RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/27/2014

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1025-7092 REVISION 3**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**04/29/2013**

QUESTION NO. 03.07.02-226:

Section 2.3 of MUAP-11007 (R2) indicates that the Poisson's ratio used in developing the Pwave velocity of the saturated soil profiles approaches values close to 0.48, and that this value is low enough "not to compromise the numerical stability of the SASSI results."

The applicant is requested to provide (i) the basis for concluding that the numerical stability of the SASSI results is not compromised and (ii) the details of any specific sensitivity study that show that the ACS-SASSI results for APWR SSI analysis are numerically stable for the selected site-independent soil profiles and the assumed values of Poisson's ratio.

ANSWER:

As discussed with the Nuclear Regulatory Commission (NRC) Staff during the Design Certification Document (DCD) Tier 2, Section 3.7.1, 3.7.2, and 3.7.3 Audit conducted in September 23-27, 2013, this answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-13154 (ML13199A063).

As described in Section 2.3 of Technical Report MUAP-11007, Rev 2, the generic soil profiles 270-200, 270-500 and 560-500 used for site-independent soil-structure interaction (SSI) analyses of the US-APWR standard plant are representative of saturated soil properties and have values of the Poisson ratio (nu) approaching but not exceeding 0.48. The top layers of the corresponding unsaturated soil profiles have compression wave velocities (V_P) reduced to reflect dynamic properties of unsaturated soil. As shown in Tables 3-1, and 3-2 of Technical Report MUAP-11007, Rev 2, the reduced V_P for the generic unsaturated soil profiles 270 resulted in values of Poisson ratio that do not exceed 0.45 for 270-200Dry and 270-500Dry profiles. The value of the Poisson ratio for the generic unsaturated soil profile 560-500Dry is below 0.41. In addition to serving to illustrate the effects of ground water on the response, the comparison of the transfer functions obtained from the SSI analyses of saturated and unsaturated generic soil profiles serves to demonstrate that the use of soil Poisson ratio approaching a value of 0.48 did not compromise the numerical stability of the results. Any abrupt changes or spurious peaks in the transfer functions, as well as inconsistencies between the results obtained from SSI analyses of saturated profiles having values of Poisson ratio approaching 0.48 and

unsaturated profiles with lower values of the Poison ratio, are used as indicators of possible numerical instabilities.

Figure 1 through Figure 12 below present comparisons of transfer functions results for the response of the Reactor Building (R/B) complex and Auxiliary Building (A/B) in the direction of the applied control motion for saturated generic profiles 270-500 and 560-500 and unsaturated generic profiles 270-500Dry and 560-500Dry. Transfer function results obtained from the SSI analyses of structural models with full and reduced stiffness properties are presented for two nodes, located at basemat bottom and plant grade elevations, where possible numerical instabilities in the SSI results due to high value of the soil Poisson ratio would be most apparent. Figure 1 through Figure 6 show the amplitude of the transfer functions at the center of the containment foundation bottom. Figure 7 hrough Figure 12 present transfer function results for the response at the center of the Auxiliary Building (A/B) basement at plant grade elevation. The interpolated transfer function results obtained from the SSI analyses of saturated and unsaturated profiles with higher and lower values of the soil Poisson ratio are shown with solid and dashed lines, respectively. The plots show the calculated values of the transfer functions with dots.

The figures show that the transfer function results do not indicate numerical instabilities in the results of the SSI analyses. The transfer functions obtained from SSI analyses of saturated profiles with a soil Poisson ratio approaching a value of 0.48 are very close and consistent with those obtained from the SSI analyses of unsaturated profiles with lower values of the soil Poisson ratio that remain below 0.45. The interpolated transfer functions are smooth curves without abrupt changes or spurious peaks, which indicates that no numerical instabilities exist.

