Session 8: SASSI Approach to Incoherency (Simulation and Algebraic Sum Methods)
SShort
4:15 – 4:45

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SASSI Incoherency Approaches

- There are four methods for considering incoherent ground motion in SSI analyses by SASSI
  - SASSI-SRSS
  - EPRI-INCOH
  - SASSI Simulation
  - SASSI-AS
- Treatment of the spatial modes distinguishes these methods
- SASSI Simulation and SASSI-AS are implemented in ACS SASSI, a commercially available version of the program (Dan Ghiocel, GP Technologies, Inc.)

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SASSI – Simulation (Randomization)

- Perform Monte Carlo simulations varying the random phase θ for each spatial mode
  - $\{U_g^l\} = [\phi(\omega)]\,[\lambda(\omega)]\,\{\eta_\theta(\omega)\}\,U_0(\omega)$
- Loop on number of simulations (5, 10, 15, 20)
  - Loop on no. of SASSI solution frequencies (10s to 100s)
  - Randomly sample θ for each spatial mode
    - At each SASSI solution frequency, form $\{U_g^l\}$
    - Numerical techniques for smoothing & phase adjustment
    - Calculate SSI response for the simulation (ISRS)
- Calculate the mean of the responses

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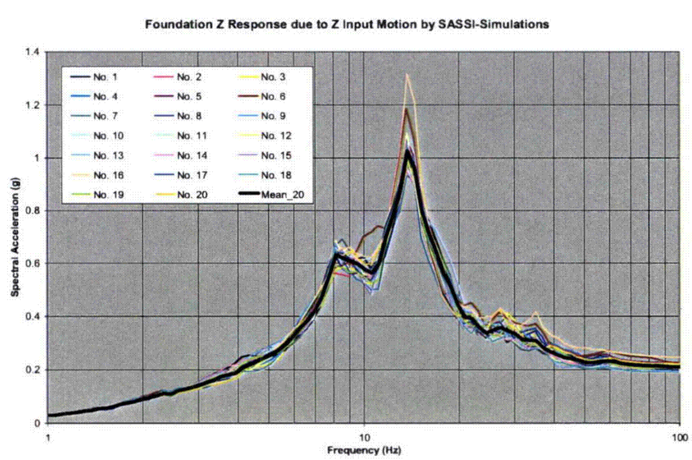
SASSI Simulation Individual Results



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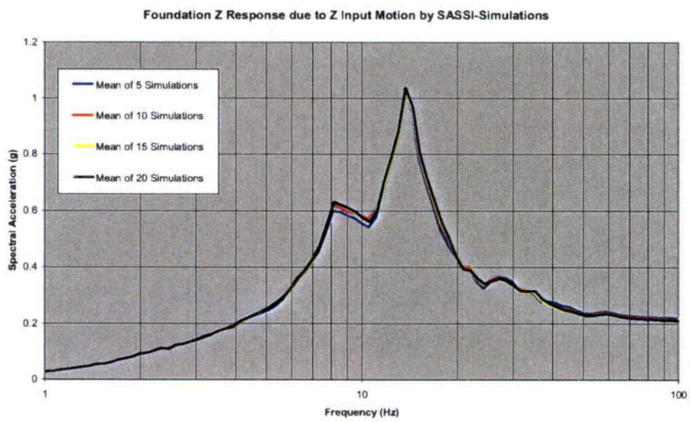
SASSI Simulation Mean Results



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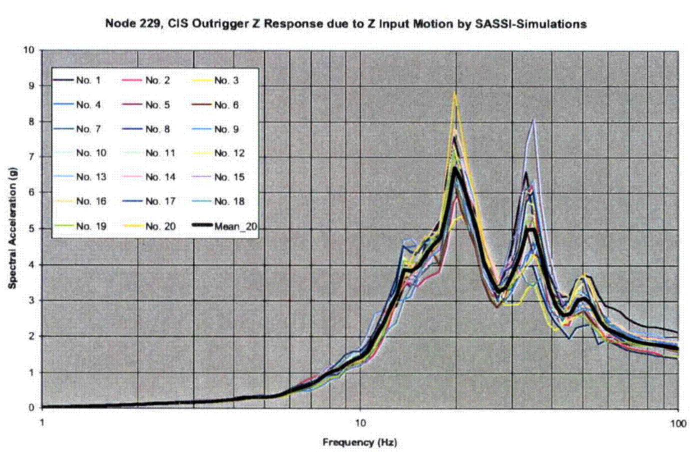
SASSI Simulation Individual Results



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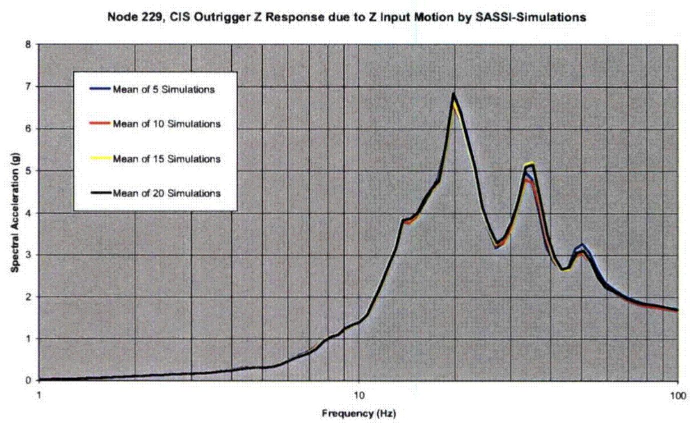
SASSI Simulation Mean Results



