ACS SASSI Application to Linear and Nonlinear Seismic SSI Analysis of Nuclear Structures Subjected to Coherent and Incoherent Inputs

TENTATIVE AGENDA FOR 5-DAYS TRAINING

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Summary:

Days 1: Understanding Seismic SSI Effects for Nuclear Facility Structures

UNDERSTANDING BASIC SEISMIC SSI EFFECTS FOR NUCLEAR FACILITY STRUCTURES

Review engineering analysis capabilities and their practical limitations. Discuss practical aspects including deep soil profiles vs. shallow soil layer above base-rock, 2D SSI vs. 3D SSI, surface vs. embedded foundations, flexible vs. rigid foundations, simple stick vs. detailed FE structural models, incoherent motion vs. coherent motion, etc. Discuss also structure-soil-structure interaction effects. Discuss seismic input, soil profiles, site response analysis and SSI analysis. Discuss the kinematic and inertial SSI effects on seismic structural response.

Review basic capabilities and limitations of the SASSI methodology. Review key modeling aspects of the complex frequency domain approach based on the Fourier representation of motion. Discuss SASSI-based methodology and implementation. Identify advantages and disadvantages. Discuss the recent the USNRC SRP 3.7.1 and 3.7.2 ASCE 4-16 requirements for SSI analysis of nuclear structures.

Review theoretical and practical aspects. Discuss stochastic modeling of ground motion including the coherence function concept. Discuss Luco-Wong and 2005, 2006 and 2007 Abrahamson plane-wave coherency models for soil and rock sites. Explain motion incoherency and wave passage effects. Discuss incoherent vs. coherent seismic loading and soil-foundation interface boundary conditions. Show simple, generic examples. Review the EPRI validated incoherent SSI methodologies (EPRI TR#1015111, Nov 2007) and the USNRC ISG-01 requirements (May 2008). Review the 2007 EPRI study and its main results and conclusions. Review stochastic simulation approach vs. simpler deterministic approaches, such as SRSS and AS. Discuss the effects of soil conditions and foundation embedment on incoherent SSI response and the incoherent SSI effects for stick models vs. detailed FE models, rigid foundations vs. flexible foundations, surface foundations vs embedded foundations.

ILLUSTRATIVE CASE STUDIES

Show different incoherent SSI studies on SSI models including flexible or/and deeply embedded foundations. Discuss effects on incoherency and embedment on ISRS, accelerations and displacements, structural forces and soil pressures. Illustrate SSI case studies for surface and deeply embedded foundations. Show also case studies including structure-soil-structure interaction (SSSI) and soil pressure computations using foundation displacements or forces. Discuss the effect of basemat flexibility effects for coherent and incoherent SSI analysis.

The investigated SSI models will include both stick with rigid foundations and detailed FE models with flexible foundations, using RG 1.60 and HRHF seismic inputs in conjunction with different site conditions. Specific SSI results are shown for the EPRI AP1000 NI model with and without embedment on firm rock and soft soil; a detailed FEA RB model with a significant embedment; and a deeply embedded UHS type structure. Present comparative results for shallowly embedded nuclear island models and deeply embedded advanced or SMR models using Flexible Volume, Modified Subtraction and Fast Flexible Volume. Include many other examples.

Days 2-4am: ACS SASSI Software Capabilities and Application

SASSI METHODOLOGY:
Review key modeling aspects of the complex frequency domain approach based on the Fourier representation of motion. Review theoretical details and key modeling aspects. Describe ACS SASSI SSI methodologies for coherent and incoherent seismic inputs. Discuss stochastic vs. deterministic incoherent SSI approaches. Describe linear and nonlinear site response and SSI analysis capabilities of the ACS SASSI software. Identify the unique capabilities of ACS SASSI software. Provide examples with results.

MODULAR CONFIGURATION:
Describe modular configuration in detail. Review in detail functionalities and associated files of each SSI modules. Review briefly functionalities using the input dialog windows for analysis options of each module.

IMPLEMENTATION:
Describe specific numerical algorithms that are implemented in ACS SASSI for generation of spectrum compatible acceleration time histories, performing nonlinear site response analysis, computing soil distributed impedances and free-field motions at the SSI interaction points, and computing linear and nonlinear SSI responses for coherent and incoherent inputs.

SSI MODELING:
Provide insights on the interpolation of complex acceleration and stress complex transfer functions, and application of the ATF error smoothing and phase adjustment for incoherent analyses. Illustrate various case studies.

POST SSI ANALYSIS CALCULATIONS AND PLOTTING:
Discuss the use of the ACS SASSI GUI to create model database, run SSI analyses and post-process SSI results. Describe MAIN and PREP module functionalities. Show how to do post-processing for ISRS, acceleration and displacement time histories, and structural stresses/forces and soil pressures. Provide different application examples. Describe converters from ANSYS cdb database files and the SASSI input fixed format files to the ACS SASSI PREP input files. Also, describe the converter from the ACS SASSI PREP input file to the ANSYS ADPL input file.

