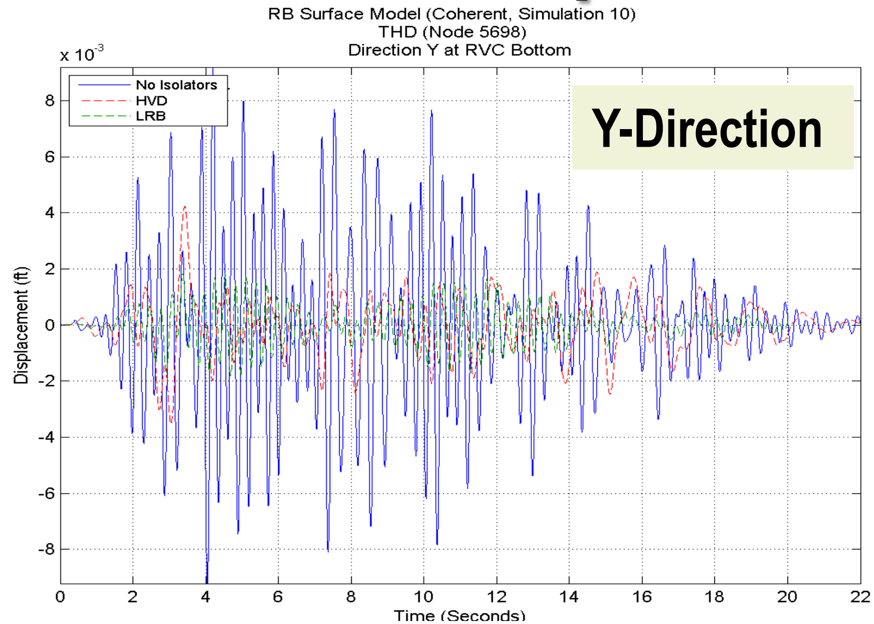
RVC Support Location

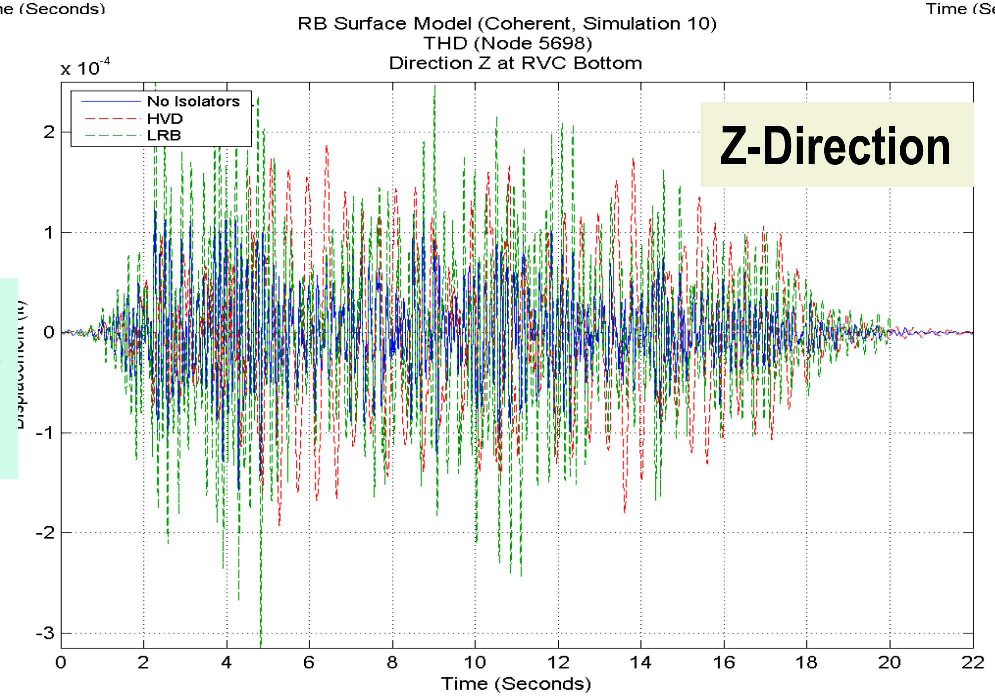


Simulation 10

Coherent Rel. Displacements wrt to Top Slab





