Soil-Structure Interaction Validation of LS-DYNA Containment Model based on Lotung Large Scale Seismic Test Program

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Advanced reactors and Department of Energy nuclear facilities are increasingly considering nonlinear elements or behaviors in the seismic design and analysis of structures, systems, and components (SSCs) to:

- Lower construction or retrofit costs
- Reduce seismic demands on SSCs
- Address unique operation challenges of advanced nuclear facilities
- Consider performance-based structural criteria

Some examples of considered nonlinear elements or behaviors include seismic isolation and damping devices, gapped supports to accommodate thermal expansion, and inelastic response of structural materials (especially where containment/confinement functions are not required). Given the advancement in software capability and computing power, nonlinear time domain methods can be employed to analyze the nonlinear response of the structure concurrent with the soil-structure interaction (SSI) effects. However, the foundation for seismic analysis and the accompanying regulatory guidance supporting the nuclear industry was built upon extensive application of the substructuring approach considering an equivalent linear approximation of the site and the structure.

To demonstrate and build confidence in an alternate SSI analysis approach, software verification, validation, and benchmarking serve a key role by comparing results against expected solutions and field observations. This is supported by the U.S. Nuclear Regulatory Commission (NRC) "Non-Light Water Review Strategy Staff White Paper" which indicates that NRC technical review relies in part on verification and validation to demonstrate the acceptability of the analysis method. Specifically related to nonlinear seismic analysis, the NRC Standard Review Plan identifies that "the results of the nonlinear analysis should be judged on the basis of the linear or equivalent linear analysis."

Toward these goals of verification, validation, and benchmarking nonlinear time domain approaches for SSI analysis, a soil-structure system model of the Lotung Large Scale Seismic Test Program containment structure and internals is analyzed using LS-DYNA in the time domain. See Figure 1 for the containment structure cross section and finite element model. The Lotung test program and accompanying experimental data have served as a foundation for validating many equivalent linear, frequency domain SSI software tools employing the substructuring approach. Thus, the Lotung soil-structure model represents part of the basis upon which the substructuring approach was founded. The LS-DYNA Lotung soil-structure model presented herein demonstrates the capability of the software and the employed time domain approach to simulate in-structure response of a combined soil-structure system considering an equivalent linear soil. A good agreement is observed between measured and numerical free field and in-structure response spectra. This validation of the combined soil-structure system response demonstrates the viability of the time domain approach for SSI analysis, offering a more flexible approach that can consider nonlinear behavior in one or more parts of the system. Thus, it serves as an initial foundation for soil-structure system analyses that incorporate nonlinear elements or behaviors such as seismic isolation, gapped supports, and inelastic structural materials.

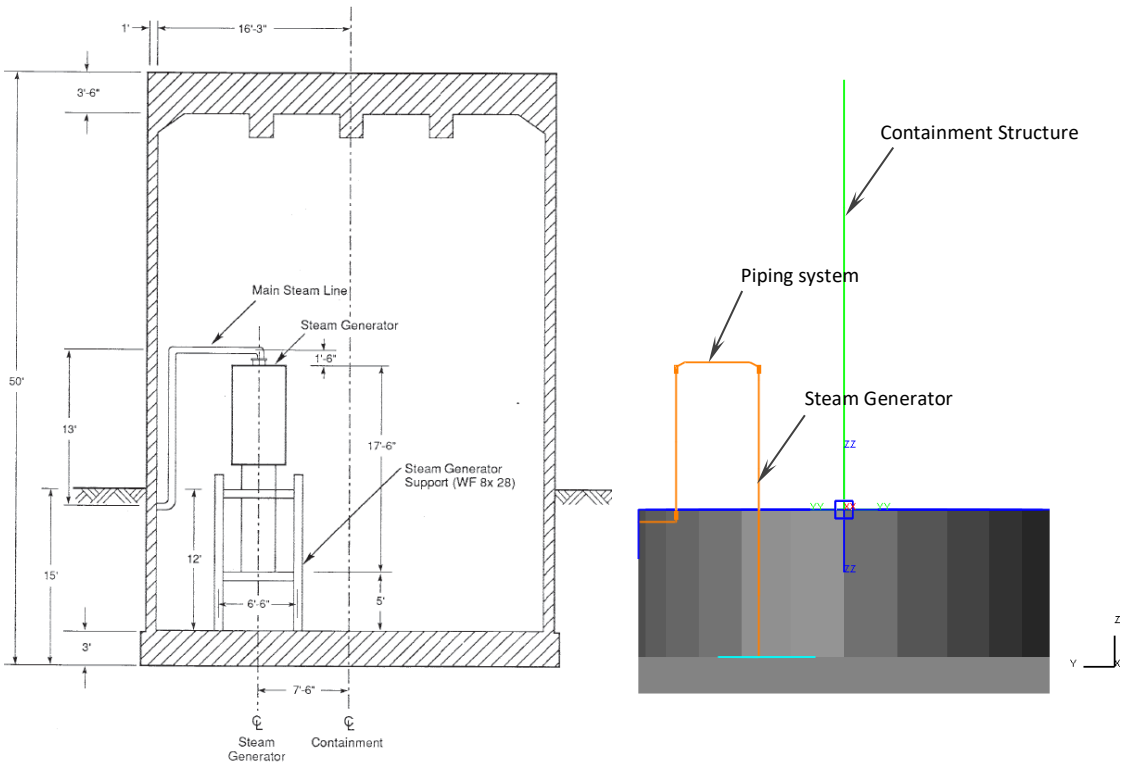

Figure 1: Vertical cross-section of containment model [EPRI NP-7305-SL]