STRUCTURAL QUALIFICATION OF THE HI-STORM UMAX STORAGE SYSTEM

USNRC Docket #72-1040

A Pre-Submittal Briefing to the SFST

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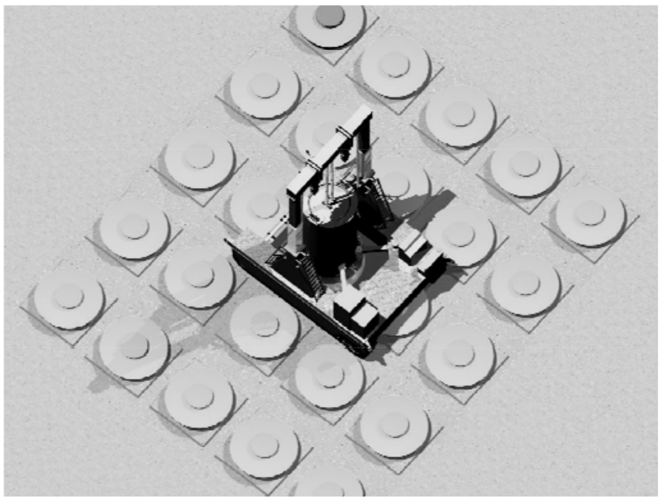
INTRODUCTION

- HI-STORM UMAX is essentially a larger version of the latest HI-STORM 100U underground storage system recently approved by the NRC.
- HI-STORM UMAX structural qualification includes Soil Structure Interaction (SSI) analyses under seismic condition, ACI strength evaluation of ISFSI concrete members, and other miscellaneous calculations.
- The HI-STORM UMAX structural qualification will be performed using the same NRC approved methodologies developed for the latest HI-STORM 100U system.

INTRODUCTION



Objectives of HI-STORM UMAX SSI Analysis

- To seismically qualify the reference ISFSI site characterized by conservatively assumed weak soil properties and bounding seismic strength so that the HI-STORM UMAX can be deployed at most US nuclear power plant sites.
- To obtain the bounding loads experienced by the cask structural members, the stored fuel and the ISFSI concrete members under the design basis seismic loading condition for subsequent structural integrity analyses.

Outline of the SSI Analysis Methodology

- Perform a two-step (SHAKE/LS-DYNA) soil seismic response analysis using the lower bound soil properties to establish the Design Basis Earthquake response spectra for the reference ISFSI site .
- Perform LS-DYNA SSI time history analyses using the developed HI-STORM UMAX FE model to obtain the bounding responses of both the cask and the ISFSI structure members.

SHAKE Soil Seismic Response Analysis

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- Use the lower shear wave velocity profile of US nuclear power plants (taken from NUREG/CR-6865) to perform SHAKE analyses for soil layers with a minimum total thickness of 100 feet.
- Synthetic time histories developed from Regulatory Guide 1.60 response spectrum are designated as the rock outcrop motion and scaled to yield the target ground surface ZPAs (i.e., 1.0 g’s in the horizontal direction and 0.75 g’s in the vertical direction).

Shear Wave Velocity Profile of US Nuclear Power Plant Sites (NUREG/CR-6865)

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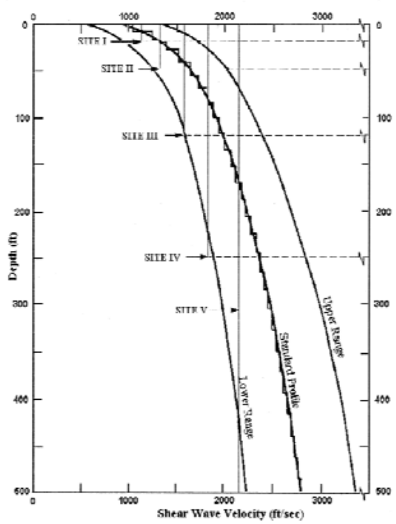