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SASSI-Simulation Analysis Considerations

- Selection of coherency function (1 through 5)
- Specification of the number of spatial modes (no reason to use less than all modes for this approach)
- Specification of random seeds and range for spatial mode phasing
- Selection of transfer function smoothing parameter
- Decide on number of simulations
- Compute the mean of the response quantities of interest

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SASSI – AS (Algebraic Sum)

- Equivalent to one simulation of SASSI – Simulation with:
  - Phase angle θ = 0 for each spatial mode
    - $\{U_g^I\} = [\phi(\omega)]\,[\lambda(\omega)]\,\{\eta_\theta(\omega)=1\}\,U_0(\omega)$
- Numerical techniques for smoothing & phase adjustment
- All spatial modes included
- SSI response calculated directly

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SASSI-AS Analysis Considerations

- Selection of coherency function (1 through 5)
- Specification of the number of spatial modes (no reason to use less than all modes for this approach)
- Choice of deterministic spatial mode phasing
- Selection of transfer function smoothing parameter

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ACS SASSI Numerical Techniques for Incoherency Analyses

- Numerical techniques to assure the proper relationship of transfer function frequency to frequency
  - Smoothing and interpolation – using the Parzen windowing technique
  - Response phasing adjusted by limiting to range of -$\pi/2$ to $+\pi/2$ to produce higher energy response time histories

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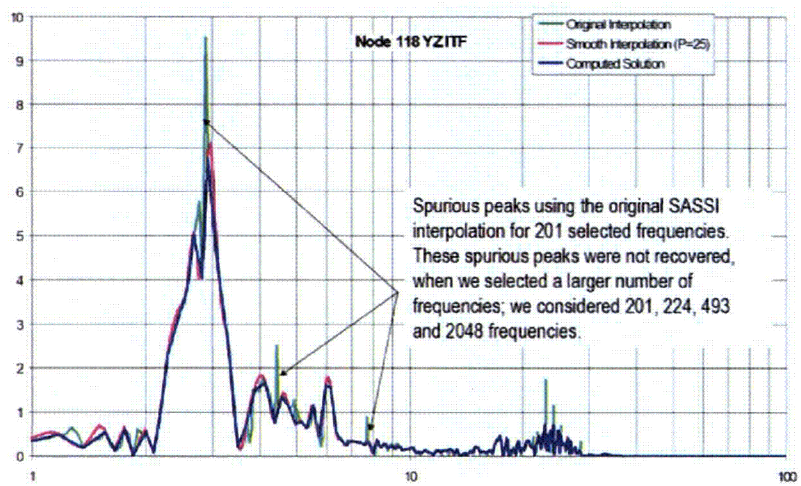
Transfer Function Smoothing



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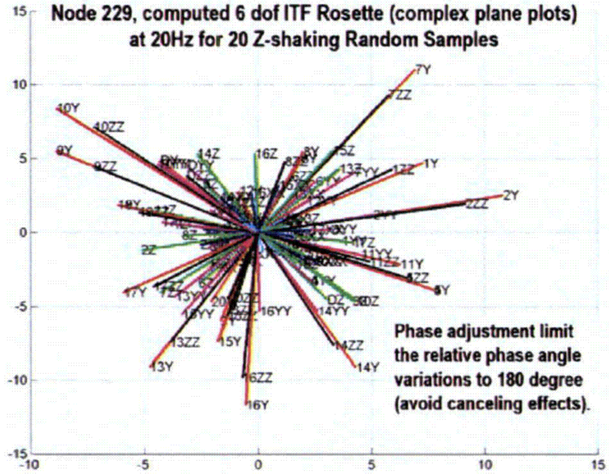
Phase Adjustment



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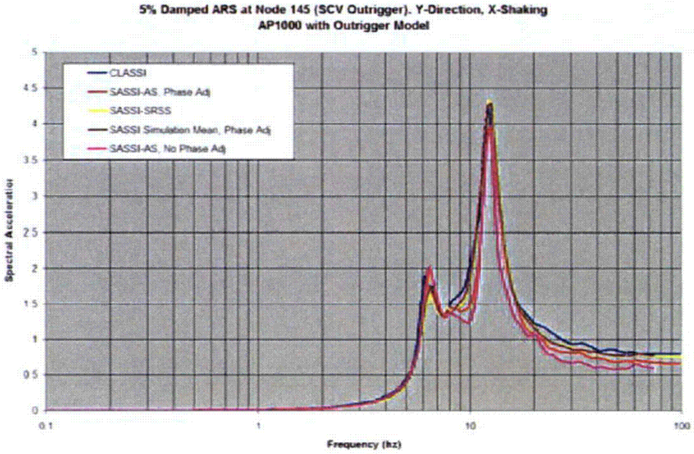
Effect of Phase Adjustment



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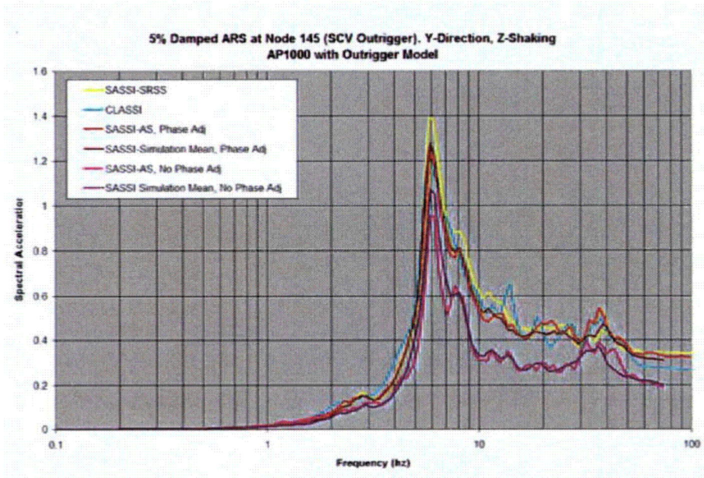
Effect of Phase Adjustment



