Luminant

Rafael Flores
Senior Vice President &
Chief Nuclear Officer
rafael.flores@luminant.com

Luminant Power
P O Box 1002
6322 North FM 56
Glen Rose, TX 76043

T 254.897.5590
F 254.897.6652
C 817.559.0403

CP-201101493
Log # TXNB-11068

Ref. # 10 CFR 52

October 27, 2011

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555
ATTN: David B. Matthews, Director
Division of New Reactor Licensing

SUBJECT: COMANCHE PEAK NUCLEAR POWER PLANT, UNITS 3 AND 4
DOCKET NUMBERS 52-034 AND 52-035
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION NO. 5947
(SECTION 3.7.2)

Dear Sir:

Luminant Generation Company LLC (Luminant) submits herein the response to Request for Additional Information (RAI) No. 5947 (CP RAI #226) for the Combined License Application for Comanche Peak Nuclear Power Plant Units 3 and 4. The RAI response addresses the seismic system analysis.

Should you have any questions regarding this response, please contact Don Woodlan (254-897-6887, Donald.Woodlan@luminant.com) or me.

The commitments made in the attached response have been captured in the Integrated Seismic Closure Plan, which will be submitted to the NRC by January 31, 2012, and is being tracked as Regulatory Commitment #8312.

I state under penalty of perjury that the foregoing is true and correct.

Executed on October 27, 2011.

Sincerely,

Luminant Generation Company LLC

Donald R. Woodlan for

Rafael Flores

Attachment: Response to Request for Additional Information No. 5947 (CP RAI #226)

D090

Electronic distribution w/attachment:

Rafael.Flores@luminant.com
mlucas3@luminant.com
jeff.simmons@energyfutureholdings.com
Bill.Moore@luminant.com
Brock.Degeyter@energyfutureholdings.com
rbird1@luminant.com
Allan.Koenig@luminant.com
Timothy.Clouser@luminant.com
Ronald.Carver@luminant.com
David.Volkening@luminant.com
Bruce.Turner@luminant.com
Eric.Evans@luminant.com
Robert.Reible@luminant.com
donald.woodlan@luminant.com
John.Conly@luminant.com
JCaldwell@luminant.com
David.Beshear@txu.com
Ashley.Monts@luminant.com
Fred.Madden@luminant.com
Dennis.Buschbaum@luminant.com
Carolyn.Cosentino@luminant.com
NuBuild Licensing files
sfrantz@morganlewis.com
jrund@morganlewis.com
tmatthews@morganlewis.com
regina.borsh@dom.com
diane.aitken@dom.com
askolhek@bechtel.com
yoshinori_fujiwara@mhi.co.jp
kano_saito@mhi.co.jp
shigemitsu_suzuki@mhi.co.jp
Luminant Records Management (.pdf files only)

shinji_kawanago@mnes-us.com
masanori_onozuka@mnes-us.com
ck_paulson@mnes-us.com
joseph_tapia@mnes-us.com
russell_bywater@mnes-us.com
william_mcconaghy@mnes-us.com
mutsumi_ishida@mnes-us.com
yukako_hill@mnes-us.com
nicholas_kellenberger@mnes-us.com
ryan_sprengel@mnes-us.com
al_freitag@mnes-us.com
masaya_hoshi@mnes-us.com
rjb@nei.org
kra@nei.org
michael.takacs@nrc.gov
cp34update@certrec.com
michael.johnson@nrc.gov
David.Matthews@nrc.gov
Balwant.Singal@nrc.gov
Hossein.Hamzehee@nrc.gov
Stephen.Monarque@nrc.gov
jeff.ciocco@nrc.gov
michael.willingham@nrc.gov
john.kramer@nrc.gov
Brian.Tindell@nrc.gov
Alicia.Williamson@nrc.gov
Elmo.Collins@nrc.gov
Loren.Plisco@nrc.com
Susan.Vrahoretis@nrc.gov
Frank.Akstulewicz@nrc.gov
ComanchePeakCOL.Resource@nrc.gov
hickste@earthlink.net

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Comanche Peak, Units 3 and 4

Luminant Generation Company LLC

Docket Nos. 52-034 and 52-035

RAI NO.: 5947 (CP RAI #226)

SRP SECTION: 03.07.02 - Seismic System Analysis

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

DATE OF RAI ISSUE: 8/22/2011

QUESTION NO.: 03.07.02-23

This is a follow-up question to RAI Letter Number 60 (2879) Question 03.07.02-16

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100. This information is also important for the staff to determine if the application conforms with the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic System Analysis.'

After reviewing the response to RAI Letter Number 60 (2879) Question 03.07.02-16, the staff has the following questions regarding the material in Appendices 3KK through 3NN of the FSAR:

Appendix 3KK-UHSRS

1. The response to item 1 states that there are 16 convective modes below 0.7 Hz, but Part 4 of the response states that the SASSI analysis frequencies were selected to cover the range from 1 Hz up to the cutoff frequency. The staff requests that the applicant clarify whether the convective effects were included in the SASSI analysis. The applicant is also requested to clarify how the convective effects were included in the SSI evaluation of the UHSRS.

2. Four of the six cutoff frequencies shown in the response to item 2 are less than the 50 Hz value recommended in ISG-01. The applicant is requested to provide justification for using the lower cutoff frequencies and should state if the models are adequately refined to transmit frequencies up to 50 Hz. If the models are not sufficiently refined to transmit frequencies up to 50 Hz, the applicant is requested to provide justification for using the models with lower cutoff frequencies.

3. Some of the transfer functions in Figures 1 through 12 contain sharp peaks, and some of the peaks occur at frequencies that do not align with the SASSI analysis frequencies. It appears that some of the peaks may be spurious and could be due to interpolation errors, or errors caused by use of the SASSI subtraction method. The applicant is requested investigate the cause of these very narrow banded peaks and provide justification to the staff that the peaks are real and not spurious. Examples are the peaks at 7 Hz in Figure 1, the peak at 35.5 Hz in Figure 2, the peak at 25 Hz in Figure 3, the peak at 26 Hz in Figure 8, and the peaks at 12.5, 21, and 48 Hz in

Figure 12. For all peaks that are determined to be real, the applicant should add analysis frequencies that correspond to the peak response frequencies.

4. In the response to item 4, the applicant stated that frequencies were added to the SASSI analysis as needed to produce smooth interpolation of the transfer functions to accurately capture peaks, and additional frequencies were added to observe that the results did not change. The addition of analysis frequencies to capture peaks does not appear to be reflected in Figures 1 through 12. The applicant is requested to update any analysis frequencies as required and provide such information to the staff for review and update Figures 1 through 12 on your response.

5. Table 4 indicates that the maximum passing frequencies for numerous soil layers are less than 50 Hz, which is the frequency recommended in ISG-01 for SSI and structural models. The applicant is requested to provide justification for its position that the use of lower passing frequencies in the soil leads to accurate or conservative results for the SSI analysis.

Appendix 3LL-ESWPT

6. Several of the cutoff frequencies shown in the response to item 2 are less than the 50 Hz value recommended in ISG-01. The applicant is requested to provide justification for using the lower cutoff frequencies and should state if the models are adequately refined to transmit frequencies up to 50 Hz. If the models are not sufficiently refined to transmit frequencies up to 50 Hz, the applicant should provide justification for using the referenced models.

7. Tables 12, 13, and 14 indicate that the maximum passing frequencies for numerous soil layers are less than 50 Hz, which is the frequency recommended in ISG-01 for SSI and structural models. The applicant should provide justification that the use of lower passing frequencies in the soil leads to accurate or conservative results for the SSI analysis.

8. In the response to item 10, the applicant mentions the examination of transfer functions to verify that interpolations were reasonable and also mentions comparisons between transfer functions, spectra, accelerations, and soil pressures for the various soil profiles. The applicant is requested to provide comparisons of the interpolated and uninterpolated transfer functions to the staff for review and to state the acceptance criteria for the transfer functions. The applicant is also requested to provide the comparisons of transfer functions, spectra, accelerations, and soil pressures for the various soil profiles to the staff for review.

Appendix 3MM-PSFSV

9. Several of the cutoff frequencies shown in the response to item 2 are less than the 50 Hz value recommended in ISG-01. The applicant is requested to provide justification for using the lower cutoff frequencies and should state if the models are adequately refined to transmit frequencies up to 50 Hz. If the models are not sufficiently refined to transmit frequencies up to 50 Hz, the applicant is requested to provide justification for using the referenced models.

10. Tables 18 indicates that the maximum passing frequencies for numerous soil layers are less than 50 Hz, which is the frequency recommended in ISG-01 for SSI and structural models. The applicant is requested to provide justification that the use of lower passing frequencies in the soil leads to accurate or conservative results for the SSI analysis.

Appendix 3NN-PSFSV – PCCV-CIS, and R/B on Common Basemat

11. The DCD applicant has committed to replacing the lumped mass SSI model of the R/B complex with a more detailed three-dimensional finite element model. In this context, the applicant is requested to clarify if the model descriptions and results contained in Appendix 3NN of the FSAR and in Calculations SSI-12-05-100-003, 4DS-CP34-20080048 and any other calculations that are based on the lumped mass stick model of the R/B complex are obsolete. If the model descriptions

and results are obsolete, the applicant is requested to provide a roadmap for updating the calculations. If the model descriptions and results are not obsolete, the applicant is requested to provide the technical basis and justification for using lumped mass stick models when the DCD applicant is using more detailed SSI models.

12. Some of the transfer functions in Appendices A, B, and C of SSI-12-05-100-003 contain sharp peaks, and some of the peaks occur at frequencies that do not align with the SASSI analysis frequencies. It appears that some of the peaks may be spurious and could be due to interpolation errors, or errors caused by use of the SASSI subtraction method. The applicant is requested investigate the cause of these very narrow banded peaks and provide justification to the staff that the peaks are real and not spurious. Examples are the peaks at 7 Hz in Figure A.2 of Calculation SSI-12-05-100-003, Rev. C, the peak at 4.8 Hz in Figure A.14 of Calculation SSI-12-05-100-003, Rev. C, the peak at 7 Hz in Figure B.29 of Calculation SSI-12-05-100-003, Rev. B, the peak at 9 Hz in Figure B.38 of Calculation SSI-12-05-100-003, Rev. B, the peak at 7.8 Hz in Figure C.5 of Calculation SSI-12-05-100-003, Rev. B, and the peak at 11 Hz in Calculation SSI-12-05-100-003, Rev. B. Numerous other examples exist. For all peaks that are determined to be real, the applicant is requested to add analysis frequencies that correspond to the peak response frequencies, or otherwise provide a basis and justification for the correctness of the results.

13. Based on the response to item 6, the staff understands that maximum passing frequencies in the soil profiles are less than 50 Hz, which is the frequency recommended in ISG-01 for SSI and structural models. The applicant is requested to provide justification that the use of lower passing frequencies in the soil leads to accurate or conservative results for the SSI analysis.

14. In the response to item 7, the applicant has stated that the lower boundary used in the SASSI model is approximately 1.75 times the effective building diameter below the building foundation. The applicant is requested to provide the technical basis and justification including parametric studies for the selection of the location of the lower boundary in the SSI model.

15. In the response to item 10, the applicant makes reference to direct integration time history analysis using ANSYS that was used to benchmark the SASSI model of the R/B complex. The staff is unaware of any ANSYS models that used direct integration time history analyses and thus requests clarification of this statement. If the statement is correct, the applicant is requested to provide details on the origin and documentation of the models, including the type of damping employed in the models.

ANSWER:

Appendix 3KK-UHSRS

1. Convective effects were not included in the the dynamic soil structure interaction (SSI) analysis of the UHSRS performed with SASSI as evident by the SASSI analysis frequencies having been selected to cover only the range from 1 Hz up to the cutoff frequency. Instead, the convective effects were accounted for in the ANSYS 3D finite element response spectra analysis used in combination with static loads for structural evaluation of the UHSRS.

   The impulsive effect of the water contained in the UHSRS is considered in the seismic SSI SASSI analysis. Since the impulsive mass is considered to behave like a mass that is rigidly attached to the tank walls, the wall flexibility is accounted for by distributing the impulsive mass to the nodes of the walls in the SSI model of the combined fluid-structure system. The SASSI model appropriately captures the dynamic response associated with the impulsive effect of a flexible structure and is used instead of the impulsive equations of TID 7024 that would only capture a rigid structure's response.

The seismic demands for the impulsive effect from SASSI consisting of dynamic soil pressures and structure seismic responses are compared with those applied in the static and response spectra analyses of the ANSYS model to confirm adequacy of the larger seismic demand applied to the ANSYS model used for structural evaluation of the UHSRS.

The fundamental convective frequencies are very low compared to the frequencies of the combined fluid structure model. The frequency of sloshing in all regions except between the baffle walls in the pump room ranges between 0.16 to 0.30 Hz and the frequency of sloshing in between the baffle walls is 0.65 Hz. The lowest response frequency of the liquid-tank system is approximately 6.8 Hz from among the local out-of-plane wall modes of the ANSYS frequency analysis of the combined fluid-structure model.

The sloshing mass used to represent the convective effect of the water is modeled by connecting a single point mass, located at the center of the sloshing region, to the walls at the ends of the slosh region by a series of springs. The spring behavior is such that its response is only dependent on motion in the direction of sloshing (unidirectional springs). The mass assigned is equal to the sloshing mass and the springs are assigned a stiffness to develop the fundamental frequency of the sloshing mode. The springs are attached at the height of the walls in which the resultant of the sloshing pressure distribution acts. The vertical mass of the water is included by assigning uniform point masses across the base slab.

The ANSYS 3D finite element response spectra analysis is based on FIRS accelerations from the site response analysis which also compares closely to accelerations from the ISRS generated at the base of the UHSRS by the SSI SASSI analysis and is deemed adequate. The response of the convective effects can be computed in the same ANSYS response spectra analysis with the response of the larger impulsive fluid mass and structure, provided conservative seismic accelerations are applied to the convective modal responses. A value of 0.5% damping is used for convective effects and a value of 5% damping is used for impulsive effects. The ANSYS 3D finite element response spectra analysis used for structural evaluation of the UHSRS considers the convective responses by increasing the amplitude of response spectra input by a ratio of 1.57. The 1.57 corresponds to the enveloping ratios of the 0.5% to 5% damped spectral values for the frequency range below 1.0 Hz which encompasses the range of sloshing frequencies.

Therefore, convective effects are accounted for in the ANSYS 3D finite element response spectra analysis instead of the SASSI analysis used in combination with static loads for structural evaluation of the UHSRS.

The information provided in the above discussion on the UHSRS modeling of the hydrodynamic (impulsive and convective) effects is consistent with information previously submitted to the NRC Staff in response to RAI 2883 (CP RAI #64) Questions 03.07.03-1 and 03.07.03-2 (ML093090163), RAI 4714 (CP RAI #162) Questions 03.07.03-3 and 03.07.03-4 (ML102240246), and RAI 5092 (CP RAI #185) Questions 03.08.04-86, 03.08.04-87, and 03.08.04-88 (ML110070358).

2. ISG-01 is intended to address seismic issues associated with high-frequency ground motion in design certification and combined license applications. Seismic issues associated with high-frequency ground motion are not applicable for the Comanche Peak Nuclear Power Plant (CPNPP), where the site specific motion is significantly below the DCD CSDRS. As discussed in FSAR Subsection 3.7.1.1, the site-specific design motion is the minimum design SSE, which is the CSDRS anchored at 0.1 g, and this motion significantly exceeds the probabilistically determined motion in FSAR Subsections 2.5.2.4, 2.5.2.5, and 2.5.2.6. FSAR Figure 3.7-201

compares the site-specific design motion (minimum SSE) to the probabilistically determined site motion, and shows that the minimum SSE envelops the probabilistically determined site motion. The ISG-01 recommendation to "cover a model refinement of at least equal to 50 Hz" is intended to "sufficiently capture the HF (high frequency) content of the horizontal and vertical GMRS/FIRS". The CPNPP site is not a high frequency site so the recommendation to cover frequencies to 50 Hz is not necessary.

Although analysis to cover 50 Hz is not considered necessary for this site, the analyses were run in such a manner as to cover up to 50 Hz with cutoff frequencies selected so the frequency range of interest was covered by the envelope of cases analyzed. The high bound case and the lower bound without fill case both were run to 50 Hz, and the upper bound case was run to just below 50 Hz (48.8 Hz). The lower bound and best estimate cases used a cutoff of 37.8 Hz. The envelope of all soil cases provides full coverage of soil variation up to 37.8 Hz and full coverage up to 50 Hz for the stiffer soils which tend to control high frequency motions.

3. Luminant concurs that Figures 1 through 12 contain some sharp spurious peaks that represent interpolation errors including the peak at 7 Hz in Figure 1, 35.5 Hz in Figure 2, and 25 Hz in Figure 3. The peak at 26 Hz in Figure 8 includes a calculated value and does not represent an interpolation error, but does show an unexpected sharp peak. Figure 12 shows a number of sharp peaks, some of which are interpolation errors and some which contain calculated values.

   It is possible that some of the calculated peaks are a result of the use of the SASSI subtraction method. The UHSRS was analyzed as both a surface structure and an embedded structure. The analysis as a surface model is not subjected to the subtraction method issues because the model did not include embedment. The embedded models may experience subtraction method issues above the natural frequency of the excavated soil volume. For the UHSRS this frequency is expected to be within the range of interest and subtraction method issues may occur. However, the effect of subtraction method issues is expected to be limited because the structure is founded on rock. As stated in the responses to RAI 4760 (CP RAI #171) Question 03.07.02-17 (ML102290040 and ML102810218), this site has a limited SSI response. The base slab ISRS from each of the soil cases are plotted in Figure 1 of RAI 4760, demonstrating that for each soil case the response is close to the input spectra with reductions in amplification at the backfill soil column frequencies as expected. The lower bound without fill provides the highest response at all frequencies. Therefore, it is expected that the subtraction method issue did not have a significant effect on the SSI analysis of the UHSRS. The issue of the subtraction method was also previously discussed in response to RAI 5798 (CP RAI #221) Question 03.07.02-21 (ML11220A306).

   ACS SASSI uses an interpolation function to allow calculation of results without calculation at each frequency step. It is not reasonable or necessary that a single SASSI analysis will contain calculated frequencies at each and every peak of the transfer function. If the interpolation errors or sharp peaks have an effect, the results are generally conservative since the interpolation or sharp peak typically shows a response value above the expected values. The frequency calculation density selected is generally sufficient to ensure the peaks are either sharp and have little effect on the ISRS or element demands, or they are sufficiently covered by calculated frequencies that further addition of calculated frequencies will not significantly improve the interpolation. An example of adding frequencies and confirming the SASSI interpolation technique is shown in the following response.

4. Figures 1 through 12 shown in the response to RAI 2879 (CP RAI #60) include all frequencies added after the review process. Consideration of additional frequencies beyond those shown in the figures was studied during the design. The primary study of the effect of sharp frequencies was performed on the PSFSV structure. Based on additional frequencies, it was determined that the changes in sharp interpolation errors and sharp peaks are not significantly affected by

additional frequencies. See Figure 1 for the transfer function with original frequencies and Figure 2 for the transfer function with added frequencies. This exercise was performed at a number of locations to demonstrate the sufficiency of the spacing of the frequency calculations to accurately predict the intermediate values.

