Application of the Computer Program SASSI for Seismic SSI Analysis of WTP Facilities

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Background

- SASSI computer code was developed in the early 1980’s to solve Soil-Structure-Interaction (SSI) problems
  - Original version of SASSI was based on the direct solution method for embedded structures
    - Requires that each soil node in the excavated soil volume be an interaction node
  - Subtraction solution method was introduced in 1998
    - Requires that only perimeter nodes in the excavated soil volume be considered interaction nodes
    - Significantly reduces computational effort
Background

- RPP-WTP facility includes two SC I (PC3) structures
  - Pretreatment Facility
    - Surface structure
  - High-Level Waste Structure (HLW)
    - Shallowly embedded structure
Background

• SSI analysis has been previously completed using the following:
  • Extensive Finite Element Model
  • Simplified Stick Model

• Correlation of dynamic properties has been demonstrated between the models
  • Both models have been described in RPP-WTP structural summary report and reviewed by PRT and DFNSB
Background

Finite Element Model of HLW Core Structure

21’ Embedment Depth
Footprint: 438’ x 236’
Background

Stick Model of HLW Core Structure
Objective

• Compare results of HLW SSI analysis using two methods
  • SASSI Direct Method
  • SASSI Subtraction Method

• Confirm adequacy of the SASSI Subtraction Method analysis of the HLW structure using the SASSI Direct Method as a benchmark
Methodology

• A Hybrid Finite Element Model and Stick Model representing the HLW Structure Core Structure is created.
• Dynamic characteristics of all three models are correlated.

<table>
<thead>
<tr>
<th>Model</th>
<th>Mode</th>
<th>Frequency (Hz)</th>
<th>Mass Participation</th>
<th>Mode</th>
<th>Frequency (Hz)</th>
<th>Mass Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite Element</td>
<td>67</td>
<td>12.1</td>
<td>61.7%</td>
<td>80</td>
<td>13.0</td>
<td>20.1%</td>
</tr>
<tr>
<td>Stick</td>
<td>3</td>
<td>12.2</td>
<td>67.5%</td>
<td>4</td>
<td>13.0</td>
<td>77.6%</td>
</tr>
<tr>
<td>Hybrid</td>
<td>3</td>
<td>12.3</td>
<td>69.3%</td>
<td>4</td>
<td>12.9</td>
<td>78.5%</td>
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</table>
SSI Model

Hybrid Finite Element Model and Stick Model of HLW Core Structure
Element Size in Excavated Soil

<table>
<thead>
<tr>
<th>Direction</th>
<th>Min (ft)</th>
<th>Max (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Dir: (EW)</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Y-Dir: (NS)</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>Z-Dir: (Vert)</td>
<td>10.50</td>
<td></td>
</tr>
</tbody>
</table>
WTP Ground Motion

RGM
Input Response Spectra

![Graph showing input response spectra for WTP Ground Motion with various curves labeled H1, H2, and VT.](image)
Soil Profile at HLW Site

Consider the Upper Bound Site-Specific soil case
# Mesh Limiting & Cut-off Frequencies

Using the maximum element size and $1/5 \lambda_s$ criteria:

<table>
<thead>
<tr>
<th></th>
<th>Critical Shear Wave Velocity</th>
<th>Mesh Limiting Freq (Hz)</th>
<th>Cut-Off Freq (Hz)</th>
</tr>
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<tbody>
<tr>
<td>LB:</td>
<td>775 fps</td>
<td>9.1</td>
<td>10.5</td>
</tr>
<tr>
<td>M:</td>
<td>1269 fps</td>
<td>14.9</td>
<td>17.5</td>
</tr>
<tr>
<td>UB:</td>
<td>1613 fps</td>
<td>19.0</td>
<td>22.0</td>
</tr>
</tbody>
</table>
Comparison of SSI Results

Acceleration Response Spectra
HLW Core Model at EL -21'
5% Damping - X due to X UB Soil - RGM Input Motion

Spectral Acceleration (g)

Frequency (Hz)
Comparison of SSI Results

Acceleration Response Spectra
HLW Core Model at EL -21'
5% Damping - Y due to Y- UB Soil - RGM Input Motion

Frequency (Hz)

Spectral Acceleration (g)
Comparison of SSI Results
Comparison of SSI Results

Acceleration Response Spectra
HLW Core Model at EL 0'
5% Damping - X due to X UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 0'
5% Damping - Y due to Y UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 0'
5% Damping - Z due to Z UB Soil - RGM Input Motion
Comparison of SSI Results

Acceleration Response Spectra
HLW Core Model at EL 13'
5% Damping - X due to X-UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 13'
5% Damping - Y due to Y-UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 13'
5% Damping - Z due to Z-UB Soil - RGM Input Motion
Comparison of SSI Results

Acceleration Response Spectra
HLW Core Model at EL 36
5% Damping - X due to X-UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 36°
5% Damping - Y due to Y-UB Soil - RGM Input Motion

Acceleration Response Spectra
HLW Core Model at EL 36°
5% Damping - Z due to Z-UB Soil - RGM Input Motion
Comparison of SSI Results
Comparison of SSI Results
**Observations**

- **Horizontal response:**
  - Subtraction method results are essentially the same as those of direct method

- **Vertical response:**
  - Subtraction method results are slightly higher than those of direct method in the higher frequency range
    - Results in a slightly higher ISRS
Conclusions

• Use of subtraction method for SSI Analysis of the RPP-WTP HLW (a shallowly embedded structure) is considered to be adequate and slightly conservative
Conclusions

• SASSI is a complex program

• Before use in any critical facility, the user must develop experience in modeling, analysis, and interpretation of results

• It is our observation that lack of experience and knowledge, as well as, overconfidence have caused issues with respect to use of SASSI
Conclusions

• Verification is critical
  • It is very important that SASSI program, as installed on the production computer, is fully verified particularly for the options utilized
  • BNI SASSI verification examples include many solutions that compare the results with reliable published papers, several SSI-related doctoral dissertations, as well as experimental data
Conclusions

• Verification is critical
  • Some users modify the program SASSI and develop additional features
  • Any developments must be carefully reviewed by the expert to ensure compatibility with SASSI formulations and methodology and proper verification before use in design
  • Simple verification examples may not be sufficient when the new features are used for complex modeling conditions
Conclusions

• Independent checking is recommended
• When in doubt, perform SSI analysis by other simple methods (soil spring, dashpot) and verify the overall global responses obtained from SASSI