Acceleration Time History of the Regulatory Guide 1.60 Earthquake

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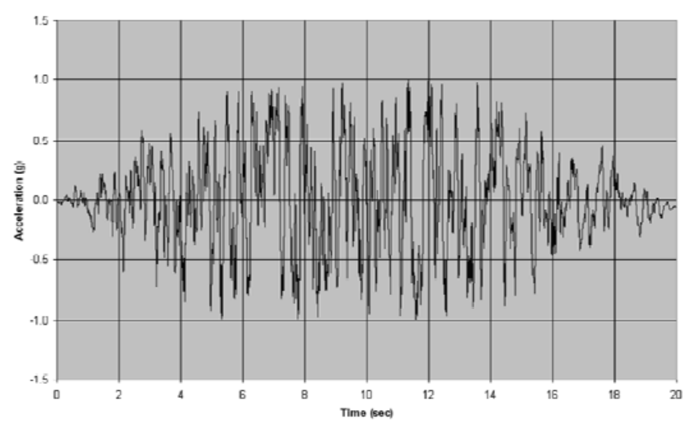

Acceleration Time History at the Base of Soil Layers (Horizontal Direction)

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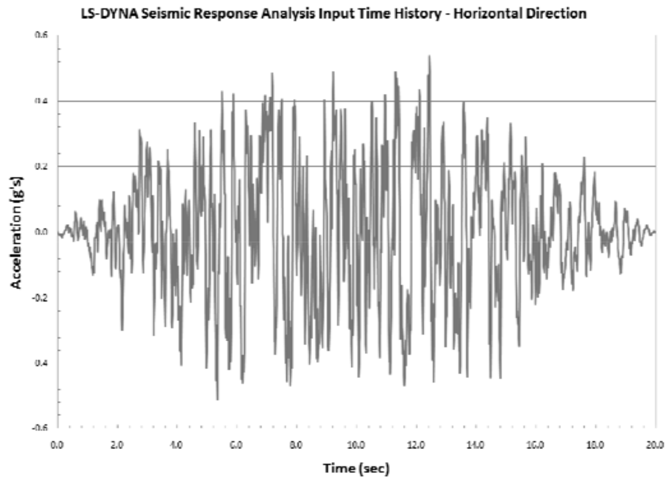

Acceleration Time History at the Base of Soil Layers (Vertical Direction)

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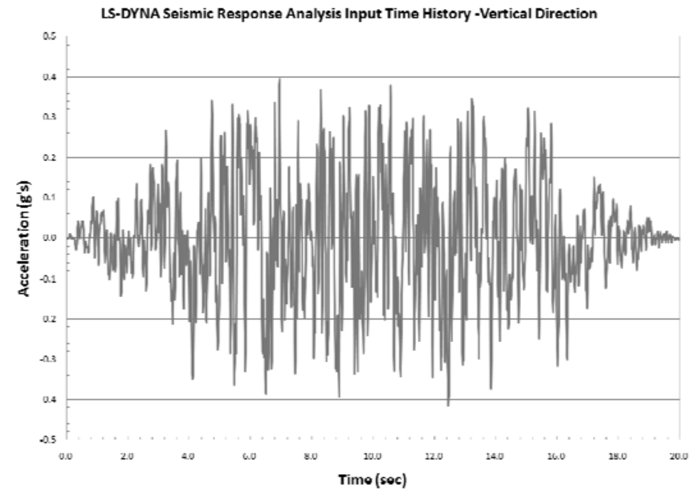

Design Basis Earthquake Response Spectrum at Ground Surface (Horizontal Direction)

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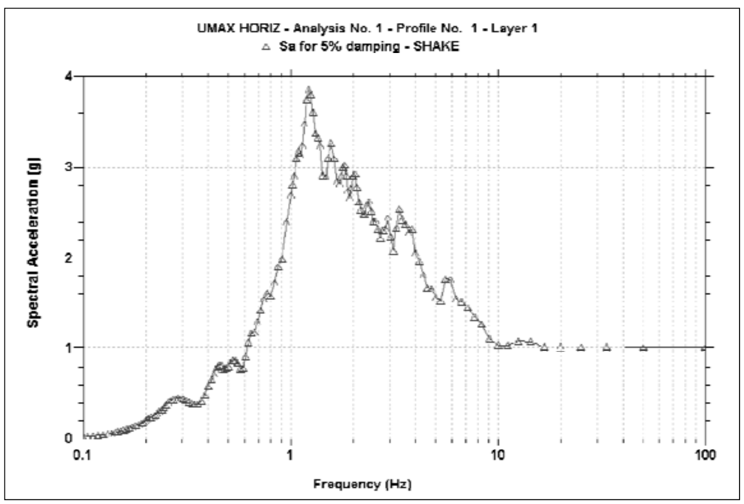