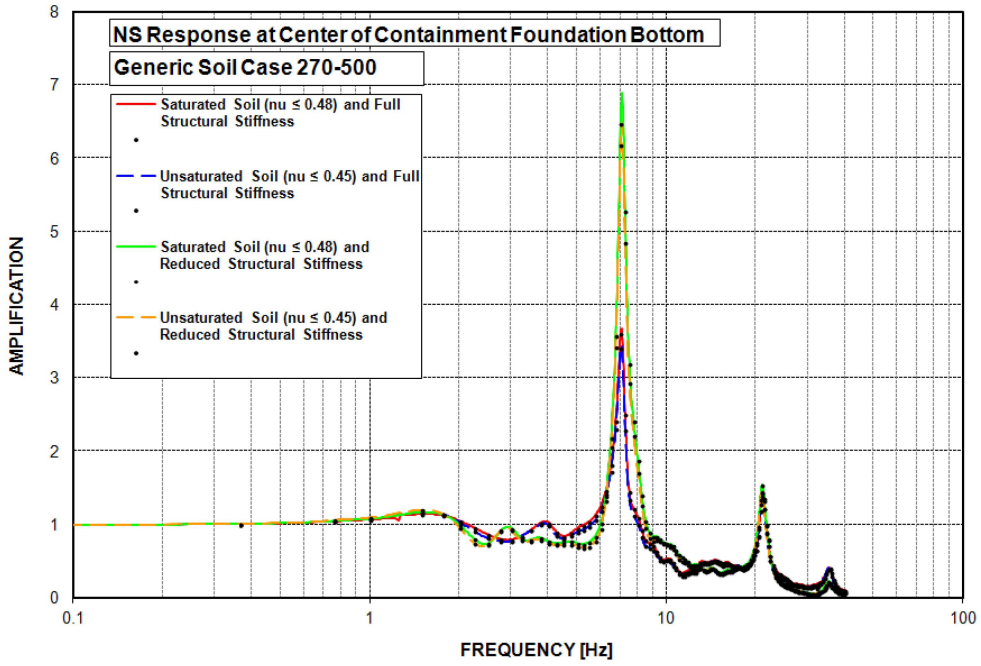

Figure 1 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 - NS Response R/B Basemat Bottom

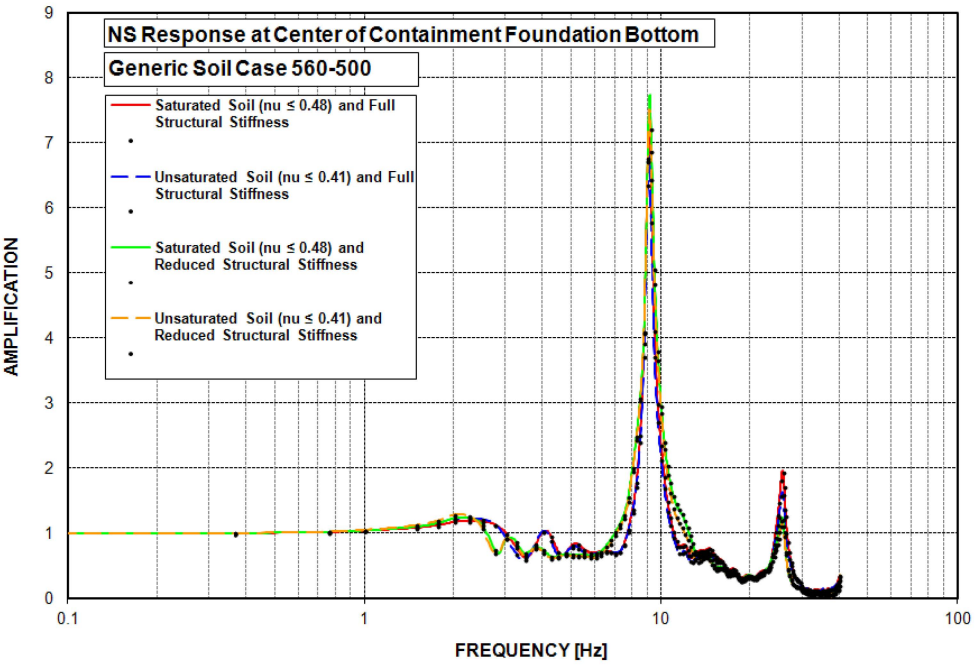

Figure 2 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 - NS Response at R/B Basemat Bottom

