Session 7
SASSI Approach to Incoherency (SRSS)

NRC Seismic Seminar

Soil-Structure Interaction (SSI) Including Coherent and Incoherent Ground Motion

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SASSI Incohrency Analysis (SRSS)

Contents

- Incoherency Models
- Implementation in SASSI
- Modal Truncation
- Verification
- General Guidelines

SASSI Incohrency Analysis (SRSS)

Abrahamson Model
(Empirical)

$$\gamma_{pq}(f,\xi)=\left[1+\left(\frac{f\ Tanh(a_3\xi)}{a_1 f_c}\right)^{a1}\right]^{-1/2}\left[1+\left(\frac{f\ Tanh(a_3\xi)}{a_2 f_c}\right)^{a2}\right]^{-1/2}$$

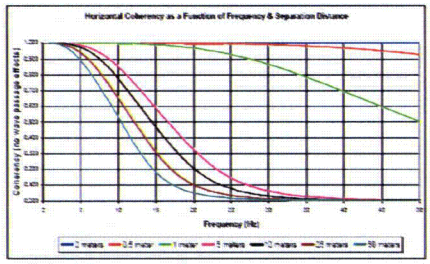
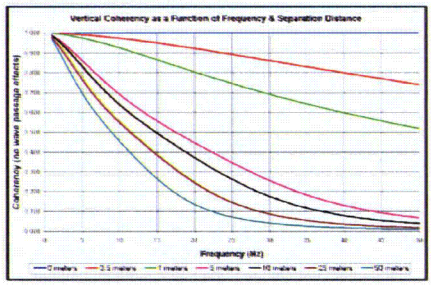


Figure 2-1
Coherency Function for Horizontal Ground Motion

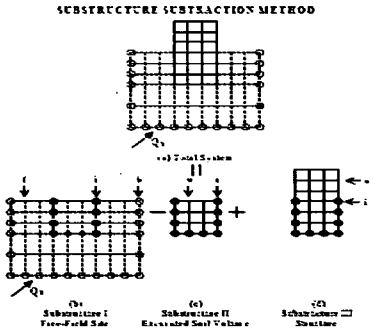


SASSI Incohrency Analysis (SRSS)

Mita and Luco (1986)
(theoretical model)
Used for few published SSI solution

$$\gamma_{ij}(r,\omega)=\exp\left\{-[\gamma\omega\,|\,\vec{r}_j-\vec{r}_i\,|\,/V_s]^2\right\}$$

SASSI-Subtraction Method



$$\begin{bmatrix} C_{ff}^{II}-C_{ff}^{I}+X_{ff} & -C_{fw}^{I} & C_{fs}^{III} \\ -C_{wf}^{II} & -C_{ww}^{II} & 0 \\ C_{sf}^{III} & 0 & C_{ss}^{III} \end{bmatrix} \begin{Bmatrix} U_f \\ U_w \\ U_s \end{Bmatrix} = \begin{Bmatrix} X_{ff} U_f \\ 0 \\ 0 \end{Bmatrix}$$

$[C_{ij}]=[K_{ij}]-\omega^2[M_{ij}]$

Subscript Notation

b	the boundary of the soil system
i	at the boundary between the soil and the structure
w	within the excavated soil volume
f	at the remaining part of the free-field system
s	at the remaining part of the structure
f	combination of i and w nodes

SASSI Incohrency Analysis (SRSS)

$$[\Gamma(\omega)] = \begin{bmatrix} 1 & \gamma_{1,2} & \cdots & \gamma_{1,m} \\ \gamma_{2,1} & 1 & \cdots & \gamma_{2,m} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{m,1} & \gamma_{m,2} & \cdots & 1 \end{bmatrix}$$

$$\gamma_{pq}(f,\xi) = \left[1+\left(\frac{f\ Tanh(a_3\xi)}{a_1 f_c}\right)^{a_2}\right]^{-1/2}\left[1+\left(\frac{f\ Tanh(a_3\xi)}{a_2 f_c}\right)^{a_2}\right]^{-1/2}$$

$$[S_g(\omega)] = \sum_{i=1}^{m} \lambda_i \{\phi\}_i \{\phi\}_i^*$$

$$[S_g(\omega)]\{\phi\}_i = \lambda_i \{\phi\}_i$$

$$\{\phi\}_i^* \cdot \{\phi\}_j = \delta_{i,j} = \begin{cases} 1, & i = j \\ 0 & i \neq j \end{cases}$$