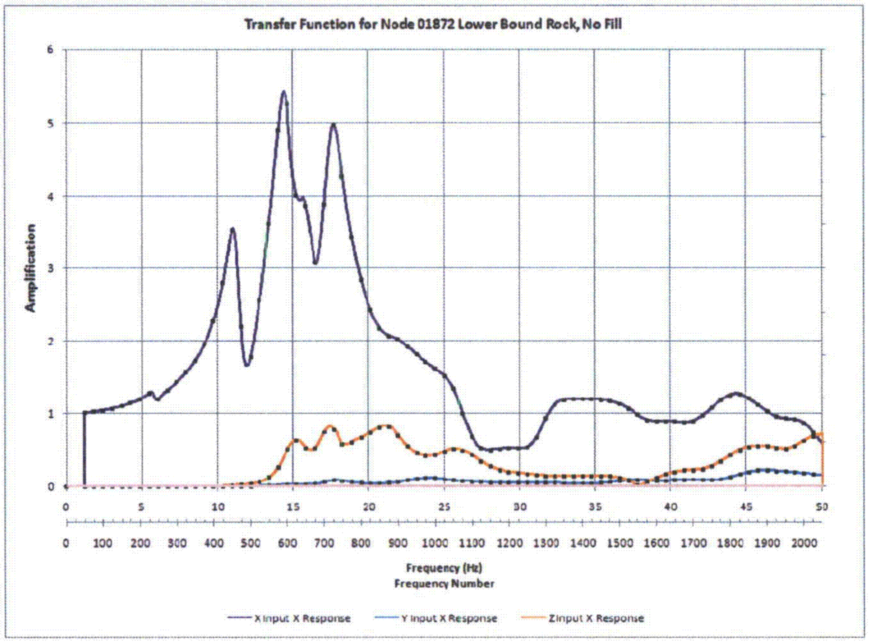


Figure 1 - Transfer function for PSFSV Node 1872, lower bound - no fill, east west (x) response, original frequencies. Black dots represent calculated values.

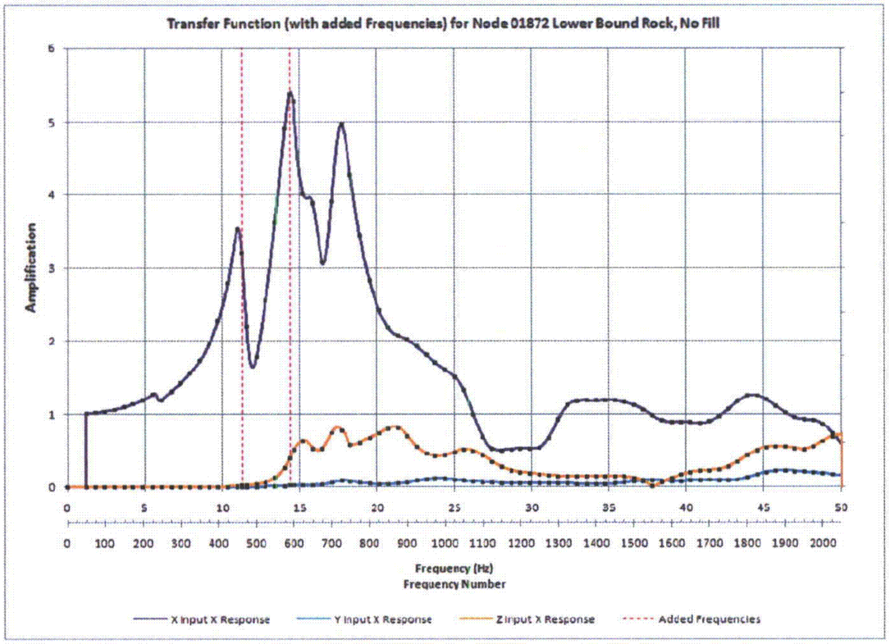


Figure 2 - Transfer function for PSFSV Node 1872, lower bound - no fill, east west (x) response, with added frequencies. Black dots represent calculated values, added frequencies identified with red dotted lines.

5. Table 4 of RAI 2879 (CP RAI #60) provided the passing frequencies of a wave passing through the soil layers under the 1/5 wavelength criteria. The input motion was applied at the top of rock, which is also the foundation support level. The primary path for seismic motion is vertically propagating through the base slab at rock level. The rock layers pass frequencies near or above the cutoff frequencies used. Although the backfill soils do not pass frequencies as high as the cutoff frequencies used, the analyses did not show abnormal behavior beyond the passing frequencies because the structural input does not rely on these soils to excite the structure and all time history energy is at low frequencies. Furthermore, the analysis was run with the lower bound rock with no backfill, and no significant differences were observed between the structural response and that for the embedded models, further demonstrating that the backfill soils are not significant in the response of the UHSRS. This comparison is shown in the response to RAI 4760 (CP RAI #171) Question 03.07.02-17 (ML102810218 and ML102290040).

Appendix 3LL-ESWPT

6. Although analysis to cover 50 Hz is not considered necessary for this site (see part 2 of the response to this RAI question under Appendix 3KK-UHSRS), the analyses were run in such a manner as to cover up to 50 Hz with cutoff frequencies selected so the frequency range of interest was covered by the envelope of cases analyzed. The high bound cases and upper bound cases were run to 50 Hz or just below (48.8 Hz or 49.8 Hz). The lower bound cases and best estimate cases used a cutoff of around 30 Hz and 39 Hz, respectively. The envelope of all the soil cases provides full coverage of the soil variation up to about 30 Hz and full coverage up to 50 Hz for the stiffer soils, which tend to control high frequency motions.

7. Tables 12, 13, and 14 of RAI 2879 (CP RAI #60) provided the passing frequencies of a wave passing through the soil layers under the 1/5 wavelength criteria. The input motion was applied at the top of rock, which is also the foundation (concrete fill) support level. The primary path for seismic motion is vertically propagating through the base slab at rock level. The rock layers pass frequencies near or above the cutoff frequencies used. The dominant seismic behaviors of the tunnel segments are transverse soil pressure and soil-induced deflections, which are both low frequency responses and vertical and longitudinal accelerations that are higher frequency motions and rely on seismic input through the base. The passing frequencies of the model are therefore considered adequate to capture these dominant modes. Additionally, the stiffer soil cases are intended to cover the higher frequencies and the high bound soil case has a minimum passing frequency of 44.9 Hz, very close to the 50 Hz. The full response is adequately covered because all of the soil cases are enveloped.

8. Transfer functions provided in RAI 2879 (CP RAI #60) Question 03.07.02-16 (ML093340447) include dots showing the calculated transfer function values. The lines in the plots show the interpolated transfer function values. Transfer function reviews were performed to observe that the low frequency response approached 1.0 for response in the direction of input motion and approached 0.0 for cross-terms. The transfer functions were reviewed to determine if the interpolations were reasonably smooth without major interpolation peaks that are not justified by adjacent calculated values. Narrow peaks less than about ¼ Hz were typically considered to be too sharp to significantly affect the response and were considered acceptable because the potential error is conservative. High frequency peaks were considered to be acceptable because the input motion contains less energy at high frequencies, and therefore the effect of transfer function peaks is less significant at higher frequencies.

   Comparison of transfer functions and response spectra at Node 1378 for all four soil cases and X response due to X direction input are shown in Figure 3 and Figure 4, respectively. The comparisons of transfer functions show very similar trends for each of the soil cases at low frequencies. At higher frequencies there is more variation. For example, the lower bound soil diverges from the smooth trend around 17 Hz resulting in numerous peaks and valleys and a sharp peak around 27 Hz. However, the response spectra comparison shown for the same node does not reflect this higher frequency response, likely because of the lack of time history input energy at these higher frequencies. The response spectra show very similar responses with shifted peaks due to the variation in soil properties. As expected, the stiffer soil cases generally control at higher frequencies. Comparisons of nodal accelerations are shown in Figure 5. These comparisons show similar response for each of the soil cases with no unusual results identified in any of the soil cases or nodal locations. Comparison of soil pressure on the side of Tunnel Segment 1 near the center of the tunnel is shown in Figure 6. The upper bound soil case results in the highest soil pressure, but other soil cases show similar shape and magnitude.

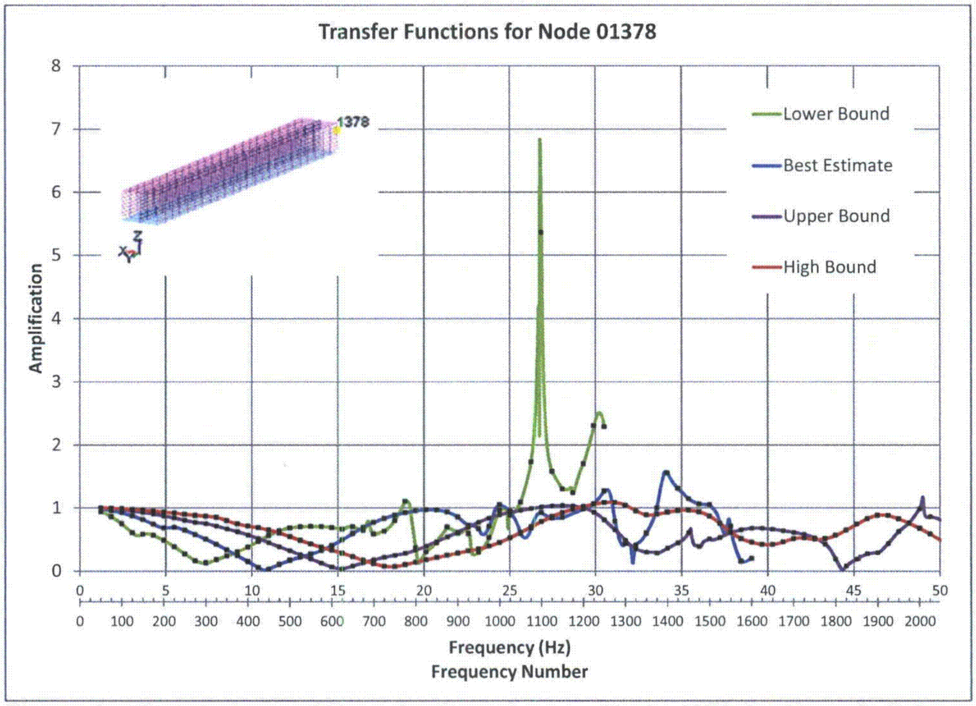


Figure 3 - Comparison of Transfer Functions at Node 1378 for Four Soil Cases at Tunnel Segment 1, X Response due to X Input

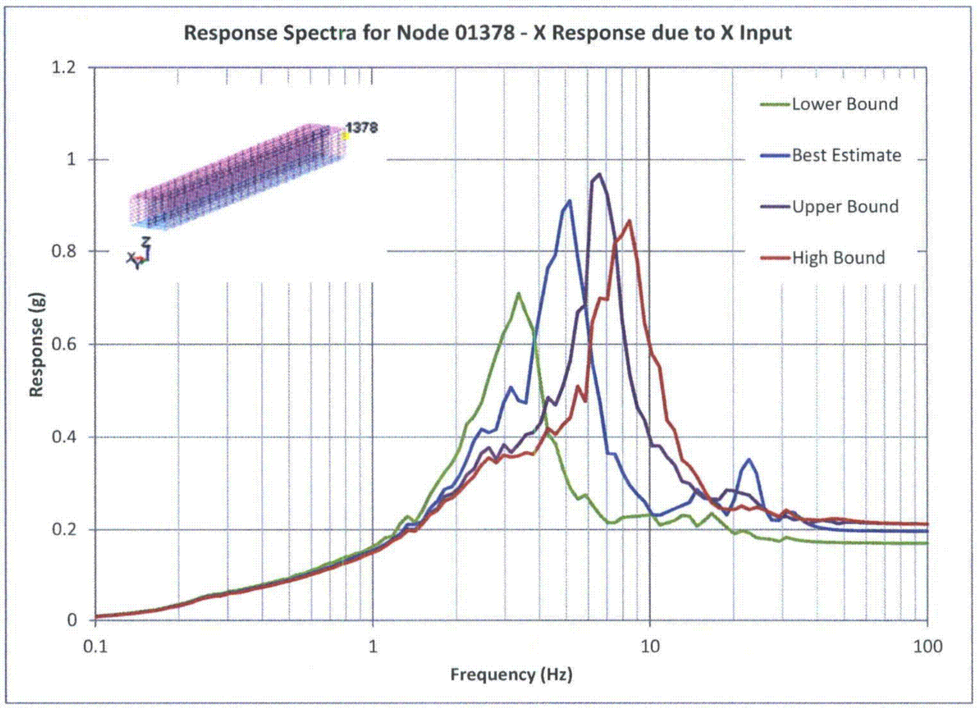


Figure 4 - Comparison of Response Spectra at Node 1378 for Four Soil Cases at Tunnel Segment 1, X Response due to X Input

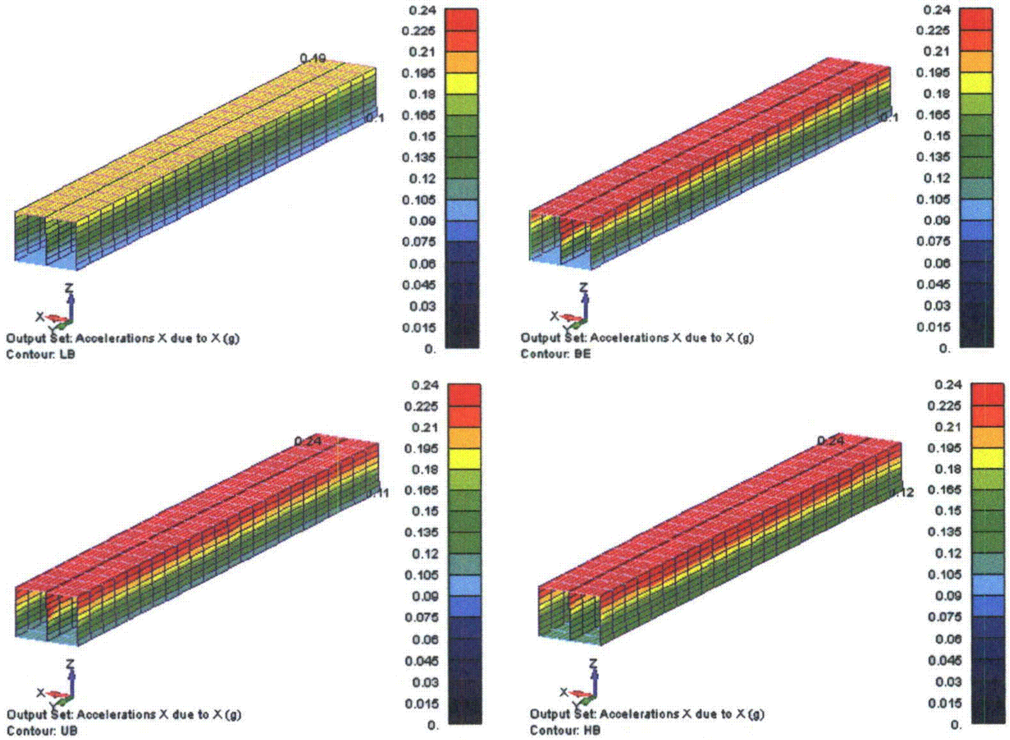


Figure 5 - Comparison of Nodal Accelerations for Four Soil Cases, X Response due to X Input at Tunnel Segment 1 (Lower Bound - Top Left, Best Estimate -Top Right, Upper Bound – Bottom Left, High Bound – Bottom Right)

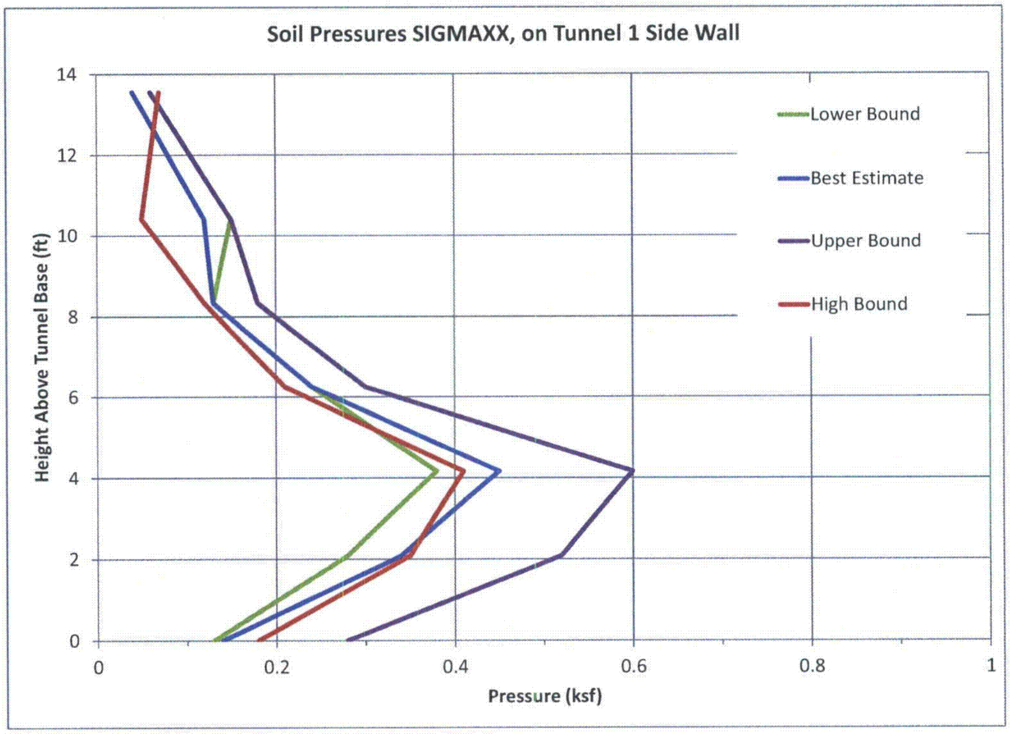


Figure 6 - Comparison Side Soil Pressures for Four Soil Cases at Tunnel Segment 1, SRSS for Response in X Direction

Appendix 3MM-PSFSV

9. Although analysis to cover 50 Hz is not considered necessary for this site (see response to part 2 above), the analyses were run in such a manner as to cover up to 50 Hz with cutoff frequencies selected so the frequency range of interest was covered by the envelope of cases analyzed. The high bound case and the lower bound without fill case both were run to 50 Hz, and the upper bound case was run to just below 50 Hz (49.4 Hz). The lower bound and best estimate cases used a cutoff of 29.9 Hz and 38.5 Hz, respectively. The envelope of all the soil cases provides full coverage of the soil variation up to 29.9 Hz and full coverage up to 50 Hz for the stiffer soils, which tend to control high frequency motions.

10. Table 18 of RAI 2879 (CP RAI #60) provided the passing frequencies of a wave passing through the soil layers under the 1/5 wavelength criteria. The input motion was applied at the top of rock, which is also the foundation support level. The primary path for seismic motion is vertically propagating through the base slab at rock level. The rock layers pass frequencies near or above the cutoff frequencies used. Although the backfill soils do not pass frequencies as high as the cutoff frequencies used, the analyses did not show abnormal behavior beyond the passing frequencies because the structural input does not rely on these soils to excite the structure and all time history energy is mostly at low frequencies. While significant differences are observed for different soil cases, the cases with less soil support (separated and no backfill) controlled, particularly at high frequencies, as shown in the example in Figure 7 below. Hence the passing frequencies used are adequate for this analysis.

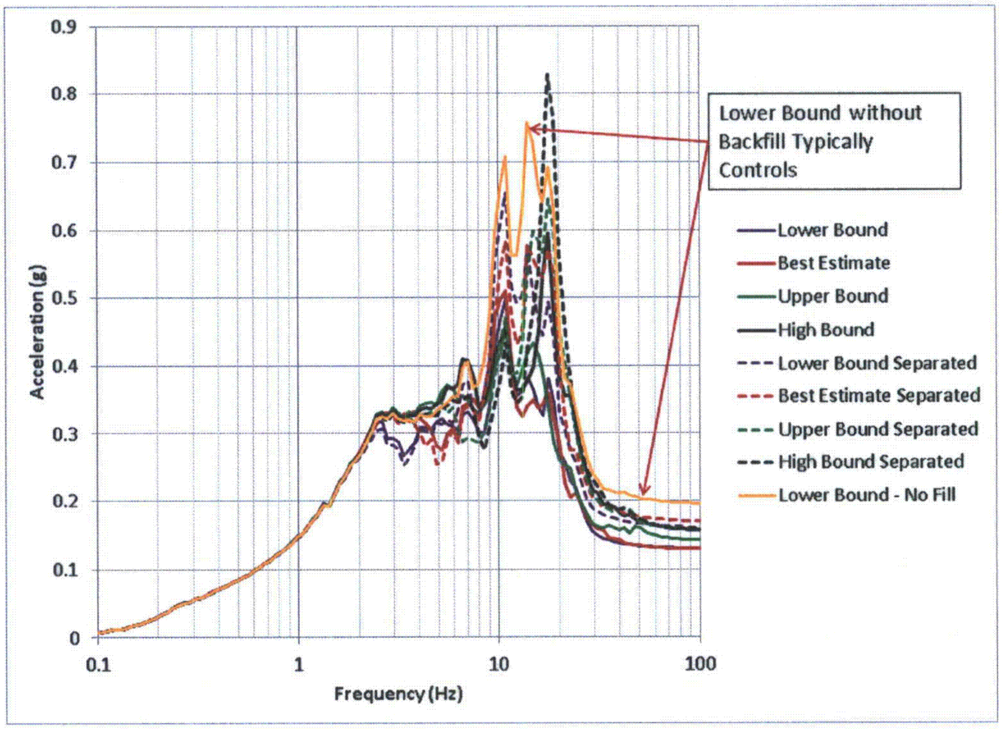


Figure 7 – 5% Damped Response Spectra for Each Soil Case at Node 1956 (PSFSV Roof), East West (x) Response

11. The model descriptions and results of the lumped mass SSI models of the R/B Complex presented in the calculations referenced in the response to RAI 2879 (CP RAI # 60) Question 03.07.02-16 (ML093340447) are obsolete in that the more detailed three-dimensional finite element models will be used for the site specific reconciliation of the standard plant R/B Complex. This will assure consistent geometry among the standard plant and site-specific ACS SASSI models. The roadmap for updating these calculations consist of revision of the same calculations with the R/B, PCCV and CIS stick models replaced with the more detailed three-dimensional finite element distributed mass models. Other changes will also be implemented such as updating the soil properties to account for a recently identified change in ground water level (GWL). A full site-dependent SASSI analysis of the R/B Complex will be performed using the modified subtraction and/or flexible volume method. It is anticipated that technical justification will be provided with the re-analyses to support a departure to eliminate any shear keys required in the standard plant design. For a "road map" of other anticipated changes, a supplemental response to RAI 5947 Question 03.07.02-22 (CP RAI #221) will be prepared.