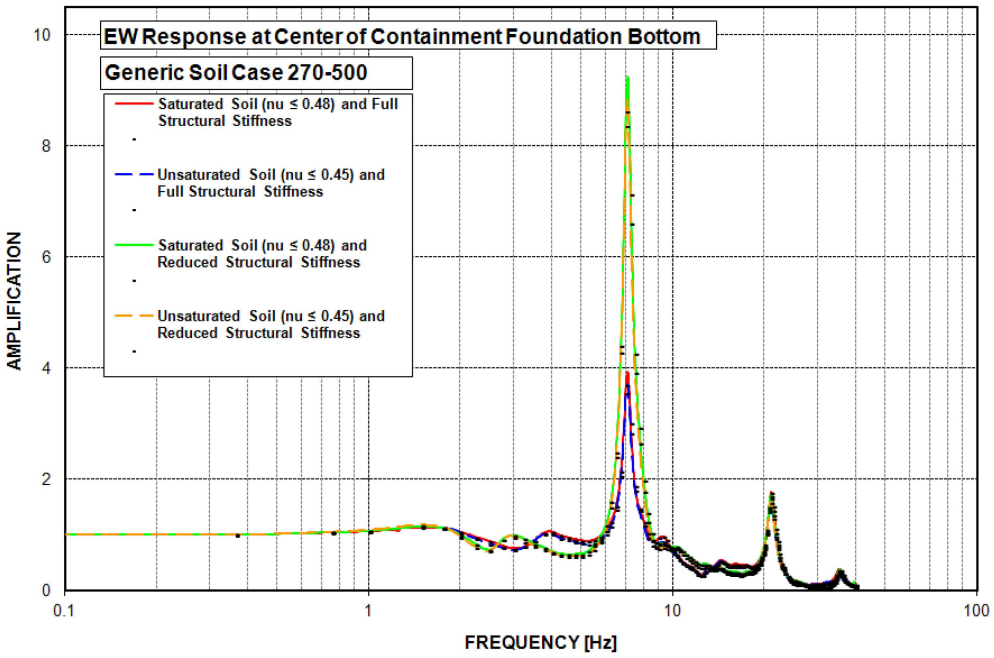

Figure 3 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 - EW Response at R/B Basemat Bottom

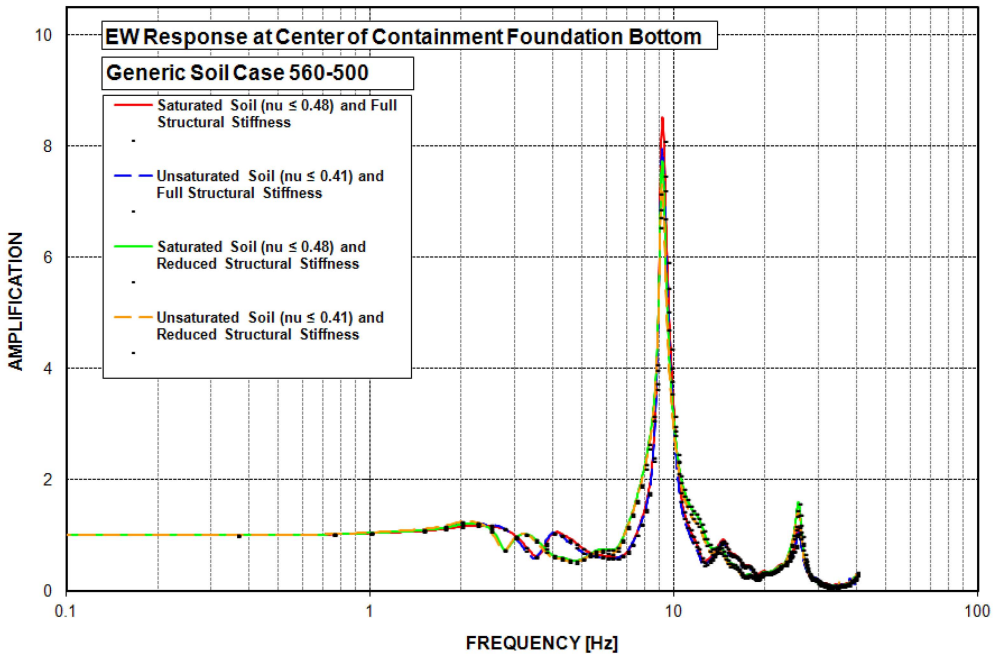

Figure 4 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 - EW Response at R/B Basemat Bottom

