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CP-201100103
Log # TXNB-11004

Ref. # 10 CFR 52

January 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. 5254
(SECTION 3.7.1) AND NO. 5255 (SECTION 3.7.2)

Dear Sir:

Luminant Generation Company LLC (Luminant) submits herein the response to Request for Additional Information (RAI) No. 5254 (CP RAI #193) and No. 5255 (CP RAI #192) for the Combined License Application for Comanche Peak Nuclear Power Plant Units 3 and 4. The RAIs involve the soil-structure interaction analyses and roof slabs for buried vaults.

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

There are no commitments in this letter.

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

Executed on January 27, 2011.

Sincerely,

Luminant Generation Company LLC

Donald R. Woodlan for

Rafael Flores

Attachments:
1. Response to Request for Additional Information No. 5254 (CP RAI #193)
2. Response to Request for Additional Information No. 5255 (CP RAI #192)

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NRO

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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.: 5254 (CP RAI #193)

SRP SECTION: 03.07.01 - Seismic Design Parameters

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

DATE OF RAI ISSUE: 12/6/2010

QUESTION NO.: 03.07.01-6

This RAI is necessary for the NRC 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; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.1, 'Seismic Design Parameters.'

In Appendices 3KK, 3LL, and 3 MM of Revision 1 of the Comanche Peak Nuclear Power Plant, COLA, Part 2 FSAR, the applicant states that several soil-structure interaction (SSI) analyses were performed with varying assumptions for the subgrade, backfill, and soil separation conditions. For each of the analyses documented in these Appendices, the applicant is requested to clarify the definitions of all backfill and subgrade conditions, and backfill separation conditions used in the SSI evaluations.

ANSWER:

The site is underlain with limestone. This stratum and everything below is termed as "subgrade." The site is excavated to the limestone, with structures placed on the limestone or on a concrete fill layer placed on the limestone. The site will then be backfilled with a granular soil which is termed "backfill."

Analyses considered uncertainties in foundation support through the use of three rock subgrade properties: Lower Bound (LB), Best Estimate (BE), and Upper Bound (UB) and four backfill properties: Lower Bound (LB), Best Estimate (BE), Upper Bound (UB), and High Bound (HB). Further details on these properties and variations are discussed in FSAR Appendix 3NN.

Soil separation is considered when the dynamic soil pressure exceeds the at-rest soil pressure, representing a condition where backfill may separate from the structure. This is modeled by reducing the stiffness of backfill soil elements adjacent to the structure by a factor of 10 as explained in the FSAR Appendices 3KK, 3LL, and 3MM.

The SSI analyses considered a number of cases with various combinations of subgrade properties, backfill properties, and soil separation. Tables clarifying the combinations of soil properties used in each analysis case have been provided in FSAR Sections 3KK, 3LL, and 3MM. Separation cases were not included for the ESWPT segments 1 and 3 in Table 3LL-16 because these are embedded tunnels and separation will not occur.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3KK-3, 3LL-2, 3LL-3, and 3MM-4, and new Tables 3KK-10, 3LL-16, 3LL-17, and 3MM-10.

Impact on S-COLA

None; this response is site-specific.

Impact on DCD

None.

- an embedded foundation without separation of the backfill from the UHSRS exterior walls for the best estimate case
- an embedded foundation with separation of the backfill from the UHSRS exterior walls for all four soil cases, namely; LB, BE, UB, and HB

The analysis with the best estimate soil including soil separation was shown to produce the larger soil pressure and response spectra, and therefore subsequent analyses with LB, UB, and HB soil cases were performed only using soil separation to produce the bounding maximum response. The backfill separation is modeled by reducing the shear wave velocity by a factor of 10 for ~~the~~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 ~~are determined to~~very little pressure is transferred in these layers and the response will not be ~~separated~~significantly influenced by the small pressures. The potential for separation of backfill is determined ~~using an iterative approach that compares~~by comparing the peak envelope soil pressure results for the best estimate (BE) case to the at-rest soil pressure. Consideration of all these conditions assures that the enveloped results presented herein capture all potential seismic effects of a wide range of backfill properties and conditions in combination with the site-specific supporting media conditions. Table 3KK-10 provides the SSI analysis cases for the UHSRS.