12. Luminant concurs that some of the transfer functions contained in Appendices A, B, and C of SSI-12-05-100-003 do contain some sharp spurious peaks that represent interpolation errors, including the peak at 4.8 Hz in Figure A.14, 9 Hz in Figure B.38, 7.8 Hz in Figure C.5, and 11 Hz in Figure C.14. The peaks at 7 Hz in Figure A.2 and 7 Hz in Figure B.29 include a calculated value. They do not represent an interpolation error, but do show unexpected sharp peaks. As stated in the RAI question, there are other examples of figures containing sharp peaks, some of which are interpolation errors and some which contain calculated values.

    It is possible that some of the calculated peaks may be a result of the use of the SASSI subtraction method. The R/B Complex analyses included ACS-SASSI runs in which the R/B

Complex was analyzed as an embedded structure. Embedded models may experience subtraction method issues above the natural frequency of the excavated soil volume. The issue of the subtraction method was previously discussed in response to RAI 5798 (CP RAI #221) Question 03.07.02-21 (ML11220A306). As stated in the response to part 11 in this RAI question, the lumped mass SSI models of the R/B Complex presented in the calculations referenced in the response to RAI 2879 (CP RAI # 60) Question 03.07.02-16 (ML093340447) are obsolete in that the more detailed three-dimensional finite element models will be used for the site specific reconciliation of the standard plant R/B Complex. During this re-analysis, the flexible volume method and/or modified subtraction method will be used instead of the subtraction method. The re-analyses are anticipated to eliminate spurious peaks in the analyses results. Further discussion of the overall "road map" for the re-analyses will be contained in a future supplemental response to RAI 5798 (CP RAI #221), which is scheduled to be issued in November 2011.

ACS SASSI uses an interpolation function to allow calculation of results without calculation at each frequency step. It is not reasonable or necessary that a single SASSI analysis will contain calculated frequencies at each and every peak of the transfer function. If the interpolation should error, very narrow banded peaks or sharp peaks can have an effect, where the results are generally conservative since the interpolation or sharp peak typically shows a response value above the expected values. The density selected for frequency calculation generally is sufficient to ensure the peaks are either sharp and have little effect on the ISRS or element demands, or they are sufficiently covered by calculated frequencies that further addition of calculated frequencies will not significantly improve the interpolation. An example of adding frequencies and confirming the SASSI interpolation technique is shown in the response to Question 03.07.02-23 item 4 of this RAI.

13. Please refer to part 2 of the response to Question 03.07.02-23 for a discussion of the applicability of high-frequency issues to the CPNPP site. As stated in part 6 of the response to RAI 2879 (CP RAI #60) Question 03.07.02-16 (ML093340447), a cut-off frequency of 50 Hz was used for all of the site-specific SASSI analyses of the R/B, PCCV and CIS with common basemat modeled as a surface foundation. The following table presents the maximum frequencies of the seismic waves that can be transmitted through the basemat mesh, which has a nominal size of 12.5 ft:

Soil Case	Top Subgrade Layer Shear wave Velocity	Basemat Mesh Size	Max. Passing Wave Frequency
SLB	4427 fps	12.5 ft	70.8 Hz
SBE	5685 fps	12.5 ft	91.0 Hz
SUB	7300 fps	12.5 ft	116.8 Hz

The maximum passing frequencies shown above are calculated based on the criteria that element size should not be bigger than 20% of the wave length of the subgrade material. The table shows that the mesh size of the basemat is adequate to transmit frequencies above 50 Hz.

With regard to the embedded condition analyses, the effects on the SSI system response due to backfill embedment resonance frequencies occur in the lower frequency ranges. Amplifications due to resonances were observed as occurring primarily at frequencies that correspond to the first natural frequency of the backfill soil column. Backfill soil column resonance in the horizontal direction was observed generally at frequencies ranging from 4 Hz for the embedded lower bound condition to 8 or 9 Hz for the embedded high bound condition as noted in FSAR Tables 3KK-3, 3LL-5, and 3MM-4. However, as noted in FSAR Table 3NN-15, in general, the horizontal response of the structures is reduced due to the dissipation of energy in the backfill. The reduction is more pronounced for cases of soft backfill, which has higher values of strain-compatible material damping. Backfill soil column resonance in the vertical direction was observed generally at frequencies ranging from 7 Hz for the embedded lower bound condition to 17 Hz for the embedded high bound condition as noted in FSAR Tables 3KK-3, 3LL-5, and 3MM-4. The backfill soil column frequencies observed are captured by the passing frequencies and cut-off frequencies used in the embedded condition analyses. As stated in part 6 of the response to RAI 2879 (CP RAI #60) Question 03.07.02-16 (ML093340447), the passing frequencies range from approximately 9 Hz for the lower bound condition to approximately 21 Hz for the high bound condition. Therefore, utilizing meshing that provides for higher passing frequencies in the embedded condition analyses will not result in more accurate or conservative results

14. SRP Section 3.7.2 Acceptance Criteria 4 recommends that for deep soil sites, the model depth generally should be at least twice the base dimension below the foundation level, which should be verified by parametric studies. The CPNPP site properties are those of rock, as opposed to deep soil. The dynamic properties of the rock subgrade at the site are presented in FSAR Table 2.5.2-227.

    The standard plant buildings of Units 3 and 4 are supported by subgrade consisting of an approximately 400 ft thick strata of limestone, sandstone and shale resting on the approximately 2,200 ft thick Strawn Formation, which consists of shales with sandstone and limestone beds. The SASSI site model layers extend to a depth of 504 ft below the bottom of foundation, and therefore extend approximately 100 ft into the Strawn Formation. The SASSI model also includes a half space which is represented by ten layers of elements, as stated in part 8 of the response to RAI 2879 (CP RAI #60) Question 03.07.02-16 (ML093340447). Therefore, the actual lower boundary of the SASSI model extends even further than twice the base dimension. Because of the extent of layering included in the modeling and the stiffness of the rock layers, parametric studies for the CPNPP site were not performed in selecting the lower boundary for the SSI model, and the depth of model chosen was deemed sufficient to capture the SSI response.

15. In the response to item 10 in RAI 2879 (CP RAI #60) Question 03.07.02-16 (ML093340447), the SSI analysis of the R/B-PCCV-CIS was originally based on lumped-mass stick models, but the Standard Plant application now commits to performing the SSI analysis with a detailed three-dimensional distributed-mass model of the R/B-PCCV-CIS as stated in the supplemental response to DCD RAI 542-4262 and associated DCD markups (ML11188A250, ML11188A251, ML11188A252). The finite element model is initially developed using the computer program ANSYS before being translated into ACS SASSI format using the built-in file converter in ACS SASSI. The ACS SASSI dynamic FE model initially developed in ANSYS is less detailed than the finer meshed detailed FE model developed in ANSYS for the detailed design. This dynamic FE model captures the essential dynamic properties of the static FE model, while reducing the number of dynamic degrees of freedom to facilitate the computation time required for the ACS SASSI analysis. The fixed base validation time history runs of the less detailed and finer meshed detailed three-dimensional distributed-mass models of the Standard Plant R/B-PCCV-CIS are performed using ANSYS by mode superposition method. With this method, damping is accounted for using constant modal velocity dependent damping.

    MHI Technical Report MUAP-11006 Revision 0 for the US-APWR standard plant documents the lumped-mass stick models, which are used in various studies as described in the report. The fixed base validation time history runs of these stick models is performed using time-history full transient dynamic analysis in ANSYS (i.e., the forward difference implicit method of direct integration). With this method, damping is accounted for using Rayleigh damping.

<u>Impact on R-COLA</u>

None.

Impact on S-COLA

None; the response is site-specific.

Impact on DCD

None.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Comanche Peak, Units 3 and 4

Luminant Generation Company LLC

Docket Nos. 52-034 and 52-035

RAI NO.: 5947 (CP RAI #226)

SRP SECTION: 03.07.02 - Seismic System Analysis

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

DATE OF RAI ISSUE: 8/22/2011

QUESTION NO.: 03.07.02-24

This question is a follow-up to RAI Letter Number 60 (2879), Question 03.07.02-11.

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100. This information is also important for the staff to determine whether the application conforms with the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic System Analysis.'

After reviewing the response to RAI 60-2879 Question 03.07.02-11, the staff has the following questions regarding the material in Appendices 3KK through 3NN of the FSAR:

1. The input motions or spectra used in the evaluation of the UHSRS in Appendix 3KK are never shown or defined. The applicant is requested to show plots of the input spectra used for the SSI analyses.

2. On the top of p. 3KK-3 it is stated that it is not required to model the convective mass. In the third paragraph on p 3KK-4, the applicant states that the response spectrum analysis includes sloshing effects and uses 0.5% damping for the simulation of sloshing effects. The applicant is requested to explain how the sloshing effects are included in the analysis if the convective mass is not modeled.

3. The first sentence on p. 3KK-5 states that the spectra used for this approach were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis. The applicant is requested to provide the comparison between the referenced spectra and the SASSI spectra.

4. In p. 3KK-5, the applicant states that the response spectrum model of the UHSRS considered a flexible base slab configuration where the slab was supported using soil springs calculated using ASCE 4 methodology. The applicant is requested to provide details of this model configuration including details of the spring calculation.

5. The second paragraph of Section 3KK.3 states that the soil pressures used for design are conservative relative to the soil pressure distributions predicted by SASSI. The applicant is requested to provide the soil pressure comparisons to the staff.

6. The applicant is requested to provide the specific location and node numbers of all nodes used for the generation of ISRS that are shown in Appendices 3KK through 3NN.

7. The input motion used in the analyses of the ESWPT segments are never shown or defined in Appendix 3LL. The applicant is requested to provide the seismic input for staff review. The applicant is also requested to explain Note 3 to Table 3LL-7 and discuss how the input for the response spectrum to segment 2 relates to the site-specific input at the foundation level of the R/B complex.

8. According to Note 3 of Table 3LL-7, ESWPT segment 2 is evaluated using a response spectrum analysis in ANSYS. The applicant should describe the configuration of that segment that was used for the modal analysis supporting the response spectrum evaluation.

9. Section 3LL.3 states that Table 3LL-4 shows frequencies and descriptions of modal responses obtained from the fixed-base ANSYS analysis of ESWPT segment 1. The applicant is requested to describe the configuration of the fixed-base model of segment 1 of the ESWPT, which is a buried structure.

10. The applicant is requested to clarify whether the results in shown in Tables 3LL-9, 3LL-10, and 3LL-11 are ANSYS output or SASSI output and to label the tables accordingly.

11. The staff notes that on p. 3LL-1, the applicant mentions the "...dynamic analysis of the SASSI 3D model in the frequency domain...". In contrast, on p. 3LL-3 the applicant refers to "nodal accelerations obtained from the time history analysis ", when evidently referring to results from the SASSI models. The applicant is requested to clarify the above statements and to use clear and consistent terminology when referring to a software program or analysis methodology in all places in the FSAR. Other examples appear in the second sentence of Subsection 3MM.3 and in Subsection 3NN.1 of Appendix 3MM of Revision 1 of the FSAR.

12. The applicant is requested to explain how the bearing pressures in Table 3LL-13 were developed and also to describe how the seismic wall pressures were developed and applied in the static evaluations of ESWPT segments 1 and 3.

13. The staff requests that the applicant provide a complete description of the development and application of the accelerations and dynamic soil pressures applied to segment 3 of the ESWPT per note 4 of Table 3LL-8.

14. In the first paragraph of Subsection 3MM.1 of Appendix 3MM of Revision 1 of the FSAR, the applicant states that "Further, the translation of the model from ANSYS to SASSI is confirmed by comparing the results from the modal analysis of the fixed base structure in ANSYS and the SASSI analysis of the model resting on a half-space with high stiffness. The close correlation between the SASSI transfer function results and the ANSYS eigenvalues results ensures the accuracy of the translation." The applicant is requested to provide these comparisons to the staff for review.

15. On p. 3MM-2 of Appendix 3MM of Revision 1 of the FSAR, the applicant states that "The natural frequencies and descriptions of the associated modal responses of the fixed-base model are presented in Table 3MM-3 for the PSFSV and these frequencies are compared to structural frequencies calculated from the transfer functions of the SASSI model." The staff is unable to find

any such comparisons in Appendix 3MM and it is not clear to the staff which ANSYS model (fine or coarse mesh) was used for calculating the modal responses. The applicant is requested to clarify which model was used and to present the referenced comparisons to the staff for review.

16. In Subsection 3MM.3 of Appendix 3MM of Revision 1 of the FSAR, the applicant states that the maximum displacements of the PSFSV are summarized in Table 3MM-7. The applicant is requested to clarify if theses displacements are absolute displacements, or maximum relative displacements within the structure.

17. In Appendices 3KK through 3NN of Revision 1 of the FSAR, it is stated that the site-specific SASSI analyses are conducted using methods and approaches consistent with ASCE 4. The applicant is requested to specifically identify which methods and approaches from ASCE 4 are incorporated in the SASSI analyses and how these methods are the same as or differ from guidance provided in the SRP.

18. The site-specific SSI analysis of the R/B-PCCV-CIS is based on lumped-mass stick models. The SSI analysis of the R/B-PCCV-CIS for the DC Standard Plant was originally based on lumped-mass stick models, but the Standard Plant applicant has since committed to performing the SSI analysis with a detailed three-dimensional distributed-mass model of the R/B-PCCV-CIS. The applicant is requested to state how their approach to the site-specific SSI analysis of the R/B-PCCV-CIS is affected, if at all, by the commitment of the DCD applicant to use distributed mass models.

19. In Subsection 3NN.3 of Appendix 3NN of Revision 1 of the FSAR, the applicant states that "The geometry and properties of the lumped-mass-stick model representing the above ground portion of the building are identical to those of the lumped mass stick model used for the R/B-PCCV-containment internal structure seismic analysis, as addressed in Appendix 3H." The applicant also refers to Appendix 3H on the bottom of p. 3NN-4 and in the last sentence of Subsection 3NN.3. Appendix 3H describes an uncoupled model of the R/B-PCCV-CIS, and that uncoupled model was later superseded by a coupled model that was documented in subsequent technical reports by MHI. The applicant is requested to describe their strategy for incorporating the results from the subsequent technical reports supporting the DCD into the FSAR.

20. In Appendices 3KK, 3LL, and 3MM, the applicant evaluated the potential for separation of backfill from the embedded portion of the structures. In contrast, the SSI evaluation of the R/B-PCCV-CIS that is documented in Appendix 3NN appears not to have considered the potential for backfill separation per the Acceptance Criteria guidelines in SRP 3.7.2.II.4. The applicant is requested to explain why the potential for backfill separation was not considered in the SSI analysis of the R/B-PCCV-CIS.

ANSWER:

1. The dynamic SSI analysis of the UHSRS was performed using SASSI to generate ISRS, and seismic acceleration responses. The structural design of the UHSRS was analyzed for response spectra seismic input and static loadings using ANSYS. The results of the response spectra analyses were compared to the results of the SASSI analyses to confirm the adequacy of the seismic demand used for evaluation of the UHSRS. These inputs to SASSI and ANSYS are presented below:

   <u>SASSI Input</u>

   The time history motions input at the bottom of the structural model are described in FSAR Subsection 3.7.1.1 and FSAR Appendix 3NN Section 3NN.2. A similar question was also asked in

RAI 5317 (CP RAI #205) Question 03.07.01-7 (ML110800596). The time history motions are the envelope of the minimum earthquake and the time histories from the site response analyses.

The portion of FSAR Subsection 3.7.1.1 titled, "Site-Specific Design Ground Motion Time Histories and Durations of Motion" describes the development of the time histories that are appropriate for the “without backfill” condition (surface condition). Figures 3.7-207, 3.7-208, and 3.7-209 provide spectra plots of the time histories converted to response spectra.

For the embedded condition (backfill condition), the time history motion is computed from an ACS SASSI SOIL module (SHAKE type) analysis to account for the strain-compatible effects of backfill. The SSI analyses performed with SASSI for the UHSRS requires in-layer time history motions as input. This time history motion input at the bottom of structural model location is an outcrop motion and is input to the SOIL module. The SOIL module calculates in-layer motion at the top of the rock layer for use as input to the SASSI SSI analyses. The outcrop motion is used as the vertical time history input for the embedded condition SSI analyses. This outcrop motion is conservative relative to an in-layer motion. The following spectra plot in Figure 1 presents the time history input motions after conversion to response spectra for the embedded condition:

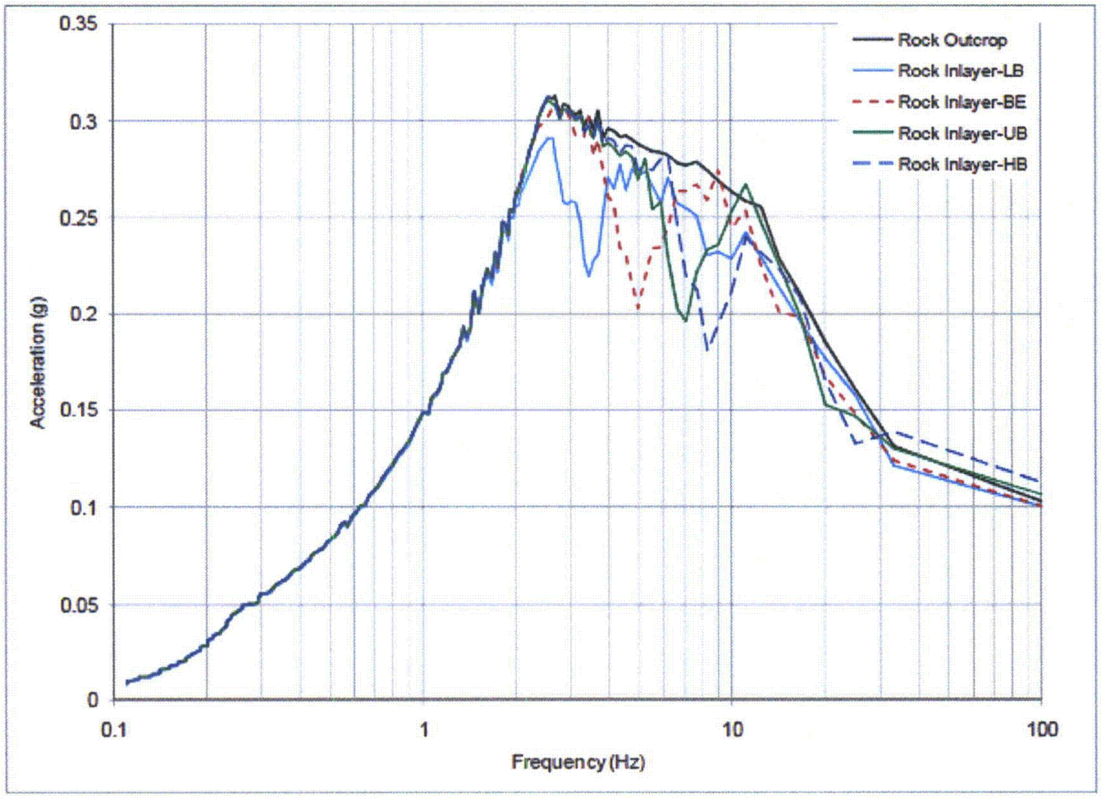


Figure 1 - Response Spectra Generated at Top of Rock - Embedded Condition

ANSYS Input

The three components of the design spectra used for the ANSYS response spectra analysis to design the UHSRS are shown in Figures 2, 3 and 4 below. The design spectra plotted in these figures correlate with plots of those generated from the SASSI SSI analysis for the LB, BE, UB, and HB soil conditions at the UHSRS structural base and Lindley -Yow Composite Design Spectra.

