RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

08/01/2013

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. 03.07.02-225:

Figures 3.6, 3.7, and 3.8 in Section 3.2 of MUAP-11007 Revision 2 present comparison plots of the 5% damped acceleration response spectra (ARS) of the free-field within layer motion used as input for the soil-structure interaction (SSI) analyses of the reactor building (R/B) complex unsaturated and saturated soil profiles. It is the staff's understanding that these results are obtained from the deterministic one-dimensional site response analyses for the particular profiles discussed using as input the time history enveloping the smooth, broad banded outcrop response spectrum (enhanced RG 1.60 spectrum) defined as an outcrop spectrum at a depth of approximately 42' (Section 2.5.1). Staff notes the following from the referenced spectral plots in Figures 3.6, 3.7 and 3.8:

a) the amplification of the smooth input outcrop motion from the foundation depth to the surface is uniform (i.e., indicates no spectral peaks) from very low frequencies to high frequencies;

b) the de-amplification from the surface down to the foundation depth of the in-column spectra shows a major dip at the first column frequency of around 7 to 8 Hz;

c) the magnitude of this dip is extremely large (surface Sa of about 0.90g to 0.35g at about 8 Hz for the 270-200 site), or a reduction of over 60%;

d) no similar dip is apparent in the vertical spectra plots;

e) the dip in the H1 (North-South) and H2 (East-West) responses are different for the same site profile;

f) the behavior between the 270-200 and 270-500 profiles is essentially the same with an even greater difference between the H1 and H2 responses;

g) the behavior of the 560-500 profile also shows large dips at between 7 and 10 Hz. The applicant did not provide a detailed description of how the in-column spectra at the ground surface and at 42' depth were generated from the certified seismic design response spectra (CSDRS). In order for the staff to evaluate the effects of groundwater level on the SSI response of the R/B complex, the applicant is requested to provide the following additional information:

(i) Reason (s) for and the design significance of the large dip between 7-10 Hz. in the horizontal in-column response spectra at the foundation depth for the three soil profiles considered for the evaluation.

(ii) For the 270-200 soil case, for both saturated and unsaturated conditions, provide a copy of the horizontal and vertical (H1, H2 and V) time histories that were used to generate the (1) spectra at the surface and (2) in-column spectra at the 42' foundation depth, both based on the CSDRS applied at a hypothetical outcrop at the 42' foundation depth. Also, identify which records were used as input to the SSI analyses.

ANSWER:

Any horizontal motion at the depth of the foundation (in-layer motion) must be deficient in components of the natural frequency of soil column above the depth. The corresponding in-layer motion response spectra will therefore show dips at proximity of the soil column natural frequency. The referred dips in the ARS of the horizontal in-layer motion that occur at frequencies between 7 and 10 Hz are accompanied with peaks in the transfer functions, as shown in Figures 3-9, 3-10 and 3-11 of Technical Report MUAP-11007, Rev. 2. The frequencies at the peaks approximate to the natural frequencies of the soil column above. Section 03.3.2 of Technical Report MUAP-10006, Rev. 3 addresses the significance of the dips of the in-layer response spectra on the US-APWR standard design by comparing the envelope of the in-layer motion ARS for all six generic soil profiles with the certified seismic design response spectra (CSDRS). Figure 03.3.2-1 through Figure 03.3.2-3 of Technical Report MUAP-10006, Rev. 3 show that for all three directions of the input motion there are no deep valleys in the envelopes in-layer motion ARS due to the wide range of soil properties considered in the standard design seismic response analyses.

The in-layer motions are consistent with the CSDRS defined as outcrop motion at the foundation bottom level. The soil structure interaction (SSI) methodology used in SASSI program, does not permit outcrop input motion at the foundation bottom level for analysis of embedded structure including embedment (Ref. 2, Section 3.2.3 item 3). Site response analyses were performed to derive the in-layer motions as input control motions for the SSI analysis. As described in Section 2.5.1 of Technical Report MUAP-11007, Rev. 2, the acceleration time histories used as input control motion for the SSI analyses were obtained by converting the standard design basis acceleration time histories developed in Part 01 of Technical Report MUAP-10006, Rev. 3, to in-layer motion using one-dimensional site response analyses. The standard design basis time histories are compatible to CSDRS that define the magnitude and frequency content of the standard design ground motion as outcrop motion at the bottom elevation of the Reactor Building (R/B) complex foundation located 42.25 ft below plant grade. In accordance with DC/COL-ISG-017 (Ref. 1), the US-APWR standard design uses outcrop design ground motion that is defined per Nuclear Energy Institute white paper “Consistent Site-Response/Soil-Structure Interaction Analysis and Evaluation,” (Ref. 2) as two times the incoming component of the motion in that layer. Technical Report MUAP-11007, Rev. 2, Figures 3-6, 3-7 and 3-8 present the five percent damped ARS of the surface motion at plant grade and in-layer motion at depth of 42.25 ft. Both are obtained from one-dimensional wave propagation analysis, in which the standard design basis acceleration time histories are applied as outcrop motion at depth of 42.25 ft.