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Validation

- SASSI Simulation and SASSI-AS have been validated for use by:
  - Comparison of results with other SASSI and CLASSI methods for a validation problem
  - Comparison to Mita and Luco, 1986 published results

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Parameters of the Validation Problem

- Coherency functions – NAA (2005, 2006)
- Free-field ground motion defined by acceleration time histories matching site specific spectra for rock site (horizontal and vertical)
- Rock site profile
- Foundation is square - 150 ft on a side – 15 ft thick with mass properties
- Structure model based, in part, on an advanced reactor structure stick model with eccentricities (160 modes)
- In-Structure Response Spectra (ISRS) (5% damped)

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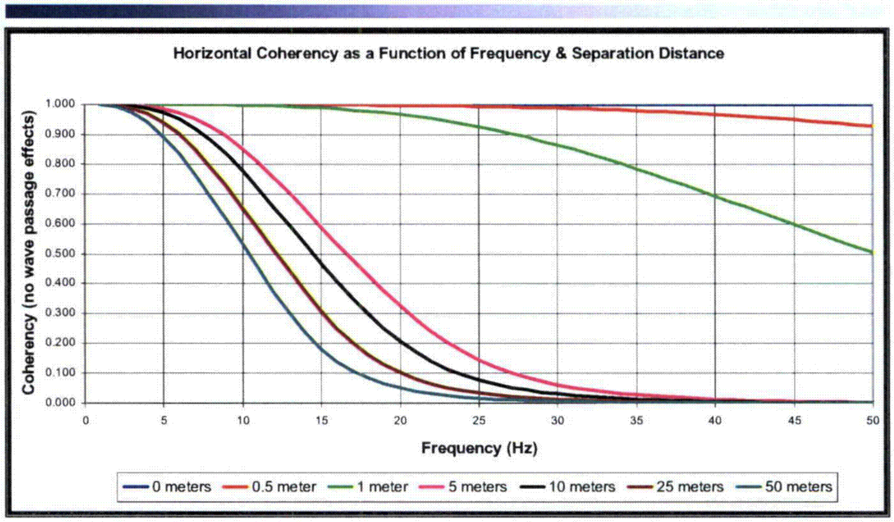
Coherency Function for Horizontal Ground Motion (NAA 2005,2006)



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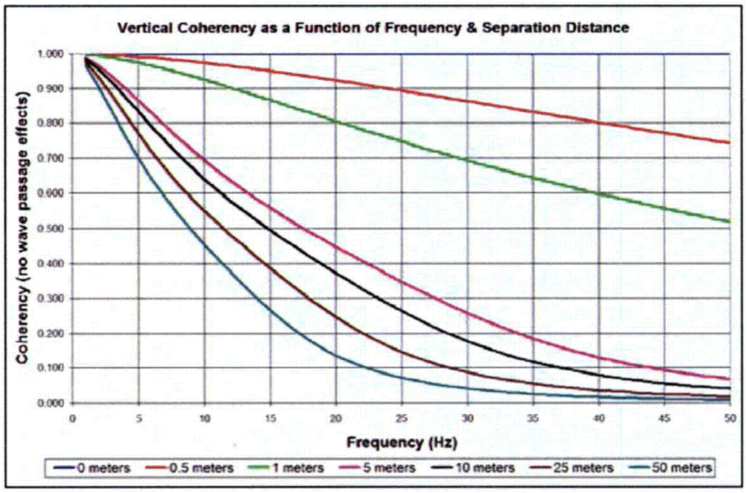
Coherency Function for Vertical Ground Motion (NAA 2005, 2006)



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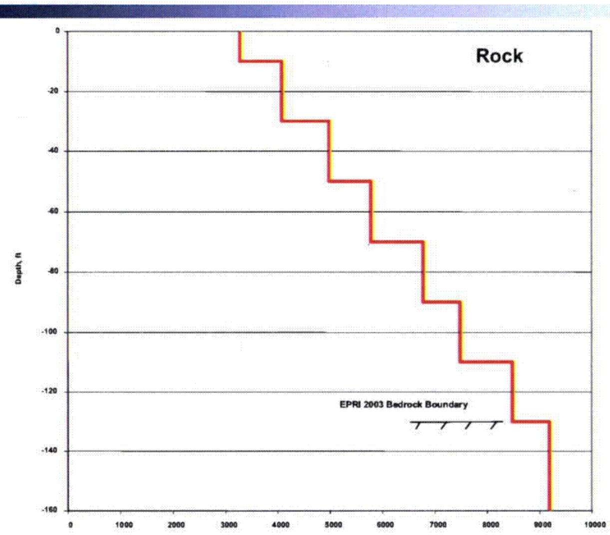
Rock Site Profile
Shear Wave Velocities vs. Depth