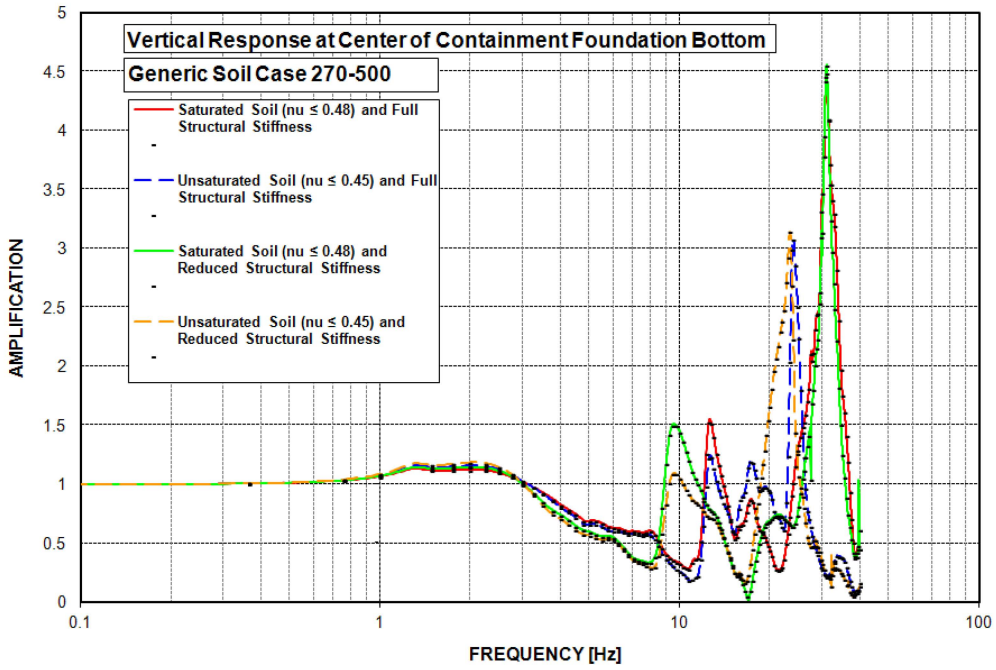

Figure 5 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 – Vertical Response at R/B Basemat Bottom

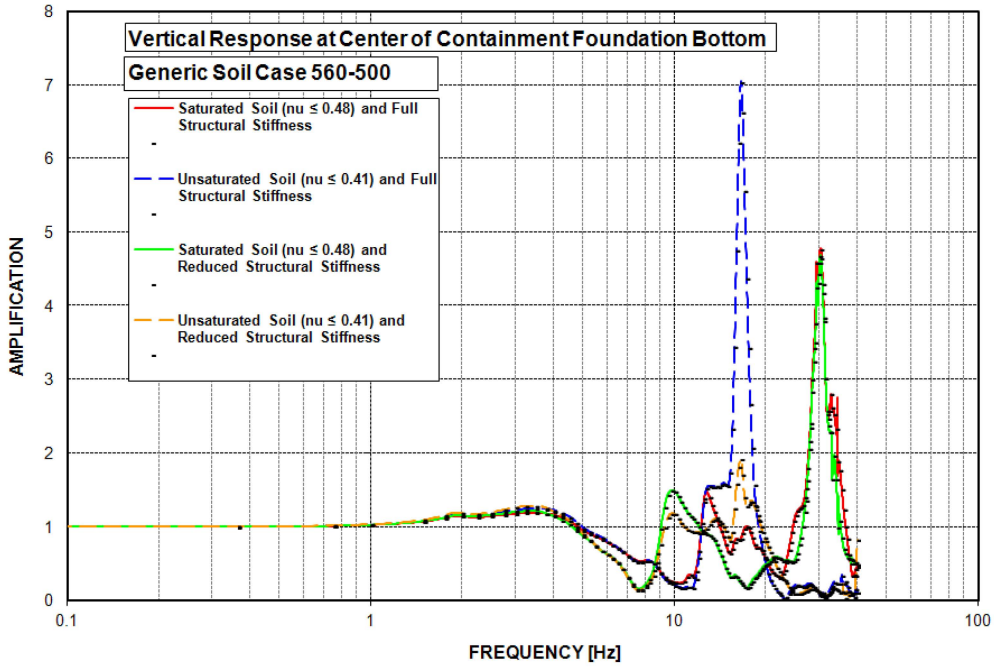

Figure 6 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 – Vertical Response at R/B Basemat Bottom