The site response analyses are performed on the columns of strain compatible shear wave and compression wave velocities without further iteration of the soil properties with strain.

The calculated in-layer motion acceleration time histories and the input outcrop motion design basis time histories define the design ground motion at the same horizon located 42.25 ft below the plant grade surface. The figures below present a comparison of (a) the five percent damped ARS of the design basis acceleration time histories with the ARS of the surface outcrop motion, and (b) in-layer motion used as input for the SSI analyses of the generic unsaturated soil profiles 270-200, 270-500 and 560-500. The ARS of the standard design basis motion are identical to the five percent damped ARS presented in Figures 01.5.1.2-4a, 01.5.1.2-5a, and 01.5.1.2-6a of Technical Report MUAP-10006, Rev. 3. The ARS comparisons show that the dips in the in-layer motion ARS are due to the different definitions of the two types of motion. The frequency domain solution of one-dimensional wave propagation in layered media permits the motion in each soil layer for each frequency of analysis to be decomposed into two components, an incoming (or within layer) component and a reflected component. The "outcrop" motion for each layer is defined as two times the incoming component of the motion in that layer. The boundary conditions at the surface of the soil column set the magnitudes of the in-layer and the reflected component to be equal. For soil layers below the column surface, the magnitudes of incoming and reflected components, and thus the in-layer and outcrop motion, depend on the dynamic properties of the soil above the layer.

The observed dips in the in-layer motion ARS are due to resonance effects at frequencies close to the frequency of the column of soil above the layer. The dips in the in-layer motion ARS of the two horizontal earthquake components occur at frequency of 7 Hz for the softer 270-200 and 270-500 soil profiles and 9 Hz for the harder 560-500 profile. The plots show that the differences between the two horizontal standard design basis acceleration time histories used in the site response analyses as input motion are reflected in the resulting in-layer motion ARS. The plots also show that the dips in the vertical in-layer motion ARS occur at higher frequencies reflecting that fact that the shear column frequencies are lower than the compression column frequencies.

The requested digital data is provided in the attached compact disc, and these data are proprietary. Two zip files, 270200-Saturated.zip and 270200-Unsaturated.zip, contain the text files of the horizontal and vertical acceleration time histories of the ground motion for saturated and unsaturated conditions, respectively. Within each of these files are three subfolders labeled H1, H2, & V for each direction of the input ground motion. Each subfolder contains two files:

- ACC001.TH containing the acceleration time history of the outcrop motion at ground surface

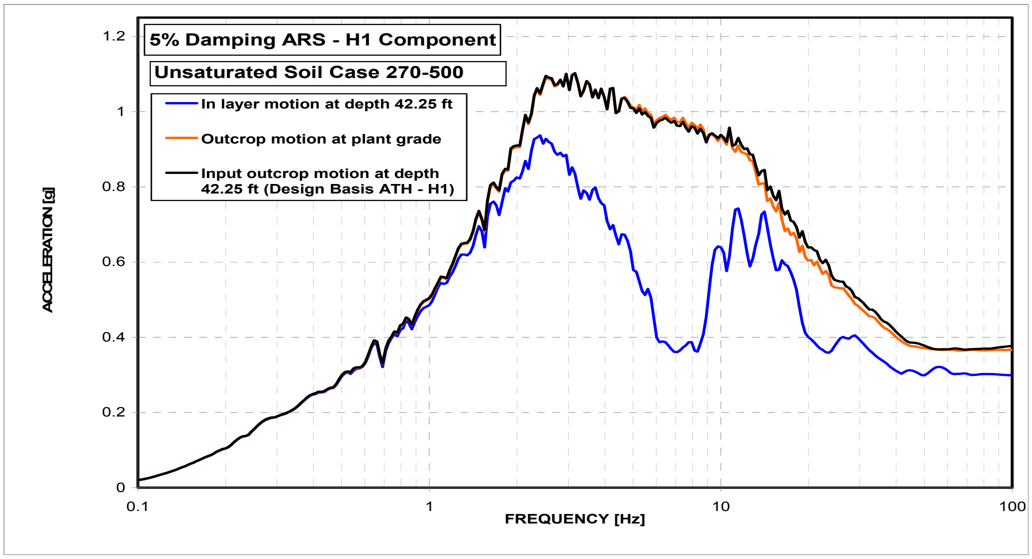
- ACC081.TH containing the acceleration time history of the in-column motion at depth 42.25 ft that were used as input for the SSI analyses.