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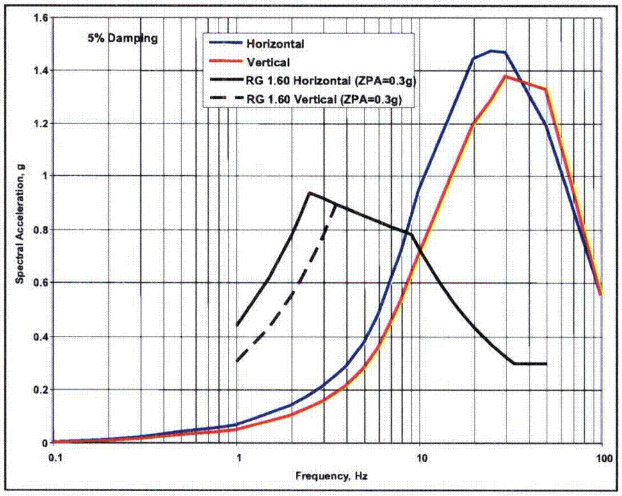
Site-Specific Response Spectra for Rock Site at Ground Surface (Depth 0-ft)



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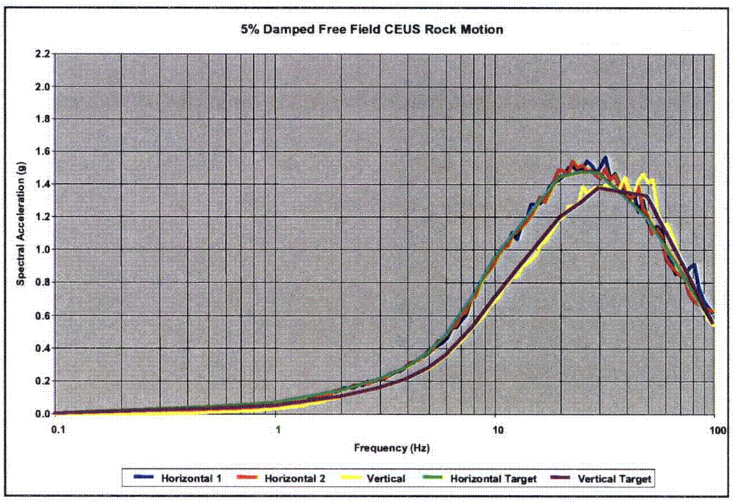
Computed and Target Response Spectra for Rock Site



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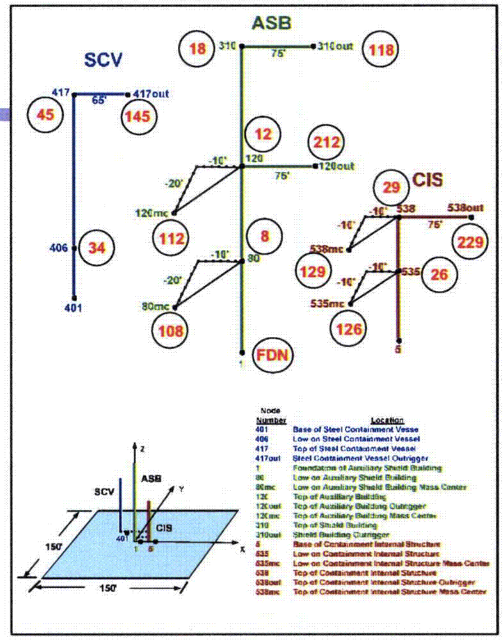
Representative NPP Structure Stick Model with Outriggers and Offset Mass Centers



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Structural Model Characteristics

- Advanced reactor structure stick model with eccentricities
  - 160 fixed-base modes model the dynamic characteristics of the structure
  - Frequencies 3.0 Hz – 141 Hz
  - Total mass (x = 92.7%, y = 92.5%, z = 93.1%)
- Three sticks are coupled at various locations – modes are coupled
  - ASB-3.2 Hz; SCV-5.5 Hz;CIS-13.3 Hz fixed base
- Relative mass distribution
  - ASB – 86%
  - CIS – 11%
  - SCV – 3%

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Validation by Comparison of CLASSI-SASSI Methods

- CLASSIinco
  - Deterministic phasing
- CLASSIinco-SRSS
  - Structure response to each foundation input motion combined by SRSS
- SASSI-Simulation (D. Ghiocel methodology)
  - Spatial modes assigned random phasing
  - Mean of structural response to spatial modes computed
- SASSI-SRSS (F. Ostadan)
  - Structural responses to each spatial mode are combined by SRSS
- SASSI-AS (D. Ghiocel methodology)
  - Linear combination (algebraic sum) of spatial modes used to compute structural response

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Results for Comparison

- Calculate three directions of seismic input and combine the results as in the seismic design/qualification process
- Compare response spectra as calculated
  - Coherent (light blue)
  - CLASSIinco (dark blue)
  - CLASSIinco-SRSS (green)
  - SASSI-SRSS (yellow)
  - SASSI-Simulation mean (black)
  - SASSI-AS (red)
- Response comparisons for each direction of seismic input separately are also discussed

