Session 3: Demonstration of SSI Effects
SShort
11:45 – 12:15

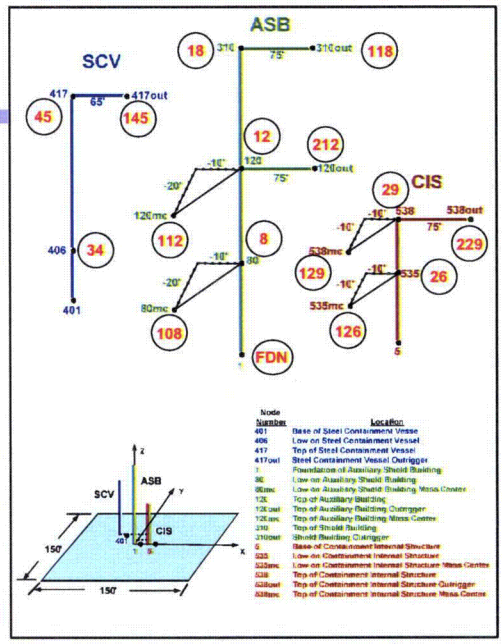
Soil-Structure Interaction Effects

- Various aspects of soil-structure interaction (SSI) result in reduced motion of the foundation basemat of a structure from that recorded by an instrument on a small pad
- These reductions are due to wave scattering effects including vertical and horizontal spatial variation of the ground motion, and radiation of energy back into the ground from the structure (radiation damping).
  - These effects always result in a reduction of the foundation motion.
- Soil-structure interaction also results in a frequency shift, primarily of the fundamental frequency of the structure.
  - Such a frequency shift can either reduce or increase the response of the structure foundation. As a result, any frequency shifting due to SSI, when significant, must always be considered.

Demonstration of SSI Effects

- A 3-stick model of a typical NPP structure on a rock site subjected to high frequency input motion has been considered
- In-structure response spectra are generated from SASSI analyses
- Both coherent and incoherent ground motion has been considered

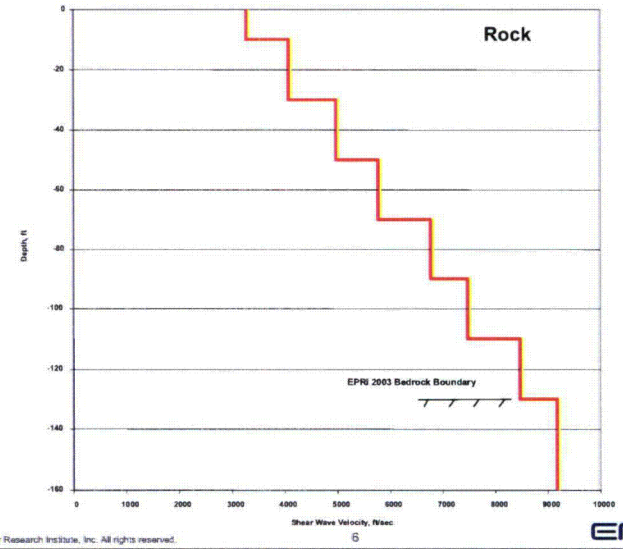
Representative NPP Structure Stick Model with Outriggers and Offset Mass Centers