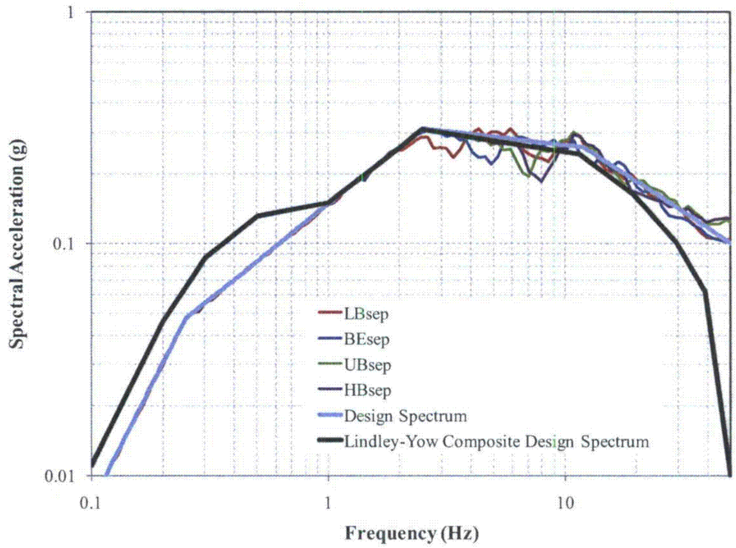


Figure 2 - Comparison of Base Response Spectra in X-direction (E-W) used for Design with SASSI Results for each soil case

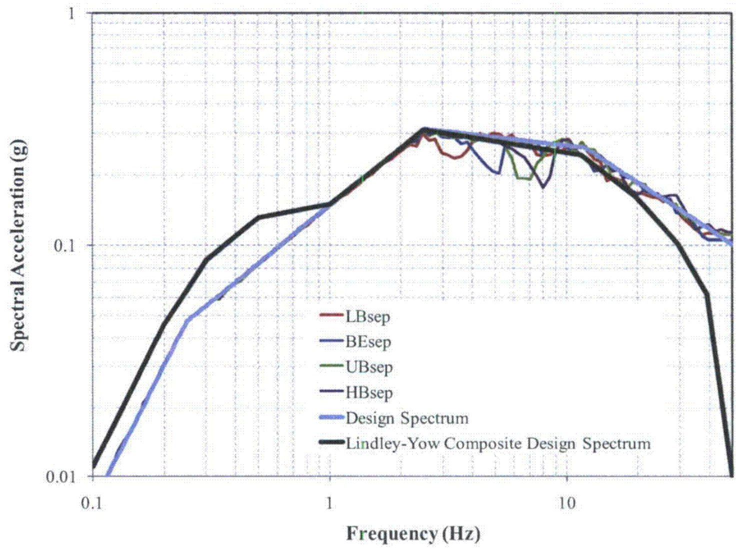


Figure 3 - Comparison of Base Response Spectra in Y-direction (N-S) used for Design with SASSI Results for each soil case

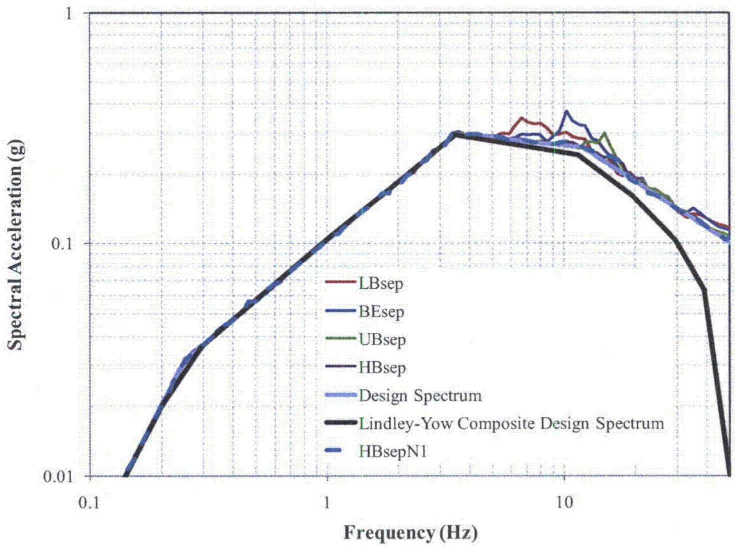


Figure 4 - Comparison of Base Response Spectra in Z-direction (Vertical) used for Design with SASSI Results for each soil case

2. The convective mass is not included in the SSI analyses that are used to generate the ISRS because the SSI models do not capture the very low frequency effects of the sloshing mass. The structural frequencies and SSI frequencies are significantly higher than the sloshing frequencies and these modes do not interact.

   The convective mass is modeled in the response spectrum analyses used to create the design loads. As discussed in FSAR Sections 3KK.2 and 3KK.3, the input response spectra to the analyses are modified to include the 0.5% spectra at low frequencies to reflect the spectra at the fluid damping levels.

3. The purpose of the design analyses was to produce design demands, and therefore the only requirement is that the demands are correct or conservative. The adequacy of the use of the input spectra to produce design demands is verified by the comparison of the resulting element demands to the demands calculated in SASSI. This comparison is shown in response to RAI 4542 (CP RAI #167) Question 03.08.04-66 (ML102240246). As a result the design spectra are adequate for use as input to determine design forces.

   The comparisons of the spectra requested are shown in the following figures. The base spectra computed in SASSI were compared to those used for the response spectra analysis used in design. The comparisons of 5% damped spectra (Figure 5, Figure 6, and Figure 7) show that the SSI spectra are close to those used for design. Since the 5% damped input spectra was used for the analyses rather than the 7% damping by RG 1.61 Table 1 for SSE, the SASSI 7% damped spectra should be compared to the design input spectra. The comparison of SASSI spectra for various levels of damping are shown in Figure 8, demonstrating that the 7% damped spectra is significantly below the 5% damped spectra.

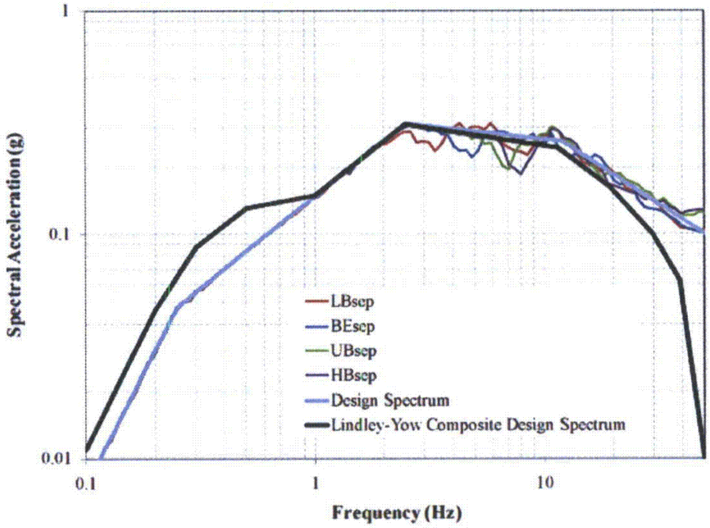


Figure 5 - Comparison of Base Response Spectra used for Design (Light Blue) to SSI Base Spectra, X Direction (5% Damped)

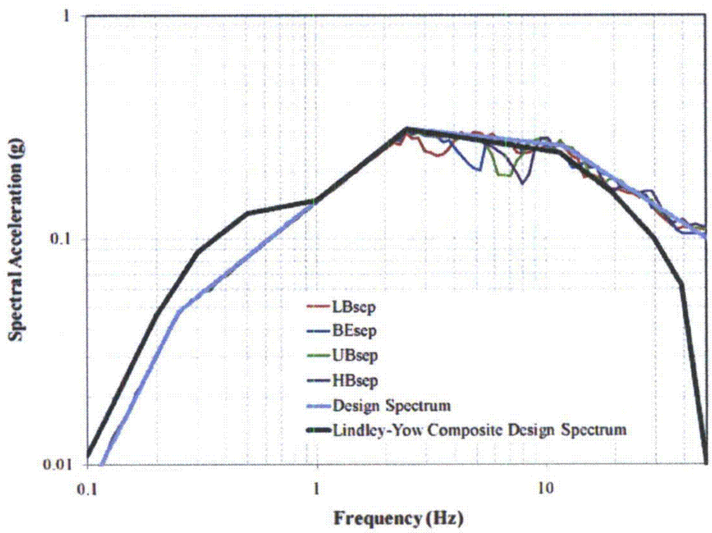


Figure 6 - Comparison of Base Response Spectra used for Design (Light Blue) to SSI Base Spectra, Y Direction (5% Damped)

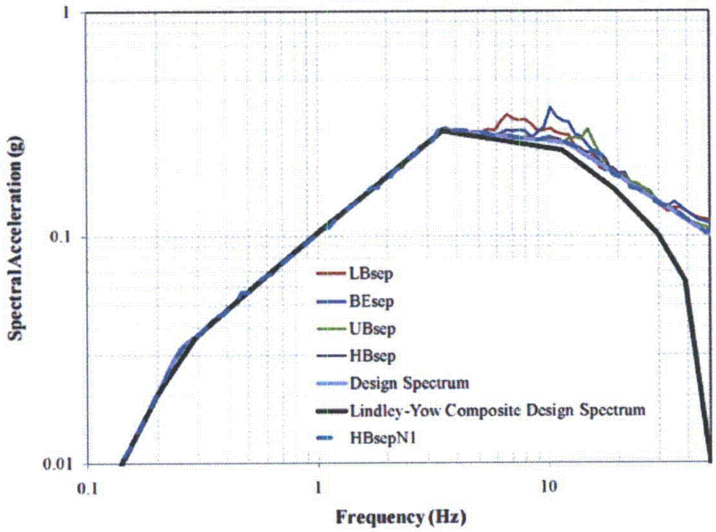


Figure 7 - Comparison of Base Response Spectra used for Design (Light Blue) to SSI Base Spectra, Z Direction (5% Damped)

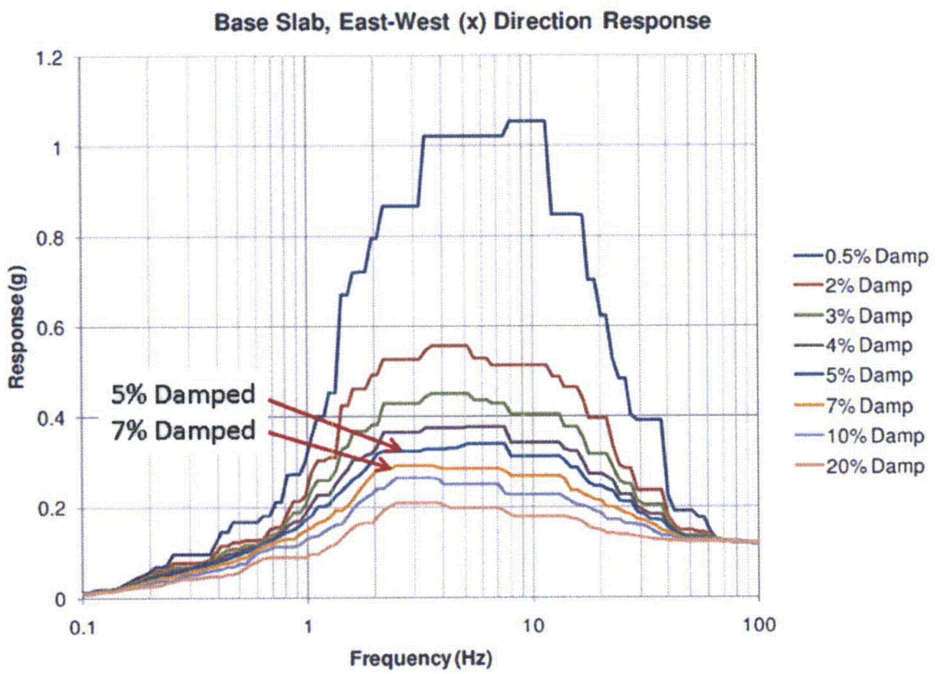
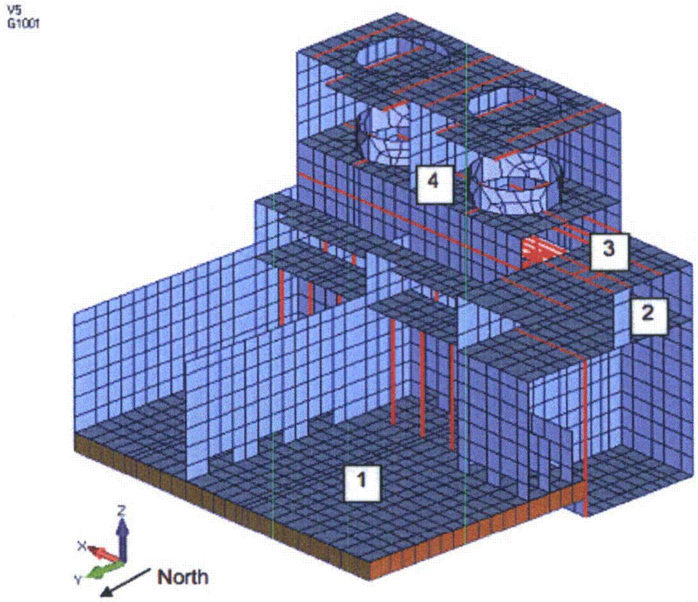


Figure 8 - East-West (x) Base Slab SSI Response Spectra for Various Damping Levels

4. The calculation of springs was described in the response to RAI 2994 (CP RAI # 108) Question 03.08.04-15 (ML093480149).

5. A comparison of soil pressures from the SASSI analyses to the soil pressures applied for design was provided in response to RAI in the response to RAI 4542 (CP RAI #167) Question 03.08.04-73 (ML102240246).

6. Figures 10 through 21 below provide specific location and node numbers used in the generation of ISRS shown in Appendices 3KK through 3NN. Figure 9 (FSAR Rev 2 Figure 3KK-1) shown below, is labeled to provide the general UHSRS model orientation and location of major slabs.



Legend:

1 = Base Slab

2 = Pump Room Elevated Slab

3 = Pump Room Roof Slab

4 = Cooling Tower Fan Support Slab

Note: ISRS are presented in Figure 3KK-3 for the locations identified in the legend above.

Figure 3KK-1 Overall SASSI Model of UHSRS (Sheet 2 of 2, Cutaway View of SASSI Model of UHSRS)

Figure 9 - Overall SASSI Model of UHSRS

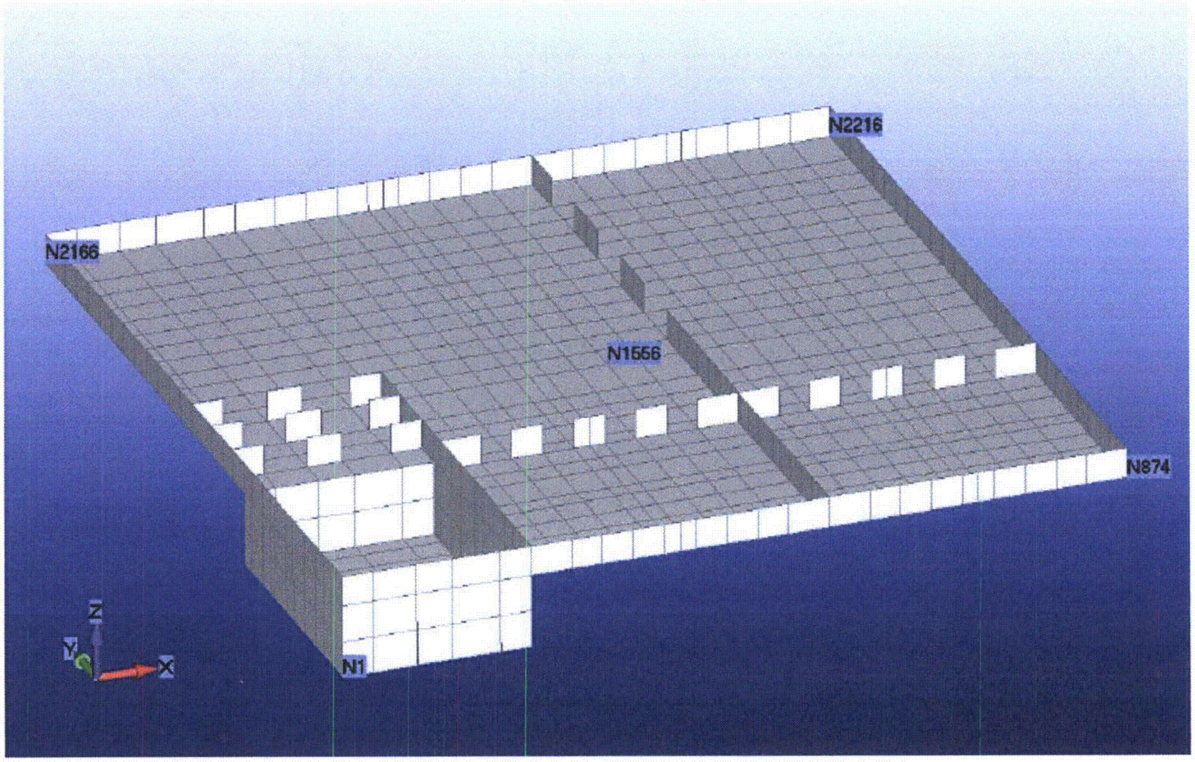


Figure 10 - Nodes used for UHSRS Base Slab Response Spectra ISRS (Relates to Figures 3KK-3, 1-3)