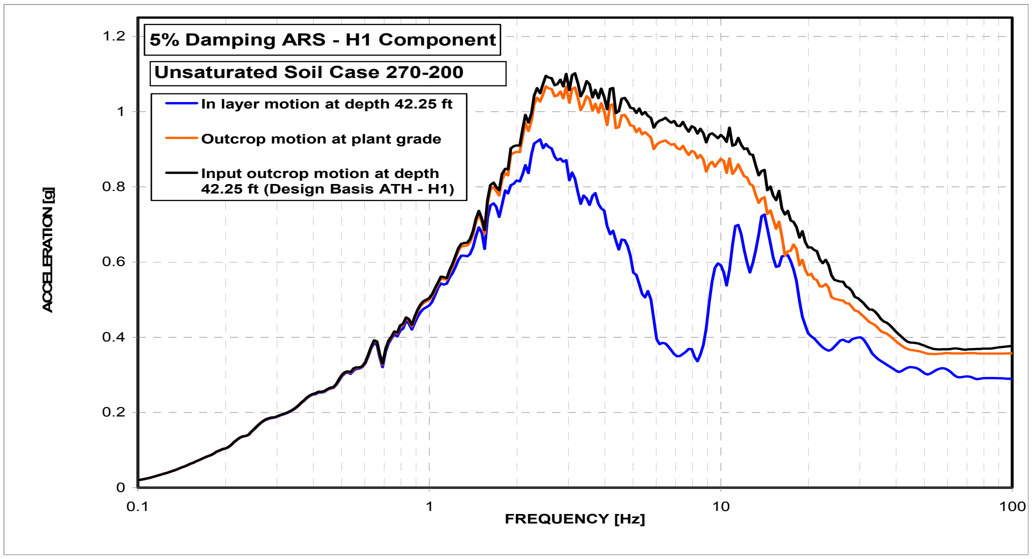
The first data point in the attached files is the time step of the time history in seconds. The subsequent data points are the accelerations as portion of Earth's gravity.

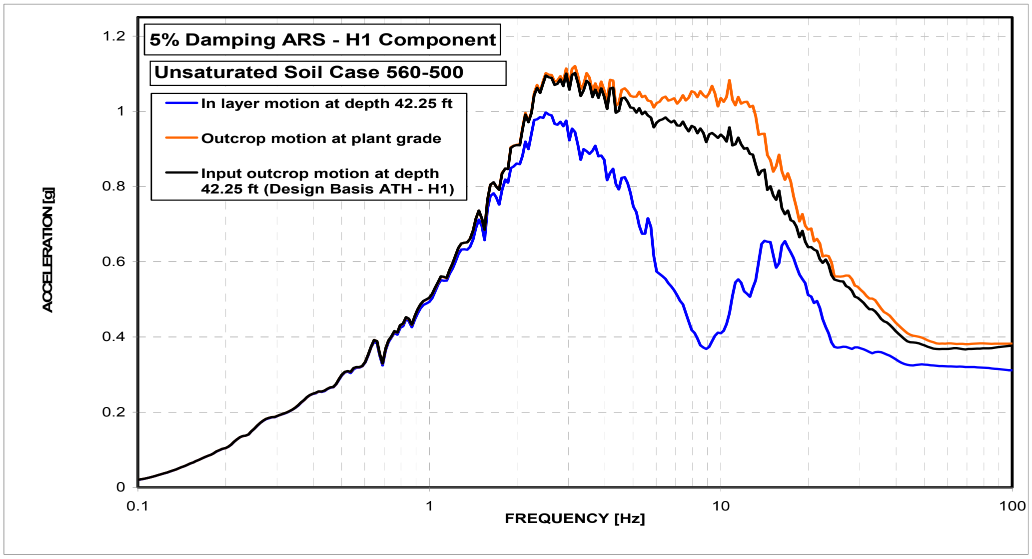
References:

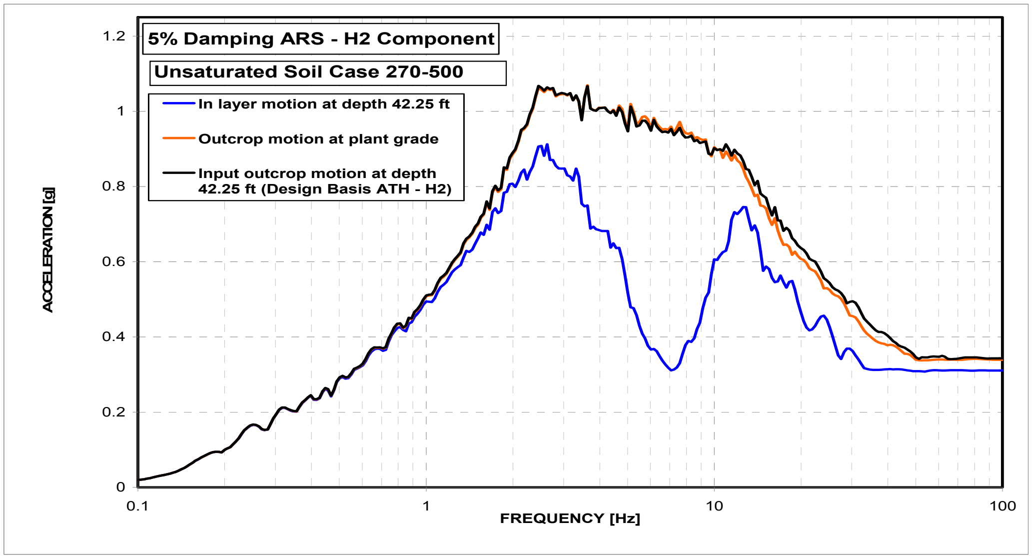
1. Interim Staff Guidance DC/COL-ISG-017: "*Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses*",

2. NEI White Paper, "Consistent Site-Response/Soil-Structure Interaction Analysis and Evaluation," NEI, June 12, 2009. (ADAMS Accession No. ML091680715).

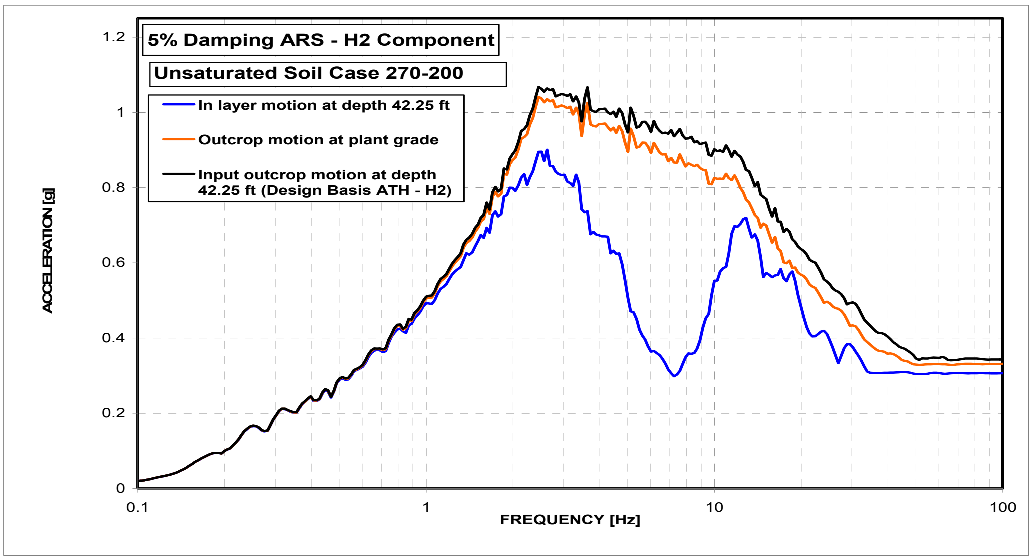

5% Damping ARS - H1 Component
Unsaturated Soil Case 270-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H1)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100


5% Damping ARS - H1 Component
Unsaturated Soil Case 270-200
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H1)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100