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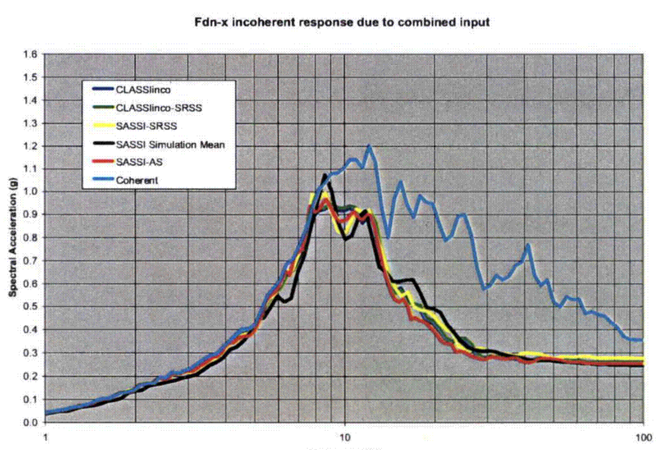
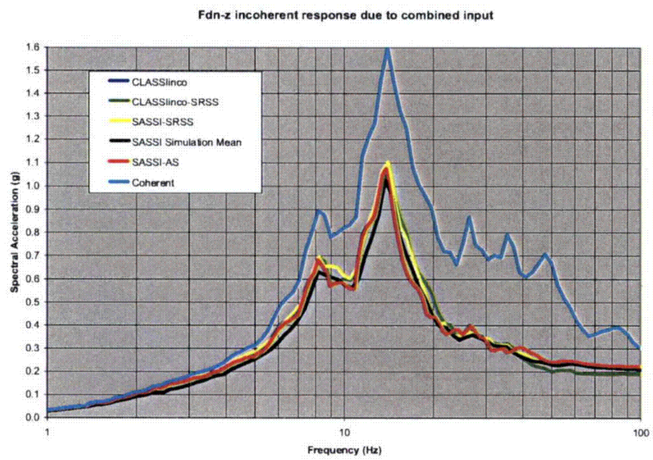
Foundation Response Comparisons

- Translations at the center of the foundation
  - Incoherent response significantly less than coherent response
  - Responses calculated by all methods are in very good agreement
- Rotations as measured by translations on the periphery of the foundation
  - Little or no reduction due to incoherency compared to coherent response
  - Responses calculated by all methods are in good agreement

Center of Foundation Response – X- Direction Coherent and Incoherent All Input Directions Combined



Center of Foundation Response – Z- Direction
Coherent and Incoherent
All Input Directions Combined



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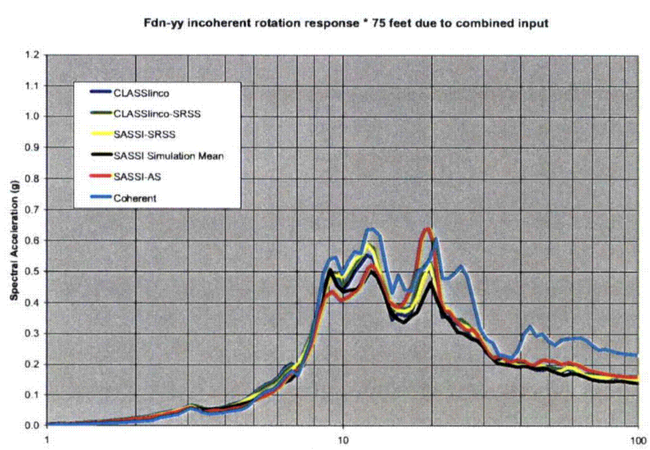
Edge of Foundation Response YY - Rotation
Coherent and Incoherent
All Input Directions Combined



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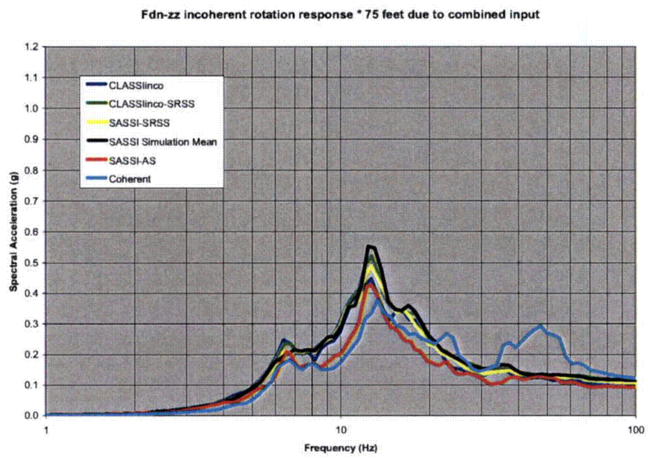
Edge of Foundation Response ZZ - Rotation Coherent and Incoherent All Input Directions Combined



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Top of Shield Building –Outrigger (Node 118 – 75 ft.)

- Incoherent response significantly less than coherent response
  - Horizontal - frequencies greater than 12 Hz up to 30 Hz (less reductions at ZPA)
  - Vertical – greater than 10 Hz
  - Outrigger reductions somewhat less than on centerline
- Responses calculated by all methods are in good agreement – generally within 10%
- Small increases in incoherent response over coherent response at peak spectral frequencies less than 10 Hz are observed – induced rotations effects

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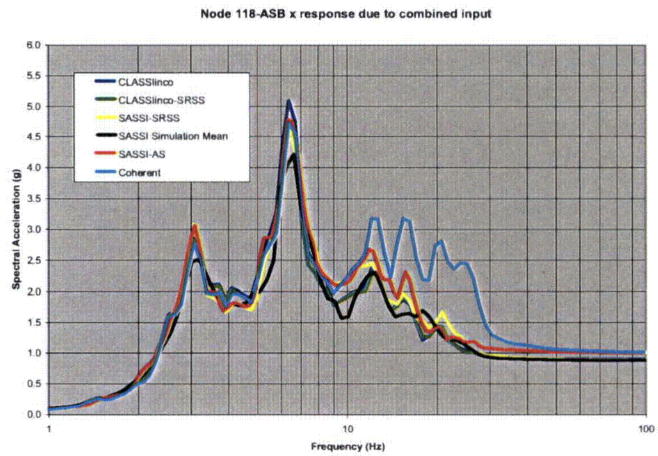
Top of Shield Building Outrigger (Node 118) - X- Direction Coherent and Incoherent All Input Directions Combined