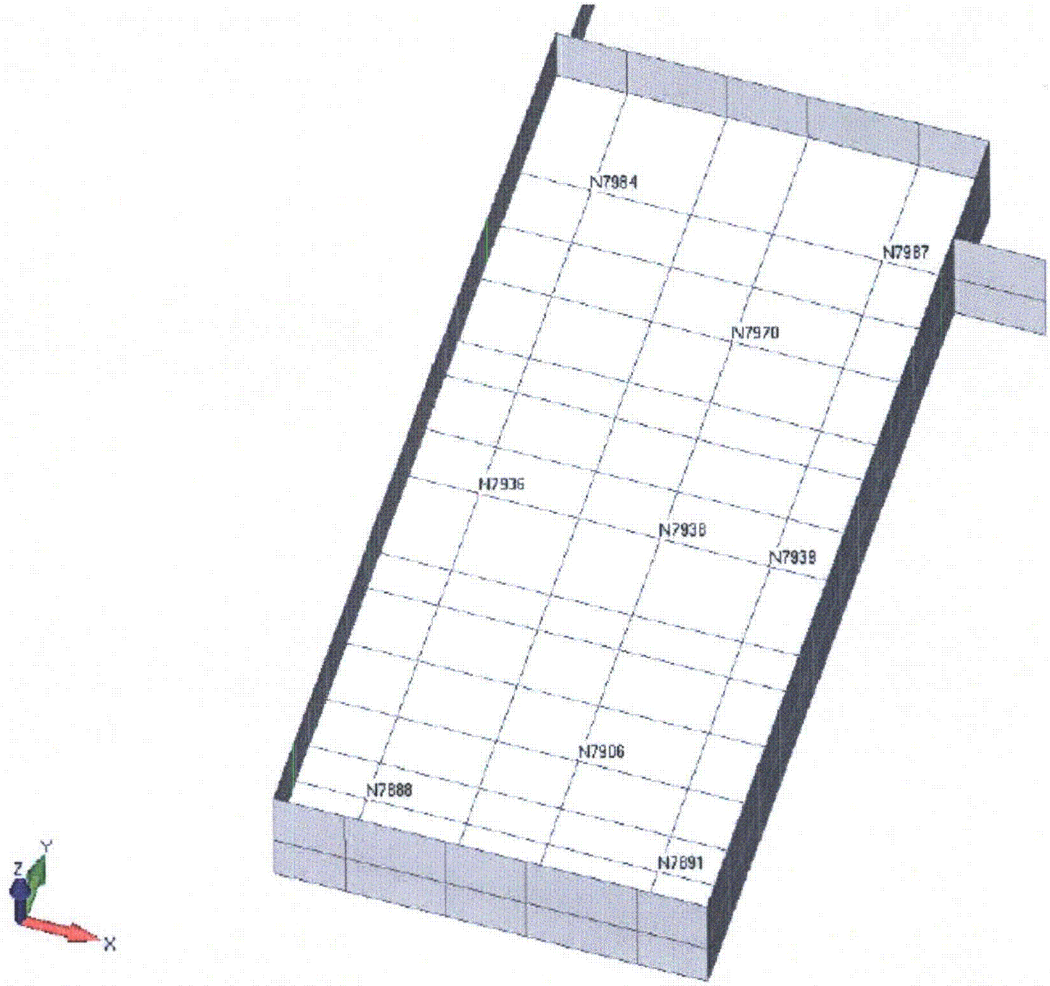


Figure 11 - Nodes used for UHSRS Pump Room, Elevated Slab ISRS (Relates to Figures 3KK-3, 4-6)

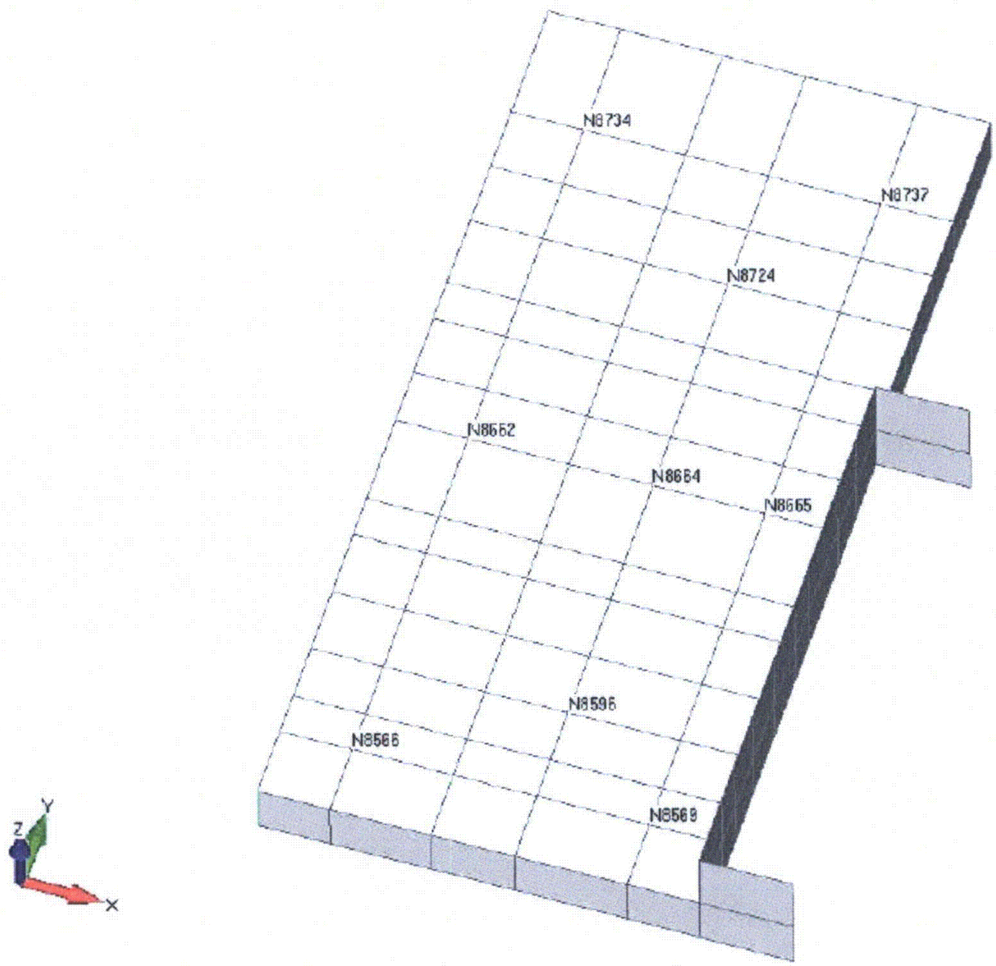


Figure 12 - Nodes used for UHSRS Pump Room, Roof Slab ISRS (Relates to Figures 3KK-3, 7-9)

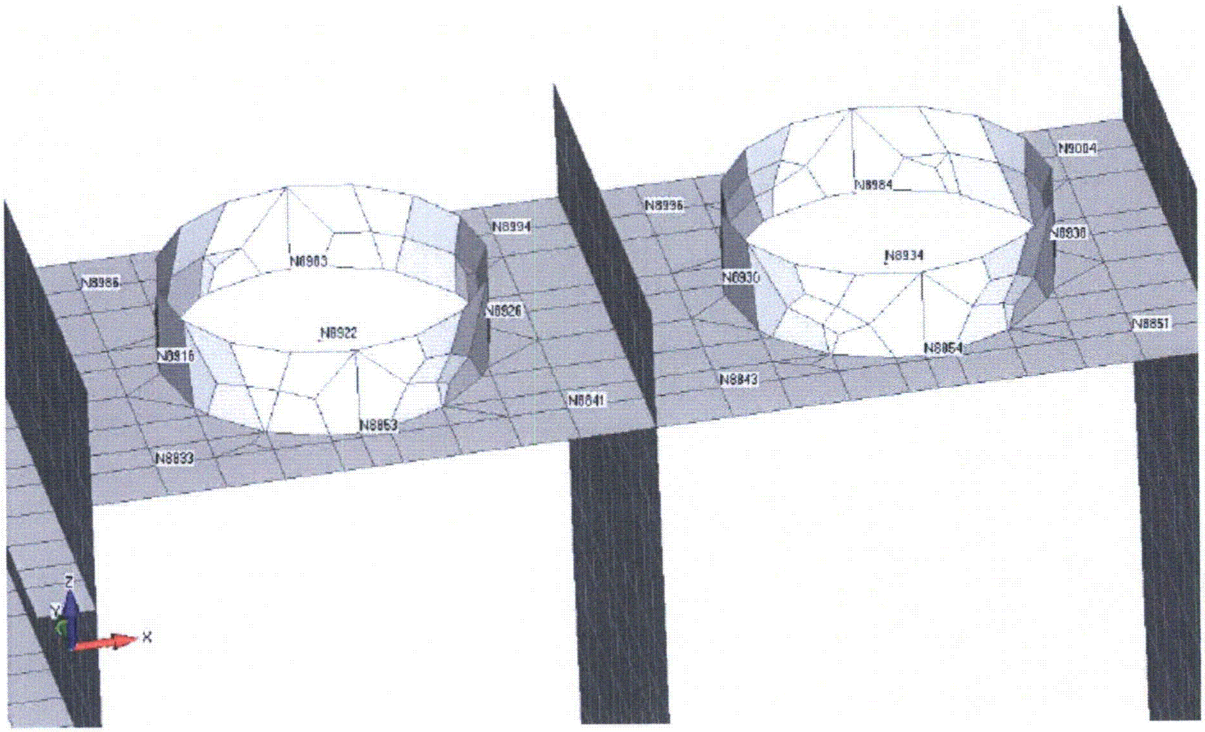


Figure 13 - Nodes used for UHSRS Cooling Tower Fan Support Slabs ISRS (Relates to Figures 3KK-3, 10-12)

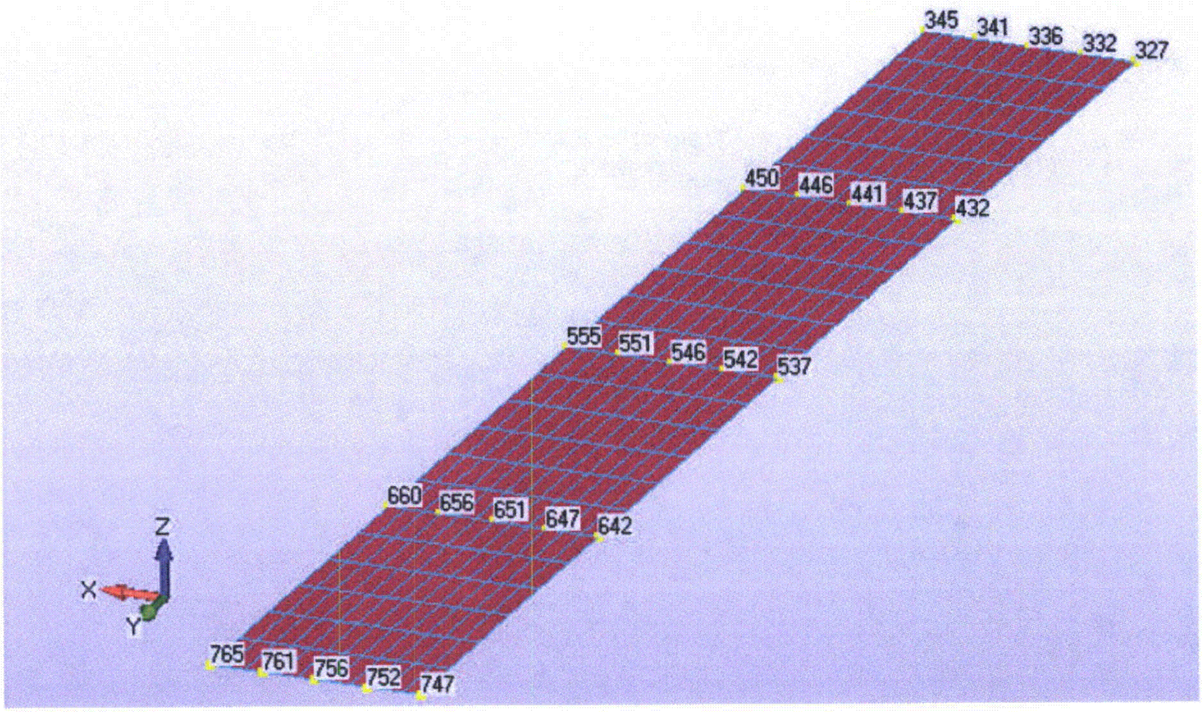


Figure 14 - Nodes used for ESWPT Segment 1 Base Slab ISRS (Relates to Figures 3LL-7, 1-3)

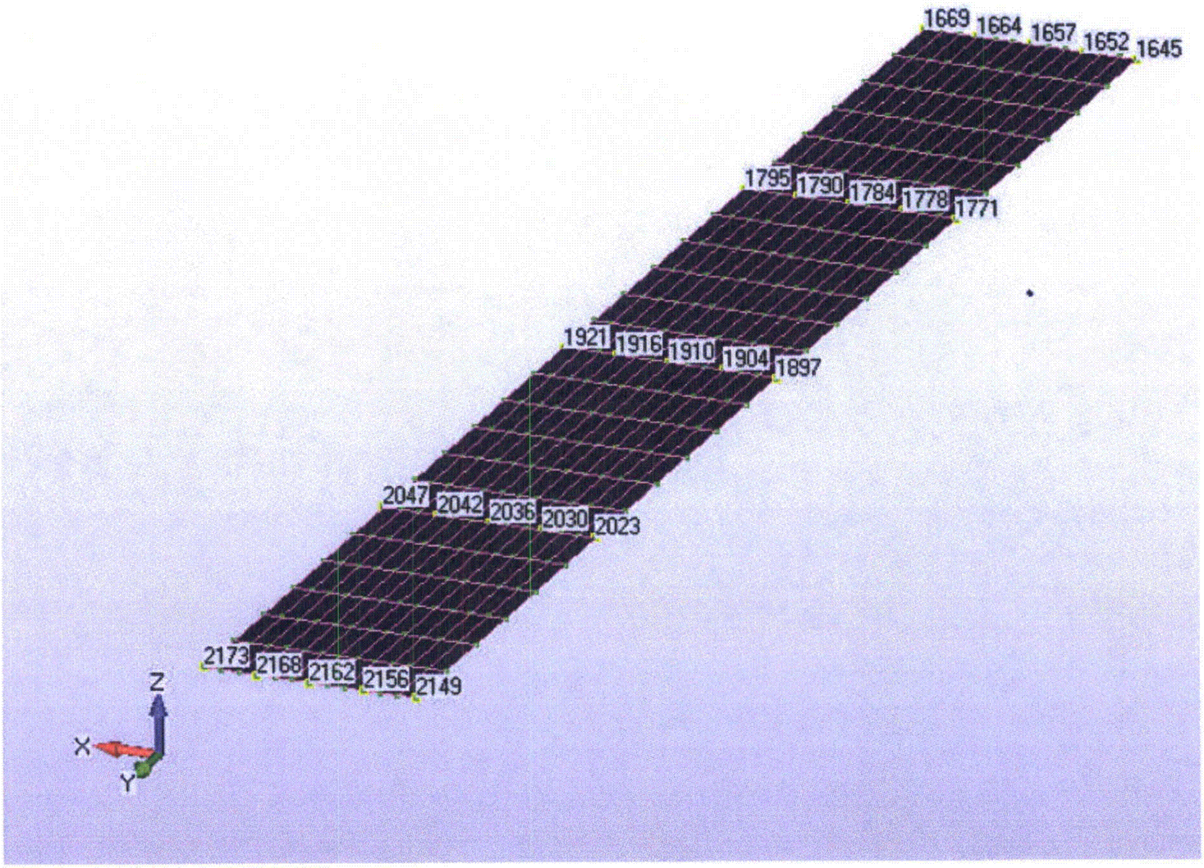


Figure 15 - Nodes used for ESWPT Segment 1 Roof Slab ISRS (Relates to Figures 3LL-7, 4-6)

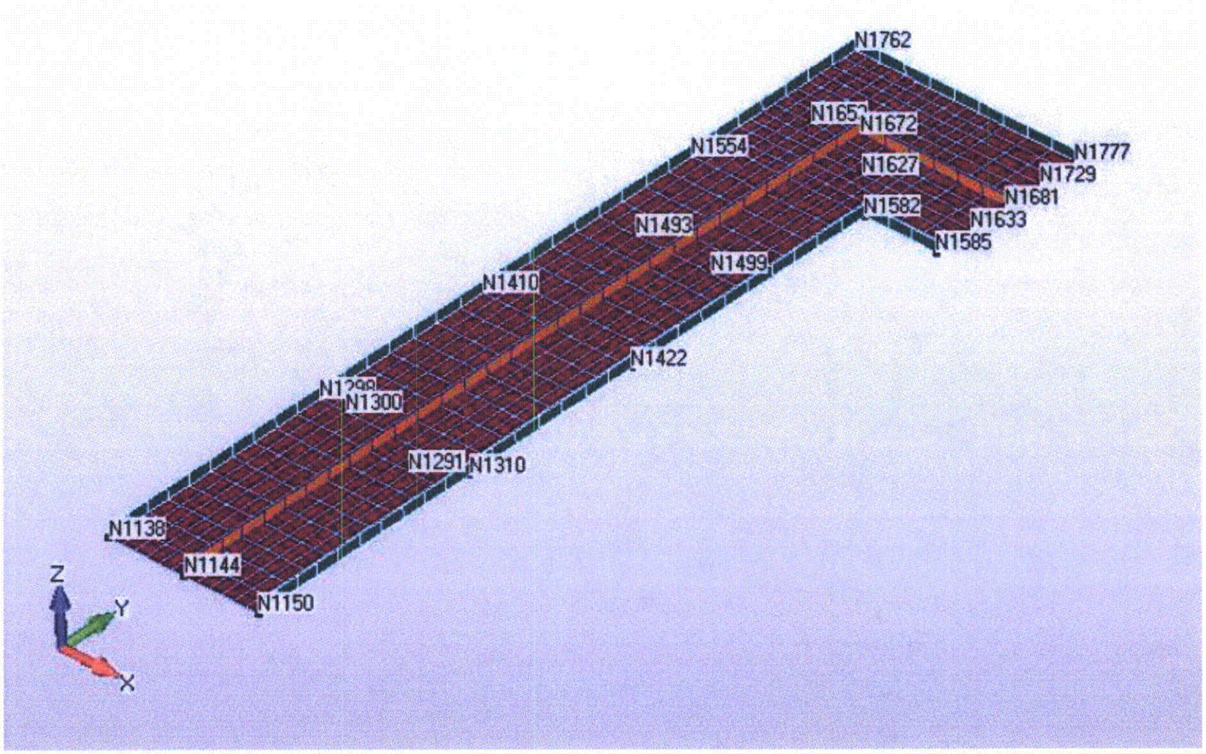


Figure 16 - Nodes used for ESWPT Segment 2 Base Slab ISRS (Relates to Figures 3LL-8, 1-2)

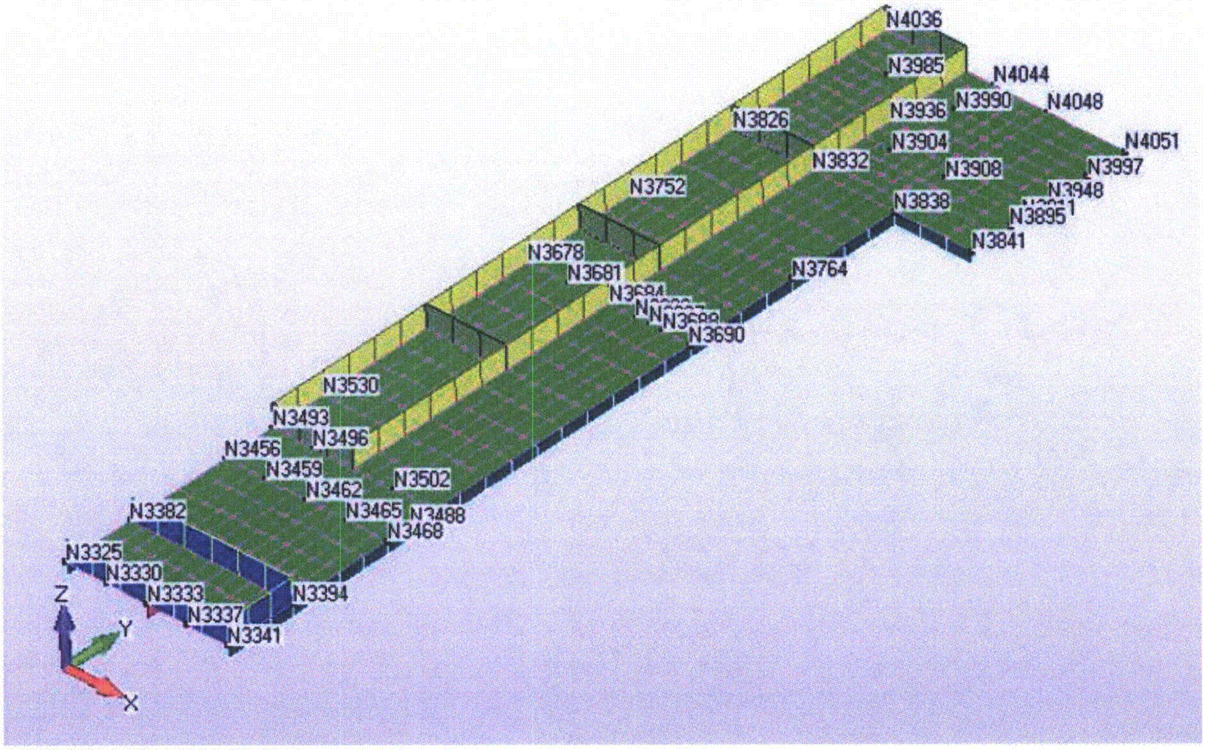


Figure 17 - Nodes used for ESWPT Segment 2 Roof Slab ISRS (Relates to Figures 3LL-8, 3-4)