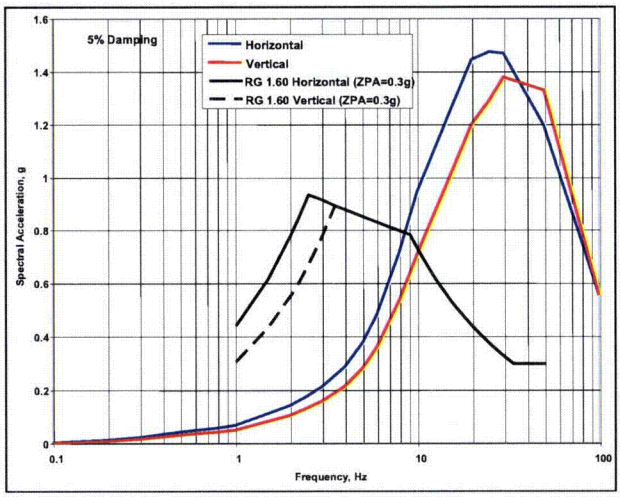
Structural Model Characteristics

- 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%

Rock Site Profile
Shear Wave Velocities vs. Depth



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



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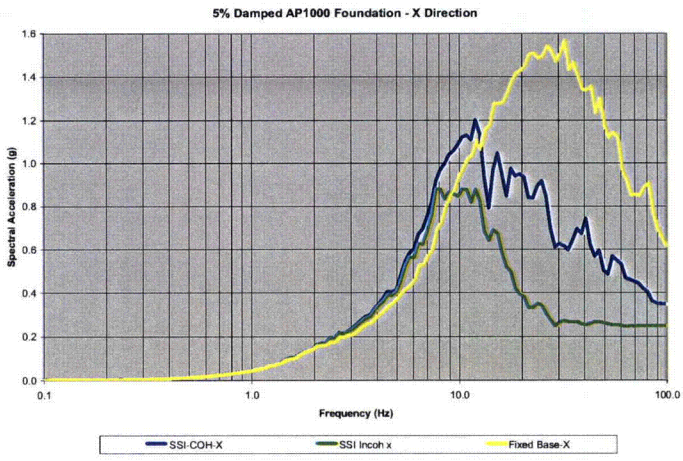
Importance of SSI – Foundation Response



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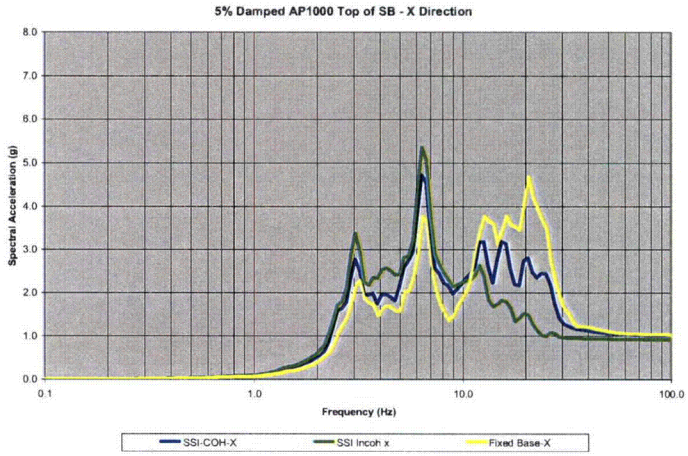
Importance of SSI – Shield Building Response



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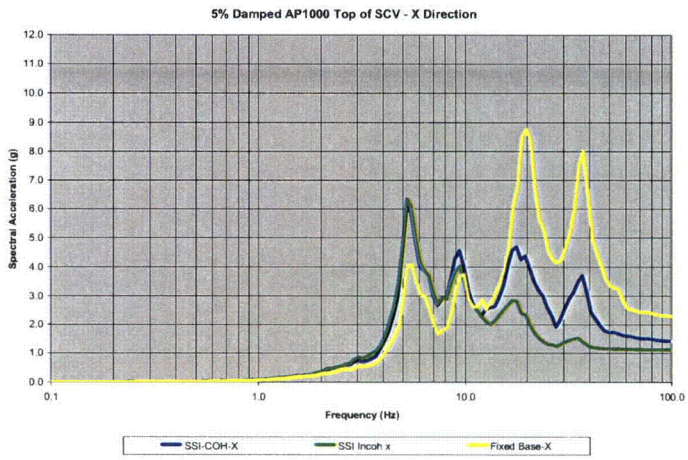
Importance of SSI – Steel Containment Vessel Response



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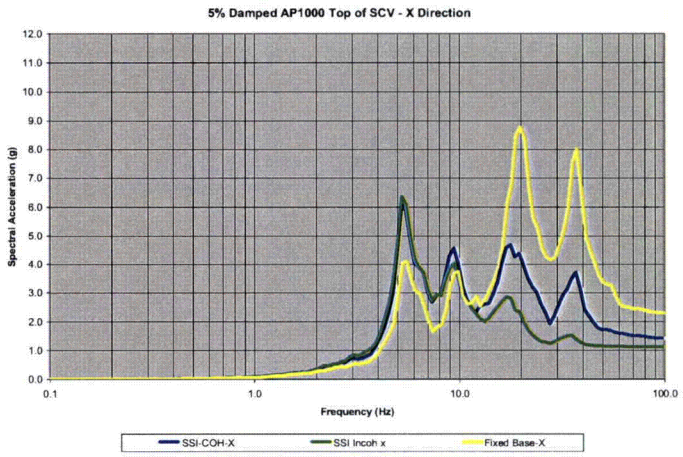
Importance of SSI –Containment Internal Structure Response