RCOL2_03.08.04-24

RCOL2_03.07.02-16

RCOL2_03.07.01-6

The maximum shear wave passing frequency for all layers below the base slab and concrete fill based on layer thicknesses of 1/5 wavelength, ranges from 30.6 Hz for LB to 50.4 Hz for HB. The passing frequency for the backfill ranges from 14.7 Hz for the LB to 37.2 Hz for the HB.

RCOL2_03.07.02-16

The lower boundary used in the SASSI analysis is 759 feet below grade. This depth is more than twice the size of foundation plus embedment (131' x 2 + 47' = 309') recommended by SRP 3.7.2. A ten layer half-space is used below the lower boundary is the SASSI analysis consistent with SASSI manual recommendations. The SASSI half-space simulation consists of additional layers with viscous dashpots added at the base of the half-space. The half-space layer has a thickness of 1.5 Vs/ f where Vs is the shear wave velocity of the half-space and f is the frequency of the analysis and it is divided by the selected number of layers in the half-space.

The cutoff frequencies for all cases are greater than 37 Hz and a minimum of 57 frequencies are analyzed for SSI analyses. The SASSI analysis frequencies are selected to cover the range between 1 Hz and the cutoff frequency. This frequency range includes the SSI frequency and primary structural frequencies. The 1 Hz lower limit was shown to be low enough to be outside the range of SSI or structural mode amplification. It was verified that as the transfer functions approached the zero frequency (static input), the co-directional transfer function approached unity while the cross-directional terms approached zero.

Table 3KK-10

SSI Analysis Cases for UHSRS

RCOL2_03.07.01-6

Analysis	Description	Backfill Soil	Rock Subgrade	Soil Separation
1	Best Estimate	Best estimate	Best estimate	No
2	Best Estimate Separated	Best estimate	Best estimate	Yes
3	Lower Bound Separated	Lower bound	Lower bound	Yes
4	Upper Bound Separated	Upper bound	Upper bound	Yes
5	High Bound Separated	High bound	Upper bound	Yes
6	Lower Bound No Fill	-	Lower bound	N/A

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. RCOL2_03.08.04-37

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. RCOL2_03.08.04-34

The ESWPT model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3LL-3) and accounting for the site-specific stratigraphy and subgrade conditions described in ~~Chapter 2~~Subsection 2.5.4, as well as the backfill conditions around the embedded portions of the ESWPT. CTS-00922

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. RCOL2_03.07.01-6

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. RCOL2_03.07.02-11 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 ~~using an iterative approach that compares~~by comparing peak soil pressure results for the BE condition to the at-rest soil pressure. RCOL2_03.07.02-11 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 combination with the site-specific supporting media conditions. Table 3LL-17 provides SSI analysis cases for ESWPT Segment 2.

RCOL2_03.07.01-6

The location of the lower boundary used in the SASSI analysis is greater than 710 feet below grade. The depth is greater than the embedment plus twice the depth of the largest base dimensions (i.e. 192' x 2 + 31' = 415' for Tunnel 1) recommended by SRP 3.7.2 A ten layer half-space is used below the lower boundary in the SASSI analysis. The SASSI half-space simulation consists of additional layers with viscous dashpots added at the base of the half-space. The half-space layer has a thickness of 1.5 Vs/ f where Vs is the shear wave velocity of the half-space and f is the frequency of analysis and it is divided by the selected number of layers in the half-space.

RCOL2_03.07.02-16

RCOL2_03.08.04-34

The maximum shear wave passing frequency for all layers below the base slab and concrete fill, based on layer thicknesses of 1/5 wavelength, ranges from 30.6 Hz for LB to 50.4 Hz for HB. The passing frequency for the backfill ranges from 11.6 Hz for LB to 44.9 Hz for HB. The cutoff frequencies for all cases are greater than 29.3Hz and a minimum of 39 frequencies are analyzed for SSI analyses.