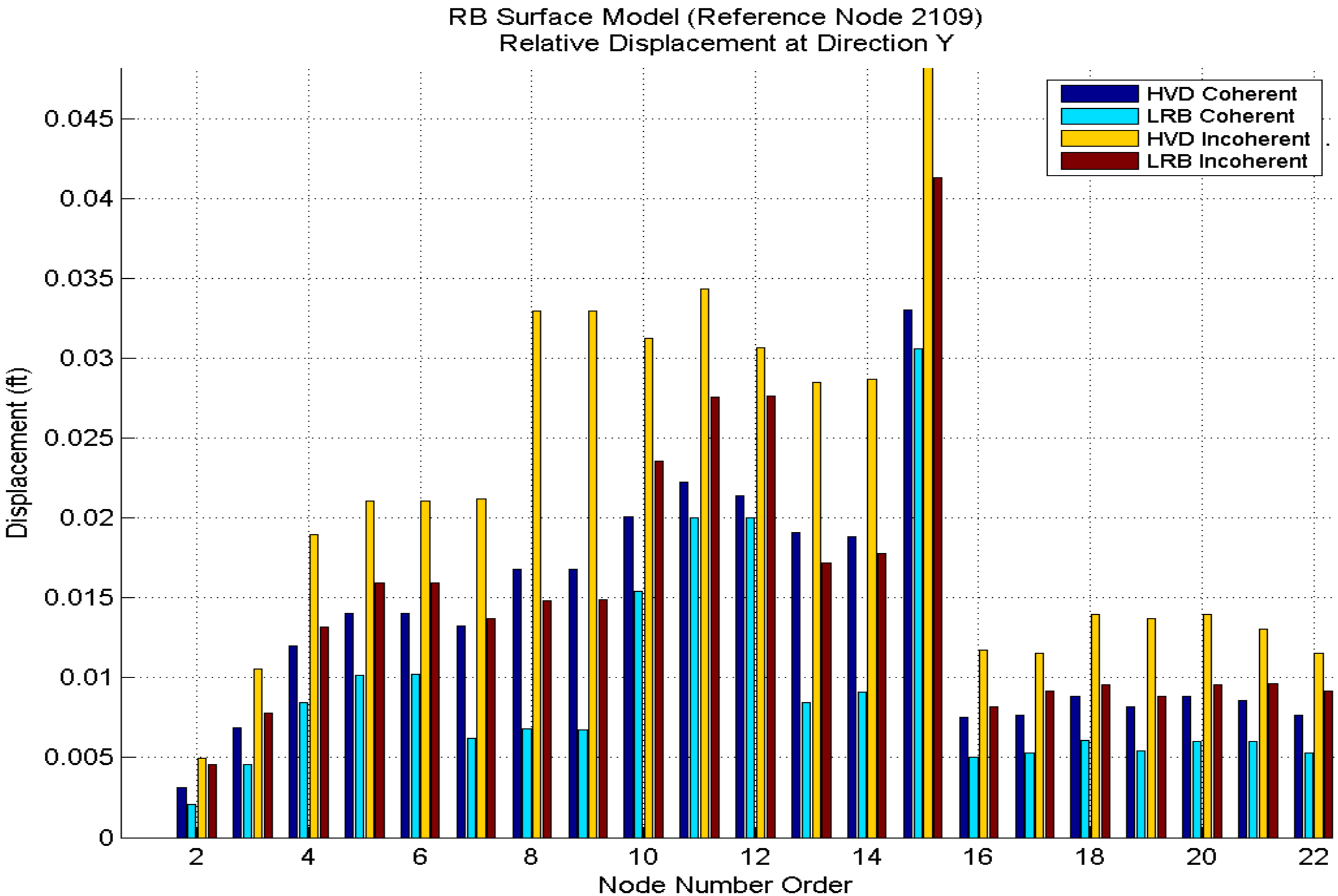


RVC Support Location

Simulation 10

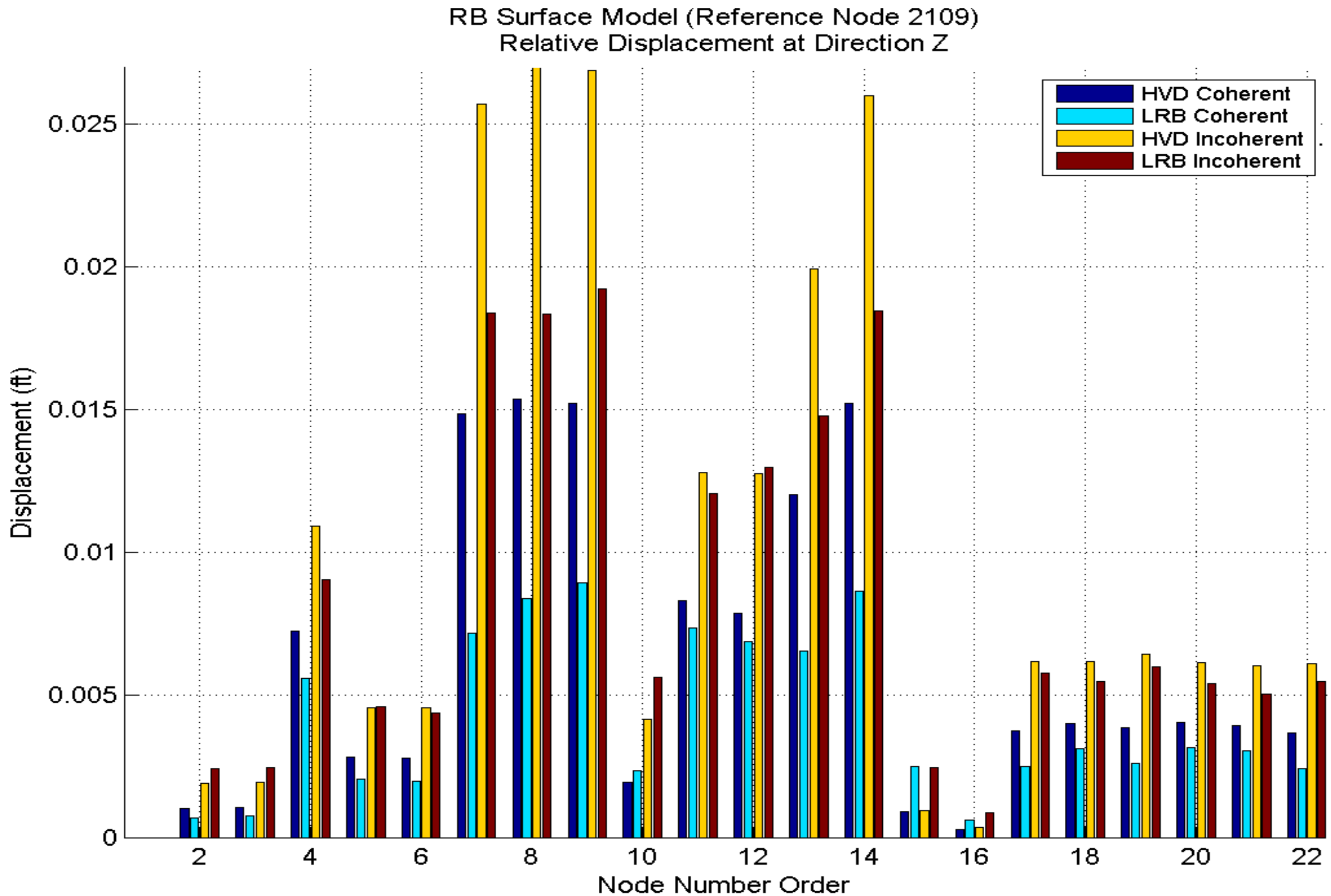
Coherent vs. Incoherent Mean of Maximum Displacements at Critical Locations for Y-Dir

