

Session 8: SASSI Approach to Incoherency (Simulation and Algebraic Sum Methods)

**SShort
4:15 – 4:45**

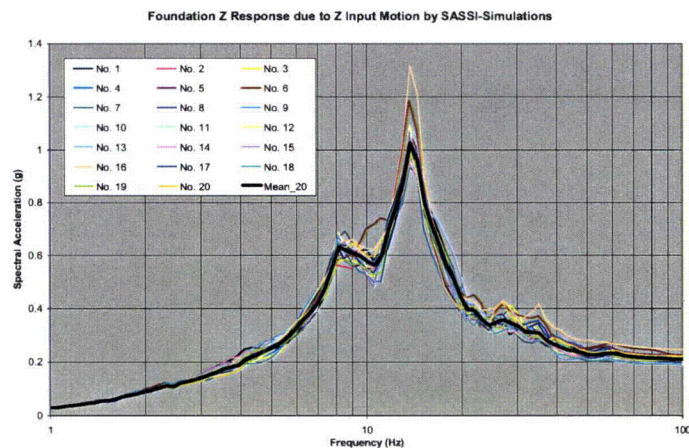
SASSI Incoherency Approaches

- 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.)

SASSI – Simulation (Randomization)

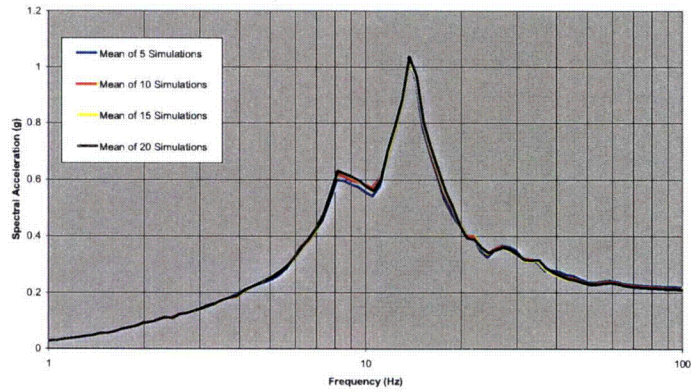
- Perform Monte Carlo simulations varying the random phase θ for each spatial mode
 - $\{U_g\} = [\phi(\omega)] [\lambda(\omega)] \{\eta_\theta(\omega)\} U_0(\omega)$
- Loop on number of simulations (5, 10, 15, 20)
 - Loop on no. of SASSI solution frequencies (10s to 100s)
 - Randomly sample θ for each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

SASSI Simulation Individual Results



SASSI Simulation Mean Results

Foundation Z Response due to Z Input Motion by SASSI-Simulations



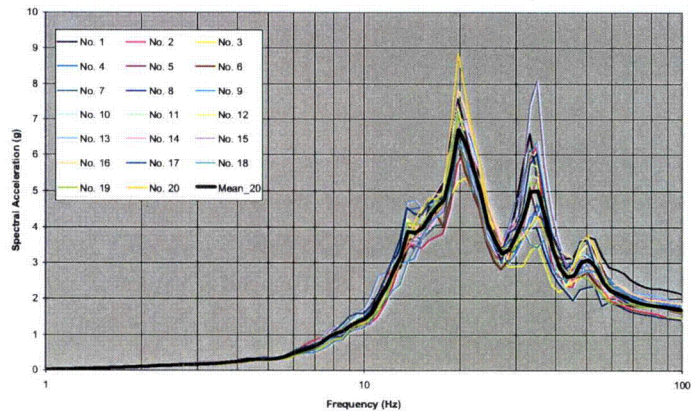
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SASSI Simulation Individual Results

Node 229, CIS Outrigger Z Response due to Z Input Motion by SASSI-Simulations

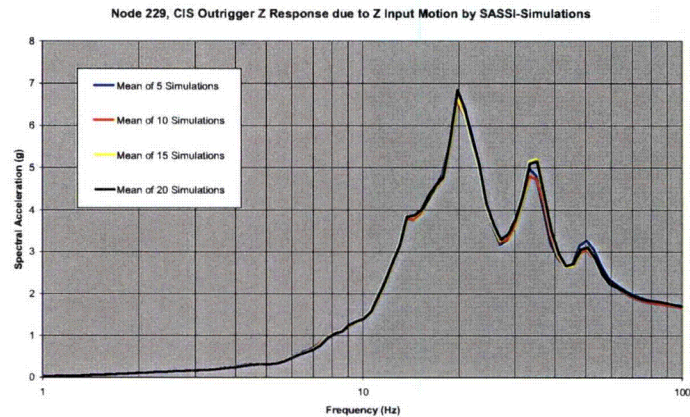


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SASSI Simulation Mean Results