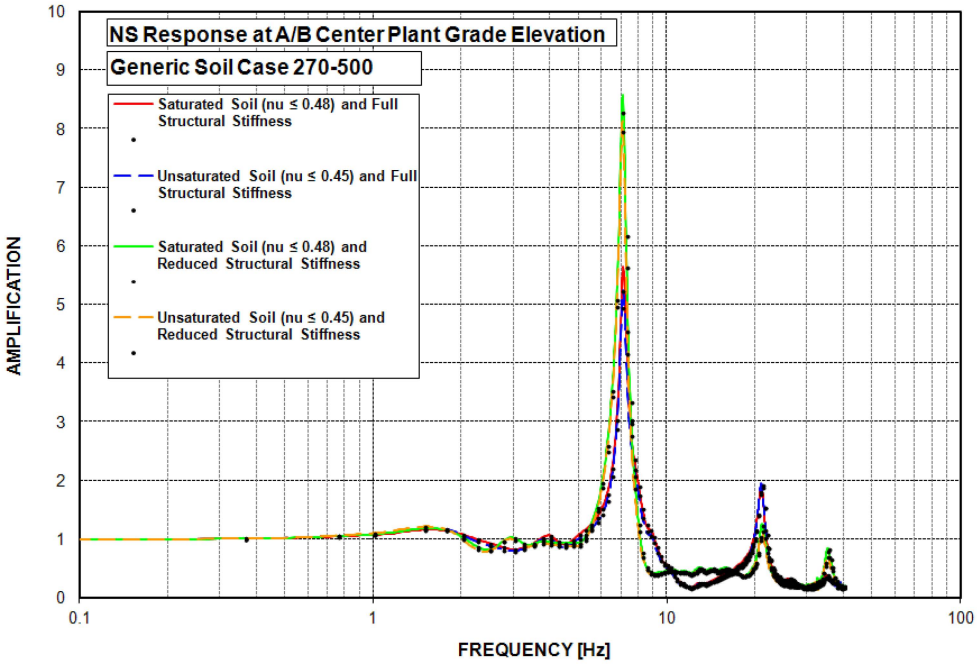

Figure 7 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 - NS A/B Plant Grade Elevation

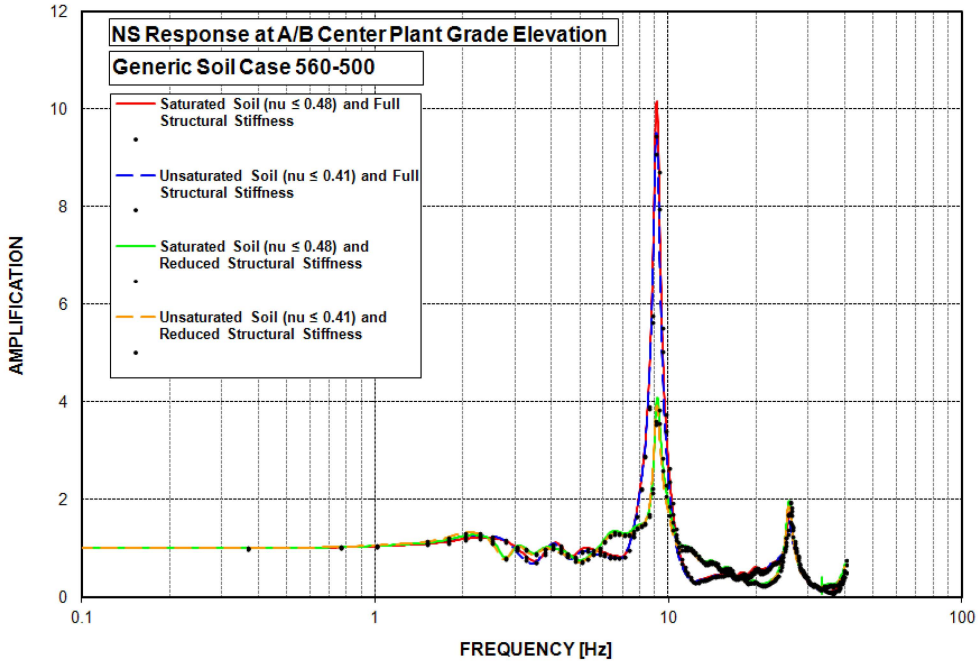

Figure 8 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 - NS Response at A/B Plant Grade Elevation