RCOL2_03.07.02-16

For the ESWPT analyses performed, benchmarking is performed to validate the results of the SASSI models. The natural frequencies of Tunnel Segment 1 are calculated for the FE model used for the SSI analysis performed in SASSI (coarse model) and a more refined FE model (ANSYS) used for the analysis of all static load cases (detailed model) and compared. Tunnel 1 is deemed representative of the coarse and fine mesh models of all tunnel segments. For this analysis both models have all nodes at the intersection of mat slab and the walls fixed against translation. Results show close comparison between the calculated frequencies.

RCOL2_03.08.04-40

RCOL2_03.08.04-40

The tunnels are simple structures and responses are significantly influenced by the surrounding soil, producing frequencies of peak response in the embedded SASSI model that do not match the eigenvalue analysis of the fixed base structure without soil which limits the ability to compare transfer functions. Therefore, the response of these structures are checked primarily through model and analysis input file checks and reviews of the transfer functions and other output to make sure that adequate frequencies are used for calculation. The SASSI analysis frequencies are selected to cover the range between around 1 Hz and the cutoff frequency. This frequency range includes the SSI frequency and primary structural frequencies. The 1 Hz lower limit is low enough to be outside the range of SSI or structural mode amplification. It was verified that as the transfer functions approached the zero frequency (static input), the co-directional transfer function approached unity while the cross-directional terms approached zero. Initially, the frequencies are selected evenly spaced. Frequencies are added as needed to produce smooth interpolation of the transfer functions and accurately capture peaks. As verification, additional frequencies are added to observe that the results did not change. Transfer functions are examined for each analysis to verify that the interpolation was reasonable and that the expected structural responses were observed. Transfer functions, spectra, accelerations,

Table 3LL-16

SSI Analysis Cases for ESWPT Segments 1 and 3

RCOL2_03.0
7.01-6

Ana;ysis	Description	Backfill Soil	Rock Subgrade	Soil Separation
1	Best Estimate	Best estimate	Best estimate	No
2	Lower Bound	Lower bound	Lower bound	No
3	Upper Bound	Upper bound	Upper bound	No
4	High Bound	High bound	Upper bound	No

RCOL2_03.0
7.01-6

Table 3LL-17

SSI Analysis Cases for ESWPT Segments 2

Ana;ysis	Description	Backfill Soil	Rock Subgrade	Soil Separation
1	Best Estimate	Best estimate	Best estimate	No
2	Lower Bound	Lower bound	Lower bound	No
3	Upper Bound	Upper bound	Upper bound	No
4	High Bound	High bound	Upper bound	No
5	Best Estimate Separated	Best estimate	Best estimate	Yes
6	Lower Bound Separated	Lower bound	Lower bound	Yes
7	Upper Bound Separated	Upper bound	Upper bound	Yes
8	High Bound Separated	High bound	Upper bound	Yes

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 ~~using an iterative approach that compares~~by comparing the peak envelope soil pressure results to the at-rest soil pressure for the BE soil case. Consideration of all these conditions assures that the enveloped results presented herein capture all potential seismic effects of a wide range of backfill properties and conditions in combination with the site-specific supporting media conditions. Table 3MM-10 provides SSI analysis cases for the PSFSV.

RCOL2_03.07.02-11

RCOL2_03.07.02-16

The shear wave passing frequency for all layers below the base slab and concrete fill, based on layer thickness of 1/5 wavelength, ranges from 30.6Hz for LB to 50.4Hz for HB. The shear wave passing frequency for the backfill ranges from 11.4Hz for LB to 31.1Hz for HB.

RCOL2_03.07.02-16

A ten-layer half-space is used in the SASSI analysis in accordance with the SASSI Manual recommendations. The SASSI half-space simulation consists of additional layers with viscous dashpots added at the base of the half-space. The half-space layer has a thickness of 1.5 Vs/ f where Vs is the shear wave velocity of the half-space and f is the frequency of analysis. The half-space is sub-divided by the selected number of layers in the half-space.