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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 $\theta = 0$ for each spatial mode
 - $\{U_g\} = [\phi(\omega)] [\lambda(\omega)] \{\eta_\theta(\omega)=1\} U_0(\omega)$
- Numerical techniques for smoothing & phase adjustment
- All spatial modes included
- SSI response calculated directly

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

ACS SASSI Numerical Techniques for Incoherency Analyses

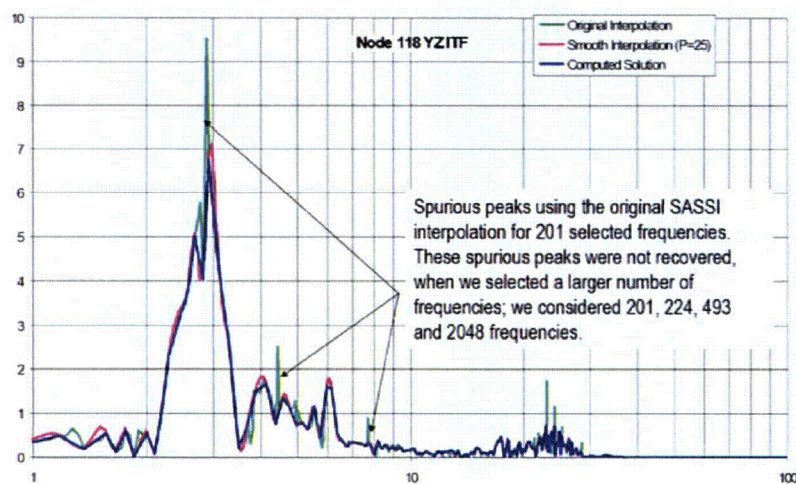
- Numerical techniques to assure the proper relationship of transfer function frequency to frequency
 - Smoothing and interpolation – using the Parzen windowing technique
 - Response phasing adjusted by limiting to range of $-\pi/2$ to $+\pi/2$ to produce higher energy response time histories

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Transfer Function Smoothing

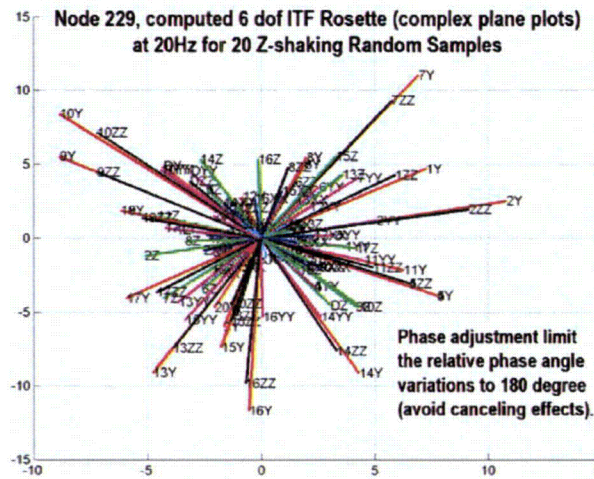


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Phase Adjustment



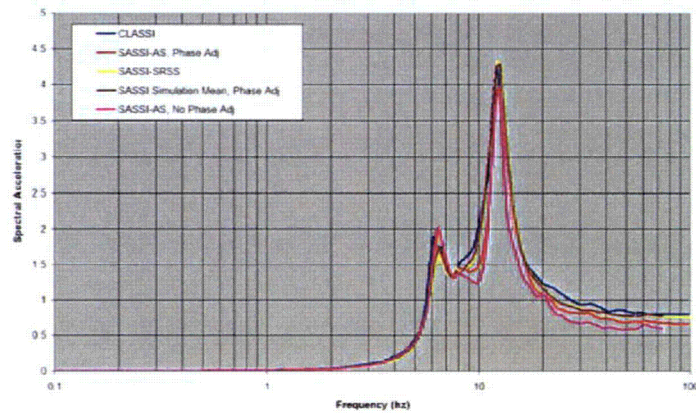
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Effect of Phase Adjustment

5% Damped ARS at Node 145 (SCV Outrigger), Y-Direction, X-Shaking
AP1000 with Outrigger Model