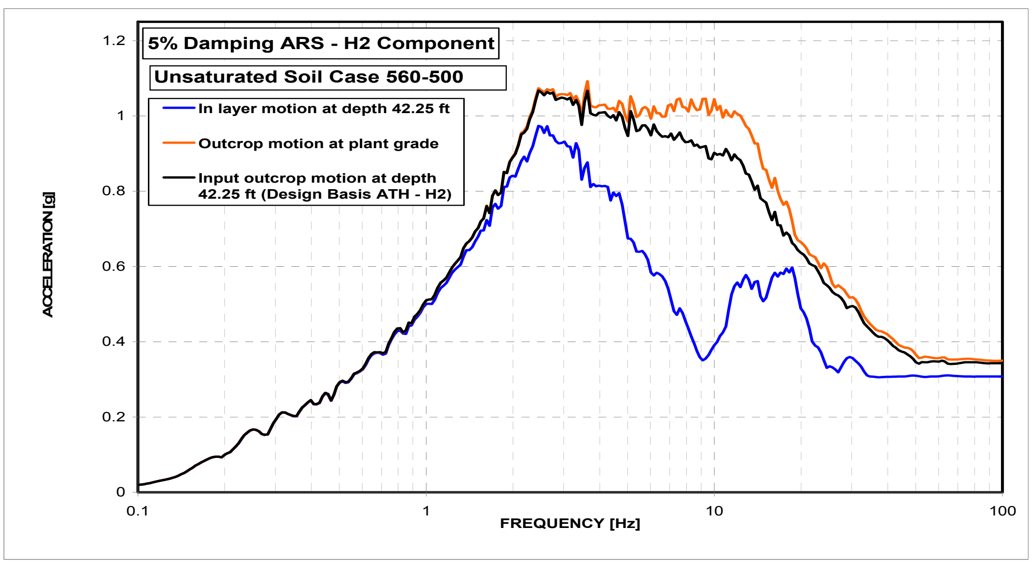

5% Damping ARS - H1 Component
Unsaturated Soil Case 560-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H1)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100



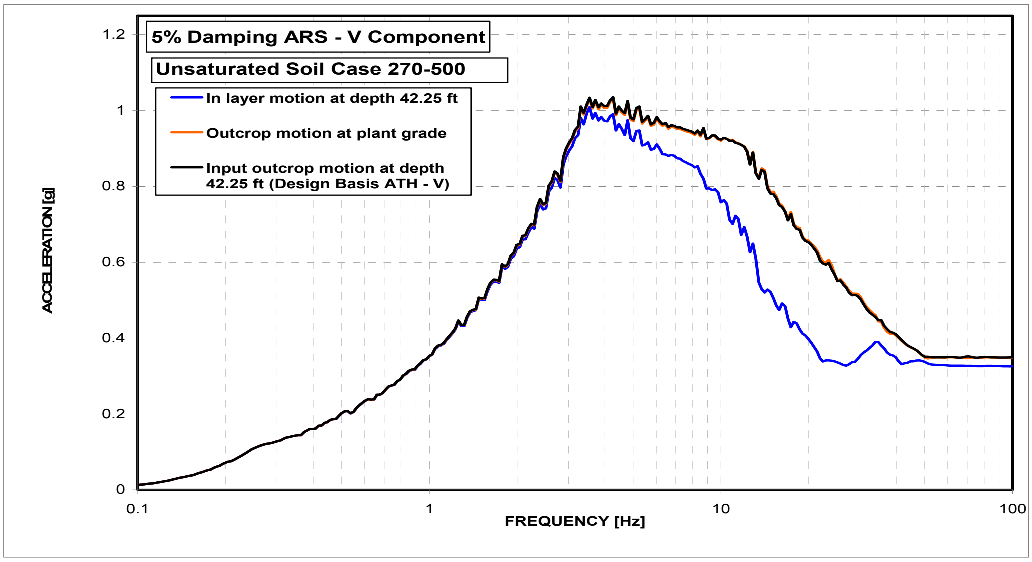
5% Damping ARS - H2 Component
Unsaturated Soil Case 270-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H2)
ACCELERATION [g]
FREQUENCY [Hz]