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SSI Effects: Soil Stiffness

- Seismic input motion
  - RG 1.60
- Soil stiffness as characterized by shear wave velocity
  - Stiff rock Vs = 6,000 fps
  - Stiff soil Vs = 2,500 fps
  - Medium soil Vs = 1,000 fps
  - Soft soil Vs = 500 fps
- In-structure response spectra (Node 18x)
- Combined Effects of Frequency Shift and Radiation Damping

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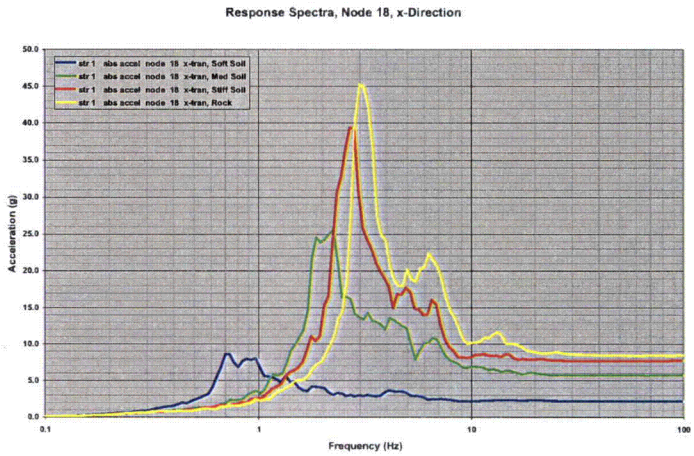
Observation of SSI Effects: Soil Stiffness



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SSI Effects: Structure Damping

- Seismic input motion
  - RG 1.60
- Soil stiffness as characterized by shear wave velocity
  - Stiff rock Vs = 6,000 fps
  - Soft soil Vs = 500 fps
- Structure Damping (4% and 10%)
- In-structure response spectra (Node 18x)
- Importance of Structure Damping dependent on SSI Effects

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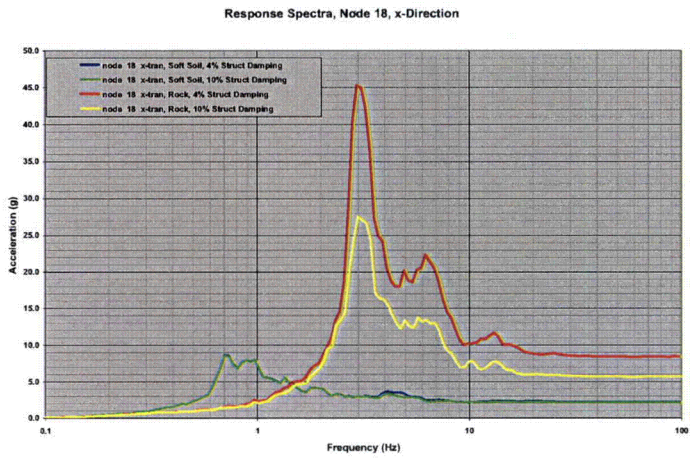
Observation of SSI Effects: Structure Damping



Observation of SSI Effects

- It is shown that SSI analysis is very important for structures on rock sites subjected to high frequency ground motion
- There are significant reductions in response at high frequencies due to frequency shifting below the power of the input and radiation damping
- There are significant increases in response at low frequencies due to induced rotations from SSI and from incoherence
- There is as much reduction in high frequency response from SSI on a rock site with high frequency input motion as there is from incoherence