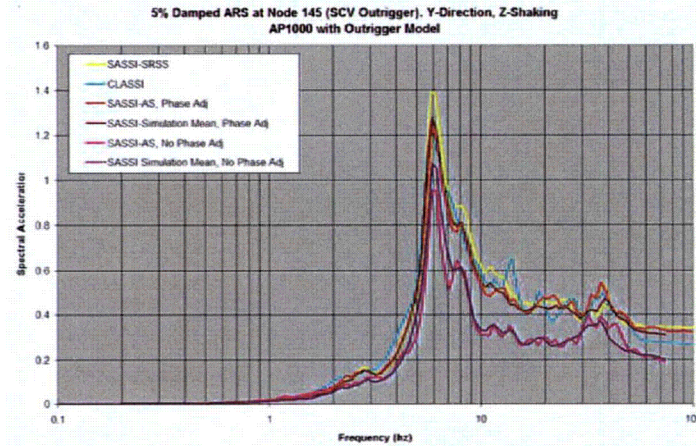


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Effect of Phase Adjustment



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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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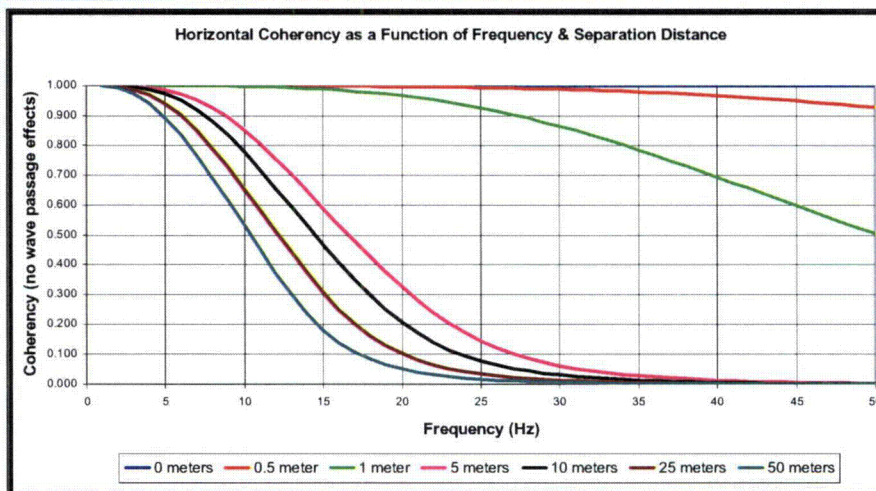
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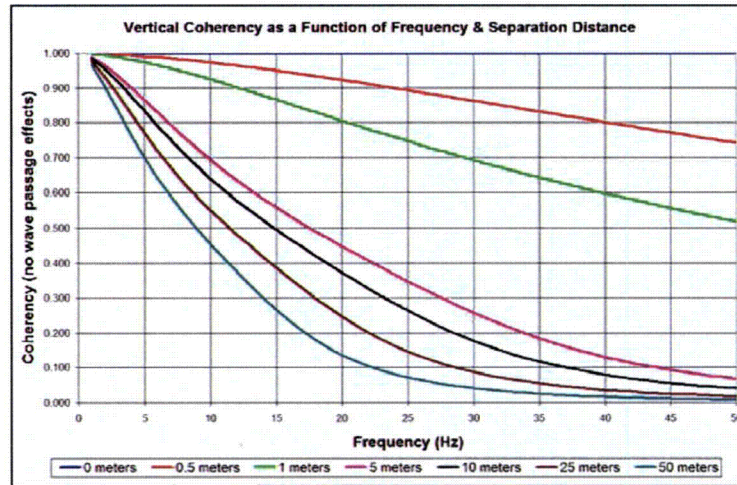
Parameters of the Validation Problem

- 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)

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



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

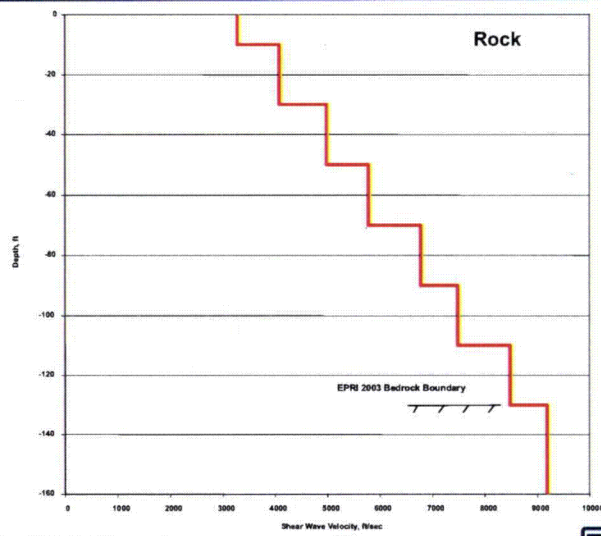


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Rock Site Profile Shear Wave Velocities vs. Depth

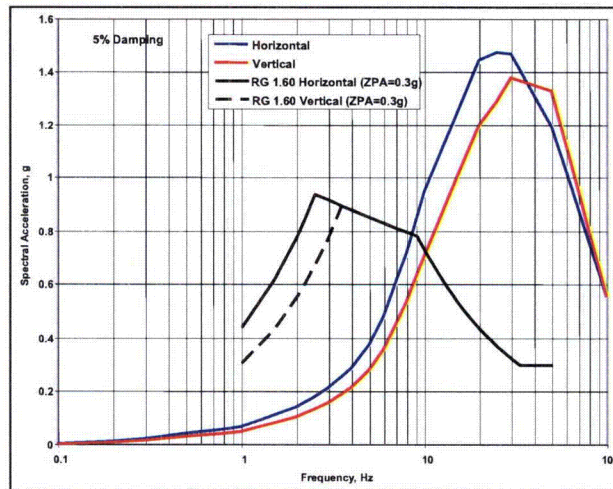


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Site-Specific Response Spectra for Rock Site at Ground Surface (Depth 0-ft)