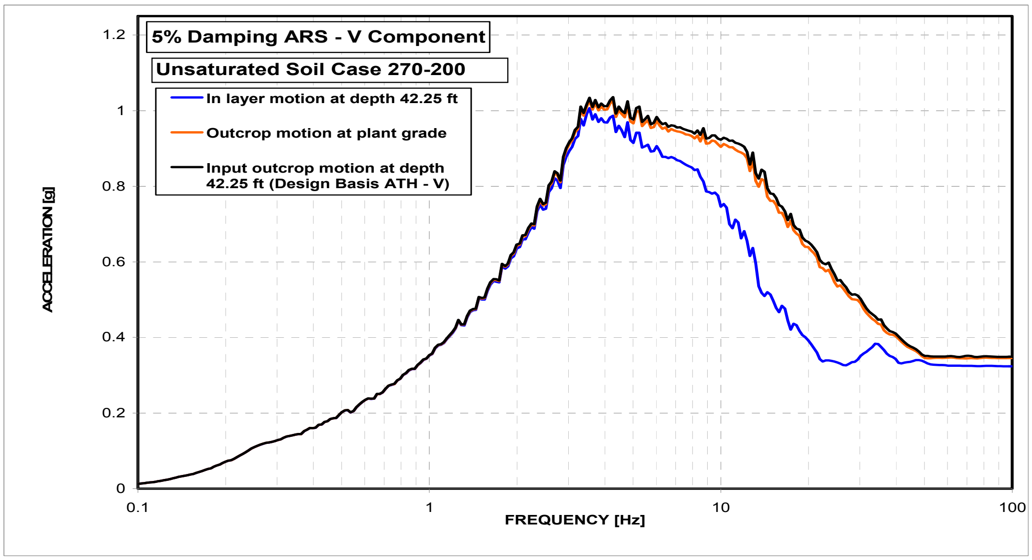


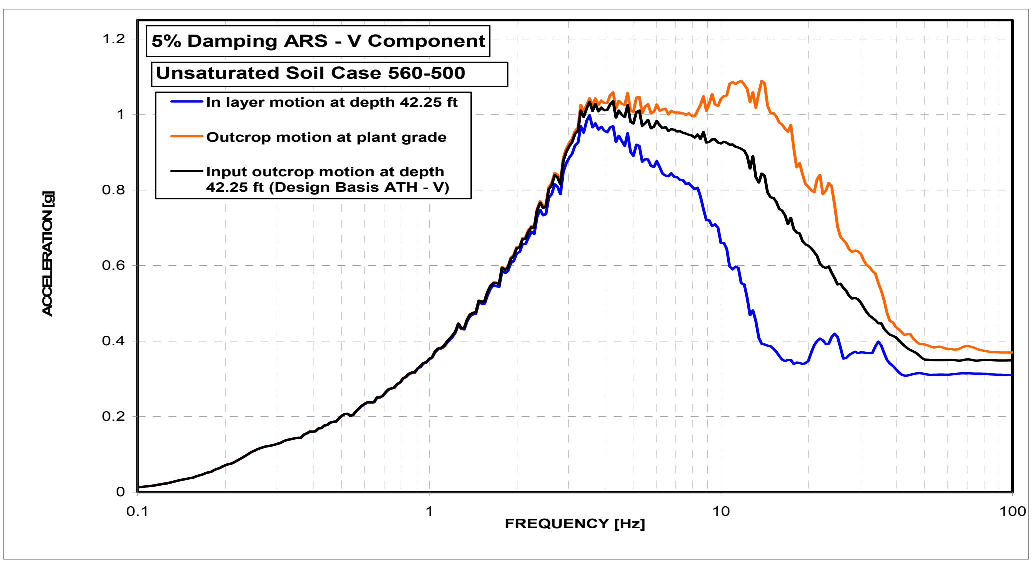
5% Damping ARS - H2 Component
Unsaturated Soil Case 270-200
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H2)
ACCELERATION [g]
FREQUENCY [Hz]



5% Damping ARS - H2 Component
Unsaturated Soil Case 560-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - H2)
ACCELERATION [g]
FREQUENCY [Hz]


5% Damping ARS - V Component
Unsaturated Soil Case 270-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - V)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100


5% Damping ARS - V Component
Unsaturated Soil Case 270-200
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - V)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100


5% Damping ARS - V Component
Unsaturated Soil Case 560-500
In layer motion at depth 42.25 ft
Outcrop motion at plant grade
Input outcrop motion at depth 42.25 ft (Design Basis ATH - V)
ACCELERATION [g]
FREQUENCY [Hz]
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100

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

There is no impact on the Technical/Topical Report.

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