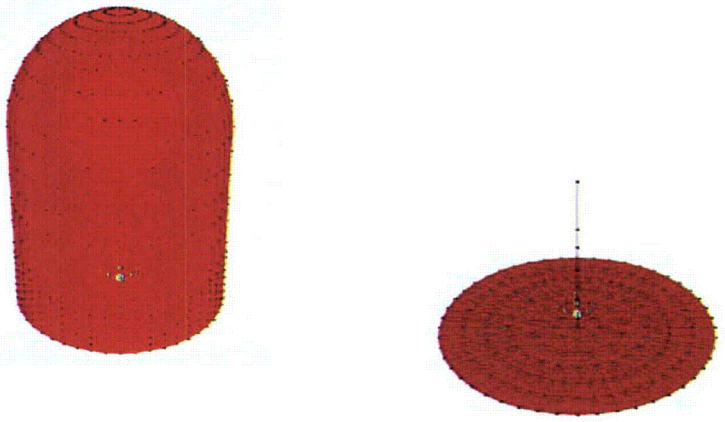
Damping

- Structure and soil damping is typically very low
  - Structure – 4% of critical Response Level 1
  - Soil – less than 10% of critical depending on earthquake strain
- Radiation damping due to SSI
  - Can be very large approaching critical damping for uniform sites
  - Can be low for shallow soil over rock site
  - Impedance mismatch of soil layers prevents radiation of energy out from the structure

Demonstration of Effects of Embedment and Incoherence

- Simple NPP structure has been investigated to demonstrate the effects of embedment and incoherence
- Four cases were evaluated
  - Surface founded, coherent ground motion
  - Surface founded, incoherent ground motion
  - Embedded, coherent ground motion
  - Embedded, incoherent ground motion
- Embedment ratio of 0.5 was considered
- The high frequency ground motion input and soil profile used for other evaluation was employed

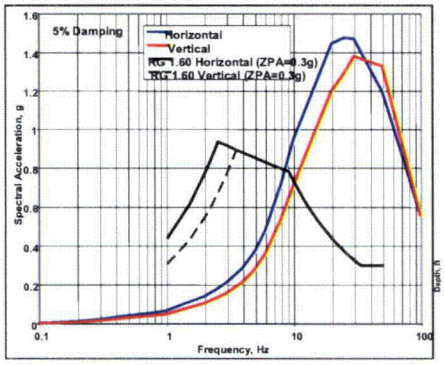
Embedment – Structural Model

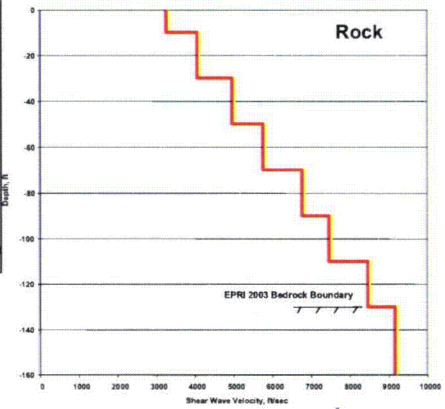


Embedment – Structural Model

- Reactor building shell radius = 84.63 feet
- Height of springline above basemat = 151.3 feet
- Wall thickness = 3.5 feet
- Basemat radius = 84.63 feet
- Basemat thickness = 10 feet
- 93 foot high internal structure
- Frequencies
  - Reactor Building shell horizontal: 3.9 Hz, 11.3 Hz
  - Reactor Building shell vertical: 10.5 Hz, 17.4 Hz
  - Internal Structure horizontal: 12.0 Hz, 17.5 Hz, 46.5 Hz
  - Internal Structure vertical: 39.4 Hz
- Embedment depth = 42 feet

Ground Motion and Soil Profile





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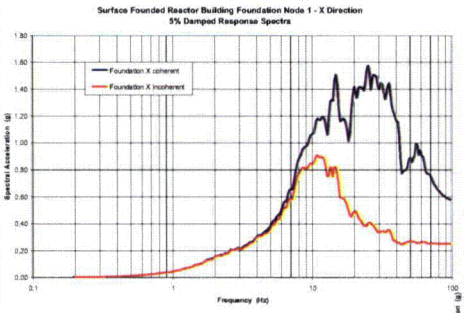
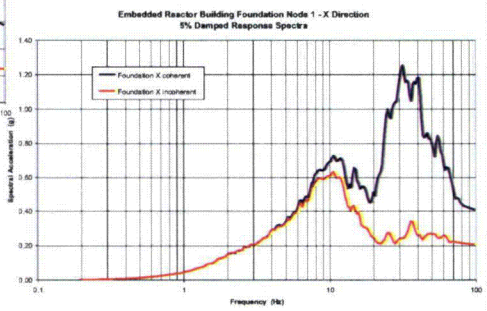
Foundation Horizontal Response