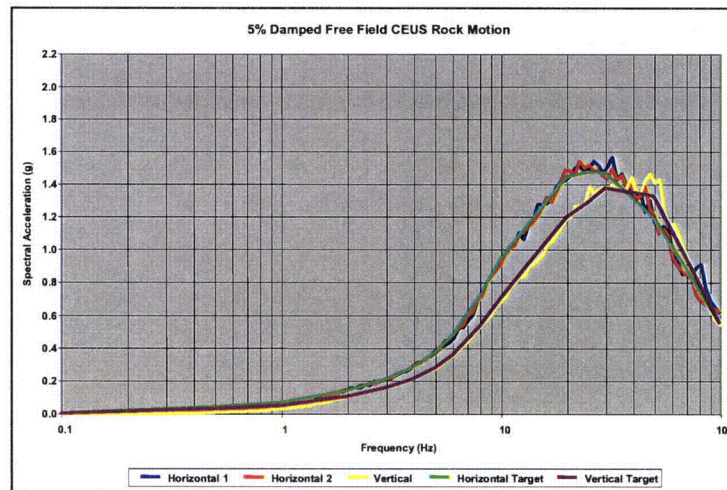


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Computed and Target Response Spectra for Rock Site

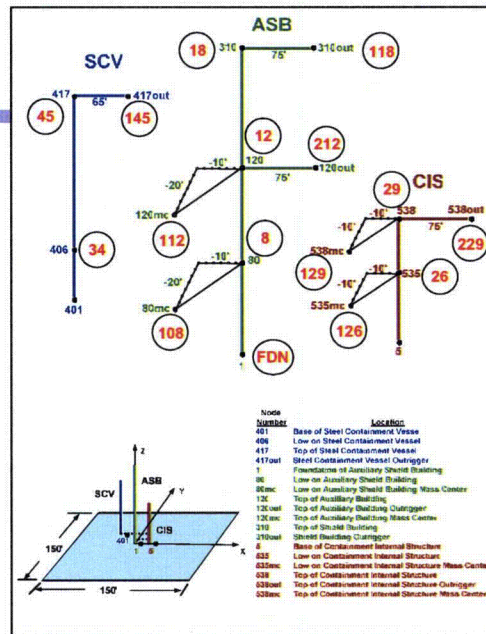


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Representative NPP Structure Stick Model with Outriggers and Offset Mass Centers



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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

- CLASSlinco
 - Deterministic phasing
- CLASSlinco-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

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)
 - CLASSlinco (dark blue)
 - CLASSlinco-SRSS (green)
 - SASSI-SRSS (yellow)
 - SASSI-Simulation mean (black)
 - SASSI-AS (red)
- Response comparisons for each direction of seismic input separately are also discussed

Foundation Response Comparisons

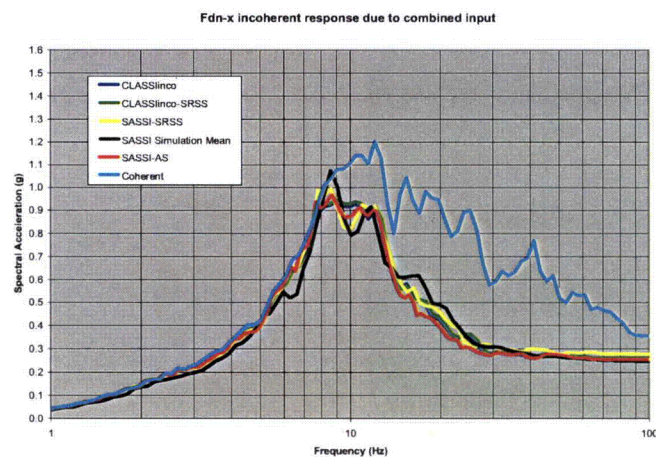
- Translations at the center of the foundation
 - Incoherent response significantly less than coherent response
 - Responses calculated by all methods are in very good agreement
- Rotations as measured by translations on the periphery of the foundation
 - Little or no reduction due to incoherency compared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