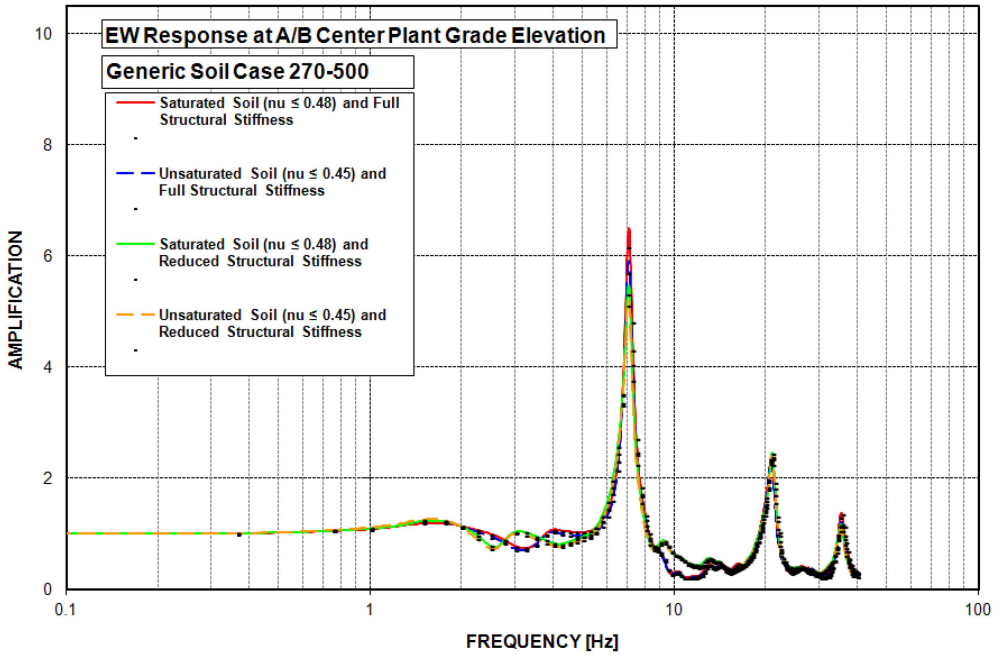

Figure 9 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 - EW Response at A/B Plant Grade Elevation