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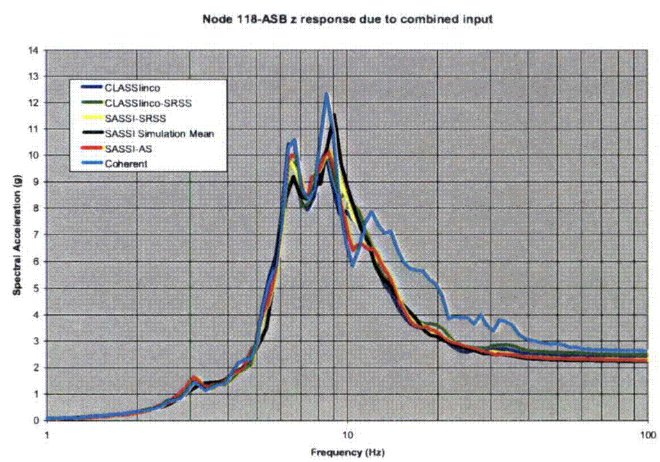
Top of Shield Building Outrigger (Node 118) - Z- Direction Coherent and Incoherent All Input Directions Combined



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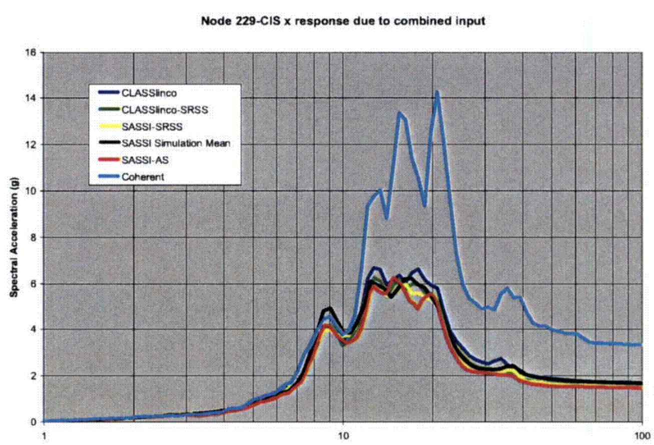
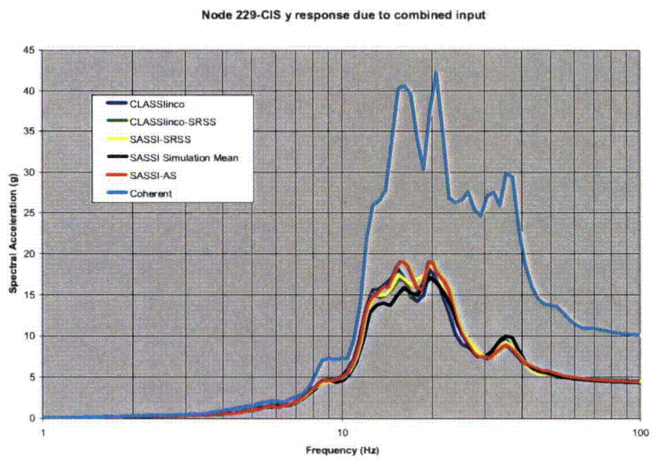
Top of Containment Internal Structure (CIS) – Outrigger (Node 229 – 75 ft.)

- Incoherent response significantly less than coherent response for frequencies greater than about 12 Hz – some reductions greater than 50%
- For this high frequency structure, responses calculated by all methods are in very good agreement – generally within 10%

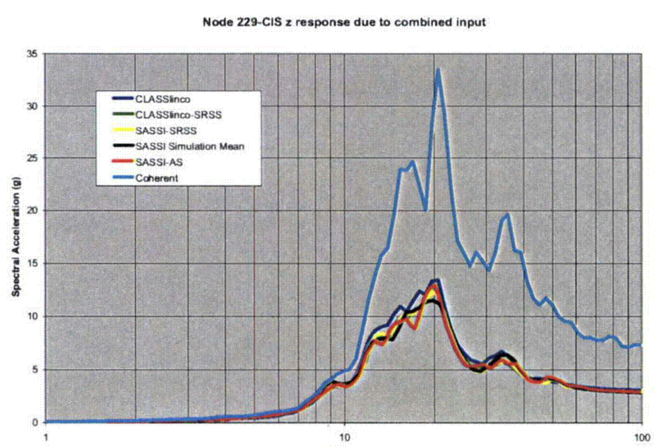
Top of CIS Outrigger (Node 229) - X- Direction Coherent and Incoherent All Input Directions Combined



Top of CIS Outrigger (Node 229) - Y- Direction
Coherent and Incoherent
All Input Directions Combined



Top of CIS Outrigger (Node 229) - Z- Direction
Coherent and Incoherent
All Input Directions Combined



Top of Steel Containment Vessel (SCV) – Outrigger (Node 145 – 65 ft.)