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

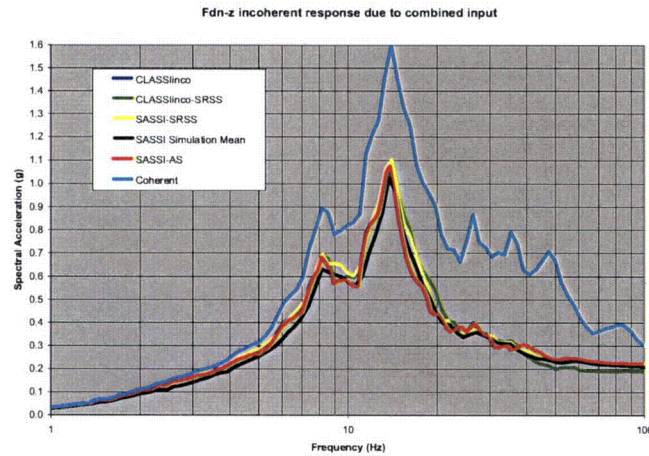


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Center of Foundation Response – Z- Direction Coherent and Incoherent All Input Directions Combined

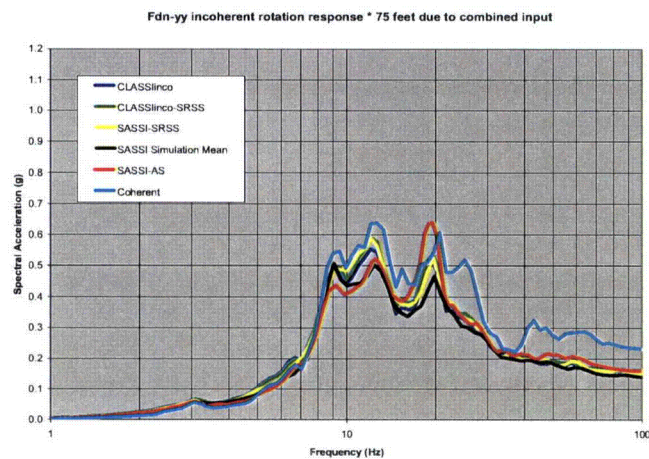


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Edge of Foundation Response YY - Rotation Coherent and Incoherent All Input Directions Combined

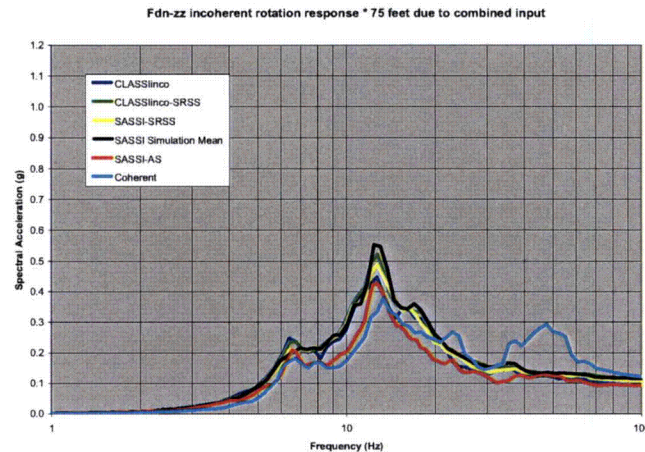


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Edge of Foundation Response ZZ - Rotation Coherent and Incoherent All Input Directions Combined



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

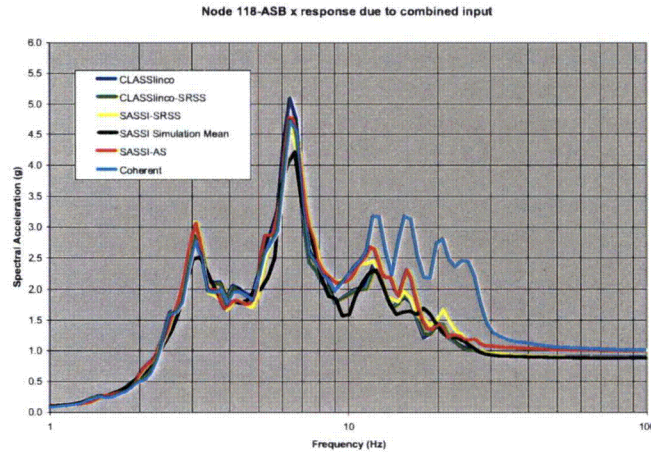
- Incoherent response significantly less than coherent response
 - Horizontal - frequencies greater than 12 Hz up to 30 Hz (less reductions at ZPA)
 - Vertical – greater than 10 Hz
 - Outrigger reductions somewhat less than on centerline
- Responses calculated by all methods are in good agreement – generally 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