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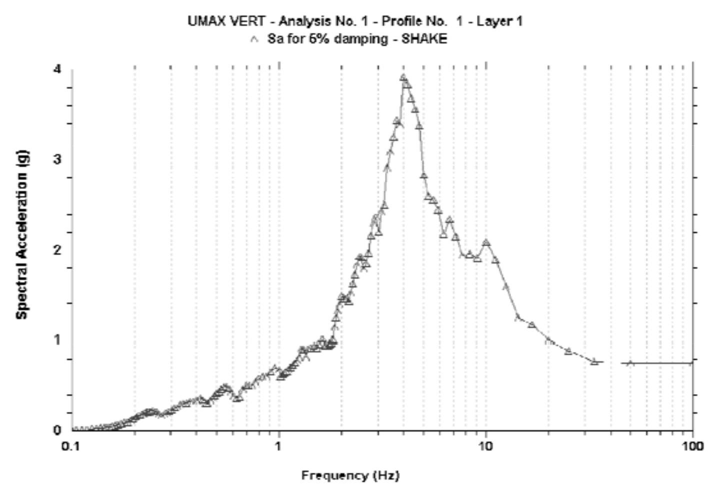

Design Basis Earthquake Response Spectrum at the SFP Elevation (Horizontal Direction)

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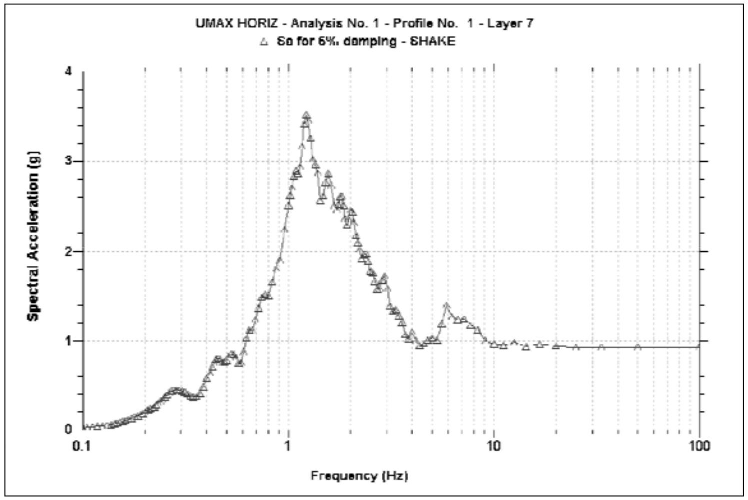

Design Basis Earthquake Response Spectrum at the SFP Elevation (Vertical Direction)

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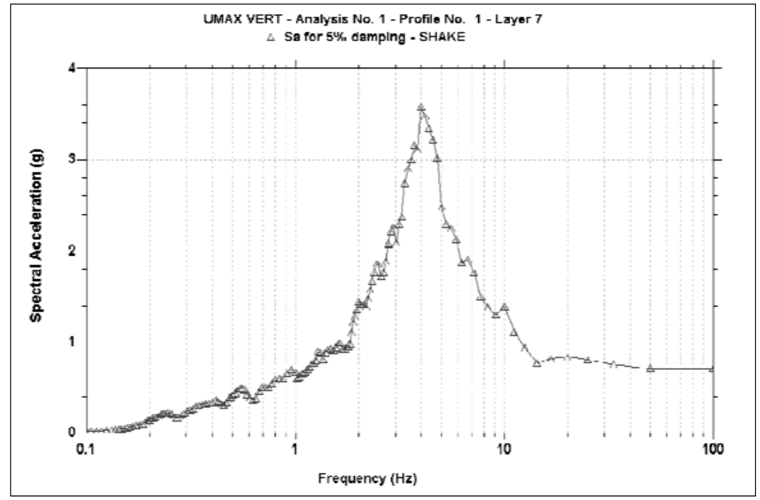