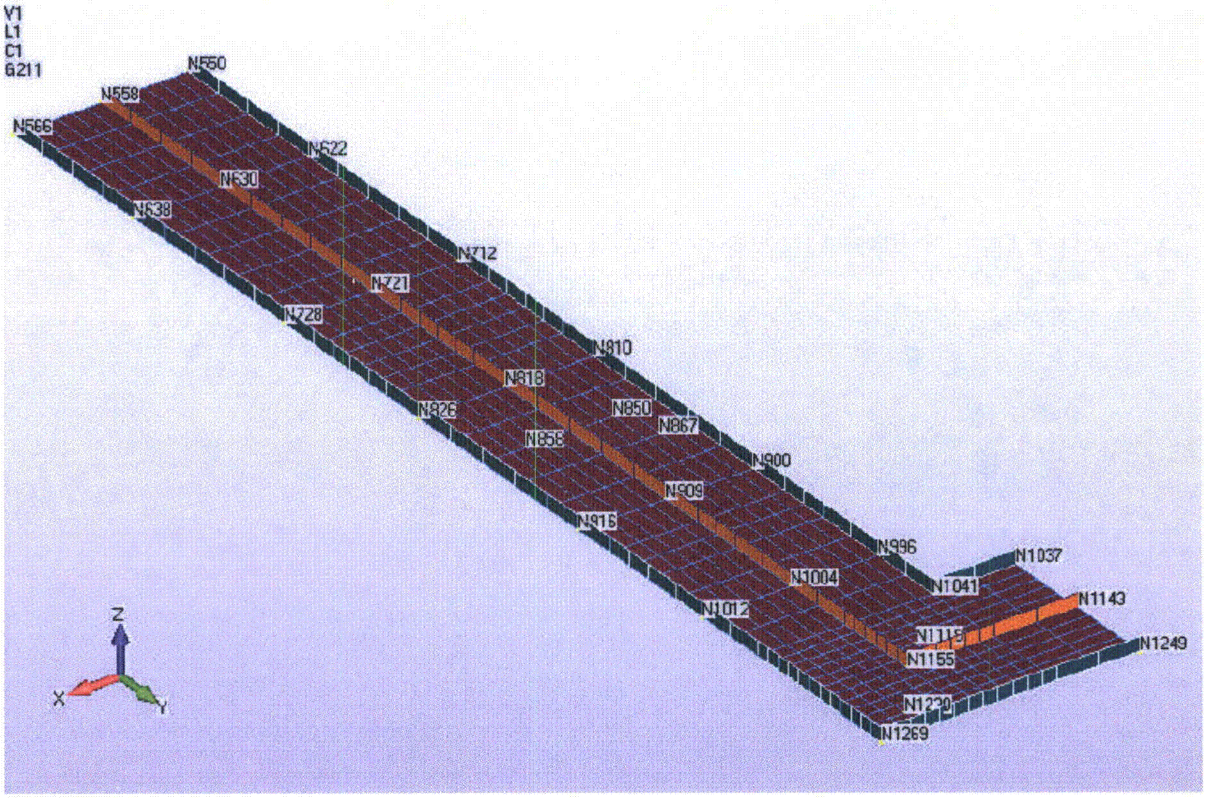


Figure 18 - Nodes used for ESWPT Segment 3 Base Slab ISRS (Relates to Figures 3LL-9, 1-3)

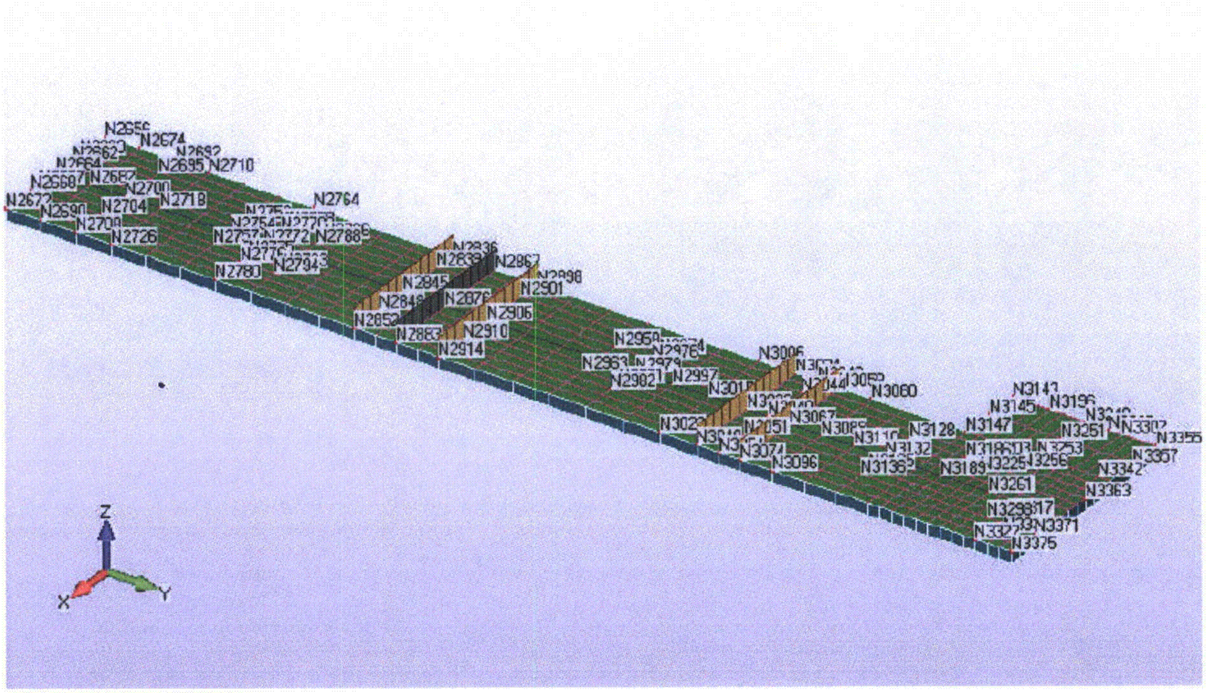


Figure 19 - Nodes used for ESWPT Segment 3 Base Slab ISRS (Relates to Figures 3LL-9, 4-6)

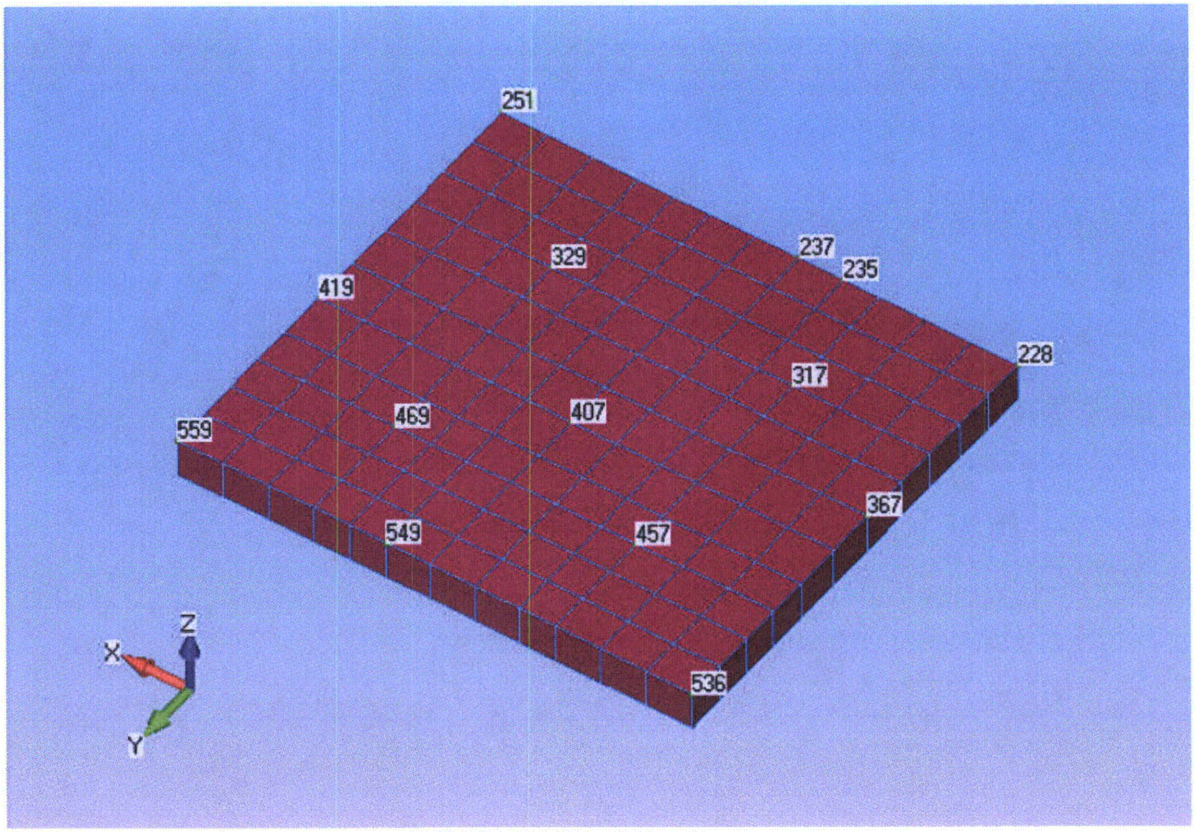


Figure 20 - Nodes used for PSFSV Base Slab ISRS (Relates to Figures 3MM-3, 1-3)

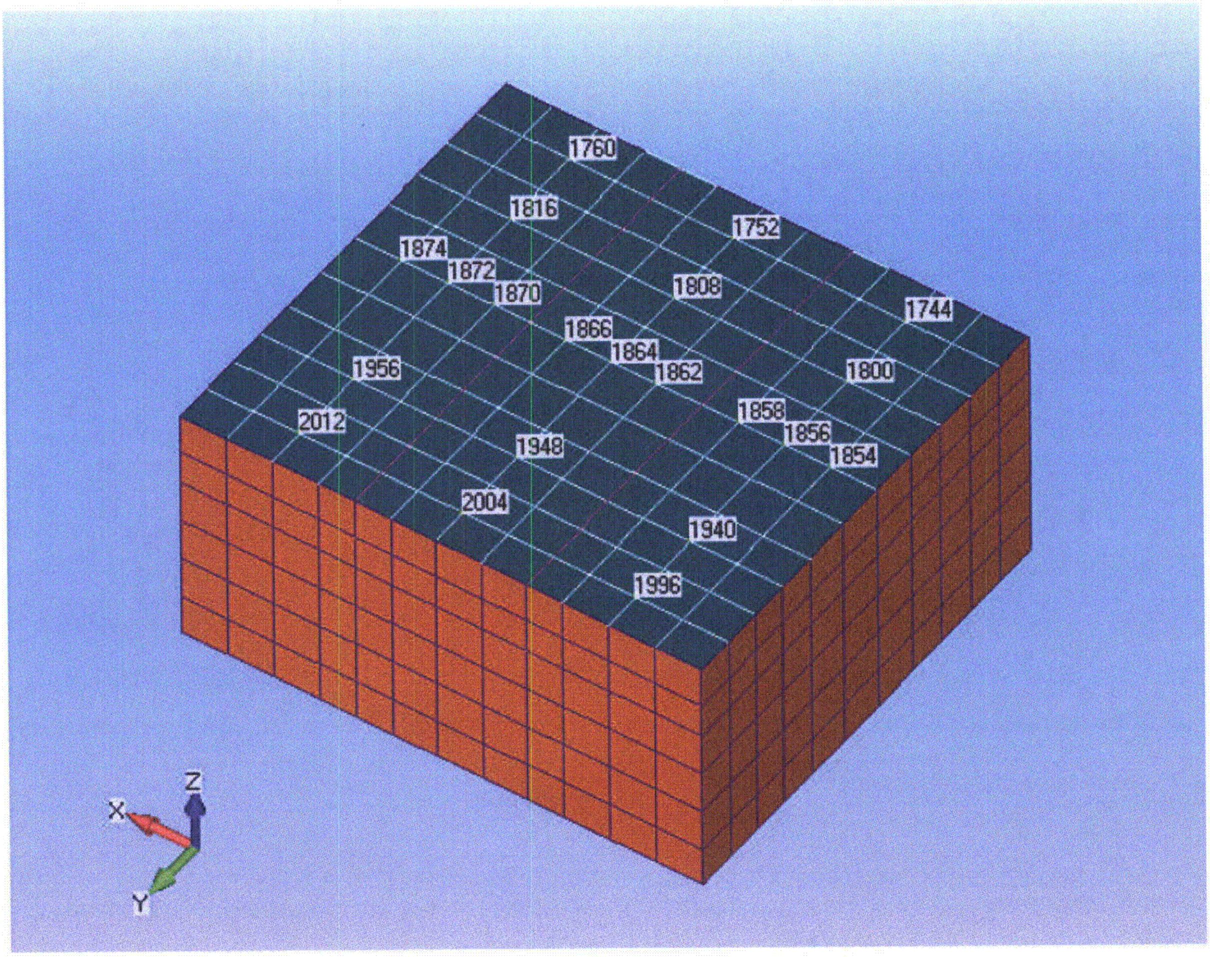


Figure 21 - Nodes used for PSFSV Roof Slab ISRS (Relates to Figures 3MM-3, 4-6)

7. The input motion used in the SASSI analyses of the ESWPT segments are time histories matching the site design response spectra as rock outcrop. Horizontal time histories were converted to in-layer rock motion for input into SASSI at the top of limestone. Because of the differences in soil profiles, the in-layer motion is different for each soil case resulting in the generation of eight horizontal time history files representing the two directions of motion for the four soil cases in addition to the outcrop motions. The response spectra for the horizontal time histories input motion are the same as that shown in the response to part 1 of this RAI Question. The vertical acceleration time history compatible to the vertical FIRS representing the vertical outcrop motion at the top of the limestone was used for all SSI analyses. The response spectra for the vertical time history input motion, representing outcrop motion, is shown in FSAR Figure 3.7-209. The acceleration response spectra of the outcrop motion envelops that of the in-layer motion, thus resulting in conservative results for the response of the structures due to vertical component of the input design motion. This motion was further discussed in response to RAI 2879 (CP RAI #60) Question 03.07.02-3 (ML093340447) and RAI 5317 (CP RAI #205) Question 03.07.01-7 (ML110800596).

Note 3 was provided in response to RAI 2879 (CP RAI #60) Question 03.07.02-12 (ML093340447) to clarify how the analyses were performed. The accelerations for Segments 1 and 2 were used as input to the design analysis to develop forces and a note to this effect was added to Table 3LL-6 and 3LL-8. Note 3 was added to 3LL-7 to indicate that a response spectra analysis was performed using the site-specific design response spectra.

The site-specific design response spectra are the same at the rock foundation level (top of limestone layer C in FSAR Table 2.5.2-227) for all seismic category I and II buildings at this site.

8. The response spectra analyses of ESWPT Segment 2 are performed without side soil support. The model is supported on base soil support springs as described in response to RAI 4542 (CP RAI #167) Question 03.08.04-80 (ML102240246).

9. As described in response to RAI 3006 (CP RAI #122) Question 03.08.04-40 (ML093500123) the fixed base model of Segment 1 of the ESWPT was performed for a mesh size confirmation with a fine and coarse mesh model. The surrounding soil is not included in the fixed base verification models. Further discussion of how the seismic demands were calculated for Segment 1 was provided in response to Question 03.08.04-40.

10. The first sentence in the third paragraph of FSAR Section 3LL.3 states "The forces and moments in Tables 3LL-9, 3LL-10, and 3LL-11 represent seismic demands produced from ANSYS seismic analyses." For clarification, the titles for Tables 3LL-9, 3LL-10, and 3LL-11 have been revised to indicate that the demands are produced from seismic analyses of the detailed ANSYS FE models.

11. This wording was identified in a previous review and modified for the current FSAR Rev. 2. For example:

    Section 3LL.3 now states: "The maximum absolute nodal accelerations obtained from the SASSI SSI analyses of the ESWPT models are presented in Tables 3LL-6 to 3LL-8."

    Section 3MM.3 now states: "The maximum absolute nodal accelerations obtained from the SASSI analyses of the PSFSV models are presented in Table 3MM-5."

    Please note that Tables 3LL-14, 3MM-8, 3KK-8, and 3.7.2-1R present summaries of the seismic analyses and the software programs used in these analyses.

12. The SASSI models contain soil elements on the sides of the tunnels to represent the backfill, and solids below the tunnels to represent the concrete fill. The analyses produced element stresses in these solid elements to represent bearing pressure and side soil pressure. These pressures are combined by SRSS for the three directions of input motion within each soil case and enveloped over all soil cases to produce the peak bearing pressures. The final result is reported in FSAR Table 3LL-13 for bearing pressures. The design side soil pressures were calculated based on a simplified elastic (Wood) method from ASCE 4-98 and are shown to exceed the SSI pressures. These pressures were applied as element pressures to the ANSYS design model. This information and additional information concerning soil pressures and their application to the design model was provided in response to RAI 2879 (CP RAI #60) Question 03.07.02-11 and Question 03.07.02-13 (ML093340449), RAI 2994 (CP RAI #108) Question 03.08.04-11 (ML093480149).

13. The development and application of accelerations and dynamic soil pressures is described in RAI 2879 (CP RAI #60) Question 03.07.02-11 (ML093340447) and reiterated below.

The SSI models were analyzed in SASSI with the applied input motion matching site-specific design response spectra. The SASSI model used OBE damping values for structural materials based on Table 2 of RG 1.61 to allow for spectra generation with no further study of damping in accordance with Section 1.2 of RG 1.61 "Special Consideration for In-Structure Response Spectra Generation". The SASSI analyses produce results including peak accelerations, in-structure response spectra, seismic element demands, and seismic soil pressures. All results from SSI analyses represent SRSS of three directions of input motion and the envelope of the soil conditions. The dynamic accelerations were calculated in SASSI at all nodal points and the envelope values are shown in Table 3LL-8.

For the seismic motion demand calculation of segments 1 and 3, an equivalent static lateral load was applied based on the peak accelerations calculated in SASSI. The accelerations applied are conservative relative to the peak accelerations calculated in SASSI as the envelope over all soil cases of peak nodal accelerations.

For all tunnel segments, seismic soil pressure was analyzed statically in ANSYS. The seismic soil pressure demands were applied on the structural elements as equivalent static pressures, where the applied pressure represents the peak seismic soil pressures. The pressures applied were shown to be conservative when compared to the calculated elastic solution used in ASCE 4-98 based on J.H. Wood, 1973 and the SASSI results.

Demands calculated from the equivalent static accelerations and soil pressure analyses performed in ANSYS for segment 3 were combined to produce the maximum demands in each direction. The maximum demands for each direction of motion and these directions were then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92).

14. Figure 22, Figure 23, and Figure 24 show SASSI transfer functions at selected nodes for the three directions of motion. Major modes from ANSYS are shown on the plot by vertical lines. The ANSYS mode shapes are also shown for each major mode. ANSYS un-damped major modes differ from SASSI damped major modes (based on the transfer function peaks) by less than 1% in the north-south and east west directions and by less than 5% for the first major modes in the vertical direction. Note that eigenvalue analyses in ANSYS compute un-damped natural frequencies, whereas ACS SASSI inherently considers damping in computation of transfer functions. This analysis demonstrates that the SASSI and ANSYS tank vault models are comparable.