- Incoherent response significantly less than coherent response
  - Horizontal - frequencies greater than 12 Hz (less reductions at ZPA)
  - Vertical – very significant reductions for frequencies greater than 10 Hz
- Responses calculated by all methods are in very good agreement – generally within 10%

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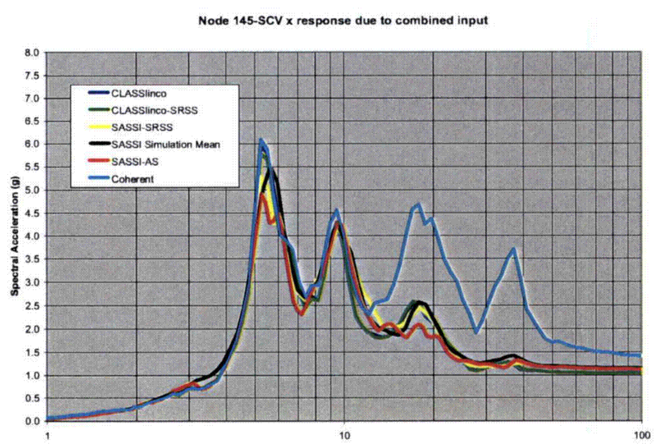
Top of SCV Centerline (Node 145) - X- Direction Coherent and Incoherent All Input Directions Combined



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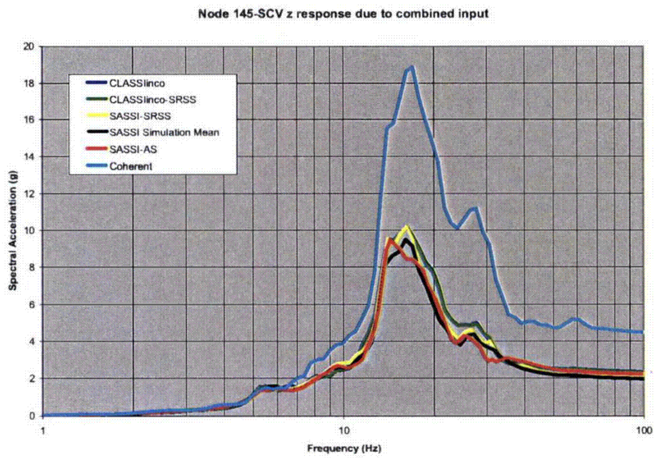
Top of SCV Centerline (Node 145) - Z - Direction
Coherent and Incoherent
All Input Directions Combined



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Individual Excitation Directions Independently

- Shows differences of CLASSIinco & SASSI-AS results from that of other methods
- Containment internal structure (CIS) outrigger (Node 229) vertical response (z) is an example

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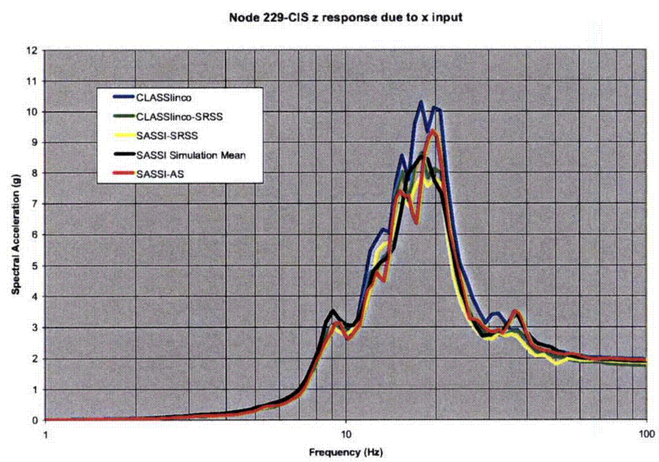
Top of CIS Outrigger (Node 229) - Z- Direction Incoherent – X Input



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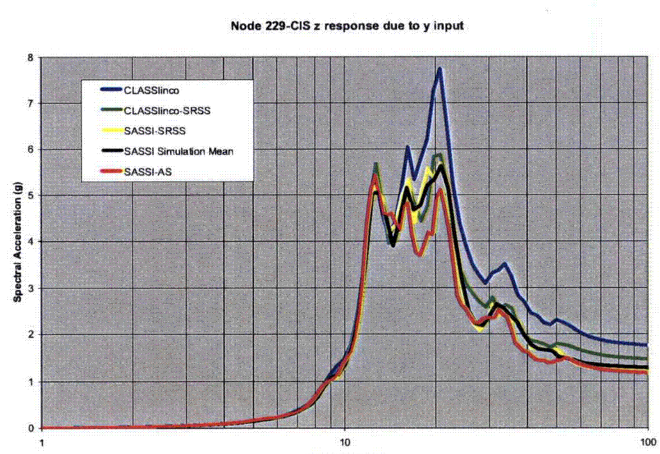
Top of CIS Outrigger (Node 229) - Z- Direction Incoherent – Y Input



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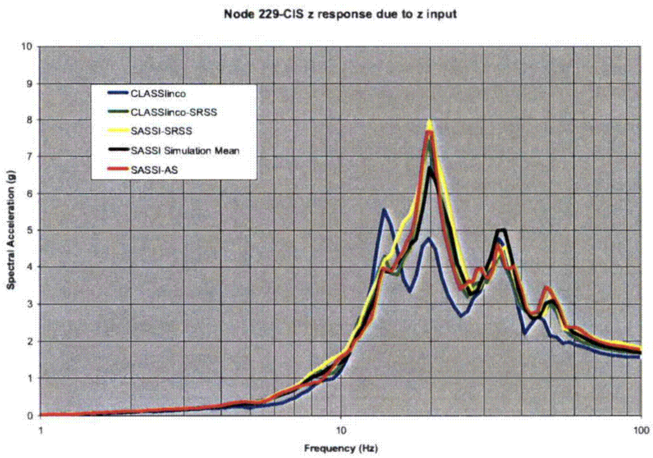
Top of CIS Outrigger (Node 229) - Z- Direction Incoherent – Z Input