LS-DYNA Soil Seismic Response Analysis

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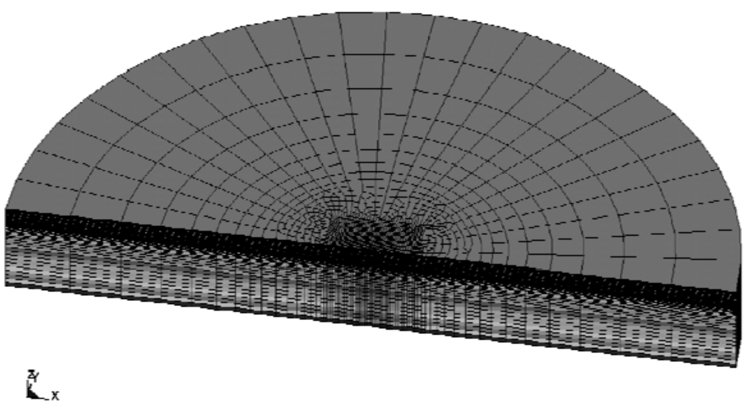

LS-DYNA Soil Seismic Response Analysis

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- The LS-DYNA soil model consists of two soil layers with properties determined based on the averaged strain compatible soil properties obtained from the SHAKE analysis for soil layers above and below the ISFSI Support Foundation Pad (SFP) elevation.
- The input acceleration time history at the base of the soil layers is taken from SHAKE analysis result. The “slave boundary condition” is used per NUREG/CR-6865.
- Objective: To demonstrate that the LS-DYNA soil model can generate similar design-basis seismic response spectra from SHAKE at both the ground surface elevation and the SFP elevation.

HI-STORM UMAX Subgrade and Undergrade Space Nomenclature

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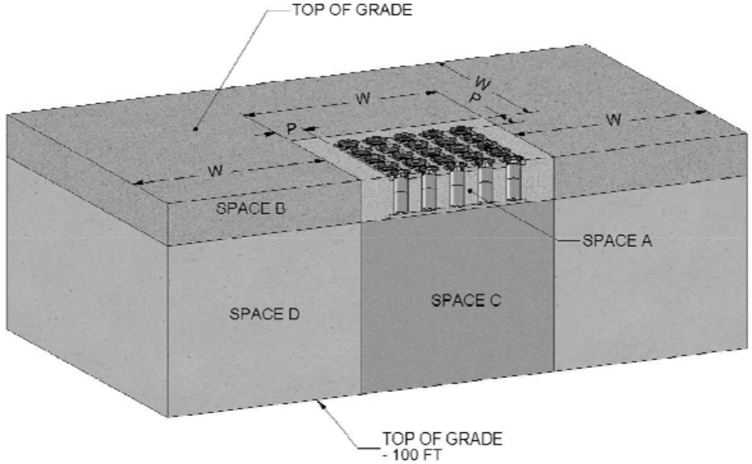

HI-STORM UMAX ISFSI Site Minimum Soil Property Requirement

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Space	Density (lbf/ft^3)	Strain Compatible Shear Wave Velocity (ft/sec)	Note
A	120	700	This space typically contains flowable fill (or CLSM), which will not settle per ACI 229R-99
B	110	450	This space typically contains native soil
C	120	485	This space may be remediated with vertical reinforcement such as pilings to limit settlement
D	120	485	This space typically contains native soil

LS-DYNA Soil-Structure Model of the HI-STORM UMAX ISFSI

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- The LS-DYNA soil-structure model is developed based on the 5x5 ISFSI configuration and consists of loaded HI-STORM UMAX VVMs, concrete pads and 4 soil regions of the same total thickness as in the soil seismic response analysis.
- The configuration with a retaining wall during the ISFSI expansion is also considered.
- The overall soil dimension and the soil boundary condition, as well as the input acceleration time history at the base of the soil layers, are identical to those used in the LS-DYNA soil seismic response analysis.