The lower boundary used in the SASSI analysis is 809 feet below grade. The depth is more than the embedment depth plus twice the depth of the largest base dimension (88' x 2 + 40' = 216') recommended by SRP 3.7.2.

The cutoff frequencies for all cases are greater than 29.9Hz and a minimum of 48 frequencies are analyzed for SSI analyses. The SASSI analysis frequencies were selected to cover the range between around 1 Hz and the cutoff frequency. This frequency range includes the SSI frequency and primary structural frequencies. The 1 Hz lower limit is shown to be low enough to be outside the range of SSI or structural mode amplification. It was verified that as the transfer functions approached the zero frequency (static input), the co-directional transfer function approached unity while the cross-directional terms approached zero. Initially, the frequencies are selected evenly spaced. Frequencies are added as needed to produce smooth interpolation of the transfer functions and accurately capture peaks. As verification, additional frequencies were added to observe that the results did not change.

For the PSFSV analyses, benchmarking is performed to validate the results of the SASSI models for verification of both the mesh and the dynamic response. The mesh used for SASSI analyses is justified with respect to with the more refined design model by calculating eigenvalues and mode shapes for the models with each mesh using ANSYS and comparing the results. The comparisons show that the two models provide similar dynamic responses.

To verify the dynamic response, fixed base eigenvalue analysis is performed in ANSYS, and a corresponding fixed base analysis is performed in SASSI by

Table 3MM-10

RCOL2_03.07.01-6

SSI Analysis Cases for ESWPT Segments 1 and 3

Ana;ysis	Description	Backfill Soil	Rock Subgrade	Soil Separation
1	Best Estimate	Best estimate	Best estimate	No
2	Lower Bound	Lower bound	Lower bound	No
3	Upper Bound	Upper bound	Upper bound	No
4	High Bound	High bound	Upper bound	No
5	Best Estimate Separated	Best estimate	Best estimate	Yes
6	Lower Bound Separated	Lower bound	Lower bound	Yes
7	Upper Bound Separated	Upper bound	Upper bound	Yes
8	High Bound Separated	High bound	Upper bound	Yes
9	Lower Bound No Fill	-	Lower bound	N/A

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.: 5255 (CP RAI #192)

SRP SECTION: 03.07.02 - Seismic System Analysis

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

DATE OF RAI ISSUE: 12/6/2010

QUESTION NO.: 03.07.02-19

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; as well as 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.'

On page 3KK-2 of Revision 1 of the Comanche Peak Nuclear Power Plant (CPNPP) COLA, Part 2, FSAR, it is stated that the use of operating-basis earthquake (OBE) damping is consistent with the low seismicity of the site. On page 3KK-3, it is stated that all roof slabs and elevated slabs are considered cracked with an out-of-plane bending stiffness of 50% of the gross section stiffness.

The assumption of cracked or uncracked concrete properties will affect the distribution of loads in the structure and will affect the demand-to-capacity ratios in the members of the structure. The applicant is requested to demonstrate that the 50% reduction in gross section stiffness for all roof slabs and elevated slabs is consistent with the concrete demands predicted by the structural models, and that the final distribution of loads is consistent with the final combined loads in the members.

ANSWER:

The assumption of cracked roofs and elevated slabs was used because:

- These slabs are subject to out-of-plane loads (dead, live, and vertical seismic) only and do not carry sustained axial compression in-plane forces. Cracking is more likely to occur under such loading conditions.
- Cracking due to shrinkage and thermal change may occur.
- The peak of the input spectra is at a low frequency such that cracked slab properties result in a frequency closer to the peak than uncracked slab properties, and result in increased flexural demands in the slabs. For example, vertical slab natural frequencies of the UHS are above 10 Hz, while the peak of the input spectra is near 3.5 Hz. Similarly, for the PSFSV vertical slab natural frequencies are above 15 Hz, while the peak of input spectra is near 3.5 Hz. Use of uncracked section properties results in higher natural frequencies and lower seismic demands.
- The primary lateral load path is in-plane shear of the shear walls. Flexural cracking of the slabs will not change this primary lateral load path.