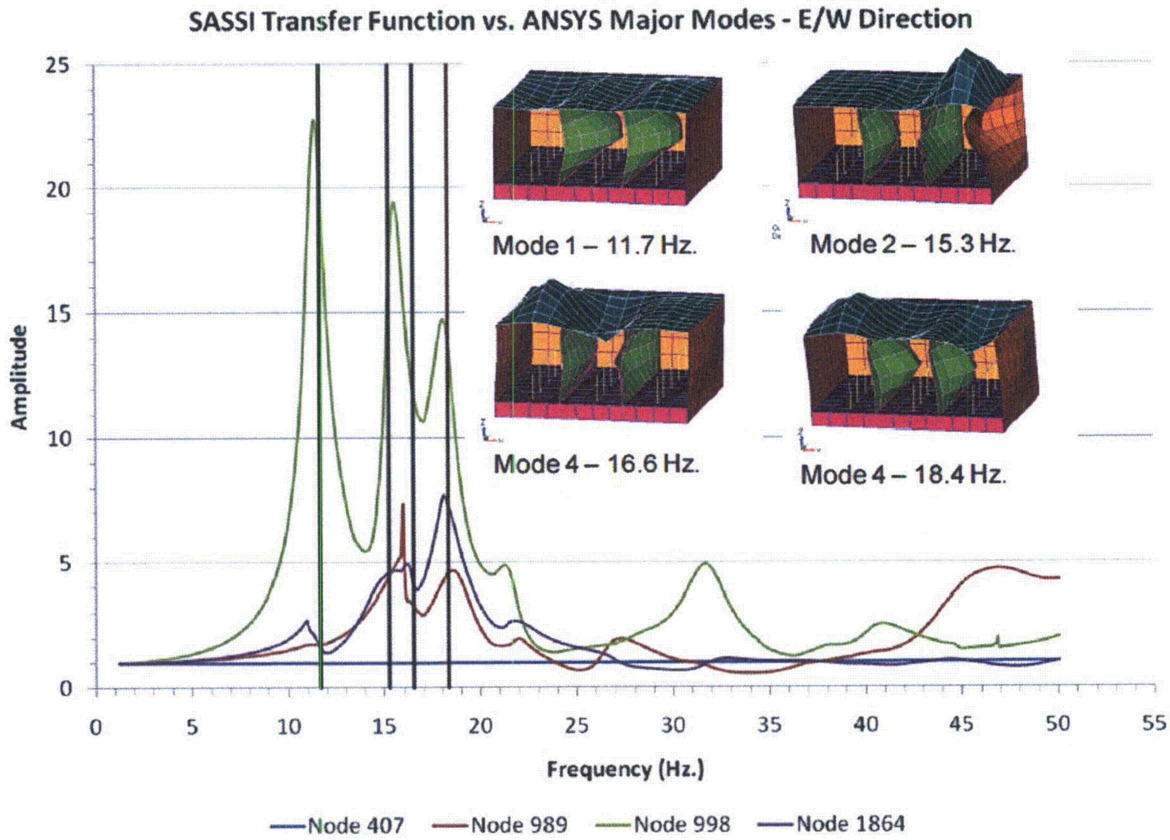


Figure 22 - Comparison of SASSI East-West Transfer Functions to ANSYS East-West Modal Frequencies (Vertical Black Lines)

Note: Node numbers refer to nodes in the SASSI model: Node 407 at the center of the base slab, Node 989 at the center of the east side wall, Node 998 at the center of an interior wall, Node 1864 at the center of the roof slab.

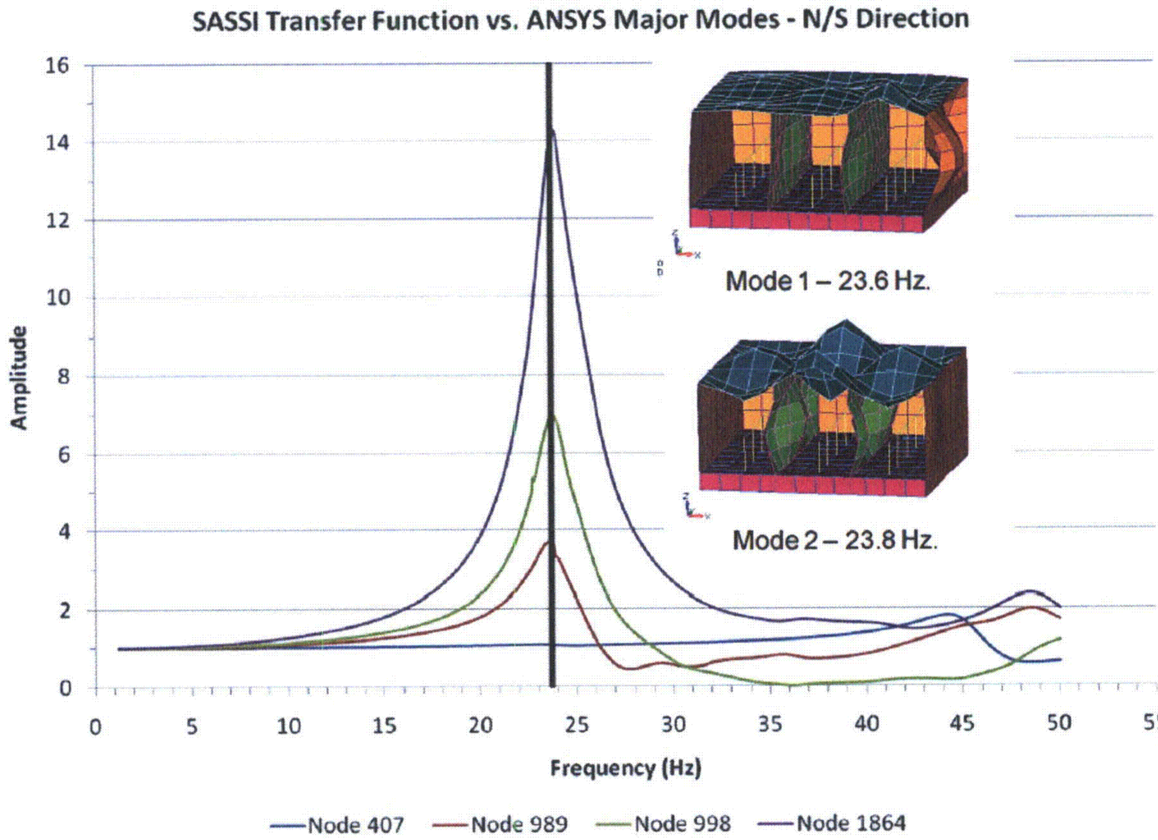


Figure 23 - Comparison of SASSI North-South Transfer Functions to ANSYS North-South Modal Frequencies (Vertical Black Lines)

Note: Node numbers refer to nodes in the SASSI model: Node 407 at the center of the base slab, Node 989 at the center of the east side wall, Node 998 at the center of an interior wall, Node 1864 at the center of the roof slab.

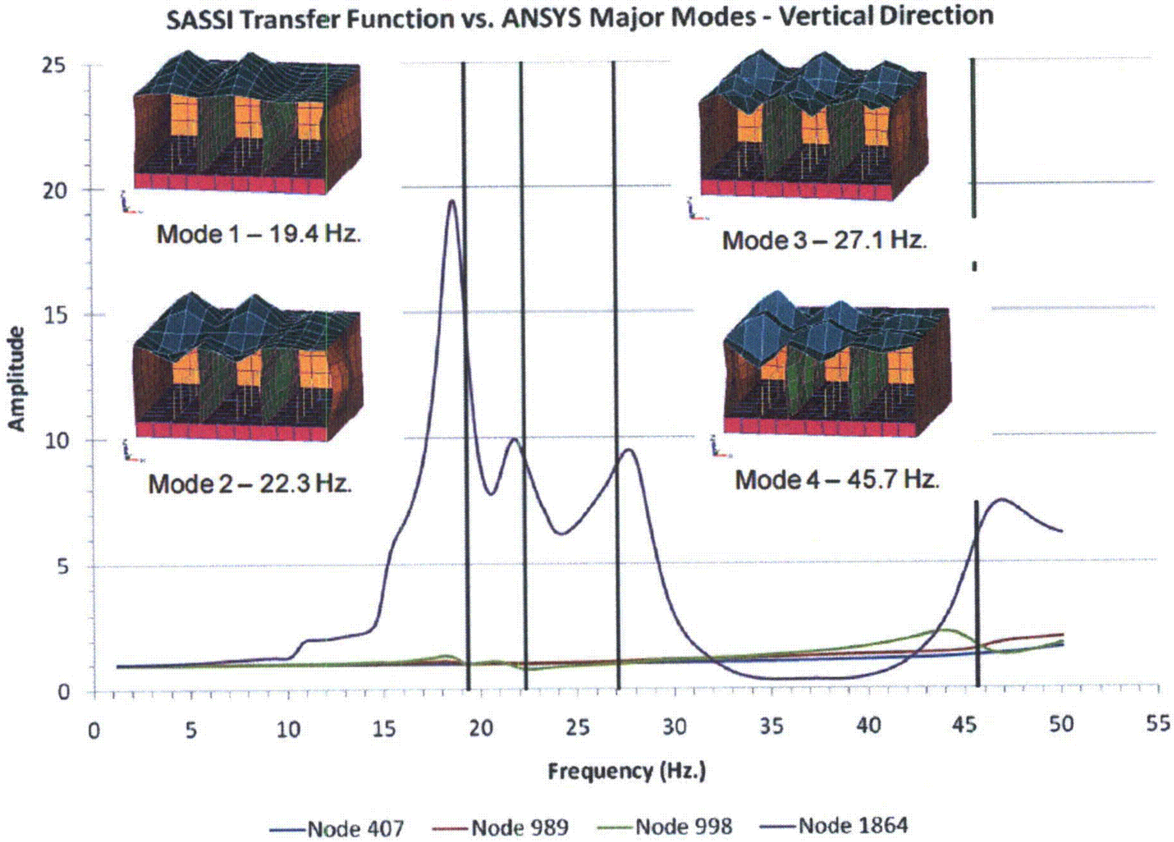


Figure 24 - Comparison of SASSI Vertical Transfer Functions to ANSYS Vertical Modal Frequencies (Vertical Black Lines)

Note: Node numbers refer to nodes in the SASSI model: Node 407 at the center of the base slab, Node 989 at the center of the east side wall, Node 998 at the center of an interior wall, Node 1864 at the center of the roof slab.

15. The coarse mesh model was used for comparison of ANSYS natural frequencies to SASSI transfer functions as shown in the response to part 14 above. As stated in Note 1 for Table 3MM-3, natural frequencies and effective masses were calculated in ANSYS using the same mesh as used for SASSI analyses. Table 3MM-3 has been updated to match the frequencies shown in the response to part 14.

16. The displacements are maximum relative displacements calculated in ANSYS for the design demands of inertia plus soil pressures. An explanatory note to this effect has been provided in Tables 3KK-6, 3LL-12, and 3MM-7.

17. The methods and approaches used in the site-specific SASSI analyses are generally consistent with guidance given ASCE 4-98, Sections 3.1 “Modeling of Structures”, 3.2 “Analysis of Structures”, and 3.3 “Soil-Structure Interaction Modeling Analysis”. The following examples are provided:

- ASCE 4-98 Section 3.1.1(a) states that the seismic response of a structure shall be determined by preparing a mathematical model of the structure and calculating the response of the model to the prescribed seismic input. This approach is consistent with the SASSI analyses performed and SRP 3.72.

- ASCE 4-98 Section 3.1.1(b) states that the hydrodynamic effects of any significant water mass interacting with the structure shall be considered in modeling the inertial characteristics. This guidance is followed in developing the seismic response of a structure shall be determined by preparing a mathematical model of the structure and calculating the response of the model to the prescribed seismic input. This approach is consistent with the hydrodynamic analyses performed, as described in the response to part 1 of Question 03.07.02-23 in this RAI and in Appendix 3KK of the FSAR, and is also consistent with SRP 3.7.2 and 3.7.3.

- ASCE 4-98 Section 3.1.1.2 describes a multistep method of seismic response analysis. The SASSI analyses performed are part of this process as described in the FSAR Appendices, consistent with guidance in SRP 3.7.2.

- ASCE 4-98 Section 3.2.4 describes the complex frequency response method as an acceptable analysis method. The SASSI analyses which are time history analyses in the frequency domain conform to this method.

- ASCE 4 Section 3.3.1.4 discusses modeling of nonlinear behavior of soil including "primary" and "secondary" nonlinearity very similarly to SRP 3.7.2, and both allow modeling of primary nonlinearity without requiring secondary nonlinearities. This is also consistent with the analyses performed.

- ASCE 4-98 Section 3.3.1.7 provides guidance on uncertainties in SSI analysis, recommending use of variation in shear modulus to address uncertainties. The guidance was met or exceeded in the selection of soil profiles covering the wide range of properties including lower bound, upper bound, and high bound. SRP 3.7.2 states in its "Specific Guidelines for SSI Analysis" that "Enough SSI analyses should be performed so as to account for the effects of the potential variability in the properties of the soils and rock at the site. At least three soil/rock profiles should be considered in these analyses, namely, a best estimate (BE) profile, a lower bound (LB) and an upper bound (UB) profile". Further description in the same section defines the application of the variation including limitations on the minimum coefficient of variation identically to that in ASCE 4-98.

The statement in Appendices 3KK, 3LL, 3MM and 3NN that "the site-specific SASSI analyses are conducted using methods and approaches consistent with ASCE 4-98" was a general statement intended to cover methods and approaches such as the ones cited in the above examples. Since ASCE 4-98 is specifically cited in several locations in the FSAR where it is used, and since the SASSI analyses also conform to applicable guidance in the SRP as documented in FSAR Table 1.9-206 and in the FSAR Appendices 3KK, 3LL, 3MM, and 3NN, the general statement has been deleted from Appendices 3KK, 3LL, 3MM, and 3NN.

18. The site-specific SSI qualification of the R/B-PCCV-CIS structure identified in the DCD (R3) as the R/B Complex will be re-run based on the detailed three-dimensional distributed-mass model of the R/B Complex. This will assure consistent geometry among the standard plant and site-specific SASSI models. Please refer to the response to Item 11 of Question 03.07.02-23 in this RAI which addresses the same subject. For a "road map" of other anticipated changes, a

supplemental response to RAI 5947 Question 03.07.02-22 (CP RAI #221) is scheduled to be issued in November 2011.

19. As described in the supplemental response to DCD RAI 542-4262 and associated markups (ML11188A250, ML11188A251, ML11188A252), the site-specific SSI qualification of the R/B-PCCV-CIS structure identified in the DCD (R3) as the R/B Complex will be re-run based on the detailed three-dimensional distributed-mass model of the R/B Complex coupled with the lumped mass stick model of the RCL. The detailed three-dimensional distributed-mass model will serve as the design basis, although the lumped mass stick models will be utilized in some studies supporting the design basis, as described in MHI Technical Reports MUAP-11006 Revision 0 and MUAP-11007, Revision 0. Accordingly, the strategy is to update the FSAR for results from the updated DCD (including Appendix 3H, which is incorporated in the FSAR by reference to the DCD) and from subsequent technical reports supporting the DCD. A "road map" for the strategy for incorporating the results from the subsequent technical reports supporting the DCD into the FSAR will be included in a supplemental response to RAI 5947 Question 03.07.02-22 (CP RAI #221) which is scheduled to be issued in November 2011.

20. The site-specific UHSRS structure was also analyzed with the best estimate soil condition including with full soil separation and without soil separation (embedded condition). The full soil separation condition in these layers was shown to produce larger accelerations to compute soil pressures and amplified response spectra. Soil pressures calculated in these layers show that very little pressure is transferred in these layers and the response will not be significantly influenced by the small pressures. Therefore, subsequent analyses with LB, UB, and HB soil cases were conservatively performed only using full soil separation even though only partial soil separation can actually occur to produce the bounding maximum response. Sensitivity studies were also performed by approximate method for the UHSRS to evaluate a partially separated soil condition which results in lower pressure at the top of the wall in the separated region but increases the pressure for the lower part of the wall that remains in contact with the soil. The potential for partial separation of backfill is determined by comparing the peak envelope soil pressure results for the best estimate (BE) case to the at-rest soil pressure along the height of wall. The partial separation soil condition was found to control under certain circumstances for the cantilever wall configuration at mid-side of the UHSRS and included in the bounding process.

    As mentioned in FSAR Subsection 3.7.2.4, the seismic design of the R/B-PCCV-CIS (otherwise identified as the R/B Complex) does not rely on the backfill present on the sides of the building to derive lateral or structural support. The designs of the exterior walls of the building basements consider the earth pressures generated by the design earthquake. The R/B Complex has backfill only along most of two of its sides that share a common corner because the other side surfaces are adjacent to other structures. See the response to DCD RAI 660-5134 Question 03.07.02-53 (ML110040071) for sensitivity studies performed to evaluate the R/B Complex for the potential of embedment effects considering various backfill conditions. The embedment effect produced only minor seismic response ISRS variations when compared to the corresponding seismic response obtained assuming a surface-supported structure condition.

    The standard plant R/B Complex SASSI models described in the DCD represent surface mounted conditions that are similar to the full separation of backfill condition. In addition, it was previously shown for other structures that the separation of backfill condition produced the bounding maximum responses for the site-specific qualification of the standard plant R/B Complex. Thus it was not necessary to repeat the separation of backfill condition comparable to the surface mounted condition already performed for the standard plant analysis.

    SASSI is a linear computer code, so non linear effects, such as progressing separation of the soil from the wall or sliding of the soil along the wall, cannot be included. While the soil pressure and moment for the cantilevering mid side wall of the UHSRS is larger for the partially separated soil condition of the UHSRS than that of a fully separated condition, this is not true for the R/B-PCCV-CIS vertical wall spans supported at both their top and bottom. Regarding soil partial separation and slippage, there is generally a significant tendency for soil partial separation and slippage at the wall interface over the upper portion of the foundation but not the lower portion of the wall (see SMiRT 18-K06-6, Reference 1 below). The embedment depth of the R/B has two upper floors bracing the exterior walls that extend below grade. The lower wall spanning vertically from mat to floor is subject to greater pressure than the wall spanning vertically above the floor. Because the lower wall span below the floor also is significantly greater than the wall span above the floor, the lower wall will have a larger moment due to soil pressure even though it has no separation or slippage. Because the outer wall reinforcement is constant for the two vertical spans, the lower span controls the exterior wall design of the R/B. Consequently, no further evaluation of partial separation or slippage of the R/B exterior walls is necessary. Therefore, since it remains to investigate the effect of non-symmetry of embedment location of boundaries in the site specific SSI evaluation of the R/B Complex, only the without separation condition (actual embedded condition on two sides) was further considered as appropriate to comply with DCD Subsection 3.7.2.4.1 and DCD COL Item 3.7(25).

Reference

1. SMiRT 18-K06-6, Evalutation of Seismic Induced Wall Pressures for Deeply Embedded NPP Structures, SMiRT 18, Beijing, China, August 7-12, 2005

Impact on R-COLA

See attached mark-up of FSAR Revision-2, pages 3KK-2, 3KK-16, 3LL-2, 3LL-16, 3LL-17, 3LL-18, 3LL-19, 3MM-3, 3MM-10, 3MM-14, 3NN-1, and 3NN-9.

Impact on S-COLA

None; the response is site-specific.

Impact on DCD

None.

equipment and impulsive hydrodynamic fluid masses, and springs and mass for elements for convective hydrodynamic fluid. This model consists of approximately 29,000 shell elements, 1600 beam elements, and 57,000 nodes. The SASSI SSI Model is the model used for soil structure interaction analyses, and consists of the same makeup of elements and masses but uses a less refined mesh to reduce the analysis time.

The UHSRS model ~~is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3KK-3), and accounting~~accounts for the site-specific stratigraphy and subgrade conditions described in Subsection 2.5.4, as well as the backfill conditions around the embedded UHSRS. The four UHSRS (per unit) are nearly identical with minor variations on backfill layout for the east and west walls. The essential service water pipe tunnel (ESWPT) is present along the full length on the south side of the UHSRS and the two structures are separated by an isolation joint. Backfill is present on the north and west sides of UHSRS B and D, and on the north and east sides of UHSRS A and C. Since the structures are otherwise identical, SSI analysis is performed only on UHSRS B/D, and the responses are deemed applicable to the other UHSRS. SSI analyses including adjacent structures was not performed because: (1) the structures are separated by an isolation joint and not directly connected and (2) the in-structure response spectra calculated in SASSI at the base slab of the UHSRS is nearly the same as the design input response spectra indicating that the SSI effects are small. RCOL2_03.07.02-24

The input within-layer motion and strain-compatible backfill properties for the SASSI analysis are developed from site response analyses described in Section 3NN.2 of Appendix 3NN by using the site-specific foundation input response spectra (FIRS) discussed in Subsection 3.7.1.1. The properties of the supporting media (rock) as well as the site-specific strain-compatible backfill properties used for the SASSI analysis of the UHSRS are the same as those presented in Appendix 3NN for the reactor building (R/B)-prestressed concrete containment vessel (PCCV)-containment internal structure SASSI analyses. To account for uncertainty in the site-specific properties (as described in Appendix 3NN), three profiles of subgrade properties are considered, including best estimate (BE), lower bound (LB), and upper bound (UB). For backfill, an additional high bound (HB) profile is also used together with the UB subgrade profile to account for expected uncertainty in the backfill properties.