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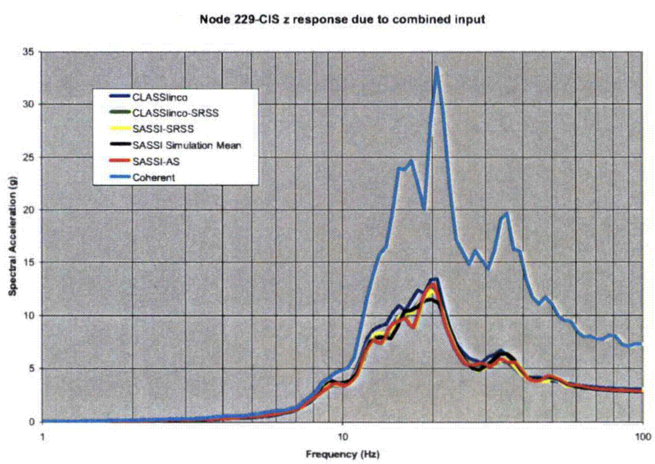
Top of CIS Outrigger (Node 229) - Z- Direction Coherent and Incoherent All Input Directions Combined



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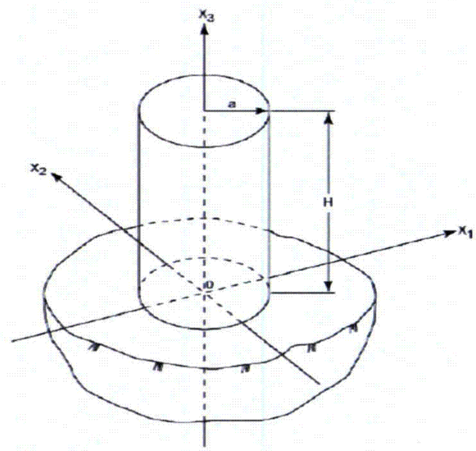
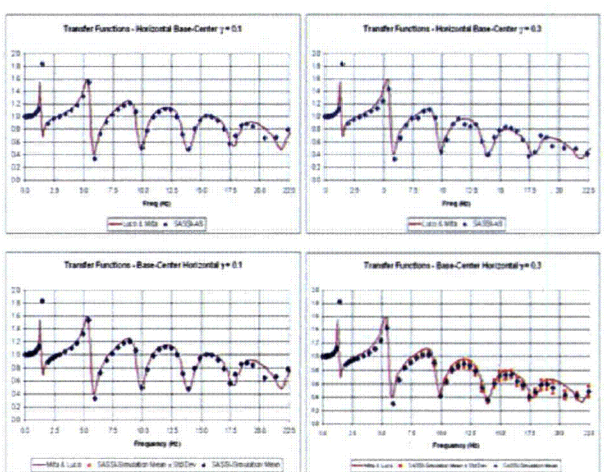
Comparison with Published Results

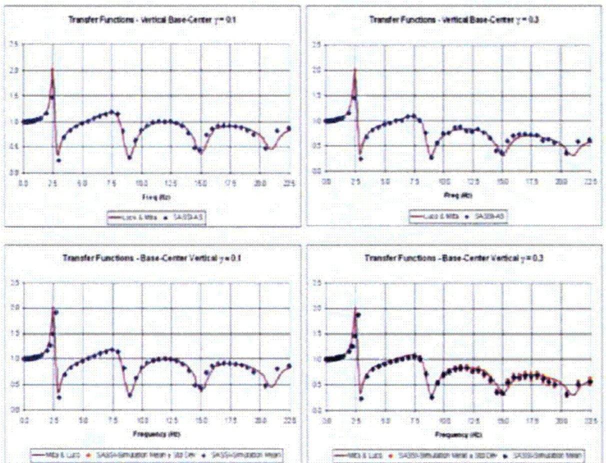
- Mita & Luco, 1986
  - 40 m high, 10 m radius cylindrical structure represented by stick model
  - Foundation has 10 m radius on 400 m/s halfspace
  - Transfer functions evaluated at base center and edge and top center and edge



Base Center Horizontal Response to Horizontal Input



Base Center Vertical Response to Vertical Input



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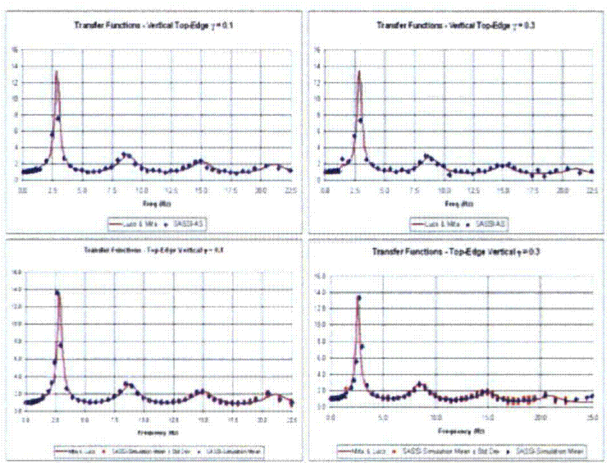
Top Edge Vertical Response to Vertical Input



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