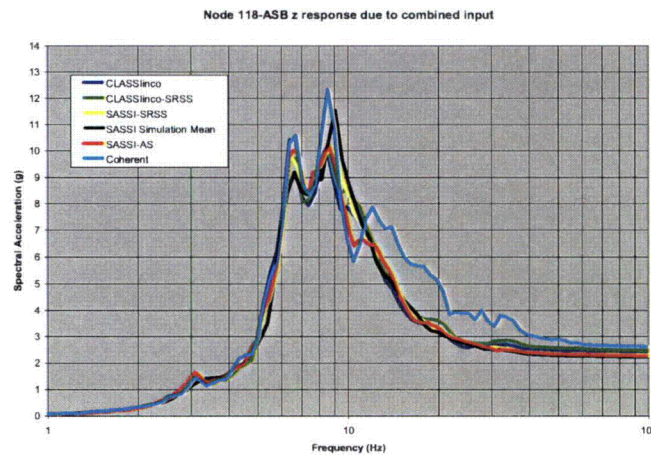


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Top of Shield Building Outrigger (Node 118) - Z- Direction Coherent and Incoherent All Input Directions Combined



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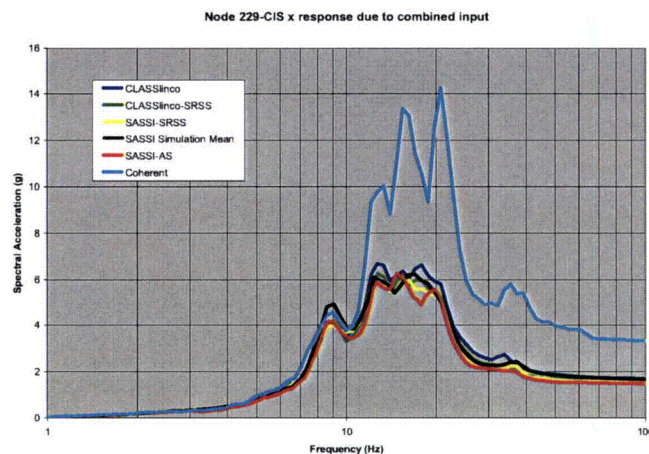
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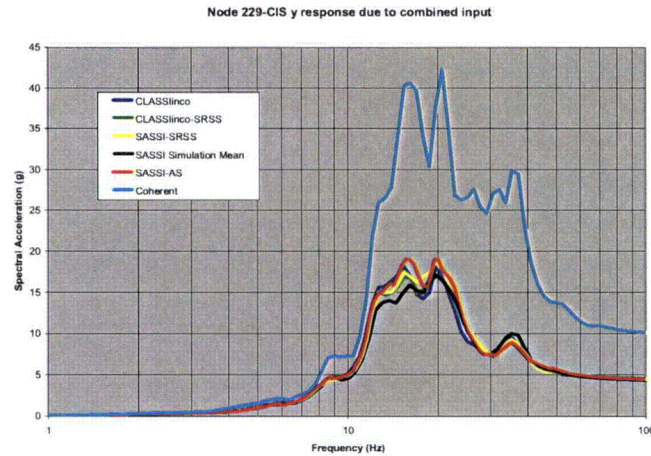
Top of Containment Internal Structure (CIS) – Outrigger (Node 229 – 75 ft.)

- 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

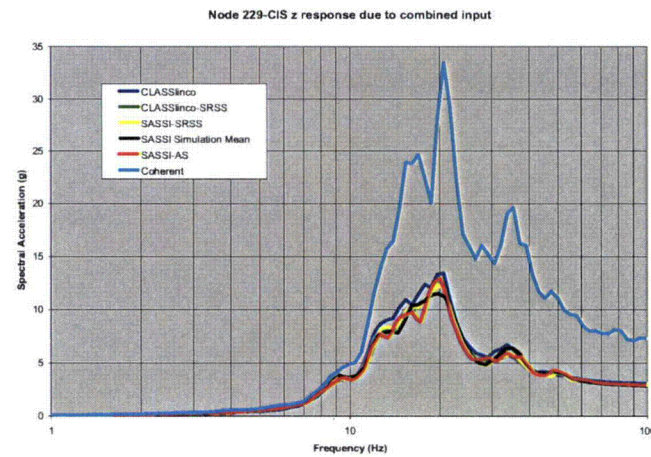


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Top of CIS Outrigger (Node 229) - Z- Direction Coherent and Incoherent All Input Directions Combined