Reference Location is Top Base Slab Center



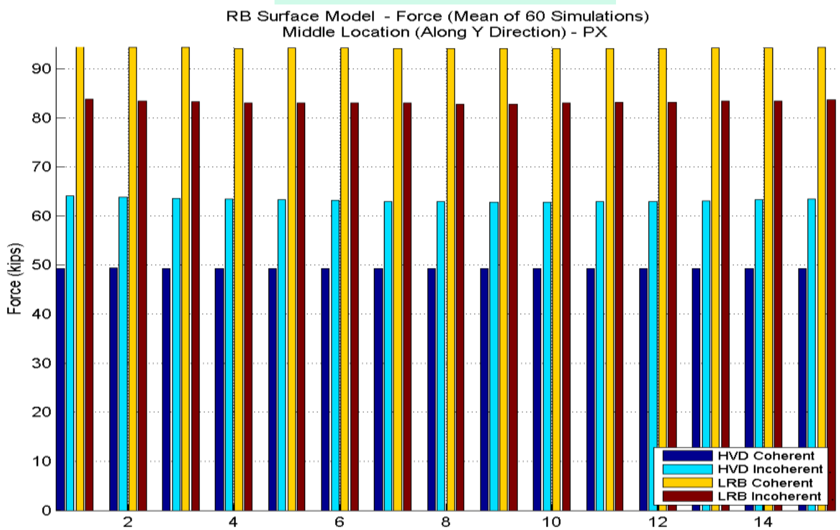
Coherent vs. Incoherent Mean of Maximum Displacements at Critical Locations for Z-Dir