HI-STORM UMAX SSI Analysis Base Model

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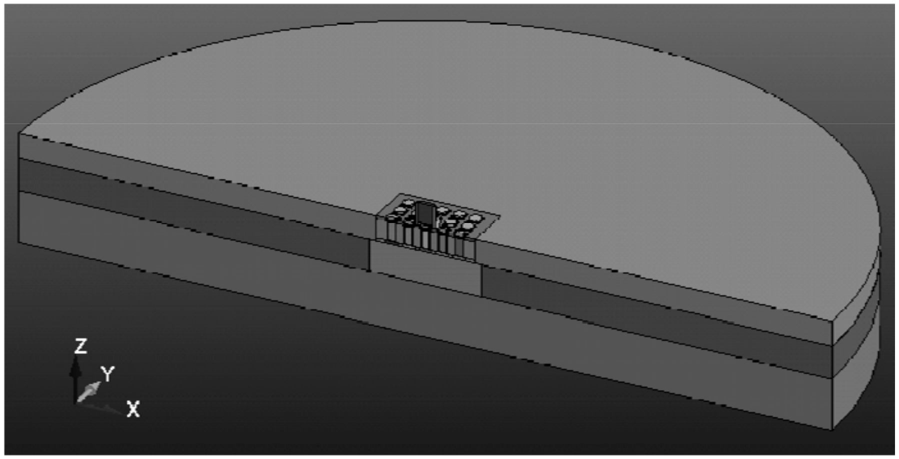

HI-STORM UMAX SSI Analysis Base Model

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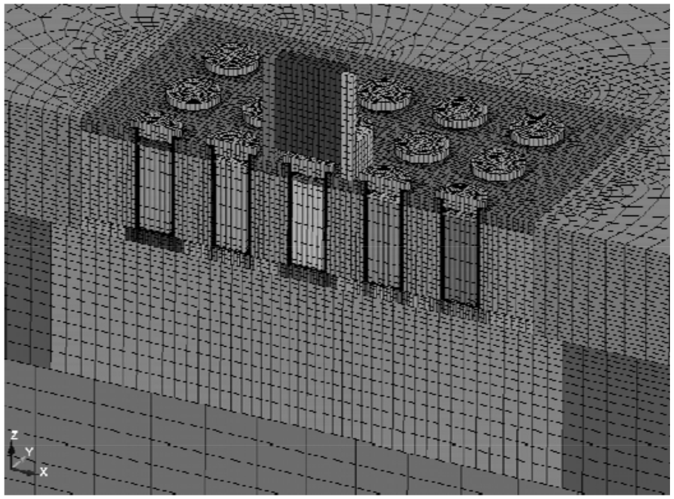

Essential Attributes of the Soil-Structure Interaction Analysis LS-DYNA Model

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- The SFP is fully loaded with 5x5 VVMs.
- MPC is modeled as a rigid cylinder. The VVM lid and the loaded Vertical Cask Transporter (VCT) are also considered to be rigid.
- The divider shell and the Cavity Enclosure Container (CEC) are modeled using shell elements.
- Elastic material model is used for all concrete parts except for the Top Surface Pad (TSP), which is characterized by an inelastic concrete material model.
- A loaded VCT is assumed to be at the center of the ISFSI.

LS-DYNA SSI Runs

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Run No.	Model Description
1	Base Model with 100% concrete modulus for the SFP
2	Same as Run 1 with 50% concrete modulus for the SFP
3	Same as Run 1 except that the subgrade is excavated down to SFP adjacent to the retaining wall and that the model does not include the VCT
4	Same as Run 3 with 50% concrete modulus for the SFP

Criteria of Qualifying a Candidate ISFSI Site Without Detailed SSI Analysis

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1. The site’s response spectra at both ground surface and SFP elevations are enveloped (checked per the corresponding SRP 3.7.1 requirements) by the Design Basis Response Spectra.
2. The soil properties of the candidate site are greater than the minimum required values.

- To demonstrate that the two criteria can be met, a SHAKE seismic response analysis needs to be performed for the candidate site.

Scenarios for Site-Specific SSI Analysis Under 10CFR72.212

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A. The site's response spectra are not completely enveloped by the Design Basis Response Spectra, however, the overall earthquake strength, represented by the resultant ZPA is bounded.

AND/OR

B. The strain compatible wave velocity in Space B and/or Space D, where the VVMs are not directly supported by the soil in these spaces, is less than the required minimum values.

ACI Strength Evaluation Using ANSYS

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- ACI strength evaluation of SFP, TSP, and retaining wall are performed using ANSYS
- The peak interface loads obtained from the SSI time history analyses are used for the ACI strength evaluation
- Effects of long-term settlement are analyzed using the same approach as the 100U submittal to obtain equivalent substrate elastic modulii under dead load.
- Load combinations per ACI 318-05.

Other Miscellaneous Calculations

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- Missile impacts onto the VVM lid and the retaining wall
- Explosion
- Handling of components
- MPC confinement evaluation for MPC to guide plate impact