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➢Spatial modes, j = 1, m

$$\{u_g\}_j = \sqrt{\lambda_j}\{\phi\}_j$$

➢SSI Equation of Motion

$$\begin{bmatrix} C_{ii} + X_{ii} & C_{im} \\ C_{mi} & C_{mm} \end{bmatrix} \begin{Bmatrix} u_i \\ u_s \end{Bmatrix}_j = \begin{Bmatrix} X_{ii} u_{g,j} \\ 0 \end{Bmatrix}$$

$$\{u\}_j = [H]\{u_g\}_j$$

➢PSD of Structural Response

$$[S_u(\omega)] = \sum_{j=1}^{m} \{u\}_j \{u\}_j^*$$

$$\sum_{j=1}^{m} \{u\}_j \{u\}_j^* = \sum_{j=1}^{m} [H]\{u_g\}_j \{u_g\}_j^* [H]^* = [H]\left(\sum_{j=1}^{m} \lambda_j \{\phi\}_j \{\phi\}_j^*\right)[H]^* = [H][S_g][H]^*$$

$$S_{u,kk} = \sum_{j=1}^{m} u_{k,j}\overline{u_{k,j}} = \sum_{j=1}^{m} |u_{k,j}|^2$$

$$|H(\omega)|_k = \sqrt{\sum_{j=1}^{m} |u_{j,k}|^2}$$

SASSI Incohrency Analysis (SRSS)

➢Truncation Error

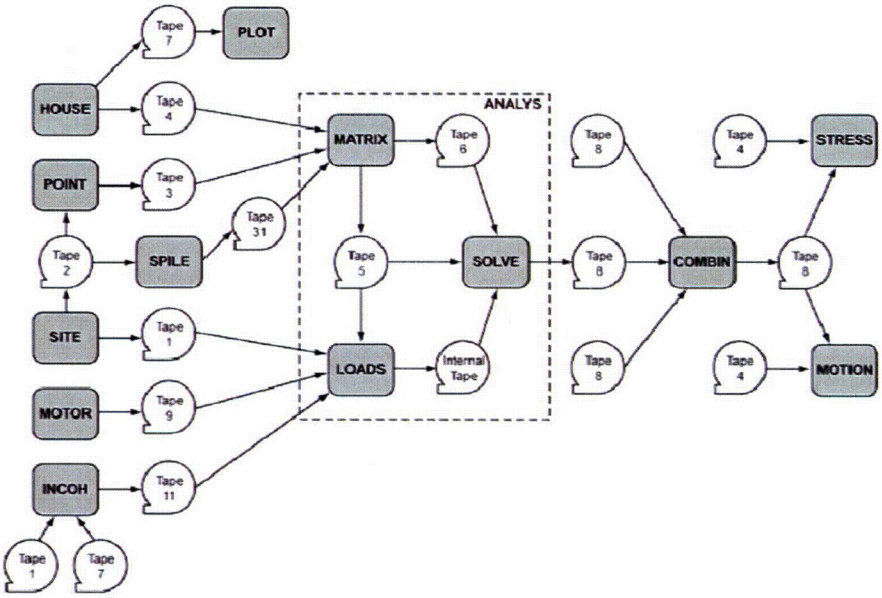
$$|\{u_j\}|^2 = \{u_j\}^* \{u_j\} = \sum_{k=1}^{m} \overline{u_{k,j}} \cdot u_{k,j} = |\lambda_j| \cdot \| \{\phi\}_j^* [H]^* [H] \{\phi\}_j \| = |\lambda_j| \cdot C_j$$

C_j is the determinant of the matrix $\| \{\phi\}_j^* [H]^* [H] \{\phi\}_j \|$

$$\sum_{j=1}^{m} |\{u_j\}|^2 = \left(\sum_{j=1}^{m} |\lambda_j|\right) C$$

$$|\varepsilon|_u = \frac{1 - \sqrt{\sum_{j=1}^{s} |u_j|^2}}{\sqrt{\sum_{j=1}^{m} |u_j|^2}} = \frac{1 - \sqrt{\sum_{j=1}^{s} |\lambda_j|}}{\sqrt{\sum_{j=1}^{m} |\lambda_j|}}$$

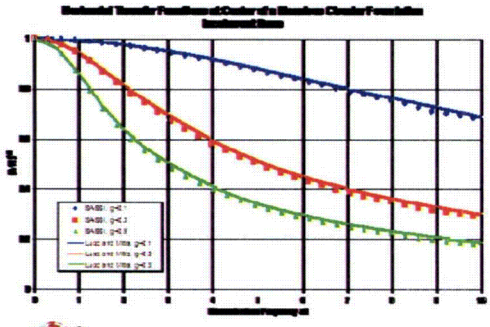
SASSI Incohrency Analysis (SRSS)-Program Layout