Reference Location is Top Base Slab Center

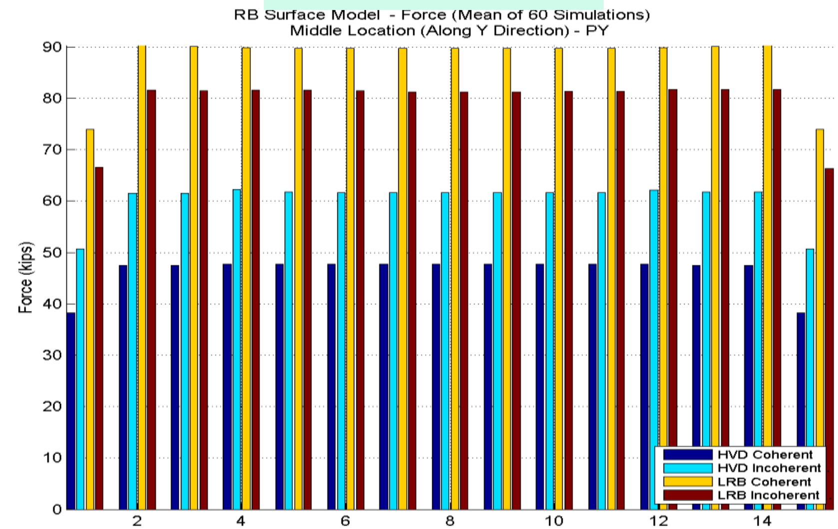


Coherent vs. Incoherent Mean of Maximum Axial Forces in LRB and BCS Isolators

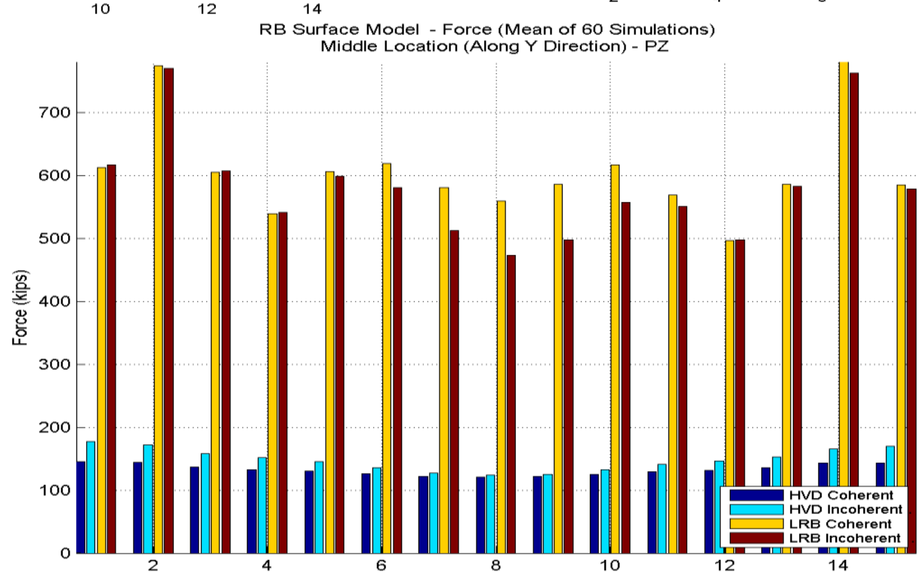
PX Forces



PY Forces



PZ Forces



HVD Coherent
HVD Incoherent
LRB Coherent
LRB Incoherent

5. CONCLUDING REMARKS

1. Seismic base-isolation is highly effective for both the rock and soil sites.

2. Motion incoherency may largely amplify the horizontal ISRS and the relative displacements within NI complex

3. 3D HVD isolators are more effective than the 2D LRB isolators, especially for the vertical motions.