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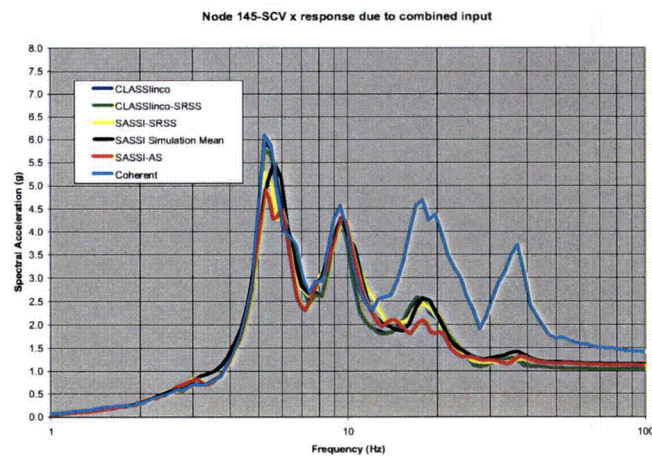
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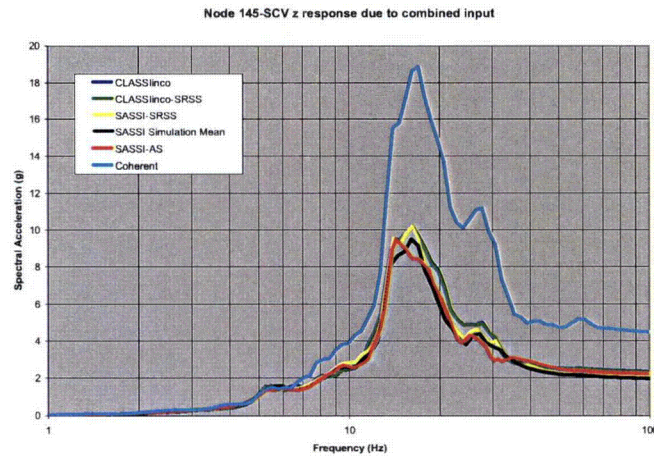
Top of Steel Containment Vessel (SCV) – Outtrigger (Node 145 – 65 ft.)

- 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%

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



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



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Individual Excitation Directions Independently

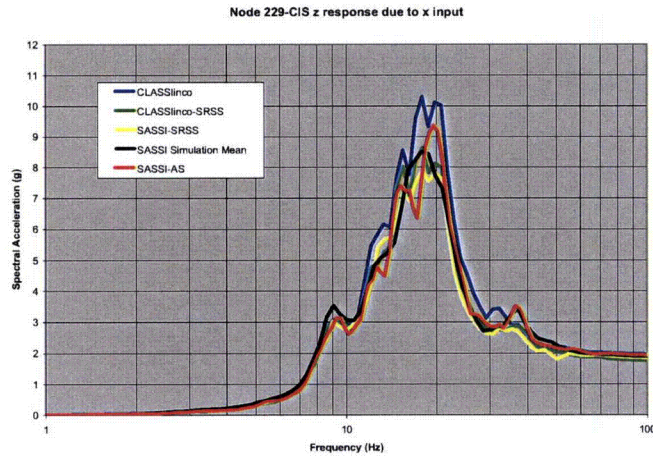
- Shows differences of CLASSlinco & SASSI-AS results from that of other methods
- Containment internal structure (CIS) outrigger (Node 229) vertical response (z) is an example

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

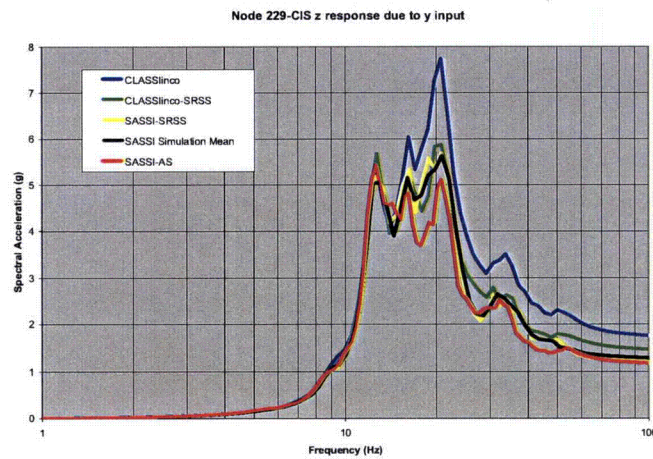


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Top of CIS Outrigger (Node 229) - Z- Direction Incoherent – Y Input

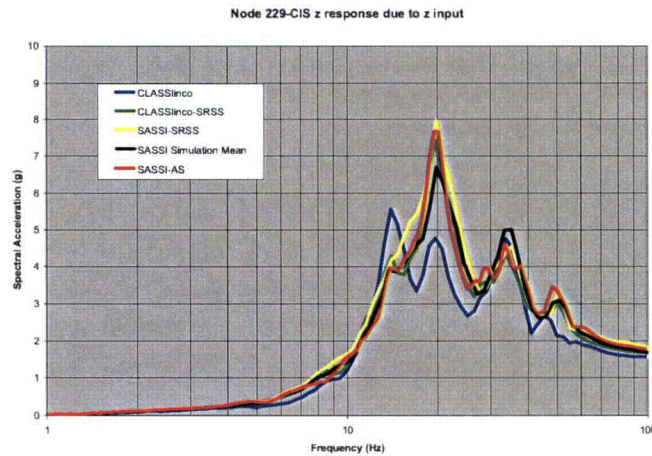


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Top of CIS Outrigger (Node 229) - Z- Direction Incoherent – Z Input