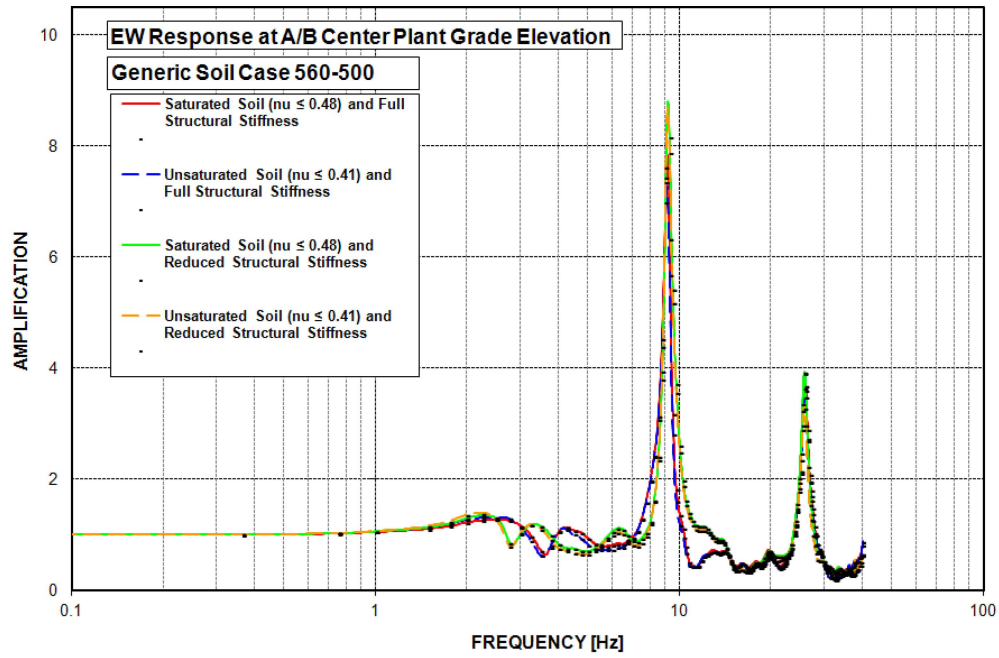

Figure 10 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 - EW Response at A/B Plant Grade Elevation

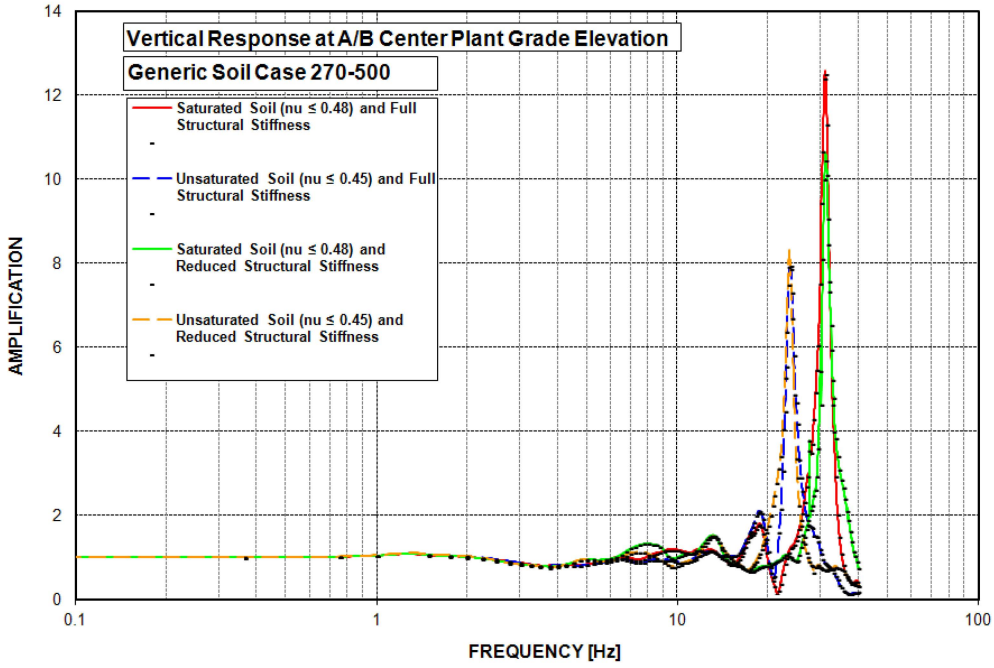

Figure 11 Transfer Function Results from SSI Analyses of Generic Profiles 270-500 – Vertical Response at A/B Plant Grade Elevation