The following SSI analyses and site profiles are used for calculating seismic responses of UHSRS:

- a surface foundation condition (without the presence of backfill) with the lower bound in-situ soil properties below the base slab (lower bound case)
- an embedded foundation without separation of the backfill from the UHSRS exterior walls for the best estimate case

Table 3KK-6

Maximum Displacements for All Enveloped Conditions at Key UHSRS Locations(1)(3)

RCOL2_03.07.02-24

Component	Maximum Displacement (inches)	Description
UHSRS South Wall	0.09	Maximum north-south displacement adjacent to ESWPT
Cooling Tower Roof Slab	0.24	Maximum horizontal displacement
Pump Room Elevated Slab	0.08	Maximum vertical (out-of-plane) displacement
Pump Room Roof Slab	0.11	Maximum horizontal displacement
Air Intake Missile Shield Top Slab	0.13	Maximum horizontal displacement
Basin Exterior Wall	0.61	Maximum out-of-plane displacement(2)
Basin Exterior Wall Top Corner	0.06	Maximum horizontal displacement at northeast and northwest corners

Notes:

1) Displacements include base flexibility, average horizontal displacements at the base slab is 0.013 inches
2) Occurs at approximately mid-span of the west basin north wall
3) The displacements are maximum relative displacements calculated in ANSYS. RCOL2_03.07.02-24

elements model the backfill and fill concrete below the ESWPT basemat. Where the shell elements and brick elements are connected, the shell element is connected to overlap the face of the brick elements. There are no locations in the models where shell elements are connected perpendicularly to the brick elements with the intention of transferring moment through nodal rotational degrees of freedom.

The input motion for the SASSI model analysis is developed using the site-specific foundation input response spectra (FIRS) discussed in Subsection 3.7.1.1 and is applied at the top of the limestone (bottom of the backfill) in the far field. The earthquake input motion for SASSI is developed by converting the outcrop motion of the FIRS to within-layer motion. Site-specific strain-compatible backfill and rock properties are used in determining the within-layer motion. This process is described further in Appendix 3NN.

The ESWPT model ~~is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3LL-3) and accounting~~accounts for the site-specific stratigraphy and subgrade conditions described in Subsection 2.5.4, as well as the backfill conditions around the embedded portions of the ESWPT. RCOL2_03.07.02-24

The input within-layer motion and strain-compatible backfill properties for the SASSI analysis are developed from site response analyses described in Section 3NN.2 of Appendix 3NN by using the site-specific foundation input response spectra (FIRS) discussed in Subsection 3.7.1.1. The properties of the supporting media (rock) as well as the site-specific strain-compatible backfill properties used for the SASSI analysis of the ESWPT are the same as those presented in Appendix 3NN for the reactor building (R/B)-prestressed concrete containment vessel (PCCV)-containment internal structure SASSI analyses. The typical properties for a granular engineered backfill are adopted as the best estimate (BE) values for the dynamic properties of the backfill. Four profiles, lower bound (LB), BE, upper bound (UB), and high bound (HB) of input backfill properties are developed for the SASSI analyses considering the different coefficient of variation. The LB and BE backfill profiles are combined with corresponding LB and BE rock subgrade profiles, and the UB and HB backfill profiles are combined with the UB rock subgrade profile. Four sets of SASSI analyses are performed on each segment of the ESWPT embedded in backfill with BE, LB, UB, and HB properties. Table 3LL-16 provides SSI analysis cases for ESWPT Segments 1 and 3.

ESWPT Segment 2 is additionally analyzed considering partial separation for all four soil property cases of the backfill from the exterior shielding walls above the roof slab. Separation is modeled by reducing the shear wave velocity by a factor of 10 for those layers of backfill that are determined to be separated. The potential for separation of the backfill along Segment 2 is determined by comparing peak soil pressure results for the BE condition to the at-rest soil pressure. The analyses also consider unbalanced fill conditions where applicable, such as for Segment 2 of the ESWPT along the interface with the UHSRS. Consideration of these conditions assures that the enveloped results presented herein capture all potential seismic effects of a wide range of backfill properties and conditions in

Table 3LL-9

ESWPT Segment Detailed ANSYS 1 FE Model Maximum Component Seismic Forces and Moments

RCOL2_03.07.02-24

Component		Maximum component forces and moments							
		N_V (k/ft)	N_L (k/ft)	Q_V (k/ft)	Q_L (k/ft)	In-plane Shear (k/ft)	M_V (k-ft/ft)	M_L (k-ft/ft)	M_{VL} (k-ft/ft)
Base Slab	+	4.75	2.38	8.83	1.77	1.07	32.60	5.56	1.00
	-	7.86	2.87	8.83	1.77	1.07	39.40	6.70	1.00
Roof Slab	+	0.33	1.06	4.22	2.15	0.83	22.60	0.72	0.72
	-	4.19	1.42	4.22	2.15	0.83	29.00	4.90	0.72
Interior Walls	+	5.57	0.79	1.91	1.08	0.58	9.55	1.62	0.29
	-	4.89	0.66	1.91	1.08	0.63	9.55	1.62	0.29
Exterior Walls	+	7.91	1.28	7.68	2.09	2.14	36.61	6.19	1.01
	-	8.57	1.17	7.68	2.09	2.14	36.61	6.19	1.01

Notes:

1) The forces and moments shown above include forces and moments due to seismic soil pressure that envelope all four subgrade shear wave velocity conditions (LB, BE, UB, and HB). The forces and moments are used for structural design as described in Section 3.8.
2) The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100%-40%-40% method.
3) In the table above the vertical and longitudinal directions define the plane of the walls. N stands for axial force, Q for out-of-plane shear and M for moment. The M_V results in normal stresses in the vertical direction of the wall and similarly, M_L results in normal stresses in the longitudinal (horizontal) direction of the wall, and M_{VL} is the torsional moment on the wall. The Q_V is out-of-plane shear force acting on horizontal cross section of the wall, and Q_L is out-of-plane shear force acting on a vertical cross section of the wall. For the roof slab and base slab the vertical axis is oriented along the east-west direction and the longitudinal along the north-south direction.

Table 3LL-10

ESWPT Segment 2 Detailed ANSYS FE Model Maximum Component Seismic Forces and Moments

RCOL2_03.07.02-24

Component		Maximum component forces and moments							
		N_V (k/ft)	N_L (k/ft)	Q_V (k/ft)	Q_L (k/ft)	In-plane Shear (k/ft)	M_V (k-ft/ft)	M_L (k-ft/ft)	M_{VL} (k-ft/ft)
Base Slab	+/-	44.99	29.32	93.44	25.14	31.03	128.74	31.82	21.56
Roof Slab	+/-	85.48	31.38	39.62	22.41	62.82	88.21	51.33	14.78
Interior Walls	+/-	58.08	141.34	12.03	4.23	62.54	22.46	7.20	2.00
Exterior Walls	+/-	76.65	216.05	47.54	24.29	76.22	142.71	30.27	17.35
Pump House Pipe Missile Shield Walls	+/-	69.99	34.46	22.68	9.29	42.20	40.75	10.93	4.64
Pump House Pipe Missile Shield Roof	+/-	1.77	24.75	1.93	3.82	7.56	7.63	10.63	4.35
Air Intake Missile Shield	+/-	46.51	18.70	18.10	9.81	23.18	31.91	14.45	6.49

Notes:

1) The forces and moments shown above include forces and moments due to seismic soil pressure that envelope all four subgrade shear wave velocity conditions (LB, BE, UB, and HB). The forces and moments are used for structural design as described in Section 3.8.
2) The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100%-40%-40% method. For Segment 2 a response spectra analysis was performed and combined with the absolute value of dynamic soil pressure. The demands obtained from this combination were found to envelope the SASSI demands.
3) In the table above the vertical and longitudinal directions define the plane of the walls. N stands for axial force, Q for out-of-plane shear and M for moment. The M_V results in normal stresses in the vertical direction of the wall and similarly, M_L results in normal stresses in the longitudinal (horizontal) direction of the wall, and M_{VL} is the torsional moment on the wall. The Q_V is out-of-plane shear force acting on horizontal cross section of the wall, and Q_L is out-of-plane shear force acting on a vertical cross section of the wall. For the roof slab and base slab the vertical axis is oriented along the north-south direction and the longitudinal in the east-west direction.

Table 3LL-11

ESWPT Segment 3 Detailed ANSYS FE Model Maximum Component Seismic Forces and Moments

RCOL2_03.07.02-24

Component		Maximum component forces and moments							
		N_V (k/ft)	N_L (k/ft)	Q_V (k/ft)	Q_L (k/ft)	In-plane Shear (k/ft)	M_V (k-ft/ft)	M_L (k-ft/ft)	M_{VL} (k-ft/ft)
Base Slab	+	29.25	26.53	58.48	21.90	25.42	54.31	23.73	15.30
	-	31.50	29.59	56.36	24.43	25.52	53.70	21.08	15.78
Roof Slab	+	32.24	59.80	22.30	19.00	35.79	46.43	25.12	7.47
	-	37.42	61.68	22.42	19.00	36.54	46.57	28.26	7.19
Interior Walls	+	59.24	93.26	12.02	4.27	36.67	18.08	5.62	1.94
	-	53.12	98.64	11.12	3.92	38.67	18.21	5.76	1.88
Exterior Walls	+	30.48	95.00	20.16	15.99	45.89	66.74	69.98	11.48
	-	31.06	98.80	19.29	16.49	46.23	65.90	67.39	11.48
PSFSV Service Tunnel Walls	+	32.95	10.05	12.16	5.94	19.81	40.35	8.50	3.64
	-	32.62	10.21	13.76	5.70	19.47	39.74	7.82	3.78
PSFSV Service Tunnel Roof	+	10.79	6.21	8.69	20.78	4.28	12.17	21.25	2.21
	-	11.80	6.56	8.63	20.69	4.44	16.00	20.98	2.17

Notes:

1) The forces and moments shown above include forces and moments due to seismic soil pressure that envelope all four subgrade shear wave velocity conditions (LB, BE, UB, and HB). The forces and moments are used for structural design as described in Section 3.8.
2) The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100%-40%-40% method.
3) In the table above the vertical and longitudinal directions define the plane of the walls. N stands for axial force, Q for out-of-plane shear and M for moment. The M_V results in normal stresses in the vertical direction of the wall and similarly, M_L results in normal stresses in the longitudinal (horizontal) direction of the wall, and M_{VL} is the torsional moment on the wall. The Q_V is out-of-plane shear force acting on horizontal cross section of the wall, and Q_L is out-of-plane shear force acting on a vertical cross section of the wall. For the roof slab and base slab the vertical axis is oriented along the north-south direction and the longitudinal in the east-west direction.

Table 3LL-12

ESWPT Maximum Seismic Displacements for All Enveloped Conditions(3)

RCOL2_03.07.02-24

ESWPT Segment	Longitudinal Direction (in)	Transverse (in)	Vertical (in)
1	0.002	0.11	0.003
2	0.09(1)	0.18	0.05(2)
3	0.10(1)	0.19	0.01

Notes:

1) The reported displacement are the north-south displacement at edge of separation joints that is about 10 ft south or north of north or south tunnels respectively. The maximum longitudinal (east-west) displacement of the east-west part of Segment 2 or 3 tunnel is less than 0.002 inches.
2) The maximum vertical occurs at the edge of separation joint edge 10 ft south of the east-west part of the tunnel, which is due to rocking behavior of the tunnel with tall shielding walls.
3) The displacements are maximum relative displacements calculated in ANSYS. RCOL2_03.07.02-24

The above approach is conservative because slab flexural cracking results in a lower frequency which is closer to the input spectra peak and produces higher design demands. Also, flexural cracking of the slabs does not change the primary load paths for the overall structure and has negligible effect on dynamic load distribution and response.

The analysis of the PSFSV produces 50 modes below 45 Hz. The natural frequencies and descriptions of the associated modal responses of the fixed-base model are presented in Table 3MM-3 for the PSFSV and these frequencies are compared to structural frequencies calculated from the transfer functions of the SASSI model.

The PSFSV model ~~is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3MM-3) and accounting~~accounts for the site-specific stratigraphy and subgrade conditions described in Subsection 2.5.4, as well as the backfill conditions around the embedded PSFSVs. The PSFSV structure is modeled using three orthogonal axes: a y-axis pointing south, an x-axis pointing west, and a z-axis pointing up. The east and west PSFSVs are nearly symmetric; backfill is present on the south and east sides of the east vault and on the south and west sides of the west vault. Due to symmetry, SSI analysis is performed only on the east vault, and the responses are deemed applicable to the west vault. RCOL2_03.07.02-24

The input within-layer motion and strain-compatible backfill properties for the SASSI analysis are developed from site response analyses described in Section 3NN.2 of Appendix 3NN by using the site-specific foundation input response spectra (FIRS) discussed in Subsection 3.7.1.1. The properties of the supporting media (rock) as well as the site-specific strain-compatible backfill properties used for the SASSI analysis of the PSFSVs are the same as those presented in Appendix 3NN for the R/B-PCCV-containment internal structure SASSI analyses. To account for uncertainty in the site-specific properties, several sets of dynamic properties of the rock and the backfill are considered, including best estimate (BE), lower bound (LB), and upper bound (UB) properties. For backfill, an additional high bound (HB) set of properties is also used to account for expected uncertainty in the backfill properties.

The above four sets of soil dynamic properties are applied for analysis of the PSFSV structure considering full embedment within the backfill and partial separation of the backfill. An additional case representing a surface foundation condition using lower bound in-situ soil properties beneath the base slab without presence of any backfill is included. The backfill separation is modeled by reducing the shear wave velocity by a factor of 10 for all soil elements adjacent to the structure within the separation depth. The factor of 10 on shear wave velocity represents a factor of 100 on soil shear modulus and Young's modulus. This value is considered adequate to reduce soil pressures sufficiently to represent soil separation. Soil pressures calculated in these layers show that very little pressure is transferred in these layers and the response is not significantly influenced by the small pressures. The potential for separation of backfill is determined by

Table 3MM-3

SASSI FE Model Natural Frequencies[1]

Frequency (Hz)	Comments
~~12.7~~11.7	East-west response, interior walls out-of plane
~~15.5~~15.3	East-west response, exterior walls out-of plane
~~18.3~~18.4	East-west response, walls in plane
~~18.9~~19.4	Vertical response, roof slab
~~23.7~~23.6	North-south response, overall structure

RCOL2_03.07.02-24

Notes:

1) Natural frequencies and effective masses were calculated in ANSYS using the same mesh as used for SASSI analyses.

Table 3MM-7

PSFSV Maximum Displacements for All Enveloped Conditions(1)

RCOL2_03.07.02-24

Component	Maximum Displacement (inches)	Description
Roof slab	0.05	Horizontal displacement equivalent to story drift; occurs at edge of slab near center of wall
East exterior wall	0.07	Horizontal (out-of-plane) displacement near center of wall
West exterior wall	0.05	Horizontal (out-of-plane) displacement near center of wall

Notes:

1) The displacements are maximum relative displacements calculated in ANSYS.

RCOL2_03.07.02-24

3NN MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR R/B-PCCV-CONTAINMENT INTERNAL STRUCTURE

3NN.1 Introduction

This Appendix documents the SASSI site-specific analysis of the US-APWR prestressed concrete containment vessel (PCCV), containment internal structure, and reactor building (R/B) including the fuel handling area (FH/A) of Comanche Peak Nuclear Power Plant Units 3 and 4.

As stated in Subsection 3.7.2.4.1, site-specific soil-structure interaction (SSI) analyses are performed to validate the US-APWR standard plant seismic design, and to confirm that site-specific SSI effects are enveloped by the lumped parameter SSI analysis described in Subsection 3.7.2.4. The SASSI computer program (Reference 3NN-1) serves as a computational platform for the site-specific SSI analysis. SASSI is used to model the overall stiffness and mass inertia properties of the R/B-PCCV-containment internal structure and the following SSI site-specific effects:

- Layering of the rock subgrade.
- Foundation flexibility.
- Embedment of the foundation and layering of backfill material.
- Scattering of the input control design motion.

The SASSI program provides a frequency domain solution of the SSI model response based on the complex response method and finite element (FE) modeling technique. The SASSI analyses of the US-APWR standard plant employ the subtraction method of sub-structuring to capture the above-listed SSI effects. Due to the low seismic response at the Comanche Peak site and lack of high-frequency exceedances, the spatial variation of the input ground motion is deemed not significant. Therefore, the SASSI analyses do not consider incoherence of the input control motion.

~~The SASSI site-specific analyses are conducted using methods and approaches consistent with ASCE 4 (Reference 3NN-2).~~ This Appendix documents the SASSI analysis of the R/B-PCCV-containment internal structure and demonstrates that the in-structure response spectra (ISRS) developed from the SASSI analysis results are enveloped by the standard plant seismic design. RCOL2_03.07.02-24

3NN.2 Seismological and Geotechnical Considerations

The R/B-PCCV-containment internal structure of Units 3 and 4 will be constructed on a rock subgrade by removing the native soil above the top of the limestone layer with shear wave velocity exceeding 5000 fps that is located at nominal elevation of 782 ft. A thin layer of fill concrete will be placed on the top of the

3NN-2 ~~*Seismic Analysis of Safety-Related Nuclear Structures*, American Society of Civil Engineers, ASCE 4-98, Reston, Virginia, 2000.~~Deleted RCOL2_03.07.02-24

3NN-3 *Combining Responses and Spatial Components in Seismic Response Analysis*, Regulatory Guide 1.92, Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, July 2006.

3NN-4 *Damping Values for Seismic Design of Nuclear Power Plants*, Regulatory Guide 1.61, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Comanche Peak, Units 3 and 4

Luminant Generation Company LLC

Docket Nos. 52-034 and 52-035

RAI NO.: 5947 (CP RAI #226)

SRP SECTION: 03.07.02 - Seismic System Analysis

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

DATE OF RAI ISSUE: 8/22/2011

QUESTION NO.: 03.07.02-25

This question is a follow-up to RAI Letter Number 60 (2789), Question 03.07.02-2.

In the response to RAI 3.7.2-2, the applicant stated the following: "Two site response analyses were performed for each of the four profiles using the two horizontal acceleration time histories compatible to the horizontal spectra of the input design ground motion. The input design ground motion matches the Regulatory Guide 1.60 minimum spectra anchored to 0.1g peak acceleration and envelopes the site-specific FIRS spectra."

The above statement is inconsistent with the statement in CP COL 3.7(6) of the FSAR which states that "The FIRS are compared to the minimum design earthquake which is defined as the certified seismic design response spectra (CSDRS) scaled to a 0.1 g peak ground acceleration (PGA)." The statement is inconsistent because on p. 3.7-3 of DCD (R3), it is stated that the CSDRS are derived from the RG 1.60 spectra by modifying the control points to broaden the spectra in the higher frequency range. That is, the CSDRS and RG 1.60 spectra are not the same.

Please explain the inconsistencies described above and correct the information in the RAI response to reflect the spectra used as input motion for soil-structure interaction analysis in Appendix 3NN.

ANSWER:

The answer corrects the inconsistency in the response to RAI 2879 (CP RAI #60) Question 03.07.02-2 (ML093340447), as follows. Consistent with FSAR Subsection 3.7.1.1, the site-specific SSE at Comanche Peak Units 3 and 4 is a minimum design earthquake which is defined as the shape of the DCD CSDRS and anchored at 0.1g. The spectra representing the minimum design earthquake are presented in FSAR Tables 3.7-201 and 3.7-202, and FSAR Figure 3.7-201. The spectra converted from the time histories used as input motion for the soil-structure interaction analyses appropriately match the target SSE design spectra which is the minimum design earthquake spectra because it also envelopes the site-specific FIRS spectra.

Impact on R-COLA

None.

Impact on S-COLA

None; the response is site-specific.

Impact on DCD

None.