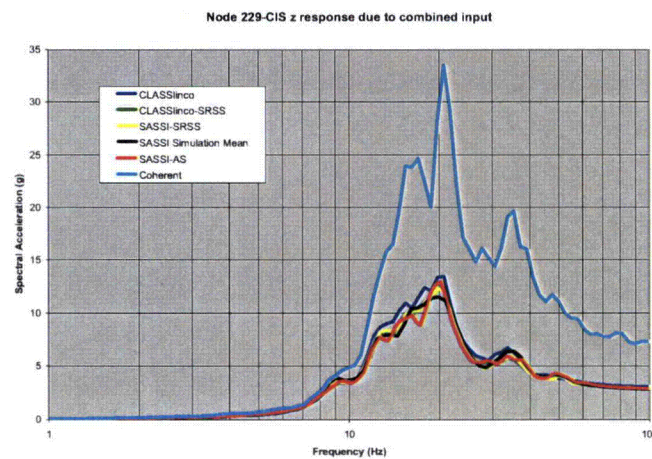


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Top of CIS Outrigger (Node 229) - Z- Direction Coherent and Incoherent All Input Directions Combined



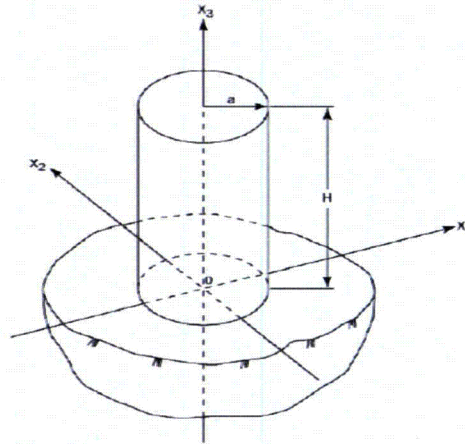
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Comparison with Published Results

- 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

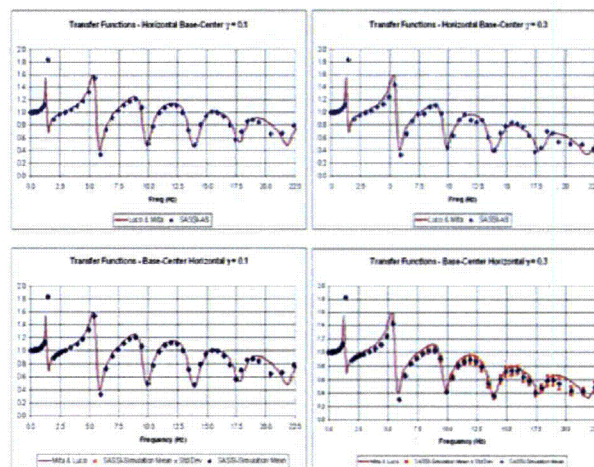


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Base Center Horizontal Response to Horizontal Input

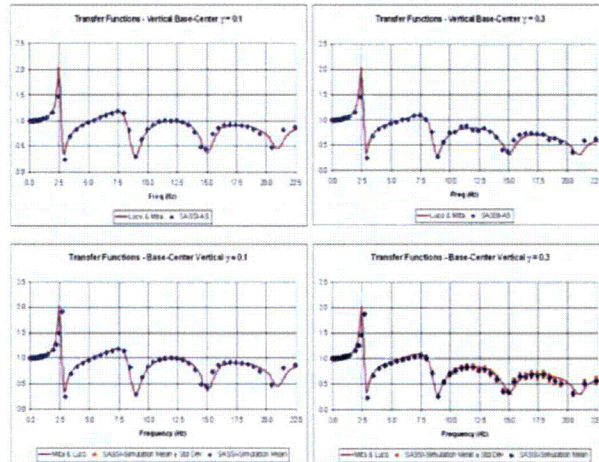


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Base Center Vertical Response to Vertical Input

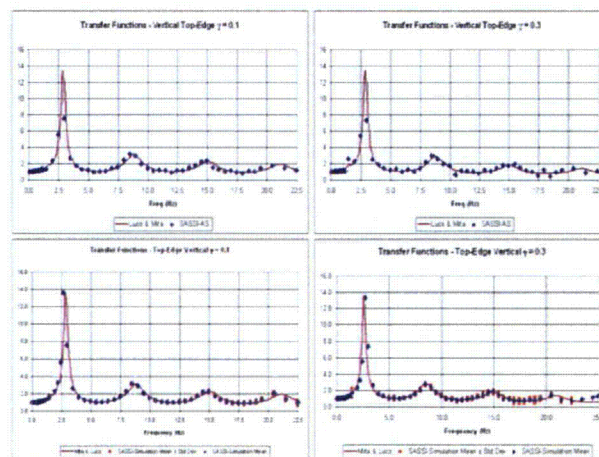


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Top Edge Vertical Response to Vertical Input



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