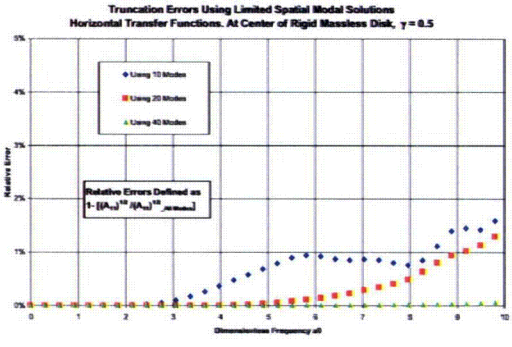


SASSI Incohrency Analysis (SRSS)-Verification

Luco, J. E., and Mita, A. (1987) "Response of Circular Foundation to Spatially Random Ground Motion," ASCE *Journal of Engineering Mechanics*, Vol. 113, No. 1, pp. 1-15, January.

Rigid massless circular foundation on uniform halfspace

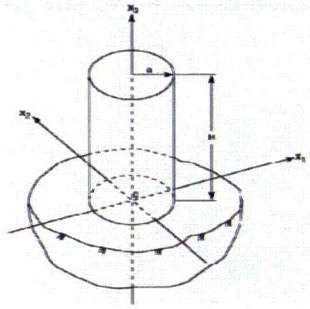


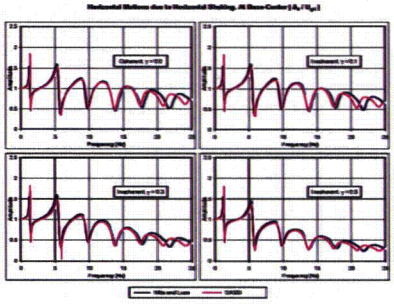


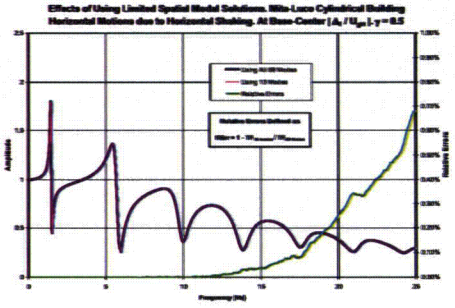
SASSI Incohrency Analysis (SRSS)-Verification

Mita, A. and Luco J.E. (1986): "Response of Structures to Spatially Random Ground Motion," Proceedings of the Third U.S. Conference on Earthquake Engineering, Charlston, South Carolina.

Cylindrical Building on Uniform Halfspace

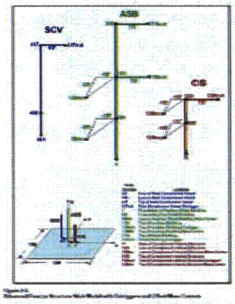


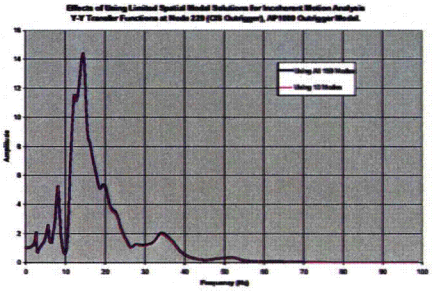


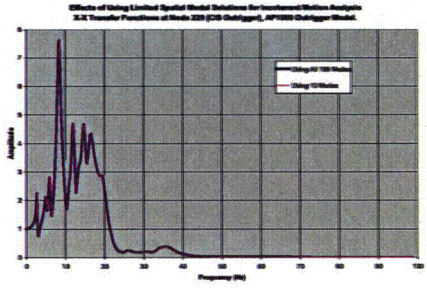


SASSI Incohrency Analysis (SRSS)-Verification

Multi-Stick Model for a NPP







SASSI Incohrency Analysis (SRSS)-Documentation

- EPRI (2007), Final Report: "Validation of CLASSI and SASSI to Treat Seismic Wave Incoherence in SSI Analysis of Nuclear Power Plant Structures, August.
- Ostadan, F., Deng. N. (2007), SASSI-SRSS Approach for SSI Analysis with Incoherent Ground Motions, Bechtel National, SF, CA.

SASSI Incohrency Analysis (SRSS)-General Guidelines

- Additional rocking and torsional modes of vibrations
- Frequencies of analysis, 50-100
- User can decide on the number of spatial modes, 10 modes appear to be adequate, error can be estimated
- Incoherency is a 3D effect (no symmetry or 2D modeling)
- Effect of foundation flexibility for vertical analysis needs further evaluation