SECTION-CUTS CAPABILITY: The Section-Cut capability is used to select shearwalls of interest from the investigated structure model and, then, to compute the cross-sectional forces and moments in these shearwalls based on the computed wall stress integration. The new section-cut capability is highly user-friendly and is implemented as a part of the UI user-interface module capabilities.

VERIFICATION AND VALIDATION:
Describe the V&V tests. Review SSI problems used for V&V of ACS SASSI NQA code.

BUILDING SSI MODELS:
Describe the typical input file contents. Review the ACS SASSI parametric language for building complex SSI models. Describe the available FE library. Show how to efficiently generate nodes and elements, and assign material and constant for different element groups. Review different input files structure and content.

Day 4pm: Demos and Description of Advanced Optional SSI Capabilities

BRIEF DESCRIPTION OF SSI ADVANCED SSI CAPABILITIES (OPTIONS):

- ACS SASSI-ANSYS INTEGRATION (OPTIONS A AND AA):
The new ACS SASSI-ANSYS integration capability provides an advanced two-step SSI approach that is capable of including more refined FEA structural models, local nonlinear material, and/or nonlinear geometric aspects within the structure or at foundation interface with the soil. There are two ACS SASSI-ANSYS interfacing options: i) *Option ANSYS* or A, and ii) *Option Advanced ANSYS* or AA. The ACS SASSI-ANSYS interface implements an efficient and accurate two-step SSI analysis capability in Option A and also permits the use the ANSYS structural models directly for the SSI analysis without the need of converting the ANSYS model to an ACS SASSI model in Option AA. The new Option AA capability uses directly the ANSYS structural model matrices, K, M and C for SSI analysis. Show application to surface and deeply embedded models. Using the ANSYS interface, local nonlinear structural aspects can be included, and realistic seismic soil pressures including soil plasticity and soil separation from foundation effects can be considered. Illustrate example problems. Use converters from and to ANSYS. Discuss how to apply Option AA to run ANSYS model directly in ACS SASSI. Show demo cases and validation studies.

- *PROBABILISTIC SSI ANALYSIS (Option PRO)*: The probabilistic SSI analysis capability includes all methods and approaches recommended by ASCE 4-16 standard in Section 5.5 entitled “Probabilistic SSI Analysis”. The probabilistic SSI analysis shall be performed by a simulation approach, most efficiently using the Latin Hypercube Sampling (LHS). Parameters significant to the seismic response shall be treated as correlated random variables. These random parameters include the structure stiffness and damping, the soil/rock layering stiffness and damping, and the seismic input motion amplitude and spectral shape. The ACS SASSI probabilistic SSI analysis uses the LHS simulation for simulating seismic inputs with spectral amplitude and shape random variations, soil profiles with spatially correlated random layer properties, and effective structural stiffness and damping with random variations that are conditional to the stress levels in structure. The effective structural stiffness and damping variable can be defined differently for various parts of the structure based on the stress levels achieved in those structure parts.

- *NONLINEAR STRUCTURE CAPABILITY (Option NON):* The Nonlinear Structure capability is related to ASCE 43-05 and ASCE 4-16 recommendations for seismic design-basis analyses and beyond the design level analyses. The nonlinear structure SSI analysis can be used to perform fast and accurate nonlinear SSI analyses, including reinforced concrete cracking and post-cracking behavior. Option NON includes sophisticated nonlinear hysteretic models for concrete behavior. Nonlinear SSI analysis with Option NON can be run at a small fraction of the runtime of a time domain nonlinear SSI analysis. An example of using Option NON for nonlinear SSI analysis of a concrete shearwall nuclear structure subjected to the design-basis seismic input and beyond-design review level seismic input will be briefly described.

Show briefly some applications using the new Options NON and PRO capabilities. Discuss applications using fast nonlinear structural SSI analysis in complex frequency domain via Option NON. Present comparisons of SSI results using Deterministic and Probabilistic SSI Analyses based on the new ASCE 4-2016 recommended methods.

DESCRIBING APPLICATION DEMOS:
The demo problems will be described to show various SSI analysis options available in ACS SASSI. The SSI analysis post-processing capabilities will be also demonstrated. Vector, bubble or contour plots and deformed shape animations will be exercised.

Day 5: Hands-On Session and Question and Answers

RUNNING DEMOS:
Selected demo problems will be executed independently by the training participants. The demo problems will include running the SSI models and reviewing the SSI results using the available ACS SASSI post-processing tools.

QUESTIONS AND ANSWERS CLOSURE SESSION:
Questions and answers regarding the software application to different types of SSI problems that interest the participants.