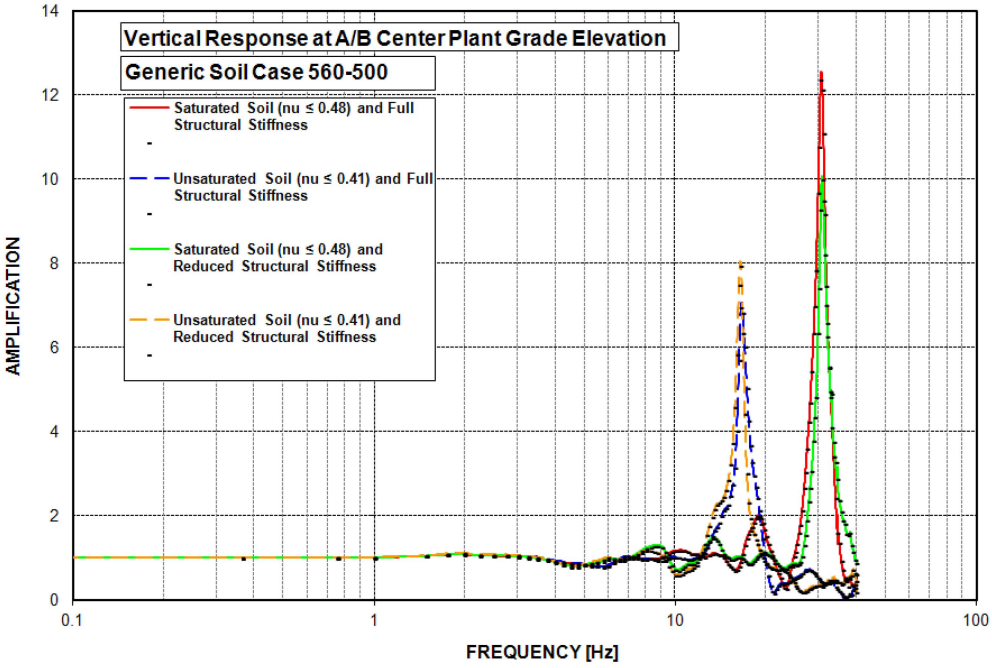

Figure 12 Transfer Function Results from SSI Analyses of Generic Profiles 560-500 – Vertical Response at A/B Plant Grade Elevation

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

Technical Report MUAP-11007, Rev. 2 will be revised as shown in Attachment 1.

This completes MHI's response to the NRC's question.

appropriate representation of the compression wave propagation in relatively soft soils if total unit weight and V_p of water are assigned to the saturated soil material.

2. Review of Literature of Water Table Effect of Structural Response

   Reference 5 presents a study of the effect of interaction of groundwater with the soil skeleton on SSI response for a typical nuclear power plant containment structure. Impedances were developed considering single phase continuum (Reference 6) and coupled two phase continuum (Reference 7). Frequency domain time history analyses were performed on the pressurized water reactor containment structure using both impedances, and the responses were compared. The study concluded that the water in saturated soils modifies the impedance functions, especially the rocking component, affecting the frequency content of the structural response of typical massive nuclear containment structures. This impedance modification can reduce the peak amplifications due to dissipation of energy associated with pore water flow. This indicates that ignoring the interaction between the soil skeleton and the pore water results in a conservative design.

2.3 Consideration of Groundwater in Design Basis Generic Profiles

TeR MUAP-10006 documents (Reference 1) the development of the saturated soil profiles representative of sites with groundwater level at plant grade. In order to account for the presence of groundwater, the V_p of the saturated soil in the design basis soil profiles are developed by:

a) Setting the value of V_p at or above 5,000 ft/s which is the V_p of water.

b) Maintaining V_p gradient that is considered realistic for saturated soil sites based on a database of measured V_p in MUAP-10006, Section 01.4.2 (Reference 1).

c) Smoothing the resulting V_p profile.

These adjustments result in a 20 to 30% increase of the V_p in the top soil layers of profiles 270-200, 270-500, and 560-500. The properties of rock materials are not impacted by groundwater since their V_p ar
realistic representation of sa
with high groundwater level
representation than setting a

The Poisson ratios of the softer strata of saturated soils in these profiles approach a value of 0.48. The values of Poisson's ratio are appropriate for US-APWR standard plant generic soil profiles and SSI analyses.

A set of site response analyses are performed as described in MUAP-10006, Part 1 (Reference 1) to develop the V_s of the design basis generic profiles. These soil V_s are compatible with the strains generated by the seismic ground motions whose spectra, as full column outcrop spectra at the R/B complex foundation bottom, are enveloped by the US-APWR CSDRS. The initial small strain V_s profiles used as input for these site response analyses are obtained from a database of measured V_s. MUAP-10006, Tables 01.5.2.2-1 to 01.5.2.2-6 (Reference 1) provide the strain compatible properties of the soil profiles used as input for the SSI and SSSI analyses. ~~The Poisson's ratio of the softer strata of saturated soil in these profiles approach values close to 0.48. This value is low enough not to compromise the numerical stability of the SASSI results (Reference 2).~~ ~~The Poisson's ratio are appropriate for US-APWR Standard Plant generic soil profiles and SSI analysis.~~