- The primary vertical load path is axial force through the walls. Flexural cracking of the slabs will not change this primary vertical load path.

Based on the reasons stated above, the concrete cracking levels assumed with this design approach are justified as conservative for the slab structural demands, and have a negligible effect on load distribution to primary structural load paths and dynamic behaviors. The cracking assumptions do not affect the design capacities which were based on ACI 349 ultimate strength design methods.

Impact on R-COLA

See attached marked-up of FSAR Revision 1 page 3KK-5.

Impact on S-COLA

None; this response is site-specific.

Impact on DCD

None.

where:

C_F = the factor for the reduction of flexural stiffness, taken as 1/2,

$t_{cracked}$ = the effective slab thickness to account for cracking

t = the gross section thickness

$\gamma_{cracked}$ = the effective unit weight to offset the reduced stiffness and provide the same total mass

$\gamma_{concrete}$ = unit weight of concrete

$E_{cracked}$ = effective modulus to account for the reduction in thickness that keeps the same axial stiffness while reducing the flexural stiffness by C_F

$E_{concrete}$ = modulus of elasticity of concrete.

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. RCOL2_03.07.02-19

Density of the structural walls and slabs is modified to include the dynamic masses of self-weight plus equivalent dead load and 25 percent of live load. Equivalent dead load is 50 psf on all interior surfaces above water (except inside the air-intake or the cooling tower walls at locations beneath the fan slab). Live load on the elevated floor slabs is 200 psf, and live load on roof slabs is taken as 100 psf. Weights are applied in the model at appropriate locations to represent the following equipment and component masses: transfer pump, essential service water (ESW) pump, tile fill located below the cooling tower fans, distribution nozzles and system, fan, fan motor, gear-reducer, driveshaft, steel grating.

~~The hydrodynamic effects of the water contained in the basins, cooling towers, and pump room of the UHS are considered in the model. The water is separated into rectangular regions in which water sloshing can develop under horizontal seismic excitation. Using the methodology specified in ACI 350.3-06 (Reference 3KK-5), the water within each region is separated into impulsive (fixed) and convective (sloshing) masses. The impulsive mass of the water is lumped uniformly along the height of the walls at each end of the rectangular region in the direction perpendicular to the wall. For the response spectra analyses performed to obtain seismic design demands, the sloshing mass is not required to be modeled since its fundamental frequency is much lower than the structural or soil frequencies. The vertical mass of the water is distributed uniformly across the basemat.~~The hydrodynamic effects of the water contained in the basins, cooling towers, and pump room of the UHS are considered for dynamic analyses used in RCOL2_03.07.03-2

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.: 5255 (CP RAI #192)

SRP SECTION: 03.07.02 - Seismic System Analysis

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

DATE OF RAI ISSUE: 12/6/2010

QUESTION NO.: 03.07.02-20

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; as well as 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.'

On page 3MM-1 of Revision 1 of the CPNPP COLA, Part 2, FSAR, it is stated that the materials and properties of the roof slabs are adjusted to reflect cracked concrete that has 50% reduction of the flexural out-of-plane stiffness. The assumption of cracked or uncracked concrete properties will affect the distribution of loads in the structure and will affect the demand-to-capacity ratios in the members of the structure. The applicant is requested to demonstrate that the 50% reduction in out-of-plane stiffness for the roof slabs is consistent with the concrete demands predicted by the structural models, and that the final distribution of loads is consistent with the final combined loads in all members.

ANSWER:

See the response to Question 03.07.02-19 above.

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

See attached marked-up of FSAR Revision 1 page 3MM-3.

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

None; this response is site-specific.

<u>Impact on DCD</u>

None.

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. RCOL2_03.07.02-20

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. RCOL2_03.07.02-16

The PSFSV model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3MM-3) and accounting for the site-specific stratigraphy and subgrade conditions described in ~~Chapter 2~~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. CTS-00922

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~~, and a surface foundation condition without the presence of any 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 those layers of backfill that are determined to be separated.~~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 RCOL2_03.07.02-11 RCOL2_03.08.04-48