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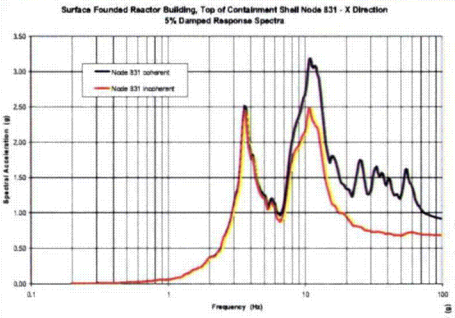
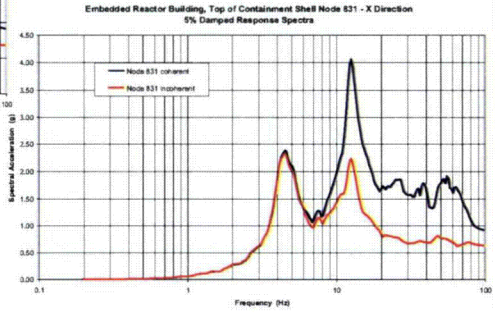
Top of Containment Shell Horizontal Response





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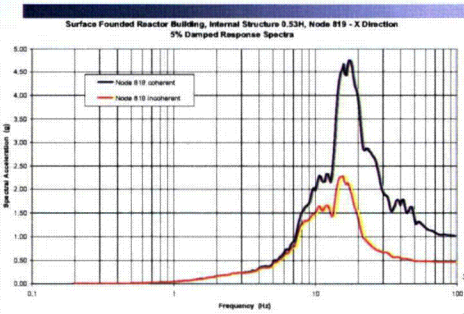
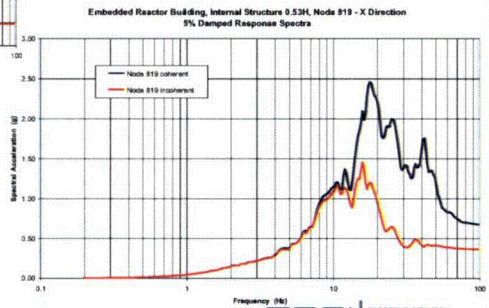
Internal Structure Mid-Height Horizontal Response





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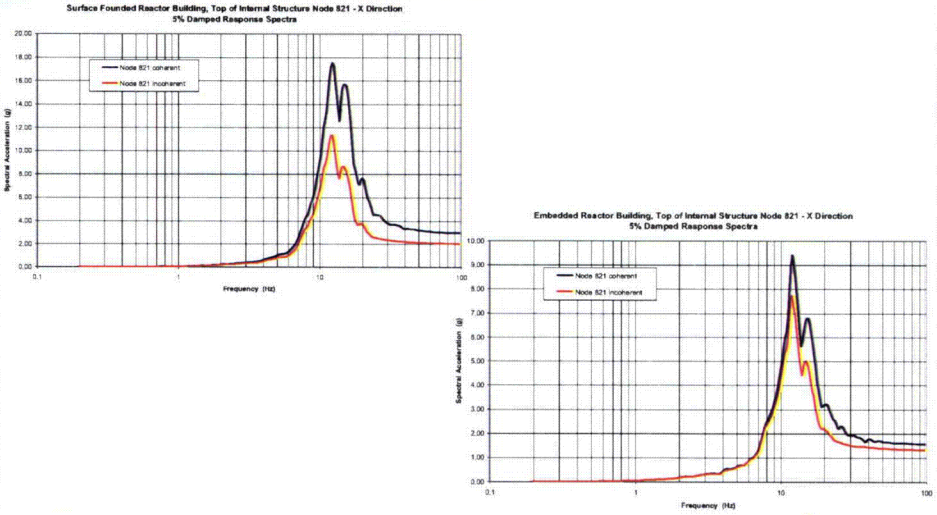
Top of Internal Structure Horizontal Response



Observations on Embedment and Incoherence

- In general, embedment produces reduced ISRS and for many cases this reduction is very significant
  - An exception is at the top of the containment shell. At this location, the 2nd fixed base mode is 11 Hz and the SSI modes are 11 Hz for the surface case and 13 Hz for the embedded case. The 13 Hz mode and high frequency input resulted in increased response for the embedded case
- Incoherency effects are independent of structure embedment
  - There is no systematic bias in the relatively small differences in incoherency effects for both surface founded and embedded structures